Quality Assembly:

designing to offsite fabrication for medium density living in New Zealand

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designing to offsite fabrication for medium density living in New Zealand

BY

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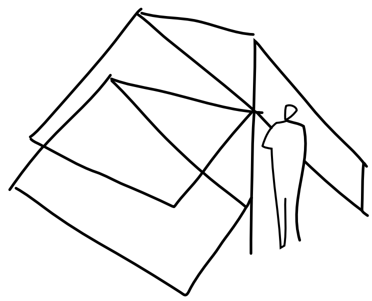

Abstract

This research portfolio looks at how consciously activating prefabrication into the design process early, and subsequently designing to the onsite assembly stage by using three key design principles, can contribute to a responsive design that embodies quality medium density living in New Zealand.

Prefabrication is at the forefront of the New Zealand Government's conversation about its residential construction industry. The potential attributes of this efficient construction method of fast on-site installation time, reduced cost, improved construction safety, and improved construction quality, have the potential to positively impact the issues that our housing industry faces.

However, the intrinsic limitations that come with prefabrication being based on the ideals of efficiency, carry the risk (as seen throughout its history) of compromising the design quality. With the motivation to integrate this construction process into New Zealand's commonplace residential construction industry based on its positive attributes, it is essential to address its relationship to the designed outcome, and consequently the design process.

Ryan E. Smith of Washington State University in Prefab Architecture expresses that prefabrication is a construction process not a product so a poor design results from a poor designer. He specifies that for a prefabrication project to achieve quality construction and aesthetics the design process must be directed to "quality assembly". This idea endorses the integration of this chosen construction process in accordance with the design intent and guide the design through various scales to the detailing of assembly.

For this integration of 'quality assembly' into the design process three principles have been interpreted from founding literature as being key drivers: standardisation, repetition, and personalisation. Standardisation is the act of simplifications to efficiently design. Based on chosen factors measurements are controlled allowing pieces, elements, and/or units to relate to one another cleanly. Repetition is the act of reducing variances within the construction, maximising the efficiency of prefabrication. Traditionally this can improve quality. Personalisation is the principle that relates the desirability of the outcome with the necessity appropriately suiting its site and occupancy.

This research is positioned within New Zealand's residential climate, which is seeing a growing demand for medium density living. The defined programme accommodates two key demographics within this density of first-home buyers and homeowners downsizing. The focus is to design a system that assists quality living – giving an alternative archetype – for New Zealand's evolving climate.

Key findings from this research support the design intent of 'designing to assembly', whereby the construction process and the outcome are integral to one another. By focussing collectively on standardisation, repetition, and personalisation, a responsive design that is suitable to various sites and occupancies can be realised. The challenge lies within balancing flexibility with restriction efficiently.

“The room within is the great fact about the building”

Frank Lloyd Wright

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Firstly I would like to extend my greatest thanks to my supervisor and mentor Hans-Christian Wilhelm, for the guidance, knowledge and interest that he has brought to this research. It allowed both me and my ideas to grow and to also have fun with it.
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1. Project Establishment

Introduction

New Zealand's building industry needs to be challenged, particularly in response to the housing shortage faced countrywide. The addressing of this issue has been initiated with the Labour government's 'KiwiBuild' initiative, aspiring to construct 100,000 new houses spanning 10 years (LabourVoices). This however is a token solution, with the root of the issue stemming from how we are building. Until our construction habits are ameliorated, the same patterns will re-emerge in the following decades (Bell and Southcombe 132).

Prefabrication

Prefabrication is a construction method that possesses the opportunity to improve New Zealand's residential industry by building more houses faster, whilst not compromising on quality (PrefabNZ 1).

Prefabrication benefits from the conditions of building away from site, typically in a controlled environment allowing project completion to be comparatively faster and more efficient, with better quality control to that of traditional means of on-site construction (The New Zealand Productivity Commission 195). The ideology is that it is a smart construction method, due to being efficient in process. This results in the potential positive attributes of fast on-site installation time, reduced cost, reduced waste, improved construction safety, and improved construction quality.

Projects from the past show the attention that prefabrication demands has the opportunity to hinder the quality of the design (Bell 40). As the design process is challenged with achieving the desired attributes and meeting the intrinsic limitations. The elemental success of a prefabricated project originates from the understanding of what this construction method is and can bring to the design. This research explores what can generate a successful prefabricated project, by examining the design process in relation to the built outcome.

Problem Statement

In this country prefabrication is a method whose integration in the construction industry is hindered by bureaucratic processes and poor judgements originating from past projects (Bell and Southcombe 132). In the past year it generated only 2% of New Zealand's construction GDP (PrefabNZ 1). To progress the integration of prefabrication into New Zealand requires an examination into what successful prefabrication can do and look like in relation to the designed process and outcome.

Put simply, the fundamental difference between traditional onsite construction and offsite construction is the difference in location. Yet due to the ideals of efficiency the positive attributes achievable by using prefabrication are much greater. Simply adopting this method will not realise the associated benefits, instead a directed intention must be activated at the beginning of the design process. It is important to note that as seen throughout history like New Zealand's Industrialised Building System these limitations can be responsible for compromising on the design quality (Bell and Southcombe 33). This is because the achieved efficiencies of prefabrication stem from the integral demands that originate from constructing offsite and assembling onsite. The relationship between prefabrication and the design of the outcome must be addressed in order to balance quality design with efficient construction.

How can the prefabrication ideology 'designing to assembly' influence the design process for quality medium density living in New Zealand?

Aims

The aim of this research is to investigate the ways in which the application of the construction process prefabrication can positively influence New Zealand's evolving residential typology. With the intention of examining the dialogue of design process to outcome, how to effectively generate the positive attributes of the system and not compromise on built quality will be the focus.

An understanding of the relationship between motivation and successful execution of a prefabricated project will be inferred to allow the conversation of prefabrication in New Zealand to develop. This is arranged within the dialogue of generating quality living for New Zealand's evolving residential typology. The aim is to conclusively illustrate a design intent that maximises the potential attributes of a 'prefabricated project'. This will be achieved in the form of a model of housing that satisfies the country's evolving societal climate.

Objectives

New Zealand's insufficient residential industry has motivated the research to focus on projected living typologies; allowing the research to be applicable to future developments. With this intention of positioning prefabrication into New Zealand's developing residential climate the objectives of this design-led research are as follows:

•To establish the desired attributes that New Zealand demands of prefabricated projects

•To establish how prefabrication can affect the design process to exploit the efficiencies of the method

•To explore the design opportunities available when the "designing to assembly" theory is applied

•To develop a medium-density design that supports and encourages New Zealand's developing residential typology by making it adaptable in location and occupancy

•To formulate a strategy of design by harnessing both quality design and efficiency in construction that is applicable for future projects

Scope

The scope of this research is to acknowledge the opportunities of prefabrication as a construction process and the required attitude to the design process to ensure that the design quality is not compromised. This will result in an understanding of the relationship that the two conversations have with one another.

Ideally this will open up New Zealand's 'prefabrication' dialogue and allow the alternate construction process to be more approachable. The idea is to touch on the positive aspects of this construction method by examining its conversation with the design process using mixed media of drawing, physical modelling, and CAD.

With the plethora of quantitative data available on the positive contribution that prefabrication can have on a project, it is essential to also analyse the qualitative nature of the end products. The bureaucratic processes that currently hinder the integration of this construction method commonly in New Zealand will naturally progress as it becomes more prevalent throughout the construction industry.

This research will be involved with the journey from the impetus of idea through to the detailed design.

Technical detailing of onsite assembly is excluded due to the period of research.

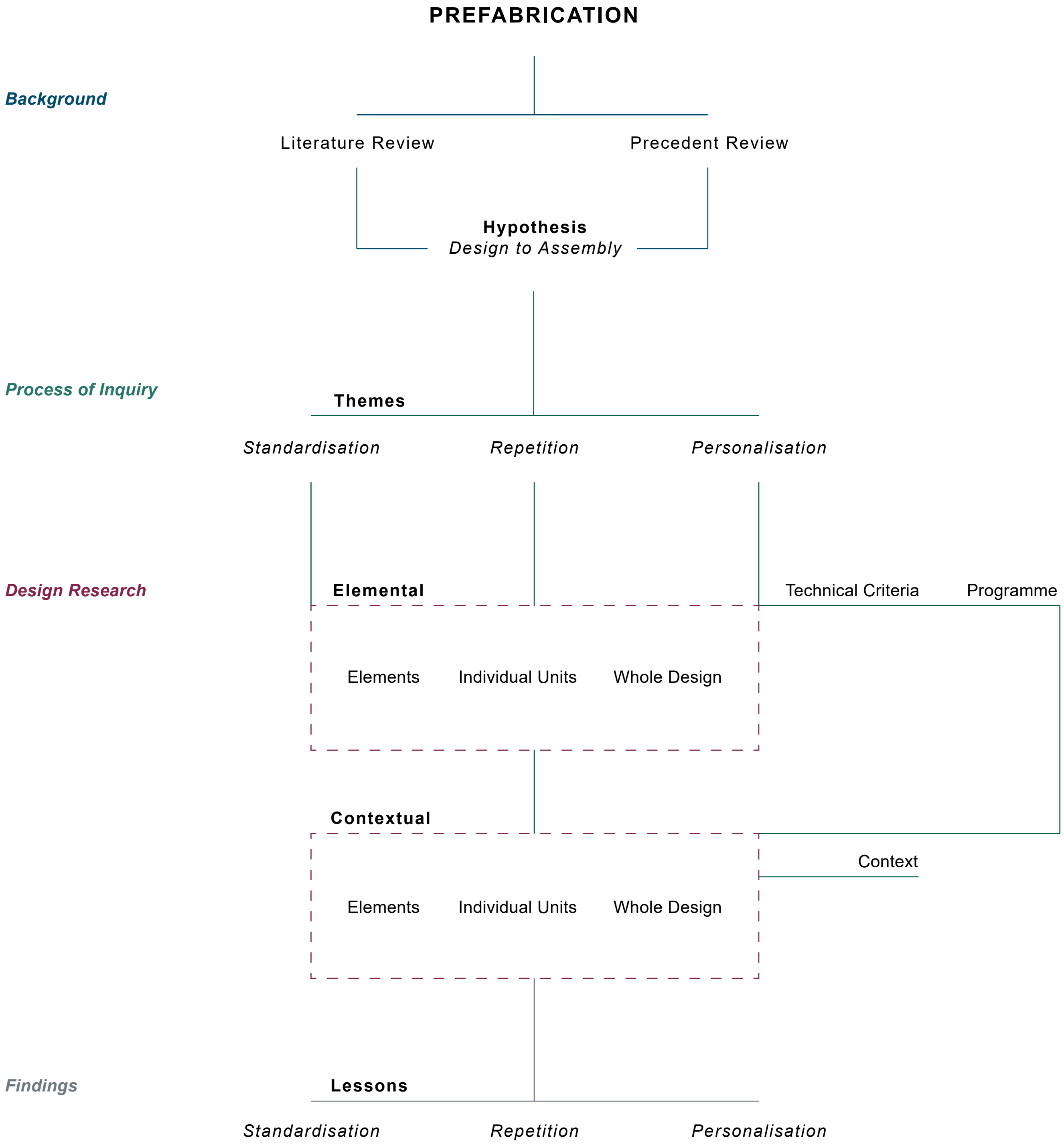

Fig.1.01. Methodology Diagram of design-led research

Methodology

This is a design-led research portfolio that uses design as the main exercise of inquiry. After the literature review and project review, a hypothesis formed. Then with a contextual search, the rationale was positioned to a programme of developing importance in New Zealand. The main process of inquiry is how the application of prefabrication during the design process can inspire a high quality medium density design outcome.

The aim was to first establish the appropriate motivation for prefabrication, then generate a design strategy that aided the desired quality outcome.

This research strives to display how the application of restrictions and criteria at the beginning and designing to assembly by following the three principles - standardisation, repetition, and personalisation - can realise a quality design. For a refined outcome the iterative process involves continuous reflection balancing these three design principles. They are explored through various design scales of various mediums: individual spaces, individual units, whole design, individual elements, sketching, physical modelling, digital modelling. All examined with reference to their relationship with one another. Starting with sketches, they are then realised as physical models, then digitally translated into a design programme. This whole process is attempted initially without a physical context, and then again with an applied context; this supports the importance of context, even for an adaptable system. Reflection is made on the relationship of the three principles with one another and how their influence is weighted in different areas of the design.

The progressive design process iterates through the scales and mediums refining the design to become an adaptable system. This suits the intentions of the research as it explores all the interrelationships of various elements and factors. It helps balance the emotive and scientific contributions of construction on the design process. This outcome frames the overall reflection of the design theory and the particular influence of each principle, and realises how the future of New Zealand housing could look.

The designed outcome will be the tool used to mark the quality of the design process, exploring the opportunities and the weaknesses, and communicating the results of the chosen strategy.

Thesis Structure

This exegesis is broken down into five chapters to filter the appropriate information. The first introduction chapter establishes the topic of interest. The second chapter 'Theoretical Framework' defines the scope of research and the resulting process and directed outcome. Chapter three is responsible for the additional 'Contextual Framework' which further forms the determined research. This includes: site, programme, and technical design criteria. Chapter four presents the design research in two parts: design stage one and design stage two. It is the narration of the final design. Chapter five recounts a summary and reflection on the process, outcome, and future developments.

2. Theoretical Framework

Literature Review

The following literature review refined the research scope. It explored prefabrication texts on the relationship of design intent and process, to the final constructed outcome quality. Emphasis was placed on theories, where the impetus was to realise good quality building. This review notes the contributions of the three texts:

- *Refabricating Architecture: How Manufacturing methodologies are Poised to Transform Building Construction*, Stephen Kieran and James Timberlake, 2004, McGraw Hill Education
- *Prefab Architecture: A Guide to Modular Design and Construction*, Ryan E. Smith, 2010, Wiley and Sons, Incorporated, New Jersey
- *Home Delivery: Refabricating the Modern Dwelling*, Barry Bergdoll and Peter Christensen, 2008, The Museum of Modern Art
- *Kiwi Prefab: Prefabricated Housing in New Zealand*, Pamela Bell, 2009, Victoria University of Wellington
- *Kiwi Prefab: Cottage to Cutting Edge*, Pamela Bell and Mark Southcombe, 2012, Balasoglou Books

The main lesson extracted from the literature is that the motivation for adopting prefabrication is for an efficient smart construction method resulting in a quality build. The contributing developed theory of "Designing to Assembly" and the three key design principles – standardisation, repetition, and personalisation - that drive efficiency and design collectively were extracted for further research.

Designing to Assembly

Looking at prefabrication with the intention of locating it for the future of New Zealand's residential construction industry narrowed the applicable research scope. Five supportive texts, that explore the idea of designing to assembly were reviewed. Whereby they all support the degeneration of the industrialisation of the home impetus as the incentive to prefabricate. All five texts were published within a window of 6 years in the 21st century, and endorse an admitted text and/or are endorsed by an admitted author. For breadth of knowledge accountability of the texts are from practicing architects, Academics, and one esteemed Victoria University of Wellington alumna Pamela Bell, now Founder and Chief Executive Officer of PrefabNZ and Victoria University of Wellington Colleague Mark Southcombe.

Prefabrication for quality

In Refabricating Architecture Stephen Kieran and James Timberlake practicing architects of KieranTimberlake do not attempt to define prefabrication in their commonly cited manifesto. The text looks at how to improve building construction, and conclude with the prospect methods of "offsite fabrication", 'smart manufacturing/production', and 'mass customisation'. In addition, should be treated as a commodity whose process requires development (Kieran and Timberlake 115). Within the New Zealand scope of prefabrication Pamela Bell Chief Executive of PrefabNZ, takes direction from Kieran and Timberlake by defining prefabrication as a process away from site to improve efficiencies (Bell 13). Ryan E. Smith in Prefab Architecture defines prefabrication as "elements intended for building construction that are produced offsite to a greater degree of finish and assembled onsite" (Smith xi). These three texts although in different wording, declare prefabrication to be a construction system that increases its efficiencies by fabricating offsite with the intention of improving built quality. In The Museum of Modern Art's commemoration book for its namesake exhibition Home Delivery, Barry Bergdoll offers his all-inclusive definition. He states it as "industry produced, offsite building" (B. Bergdoll, Home Delivery 9). With a plethora of slightly different definitions of prefabrication in the world, the summary by Kieran and Timberlake of offsite fabrication to improve efficiencies, and Smith's definition of offsite production for a higher standard of finish quality, are constructive and clear for the developing research.

This defined scope of prefabrication allows the development of the design to focus on how the efficiencies of the process can generate quality design for New Zealand.

Designing to Assembly

Prefab Architecture spells out the pragmatics of prefabrication resolve that the application of this offsite manufacturing method must be conscious. This text indicates that the aim of the design process is "quality assembly that is expressive aesthetically and good construction" (Smith 187). This quote indicates the required intention for adopting this construction method, and that it differs from a traditional onsite construction process. This book expands on this "designing for assembly" theory where prefab is suitable (Smith xiv). The idea is that the development of the "method for production" is integral to the design process (Smith 216).

The conclusion on this text is that it encourages and supports the ambition for efficiencies and high quality when using prefabrication.

The directors of KieranTimberlake support this theory. They encourage architect's engagement of design to be like product manufacturing where they "... picture how things are made, their sequence of assembly, and their joining systems" (Kieran and Timberlake 13). This encapsulates how the prefabrication process can be integrated into the design process - with intention and consideration into the onsite assembly, and logistical criteria applied at the start.

This Design and Assembly theory supports the intended dialogue of design process to outcome. With this in mind it provides a framework that can focus on maximising the efficiencies. This theory is about understanding the intention of the design process being focussed around onsite assembly as this is the determinant for the interior quality space.

Standardisation

Sven Markelius' own home is an example of how the "mass production of houses should be based on standardized parts, not standardized houses" (Wern 28). Wern explains how this "system house" type is common throughout Scandinavia where "the uniform 100-millimeter planning module" was/is applied to prefabricated designs for simplification. This then evolved into the planning of 1960s houses using the 300-millimeter grid (Wern 28,29).

This grid is discussed in Prefab Architecture by Smith. The standard dimensions act as a system of organising "building components and prefabricated elements". Applying a grid or a common dimensional denominator reduces variances and can directly improve the standard of quality.

Standardisation guides the design through set limitations to allow simplification in the design, improving the onsite assembly process. This will be seen in the form of a determined dimension factor and standardised elements.

Repetition

Repetition of processes and elements can reduce cost and time, and improve quality. However, it is also the aspect that has deterred the market from using prefabrication due to the banality of literal visual repetition.

As quoted in Kiwi Prefab: Cottage to Cutting Edge "Manufacturing processes are most efficient when they are repeated with minimal variation" (B+S 137). Co-occurring of fabrication reduces time, saving money, and assuring quality. It corresponds with Walter Gropius' mass production ideal, which is construction made to be "both profitable for the manufacturer and inexpensive for the customer" by the "repetition of the same component parts in every building project". This scale of repetition can reduce the quantity of components and joins, consequently reducing complications and assuring quality (Smith 128). This is the essence of efficiency. It is also, however, the principle that deters the market from the uptake of this methodology. Bell and Southcombe relate the unsuccessful nature of prefab buildings in the 20th Century due to the repetition resulting in poor aesthetics (B+S 134) (B+S 135)

Repetition supports the inclusion of standardised elements, and is responsible for how and what should be standardised. It respects improving process inefficiencies and not compromising on design quality.

Personalisation

Kiwi Prefab acknowledges that for prefabrication to stay current it must apprehend occupants changing needs and style (B+S 130). Kieran and Timberlake also acknowledge that attention needs to paid to "individual circumstance... personal preference... particulars of site" (K+T 107). They explain the important "desire for choice, expression, individuality, and the ability to change our minds at the last minute" (K+T 137). This is of particular importance in New Zealand (L, C, E 92) discuss "the socio-cultural perception of the home as an economic investment" which Pamela Bell explains the consequently important choice and personalisation (Bell 41). For the design this means an understanding of the variety required to allow home-owners the flexibility to configure their house to their preference. Personalisation will look at what and how elements can be altered to address a large pool of occupants.

“elements intended for building construction that are produced offsite to a greater degree of finish and assembled onsite” *Prefab Architecture - Smith*

Opportunities for the Design

The prefabrication definition of smart construction gives the motivation of higher standard of finish quality and improve inefficiencies. This suitable situates the research to New Zealand's residential context. Designing to assembly theory supports integrating the construction method with design process. To allow quality design to develop prefabrication must be active throughout the design process, with consideration to the onsite assembly.

Standardisation allows the design to formulate through a set of limitations that improve the assembly quality and reduce inefficiencies. Repetition controls the variances. Looking at increasing efficiencies and not compromising on design quality. It oversees the inclusion of standardised elements. Personalisation is the human element to the design. It addresses the understanding of personalities, site, programme, and ownership. This is key to addressing the market gap for New Zealand. These principles will then be addressed through the medium of reviewing existing prefabrication projects.

Project Review

From the preceding literature review the Design and Assembly theory provides an intended dialogue of design process to outcome, and gives a framework that focuses on maximising efficiencies. The three extracted supporting principles are reviewed, using existing physical projects. Each project distinctly communicates a principle.

- Standardisation - House R.
- Repetition - B.B.B. Kvistgaard
- Personalisation - Dalsland Cabin 2.0
- S. R. P. - Muji Vertical House

Focus was on projects within countries where offsite construction is a common construction method. Reflection was paid to how the outcome of each project communicates its conversation with prefabrication during the design process. This looks at what works and what doesn't and how the precedents and principles relate to one another for the New Zealand setting.

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Fig.2.01. External aspect of House R

redacted

Fig.2.02. Internal view of House R

redacted

Fig.2.03. Entry foyer of House R

Standardisation

House R

Nilsson Pflugfelder
Cambridge, England
2017

House R embodies the principle of standardisation, in the understanding of the benefits that efficiency provides. The house was designed using Cross Laminated Timber panels from the Baufritz company. This decision brought the limitations on spans, and consequently efficient spans based on material, cost, and impact. Panel specifications, a 625x625mm grid, defined room heights, wall types, shop designs, and standardised windows were provided. The panels arrived onsite pre-clad, with the assembly of the house fully weather tight within three days. The restrictions provided are more than most, and although the design is still personal and site specific this example shows that the results of ultimate standardisation will be regular. The overall form provides little discussion on design, with the box being disjointed only by the annexed window. In plan, the spans are clearly read with a uniformity to each room volume, excepting the open living room which reads as a double volume. The act of design has played a role for the designated programme and situation on the site, however the essence of personality is not clear. Although this project is an example on quality execution using provided standardised elements and grids with the intention of reducing costs, the design is restricted.
Like House it is essential to note that a common design simplification made by prefabrication restrictions are the application of a flat roof. It is important to imagine the challenged dialogue that this would have meeting New Zealand's residential typology.

