~ get
wavy

get wavy

**Introducing irregularity into modular
timber housing in New Zealand**

by Brittany Irvine

A thesis submitted to the Victoria University of
Wellington in partial fulfilment of the requirements for
the degree of Master of Architecture (Professional)

Victoria University of Wellington

2019

wavy

get

02.

01.

Acknowledgements

My family - thank you for your unwavering support in all aspects of my life. Proof-reading, phone calls, dinner and trips home, your support is always above and beyond.

My friends - countless memories shared drinking coffee, lunching, laughing, celebrating ... and working hard. I'm smiling writing this and I think that says it all.

My supervisor - Guy Marriage, what a guiding light and guru of the construction world. Your belief in me goes further than just my thesis and I am so grateful for your support.

Figure 01 - Brittany, review two

Figure 02 - Thesis workspace + project inspiration

Figure 03 - Taranaki St entrance

Figure 04 - Two story dwelling atmospheric interior

04.

03.

wavy

06.

05.

Figure 05 - Frederick Street Elevation
Figure 06 - Dwelling Type P
Figure 07 - Detail section of final design

07.

All images are authors own unless otherwise specified.

Abstract

The construction industry accounts for 23% of global CO₂ emissions each year¹. Coupled with contemporary pressures of urbanisation, there is demand for increased density construction². To improve the relationship the industry has with the environment it must reconsider its construction methods and material choices. Engineered timber is a sustainable and structural solution for these issues.

Commonly when building with engineered timber, traditional construction methodologies are applied. The material is simply used as a replacement for steel and concrete and does not explore the tectonic opportunities available. This results in the same monolithic multi-story buildings.

This research portfolio offers a new approach to flexible modular housing using cross-laminated timber (CLT). It is researched through an adaptable urban housing complex. It explores the tectonics of CLT and develops a diverse design language that offsets how the material has been traditionally used.

The design research was conducted through a series of design-led experiments comprised of four key phases; the problem, the exploration, the parts and the test. The problem researched key issues around CLT. This highlighted current deficiencies in the design of timber medium-density housing in New Zealand. The research explores the specific tectonics of CLT as an engineered timber product. Developing a series of components that can be assembled on various urban sites. This process translated into a singular site-specific test in Te Aro, Wellington.

The implications of this research are to provide an alternative approach to urban medium-density housing using engineered timber technology. The result of this process is the design of a modular system of interlocking dwellings that can be optimized to site and that optimise the visual and spatial opportunities of engineered timber. Offsetting the current design language of medium-density timber buildings and proposing visual and spatial improvements to inner-city living in New Zealand.

1 (Huang, Krigsvoll, Johansen, Liu, & Zhang, 2018)
2 (Wellington City Council, 2015.)

08.

09.

10.

Figure 08 - Frederick Street courtyard
 Figure 09 - Shared terrace on Taranaki Street
 Figure 10 - Brittany, review three

Table of Contents

Acknowledgments	iv	Single-story Interiors	85
Abstract	vi	Two-Story Models	93
Table of Contents	viii	Two-Story: Development	100
Research Portfolio Structure	x		
Research Question	xii		
Aims and Implications	ix		
Methodology	xiv		
Chapter One:	1	Chapter Four:	115
The Problem: <i>Background and Problem</i>		The Book of Parts: <i>Assemble and apply a system</i>	
Introduction: Timber through the ages	3	Elements	118
Problem Overview	8	Structure	120
Problem 1.1: Urbanisation	10	Access	124
Problem 1.2: Environment	12	Courtyard	126
Cross-laminated Timber	14	Interstitial Program	128
CLT Construction Types	18	Facade Variation	130
Problem 2.0: Existing timber buildings	20	Comparing Design Language	132
Tall Timber Buildings	22	Visual Experiments	134
Case Study One: Puukuokka	24		
Problem 3.0: Research question	30	Chapter Five:	139
Chapter Two:	31	The Sited: <i>Context and Site</i>	
The Exploration P1: <i>Design response to CLT issues</i>		From site-less to sited	145
Issue One: Flat facades	34	Te Aro mapping	145
Issue Two: Acoustic transfer	40	129 / 133 Taranaki St	155
Issue Three: Variation in plan	42	Early sited designs	162
Issue Summary	45		
Linear Geometry	47	Chapter Six:	173
Linear Models	49	The Test: <i>Design test in a sited context</i>	
Expand and Contract	50	Four key decisions	177
Timber slab	51	Site Response	178
Case Studies 2+3: Modular Precedents	52	Plans: Ground to Level 4	184
Developing the Modules	59	Interior Atmosphere	from 196
Offset Models	61	Detail Section	from 198
Block Assembly	64	Exterior Atmosphere Images	214
		The Circulation	218
Chapter Three:	69	The Facade	220
The Exploration P2: <i>The apartment module</i>		Chapter Seven:	225
Base Module	71	The Conclusion: <i>Reflections and Implications</i>	
Single-story Plans	72	Conclusion: Overview	226
		Reflections + Implications	228
		Bibliography	234
		Figure List	236

Research Portfolio Structure

Chapter One

● **Background + Problem** 01.

A summary of the background and premise to the design research of this portfolio.

Chapter Two

● **Exploration - Parts** 02.

A series of design research that began by responding to current issues with cross-laminated timber construction.

Chapter Three

● **Exploration - Development** 03.

Further design research into apartment configuration and atmosphere, both the visual and spatial.

Chapter Four

● **The Book of Parts** 04.

A summary of the exploration research that collects a series of successful parts for assembly in a sited experiment.

Chapter Five

● **The Context + Site** 05.

Touching on why Te Aro, Wellington is a good location for increased medium density housing and urban timber architecture.

Chapter Six

● **The Design Test** 06.

As a proof of concept, the final design that attempts to pull together the previous design research into a sited response.

siteless

sited

How can a diverse design language of engineered timber improve modular medium density housing? (MDH)

Aims and Implications

This research portfolio designs a modular housing system which explores the diverse visual and spatial design languages available with engineered timber housing. In order to achieve this the aims of this research were:

Aims

- **Introduce spatial diversity into a modular housing system, using a standardised structural element.**
- **Explore the visual language of a structural panel system, as opposed to a post and beam system.**
- **Experiment with methods of introducing space and light into an inner city housing development.**

Implications

New Zealand is amid a global push towards urbanisation and consequent densification. The New Zealand government have responded to this with a proposal for 100,000 new homes within the next decade. How this new portion of housing stock will be constructed, look and effect our people and cities is still up for questioning.

The implications of this research are to question the outcomes of these homes. By proposing an alternative method towards constructing housing with a sustainable material, this investigation is directly questioning how we will build denser cities. Starting with autonomous studies of form and space, the exploration questions the method of implementing engineered timber in apartment blocks. Moving to a singular housing block in the centre of Wellington city, the consequences become deeply rooted to New Zealand's existing housing context.

Methodology

Chapter One

1. The Problem

01.

This highlighted these three problems: 1. The environmental impact of the built environment, 2. Current issues with multi-story residential CLT buildings, 3. Modular CLT is preferable, but what does a new design language that enriches timber architecture look like.

Three issues with CLT construction were also highlighted – façade experimentation, acoustic transfer and plan variation.

2. The Exploration

02.

The purpose of the exploration was to understand the tectonic possibilities of CLT. Through breaking CLT down to first principals a series of design experiments occurred. These were done through a series of façade model making explorations, interior atmospheric collages and digital modelling. This process continued to be refined and eventually focused on the development of various interlocking modular apartment types. Single story and two-story dwellings, plus façade and circulation variations.

03.

3. The System

04.

The development of the system was done by treating the design as a flexible series of parts that can be placed in various contexts. At the end of this phase there was a set of parts that can be re-purposed and reorganised for a variety of different sites and locations.

4. The Test

05.

Using the richness of the specified Te Aro site, a housing scheme was developed. The system was assembled in response to the context. This was used as a testing ground with a focus on adapting the proposed flexible system. This tested the ideas and theories developed throughout the design research.

06.

get

the problem

Background + Problem

Timber in Context

Chapter One

01.

- 1.2. Introduction :** *Timber through the Ages*
- 1.3. Research Question :** *An explanation*
- 1.4. Problem One :** *Urbanisation and the environment*
- 1.5. Problem Two:** *Existing timber buildings*
- 1.5. Problem Three:** *Revisiting modular housing*

Image redacted, see print copy

then . _____ . **now**

11.

Figure 11 - Then to Now; a time-line image of construction materials throughout history

2. **Get Wavy** : Introducing Irregularity in to Modular Timber Housing

Introduction

Timber through the Ages

For centuries timber was used as a construction material due to its vast availability, workability and structural properties. From pagodas in Japan to churches in Norway, timber combines functionality with beauty, connecting mankind to the natural world¹. It is a strong, durable and renewable resource that has shaped architectural history.

Increased urbanisation in the 19th century required denser cities and taller buildings. Technological advances dared architects to envision new utopian worlds built of steel, concrete and glass. Competition from these suddenly widely available and non-flammable materials relegated timber to a building material for lower, sometimes temporary buildings². Despite the known benefits of timber, the material temporarily lost its place in growing cities.

Steel and concrete have continued to dominate all forms of construction since the industrial revolution, however continuing to build with them is one of the most environmentally detrimental options. Concrete is the second most used substance in the global economy, second only to water – and one of the largest single sources of greenhouse gas emissions³.

This research portfolio therefore explores how a return to timber might occur within our urban environments.

1 (MGA & Architecture, 2017)
2 (Krötsch & Müller, 2018)
3 (Lehne & Preston, 2018)

12.

Figure 12 - Photo by Nik on Unsplash, edited with text by author (Nik, 2017).

“Taking in all stages of production, concrete is said to be responsible for 4-8% of the world’s CO₂”

(Lehne & Preston, 2018)

13.

Figure 13 - Photo by Tod Seitz on Unsplash, edited with text by author (Seitz, 2018).

**1m³ of timber
sequesters
225kg of
carbon**

(Hafner & König, 2018).

How can a diverse design language of engineered timber improve modular MDH?

This question was the result of
the following three problems.

KEY

- + problem
- = solution

Problem One

Increasing urbanisation means increasing construction. As an industry that contributes 23% of all CO₂ emissions, we are in need of better methods of constructing our environment. Prefabricated use of engineered timber could be a solution.

- + Increased Urbanisation
- + Environmental Issues
- = **Building with engineered timber**

Problem Two

Most engineered timber buildings do not utilise the modular potential of cross-laminated timber. They are still using the methodologies of concrete and steel buildings. Modular construction is a method that utilises the properties of CLT.

- + Using old methodologies
- + Not utilising technology opportunities
- = **Modular system with CLT**

Problem Three

*Modular design often results in homogeneous design language. How might a diverse design language be introduced within a modular framework? **How can a diverse design language of engineered timber improve modular MDH?***

- + Modular commonly = homogeneity
- + How can modular create a more diverse design language?
- = **Get wavy**

The following three subsections further explain each of these points.

Problem One

Urbanisation and the Environment

Urbanisation in New Zealand

Urban densification is important for New Zealand's development and this research portfolio recognises the importance of this ongoing trend. In this context it supports densification as a strategy of sustainable urban development.

86% of New Zealand's population live in urban areas, this is only going to continue to increase as the population rises. By 2050, New Zealand's population is projected to rise from 4.6 to 6 million¹. A projected increase of over 20% of continued urban densification is both a reality and a necessity. History has shown that population increases can likely lead to inflated house prices when the housing industry falls out of the supply and demand balance².

For generations owning a home in New Zealand has been a rite of passage. It not only offers financial security, but also plays a role in national identity³. House prices have been consistently rising in parallel with increased population and urbanisation. Subsequently home-ownership rates are falling, and people are priced out of the market – particularly for young people. The home ownership rate of people in their late thirties dropped 11% from 2001 to 2013, from 61% to 50%⁴. This provides a problem that intersects politics, economics, architecture and the construction industry.

Kiwibuild has been the New Zealand government's answer to this problem. Beginning in 2018, residential dwellings are intended to be erected at speed and scale. This is proposed to occur at a rate of 100,000 homes over 10 years⁵. Action is required to alleviate issues with housing quality and shortage.

In order to produce these houses, the New Zealand government is looking to prefabrication as part of the answer.

*"Off-site manufacturing is the disrupter that our construction industry desperately needs."*⁶

– Phil Twyford

Wanting to utilise the off-site efficiencies of prefabrication in order to produce high quality mass-housing. Cross-laminated timber is produced in New Zealand and an ideal material for off-site construction; thus it is an obvious solution for a multi-residential structural system.

1 (Statistics New Zealand, 2006)

2 (Eaqub, 2015)

3 (Eaqub, 2015)

4 (Eaqub, 2015)

5 (Ministry of Housing and Urban Development, 2018)

6 (Stock, 2018)

14.

Figure 14 - Mount Victoria, New Zealand (Drew, 2017).

1.2

Problem One

Urbanisation and the Environment

Environmental Effects of Building

As New Zealand continues to urbanise⁷, the carbon dioxide emitted into our atmosphere continues to grow. This is having an irreversible effect on the environment we all share. Construction is an inevitable by-product of urbanisation, but we cannot afford to continue to build in the same manner, for the sake of our planet's future.

The construction industry contributes 13% of global carbon emissions, with the production of steel and concrete equating for 56% of this. To produce the cement that binds concrete one tonne of CO₂ per cubic metre is emitted⁸.

When contrasted to timber, concrete falls short. Timber is the optimum material for urban construction as it allows faster building methods; its lightness leads to more affordable structures; and it's the most environmentally friendly building material, being both a renewable resource and a carbon sequestering material. Wood stores CO₂ at a rate of 225kg of carbon per 1m³.

*"The steel and concrete designs embody 26% and 57% more energy relative to the wood design, emit 34% and 81% more greenhouse gases, release 24% and 47% more pollutants into the air, discharge 400% and 350% more water pollution, produce 8% and 23% more solid waste, and use 11% and 81% more resources (from a weighted resource use perspective)."*⁹

Globally, however, only 5-10% of urban construction is timber¹⁰. Mass timber construction can help alleviate issues with climate change, high-density cities, and the housing crisis. CLT buildings are 30% faster to erect due to prefabrication and they weigh a quarter of a concrete building¹¹. CLT is a major new development in the construction industry and presents a new way of achieving higher densities on tight sites and in a more sustainable manner.

One reason for a limited uptake of mass timber is predominantly due to education and understanding of the material. In the tight time restraints of an architectural design there is limited time to learn new skills and implement new technologies. Thus, many designers fall back on to what they already know works in order to favour efficiency of production.

7 (Zealand, 2006)

8 (Mayo, 2015)

9 (Canadian Wood Council, 2004)

10 (Mayo, 2015)

11 (Mayo, 2015)

15.

16.

Figure 15 - The Concrete City
Figure 16 - The Timber City

CLT

Cross-laminated Timber

What is CLT?

Cross-laminated timber (Lehmann) was first developed in Austria and Germany in the early 1990's and has been gaining traction and popularity in the past decade. It can be used for residential and non-residential applications and it is considered a complete building system as it facilitates the construction of a multi-story building¹².

CLT is a system of engineered solid wood panels. Each of these panels commonly made up of 3, 5 or 7 layers. These layers are glue laminated perpendicular to each other, resulting in the 'cross laminated' name. By alternating the grain directions of each layer this reduces the structural weakness that other timber products are susceptible too.

The thickness of a CLT panel manufactured in New Zealand is between 60mm and 405mm, with the most commonly used panel thickness being 105mm and 165mm¹³. The maximum size of a panel from XLam (a NZ manufacturer), is a result of the press size which measures 15m x 3.5m¹⁴. These panels can span two directions which is why they can be used for load bearing walls and floor spans.

There is currently only one CLT plant in New Zealand, owned and managed by XLam. This produces 10,000m annually. There have a second plant that opened early 2018 in Australia, this produces 60,000m³ annually¹⁵. New Zealand will have a second CLT factory in 2019 owned by Red Stag. This plant will have an annual output of 55,000m³ ¹⁶.