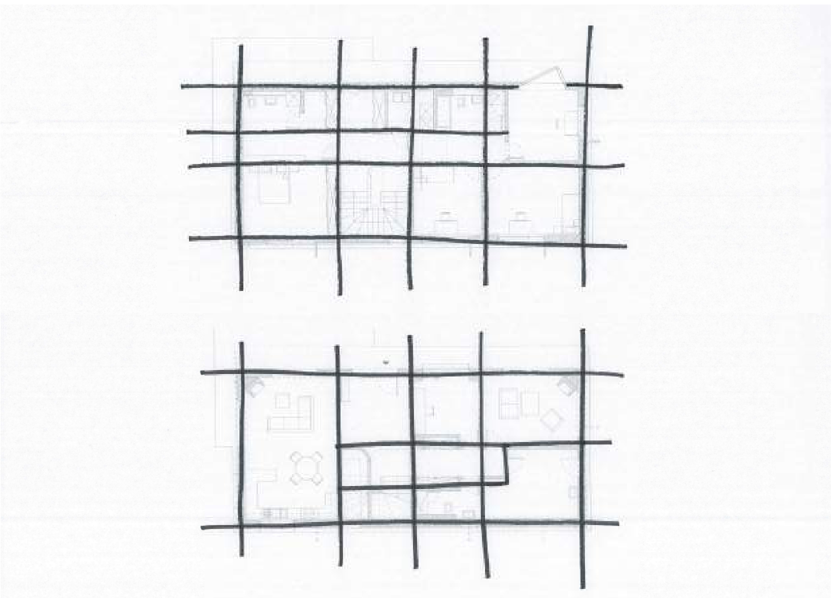

Fig.2.04. Ground Floor Plan displaying the structural grid

redacted

Fig.2.05. Volumes pre onsite assembly of BBB

redacted

Fig.2.06. External aspect of BBB

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Fig.2.07. Internal aspect of landing in BBB

Repetition

Bedre Billige Boliger

Tegnestuen Vandkunsten
Kvistgaard, Elsinore, Denmark
2008

This project examples the concept of repetition of a design on a large scale. The translation of this project is ‘Better, Cheaper, Houses’ where the aim was to design and build as many houses as possible, to quality, and as cheap as possible. Thus the decision was made to design one house and repeat it. The plan consists of four 5x5m squares, per household. This is fitted with the standard, kitchen, living, bathroom, and bedroom. From thereon a first floor unit can be added. Variety can be provided with the arrangement of units, how they are orientated and their connection to neighbouring units. This act of literal repetition, allows the design and build to maximise on the efficiency of construction, and reduces costs. However, this cost saving method is implicated within the design. The repetition is clear, and an understanding of lack of design is evident.
The idea of designing one quality house and literally repeating it is the idea that generated the industrialisation of housing construction. And aligns with Walter Gropius’ mass production ideals (?). It is the epitome of efficiency of design. “most efficient... with minimal variation” (Bell and Southcombe 137) The challenge lies in how to allow personalisation to remove the banality but to balance it with assuring the desired level of efficiency for quality. The idea of an adjustable unit that can be translated throughout is a particular theme to investigate.

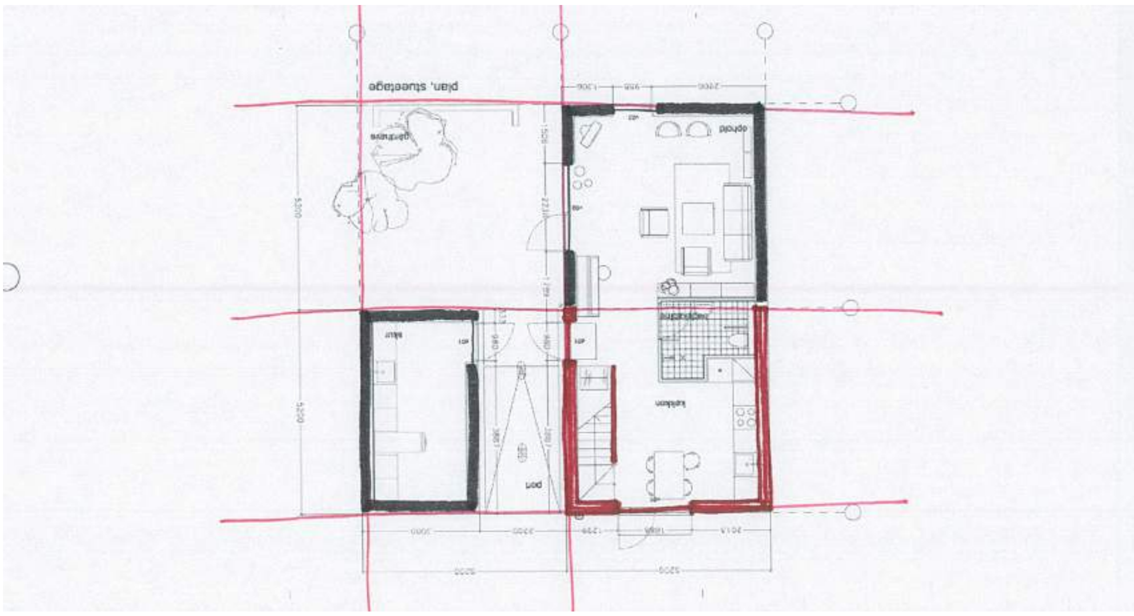

Fig.2.08. Floor Plan displaying the 5x5m grid of 100sqm

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Fig.2.09. External elevation of Dalsland Cabin 2.0

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Fig.2.10. Internal aspect of Dalsland Cabin 2.0

redacted

Fig.2.11. Internal aspect of Dalsland Cabin 2.0

Personalisation

Dalsland Cabin 2.0

Jimm Brunnestom, Magnus Hellum, Hampus Berndtson
Bengtsfors, Sweden
2018

This project is exemplar on personalisation being integrated into the overall design. It is constructed of Cross Laminated Timber panels to allow generous internal volumes and an open façade. The premise for this design's personalisation is how it extends horizontally depending on the chosen programme. As the programme increases, so too can the house. A 'minimum' has been designed with rooms that can be added in sync with service cores, depending on desired occupancy. This represents an understanding of different preferences and priorities, occupants, and locations. The structure lends the internal aesthetics, and the service cores support the spatial qualities The success of this personalisation lies with how the design is not compromised by alterations. This makes the design accessible to different habitations.

"individual circumstance... personal preference" (Kieran and Timberlake 107)
This is a study into intentional programme personalisation. It addresses the reality of personal preference, yet it is provided in a way that does not compromise on the design. The idea of the service core as an anchor for a growing unit is worth exploring.

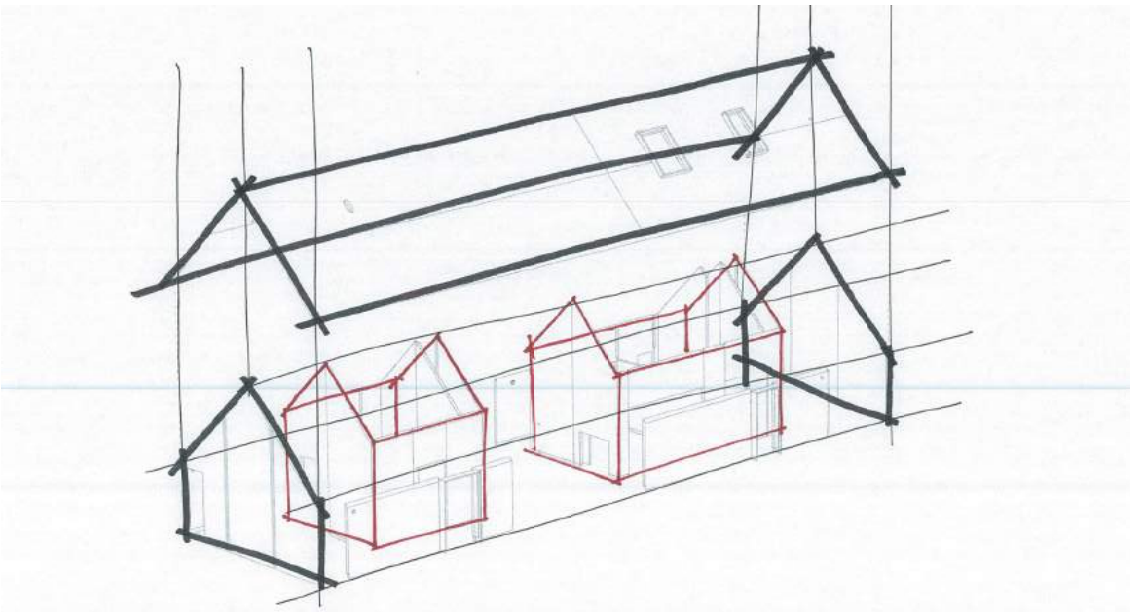


Fig.2.12. Exploded axo displaying the structure and planning relationship

Muji Vertical House

redacted

Fig.2.13. External elevation of Muji Vertical House

redacted

Fig.2.14. Internal view of Muji Vertical House

redacted

Fig.2.15. Internal view of a kitchen in Muji Vertical House

Muji
Tokyo, Japan
2015

The Muji Vertical House embodies the three principles standardisation, repetition, and personalisation respectfully. Its design was in response to the growing demand of flat pack houses from this homewares giant. Consequently, the outcome is a product that is tailorable to each individual customer, with the personalisation aspect being the leading driver of this design. The Vertical House involves a standardised 3.64x8.19m floor plan, which has been defined by common tight Tokyo sites. It has at least 3 levels connected by a central open step steel staircase. The structure is a standardised steel post and beam system, with applied white walls and timber flooring. The spaces have been designed with the idea of their homewares integrating cleanly, thus the standardisation of this product is influenced by all their other products. The programming of the house is the personalisation aspect, where no activity is designated to a particular level or side, and additional levels can be added depending on occupancy. The level of personalisation and the success of the designed form allows and has been designed with the express purpose that this house can be repeated comfortably throughout urban environments.

With the embodiment of the three principles the aspect of personalisation is strongest. What this results in is a design that is as yet to be designed. It has created a discord between the overall form and the determined volumes per programme. This examples the compromise made when the efficiency is maximised – there is little room for design.

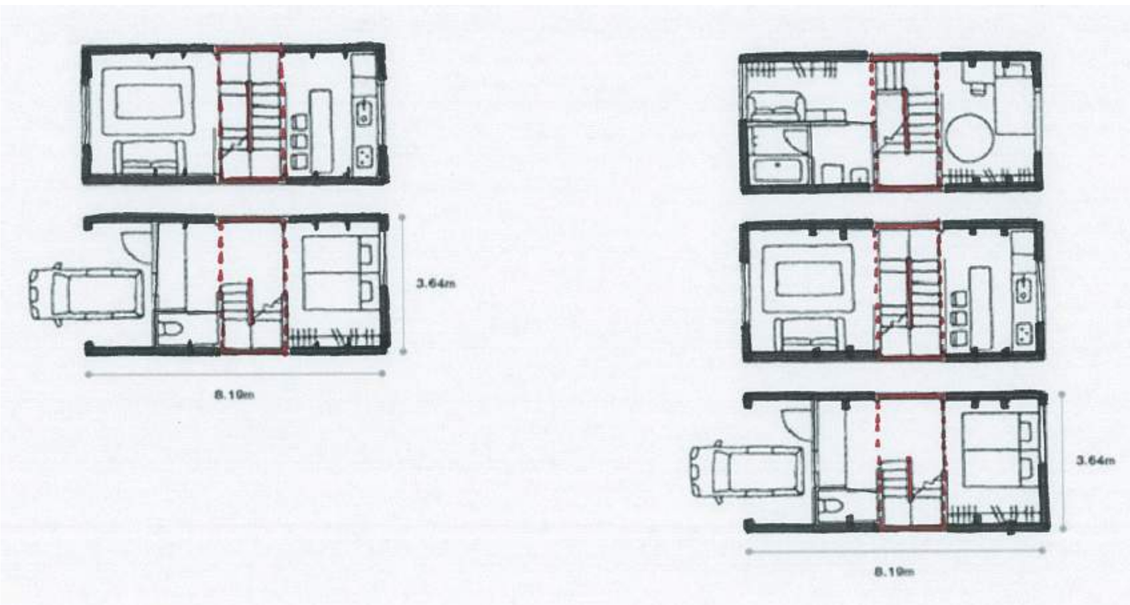


Fig.2.16. Floor plans showing how the organisation of programmes can be tailored per occupancy

Motivations, Compromise, Consequence

The standardisation that house R displayed, is clear in showing the results of total efficiency by using a structural inspired grid. However the freedom of expression is compromised. This was intentional though and the outcome is a well crafted home to budget.
The repetition of BBB Kvistgaard shows that the motivations and consequences of literally copying and pasting are clear. This embodies the efficiency where repeating a drawing, connection, element or process saves time and money. But design is compromised.
Dalsland Cabin 2.0 displays a fair control of personalisation owed to a home-buyer. It suitable covers preference and occupation and the design is not compromised.
The final project precedent displays the three principles. It is the definition of high personalisation high standardisation and high repetition. The threat with this design is that personalisation is so high the design contribution is lost.

Next developments:

- Understand/define the level of standardisation to balance framework with flexibility
- Understand/define the benefits of literal repetition – maximise but respect when it impedes on design quality
- Understand/define the demands of personalisation centred around service cores
- Understand the balancing and weighting of all 3 principles

Prefabrication - the NZ Setting

The following is a condensed timeline of the history of prefabrication in New Zealand's residential construction industry. It primarily highlights the importance of the relationship between the motivation for applying this construction method, and the final designed outcome.

- Necessity: Portable Colonial Cottage; Treaty House
- Mass Housing: State Housing; Hydro-electric Scheme
- Industrialisation: Industrialised Building System; Beazley Homes
- Quality Construction: Meridian First Light House; Motu Kaikoura

This historical run through of New Zealand's prefabrication history indicates its past contribution. It consequently indicates where the attitude of this offsite strategy is projected for our residential industry's developing climate.

redacted

Fig.3.01. Treaty House Image

redacted

Fig.3.02. Portable Colonial Cottage Drawings

Treaty house
1833
John Verge

Portable Colonial Cottage
1833
H. Manning

Necessity

Necessity is a common prefabrication motivation as was experienced during New Zealand's colonisation. Where the site was inadequate to construct the required buildings. The Treaty House (see fig.3.00) is a classic example (Bell, Progressing Prefab 29). The house was designed and built by John Verge in Sydney and shipped over for the residence of permanent British resident James Busby (Ministry for Culture and Heritage). The house design of colonial Georgian is respondent to the location it was built in rather than that for its destined location (Ministry for Culture and Heritage).

H. Manning's Portable Colonial Cottage (see fig.3.00) was a successful prefabrication for necessity product due to the consideration paid to the assembly of the structure. Manning designed the cottage for his son emigrating from England, and consequently developed it into a product that was widely purchased throughout Australia and New Zealand (Herbert, The Portable Colonial Cottage 12) (Bergdoll and Christensen, Home Delivery 40). The success of the design can be attributed to the pieces being light enough to be carried by a boy, and assembled with the use of only a wrench (Herbert, The Portable Colonial Cottage 9,11). Standardisation of pieces was escalated to increase piece translation reducing confusion and consequently onsite assembly time. Once fitted together the cottage was fully watertight, visually finished, and ready for occupancy.

The restrictions placed on the design and construction of both structures were limited to that of the onsite assembly.

redacted

Fig.3.03. State Housing

State Housing
1930s -
Department for Housing Government

redacted

Fig.3.04. Working Mens huts in Otira

Railways Department Housing Scheme
1940s - 1970s
Ministry of Works

Mass Production

Mass-housing was driven by constructing as many as possible as fast as possible. The Railways Department prefabricated housing (see fig.3.00) for its workers is a high production housing example. Using locally grown and sawn timber, the houses were made in a factory in Frankton, and then trained all around the North Island (Bell, Progressing Prefab 29). Efficiency of construction was assumed by limiting the set designs. They mainly accommodated a family of 4, and overall costs were limited due to the reduced house size that prioritised the kitchen as the family fulcrum (Ministry for Culture and Heritage). Ironically it was the success of the production efficiency that spanned three years from 1923 that saw it drive itself out of business (Ministry for Culture and Heritage).
New Zealand's first "Public State Housing Scheme" of the 30s and 40s is one of the most successful schemes (Bell, Kiwi Prefab: Prefabricating Housing in New Zealand: An Historical and Contemporary Overview with Recommendations for the Future 73). The Labour government instigated this to improve the countries standard of housing (Schrader). It was achieved by cost savings through design efficiencies: generating over 400 different designs (see fig.3.00) that used a set of specified details and principles. During this period the success is owed to the understanding of repetition with variation while future proofing the design (Schrader).
These two mass-housing schemes relate to the value of limiting variance for efficiency yet providing smart design.

redacted

Fig.3.05. Unit of an Industrialised Building System House

Industrialised Building System
1960s - 1978
Keith Clark

redacted

Fig.3.06. Beazley Home construction factory

Beazley Homes
1953
Barry Beazley

Industrialisation

Industrialisation builds from mass-housing with the house positioned as a product. The 1970s had a number of businesses providing prefabricated houses including Beazley Homes, McRae Homes, Modulock Homes, Industrialised Building System, Vintage Homes (Bell, Progressing Prefab 29). However, not many survived. The following are two examples of successful businesses that did not survive.

The Industrialised Building System (IBS) (see fig.3.00) run by property developer Keith Clark was a mass-production of housing business for New Zealand. It involved the component additive technique mirroring the growth and reduction that families naturally experience(Pam Bell thesis 83). The downfall to this business in 1978 was spurred on by the wider economic recession and aggravated by the modernist inspired flat roof not being well received (Pam Bell thesis pg83).

Beazley Homes (see fig.3.00) established in 1953 by Tauranga man Barry Beazely was an example of producing the product for the masses. The system was a well received design of "pre-cut component kitset" (Pam bell thesis 79). The business continued to flourish until the 80s when a growth in the industry forced them to sell out to Fletcher Homes. What is essential from both housing products is that it is essential to be designing appropriately to the intended client.

redacted

Fig.3.07. The Meridian First Light House

redacted

Fig.3.08. Motu Kaikoura

The Meridian First Light House
2011
First Light Studio

Motu Kaikoura
2018
Strachan Group Architects

Quality Construction

Quality construction reflects the values aspired to today with prefabrication. The success of Meridian First Light house (see fig.3.00) originates from pushing the design through layers of restrictions. This design was an entry for the Solar Decathlon competition in 2011. The prefabrication aspect originated from general limitations from entering an international competition. The maximum sizes for transportation, and the understanding of the service connections, and overall assembly, allowed the house to be transported and installed a multitude of times. The overall quality of this design and build does not communicate its 'prefabricatedness', and instead delivers everything required and nothing extra.

The Motu Kaikoura community trust building (see fig.3.00) was a collective community enterprise. Due to budgeting a plan was formulated to develop this project to be built by incorporating it as a workshop for Architecture + Women NZ members, teaching construction and prefabrication skills. The intrinsic limitations for this prefabrication was controlled by the land, sea, and sky transport and the onsite assembly that used amateur volunteers. The design displays the careful onsite assembly with detail into assuring the simplistic mass, and materials speak the values of the community trust. (PrefabNZ)

These two examples are indicative of what is to come for the future of prefabrication for New Zealand. When the challenges and demands of a site build are addressed by using prefabrication but not losing site of the design can turn out a quality product.

3. Contextual Framework

Technical Design Criteria

The following outlines the determined criteria which the design outcome will be structured to follow. The principle factors to prioritise are the level of prefabrication, and the chosen structural system. These initial limitations will highly influence the final outcome and quality of said outcome.

Prefabrication

Prefabrication is the smart construction process that uses an offsite environment to efficiently produce elements that are assembled onsite to create a quality building. The definition extracted from the literature review is condensed as: offsite fabrication to improve efficiencies and for a higher standard of finish quality. Prefabrication is a liberally used term. This research has been careful to follow only the provided definition.

Prefabrication not only covers various terms but it is applied to varying degrees. For example a nail made in a factory is technically prefabricated but also a complete home can be fabricated offsite. This research follows the work of designing the prefabrication scale of elements that can be flat packed. This is the most efficient scale for balancing transportation.

As this research is exploring the relationship of the efficiency being balanced with the design, the 2 dimensional elements will be the design elements rather than volumes.

Onsite Assembly

This is a key term used throughout literature explaining the particulars of prefabrication. It is the exercise of elements or element being placed at the site, in situation. The importance of this stage is due to it embodying the quality of the final outcome. How the assembly is detailed will determine the final finish. This onsite assembly is the point to strive for within the provided design focus. This is the point where the orchestration is most important. This onsite assembly stage is highly influential due to the particulars of the site, whether it is topography, weather events, and/or traffic.

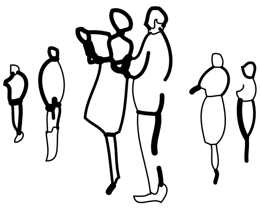
Cross Laminated Timber

Decision of the structural type is best provided sooner rather than later. With the decision of using engineered solid timber due to its embodied positive environmental characteristics, successive decisions were made. The structural system then determined the grid to be planar with the wall panels as structural. Removing the common post and beam plan for prefabrication.

Cross laminated timber is an engineered timber product that amalgamates young thin timber to generate a panel of bi-dimensional strong timber. It creates solutions with larger floor spans, and integrates timber into large products compared to non-engineered timber structures. It contains the existing positive attributes of timber.

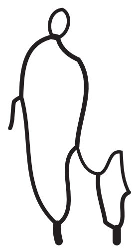
XL3/105

On return from a factory floor tour of XLam in Nelson the decision was made in agreement with their design team of the efficiency of the 3 layered 105mm thick panel type. Through example this panel type has been found by them to accommodate the best height and spans whilst using the least amount of volume, reducing costs.



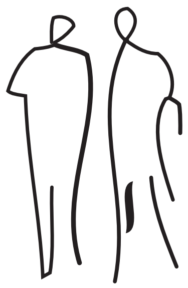
Programme

The following outlines the designated programme for the research to follow. The priority is to look into a defined typology or demographic of which faces high growth within New Zealand over the next 20 years

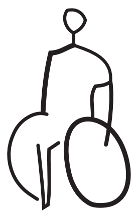


First-Home Buyer
approx. 100 sqm
Parent + Child

First-Home Buyer
approx. 140 sqm
Two Parents + Two Children



Homeowner Downsizing
approx. 90 sqm
Couple



Homeowner Downsizing
inclusive architecture
Single

Fig.3.09. Defined demographics of design

Medium Density Housing

The Future of New Zealand Living

With the current state of the New Zealand housing industry is struggling beyond capacity, it is important to look towards how we are designing and building to prevent the situation arising again. The main issue is that in the past, the projected living typology hasn't been accounted for, and now we are at the stage where providing for past living typologies is not suitable. Thus looking to who we need to accommodate for and how to do this is essential. The projected population growth over the next 2 decades sees an increase in single bedroom units, with the average overall occupancy of a dwelling dropping from 2.6 to 2.5 (see Appendix A). Additionally in the BRANZ report of 2017(BRANZ) detached dwellings made "up 80.1% (1,193,358 dwellings) of current housing supply. (Page 16) The BRANZ supply and demand study report on MDH notes that the rising prices of housing, plus social changes are leading towards a greater uptake of MDH (Page 2).

Required Future Housing Typologies

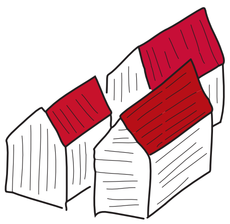
This drop in occupancy rates indicates that an increase in density is essential. Cities throughout the country are now developing their city plans with this typology. Back in 2014, Wellington City Council advised that "Medium-density housing is encouraged in and around key suburban centres... supported by improvements to transport infrastructure between these centres and the central city" (Wellington City Council 9). In addition, Hamilton proposed an intense address of this issue by accommodating "50% of its new dwellings within existing areas of the city" (BRANZ 13). "The most affordable units for median-income households are likely to be flats and terraced houses on the city fringe and outer suburbs" (Page 43). Using BRANZ study report on the supply and demand of MDH, the chosen category of 'Terraced Housing' as "a row of 2 or 3 storey units, consisting of 3 or more units per building. The roof lines are individual to each unit. (Page 6) "Flats and terraced housing to 3 storeys make up much of these, at a 60% share of all new MDH in the next 5 years" (Page 43)

Definition of MDH

For clarity of the following research Medium Density Housing (MDH) in this context is required to be defined. The need for this originates from the scale of the typology being so broad. MDH is not a single house on a quarter acre property and it also isn't a 40 level apartment building. What is in between? For this exact reason, BRANZ undertook a report study to clarify for their sake that all past research and future research fits under their established MDH definition. In this report they note that there are many different definitions, and conclusively they choose a broad summary to ensure transferability of the term in the future. It is "multi-unit dwellings (up to 6 storeys)" (BRANZ 5). However, this design-led research requires a more specified definition of MDH to accentuate the important aspects and motivations of adopting this density. It is as follows: unit size of no less than 60 sqm and with an average site density of 250sqm per unit. This assures a minimum that will accommodate generously the smallest occupancy, whilst assuring a suitable density increase comparatively to a neighbouring single house site.

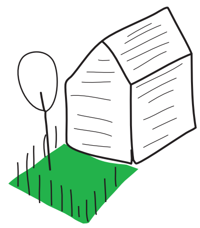
Defined demographics

In research instigated by BRANZ under Page and Rosevear 2015, they indicated both existing residents and potential residents for this density. They include "first-home buyers, young professionals, students, families with children, single-parent families, retirees and empty-nesters" (Pages & Rosevear 2015). Following this research the BRANZ Defining Medium-Density Housing report noted that professional singles and couples occupy majority of this density noting that the lower deposit demanded of new builds was a potential draw card. They also state that "post-family households" are common, due to the want of downsizing, freeing up capital, and not having to leave their existing neighbourhood. (BRANZ MDH) Another third and well represented group occupying medium-density housing in New Zealand are "new (New) Zealanders" this may be linked to having familiarity with this density in the past home countries (Gray Partners Limited, 2016, pg1).



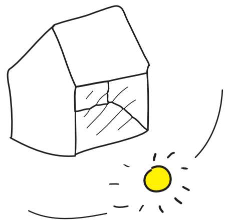
Individual

The opportunity to individualise, both internally and externally. Allowing the ability to point out own home from the other units.



Garden

Direct access from living space to personal outdoor garden, expanding the living space, and increasing sense of place.

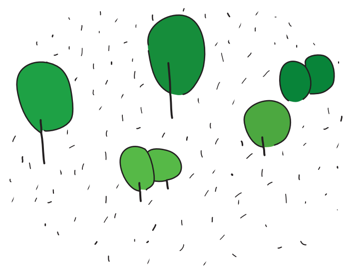


Living

North facing living spaces, maximising on light and warmth. Approximately 4 hours per day. (Calculated on the shortest day of winter).

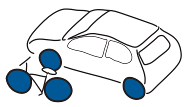
Communal

Creating space that encourages positive interactions with residents. Improving the chances for direct neighbours to live harmoniously.



Space

Maximise on the benefit of sharing the property by the opportunity to enjoy a larger, better quality outdoor environment.



Storage

Ensuring quality of living by providing ample, quality storage for vehicles and larger life possessions.

Fig.3.10. Defined demographics of design

MDH Design Principles

Generated from the previously noted BRANZ study report defining MDH, a collection of principles essential for developing a quality living environment for New Zealand that encourages higher density living has been developed. (See fig.3.01.) It ignores the commonly compromised aspects that turn buyers off higher density living - wrong location and cost - as these require a high level study on their own. The main principles of this design is to provide a high quality shared environment that increases the desirability of higher density living, and provide smart design that includes smaller spaces.

Context - Site

For the second stage of the design research a site was applied as an additional factor. The chosen site was determined by factors that relate to integrating MDH suitably in New Zealand's existing cities. To align with projected population growth, and BRANZ's reports on MDH a site within an established suburb that is in short radius to local amenities and directly connected to the CBD with public transport. Adding elements of limitation that would ultimately allow the design to grow towards a system suitable for interesting New Zealand site plots.

- 132 Coromandel St, Newtown, Wellington, New Zealand

With the application of the site, elements of limitation increased. This will be seen to allow the design to grow towards a system that is suitable to unusual New Zealand site plots.

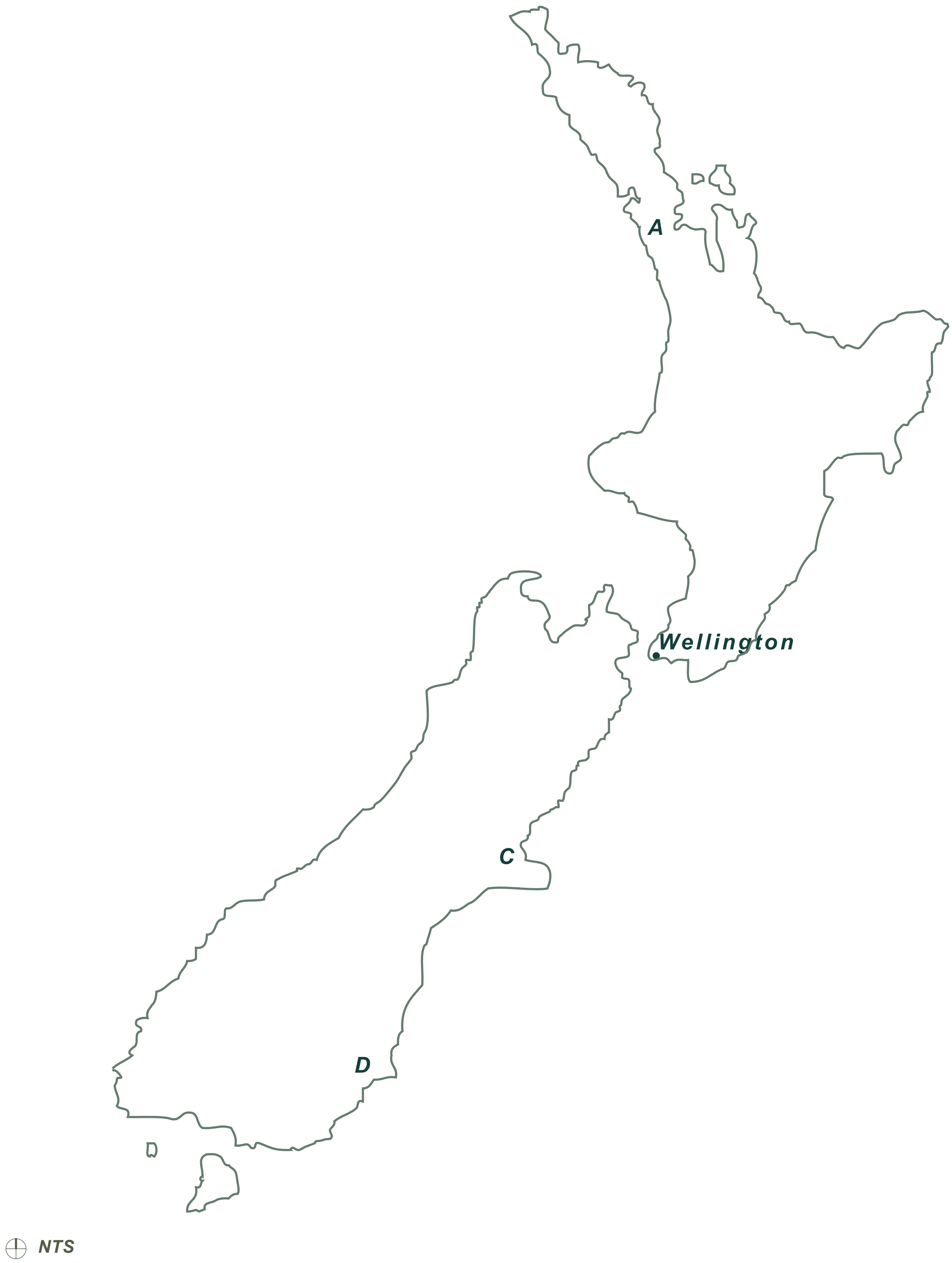


Fig.3.11. Outline of New Zealand, Wellington indicated

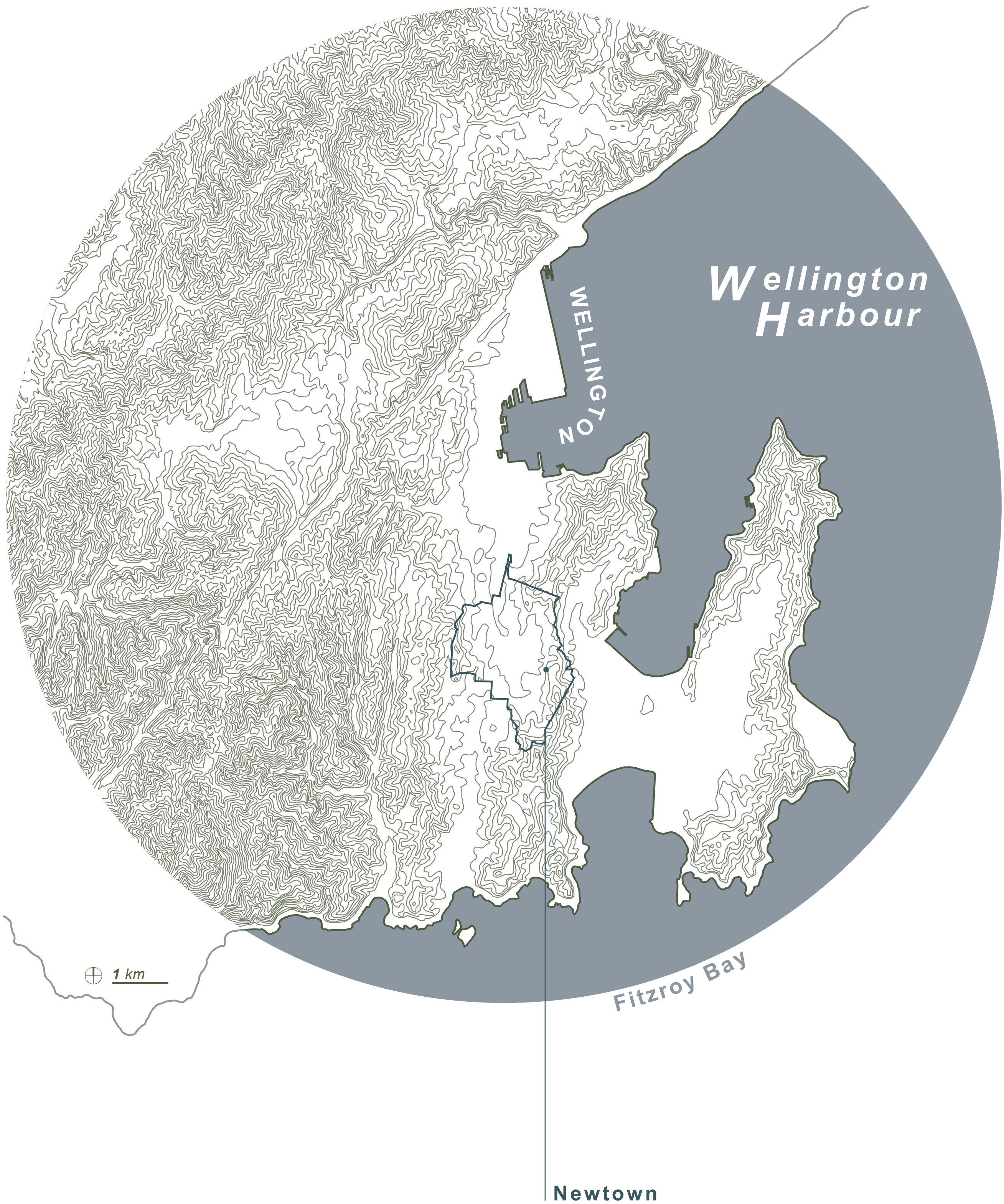


Fig.3.12. Image of Wellington, Newtown indicated

Fig.3.13. Image of Newtown, site indicated

Fig.3.14. Site looking West

Fig.3.15. Site looking North West

Fig.3.16. Site looking North East

Fig.3.17. Site looking East

Fig.3.18. Site looking East

Fig.3.19. Site looking South East

Fig.3.20. Site looking south

Fig.3.21. Site looking South West

Fig.3.22. Map of site

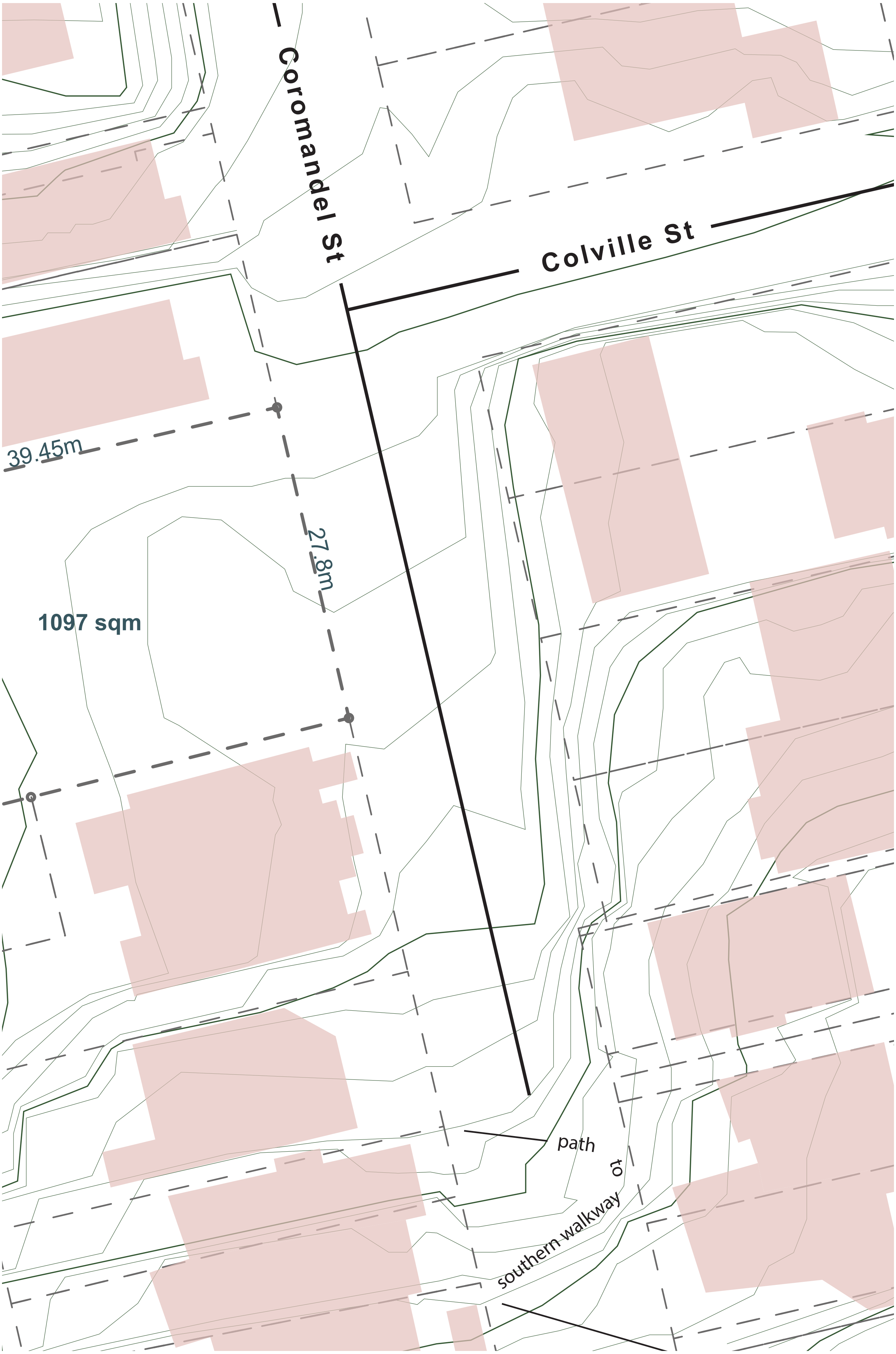

Coromandel St
Colville St
39.45m
27.8m
1097 sqm
path to southern walkway

Fig.3.23. Site Analysis noting main weather characteristics of the location

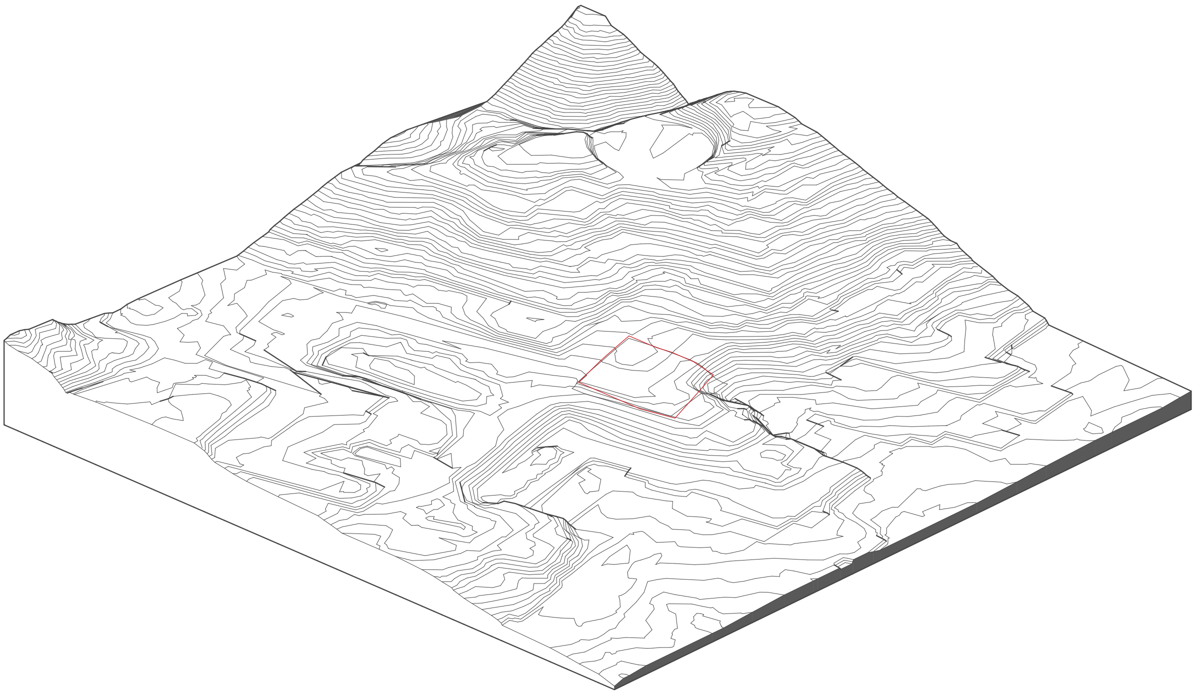


Fig.3.24. Site Analysis noting main weather characteristics of the location

Weather Analysis of Site

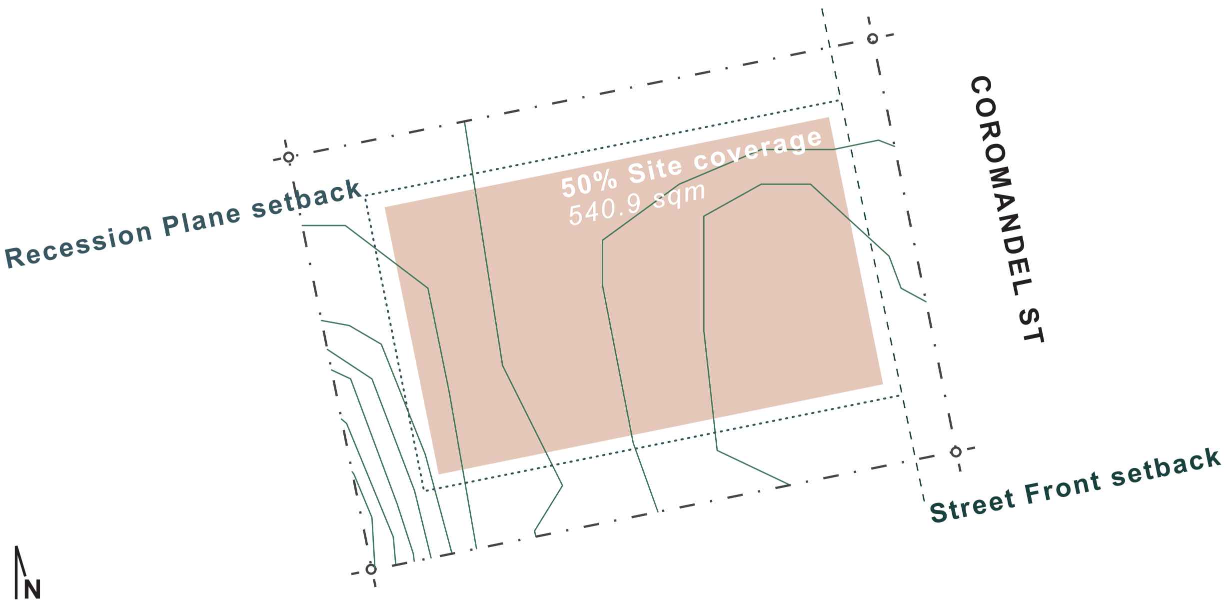
See fig.3.23. for a visual breakdown of the weather characteristics of the location. This site sits on the borders of the southern walkway, with the Newtown Valley to the North West. The prevailing winds channel down here, with the South-East face receiving little wind exposure. The Summer and Winter Solstice sunrises and sunsets are indicated. Acknowledgement of the summer sunrise being blocked by the hilly southern belt behind. The main views over Newtown to Brooklyn and the main sun exposure also experience the brunt of the winds.

The Building plans indicate the surrounding typology of a mixture of detached homes, and medium-density housing.

The contours are set at 2 metre and consequently show the property height change of 7 metres and the surrounding steep terrain that shades and protects from the South East.

This site provides many challenges, including the following to be addressed through the design:

- •- How to build with a sloped site
- •- Two built up neighbours
- •- Ensuring generous sun exposure to the internal living rooms, and protecting them from the winds
- •- Variance of sun gains from summer solstice to winter solstice



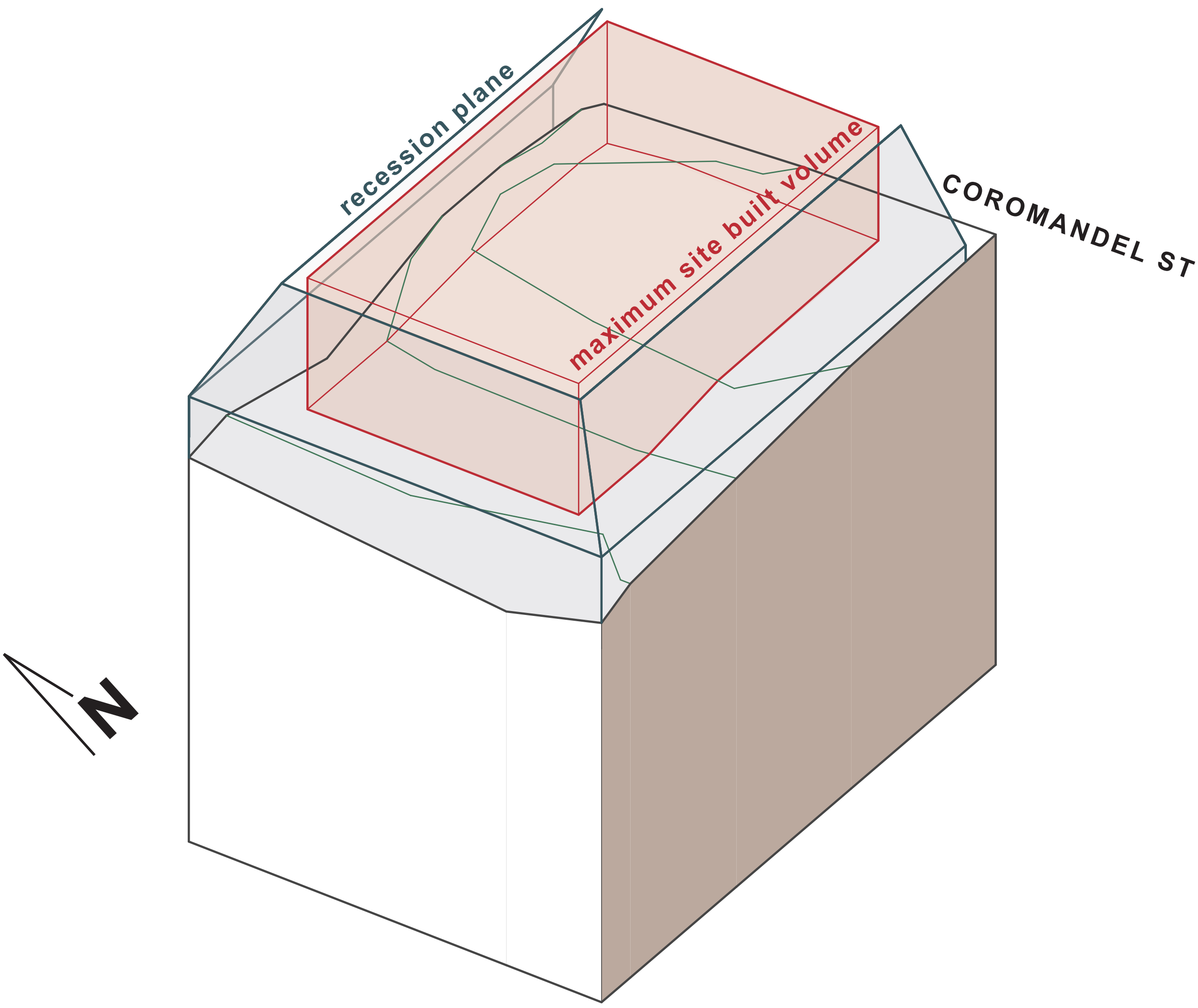
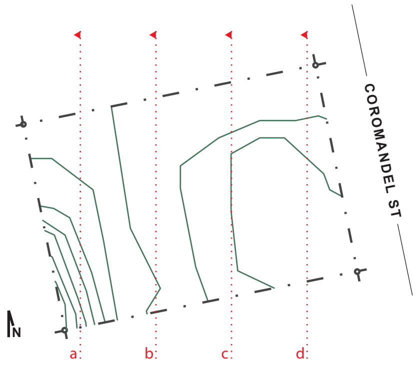
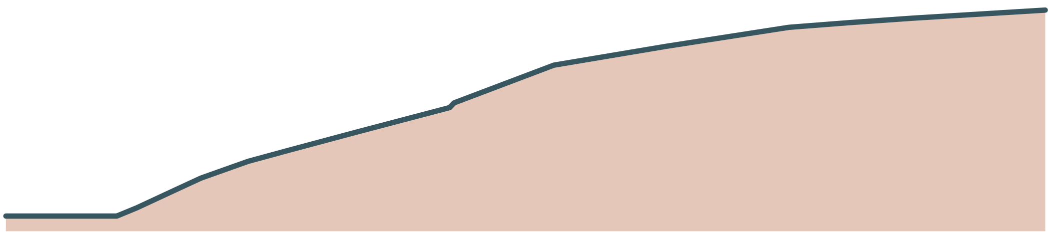


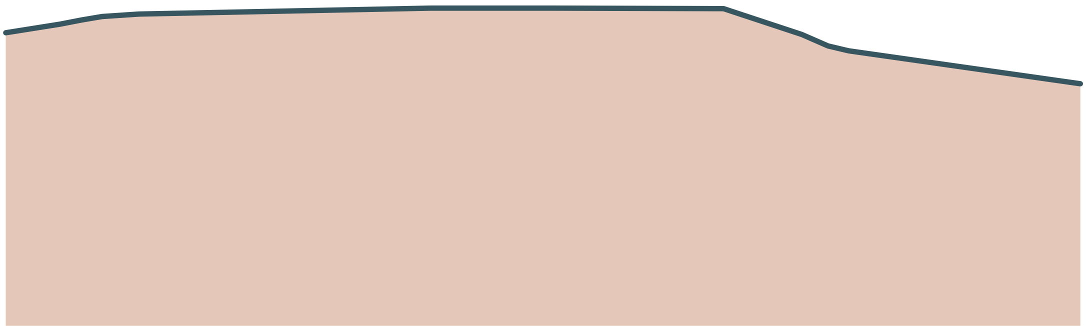
Fig.3.25. Site details, plan and axo





Section Aa.