12 (Goodison, Hall, Jack, & Barry, 2013)

13 (XLam, 2019)

14 (XLam, 2019)

15 (XLam, 2019, Technical)

16 (Guy, 2018)

17.

Figure 17 - Cross laminated timber diagram, annotation adapted from (Krötsch & Huß 2018)

A note on sustainable timber production in New Zealand

The previous environmental advantages of building out of wood are one of the leading reasons why it is becoming a popular building material choice. The individual is becoming more and more aware about the environmental impacts of their decisions. A common concern however, that sits alongside the use of wood, is ensuring the sustainable management of forests.

In New Zealand most forests are certified by the Forestry Stewardship Council (FSC). As of August 2016, 72.3% (1,240,724 ha) of New Zealand forests were certified ¹⁷. Being a certified forest means that they provide the highest level of protection for rare and endangered forests and wildlife, have a high transparency of environmental policies, and ensure that they're consulting with indigenous people in order to protect their rights. It also means replanting land in order to produce more trees and sequester as much carbon as possible.

17 (Forestry Owners Association NZ, 2017)

18.

19.

20.

21.

Figure 18 - Visit to XLam Nelson - planing the wood for a CLT panel

Figure 19 - Visit to XLam Nelson - the making of a CLT panel

Figure 20 - Visit to XLam Nelson - Tables with panels laid out for CNC cutting

Figure 21 - Visit to XLam Nelson - Hand and phone for comparison of a 400mm thick flooring panel

CLT Construction Types

Three variations of multi-residential CLT construction

22.

Single-leaf apartment partition

23.

Two-leaf apartment partition

Figure 22 - Single-leaf apartment partition

Figure 23 - Two-leaf apartment partition

Figure 24 - Modular construction

All figures adapted from KLH's 'Component Catalogue for Multi-Story Residential Buildings'. (KLH Massivholz GmbH, 2012).

24.

Modular Construction

1. Single-leaf partition

A single-leaf apartment partition system results in a repetitive and systematic construction solution. Using walls and floors as CLT, each floor and wall panel is brought flat packed and then erected on site. The floors span the opposite direction to the walls allowing a simple criss-cross structure.

2. Two-leaf partition

The two-leaf apartment partition allows for more variation in plan. Freeing up spaces, and allowing the designer to customize floor penetrations and wall configurations.

3. Modular Construction

Modular construction allows for prefabricated and self-supporting volumes to be stacked together on-site. This results in double walls for increased acoustic performance. A completely open façade is possible, and each module is stacked upon a strip or point bearing foundation. Because wood is so much lighter than concrete (up to 20% the weight of concrete) is more easily be transported and lifted into place on site.

2.

Problem Two

Existing Timber Buildings

There is an increasing number of timber buildings that incorporate cross-laminated timber as a structural wall panel system. Implemented as both the floor and wall system (figures 25, 26, 27) or as a hybrid, in conjunction with other engineered timber products (figures 28, 29, 30).

Figures 25, 26 and 27 show three early CLT buildings that have been constructed using CLT walls and floors. The visual language of each of these buildings follow a similar column and beam rhythm. Combined with the thick nature of timber structure, the result is an array of visually homogeneous buildings. While each are innovative in their structural and construction methodologies, little regard has been given to how the novel structural system might positively impact the buildings formal and visual appearance.

Images redacted, see print copy

25.

28.

26.

29.

27.

30.

Figure 25 - Dalston Works by Waugh Thistleton Architects (Waugh Thistleton Architects, 2017).
Figure 26 - Murray Grove by Waugh Thistleton Architects (Waugh Thistleton Architects, 2009).
Figure 27 - Moholt Timber Towers by MDH Arkitekter (MDH Arkitekter, 2016).

Figure 28 - International House, Sydney by TZANNES (Guthrie, 2017).
Figure 29 - Earth Sciences Building by Perkins + Will (Construction Canada, 2014).
Figure 30 - Bullitt Center by Miller Hull Partnership (Stamets, 2012).

Tall Timber Buildings

These drawings have been extracted from a Thinkwood poster identifying “Over 21 tall wood buildings (7 stories or taller) that are underway or have been built”¹⁸. The buildings are categorised by the structural system they employ and how they are occupied. The homogeneous language previously mentioned, is reinforced through each of these buildings.

Puukuokka Housing Block by OOEPA, explores an alternate construction methodology, in the form of CLT modular. This opens the door for a new approach to how the visual composition of the buildings may begin to change.

18. (Thinkwood, 2018)

Information Key		Residential
	Commercial
	CLT Modular
	CLT Floor and Walls
	CLT Floor / LVL Columns

Figure 31 - Dalston Lane
 Figure 32 - Treet
 Figure 33 - Banyan Wharf
 Figure 34 - Puukuokka Housing Block
 Figure 35 - Banyan Wharf
 Figure 36 - Aebora
 Figure 37 - T3
 Figure 38 - Brock Commons
 Figure 39 - Origine Condos
 Figure 40 - 25 King
 Figure 41 - Sanctuary
 Figure 42 - Mjostårnet

Figures 33-44 adapted from Tall Wood Buildings' poster. (Thinkwood, 2018).

31.

Dalston Lane
 By Waugh Thistleton

London, UK
 10 stories
 2013

32.

Treet or 'The Tree'
 By Artec AS

Bergen, Norway
 14 stories
 2015

33.

The Cube
 By Hawkins \ Brown

London, UK
 10 stories
 2015

34.

Puukuokka Housing Block
 By OOEPA

Jyväskylä, Finland
 8 stories
 2015

35.

Banyan Wharf
By Hawkins \ Brown

London, UK
10 stories
2015

39.

Origine Condos
By Yvan Blouin Architect

Quebec City, Canada
13 stories
2017

36.

Arbora
By Provencher Roy

Montreal, Canada
8 stories
2016

40.

25 King
By Bates Smart, in partnership w Lendlease

Brisbane, Australia
10 stories
2018

37.

T3
By Micheal Green Architecture + DLR

Minnestoa, US
7 stories
2016

41.

Sanctuary
By MAST Architects

Glasgow, Scotland
7 stories
2018

38.

Brock Commons Tallwood House
By Acton Ostry Architects

Vancouver, Canada
18 stories
2017

42.

Mjøstårnet
By Voll Arkitekter

Brumunddal, Norway
18 stories
2019

Case Study One

Puukuokka Housing Block

OOPEAA

Jyväskylä, Finland

2015

43.

44.

Puukuokka Housing Block is an important case study for the application of CLT construction methods.

It is one of the first housing blocks to explore the opportunities of prefabricated modular construction.

The first housing block, Puukuokka One was completed in 2015, with Puukuokka Two in 2017 and Puukuokka Three in August 2018. Puukuokka One was the first eight story tall timber apartment building in Finland. It is characterised by the innovative use of room modules, a wet module and a series of dry modules for each apartment. The website of the architects OOPEAA states:

“The goal was to find a solution that makes the best possible use of the technical and aesthetic qualities of CLT and to create a wooden building in large scale with a distinct architectonic expression of its own.”¹⁹

This quote identifies Puukuokka Housing block as a key precedent for utilising the benefits of CLT. The material was a key guiding element in the design, and the tectonic possibilities were explored in both visual, spatial and construction areas.

19. (OOPEAA, 2018)

45.

46.

47.

48.

Figure 43 - Puukuokka housing block exterior (Auerniitty, 2018).
 Figure 44 - Puukuokka exterior photograph (Auerniitty, 2018).
 Figure 45 - Site layout diagram (OOPEAA, 2018).
 Figure 46 - Puukuokka interior photograph (Auerniitty, 2018).
 Figure 47 - Puukuokka circulation photograph (Auerniitty, 2018).
 Figure 48 - Puukuokka 1, 2, and 3 exterior photograph (Auerniitty, 2018).

Concept

Flexibly customizable modular system based on the use of prefabricated volumetric CLT

Cross Laminated Timber

Flexible Modular System

49.

Flexibly customisable modular system

50.

51.

“Each apartment is made of two modules, one housing the living room, balcony and bedroom, the other the bathroom, kitchen and foyer. Also the facade elements that are prepared separately and brought to site ready for assembly are entirely of wood. The modules are prefabricated in a local factory less than two hours away from the site.

The use of prefabricated modules made it possible to cut the construction time on site down to six months per building and to reduce the exposure to weather conditions. That made it possible to achieve a higher quality end result.”²⁰

52.

20. (OOPEAA, 2018)

Figure 49 - Concept Diagram (OOPEAA, 2018).

Figure 50 - Flexibly customisable modular system (OOPEAA, 2018).

Figure 51 - Typical floor plan and modular elements (OOPEAA, 2018).

Figure 52 - Diagram of module assembly (OOPEAA, 2018).

3.

Problem Three

Final research question

How can a diverse design language of engineered timber improve modular MDH?

As a result of this question, the design research proceeded through to the **exploration** stage. This involves a '**site-less**' development in order to address New Zealand's need to produce mass housing.

This is done by revisiting modular housing through the lens of 21st century technology.

53.

Figure 53 - Modular construction

get

the siteless

Exploration : Part One

Design response to cross laminated timber issues

Chapter Two

02.

2.2. CLT Issues : *Flat Facades;*

2.3. CLT Issues : *Acoustic Transfer*

2.4. CLT Issues : *Variety in Apartment Plan*

2.5. Key learnings

2.6. Linear Series

2.7. Expand and Contract: A flexible system

2.8. Takings from a timber slab methodology

2.9. Habitat 67 - Moshe Safdie

2.10. Toronto Tree Tower – PENDA

2.11. Offset Series and Models

2.12. Material and Aspect

2.13. Inverted Treatment: The Courtyard

54.
Figure 54 - Facade explorations

Exploring modular timber

The exploration began by researching through design to provide explorative solutions to issues with cross-laminated timber. The problems that had been identified in earlier research included flat façades, acoustic transfer and lack of variation in plan.

VISUAL

SPATIAL

Throughout the following pages there are icons which identify whether a visual or spatial idea is being explored.

Facade depth and experimentation

The façade is a tangible edge for the social, political and economic factors which impact the built environment. How it is articulated, can be a direct response and expression of these forces. This design research recognises the limited experimentation in the visual language of CLT housing complexes. The façade is therefore the first point of exploration and experimentation for this research.

The experiments undertaken were explored in both the digital and physical realm. Utilising balsa modelling wood, for its ability to assimilate the visual qualities of timber.

These models were inspired by the work of Urban Timber authors Anna Esbjörnsson, James Ford and Patrik Magnusson. Where they defined CLT's architectural language using six 6 elements. Surface and edge, CLT and glulam, the rigid plate I and II, wall cut-out I and II (see figure 56)¹ These all act in section and define the components of a vertical language.

While there have been many innovative steps in the field of CLT construction, few explore extrusions in section. They explore the mechanisms of 'the edge', 'the angle', 'the join' and 'the shadow'. This allowed shadow to play out for more dynamic and livelier facade elements.

These first models explored the CLT as a 'plate' with a simple faceted, or sharp-edged wave moving up the façade (see figures 57 and 58 on the following pages). This created a depth and one that changed throughout the day with the sunlight. The simplicity of such simple repeated geometry and one material created a beautiful stage for the façade.

The development became harder when inhabitation and glazing was included into the experiments. Where will the floors sit? Where will glazing penetrations occur? What scale would this best be suited too? Will the outside still be timber?

¹ (Esbjörnsson, Magnusson, & Ford, 2014)

Image redacted, see print copy

55.

*Figure 55 - Urban Timber, a systemic approach to architecture
(Esbjörnsson, A., Magnusson, P., & Ford, J. (2014))*

VISUAL

the edge

the angle

the join

the shadow

56.

Figure 56 - Facade exploration: The wave

VISUAL

the edge

the angle

the join

the shadow

57.

Figure 57- Facade explorations: Angled panel

58.

Figure 58 - Facade Testing

Various facade iterations. Further developments from the initial physical models. Including various materials and formal language.

VISUAL

2.

Issue Two

Acoustic transfer

Another issue that was identified when assessing literature on cross-laminated timber was the need to more closely consider acoustics. Because timber is a lighter weight than concrete the sound transmission is much higher². Often this is resolved through two layers of CLT to create a party wall between apartments with insulation and an air gap between³. While this deals directly with the issue, it is an excessive use of timber. As a result, the question morphed into how two CLT walls next to each other can be used differently? Prefabricated modular construction is a methodology which this research portfolio explores as a potential solution. Figure 60 is a first step in this exploration, re-interpreting how the air gap can be used as a habitable space

This diagrammatic design is a very simple cross-form in plan containing two apartments on a square slab. It allows for no neighbouring walls to be touching, therefore using the same quantity of timber, but providing interstitial space in-between dwellings. Facilitating the potential for additional outdoor gardens or shared balconies. The design compromises the floor area for the introduction of third spaces in apartment design.

2 (Esbjörnsson et al., 2014)

3 (Green, 2017; Kaufmann, Krötsch, & Winter, 2018)

59.

Figure 59 - Acoustic spatial iteration

Variation in plan

Spatial variation was another issue identified when looking to existing timber buildings. The Manual for Multi-Storey Timber Construction contains 22 case studies of engineered timber buildings, all of which have orthogonal, reflected plans⁴.

Diagram in figure 60 explains four variations of apartments types⁵. Derived from Function of Style by Farshid Moussavi, through the analysis of a variety of successful multi-unit housing developments these were determined as the common denominators of form. The key example here is the interlocking unit – “apartments overlap in either plan or section”⁶.

Spatial variation is a primary concern in CLT construction. While column and beam construction can allow for freedom in building planning, modularity restricts the arrangement of each individual apartment. Making structural adjustments is difficult. Therefore, initial variety is key to successful modular design. In Flexible Housing by Tatjana Schneider and Jeremy Till, chapter seven illustrates ‘A Manual for Flexible Housing’. In plan it asks questions such as:

- Can the unit accommodate a variety of living patterns?
- Can the unit be adapted by its users?
- Can the room be furnished in a variety of ways?⁷

It is derived that an interlocking plan of various apartment types would provide flexibility. If each CLT apartment is a different interlocking shape with non-structural internal partitions the interior arrangement can be altered to suit a range of personal requirements.

⁴ (Kaufmann et al., 2018)

⁵ (Moussavi, 2014)

⁶ (Moussavi, 2014)

⁷ (Schneider, 2007)

60.
Figure 60 - Types of apartments in a housing block

Key learnings

1.

Facade

The facade experiments illustrated various facade patterns and combinations for future development. Keeping a continuous exterior provided a variety of benefits visually but spatially restricts what and can and cannot be achieved.

2.

Two bedroom
80m²

Acoustic

The acoustic design reveals the value of interstitial space as an acoustic barrier and as an opportunity for diversity of function within shared apartment living.

3.

Plan

Interlocking each module allows for spatial efficiency throughout the building and spatial variation within each apartment. This lead to the development of a system of parts (in the following pages) that can interlock while still providing variation within a broader system of parts

Linear geometry series

Although New Zealand CLT panels come in 3m widths, a better dimension for an apartment is a 4.0m module. The following designs have been designed around a basic cube form of 4.0m x 4.0m in plan, and 3.5m in height. Two CLT panels would be used for each floor slab.

These blocks of modules each represent a piece of an interlocking series. The idea here is that there can be a variety of different apartments and they can each come together imperfectly or perfectly to form a variety of building iterations.

SPATIAL

61.

Figure 61 - Linear geometry series modules

One bedroom

64m²

Two bedroom

80m²

Three bedroom

96m²

Linear Geometry

One bedroom
64m²

Two bedroom
64m²

Two bedroom
64m²

Three bedroom
80m²

Three bedroom
80m²

Two bedroom
80m²

Three bedroom
96m²

Three bedroom
96m²

Two bedroom
96m²

Linear geometry assembly

62.