Section Bb.



Section Cc.

Section Dd.

Fig.3.26. Site details, plan and axo

Fig.3.27. Collage of viewed MDH in Newtown from town belt

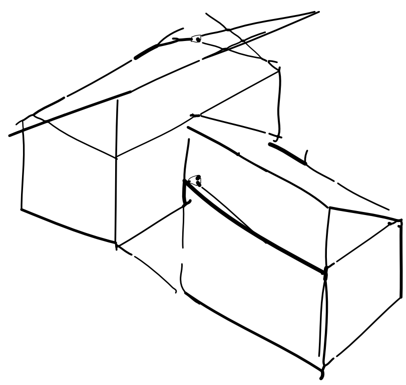
Clear Opportunities for the Design

Technical Design Criteria
The degree of prefabrication for this research will design two-dimensional elements, as they harmonise the demands of transportation and of onsite assembly. They will be formed using XLam's 3 layered 105mm thick Pinus Radiata panel

Programme
The programme will accommodate the two key demographics living in MDH in NZ as first-home buyers and home-owners downsizing. It will aspire to the average unit occupancy of 2.4, with a unit density of 240 sqm on the site. The design will prioritise direct connection to quality outdoor environments, and the contribution of the overall form to the system

Context Site
The site is a classic example suited for MDH with a close connection from the Southern Belt and to public transport and to local shops. It has an interesting topography that will require addressing as will the view aspects and consideration for the wind and sun

4. *Design Research*



Stage One - Preliminary Design

Stage One involved the initial design intervention that explored the three design principles exclusive of a context. It explored how the design responded to each principle, and consequently how the principles responded to one another. An understanding of standardisation, repetition, and personalisation was formed. This stage concluded that maximisation of each principle must come with a set of limits to ensure the idea of efficiency and quality design are not lost. It also clarified the need to shift the design approach for Stage Two.

Principles Approach

'Designing to Assembly' understands that each design decision will affect the overall spatial quality, overall form, and connections in respect to aesthetic and efficiency of installation. The aim is to provide a quality MDH design that endorses the efficiencies of prefabrication.

The determined level and scope of standardisation will determine the overall efficiency of the designed project. Too much restriction will assure uniformity and be unsuccessful with the overall form. Too little restriction will assure complexity in the form and the project, removing the need for prefabrication to be adopted for the project. Standardisation will be in the form of a planning grid, and in the provision of standardised elements.

Repetition is a direct reaction to standardisation. Exploration of repetition will allow both interest in the design and simple construction with straightforward onsite assembly. Repetition will be explored to understand when, where, and how, standardised elements can be repeated that do not hinder the design.

Personalisation respects that different personal circumstances demand different approaches to the design. It will allow suitable flexibility in the designed system that may override the standardisation and repetition aspects.

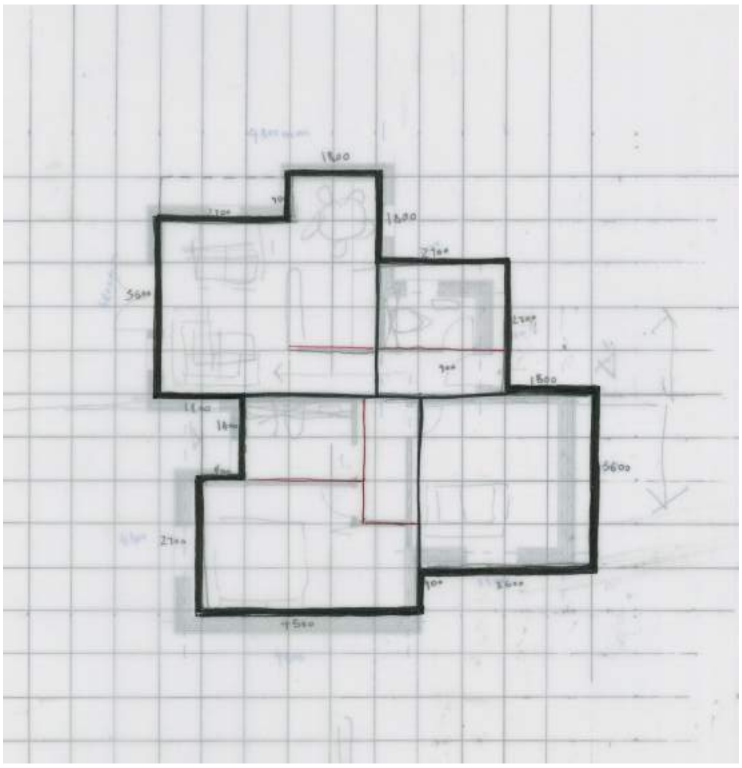


Fig.4.01. Oversketch of single unit with 300mm grid applied

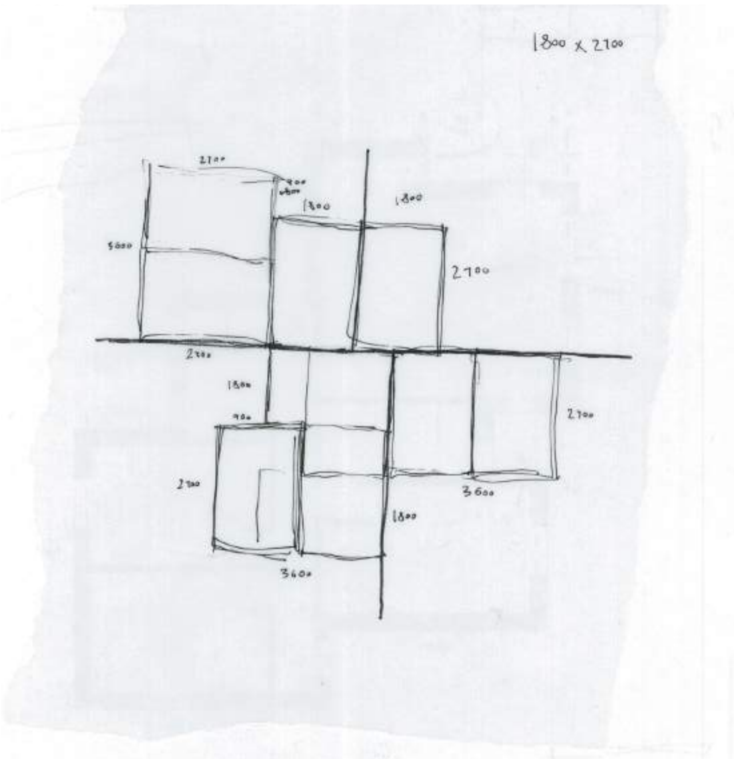


Fig.4.02. Standardisation of areas into common 1800x2700mm size

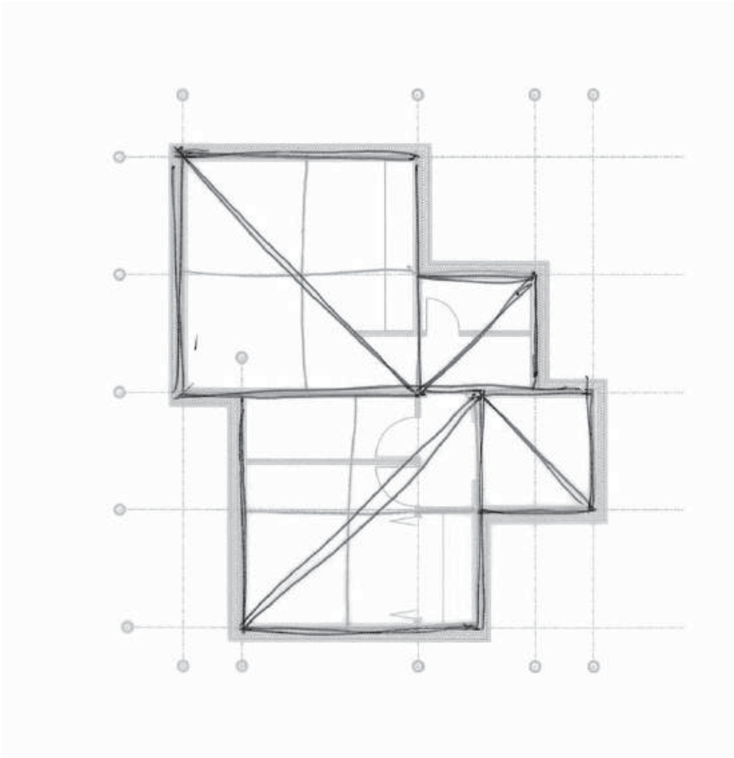


Fig.4.03. Standardisation of areas as 1200mm factor squares

Standardisation

Due to the primary concern with the designed system being the spatial qualities, the standardisation process began with quick iterative floor plans. These plans were the tools to understand the effect of applying a dimensional grid. The floor plan was drawn up assuming the 300mm denominator using determined average volumes per programme. Attention was paid to the reduction of circulation, and a set division between the public and the private living sections. The 900mm and 1200mm grids were then overlaid and the floor plan realigned (see fig.4.01) The results of this exercise established the need for a further look into the differences between the 900mm and 1200mm grid.

With the determined system of standardisation, it is important to explore the degree of prefabrication. Ryan E. Smith explains the role of structural and module grids. “Structural systems are often placed on an axial grid while panels and modules are developed on a modular grid” (Smith 125). The previous pages showed some of the sketches involved with exploring the determined hall and wall grids. The sketch designs were explored by addressing a variety of planning options to ensure that the chosen grid type would not hinder the overall designed spatial quality.

The wall grid matrix addresses the understanding of the command a wall panel will have over the use of space.

The previous five grids are determined matrices that can harness the potential to deliver a framework from which a design can evolve. The hall grid has been based on the implementation of a circulation axis, with programme volume between. The five matrix were drawn to facilitate the 300mm grid that incorporates a designated circulation axis. This framework adds structure to the circulation to reduce the strain on the designed volumes.

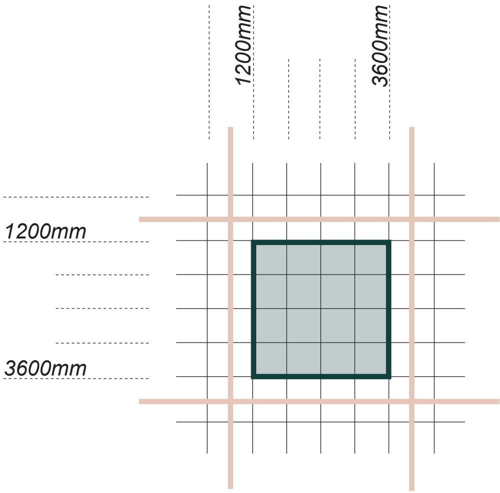


Fig.4.04. Hall Grid Matrix #1 4800 x 4800mm

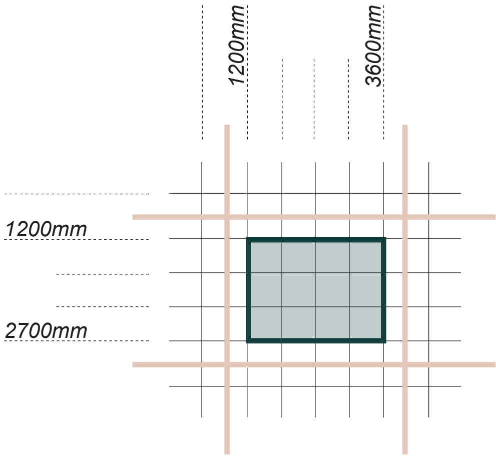


Fig.4.05. Hall Grid Matrix #2 4800 x 3900mm

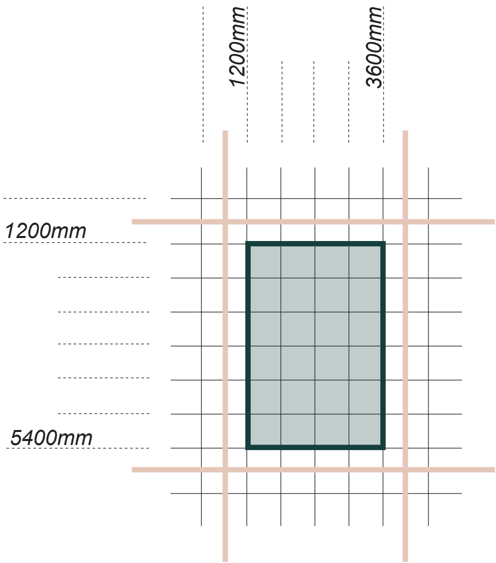


Fig.4.06. Hall Grid Matrix #3 4800 x 6600mm

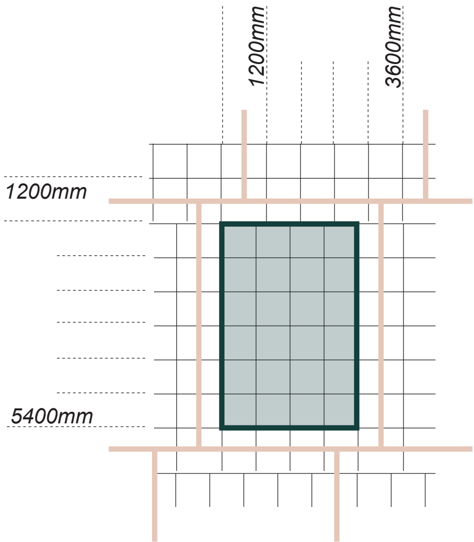


Fig.4.07. Hall Grid Matrix #4 4800 x 6600mm offset

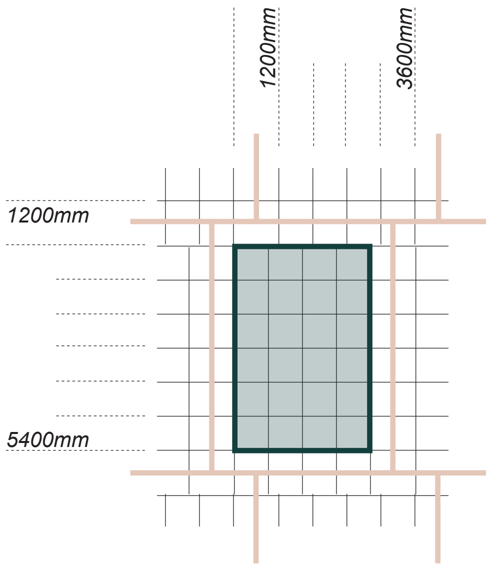


Fig.4.08. Hall Grid Matrix #1 4800 x 4800mm

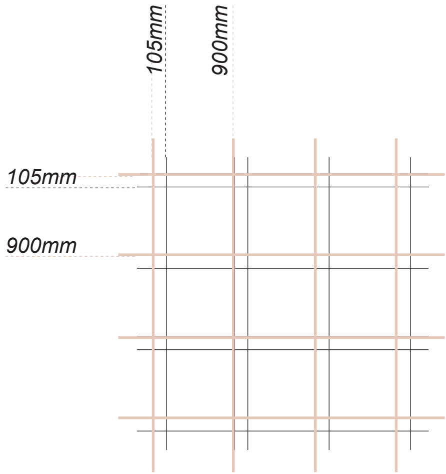


Fig.4.09. Wall Grid Matrix #1 at 1005x1005mm

Standardisation

300mm Grid

With the determined hall modular grid using 1200mm for circulation and 900mm for programming, standardisation of the vertical and horizontal panels is required. Fig.4.12 displays the horizontal panels, also viewed as a module floor panel. The sizes of the panels build incrementally, fig.4.12 displays the visual breakdown of the determined panels. Fig4.13 displays the criteria standardising the vertical panels. This was influenced by the research from Brander et al. and the site visit to the XLam factory in Nelson. With the decision for panels to be picked up on their edge, consideration for the placement of the voids was essential. Additionally the voids here were explored by how they can relate to one another – see the aligned centre lines.

"grids are a geometric system of organisation allowing building components and prefabricated elements to have standard dimensions"

(smith 125)

Fig.4.10. Scans of hand sketches of initial exploration of potential designs using a small unit

Fig.4.11. Floor Plan of 3 unit medium-density housing trialling out the hall grid.