Assembly Testing

This linear assembly test used the previous series of digital models as physical volumes. These single-story units were assembled around a vertical point access core. There is a infinite number of possible combinations, each assembly iteration produces various opportunities for interstitial space and program.

Figure 62 - Linear assembly combination
Figure 63 - Linear assembly process

A square that breathes

64.

65.

66.

These still images are taken from a diagrammatic video (by author) explaining the possibilities of ‘expanding and contracting’. Showing that the assembly can sit tightly together for the densest volume or expand to facilitate additional program, light and air. This idea of ‘breathing’ was extrapolated from sketch by Aldo Van Eyck.

Van Eyck used this image to express the concept for his Congress Building in Jerusalem, Israel (1958,

unrealised)¹. The pattern of space that results from the building design, is both “open and closed, symmetrical and asymmetrical, expanding and contracting, ordered on rectangular geometry but occupied through diagonal views and movement”². The notion of a building breathing through these formal gestures are ideas that could also be successful in a vertical arrangement.

1 (McCarter, 2015)
2 (McCarter, 2015)

Figure 64 - Expanded volumes process

Figure 65 - Expanded volumes final

Figure 66 - Aldo Van Eyck’s ‘Square that Breathes’ (Van Eyck 1968)

Takings from a timber slab methodology

Levels to edges

The surrounding diagrams show early thinking for the development of a multi-story building but using traditional methodologies.

This was done by making basic formal movements such as shifting the floor plate, creating a light well, staggering the stud height and then curving the edges. That final development of curving the edges was revisited after the linear set of forms were developed resulting in a simple but significant change. See 'The Offset'.

Habitat 67 By Moshe Safdie 1967

Images redacted, see print copy

68. ▲

69. ▲

Habitat 67 by Moshe Safdie is a housing community and complex in Montreal, Quebec, Canada. Safdie's seminal work was built for the World Fair in Canada - Expo '67. Safdie had a vision to revolutionise prefabrication and this project was a tangible example for how the future could be constructed.

Every apartment has a private balcony that is large enough to support a garden, and the double height apartments are made from two prefabricated concrete modules. Unlike the work of the Metabolists at the time, Habitat 67 had no overarching 'mega-structure'. Instead of 'plugging' units into a greater whole, each module interlocks into another³. He went on to design more Habitat iterations such as a Habitat Puerto Rico which utilised a rhombus form (figure 75.)⁴.

The completed complex explores the many benefits of prefabricated architecture, but the expo format allows the complex to avoid the complications of inner-city construction. It was built upon a man-made island with excess soil from the city's metro construction⁵. Without the need to adapt to the rhythm of existing streets and buildings, this complex represents half of the objectives of this research portfolio.

In contrast to my research, this precedent offers a single type of module that can be arranged into a variety of plans internally. This research is instead proposing a room scale module type that assembles variety into each apartment size module.

- 3 (Bergdoll, Christensen, Broadhurst, & MOMA, 2008)
- 4 (Safdie, 1974) (Safdie, 1970)
- 5 (Bergdoll et al., 2008)

70.

An original plan configuration of the simplest one bedroom unit.

71. | An original plan configuration of a three or four bedroom penthouse. Double-story living and two large terraces.

72. | An original plan configuration of a two bedroom house.

74. ▶

73. ▶

Figure 68 - Habitat 67 photograph exterior 1 (Sixty7 Architecture Road, 2014).
Figure 69 - Habitat 67 photograph exterior 2 (Sixty7 Architecture Road, 2014).
Figure 70 - Habitat 67 one bed plan
Figure 71 - Habitat 67 three/four bed plan

Figure 72 - Habitat 67 two bed plan
Figure 73 - Exploded axonometric of a section of Habitat 67
Figure 74 - Habitat Puerto Rico module

SPATIAL

Toronto Tree Tower By PENDA / Studio Precht 2017

Images redacted, see print copy

A unbuilt project in Canada, this modular CLT design creates a visionary outlook on life in high rise timber.

Inspired by Habitat 67 fifty years on, it uses a modular building process where CLT panels are assembled off-site then fully finished modules are craned into place (see figure 78). The use of timber is paired with an increase in the amount of nature incorporated into the exterior of the building. Further re-enforcing the value of natural materials and biophilia in a city context.

“The Toronto Tree Tower symbolizes an ecological system for wooden high-rises worldwide. The building should be seen as a catalyst for future residential buildings that are ‘more efficient to construct’ and ‘more ecological to our environment’ than common construction methods.”⁶

The design is a direct reflection of the modular construction system, while also reflecting its timber roots in the external façade. Similarities can be drawn with Habitat 67, through the orthogonal geometries of its spatial layout. Although placed within the city context of Toronto, the building still appears very autonomous in its contextual relationship. A relationship to site however, is something that this research seeks to achieve in its sited studies.

⁶ (Precht, 2017)

75. ▲

76. ▲

77. ▲

78. ▲

Figure 75 - Toronto Tree Tower, exterior (Penda, 2017)
Figure 76 - Toronto Tree Tower, interior (Penda, 2017)
Figure 77 - Toronto Tree Tower, prefabrication diagram (Penda, 2017)
Figure 78 - Toronto Tree Tower, construction process (Penda, 2017)

79. ►

Figure 79 - Offset diagram

The offset

Introducing a simple offset curve into the regular gridded plan. This geometric tool is introduced to create a multitude to spatial variations throughout the building. An arc sliced into a square creates two pieces. These two pieces inform the offset series of volumes which resulted in the following iterations

Linear to offset geometry series

The following offset series was developed as a response to the previous experiments undertaken. This involved either addition or reduction in the form of the split cube (see figure 81.).

Developing the Modules

This diagram shows a curved cut through a square volume resulting in two pieces. Both pieces can fit into various corners and faces in a linear series. See below (figure 82.).

80. ▲

Square

Two bedroom
64m²

Offset

Two bedroom
60m²

Square

Two bedroom
64m²

Offset

Two bedroom
60m²

Two bedroom
80m²

Two bedroom
92m²

Three bedroom
80m²

Two bedroom
76m²

Two bedroom
96m²

Three bedroom
112m²

Three bedroom
96m²

Three bedroom
100m²

◀▲ 81.

Figure 80 - Offset logic
Figure 81 - Offset series

Offset series assembly

*Internal curved glazing opening
onto outdoor space*

Curved glazing

Extruded balcony

Open space on ground floor

82 ▲

Assembly critique

This series of images shows one of many options for assembling the components of the offset series. From these assemblies' gaps and miss-alignments allow spaces to be imagined. It was most successful when the straight edges are focused inwards, aligning with other straight edges, and the curved edges are expressed on the outside. This logic still allows for miss-connections and interstitial space in-between but gives more cohesion to the exterior and more functionality in the centre.

*Figure 82 - Offset assembly combination
Figure 83 - Offset assembly process*

Offset Models

Offset + linear series assembly

Internal light-well / courtyard

Shared courtyard between two apartments

Step down for water protection

84. ▲

Assembly critique

By putting together both the offset and linear series of pieces, visually the resulting assembly has many more geometry clashes. The exterior now has right angled edges. This was a less successful combination because now the visual coherency of the block is disrupted.

Spatially, there is now a much smaller proportion of curvature in the overall assembly, there is less opportunity for a curve to sit within a curve. This then creates more chances for an irregular interstitial space to appear upon a curve, but less chance of a linear one.

Therefore it is important to understand the proportion of curves to straight edges. If the curves are what creates an offset, you do not want an excessive amount otherwise they will cancel each other out. Linear edges on the other hand, are good to align (and thus cancel each other out and create a party wall).

SPATIAL

Figure 84 - Linear and offset assembly combination
Figure 85 - Linear and offset assembly process

Offset Models

85. ►

Early material assembly

86. ▲

In *Refabricating Architecture*, it discusses ‘quilt management’. This is the idea that “to work with a modular system or to use component assemblies, it is necessary to have a thorough understanding of the completed whole”¹. It is especially important to have a vision of the completed outcome in the engineering industry (the book talks in reference to the aviation and automobile industry). This prevision “must occur as the originating act of the design process”². Therefore, these images speculate what an apartment assembly may look like with increased detail.

When the models were taken back into the digital sphere materials, windows and doors were applied. What happens when we envisage these assemblies with materiality? What happens when windows and doors are added? How does the composition translate from autonomous model to block assembly?

This arrangement attempted to express the various modules through a change in materiality for each. Doing this resulted in an unsuccessful and in-cohesive composition. There were too many elements clashing together, and so further façade attempts sought to refine this.

87. ►

88. ►

89. ►

1 (Kieran & Timberlake, 2004)

2 (Kieran & Timberlake, 2004)

Figure 86 - North view of material assembly test
Figure 87 - East view of material assembly test

Figure 88 - South view of material assembly test
Figure 89 - West view of material assembly test

VISUAL

Apartment aspect diagram

90. ▶

When designing apartments considering the aspect the dwellings is important for a variety of environmental factors including cross ventilation and daylighting.

For this project the developed units will ideally have either double aspect or corner aspect arrangements.

Figure 90 - Apartment aspect diagram

Inverted treatment : The courtyard

These diagrams explain a key turning point in the project – the courtyard.

These images express the various courtyard opportunities within a block typology. Instead of focusing on a central internal core as the earlier iteration did, this diagram shows how an internal courtyard can enrich the building. Not only does it create an outlook, and break down the block volume, it allows more opportunities for cross ventilation and outdoor wind protected areas. The courtyard creates a sanctuary in the city.

This uses the concept from Van Ecyk's Square the Breathes' diagram in a plan formation in contract to the 'expand and contract' diagram expressing it in elevation and section.

By extending to the boundary of a city site it utilises the land edges. It pulls the area of often unused corners into the centre, allowing the land to have more purpose. Instead of aggregating around a central core, this option allows aggregation to happen at the edges.

91. ▲

Figure 91 - 7x10 modules, 'C' shaped block, edge courtyards
 Figure 92 - 10x12 modules, central courtyard with edge indents
 Figure 93 - 4x6 modules, corner courtyard
 Figure 94 - 5x5 modules, sliced courtyard

SPATIAL

92. ▲

93. ▲

94. ▲

the siteless

Exploration : Part Two

Apartment module developments

Chapter Three

03.

- 3.1. Apartment development: *Single-story plans*
- 3.2. Apartment development: *Single-story interior*
- 3.3. Two-story development: *Models*
- 3.4. Two-story development: *Plans + Interiors*

Establishing the base module scale

Base generation

In order to transition the apartment block modules into apartment plans, a more detailed level of scale was needed. These six diagrams show the development of a 4.0m x 4.0m floor plate.

The development is based on a minimum bedroom size under the assumption that it is the smallest space within the home that would be enclosed by walls. This is except for the bathroom which would be installed as a bathroom pod with the ability to sit across the join of two floor plates once installed.

SPATIAL

95. ►

Figure 95 - Development of base module size diagram

1.

4.0m x 4.0m

2.

Offset 150mm for CLT wall

Note: There won't be CLT 165mm walls on all sides, but this accounts for other walls and CLT thickness variations.

3.85m x 3.85m

Base Module

3.

900mm corridor
2.95m x 2.95m

4.

9.0m²

*Area excludes 1800x600mm wardrobe.
Queen bed 2.0m x 1.5m*

5.

Stair Option #1

6.

Stair Option #2

Wardrobe under stair

Single-story apartment plan variations

A

96. **One Bedroom 48m² + 4m² terrace**

The smallest of the apartment typologies. A simple 3 block, single bedroom unit. Currently no fixed terrace, by 3 options as indicated.

B

97. **One Bedroom 64m² + 12m² terrace**

A larger one bedroom unit. Allows for full dining table, or study. Larger living space to suit a variety of occupants.

Note: Windows and doors are subject to change due to interlocking nature of the components. This varies on a site by site basis.

Courtyard Opportunity ■
Window / Opening ■

Figure 96 - Unit A Plan
Figure 97 - Unit B Plan
Figure 98 - Unit C Plan
Figure 99 - Unit D Plan

C

98. **One Bedroom 56m² + 12m² terrace**

This unit is designed to still provide light to living and bedroom via one balcony or courtyard. All other walls can be locked in and the space is still functional.

D

99. **One Bedroom 64m² + 16m² of terraces**

As above, this unit can function with one windowed courtyard. Additional exposed walls allow for additional daylighting.

Single-story apartment plan variations

E

100. Two Bedroom 64m² + terrace options

The first instance of using two ground panels as two bedroom plus bathroom. In this case a bathroom pod would be used to site across the ground panels (probably lifted in via the lift shaft) once floors are laid.

F

101. One Bedroom 64m² + Terrace options

A double curved dwelling, extensions of type B. No windows intersecting curved glazing.

Note: Windows and doors are subject to change due to interlocking nature of the components. This varies on a site by site basis.

Courtyard Opportunity ■

Window / Opening ■

Figure 100 - Unit E Plan

Figure 101 - Unit F Plan

Figure 102 - Unit G Plan

Figure 103 - Unit H Plan

G

102. **Two Bedroom 60m² + terrace options**

The transitional sister the unit E on the left. Basic square form with single curve and no replacement of cut.

H

103. **Two Bedroom 80m² + 12m² terrace**

A large open plan living space defines this iteration with a courtyard. It can be combined with elements from unit F (left) to add more curves and turn unit F into a two bedroom.

Single-story apartment plan variations

104.

Two Bedroom 80m² + 12m² of terraces

Dependant on neighbouring modules, unit 1 could have two courtyard spaces, creating the potential for a public and private outdoor space.

Note: Windows and doors are subject to change due to interlocking nature of the components. This varies on a site by site basis.

Courtyard Opportunity ■
Window / Opening ■

Figure 104 - Unit I Plan
Figure 105 - Unit J Plan

105. J Two Bedroom 80m² + 12m² terrace

Already incorporating a sun-room and outdoor space, unit J uses both parts of the sliced floor plate. The remainder small piece in the bedroom is less successful due to the tight corner produced.

Single-story apartment plan variations

106. **K** Two Bedroom 80m² + 16m² of terraces

Two-bedroom apartment, primarily orthogonal with wavy balconies made up of both cut pieces. Open plan living space with 2 bedrooms and bathroom.

Note: Windows and doors are subject to change due to interlocking nature of the components. This varies on a site by site basis.

Courtyard Opportunity ■
Window / Opening —

Figure 106 - Unit K Plan

107.

Three Bedroom 96m² + 16m² of terraces

A three-bedroom extension of model K. A third room is slotted into the entrance space, and the entrance door is shifted into the dining space.

Single-story apartment plan variations

108.

M

Two Bedroom 80m² + terrace options

Two-bedroom apartment, with large curved glazing area in living / dining space. The placement of the 'curve cut-off' makes it difficult for an effective plan. In this case it has been split between a bedroom and living space.

Note: Windows and doors are subject to change due to interlocking nature of the components. This varies on a site by site basis.

Courtyard Opportunity ■
Window / Opening ■

Figure 108 - Unit O Plan
Figure 109 - Unit P Plan

109.

N

Two Bedroom 92m² + terrace options

A more difficult form to assemble a functional plan within, however it also opened some interesting qualities such as a curved hallway wall. The design is anchored by 3 rooms, bedrooms and the kitchen, with the central area for living.

Single-story apartment plan variations

110.

Three Bedroom 80m² + 28m² of terraces

Three bedroom apartment with a large terrace. The third bedroom can be converted to a flex space or study through a folding door – the tenant would be able to build a more permanent wall if necessary.

Note: Windows and doors are subject to change due to interlocking nature of the components. This varies on a site by site basis.

Courtyard Opportunity ■
Window / Opening ■

Figure 110 - Unit O Plan
Figure 111 - Unit P Plan

111.

P

Three Bedroom 96m² + 12m² of terraces

A second three bedroom apartment with a long open plan living space. A glazed lounge, with a second intermediate space able to be a sun room, glass house, or outdoor terrace.