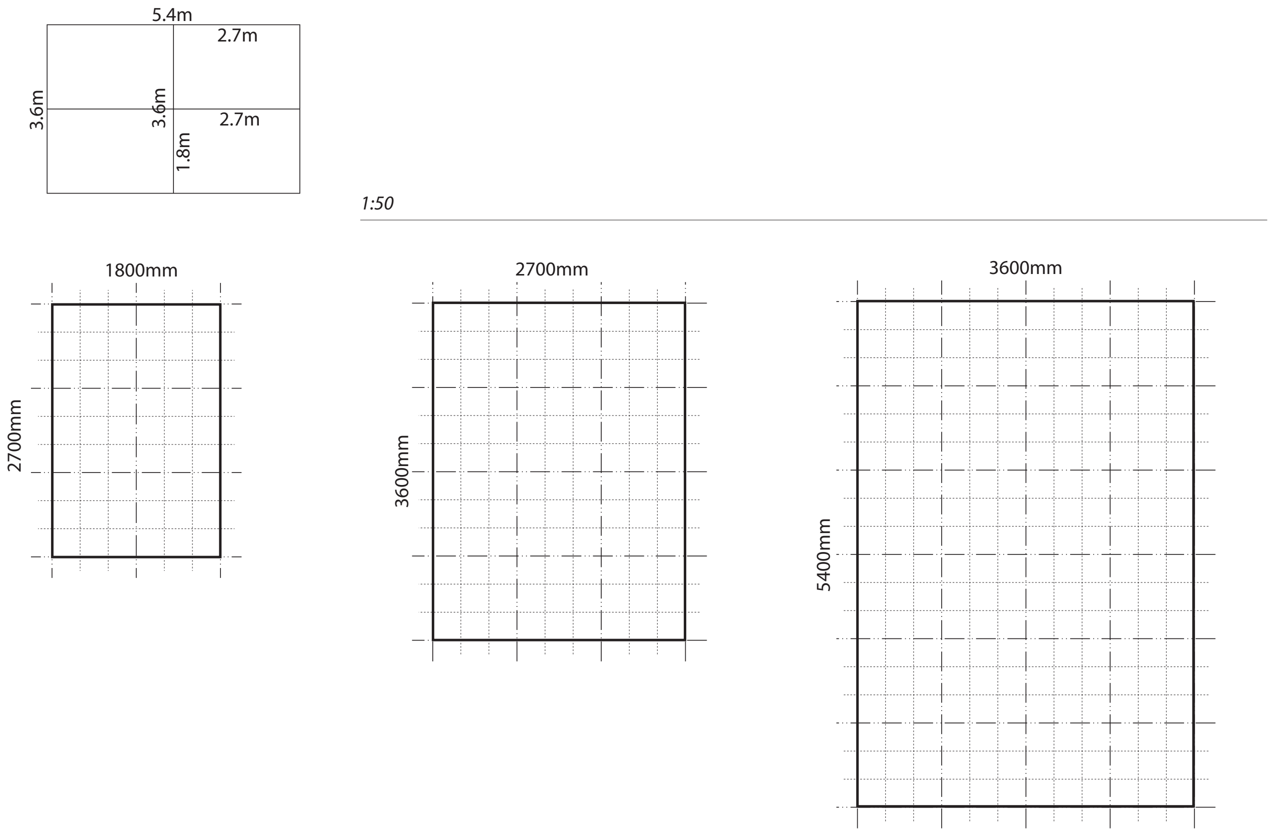


Fig.4.12. Horizontal panels standardised

Standardisation

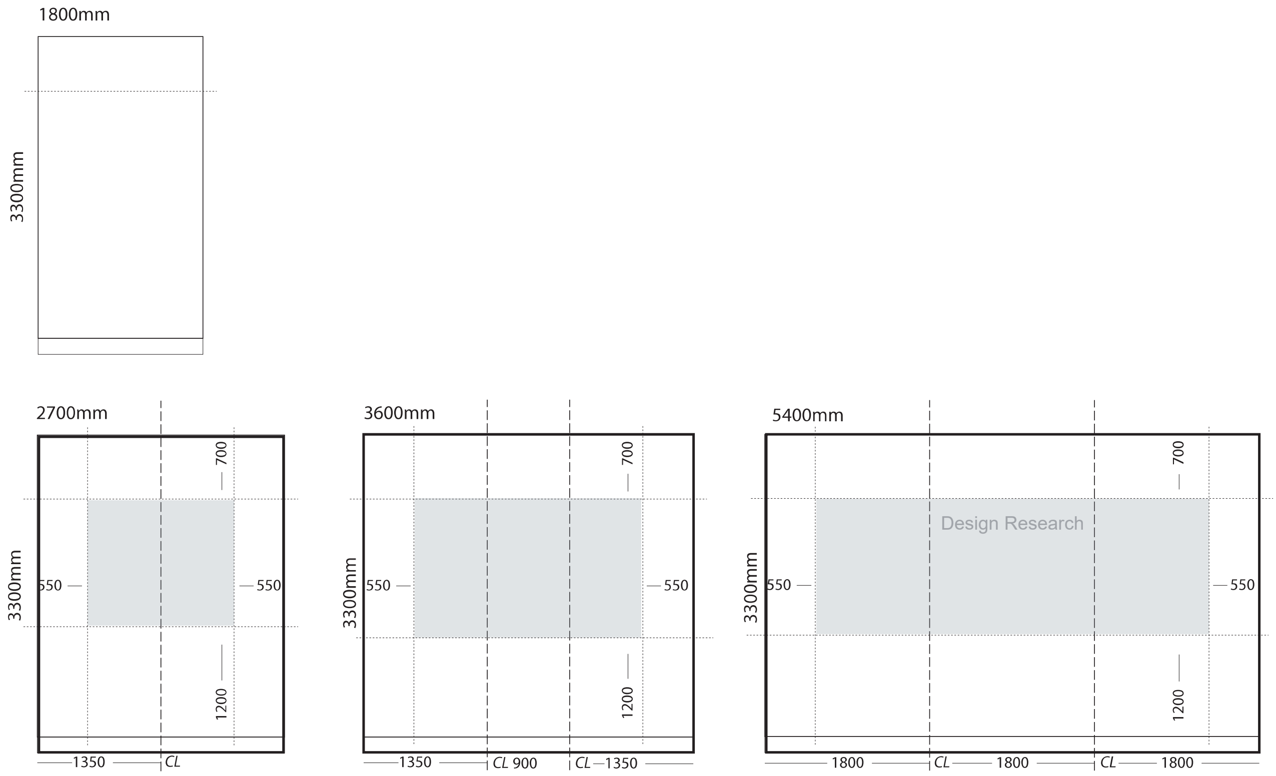


Fig.4.13. Vertical panels standardised with indicated optional voids

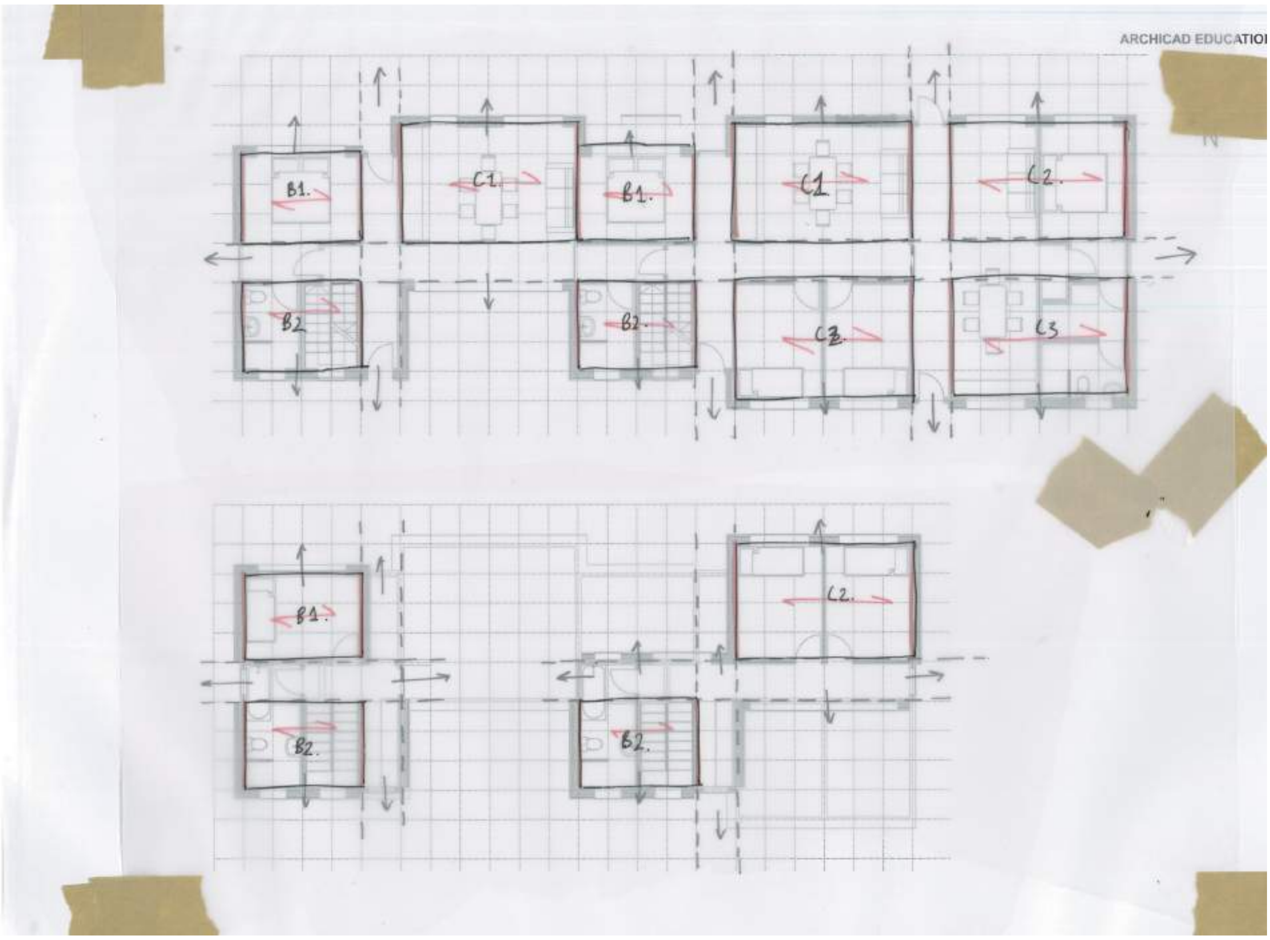


Fig.4.16. Oversketch of designed floor plan extracting common volumes, disregarding programme

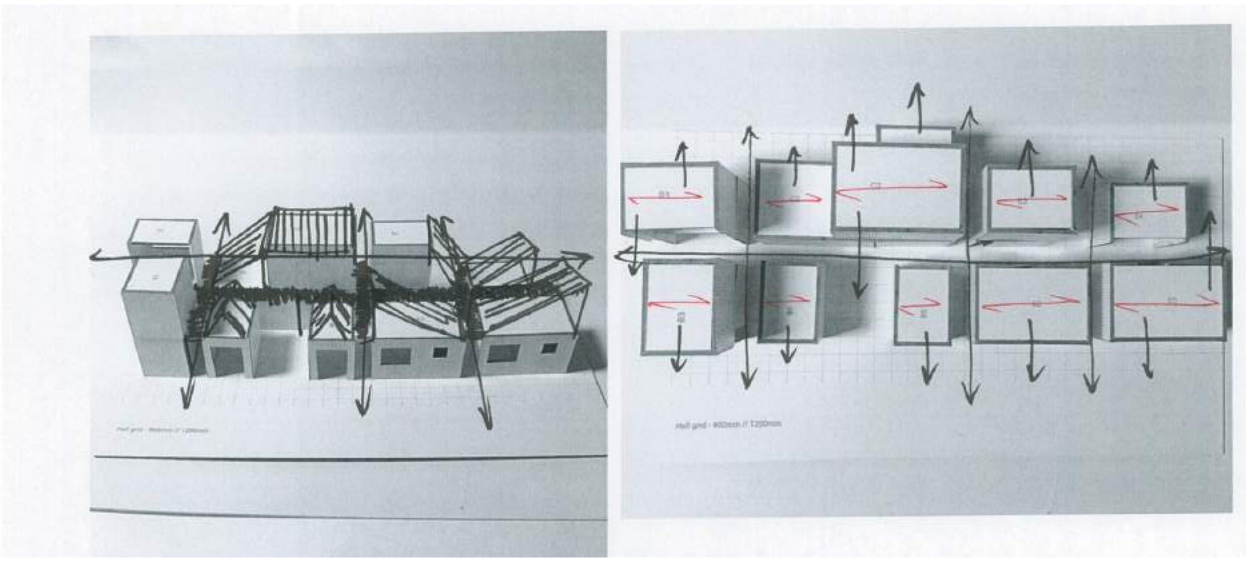


Fig.4.17. Oversketch of model photographs exploring optional roof treatment, and the relationship of circulation and structure

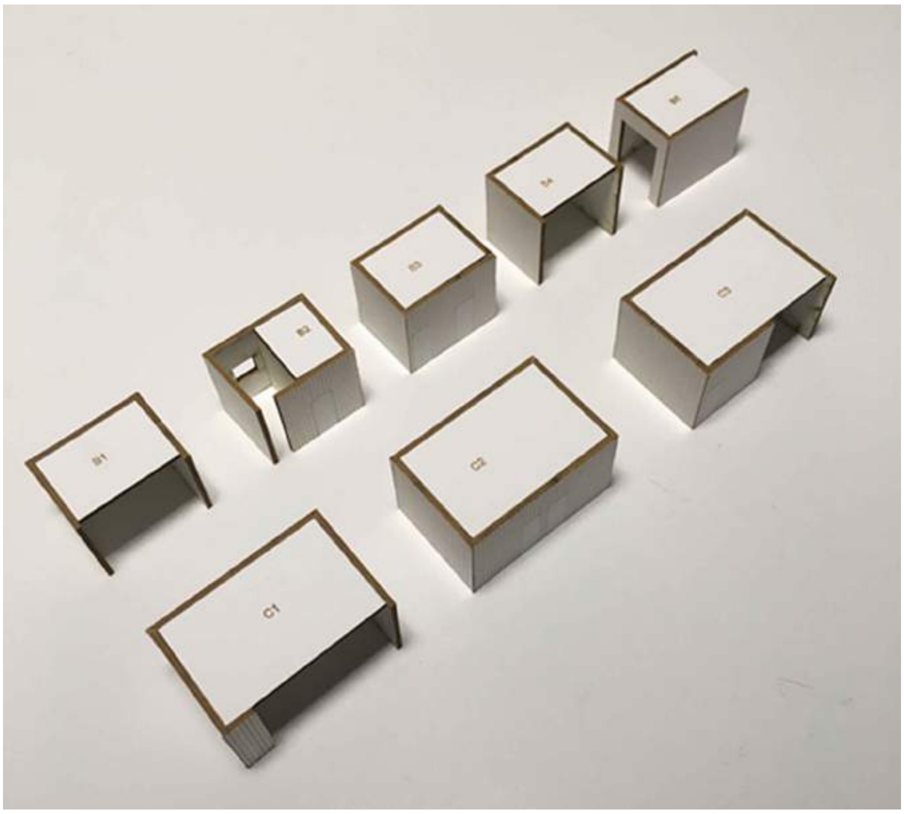


Fig.4.18. Photograph of 8 defined volume units

Repetition

Repetition of Standardisation

With the standardisation of units, exploring the relationship of repeating these units in various configurations was the next step. Placed on the defined 900mm and 1200mm regular modular grid, a level of uniformity was created, yet there is still room for difference and variation. See the opportunity of a small unit relating to a large unit. Based on the provided module floor size, there is the option to integrate two modules in the space of one, allowing a level of flexibility within the provided framework. The options of repeating the set 8 units in different configurations are innumerable. So now the question lies with how various personal circumstances can be addressed and what the overall form provides.

Fig.4.19. Oversketch of designed floor plan extracting common volumes, disregarding programme

Fig.4.20. Oversketch of designed floor plan extracting common volumes, disregarding programme

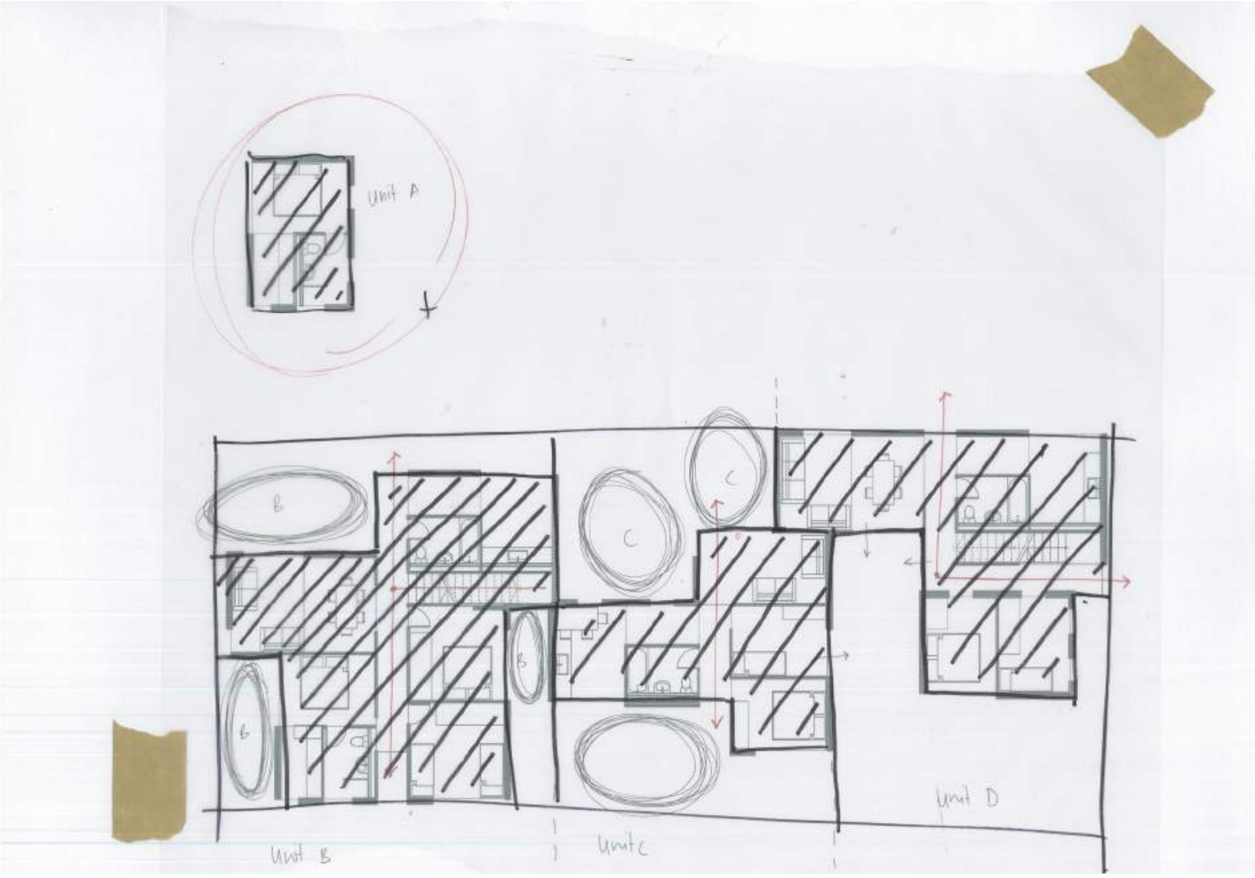


Fig.4.21. Oversketch of designed floor plan extracting common volumes, disregarding programme

Design

Iterations

With the provision of modules and a framework of which they can be arranged, the floor plan for the whole design was developed. Four units: Unit A contains three bedrooms and an attached flat unit; Unit B is a two bedroom unit, Unit C is a single studio; Unit D is a 3 bedroom unit.

The design iterations involved exploring the relationship between the modules themselves within a unit and then intra-units, exploring the creation of positive and negative spaces. All whilst concerning with optimising north sunlight gains, and interest with the exterior aspects, and providing suitable privacy. Planning has been assumed to involve direct external connection from the living rooms. The entrance is to the South of the site. With external aspects, placement of windows and doors has tried to be limited to space designated to the said unit. With all three sketches, the top of the page is assumed North, with sun moving East to West.

The largest development from fig.4.22 involves the spaces surrounding Unit C. With the idea that although it is the smallest by far it still deserves a quality direct external environment.

In fig.4.23 the priority for the zoning of Unit C resulted in a stretched design plan that was inefficient in land use. This can be attributed to the simple orthogonal form of the single module unit. As a result in Unit C has been extracted (see fig.4.24.). This has resulted in the opportunity for the three larger units to compress into an efficient floor plan. Yet to note the failings of this design is there is no efficiency in the building itself. With four units there is only one party wall measuring 1800mm.

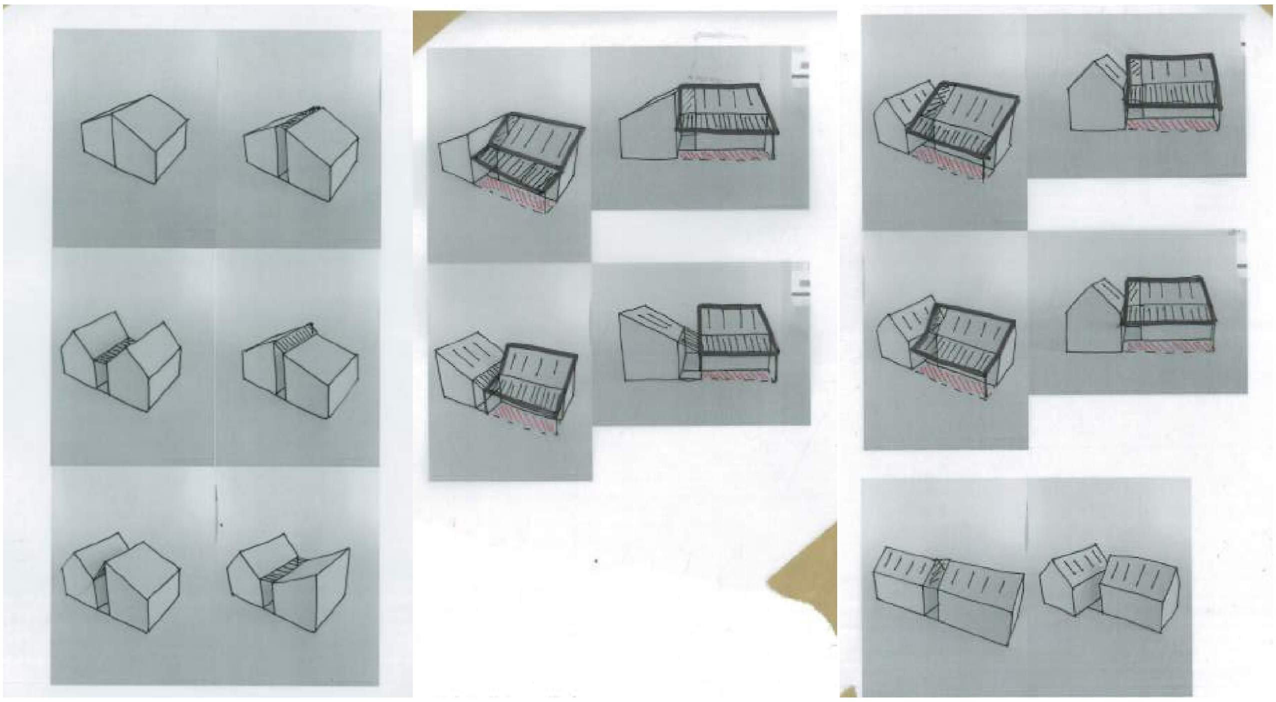


Fig.4.23. Over-sketching of physical models exploring roof connections

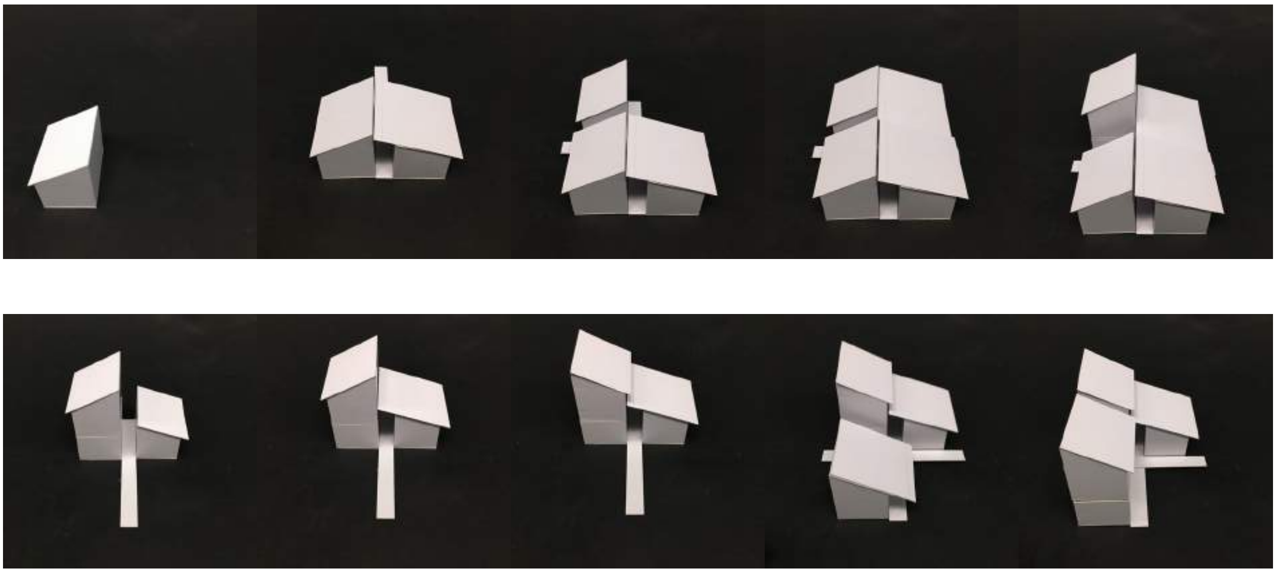


Fig.4.22. Physical modelling exploring roof connections

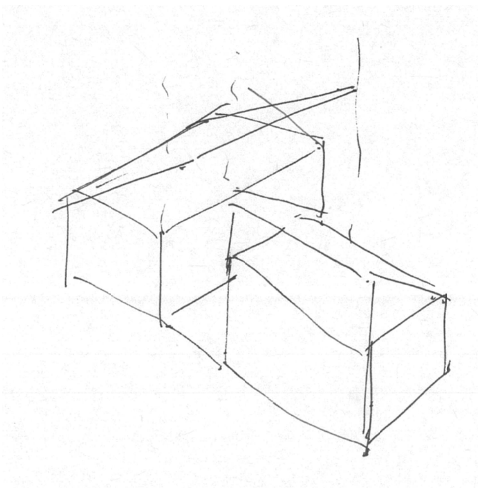


Fig.4.24. Quick sketch of components connecting

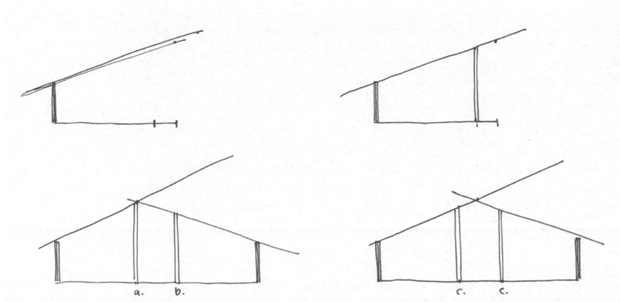


Fig.4.25. Quick sketch of connecting with circulation

Design

Roof

“A pitched roof freezes a plan into one limited form” (Bell and Southcombe 33). However as stated with IBS, the lack of formal dialogue to the climate made the product unsavoury (Bell and Southcombe 33) . An angled roof has the opportunity to increase the acceptability of the external form and the internal spatial quality. Challenge lay with the component/ circulation roof connection as the level of flexibility had already been assured. Consequently the modules measurements were refined to freeze spans and allow slope and eave alignment. With this set the rood forms developed to internal, external and sloped roof.

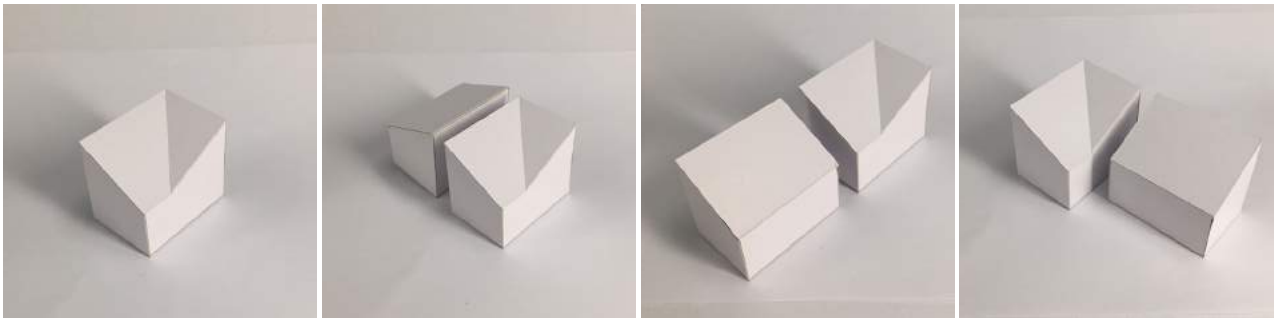


Fig.4.26. Physical modelling of ‘Internal’ roof and sloped roof. ‘Internal’ roof pictured above left

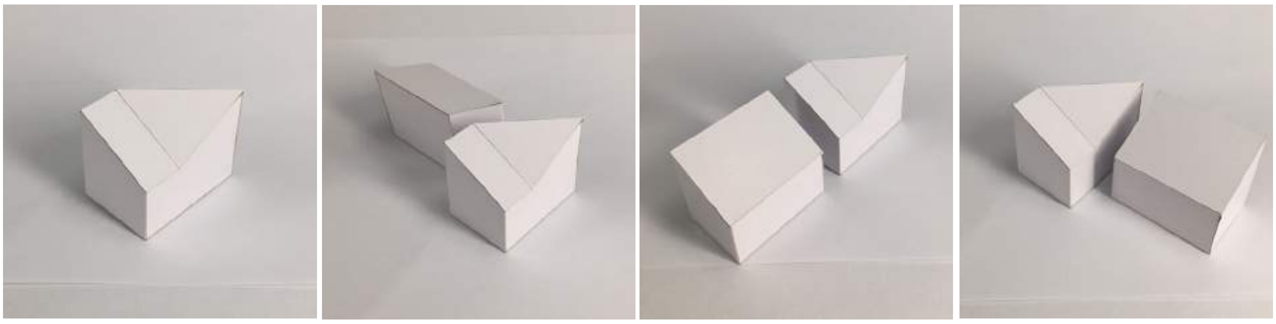


Fig.4.27. Physical modelling of ‘external’ roof and sloped roof. ‘External’ roof pictured above left

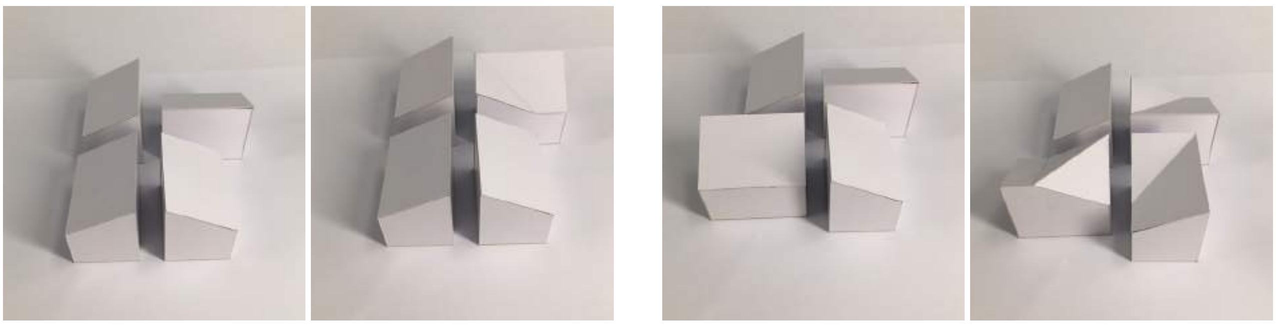


Fig.4.28. Physical modeling displaying the opportunities for ‘internal’ and ‘external’ roofs connecting with a ‘sloped’ roof

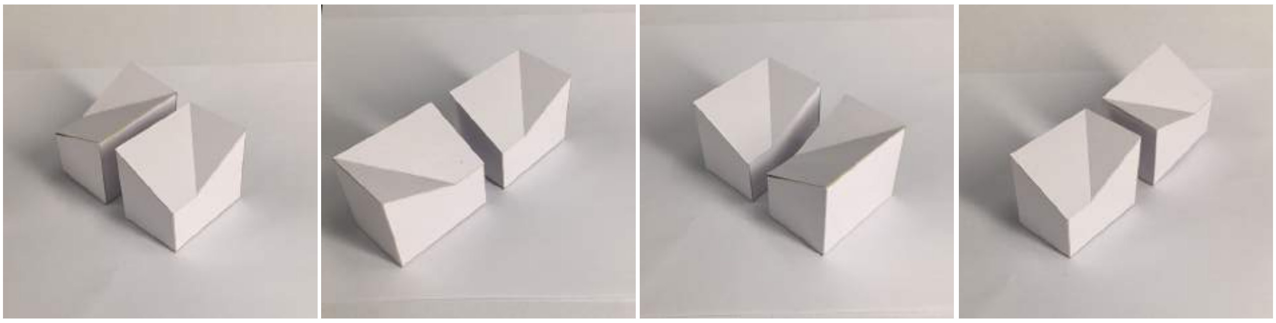


Fig.4.29. Physical modelling of ‘internal’ roof with itself

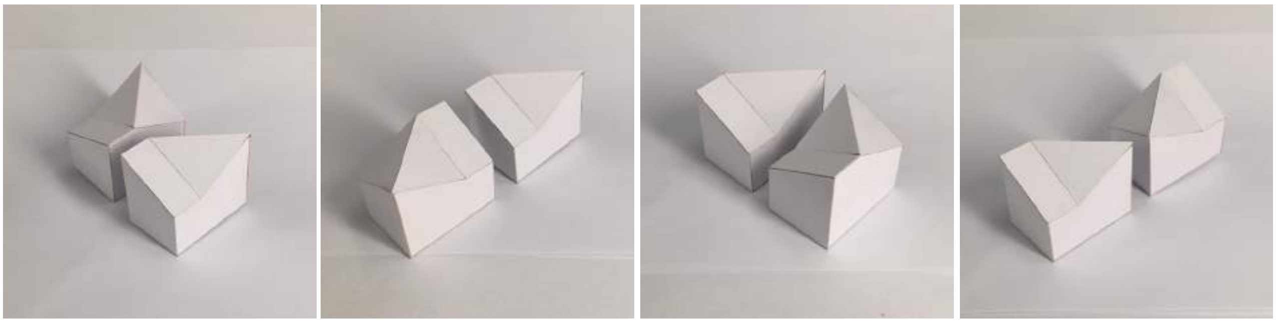


Fig.4.30. Physical modelling of ‘external’ roof with itself

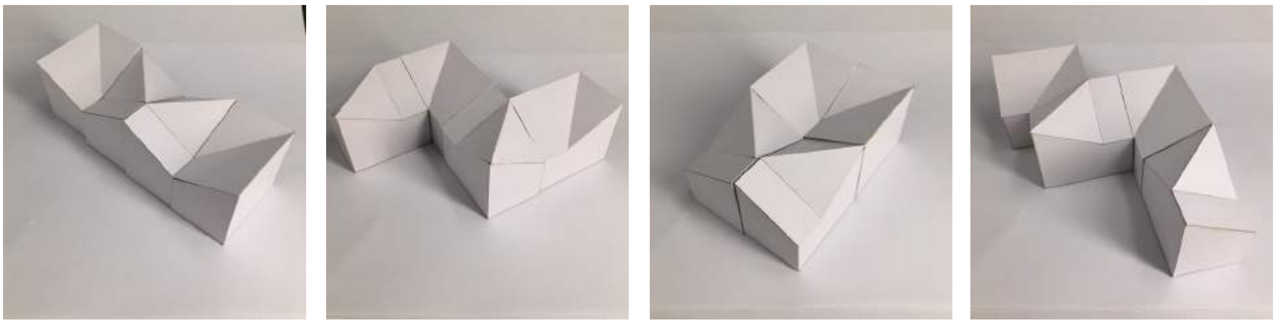


Fig.4.31. Physical modelling displaying more opportunities with the inclusion of the ‘internal’, ‘external’ and ‘sloped’ roof

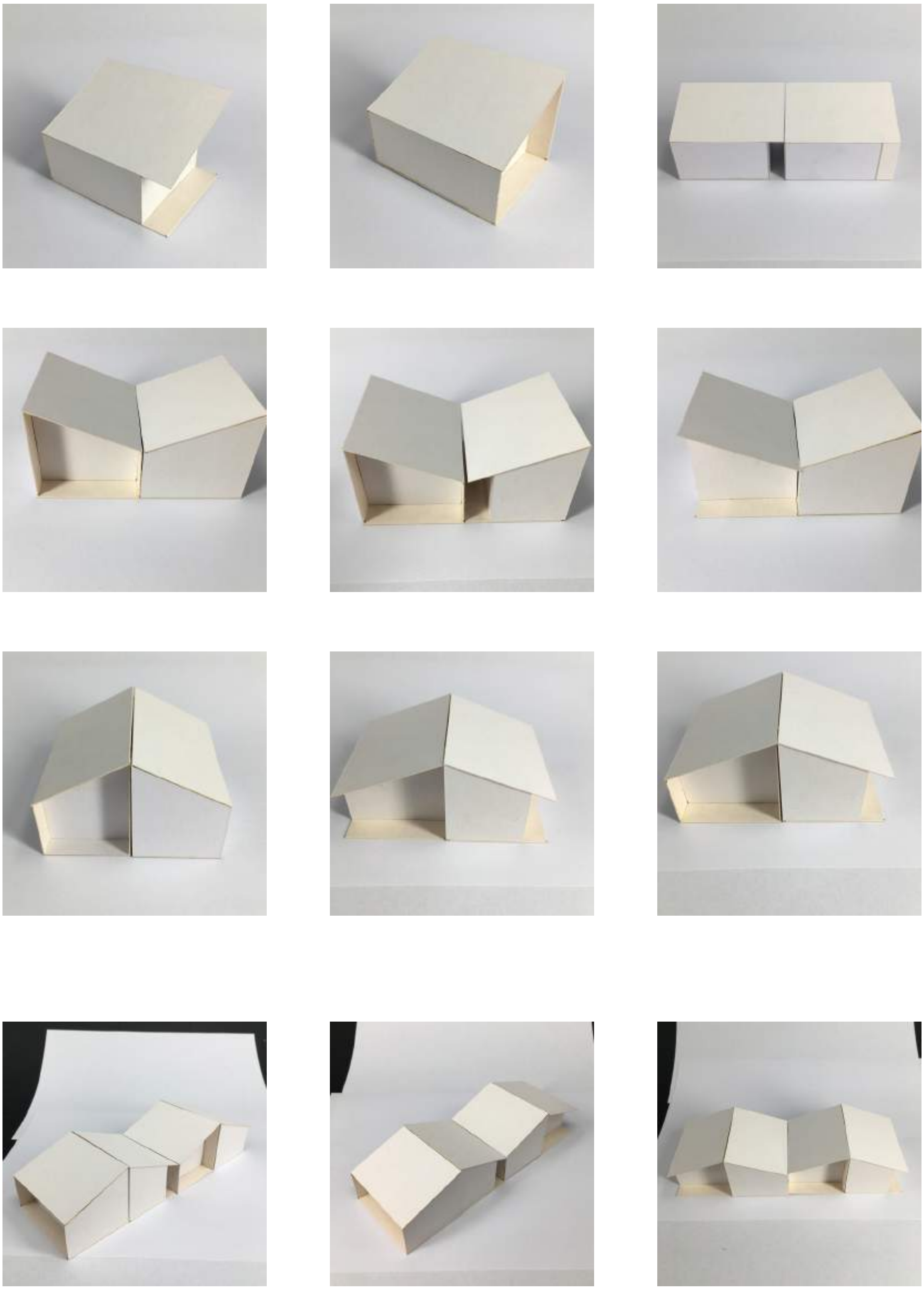


Fig.4.32. Physical modeling displaying the circulation integration

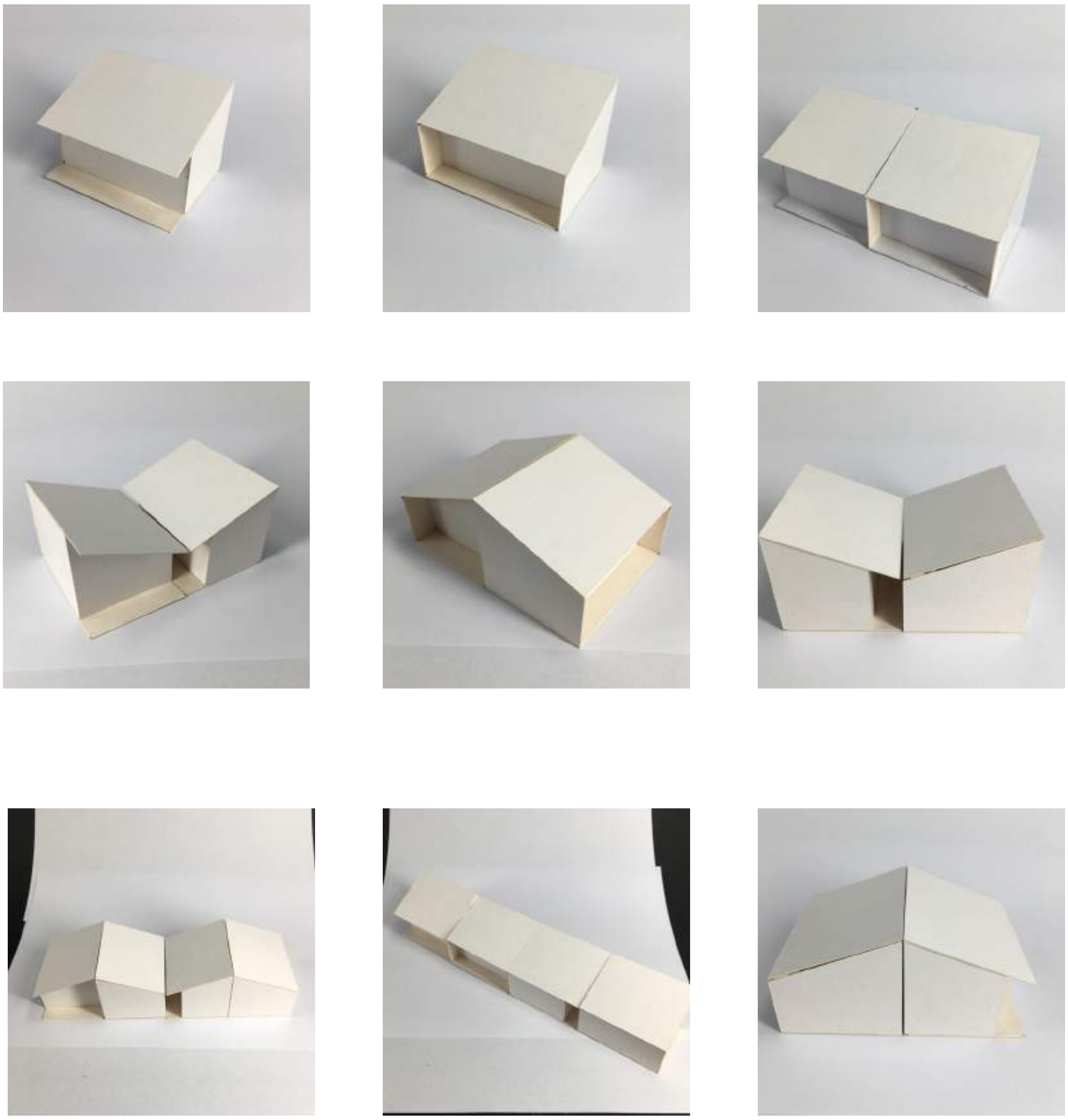


Fig.4.33. Physical modeling displaying the circulation integration

Stage One - Designed System

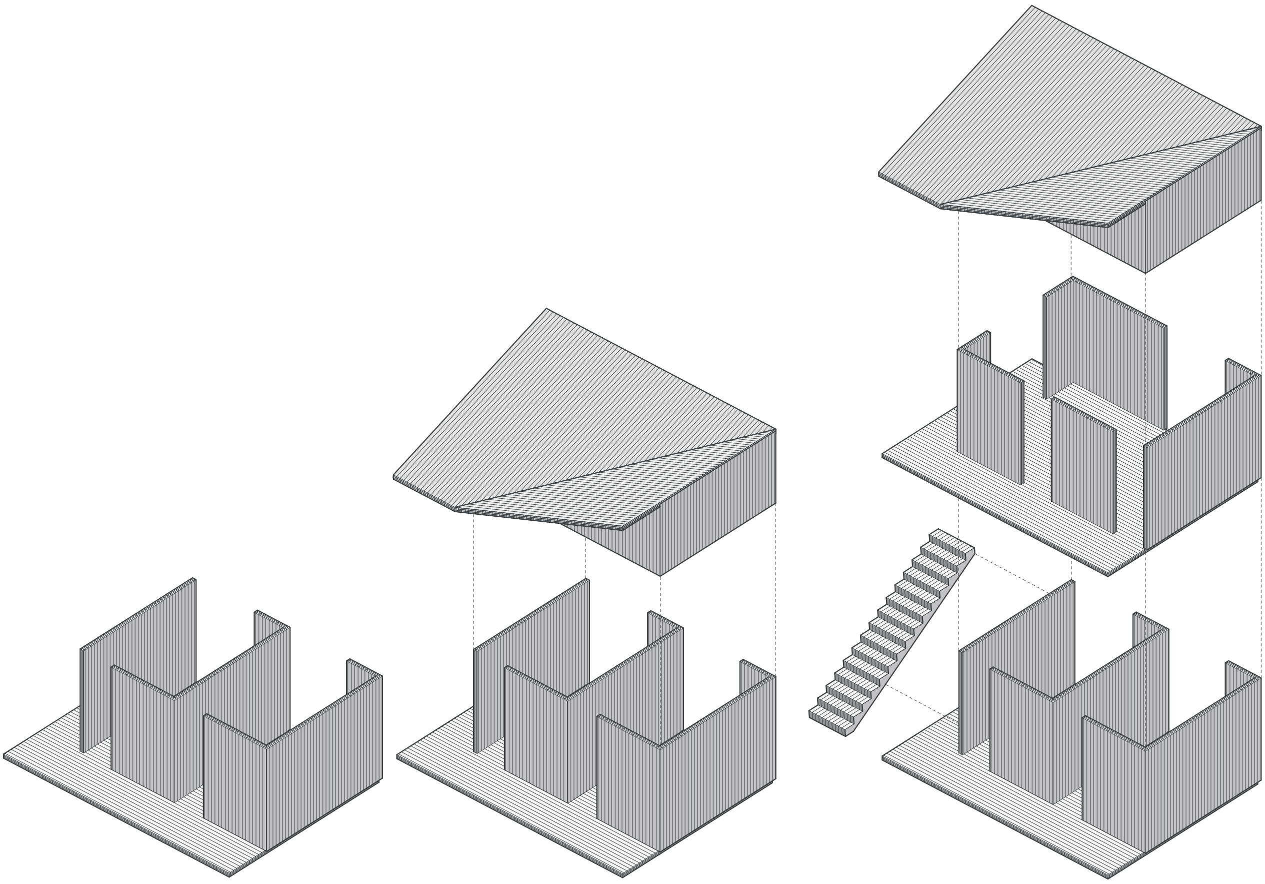


Fig.4.34. Image of system amalgamating

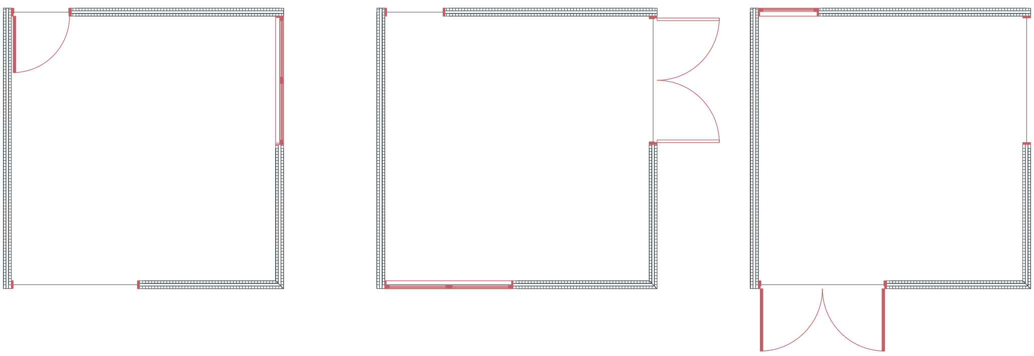
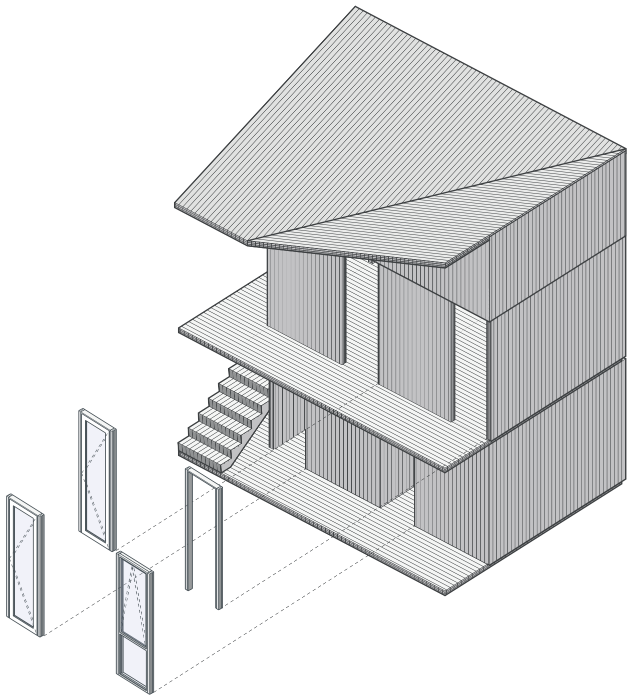


Fig.4.35. Image of system integrating various ingress



The System

The following is the designed system, it is a catalogue of component volumes that make any arrangement. All voids are bare and can (see fig.4.03) be filled with a provided egress (window or door, internal or external). The structural properties allow any unit can be stacked on any unit. The roof units are secondarily determined by the placement of surrounding units. This means that the associated volume is determined by the roof connections and is a weakness. The system also lacks variance in the volumes they are monotonous and flat. (Fig4.29.) Shows how the previous catalogue of 'room components' and 'roof components' amalgamate to form a living volume (fig.4.31) and how various ingress can input to the same voids as seen in (fig.4.30.)