Single-story apartment interior

112. ▲

J

Two Bedroom 80m² + 12m² terrace

Atmosphere explored for the interior of unit J. The full height glazing leading out to private balcony. CLT timber ceiling, with raised flooring.

SPATIAL

Single-story Interiors

113. ▲

VISUAL

Figure 112 - Unit J detailed axonometric
Figure 113 - Unit J interior atmosphere sketch

Two bedroom

Single-story apartment interior

114. ▲

G

Two Bedroom 60m² + 20m² terrace

Apartment G plays with the effects of an exterior screen. This is for privacy and light and shadow purposes. In figure 116 you can begin to see the atmospheric effects of this.

SPATIAL

Single-story Interiors

115. ▲

VISUAL

Figure 114 - Unit G detailed axonometric
Figure 115 - Unit G interior atmosphere sketch

Two bedroom

Single-story apartment interior

116. ▲

K

Two Bedroom 80m² + 12m² terrace

Apartment K appears to have more timber prominence than the previous two images. The furniture selection does contribute to this, however there is a warmth within the space due to the depth and ceiling height.

SPATIAL

Single-story Interiors

Figure 116 - Unit K detailed axonometric
Figure 117 - Unit K interior atmosphere sketch

117. ▲

VISUAL

Two bedroom

118. ▲

Figure 118 - Two-story iteration diagram

119. ►

Figure 119 - Two-story assembly pieces

Two-story

The next series of designs took a succession of parts from the single-story test and assembled them into a two-story design. These are shown below. A two-story volume can bring light deeper into a space, whilst increasing a sense a spaciousness.

This series of modeling pieces (bar the curved wall) were laser cut (a similar process to CNC). These were then assembled into the following model series.

Double height individual models

120. ▲

Individual apartments

A series of 1:250 physical models were created to explore this design shift. The models are ordered by the first principle components of common urban apartment design. Using the ground plane, slab variations and existing buildings as the only variables.

Each iteration critically applies and rejects aspects of their predecessor. Beginning with a rectilinear apartment plan, exploring how individual complexities through right angles can allow for multiple apartments to interlock. The ground plan models introduce the repetition of a simple structural arch. This allows for

a solid foundation, while also encouraging maximum pedestrian opportunity on the ground floor. This arch language is then continued in the apartments, exploring how the whole can come together. Finally the offset is introduced into the final models, exploring how third spaces of social interaction might be interspersed throughout the eventual complex.

There is a quality evoked through these models that is a significant driver throughout the continuation of this thesis.

SPATIAL

Figure 120 - 2S: Iteration 1

Two-Story Models

121. ▲

122. ▲

123. ▲

124. ▲

125. ▲

126. ▲

127. ▲

128. ▲

129. ▲

A selection of iterations

Figure 121 - 2S: Iteration 1
Figure 122 - 2S: Iteration 2
Figure 123 - 2S: Iteration 3

Figure 124 - 2S: Iteration 4
Figure 125 - 2S: Iteration 5
Figure 126 - 2S: Iteration 6

Figure 127 - 2S: Iteration 7
Figure 128 - 2S: Iteration 8
Figure 129 - 2S: Iteration 9

Two-Story Models

130. ►

Figure 130 - Collage of
two-story set of parts
models

Two-Story Models

131. ►

*Figure 131 - Collective
images of two-story part
models*

Two-Story Models

▲ 132.

▲ 133.

▲ 134.

▲ 135.

Various assemblies of these models were tested (as shown). Experiments with an open ground floor were a common theme. Thin vertical combinations, contrast shorter block style assemblages.

In contrast to the single-story assemblies in the previous chapters, the double height volumes apply an increased level of complexity. The new set of parts allowed more opportunities when designing in section.

Figure 132 - Two-story assembly
with open ground floor V1
Figure 133 - Two-story assembly
with open ground floor V2
Figure 134 - Two-story assembly
with open ground floor V3
Figure 135 - Tower assembly

136.

Figure 136 - Variations of assembly
options for the two-story models and
parts.

Two-story plan variations

Q

Three bedroom 120m²

L1: 60m² + L2: 60 + 16m² of terraces

Two-story unit with double height living space. There is a bedroom that is on an mezzanine, overlooking the area below. The ground floor also has a office space with ground floor toilet. The second floor has two double rooms and a single room.

137.

Figure 137 - Unit Q plans for stories 1 and 2

Courtyard Opportunity ■
Window / Opening ■

Q

Unit Q axo render

Section cut at first floor

This axo shows the configuration of the first floor in axonometric. You are able to see the double height space in the lower left hand side of the image. There is a curved wall at the top of the stairs, that backs onto the upstairs shower.

138.

Figure 138 - Unit Q interior render

Two-story plan variations

Q

Unit Q ground floor axo

L1: 60m² + 16m² of terraces

Ground floor axonometric showing more detail of the space. There are two arches on the ground level. These act as space dividers. Furniture needs to be placed against the far wall in order for the glazing edge of the space to be a corridor.

139.

Figure 139 - Unit Q interior axonometric

Two-Story Apartments: Development

140.

Q

Unit Q interior

Ground Floor view

Figure 140 - Unit Q interior

Ground floor render, looking from kitchen into living space. Feature arch spanning across the room. An example of how it could be incorporated into an interior.

Two-story plan variations

R

Two bedroom 100m²

**L1: 56m² + L2: 44m² +
44m² of terraces**

This two-story, two bedroom unit is characterised by a double height exterior void. This void has a terrace at the bottom. There is a study and toilet, with open plan living and kitchen on the ground floor. Two bedrooms and a bathroom are upstairs.

141.

Figure 141 - Unit R plans for stories 1 and 2

Courtyard Opportunity ■
Window / Opening ■

R

Unit R axo render

Section cut at first floor

This axo shows the configuration of the first floor in axonometric. There is a second terrace on the ground floor, which is sheltered from above by a third terrace off the bedrooms.

142.

Figure 142 - Unit R axonometric render

143.

R

Unit R interior one

Ground Floor view

Figure 143 - Unit R interior render

Ground floor render, looking from living space into kitchen, sheltered terrace and peeking through to study. The kitchen has a rounded benchtop to ease the inhabitants through the space. Left to the stairwell, or right to the study and WC.

144.

R

Unit R interior two

Ground Floor view

Figure 144 - Unit R interior render

This second render is intended to show the curved balcony. These doors fold back to reveal the second ground floor outdoors space. Dependant on wind, rain, sunshine, or time of day - one should be suitable.

Two-Story Apartments: Development

S

Three bedroom 128m²

**L1: 64m² + L2: 64m² +
48m² of terraces**

This two-story, two bedroom unit is currently all angular, but a terrace on the ground floor could be adjusted.

There is one bedroom on the ground floor, along with an en-suite. The upper floor has a study, bathroom, two bedrooms and access to a optional third terrace.

145.

Figure 145 - Unit S plans for stories 1 and 2

Courtyard Opportunity ■
Window / Opening ■

S

Unit S axo render

Section cut at first floor

This axo shows both the ground floor and the first floor. Here you can see the left hand terrace on the ground floor has been turned into a sun room, or glasshouse. The second floor study space looks down over the stair.

146.

Figure 146 - Unit S axonometric render

147.

S

Unit S interior one

Ground Floor view

Figure 147 - Unit S interior render

This ground floor render shows a closed riser stair iteration. The kitchen at the rear of the image is boxed in under the stair, creating flush cabinetry to the ceiling. The double height living space allows twilight shadows to play upon the exposed timber.

Two-Story Apartments: Development

Multiple view of the same apartment,
but various stair options .

148

*Figure 148 - Interior view
of apartment 'Type S':
Cantilevered stair.*

149

*Figure 149 - Interior view
of apartment 'Type S':
Open riser stair.*

T

Three bedroom 136m²

**L1: 76m² + L2: 60m² +
64m² of terraces**

This two-story, three bedroom unit has a feature curved staircase. It is also the largest apartment, featuring a second living space / or rumpus room. One upstairs bedroom and two downstairs. There is a bathroom per floor. The rumpus room at the top of the stairs leads out onto a large terrace.

150.

Figure 150 - Unit T plans for stories 1 and 2

get

the parts

The Book of Parts

How to assemble and apply the system

Chapter Four

04.

4.1. Elements

4.2. Structure

4.3. Access

4.4. Courtyard

4.5. Program

4.6. Facade

4.7. Assembly

4.8. Visualisations

156 | Figure 156 - Cross-laminated timber parts

A book of parts

The *Book of Parts* is the conclusion to the initial site-less exploration phase. The following pages present a simple set of parts that can be assembled in various ways to create any of the apartment typologies explored within the previous pages as well as an infinite amount more.

This 'book' summaries and critically reflects on the site-less exploration research and proposes a framework to which a new modular design language of mass assembly can take place. This is then the precursor and transition period from site-less to sited.

Elements of Architecture

The following are vital elements of urban apartment design. Each is considered as the design research transitions from sited to site-less.

01 City context

A sited design needs to respond to the context of the city it is placed within.

02 Ground floor

A sited design needs a ground floor that communicates with the surroundings and considers pedestrians.

03 Facade

A façade needs to have a conversation with the surrounding language of the street.

04 Structure

In this case the structure will be prefabricated volumetric cross-laminated timber elements.

Figure 157 - Elements; city
Figure 158 - Elements; ground floor
Figure 159 - Elements; structure
Figure 160 - Elements; facade

elements

Cross-laminated timber parameters

It is important to note that the cross laminated timber produced in New Zealand (as of 2018) can only be produced within the bed parameters of 15m x 3.4m (XLAM). Therefore, the largest square panel would be 3.4m x 3.4m. For this thesis however, the largest square panel size is 4.0m x 4.0m. This was derived from the development of the optimised floor panel function (see page 70-71). Therefore, a CLT panel can be cut into 2.0m x 4.0m panels, and then assembled parallel spanning 4.0m between two structural walls. The additional 1.4m on the edge of the 2.0m cut or can also be left as a cantilevered balcony or access path.

Structure

The basic structural cross-laminated timber components used to assemble the apartment units are the following pieces. As explored in the previous chapter, the simple addition of the offset curve allows for interstitial space and variety in plan that otherwise doesn't typically exist.

-
- 01** The linear floor panel is a standard CLT floor panel CNC'd to size. 4.0m x 4.0m (or 2x 2.0m x 4.0m).
-
- 02** The offset floor is the first disruption in the design language. A square panel, with a corner to corner curve cut through it.
-
- 03** The wall is standard straight CLT panel CNC'd to length. Length 4m with a height of 3.5m.
-
- 04** The curved wall here is a theoretical element. Not currently in standard production, but a curved panel with a single radius can be made by Structurecraft, a Canadian timber engineering and construction firm
-
- 05** XLAM NZ produced an 'Air Stair' which is CNC'd out of a single block of CLT. This a structural stair and already prefabricated.
-
- 06** A stair in the offset position is not a common part, but this is able to be achieved by connecting individual risers in a circular array.

Figure 161 - Floor, linear
Figure 162 - Floor, offset
Figure 163 - Window, linear
Figure 164 - Window, offset
Figure 165 - Stair, linear
Figure 166 - Stair, offset

01
161.

floor

02
162.

wall

03
163.

stair

05
165.

04
164.

06
166.

-
- 07** The linear window is a square that reflects the underlying rigour that defines the initial floor plate.
-
- 08** The offset window, or curved window is a multiple panels of glazing. Commonly these will also include a door, so each panel is 1m wide.
-
- 09** In the situation where a square arch is required, a LVL or glue laminated beam will be used.
-
- 10** The curved arch is an element that can be used within an apartment, or in a grid to create an open ground floor.

Figure 167 - Window, square
Figure 168 - Window, curve
Figure 169 - Arch, curved

07
167.

window

08
168.

offset

A linear arch takes the form of a LVL or glue-laminated beam.

arch

09

10
169.

“The 1990’s brought architects’ obsession with CNC, but we were merely attempting to do analogue actions digitally.”

(Retsin, 2019)

CNC and CLT

This research has grown from advances in digital fabrication, specifically off-site CNC capabilities. It is important to note that it is not within the scope of this research to explore the methods of digital fabrication. Rather using its limitations as base for defining my own design parameters.

By applying this technology, this research also acknowledges an advance from the modernist ideas of assembly. Where mass-assembly lines prioritised efficiency of output, current flexibilities in manufacturing allow a conscious return to customisation in mass-production. This is an avenue that is directly explored through this research, question how we might begin to take advantage of the tools we have at our disposal today.

123.

Access

Types of apartment access and circulation.

01	Point vertical access
A vertical circulation system provides direct access to individual apartments
02	External gallery access
Apartments are entered from a corridor, usually external, on one side of the building
03	Skip-stop corridor
Corridors do not occur on every level and the elevator skips floors
04	Double-loaded corridor access
A corridor with apartments on both sides
05	Point vertical access (double)
A vertical circulation system provides direct access to individual apartments

Figure 170 - Skip-Stop corridor
Figure 171 - Point vertical access
Figure 172 - External gallery access
Figure 173 - Double loaded corridor
Figure 174 - Double point vertical

03
170.

01
171.

01.
point
vertical
access

02
172.

02.
external
gallery
access

04
173.

04.
double-
loaded
corridor

05
174.

05.
double
point
vertical

Courtyard

Variations of arranging apartment modules around open space.

01

Centre courtyard

Most commonly seen in European block housing, a central courtyard allows from cross ventilation and outlooks from both sides. Pressed to the edge of a site, it allows for a private community outdoors area.

02

Edge courtyard

The edge courtyard is implemented on a smaller site, in this diagram 20x20m. A courtyard like this is useful when there are neighbours on 3 of the 4 edges. This allows light to penetrate further into the volume.

03

Corner courtyard

A corner courtyard, again on a smaller lot, would be successful on a corner site. Peeking with a smaller reveal on the x axis (the busier street) and more open on the y axis (the quieter street).

04

Side courtyard

The side courtyard creates a 'C' shaped architecture. This can be focused to create shelter from winds and open up to the northern sun.

Figure 175 - Edge courtyard

Figure 176 - Central courtyard

Figure 177 - Corner courtyard

Figure 178 - Side courtyard

court-
yard

02.
edge
courtyard

01. centre courtyard

01
176.

03. corner courtyard

03
177.

04. side courtyard

04
178.

Interstitial program

01 Private outdoors space

A private outdoors space allows apartment living to merge with the ideal of the suburban lot. By having a large balcony, it imitates the private 'backyard'. Including outdoor dining, vegetable planters and potentially a green wall.

02 Shared laundry

A shared laundry saves space inside an apartment and creates a place to dry clothes outside of your apartment. This is especially important in winter when added humidity inside can contribute to health problems. It also creates an indirect place of community.

03 Shared workspace

A shared workspace within an apartment caters for anyone contracting, working from home, or student wanting a quiet study space.

04 Vegetable garden

Urban agriculture and ethics around food is a growing conversation. Having the facilities to grow your own food in a community is not only a place to interact with others, but also where knowledge can be shared through generations.

05 Playground

A simple structure like that of Aldo Van Eyck's playgrounds in the Netherlands post WWII. An opportunity to encourage outdoor play and families to live urbanely.

06 Miscellaneous space

Miscellaneous space can be used for a variety of programs. This can be an outdoor cinema, or café / retail space. These are areas to be fitted out by residents or businesses.

Figure 179 - Private outdoors space

Figure 180 - Shared laundry

Figure 181 - Shared workspace

Figure 182 - Vegetable garden

Figure 183 - Playground

Figure 184 - Miscellaneous spaces

01

179.

01.
private
outdoors

02

180.

02.
shared
laundry

03
181.

03.
shared
workspace

05
183.

05.
play-
ground

04
182.

04.
vegetable
garden

06
184.

06.
miscella-
neous

Facade variations

Variations of facade developments from Exploration: Part One.

- 01 Two wave panel**
Two angled CLT panel across one floor. Extruded outwards from the face, can also be inverted for a push and pull effect.

- 02 Two tone grid**
Expressing the module grid on the exterior of the building, a similar technique used in The Cube by Hawkins Brown. The 'wavy' apartment edges would sit behind and through the grid at various points.

- 03 Angled panel**
The angled panel is comprised of a single panel angled the length of a floor and rotated 90 degrees. This creates a faceted pattern.

- 04 Angled screen panel**
The angled screen panel is a screened version of 03. This removed the heavier structure from the façade edge, and instead creates a permeable relationship to the outside.

- 05 The weave**
The weave creates a wave formation horizontally. By offsetting each floor by a panel shift, the inverse is then created below. There is a strong sense of depth and shadow.

- 06 Extended angle**
The extended angle horizontally extrudes the angled panel. This allows for a housing module per panel.

Figure 185 - Facade: Two panel weave

Figure 186 - Facade: Two tone grid

Figure 187 - Facade: Angled panel

Figure 188 - Facade: Angled screen panel

Figure 189 - Façade: The weave

Figure 190 - Facade: Extended angle

01

185.

01.
two
panel
wave

02

186.

02.
two
tone
grid

03
187.

03.
angled
panel

05
188.

05.
the
weave

04
189.

04.
angled
screen
panel

06
190.

06.
extended
angle

131.

Comparing design language

When comparing design language, it is important to place this experimental set of parts within a context of existing ideas. The following precedents are key points of progression for autonomous, assemblage studies.

1. Maison Dom-Ino - Le Corbusier (1914-15)
2. WikiHouse - Alastair Parvin (2011)
3. Tallinn Architecture Biennale (TAB) - Gilles Retsin Architecture (2017)

01. Dom-Ino House, Le Corbusier, 1914-15

The Dom-Ino house model, developed by Le Corbusier is a prototype developed for mass-housing in the primitive days of the modernist movement. Comprising of three set parts; the slab, column and stair. The concept derived from classical orders of architecture, distilling a potential house down to its base tectonic elements. The system responds directly to the technological advances of the time, and visually represents this through its distilled visual language. The study allows for greater spatial freedom by removing all load bearing walls¹. The intentional focus on interior planning, compromises the role the wall plays as both a partition and a façade. This comes as a direct critique of the façade often being used as a symbol of wealth during much of the 19th century architecture. However, by removing the façade as a tool to engage with the public, the autonomous study fails to be critically applied in existing contexts. Consequently, we have seen various developer models take hold of the 'modernist style' and apply it poorly across cities all over the world. The model is now a poor excuse for what the base standards of a building are. Disregarding the visual and per-formative role the roof, and walls play in responding to peoples needs as well as broader urban needs.

1 (Le Corbusier, 2000)

Figure 191 - Maison Dom-Ino (Le Corbusier, 1914)

Figure 192 - Wiki-House Assembly (Parvin 2017)

Figure 193 - Gillies Retsin Pavilion Tallin (Retsin 2017)

02. WikiHouse, Alastair Parvin, 2011

Almost a century on, Alastair Parvins, WikiHouse, provides a more democratised addition to modular mass housing. The system allows for mass-customisation of simple parts via an open-sourced creative commons website². With each user requiring limited technology, they are able to draw and cut their own home. In theory. The idea introduces greater flexibility in how we perceive modular housing today. However, this flexibility comes at the cost of scale. Where the system at its best is a great solution for a custom backyard shed, and at its worst as a viable asset to a housing crisis.

03. Tallinn Architecture Biennale (TAB, Gilles Retsin Architecture, 2017)

Gilles Retsin architecture applies a similar technology to the customisation of its modular pieces. However, his pavilion applies a much larger focus on material efficiency. Utilising the technology to mass produce structural elements with maximum efficiency³. Retsin's pavilion is based upon just a few "lego like" pieces. They intend to act as both column, beam and cladding. Taking hold of Parvin's ideas of greater flexibility in how and where we manufacture. But, allowing the system to develop structural elements for much larger forms of construction. In doing so, the lego like approach again develops its own visual language based directly off of the system that creates it.

2 (WikiHouse Foundation, 2019)

3 (Retsin, 2019)

Images redacted, see print copy

01.

191.

02.

192.

03.

193.

All of these systems of parts explore a particular construction methodology autonomously. None of the above examples respond to the role of buildings becoming a suitable addition to an existing city. The Dom-Ino model turns its back to historic methods of visual language, while WikiHouse and Restins pavilion are both autonomous outputs, with little inbuilt flexibility to deal with how a streetscape might function. The book of parts developed in this thesis recognises the difficulties of successfully applying autonomous studies into existing situations. The research therefore develops a series of parts that both deal with the space and form each individual apartment, as well as the façade.

These images were developed from two different designs of a site-less assembly test. These were experiments to compose the developed 'pieces' including apartments, access and façades into a 'whole'. Again, these had a disjointed composition like when stacking apartments around a central core. This question of cohesion continued to plague the development. However, from these images we can begin to gain a sense of atmosphere and environment. Additional functions such as glass houses and shared central social stairwells were implemented.

-
- 01** Experiment Two: Site-less assembly test. A compositional assemblage and atmospheric response. View one.
-
- 02** Experiment One: Facade assemblage testing. View one. Colour and material contrasts to add contrast.
-
- 03** Experiment One: Facade assemblage testing. View two. Contrasting colour grid with early CLT 'wave' developments.
-
- 04** Experiment Two: Site-less assembly test. Glasshouses and arches. To many contrasting materials. View two.
-

Figure 194 - Site-less Visualisation One
Figure 195 - Site-less Visualisation Façade One
Figure 196 - Site-less Visualisation Two
Figure 197 - Site-less Visualisation Facade Two

01 / 194.

03 / 196.

02 / 195.

04 / 197.

198.

The final still from a conceptual GIF of 'assembling' a community apartment. Starting with the central circulation, various apartments are interlocked around this. Additional functions and programs are then slotted into the 'gaps', including vegetable gardens, patios and a playground. The facade then encloses this.

Figure 198 - Still from GIF of elements building together

get r
v

the sited

Site and Context

Analysis and Selection of Site Location

Chapter Five

05.

- 5.1. *From site-less to sited*
- 5.2. *Te Aro empty site mapping + studies*
- 5.3. *Te Aro existing apartment mapping*
- 5.4. *Site introduction: corner Taranaki and Frederick Streets*
- 5.5. *Early sited concept designs*

199.

site

200.

Figure 199 - Above: Aerial image of Wellington, New Zealand ▲
Figure 200 - Left hand image by James Coleman on Unsplash ◀
(Coleman, 2018).

201.

- ▲ *Figure 201 - Above: Aerial image of Wellington, New Zealand*
- ▶ *Figure 202 - Left hand image Wellington from airplane (both images authors own)*

202.

Images redacted, see print copy

203.▲

204.▲

*Figure 203 - Wellington City, Wellington. 0.1m Urban Aerial Photos (LINZ, 2017).
Figure 204 - Te Aro, Wellington. 0.1m Urban Aerial Photos (LINZ, 2017).*

From site-less to sited

When transitioning from a site-less concept design to sited design there are an array of factors to consider. The site-less is intended to satisfy any site condition, in contrast to a sited design which has a series of specific parameters.

The purpose of testing it on a site is to address how the conceptual development of a series of prefabricated parts can be assembled on site. This reiterates New Zealand's need to build 100,000 houses within 10 years .

Te Aro, Wellington

Te Aro is central suburb of Wellington City. As of 2013 it had a population of 9,700 people, and this is anticipated to increase by 56% over the next 30 years (2043). Compared to the wider Wellington region which is predicted to increase by 18%.

Te Aro is already a dense suburb (see figure on left). It is made up of residential and commercial buildings and is home to large selection of cultural venues, art galleries and eateries.

Te Aro site study

This map selected empty sites within the Te Aro suburb. These were analysed for their area. This was done to understand what scale to experiment with assembly aggregations.

205.▲

Figure 205 - Te Aro site study map

-
- 1.** ADDRESS
79 Dixon St
Te Aro, Wellington
- AREA
1789m²
-
- 2.** ADDRESS
36 Ghuznee St
Te Aro, Wellington
- AREA
1277m²
-
- 3.** ADDRESS
151 Cuba St
Te Aro, Wellington 6011
- AREA
1007 m²
-
- 4.** ADDRESS
48 Tory St
Te Aro, Wellington 6011
- AREA
718 m²
-
- 5.** ADDRESS
16 Holland St
Te Aro, Wellington 6011
- AREA
2722 m²
-
- 6.** ADDRESS
16 Bute St
Te Aro, Wellington 6011
- AREA
1137m²
-
- 7.** ADDRESS
87 Taranaki St
Te Aro, Wellington 6011
- AREA
1503 m²
-
- 8.** ADDRESS
24 Tennyson St
Te Aro, Wellington 6011
- AREA
296 m²
-
- 9.** ADDRESS
10 Alpha St
Te Aro, Wellington 6011
- AREA
928 m²
-
- 10.** ADDRESS
90 Tory St
Te Aro, Wellington 6011
- AREA
348 m²
-
- 11.** ADDRESS
31 Jessie St
Te Aro, Wellington 6011
- AREA
210 m²
-
- 12.** ADDRESS
14 Jessie St + 102 Vivian St
Te Aro, Wellington 6011
- AREA
811 m²
-
- 13.** ADDRESS
54 Vivian St
Te Aro, Wellington 6011
- AREA
347 m²
-
- 14.** ADDRESS
129/133 Taranaki St + 40-46 Frederick St
Te Aro, Wellington 6011
- AREA
1464 m²
-
- 15.** ADDRESS
30 Kent Terrace
Te Aro, Wellington 6011
- AREA
384 m²
-
- 16.** ADDRESS
59 Vivian St / 18 Frederick St
Te Aro, Wellington 6011
- AREA
1125 m²
-
- 17.** ADDRESS
40 Haining St
Te Aro, Wellington 6011
- AREA
240 m²
-
- 18.** ADDRESS
35 Kent Terrace
Te Aro, Wellington 6011
- AREA
1105 m²
-
- 19.** ADDRESS
24 Haining St
Te Aro, Wellington 6011
- AREA
231 m²
-
- 20.** ADDRESS
40/42 Kent Terrace
Te Aro, Wellington 6011
- AREA
884 m²
-
- 21.** ADDRESS
7 Frederick St
Te Aro, Wellington 60
- AREA
287 m²
-
- 22.** ADDRESS
200 Taranaki St
Te Aro, Wellington 60
- AREA
1246 m²
-
- 23.** ADDRESS
54 Webb St
Te Aro, Wellington 60
- AREA
503 m²
-
- 24.** ADDRESS
26 Martin Square
Te Aro, Wellington 60
- AREA
227 m²
-
- 25.** ADDRESS
54 Kent Terrace
Te Aro, Wellington 60
- AREA
1017 m²
-
- 26.** ADDRESS
175 Taranaki St / 65 M
Te Aro, Wellington 60
- AREA
1335 m²
-
- 27.** ADDRESS
224 Taranaki St
Te Aro, Wellington 60
- AREA
987 m²
-
- 28.** ADDRESS
7 Hopper St
Te Aro, Wellington 60
- AREA
587 m²

Te Aro site study analysis

Average area = **882m²**

▲ 206.

Lower Half (small area) average = **400m²**

▲ 207.

Figure 206 - Empty sites in Te Aro
Figure 207 - Lower area quartile of empty sites in Te Aro
Figure 208 - Upper area quartile of empty sites in Te Aro
Figure 209 - Diagram of module results

Upper Half (large area) average = **1302m²** ▲ 208.

▲ 209.

Large half average area = 1302m²
Small half average area = 400m²

Large = 3.25 x small

This study was done in order to understand the size and scale of existing opportunities within the Te Aro context.

Te Aro apartment study

This map looked at existing apartments. Their area, number of floors and open sides. This was done to create a picture of how existing apartments have responded to their context.

210. ▲

Figure 210 - Te Aro existing apartment study map

<p>1.</p> <p>ADDRESS The Peak Apartments 170 Taranaki Street Te Aro, Wellington</p> <p>AREA 560 m²</p> <p>NUMBER OF FLOORS 10</p> <p>NUMBER OF OPEN SIDES 4 - exception of ground floor</p>		<p>7.</p> <p>ADDRESS Soho Apartments 72 / 80 Taranaki Street Te Aro, Wellington</p> <p>AREA 1956 m²</p> <p>NUMBER OF FLOORS 15</p> <p>NUMBER OF OPEN SIDES 2 (floors 1-5) 4 (floors 6-15)</p>		<p>13.</p> <p>ADDRESS Bellagio Ataahua 39-43 Taranaki Street Te Aro, Wellington 6011</p> <p>AREA 586m²</p> <p>NUMBER OF FLOORS 12</p> <p>NUMBER OF OPEN SIDES 3.5</p>
<p>2.</p> <p>ADDRESS 153 Taranaki St Te Aro, Wellington</p> <p>AREA 978m²</p> <p>NUMBER OF FLOORS 8</p> <p>NUMBER OF OPEN SIDES 3.5 (4th side 1/2 open)</p>		<p>8.</p> <p>ADDRESS 25A Marion St Te Aro, Wellington</p> <p>AREA 720 m²</p> <p>NUMBER OF FLOORS 8</p> <p>NUMBER OF OPEN SIDES 3</p>		<p>14.</p> <p>ADDRESS 25 Taranaki Street Te Aro, Wellington 6011</p> <p>AREA 677 m²</p> <p>NUMBER OF FLOORS 16</p> <p>NUMBER OF OPEN SIDES 2 (bottom half), 4 (top half)</p>
<p>3.</p> <p>ADDRESS Croxley Mills Apartments 33 Haining St Te Aro, Wellington 6011</p> <p>AREA 796 m²</p> <p>NUMBER OF FLOORS 6</p> <p>NUMBER OF OPEN SIDES 1</p>		<p>9.</p> <p>ADDRESS 132 Vivian St Te Aro, Wellington 6011</p> <p>AREA 604 m²</p> <p>NUMBER OF FLOORS 8 (including open GF)</p> <p>NUMBER OF OPEN SIDES 4</p>		<p>15.</p> <p>ADDRESS One Market Lane 1 Market Lane Te Aro, Wellington 6011</p> <p>AREA 1344 m²</p> <p>NUMBER OF FLOORS 11</p> <p>NUMBER OF OPEN SIDES 4</p>
<p>4.</p> <p>ADDRESS The Wigan 8 Wigan St Te Aro, Wellington 6011</p> <p>AREA 719 m²</p> <p>NUMBER OF FLOORS 10</p> <p>NUMBER OF OPEN SIDES 4 (exception of ground floor)</p>		<p>10.</p> <p>ADDRESS 142 Vivian St Te Aro, Wellington 6011</p> <p>AREA 599 m²</p> <p>NUMBER OF FLOORS 6</p> <p>NUMBER OF OPEN SIDES 4</p>		<p>16.</p> <p>ADDRESS Gated Community 10 Ebor St Te Aro, Wellington 6011</p> <p>AREA 2 housing blocks = 1726 m² Full site = 6235 m²</p> <p>NUMBER OF FLOORS 8</p> <p>NUMBER OF OPEN SIDES 3</p>
<p>5.</p> <p>ADDRESS Tattoo Apartments 42 Abel Smith St Te Aro, Wellington 6011</p> <p>AREA 822 m²</p> <p>NUMBER OF FLOORS 4</p> <p>NUMBER OF OPEN SIDES 4</p>		<p>11.</p> <p>ADDRESS Victoria Street Precint 160 Victoria Street Te Aro, Wellington 6011</p> <p>AREA 1542 m²</p> <p>NUMBER OF FLOORS 12</p> <p>NUMBER OF OPEN SIDES 3</p>		<p>17.</p> <p>ADDRESS The Piermont 82 Cable Street Te Aro, Wellington 6011</p> <p>AREA 1444 m²</p> <p>NUMBER OF FLOORS 9</p> <p>NUMBER OF OPEN SIDES 2</p>
<p>6.</p> <p>ADDRESS 115 Vivian St Te Aro, Wellington 6011</p> <p>AREA 986 m²</p> <p>NUMBER OF FLOORS 7</p> <p>NUMBER OF OPEN SIDES 2.5</p>		<p>12.</p> <p>ADDRESS 83 Able Smith Street Te Aro, Wellington 6011</p> <p>AREA 222 m²</p> <p>NUMBER OF FLOORS 4</p> <p>NUMBER OF OPEN SIDES</p>		<p>18.</p> <p>ADDRESS 52 Cable Street Te Aro, Wellington 6011</p> <p>AREA 926 m²</p> <p>NUMBER OF FLOORS 9</p> <p>NUMBER OF OPEN SIDES 2 (with 2 light well insets on ott</p>

Te Aro apartment study

This map looked at existing apartments. Their area, number of floors and open sides. This was done to create a picture of how existing apartments have responded to their context.