Fig.4.36. Image of system amalgamating with the ingress

System Units - Room

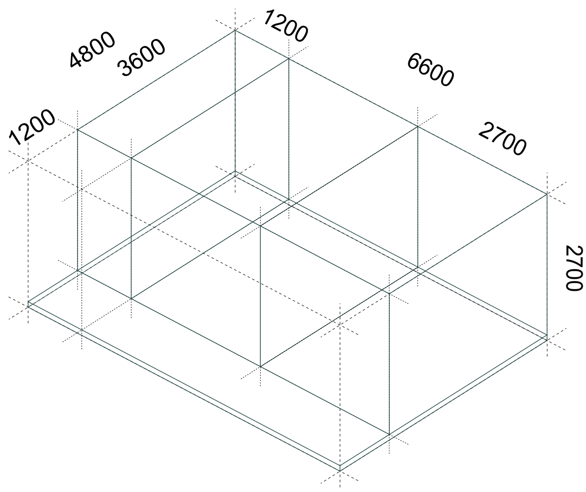


Fig.4.37. Image of 'Room Module' measurements

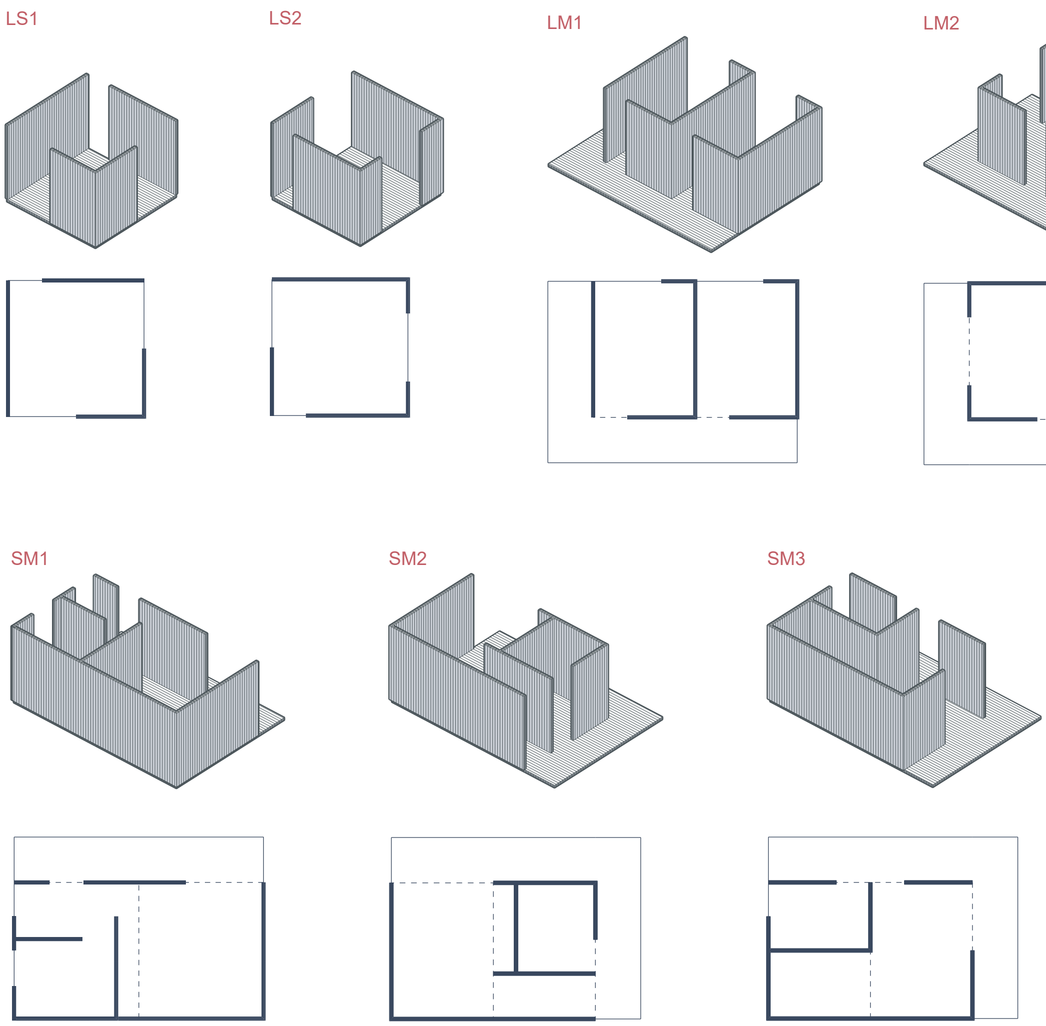


Fig.4.38. Catalogue of 'Room Modules' in perspective and plan

System Units - Roof

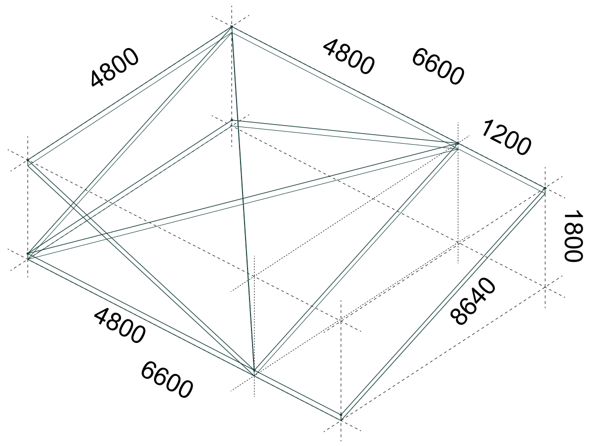


Fig.4.39. Image of 'Roof Module' measurements

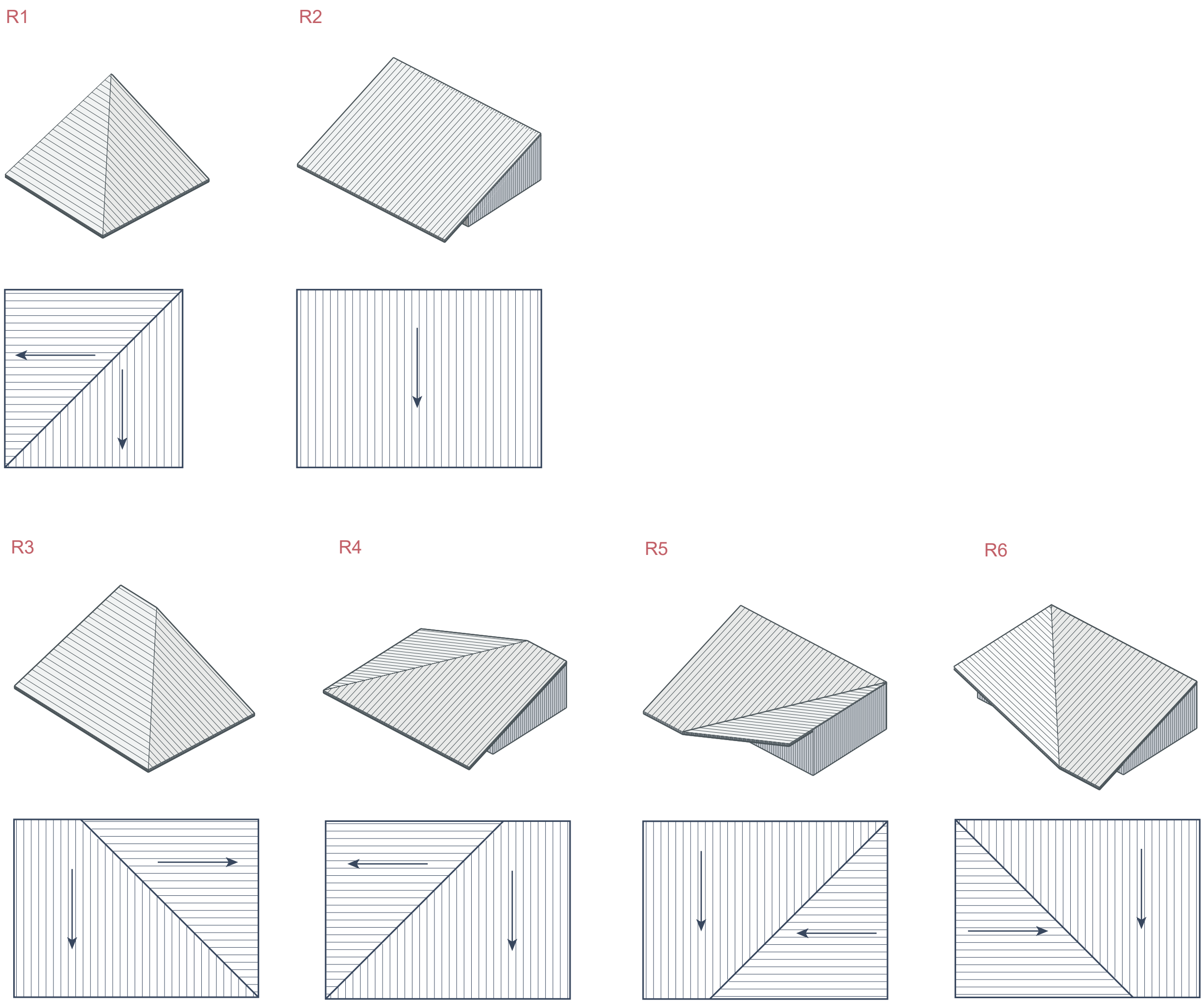


Fig.4.40. Catalogue of 'Roof Modules' in perspective and plan

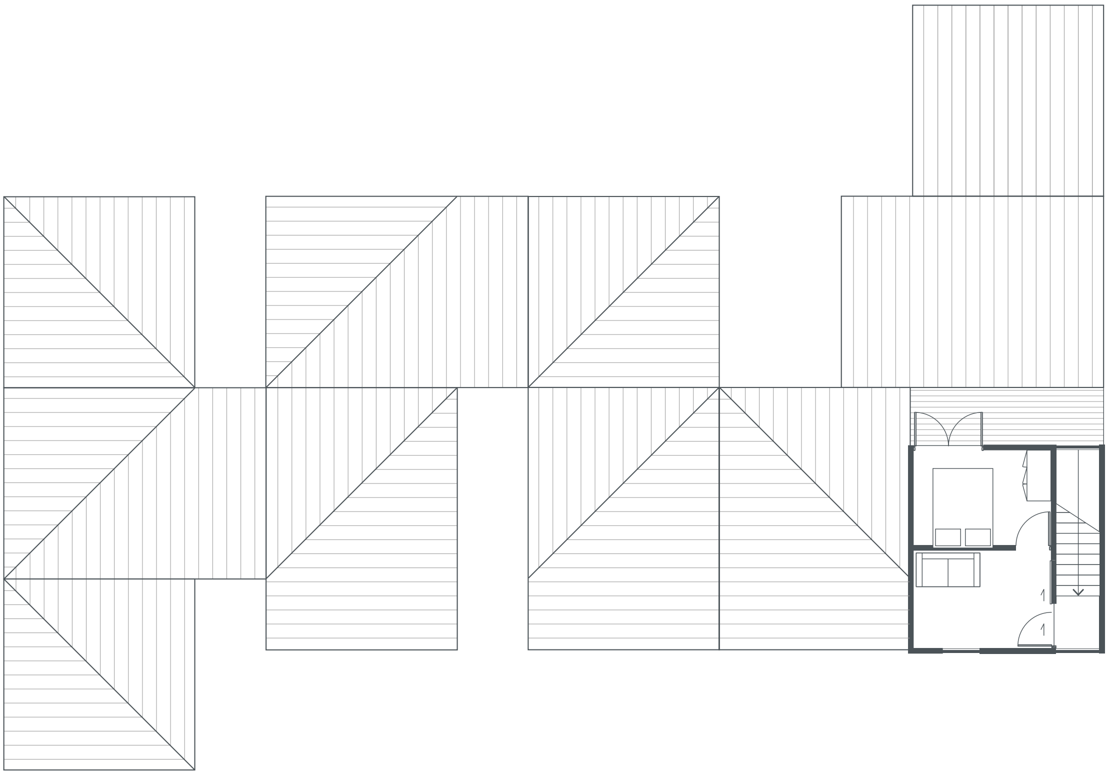


Fig.4.41. MDH Design First Floor

Fig.4.42. MDH Design Ground Floor

The Design

With sufficient iteration of applying repetition and personalisation throughout the standardised framework, the design was set. This gave the chance to understand and reflect conclusively on what worked and what didn't. In (fig.4.40.) the final design is used to assess the designed system. (See fig.4.39) the units have compact floor plans. At least one party wall connects each unit, with voids defining ownership.

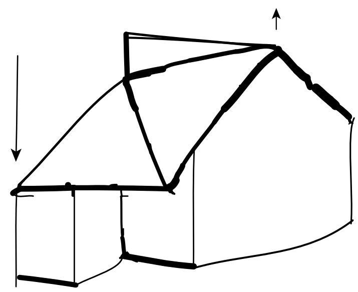
As it can be seen in the design the application of a first floor has not been achieved. This is due to the requirements of the staircase taking up too much space. The compact floor plan can be attributed to the units stretching North-South. As expected this has reduced the exposure to North light with each unit but allows the external voids between to expand the internal space.

Fig.4.43. Image of system amalgamating with the ingress

Fig.4.44. Physical Model of Design with room modules only

Clear Opportunities for the Design

At this stage it is appropriate to reflect back to how this designed system addresses the issue. The stages of the design are broken down: standardisation was implemented using a modular grid. Iterative sketching at the beginning that balanced spatial programming established with the 1200mm spacing for circulation, and 900mm for programming. This developed the module grid. The module sizes were determined with additional planning. Then based on the research by (Brandner, Flatscher and Ringhofer 346) and the factory visit to XLam the vertical panel restrictions was established.
To obtain the right level of repetition, the lengthy process of component iterations, primarily concerned with how personalisation could be integrated began.
All the while this was going on the roof was being addressed, as it was determined to be the key aspect that connected the designed system with New Zealand's residential typology. It was also the factor that added depth to the internal volumes. Over time the issue remedied due to the integration of the circulation per unit. This meant that there were set spans and all angles of the 'sloped', 'internal', and 'external' roofs cleanly connected up – an example of the opportunities that standardisation can provide.
The system is an open slate for how and what to design and it is thus concluded that there is no design. The systems high flexibility of resolve has lost the design and aesthetic. There is also the excessive nature of external wall that fails efficiency.
What needs to be changed is the removal of the components, and instead look to develop a unit that can be tailored to various needs and add a site context.



Stage Two - Design Research

Stage Two develops the theories further. The catalogue of modules was abandoned and replaced with a unit that can be repeated and translated. Information carried through includes: 900mm for spatial programme, 1200mm for circulation, understanding the connection of the angled roof to New Zealand's residential typology, and the relationship of the roof or ceiling to the internal volume. The relationship of the units to each other in regards to party wall, reduced external envelope, visual voids, indoor/outdoor connection. This stage involves the integration of a site as specified previously of 132 Coromandel St, Newtown, Wellington, New Zealand. This helps to undertake an exploration into diverging from the common New Zealand terrace housing and instead look into a solution that best resolves various site conditions of size, topography, and neighbours.

Standardisation

The standardisation principle has been refined. Measurements will be defined to rationalise the design, and elements will be standardised. However, the limitations to this applied strategy will be stronger. The Scandinavian 300mm grid will still be applied. This was a successful design driver in the previous stage, and will help further the refinement during this second stage. For the standardised elements, stronger influence from Muji's vertical house, and Dalsland Cabin 2.0 was applied. The standardised elements will be explored in relation to how they can provide different internal arrangements while still contributing to the collective. The understanding that a unit that can be designed and tailored to various situations while still allowing the element of design to carry through.

Repetition

The repetition principle in Stage One was so broad that the system lost the element of design. Additionally, the level of efficiency for the construction process was lost due to the number of factors that the catalogue had. Consequently, Stage Two has refined the repetition transmission. It will explore how the literal translation of a form (like that seen with BBB Kvistgaard), can create different complete forms. Thus the design of the unit, will continuously explore how its complete arrangement can be different. The catalogue of elements is cut down, so that the processing efficiency will be achieved. All whilst balancing the contribution to the design both internally, and externally to the community.

Personalisation

This stage saw a higher level of personalisation in relation to how the unit is fitted out. It balanced the personalisation found in the Dalsland cabin 2.0 and Muji Vertical house. Where volumes are yet to be determined a programme. This removes itself from Stage One that saw the system prosper due to its versatility but lack the personalisation of personal space. There was opportunity for the system to customise itself to any occupancy but this was left at the discretion of the design/planner at the beginning of the design phase. Using standardised elements, the chosen configuration per unit, and placement within the whole arrangement allows a level of personalisation that brings autonomy of unit to the occupant.

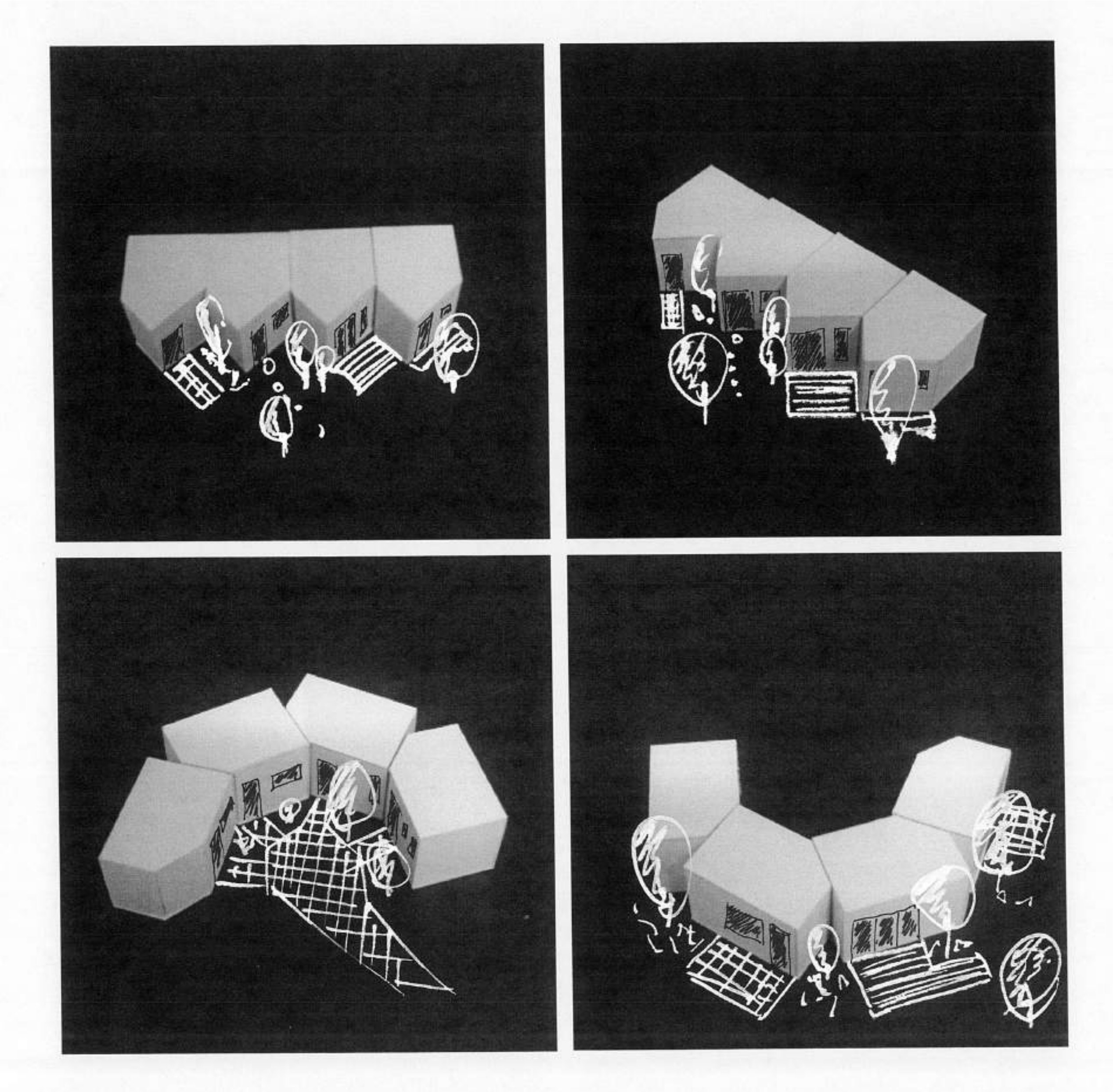


Fig.4.45. Over-sketches of physical models imagining context

Design

Units as a collective

Stage Two approached the collective whole idea - how the individual unit within suits the occupant and also contributes to the whole. The design research now applies the 'design to assembly' theory by integrating the three design principles into a re-imagined New Zealand terrace house.

The development of the design and of the system is more united in this stage. The same design process that saw the inter-relation of physical modelling, sketching, CAD drawing while exploring the different scales of elements to units, to the whole design, to the system is followed.

The revised aim is to generate a form that can be repeated within the same design to determine the whole form with its variances. The unit itself must contribute to the whole design and also form its own space. It must tailor to personal preference, yet not let the personalisation impede on the overall design. The overall form must create positive remaining spaces that can extend out the internal living room and improve quality of living. All the while including the noted MDH principles stated in chapter three.

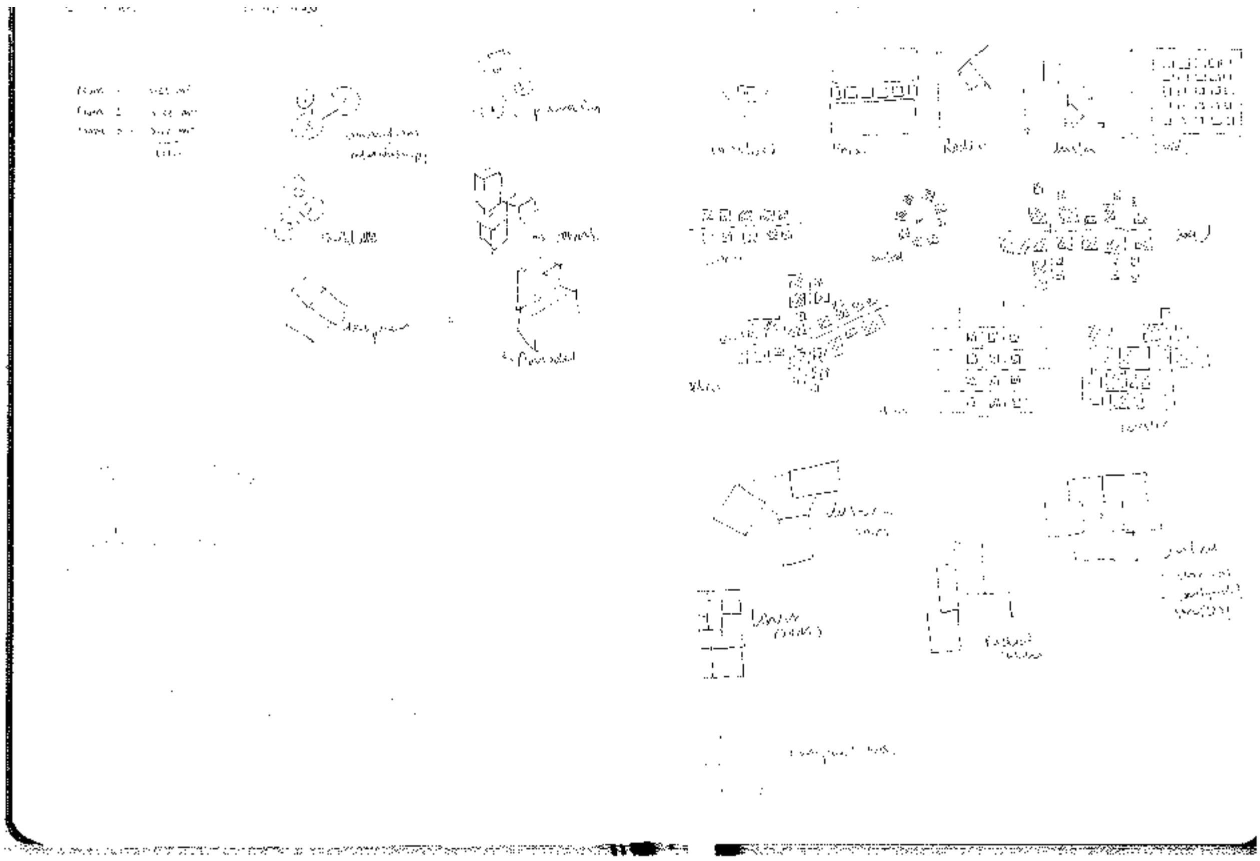
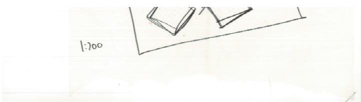