Average Area:
1040m²

Average Height:
9.0

Average Open Sides:
3.0 (after an average of 2 floors)

Site selection

Te Aro empty sites

Te Aro existing apartments

Combined

35x27m

45x21m

*Overlay of both apartment
and site studies*

945m²

Site location

129 / 133 Taranaki St
Te Aro
Wellington

-41.296044,
174.777290

211.

Figure 211 - Te Aro, Wellington. Site within context (LINZ, 2017)

212.

Figure 212 - Site and surrounding property boundaries

213.

Figure 213 - Site location aerial image (LINZ, 2017).

214.

Figure 214 - 129/133 Taranaki Street overlay with site boundaries

Site selection + model

The proposed site is an empty lot on the corner of Taranaki and Frederick streets. The 129/133 Taranaki Street site is close to the city centre, schools, and public amenities such as waterfront parks, shopping areas and universities. The area of the site is 1464m², falling within the upper quartile of empty sites with the area. The site is also home to one of the last pieces of Chinese Heritage in the area, the 'Chinese Mission Hall'. It has a heritage listed façade, and the building is in disrepair.

There is cross connection through the west edge of the site. Frederick St is a one-way street, with Victoria also running one way in the same direction. This creates a dichotomy entering and existing the site via vehicle.

A site model was developed at 1:250 scale. The process of building the model helped to understand the site and the surrounding buildings, their heights and characteristics.

215. ▲

Figure 215 - Site model plan view

219. ▲
Figure 219 - View from Frederick Street

216. ▲
Figure 216 - Site model with Chinese Mission hall

217. ▲
Figure 217 - Site in reference to Vivian

220. ▲
Figure 220 - Chinese Mission hall street-front

221. ▲
Figure 221 - View from Taranaki St

218. ▲
Figure 218 - Site model perspective

Site shading studies

Maximum 30m

The maximum is extruding to the height of the 10 story apartment block corner Taranaki and Wigan Streets.

222. ▲

Figure 222 - Maximum height shading effects

Minimum 9m

If a 3 story medium density complex was to be designed. This proposes issues with density + site cost ratio.

223. ▲

Figure 223 - Minimum height shading effects

Chinese Mission Hall 40-46 Frederick Street

A series of questions arose around how to deal with the heritage value of the Chinese Mission Hall on the selected site. The following are a series of heritage points from the Wellington City council:

- Built in 1905 and designed by Frederick de Jersey Clere, this building has architectural value as a Gothic Revival style church.
- The building has historic value as one of just two buildings associated with Wellington's Chinese community still standing in the Haining/Frederick Streets precinct, once the centre of Chinese life in Wellington in the late 19th and early 20th centuries.
- The building has authenticity as its façade has retained a significant amount of its original fabric.¹

¹ (Wellington City Council, 2017, Chinese Mission Hall)

As you can see in the thought process below, demolishing the building was considered out of the question. The building is most definitely in a state of disrepair and needs work. Keep parts considered whether the building was to be maintained in spirit through keeping a community space on the existing area, or the façade of the building be incorporated into a new development. 'Keep' established that renovate with something a little but new was the best option.

Point three, 'Renovate + open up to allow cross programming' was the method which the final design employed. This maintained the heritage facade and the community ideals. By opening the sides of the hall a more versatile space was developed.

Question 1.

What to do with the existing church on site?

Question 2.

Keep: How to deal with the church in relationship to the new?

1. Restore facade with new open body

2. Restore full mission hall

3. Renovate + Open up to allow cross programming

224. ▲

Figure 224 - Chinese Mission hall options

225. ▲

Figure 225 - Chinese Mission hall on site model

Early sited design

The following pages detail a design that precedes all the previous work shown. It acted as a large learning curve in order to develop the research ideas. It is placed here as point of reflection before the final design.

Early sited design

Concept One

A low-rise medium density housing scheme was first proposed for the Te Aro site. This was a diagrammatic concept that took direction responses from the site, instead of from the CLT material.

Concept One proposed to aggregate the historic module of the Te Aro area - the worker cottage (3.3m x 5.2m). This was an attempt to also maintain the settler and pa heritage of the area.

“Te Aro is noted as one of the few remaining physical examples of working-class life and culture in New Zealand. This makes it incredibly important that efforts are made to preserve the heritage aspects, while accommodating the greater needs of the city, and the region.”

As you can see from the notes below, this initial design was concerned with how a developer might react to it. Comments on “ratio of dwelling to site cost” are a response to research on the value of the site, and thus the land cost per dwelling. Affordability began as a concern but this was primarily out of the scope of the project.

The smaller urban gain sought to emulate a suburban medium density townhouse typology. This was essentially a concept of the ‘minimum density’.

Smaller grain
Provides community feeling
Additional green space to the area.

Ratio of dwellings to site cost will not be sufficient
Surrounding building will be overpowering.
Light levels on ground floors will not be enjoyable for inhabitants.

226. ◀

Figure 226 - Early site design, concept one perspective

Early sited design

Renovate + Open

Minimum height
9m

Restore facade

Split volume
along length

Historic module

Original workers cottage.
Module 3300x5200mm

227. ▲

Figure 227 - Early site design, concept one diagram

2.

Early sited design

Concept Two

Concept two was primarily concerned with density and light. How can a appropriate number of dwellings be built, all with a good level of natural light.

The site was split along its width, creating two volumes connected by central circulation. The upper floors of these volumes were angled back on the north face to allow more light throughout the day.

At this stage a single leaf partition CLT method was being considered. This resulted in an apartment plan that looked like it could have been made from any construction method ... especially concrete (see next page). Along with the plan, the facade was also not reflecting any timber qualities - thus began the exploration into CLT tectonics.

The design built above the existing hall, but opened the rear of the building to the sky. This was done to employ a connection to the sky, and to the rest of the building. In hindsight this void would carry sound throughout the building and make the update hall hard to have acoustic privacy.

More likely to meet site cost to dwelling affordability.
More affordable to prefabricated with a larger set of repeating elements.

Effects on neighbours.
Large site coverage percentage.
Placement of crane for panels being erected etc.

228. ◀

Figure 228 - Early site design, concept two perspective

229. ▲

Figure 229 - Early site design, concept two diagram

230. ▲

Level 2

Figure 230 - Early site design, concept two plan

231. ▲

Generic Floor (levels 4/5/6)

Figure 231 - Early site design, concept two plan

Sketch renders

Exterior

232.

View looking to corner of
Taranaki St and Frederick
Street

Interior

233.

Internal view looking onto strip
balcony. Timber wall attempt.

Figure 232 - Early site design, C2, exterior render

Figure 233 - Early site design, C2, interior render

Perspective sections

A-A1
234.
Axo Floor Section
Level 3 - Residential

B-B1
235.
Axo Vertical Section
Centre of building

Figure 234 - Early site design, C2, A-A1
Figure 235 - Early site design, C2, B-B1

get

the sited

The Design Test

The Design Test : A Possible Answer

Chapter Six

06.

- 6.1. Site response
- 6.2. Exterior and Entrance
- 6.3. Plans
- 6.4. Perspectives + Details
- 6.5. Facade

The Design Test

The Test is where the *Book of Parts* is implemented. This is done on a selected site, with a specific set of limitations, inhabitants and functions. Here the question ‘how does this design language come together?’ is explored.

wavy

A.

A note on apartments

All internal partitions of the designs are non-load bearing walls; therefore, it becomes easier to create a flexible plan within your own ownership area. In contrast, it becomes much harder to extend the existing boundary of the apartment as that would require piercing a structural CLT wall, which is very hard to do in-situ. The apartments vary in size throughout the development, therefore if you require more space in theory it would be possible to find a size that suits your new living situation within the same complex.

B.

A note on services

Each apartment is located next to a service riser or within proximity to one. This allows the services that run underneath a raised floor (horizontal) to connect to the vertical riser and then into a services room.

C.

A note on interiors

The atmospheric qualities of each interior were strong drivers for the arrangement of the apartments. Various images were produced at different times of the day to understand how the formal shape and glazing arrangement effected the interior space.

D.

A note on layout

The layout of the site, and the courtyard allows the apartments to sit in a singular depth. This allows for cross ventilation to draw fresh air through the apartment. It also allows for private and public outdoor space.

Four key decisions

In alignment with the book of parts, and the site decisions in the previous chapter, below are the broad design decisions.

236.

Site Response

Height of building will be sympathetic and fit within its context.

238.

Heritage Response

Maintaining the same revitalisation strategy as initial concepts.

237.

Site Configuration

Side courtyard variation due to the proportions and orientation of the selected site.

239.

Access and Circulation

External gallery access in response to the height courtyard type.

Figure 244 - Site Response

Figure 245 - Site Configuration

Figure 246 - Response to Heritage

Figure 247 - Access and Circulation

Site response

1.

Location: The site is in a dense area of Te Aro, Wellington. It is located on the corner of Taranaki St and Frederick Street. It is in proximity Cuba Street, a hub for the arts, cultural activities and various coffee shops and eateries.

240.

2.

Location: The surrounding buildings are residential and commercial. A series of apartments on the opposite side of Frederick St, and hostel accommodation on the opposite side of Taranaki St.

241.

3.

Heritage: Located on the site is one of the last pieces of Chinese Heritage. The facade of the Chinese Mission hall is heritage protected. Historically it has been a place of community, from a community hall to the home of Wellington's 'Light and Sound Exploration Society'.

242.

4.

Shadow: As the site sits on the southern side of a five-story building, there is a shadow cast from the morning through till just after midday. This building is currently an empty commercial building. Potential development include a student residence or refurbished offices.

243.

244.

5.

Area: The total area of the site is 1500m². The height has been determined by the surrounding buildings in order to adhere to neighbourhoods' grain of development. Providing appropriate density with respect to the neighbouring inhabitants.

245.

6.

Courtyard: 500m² has been allocated for the mission hall and the central courtyard. This punctures the side of the volume allowing more surface area for increased natural light penetration.

246.

7.

Access: For access into the dwellings a single point vertical access with external gallery connection horizontally has been employed. There is a stair that runs up alongside the lift shaft that is accompanied by larger landings for shared gardens.

247.

8.

Services: Services run under the floors of each of the units, these then connect into one of four vertical service risers.

248.

180. **get wavy** : *Introducing irregularity into modular timber housing*

◀ *Figure 248 - View from Frederick Street into central courtyard. Envisages a changes to Frederick St that allows the landscape to bleed into the one-way street.*

▶ *Figure 249 - View from Vivian Street lane way entrance into central courtyard. Light able to pour down 'gaps' within structure.*

Entrance

The entrance from Taranaki Street, a lane way which leads you into the central courtyard. This pathway transitions from a concrete foundation into a timber slated walkway. This walkway is elevated above the grassed area below. This creates a distinction between the primary access route to the circulation (green door on left side background) and the courtyard space.

249.

Ground Floor

Summary

Retail Spaces x 2

Communal

- Garden courtyard
- Revived hall space
- Bike storage
- Shared electric car charging stations

2 x apartment entrances.

- 2 x 1 bedroom
 - 10. 54m² + 16m² terraces
 - 11. 60m² + 19m² terraces

-
01. Retail space off Taranaki Street, small boutique space that has a store room. Access to the courtyard through rear doors. Mainly intended as a destination goods retailer.
 02. Second retail space is intended for a cafe or coffee shop. The space allows a flow through to the outdoor dining space.
 03. The lane way entrance off Taranaki. This allows the building to act as acoustic barrier to the road noise. The lane way creates a moment of compression and release as you enter the block and leads you into the courtyard.
 04. The courtyard features two deck areas, one connected to the cafe space and one off the reconstructed hall space. Between these two social

spaces is a series of gardens and grass. This is there to create a pleasant outlook from the apartments above.

05. The pathway continuing from the Taranaki entrance creates direct route to vertical access core.
06. Bike storage to encourage sustainable city living, these space could also include additional ground floor storage for each apartment.
07. Access core, including elevator and stairwell. Single stair access therefore apartments are sprinkled for fire safety.
08. Restored Chinese mission hall. The hall opens onto a more private outdoor space (screened by planting from the cafe space). The glazed and frosted roof creates a light space to inhabit as a shared meeting space.
09. Private ground floor area, no public access.
10. Ground floor apartment : A single bedroom accessible apartment for a couple, or an elderly couple / single.
11. Same as above.
12. Shared electric car parking space for three cars. No underground car park has been included in this development due to them being "hella expensive".
13. One way car and service access, entrance off Frederick Street continuing through to Vivian St.

Taranaki St

Frederick St

250.

Figure 250 - Ground Floor

First Floor

Summary

Communal

Balcony and kitchen space
Vegetable glasshouses

4 x apartment entrances.

04. Three bedrooms - 96m² + 32m² terraces

05. Two bedroom - 97m² (over two floors)
L1 56m² + L2 41m² + 44m² terraces

06. Two bedroom - 80m² and 32m² terraces

07. One bedroom - 64m² + 16m² terraces

01. Communal balcony and area that overlooks Taranaki Street. It receives afternoon sun and would be an enjoyable space to inhabit after work or on the weekends for shared dinners.

02. Communal kitchen space. During the day can be used as a shared workspace, can be rented out for education classes etc.

03. Core circulation with dual access to a family apartment, both shared glasshouses and kitchen, and three apartments.

04. A single-story family apartment with three bedrooms. Open plan living with balcony spaces on three sides.

05. A double story two-bedroom apartment, with its ground floor on the first floor. Three outdoor spaces, one private one for morning sunlight, one for midday light looking into the courtyard and afternoon light looking over Frederick Street.

06. A single-story apartment with two bedrooms. Private outdoor space overlooking rear lane way, and entrance courtyard on northern side.

07. One bedroom dwelling with a vegetable glasshouse next to the circulation space.

251.

Figure 251 - First Floor 1:200

2.

Second Floor

Summary

6 x apartment entrances.

01. One bedroom - 48m² + 12m² terrace

02. Three bedroom - 120m² (over two floors)
L1 60m² + L2 60m² + 18m² of terrace

03. Three bedroom - 96m² + 28m² of terrace

04. Two bedroom - 60m²

05. Three bedroom - 132m² (over two floors)
L1 64m² + L2 68m² + 16m² terrace

06. Three bedroom - 108m²

07. Second Floor.

Two bedroom - 97m² (over two floors)
L1 56m² + L2 41m² + 44m² terraces

01. Single bedroom apartment with north facing terrace.

02. Double height apartment with feature curved CLT staircase. Terraces facing into courtyard.

03. Three-bedroom, single story apartment with private glasshouse or sun room on courtyard side.

04. Single floor two bedroom, an efficient 60m² with no private terrace but area of additional space onto walkway.

05. Two-story apartment with double height living space with a large sheltered outdoor dining space.

06. Three-bedroom single story dwelling, with long open plan living and dining space.

07. The upper half of a two-story dwelling containing the bedrooms, a bathroom and two terrace spaces.

252.

Figure 252 - Second Floor

3.

Third Floor

Summary

5 x apartment entrances.

01. One bedroom - 48m² + 20m² terrace

02. Second Floor.

Three bedroom - 120m² (over two floors)
L1 60m² + L2 60m² + 18m² of terrace

03. Three bedroom - 120m² (over two floors)
L1 60m² + L2 60m² + 41m² of terrace

04. Two bedroom - 103m² (over two floors)
L1 58m² + L2 45m² + 24m² terrace

05. Second Floor.

Three bedroom - 132m² (over two floors)
L1 64m² + L2 68m² + 16m² terrace

06. Two bedroom - 124m² (over two floors)
L1 64m² + L2 60m² + 12m² terrace

07. One bedroom - 60m² + 12m² terraces

01. Single bedroom apartment with long balcony looking over Taranaki Street.

02. Second floor of apartment. Two bedrooms, bathroom and hallway study nook.

03. Ground floor of a two-story dwelling. Private terrace opening up to northern sun.

04. Ground floor of two-story apartment with a feature inset curved glazed window.

05. Second floor of two-story apartment. Hallway study space looks over stairwell and double height living space.

06. Ground floor of apartment featuring private terrace overlooking back lane way. Shared vegetable planter at entrance.

07. Single story, one bedroom with views onto Frederick Street. Dining space is a sun room, with private outdoor terrace on rear side.

253.

Figure 253 - Third Floor 1:200

4.

Fourth Floor

Summary

3 x apartment entrances.

01. Three bedroom - 108m² + 28m² terrace

02. Second Floor.

Three bedroom - 120m² (over two floors)
L1 60m² + L2 60m² + 41m² of terrace

03. Second Floor.

Two bedroom - 103m² (over two floors)
L1 58m² + L2 45m² + 24m² terrace

04. One bedroom - 60m² + 12m² terrace

05. Second Floor.

Two bedroom - 124m² (over two floors)
L1 64m² + L2 60m² + 12m² terrace

06. Two bedroom - 76m² + 28m² terrace

01. Family three bedroom apartment spread across a single story. Large private outdoor terrace as well as large entrance space.

02. Second floor of apartment. Two double bedrooms, a single bedroom, bathroom and sun room or temperate garden space off master.

03. Second floor of dwelling with two bedrooms and a bathroom. Shower has feature curved wall.

04. Single level, one bedroom apartment. Had as sun room space, connecting through to dual outdoor spaces. One common, and one private.

05. Second floor of two-story apartment. Two bedrooms, one bathroom.

06. Two bedroom apartment with dual private outdoor spaces. Dining space (as shown, or could be living) acts as sun room with glazed exterior.

254.

Figure 254 - Fourth Floor

255.

Figure 255 - Full building section showing various thicknesses between double units and single units and relationship between east and west wings with courtyard.

256.

Figure 256 - Double outdoor space apartment, looking out onto rest of complex. Balcony curving into interior of apartment. With stacking concertina doors either side.

257.

Roof Connection:

1. Finish with concrete tiles, 500x500
2. Nurajack floating deck system
3. Waterproof membrane
4. Rigid insulation 200mm, falling to 100mm.
5. XLam CLT/3 165mm, exposed as ceiling finish.

258.

Figure 257 - Building Section Detail - Part One 1:50.

Figure 258 - Building Section Key - Not to scale

259.

Figure 259 - Double outdoor space apartment, looking out onto rest of complex. Balcony curving into interior of apartment. With stacking concertina doors either side.

260.

Floor Connection:

1. 10mm parquet flooring
2. 10mm plywood
3. 200x50 floor joists
4. 200mm cavity for services w insulation
5. XLam CLT/3 165mm, exposed as ceiling finish.

Figure 260 - Building Section Detail - Part Two 1:50.

261

Figure 261 - Interior view of apartment type J. Open plan living area and large window provide for a sunlit space that opens onto a private terrace.

262.

Wall Connection:

1. Herman Pacific Board and batten weather-board
2. Aridon wall system 60mm
Rigid insulation, weatherproofing and cavity batten
3. XLam CLT/3 105mm, exposed as interior finish.

Figure 262 - Building Section Detail - Part Three 1:50

263

Figure 263 - Interior view of apartment type J. Open plan living area and large window provide for a sunlit space that opens onto a private terrace.

264.

Balcony :

1. 30/80mm cedar decking
2. Nutradeck floating deck system
3. Waterproof membrane
4. XLam CLT/3 165 Floor Panel, exposed underneath.

Balcony Edge

Straight: 20mm horizontal cedar cladding
Curved: Aluminium flashing powder-coated white

Figure 264 - Building Section Detail - Part Four 1:50.

265

Figure 265 - Interior view of apartment type J. Open plan living area and large window provide for a sunlit space that opens onto a private terrace.

266

Figure 266 - View from Frederick Street, looking into courtyard. Planter acting as a divider between the grass area the connects to cafe, and the outdoor seating of the renovated Chinese Mission hall.

267

Figure 267 - Interior view of the renovated Chinese Mission Hall. A glazed section of roofing has been added to bring additional light into the space. Large doors now open up to a deck with seating.

268

Figure 268 - View of the communal balcony overlooking Taranaki Street. Plants act as acoustic and visual barriers from the traffic below. It is placed to receive northern sun and a space for all residents to enjoy.

269

Figure 269 - View from the western wing walkway back across the development.

The Circulation

The access and circulation for the building is oriented around a single point of vertical access. Horizontal movement employs a 'streets in the sky' approach, made popular through the 1960's by prominent British architects Alison and Peter Smithson. This tactic sought to re-imagine mundane circulation routes as moments of social interaction, capturing the magic of street activity, but within a dense urban context. This is shown through the design, with direct emphasis being placed on the amount of space and quality of space throughout the circulation routes. Another key precedent is the Leth and Gori 'Very social housing'. Where the core is recognised as a primary point of interaction, and is therefore designed in response to this.

Very Social Housing LETH & GORI + Bessards Studio

Unbuilt - Copenhagen, Denmark
2014

Leth & Gori's 'Very Social Housing' was used as a key precedent for the development of the central core of the apartment block. The idea of this part of the project is to bring shared social spaces into shared access. This is where the most interactions are likely to occur and develops a sense of community around the stair.

Small details such as a bench seat outside the entrance, double height common area volumes and winter garden spaces all make the space enjoyable to inhabit (see perspective section).

"In addition the vision focuses on the strong connection between the project and the city and the potential to cultivate this connection in a way where the inhabitants and the city benefit from each other. We are interested in shifts in the hierarchy between the private and the public sphere and the potential these shifts have to create life and interaction."

(Leth & Gori, 2014).

Image redacted, see print copy

270

*Figure 270 - Perspective section - Common stairwell.
(Leth & Gori Architects, 2014).*

271.

Figure 271 - Facade close up, Frederick Street, closing panels

Figure 272 - Facade close up, Frederick Street, opening the panels

The Facade

273.

274.

The façade was a challenging design component of this sited study. Due to the structure and configuration having priority at the beginning of the design the façade was something that in the end, came secondary. Although many studies had been conducted at the beginning of the research there was a lot more required than simply selecting one. Achieving a successful composition and balance in the façade was a major difficulty. Attempting to strike a balance between breaking down the formal mass of the building and splitting up the façade types. Questions arose such as; how dominating will the façade be? Is the priority to express the structure or add interest with façade too?

Precedents and formal rules were applied in order to test out different iterations.

The final façade design developed from considering the facade not as a static element, but as a movable object. Something that has a life of its own. Therefore, the façade design as illustrated begins to work with the building and the structure even though it is essentially a separate entity. The operable shutters breathe a life into the building, creating a third dimension of movement and inhabitation. It controls light and privacy from the interior and expresses the weather and sneak peaks of timber from the exterior. The folds of the screen are an extension of 'The Weave' façade iteration.

Figure 273 - Facade testing one

Figure 274 - Facade testing two

275. Taranaki Street elevation

276. Frederick Street elevation

Figure 275 - Taranaki street elevation
Figure 276 - Frederick street elevation

get

the final notes

Conclusion

Evaluation and Final Notes

Chapter Seven

07.

7.1. Conclusion Overview

7.2. Looking Backwards : In reflection

7.3. Looking Forwards : Further development

Louis Kahn: When you want to give something presence, you have to consult nature. And there is where design comes in. If you think of **clt** , for instance, you say to **clt** , “What do you want, **clt** ?” And **clt** says to you, “I like an arch.” And if you say to **clt** , “Look, arches are expensive, and I can use a concrete lintel over you. What do you think of that, **clt** ?” **brick** says, “I like an arch.”

Adapted from original quote by Louis Kahn

Like the brick, cross-laminated timber is a material that needs to be ‘honoured’. It has its own unique opportunities and can do more than what its rectilinear form implies.

Louis Kahn: And it’s important, you see, that you honor the material that you use. You don’t bandy it around as though you said, “Well, we have a lot of material around. We can do it one way, we can do it another.” It’s not true. You can only do it if you honor the **clt** , and glorify the **clt** , instead of just shortchanging it.

Conclusion

Overview

So, how can a diverse and modular, timber design language improve urban housing?

This thesis explores the visual and spatial opportunities of cross-laminated timber in urban medium-density housing. In doing so, the research directly critiques the status quo of urban housing in New Zealand. There is a current pressure to produce a large quantity of residential buildings across New Zealand's major centres. It is therefore a necessity to research and critique the way in which we do this.

The thesis does this through the perspective of cross-laminated timber. Taking the assumption that more sustainable material choices, such as CLT, are an inevitability in the industry. The research explores how we utilise this in urban housing, specifically exploring the visual and spatial opportunities that the material has. The researches design-led methodology enabled a broader discussion on the way we respond to New Zealand's imminent housing crisis. The following chapter summarises each of the steps taken towards answering the research question.

Concluding reflections

C1. The opening chapter reviews and critiques existing issues with CLT construction. Recognizing the innovative approaches to its structural implementation, while still following the familiar visual language pattern of post and beam buildings. This formed the base of the primary research question; how can a diverse design language of engineered timber improve modular medium density housing?

C2. The Exploration - parts one and two, explored a variety of interlocking forms both digitally and physically. A primary finding from these studies was the introduction of intentional interstitial space. Third spaces between and around apartments, allowed for the spatial and visual variety necessary for urban living. This contrasted heavily with an early-sited study, which prioritized economies of scale and density over the value of quality light and space.

C3. This study expanded single story and two-story apartment designs. Here, the interior quality of space was experimented with through the medium of interior renderings. Each apartment was made from the same series of CLT components, however their spatial and visual opportunities when placed within a complex were richer due to the small offsets. The efficiencies of material remained a constant criterion throughout the experiments; however, a greater emphasis was placed on internal quality of light, space and atmosphere. As opposed to maximum density, this chapter began to explore how the intangible qualities of an apartment are as important to human health and well-being as ensuring maximum profit per square meter. This research does recognize the relative freedom regarding density; however its scope remains on how flexibility of space can be achieved through modular methodologies.

C4. The CLT components developed in the prior chapters are laid out in Chapter Four: The Book of Parts. This section acts as a visual guide, and an important step towards the application of the modular system in an existing urban context.

C5. Chapter Five: Site-less to Sited introduces the Te Aro site, and the contextual implications of it. The first sited iteration aimed to maximize the number of dwellings, while remaining economically viable as a housing complex. This design, however, failed to capture the opportunities of using CLT as a structural system, instead coinciding with existing timber trends. The complex did not explore the spatial opportunities possible for urban housing, continuing a trend of mass housing. This design experiment led to broader questioning of how we house people in New Zealand cities. Te Aro specifically is on the cusp of a large densification and therefore is used as a location to imagine how we might begin to house people today. This led to the changes implemented in the final sited study.

C6. The final design intervention embraces the spatial and visual opportunities of CLT, explored in-depth through chapters two through four. It brings together the most successful of the diverse one and two-story dwellings above a considered ground floor. The proposal combines the modular set of parts into a housing complex for an existing urban location. Introducing a spatial and visual diversity into modular CLT construction. This is evident through the floor plans and visual representation. This transition from autonomous to sited is the primary point for further research. The intricate apartment arrangements are successful when combined in small numbers. However, this methodology was less successful when applied to the scale of the full block. An intermediate massing strategy which connected the small-scale apartment combinations with the large-scale block strategy would have aided the overall design response. Allowing the scheme to better deal with existing site complexities such as the Chinese mission church.

277

Figure 277 - Exterior render of courtyard from Frederick Street.

Concluding reflections

This thesis recognises that the contemporary housing demands we are currently faced with in New Zealand may not last forever. If we are to intervene in our cities, it must be done with the next hundred years in mind. Therefore, the housing explored in this research emphasises housing as a home. Housing as a place where people live. Housing not as a numerical figure, thrown around as an attempt to solve social issues. Tied to our problems with housing people, are equally large problems of mental health in New Zealand. Having a quality place to live is a root to this issue. This was a primary finding from the first design investigation on site. Where there was a larger focus on striking a balance between monetary input and density outputs. The second design investigation, 'get wavy', sought to place people at the forefront of the design. By introducing small offsets into the design language; space, light and material become the key considerations for each apartment design. Aligning with the initial objectives of the thesis, which were to research how moments of spatial and visual flexibility can be introduced into a prefabricated and modularised housing system.

The second objective of the research was to explore the visual language of a structural panel system, as opposed to a post and beam system. Recognising the implications this change in structure can have on the visual language of a building. Without the need for direct load transfers due to the CLT floor panels, the façade and internal arrangements of each building can be manipulated with. The research spatially explores this through a small offset in an otherwise rectilinear grid. This small offset, allows for a shared garden between two apartments, a communal courtyard between five and a rich visual identity for the entire complex. The small offset is derived from the ease of which it can be produced via a CNC machine. Adhering to the specific nature of how a CLT panel is produced. Exploring this specific material is not a matter of subjectivity, but rather a necessity for our urbanising world. The impact the construction industry has on the environment is only going to increase, therefore research must be done into how we can implement the most sustainable materials we have on offer.

Contrast between start and end of design research

279

Figure 279 - Plan view, apartments are straight units. Determined by grid, and CLT system. Everything appears sharp and individualistic.

278

Figure 278 - Variation in plan, single and two-story dwellings interlock. The irregular nature of the apartments contributes to more outdoor spaces, both private and shared.

Note: Exterior render made black and white to understand formal expression more clearly

Conclusion

280

Figure 283 - Exterior render, early design concept two: single-leaf apartment partition and straight balconies causing a linear slab extrusion. Rectangular doors and windows contributing to a column and beam homogeneity.

281

Figure 282 - Exterior render from the final design. The ground floor has more variation, as with the form. There has been facade consideration, and consideration from the human perspective.

282

Figure 281 - Interior render from early design, concept two: Showing simple rectangular CLT cut for straight balcony.

283

Figure 280 - Interior render from the final design. Showing arch way traversing through the dining space. Through to double height curved living room.

Further research

The use of engineered timber to build more medium-density homes in New Zealand is a critical step towards sustainable construction practices. Practices that benefit our cities and the environment.

The design research focused very heavily on apartment composition, both spatially and internally. This resulted in an imbalance with the overall composition when assembled together. The exterior did not match the quality of the interior spaces explored. This is due to the tight urban complexities that the project faced. None of the precedents researched engaged with a complex urban site. Therefore, a key point to research for further set of part designs, is how to engage with a dense urban context.

Evoking the qualities of timber was another important driver for the development of the interior. This did not manifest successfully on the Taranaki street façade. Another point for further research is how the irregular modular system can be expressed to the street in an honest and coherent manner.

This thesis seeks to provide a tangible vision for how we can build alternatively and hopes to educate and advocate for more sustainable choices in the built environment. Sustainable choices that are functional, desirable and indisputable.

Conclusion

“Before us then we have immense challenges in housing burgeoning urban populations and mitigating environmental disaster, but also fantastic opportunities - **we have a new architecture to discover.**”

Andrew Waugh

Thistleton + Waugh Architects

Forward for SolidWood (Mayo, 2015)

Bibliography

- Bergdoll, B., Christensen, P., Broadhurst, R., & Museum of Modern, A. (2008). *Home delivery : fabricating the modern dwelling / Barry Bergdoll and Peter Christensen ; [edited by Ron Broadhurst]*. New York: New York : Museum of Modern Art.
- Corbusier, L. (2000). The modulator : a harmonious measure to the human scale, universally applicable to architecture and mechanics / by Le Corbusier. In: Basel ; Boston : Birkhäuser.
- Eaqub, S. (2015). *Generation rent : rethinking New Zealand's priorities / Shamubeel Eaqub and Selena Eaqub*: Wellington, New Zealand : Bridget Williams Books.
- Esbjörnsson, A., Magnusson, P., & Ford, J. (2014). *URBAN TIMBER: a resilient timber architecture in the city and a vision for mass customization*. (MSc in Architecture), Chalmers University of Technology, Göteborg.
- Forestry Owners Association, (2017). *Facts & Figures 2016/17: New Zealand Plantation Forest Industry*. Retrieved from https://www.nzfoa.org.nz/images/stories/pdfs/Facts_Figures_2016_%C6%92a_web_version_v3.pdf
- Green, M. (2017). Tall wood buildings : design, construction and performance. In ProQuest & J. Taggart (Eds.): Basel, Switzerland : Birkhäuser.
- Guy, A. (2018). New \$20 million Red Stag plant to create 40 jobs in Rotorua region. New Zealand Herald. Retrieved from https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12008847
- Hafner, A., & König, H. (2018). Life-cycle assessment. In H. Kaufmann, S. Krötsch, & S. Winter (Eds.), *Manual of multi-story timber construction*. Munich: Detail Business Information GmbH, Munich.
- Huang, L., Krigsvoll, G., Johansen, F., Liu, Y., & Zhang, X. (2018). Carbon emission of global construction sector. *Renewable and Sustainable Energy Reviews*, 81(P2), 1906-1916. doi:10.1016/j.rser.2017.06.001
- Kaufmann, H., Krötsch, S., & Winter, S. (2018). *Manual of Multi-Story Timber Construction* (Vol. 1). Munich: Detail Business Information GmbH.
- Kieran, S., & Timberlake, J. (2004). *Refabricating architecture : how manufacturing methodologies are poised to transform building construction*. New York, N.Y. ; London: McGraw-Hill.
- Krötsch, S., & Huß, W. (2018). Structural components and elements. In H. Kaufmann, S. Krötsch, & S. Winter (Eds.), *Manual of multi-story timber construction*. Munich.
- Krötsch, S., & Müller, L. (2018). The development of multi-story timber construction. In H. Kaufmann, S. Krötsch, & S. Winter (Eds.), *Manual of multi-story timber construction*. Munich: Detail Business Information GmbH, Munich.
- Lehmann, S. (2012). Developing a prefabricated low-carbon construction system using cross-laminated timber (clt) panels for multistorey inner-city infill housing in australia. *Journal of Green Building*, 7(3), 131-150. doi:10.3992/jgb.7.3.131
- Lehne, J., & Preston, F. (2018). *Making Concrete Change Innovation in Low-carbon Cement and Concrete*. Retrieved from <http://www.chathamhouse.org/sites/default/files/publications/2018-06-13-making-concrete-change-cement-lehne-preston-final.pdf>
- Mayo, J. (2015). *Solid wood : case studies in mass timber architecture, technology and design / Joseph Mayo*: New York : Routledge.
- McCarter, R. (2015). *Aldo van Eyck / Robert McCarter*: New Haven, CT ; London : Yale University Press.
- Menzies, E. (Unknown). 'Progress' v 'Preservation'; A history of Te Aro, Wellington.
- MGA, & Architecture, M. G. (2017). *The Case for Tall Wood BuildingsHow Mass Timber Offers a Safe, Economical, and Environmental Friendly Alternative for Tall Building Structures* (Second Edition ed.).
- Ministry of Housing and Urban Development, (2018). Ki-wibuild. Retrieved from <https://www.hud.govt.nz/residential-housing/kiwibuild/>

- Motu Economic and Public Policy Research. (2008). *Housing markets and migration: Evidence from New Zealand*. Retrieved from <https://www.mbie.govt.nz/dmsdocument/1092-housing-markets-and-immigration-evidence-from-nz-pdf>
- Moussavi, F. (2014). *The function of style / Farshid Moussavi ; edited with Marco Ciancarella, Jonathan A. Scelsa, Mary Crettier, Kate Kilalea*. New York : Actar ; Massachusetts : Harvard University Graduate School of Design ; London : FUNCTIONLAB ;
- OOPEAA. (2018). Puukuokka Housing Block. Retrieved from <http://oopeaa.com/project/puukuokka-housing-block/>
- Precht, C. (2017). Toronto Tree Tower. Retrieved from <https://www.precht.at/toronto-tree-tower/>
- Retsin, G. (2019). Bits and Pieces: Digital Assemblies: From Craft to Automation. *Architectural Design*, 89(2), 38-45. doi:10.1002/ad.2410
- Safdie, M. (1970). *Beyond Habitat. / Edited by John Kettle*. Montreal: Montreal Tundra Books of Montreal.
- Safdie, M. (1974). *For everyone a garden. / Edited by Judith Wolin*. Cambridge: Cambridge, M.I.T. Press.
- Schneider, F., Heckmann, O., & ProQuest. (2011). *Floor plan manual housing / edited by Oliver Heckmann and Friederike Schneider ; [translated from German into English, Elizabeth Schwaiger, David Bear]*. 4th, rev. and expanded ed
- Schneider, T., & Till, J. (2007). *Flexible housing* (1st ed.. ed.). Amsterdam ; Boston : Amsterdam ; Boston : Architectural Press, an imprint of Elsevier.
- Statistics New Zealand. (2006). *Urban and Rural Migration*. Retrieved from: http://archive.stats.govt.nz/browse_for_stats/population/Migration/internal-migration/urban-rural-migration.aspx
- Statistics New Zealand. (2013). *Urban area unit population projections*. Retrieved from: <http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE7563&ga=2.166276792.700644521.1552953874-1406400840.1551818689>
- Stock, R. (2018). KiwiBuild needs you, Twyford tells prefab home builders. Stuff. Retrieved from <https://www.stuff.co.nz/business/102073526/kiwibuild-needs-you-twyford-tells-prefab-home-builders>
- StructureCraft. (2018). Cross Laminated Timber – CLT. Retrieved from <https://structurecraft.com/materials/mass-timber/cross-laminated-timber>
- Tanney, J. (2014). *Modern modular : the prefab houses of Resolution: 4 Architecture / authors, Joseph Tanney and Robert Luntz ; foreword by Allison Arieff*. New York : Princeton Architectural Press.
- Venturi, R. (1977). *Complexity and contradiction in architecture / Robert Venturi ; with an introd. by Vincent Scully* (2d ed.. ed.). New York : Boston: New York : Museum of Modern Art ; Boston : distributed by New York Graphic Society.
- Wellington City Council. (2004). Embodied Energy of WOOD Products. *Quick Facts: Sustainable Building Series*.
- Wellington City Council. (2015). *Wellington Urban Growth Plan*. Retrieved from Web: <https://wellington.govt.nz/~media/your-council/plans-policies-and-by-laws/plans-and-policies/a-to-z/wgtn-urban-growth/wgtn-urban-growth-plan2015.pdf>
- Wellington City Heritage. (2017). *Chinese Mission Hall*. Retrieved from Wellington City Heritage website: <http://wellingtoncityheritage.org.nz/buildings/1-150/124-chinese-mission-hall>
- XLam. (2019). Technical. Retrieved from <https://www.xlam.co.nz/technical.html>

Figure List

All unattributed figures are authors own.

1. Chapter One : Background + Problem

Figure 12: Hello I'm Nik (2017). This way... Retried from <https://unsplash.com/photos/MAGPyHRO0AA>

Figure 13: Seitz, Tod (2018). Curved timber photograph. Retrieved from <https://unsplash.com/photos/IgnEI-45raTI>

Figure 14: Drew, Kirsten (2017). Mount Victoria, New Zealand. Retrieved from <https://unsplash.com/photos/ST-P6oSg-0HU>

Figures 22-24. Own graphic based on image from: KLH Massivholz GmbH (2012). Floor Plan Types (Pages 8, 10, 11). Retrieved from https://www.klh.at/en/download/public/Kreuzlagenholz/KLH_Residential_en.pdf

Figure 25: Waugh Thistleton Architects (2017). Dalston Works exterior photograph. Retrieved from http://waughthistleton.com/media/_img/dalston-lane/_U4A4310_edit.jpg.1200x800_q90.jpg

Figure 26: Waugh Thistleton Architects (2009). Murray Grove exterior photograph. Retrieved from http://waughthistleton.com/media/_img/murray-grove/Slide-show_1-285-1.jpg.1200x800_q90.jpg

Figure 27: MDH Arkitekter (2016). Moholt Timber Towers exterior photograph. Retrieved from <https://mdh.no/wp-content/uploads/2016/03/Moholt-1-1009x1400.jpg>

Figure 28: Guthrie, Ben (2017). International House interior photograph. Retrieved from https://images.adsttc.com/media/images/5922/751e/e58e/cef3/1700/07e4/slideshow/Barangaroo_C2_Interior_163_BenGuthrie_PrintRes.jpg?1495430388

Figure 29: Construction Canada (2014). Building the earth sciences building at the University of British Columbia. Retrieved from <https://www.constructioncanada.net/wp-content/uploads/2014/07/ESSB-flying-panel-1.jpg>

Figure 30: Stamets, John (2012). Bullitt Center, Ceiling of level 3. Retrieved from http://blogs.djc.com/blogs/BuildingGreen/wp-content/uploads/2012/04/bullitt_glulam21.jpeg

Figures 31-42: Thinkwood (2018). Tall Wood Building Poster. Retrieved from https://www.thinkwood.com/wp-content/uploads/2018/11/Think-Wood_Tall-Wood-Buildings-around-the-world-poster.jpg

Figure 43: Auerniitty, Mikko (2018). Puukuokka housing block exterior. Retrieved from https://images.adsttc.com/media/images/5be4/4028/08a5/e5f7/ac00/09db/slideshow/OOPEAA_Puukuokka_Housing_Block_Mikko_Auerniitty_1_Lr.jpg?1541685276

Figure 44: Auerniitty, Mikko (2018). Puukuokka exterior photograph. Retrieved from https://images.adsttc.com/media/images/551a/c289/e58e/ce72/dc00/00ed/slideshow/portada_Puukuokka_hires_2.jpg?1427816963

Figure 45: Auerniitty, Mikko (2018). Puukuokka interior circulation photograph. Retrieved from https://images.adsttc.com/media/images/5be4/3e0e/08a5/e549/e300/03c1/slideshow/OOPEAA_Puukuokka_Housing_Block_House_2_Mikko_Auerniitty_3_Lr.jpg?1541684739

Figure 46: Auerniitty, Mikko (2018). Puukuokka interior photograph. Retrieved from https://images.adsttc.com/media/images/5be4/3f54/08a5/e5f7/ac00/09d7/slideshow/OOPEAA_Puukuokka_Housing_Block_House_1_Mikko_Auerniitty_5_Lr.jpg?1541685064

Figure 47: OOPEAA (2018). Site layout diagram. Retrieved from http://oopeaa.com/wp-content/uploads/2014/05/Puukuokka_completed_webmaterial-3.jpg

Figure 48: Auerniitty, Mikko (2018). Puukuokka 1, 2, and 3 exterior photograph. Retrieved from https://images.adsttc.com/media/images/5be4/4130/08a5/e5f7/ac00/09fd/slideshow/Feature_Image.jpg?1541685537

Figure 49: OOPEAA (2018). Concept diagram. Retrieved from http://oopeaa.com/wp-content/uploads/2014/05/Puukuokka_completed_webmaterial-4.jpg

Figure 50: OOPEAA (2018). Flexibly customisable modular system. Retrieved from http://oopeaa.com/wp-content/uploads/2014/05/Puukuokka_completed_webmaterial-5.jpg

Figure 51: OOPEAA (2018). Typical floor plan and modular elements. Retrieved from http://oopeaa.com/wp-content/uploads/2014/05/Puukuokka_completed_webmaterial-6_.jpg

Figure 52: OOPEAA (2018). Diagram of module assembly. Retrieved from http://oopeaa.com/wp-content/uploads/2014/05/Puukuokka_completed_webmaterial-7_.jpg

2. Chapter Two : Exploration, Parts

Figure 55: Esbjörnsson, A., Magnusson, P., & Ford, J. (2014). Urban Timber, a systemic approach to architecture. Pg. *URBAN TIMBER: a resilient timber architecture in the city and a vision for mass customization*. (MSc in Architecture), Chalmers University of Technology, Göteborg.

Figure 69: Sixty7 Architecture Road (2014). Habitat 67 - Montreal photograph 1. <http://sixty7architecture-road.ca/2014/07/01/happy-canada-day/#jp-carousel-7128>

Figure 70: Sixty7 Architecture Road (2014). Habitat 67 - Montreal photograph 2. Retrieved from <http://sixty7architecture-road.ca/2014/07/01/happy-canada-day/#jp-carousel-7129>

Figure 76: Penda (2017). Toronto Tree Tower exterior render. Retrieved from <https://www.behance.net/gallery/55626045/Toronto-Tree-Tower>

Figure 77: Penda (2017). Toronto Tree Tower interior render. Retrieved from <https://www.behance.net/gallery/55626045/Toronto-Tree-Tower>

Figure 78: Penda (2017). Toronto Tree Tower prefabrication diagram. Retrieved from <https://www.behance.net/gallery/55626045/Toronto-Tree-Tower>

Figure 79: Penda (2017). Toronto Tree Tower construction GIF stills. Retrieved from <https://www.behance.net/gallery/55626045/Toronto-Tree-Tower>

3. Chapter Two : Exploration, Development

4. Chapter Four : Book of Parts

Figure 191: Le Corbusier (1914), Maison Dom-Ino. Retrieved

from https://www.researchgate.net/profile/Non_Arkaraprasertkul/publication/232939554/figure/fig2/AS:548097480552448@1507688030907/Le-Corbusier-Maison-Dom-Ino-1914-Plan-FLC-19209q-FLC-DACS-2008-Source-Le-Corbusier.png

Figure 192: Parvin, (2017), How it works. Retrieved from <https://tedconfblog.files.wordpress.com/2013/05/howitworks6-framed.jpg>

Figure 193: Retsin (2017). TAB Pavilion Assembly. Digital Material MAJA 2018. Pg. 63.

5. Chapter Five : Site-less to Sited

Figure 199: Coleman, James (2018). Wellington, New Zealand. Retrieved from <https://unsplash.com/photos/YFx61dtVvHA>

Figure 203: LINZ - Land Information New Zealand (2017). Wellington 0.1m Urban Aerial Photos. Retrieved from <https://koordinates.com/search/?q=wellington+aerial>

Figure 204: Land Information New Zealand (2017). Wellington 0.1m Urban Aerial Photos. Retrieved from <https://koordinates.com/search/?q=wellington+aerial>

Figure 211, 213: Land Information New Zealand (2017). Wellington 0.1m Urban Aerial Photos. Retrieved from <https://koordinates.com/search/?q=wellington+aerial>

6. Chapter Six: The Design Test

Figure 270: Leth & Gori Architects (2014). Perspective section - Common stairwell. Retrieved from https://lethgori.dk/wordpress/wp-content/uploads/2013/05/1300-PerspectiveSectionOverview_FINAL-copy1.jpg