Fig.4.46. Scanned sketch book exploring spatial arrangement



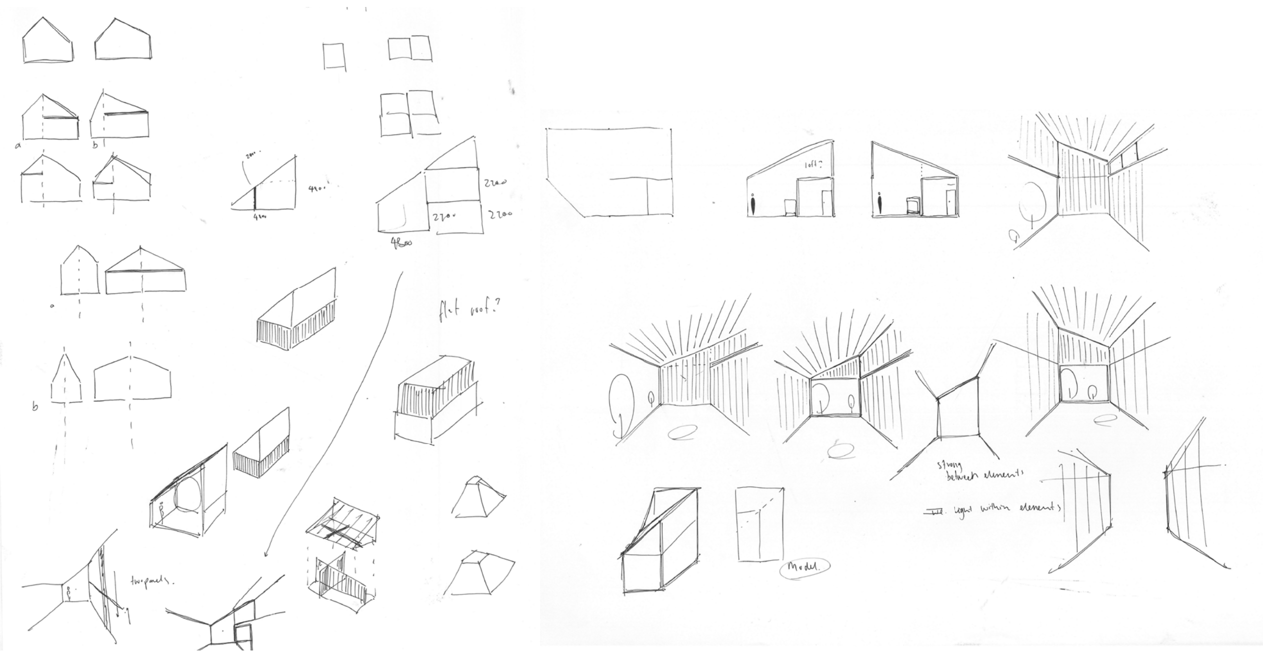


Fig.4.47. Scanned sketch book exploring volume determined by roof

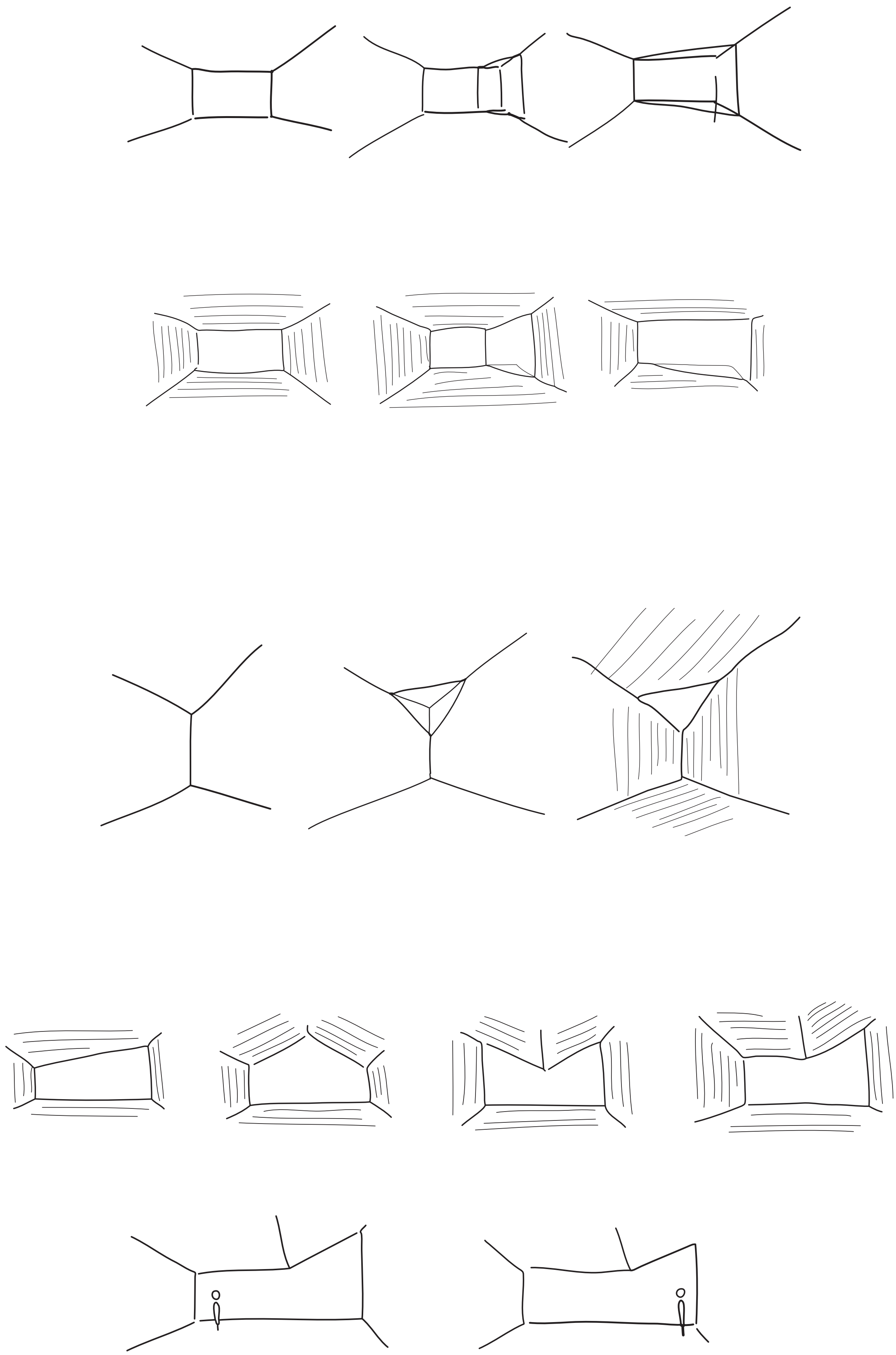


Fig.4.48. Digitised scanned sketches of internal volumes

Fig.4.49. Physical Models exploring the slice

Design

Overall Form

Initial design explorations focussed solely on the relationship of the unit to the whole design. With attention to how the unit itself could create its own space within the whole design. Sliced rectangle physical models were used. Straight away, this approach proved to be the suitable outcome, yet required refinement.

The process started with relating a sliced corner to its neighbour. This posed multiple questions: how wide is the front, how narrow is the back, what is the angle of the slice, does the slice connect to the front corner, does the slice act as the fourth face.

This was then applied to the scope of the context, thus four units within the whole were explored. This process started with slicing the front face to assure uniformity but also allow each unit to create its own space. However, this investigation did not meet the design brief. The iterations then explored again how the slice affects the overall form using various measurements of the 300mm grid. The last iteration is the idea that the form should be an irregular pentagon. This solution retained the idea to keep the slice, which pivoted the units beside each other, but also defined an associated space to the front. This was finally developed.
While this was being explored, the idea of the roof as an element (carried through from design stage one) began to take shape. This relationship was again (as addressed in design stage one) the key to connecting and relating all forms precisely.

As explored previously with the physical modelling, the peaked roof was an element that suited the brief. It allowed the visual external volume to be reduced, whilst creating different volumes within. It allowed the whole form to relate to the New Zealand residential typology and it involved the inclusion of an eave.

The roof and internal volumes were explored through physical sketching, attempting to find a balance between creating sufficient volumes that were not excessive.
The CAD over-sketches are an example of the iterative process, that looked at how the plan was made up of elements that could be fitted out for various programmes, and rotated for different orientation. The bottom image is an over-sketch of how the grid has been applied to the walls, and how they are free for the injection of any programme.

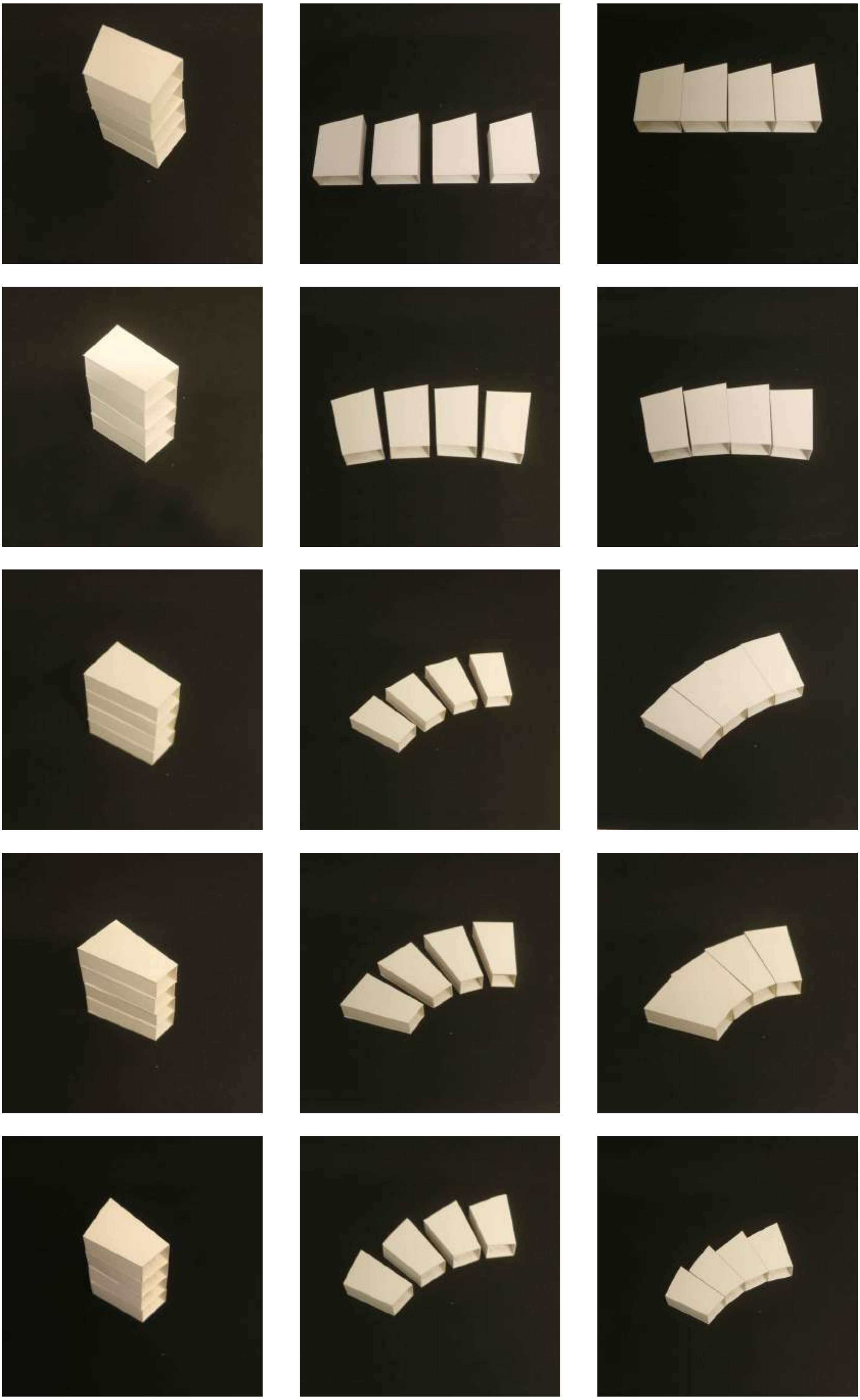


Fig.4.50. Physical Models exploring the slice as the whole design

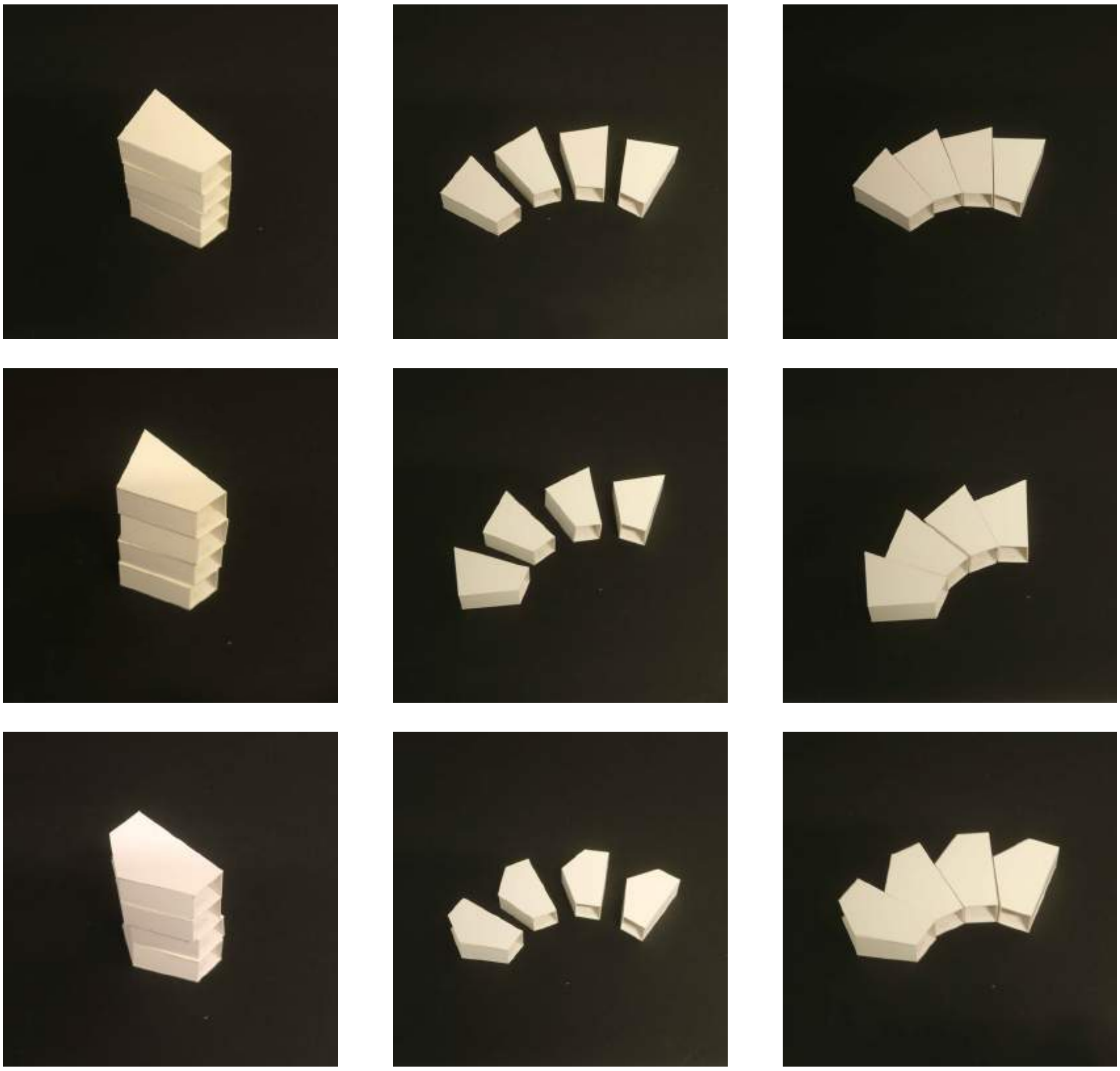


Fig.4.51. Physical Models exploring the slice as the whole design

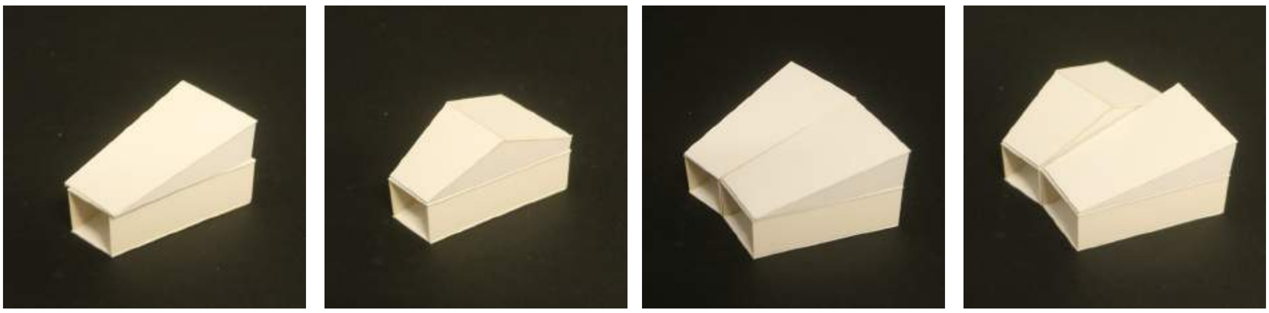


Fig.4.52. Physical Models exploring roof element

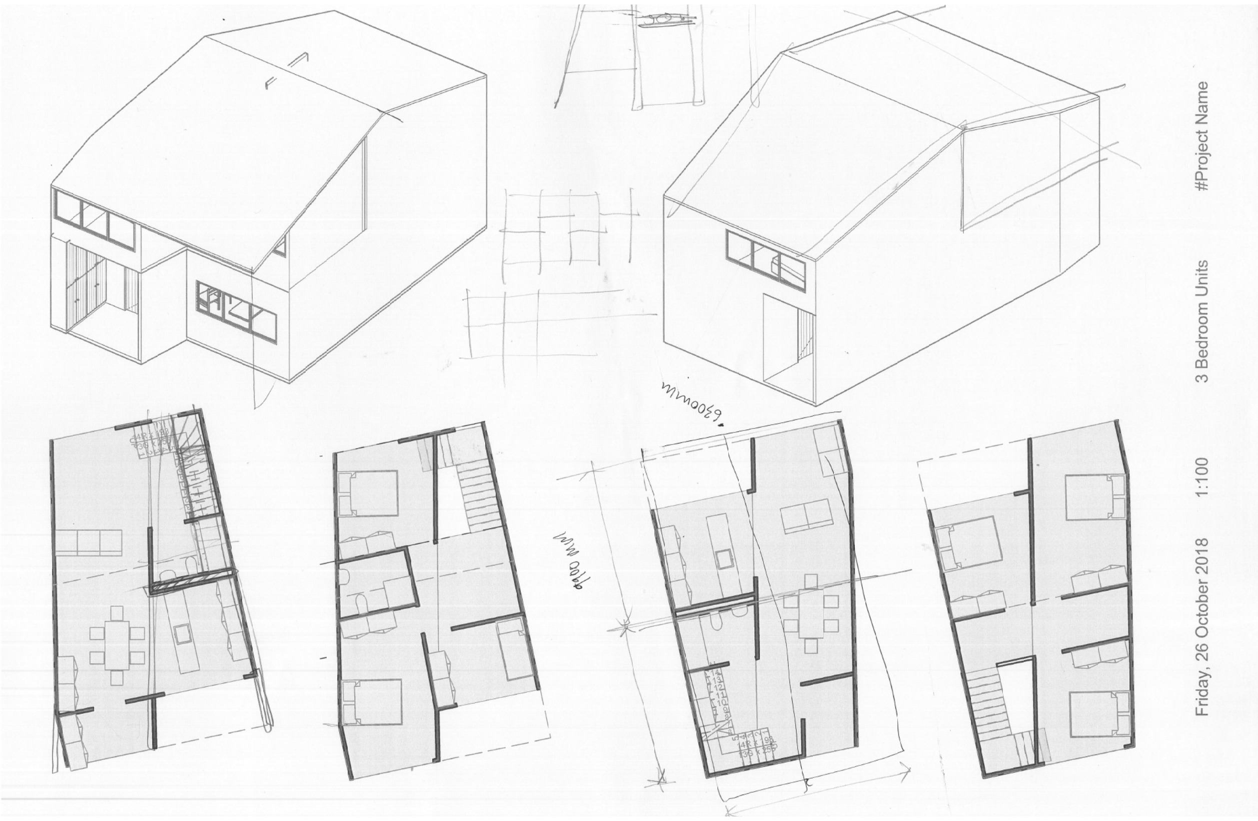


Fig.4.53. Over-sketches of CAD drawn unit

Fig.4.54. Over-sketch of CAD drawn unit

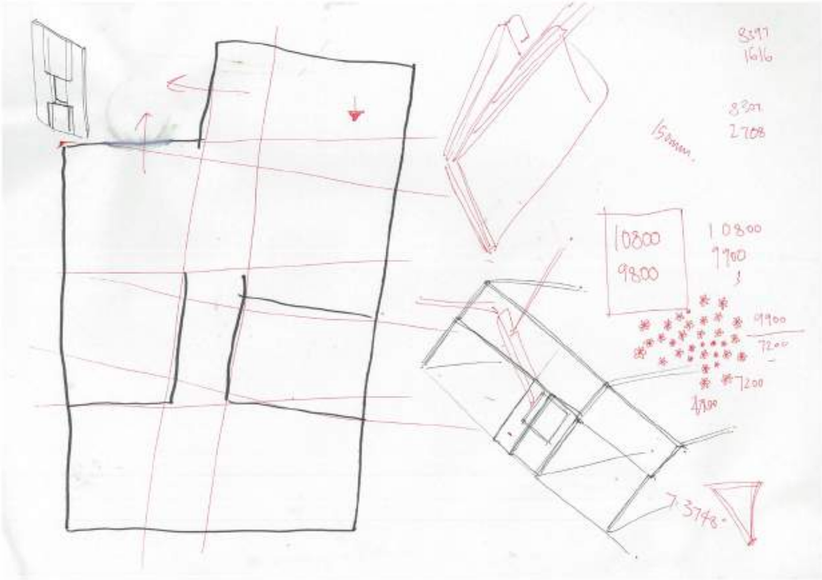


Fig.4.56. Over-sketch of unit planning

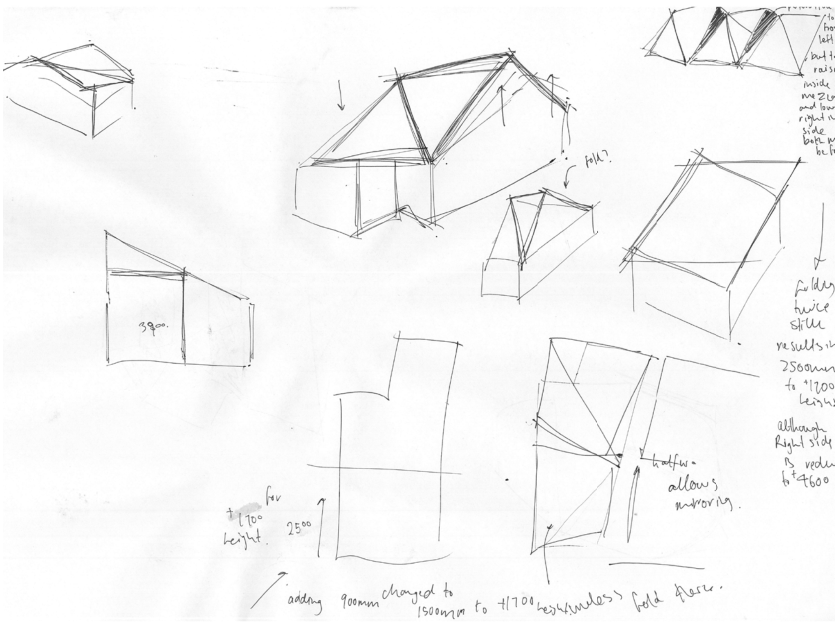


Fig.4.55. Over-sketch of roof formation

Clear Opportunities for the Design

With the aim of Stage One to explore the three principles relationships, Stage Two was an exercise in applying these learnings to a context, with a refined brief. Thus the process followed which had been used in design stage one, but took the ideas further. The system developed from a kit-of-parts that could be tailored to any development to a tailorable unit within a collective form. The adjusted approach for design stage two allowed the design to be at the forefront of the research, whilst applying the learnings of the previous literature review, project review, and self design research.

5. Developed Design

Fig.5.01. South East perspective of final design

Developed System

Following the non-contextual prefabrication design exploration, the learned findings were applied to a context. 'Stage Two' applied the appropriate use of the three design principles, and was a clear exploration of the three interrelationships. Consequently a final designed system which can be applied to various scenarios within New Zealand was formed. Additionally the process has produced a framework that future prefabrication developments can follow. The outcome notes the influence and contribution of a roof element to the external form and spatial internal qualities.

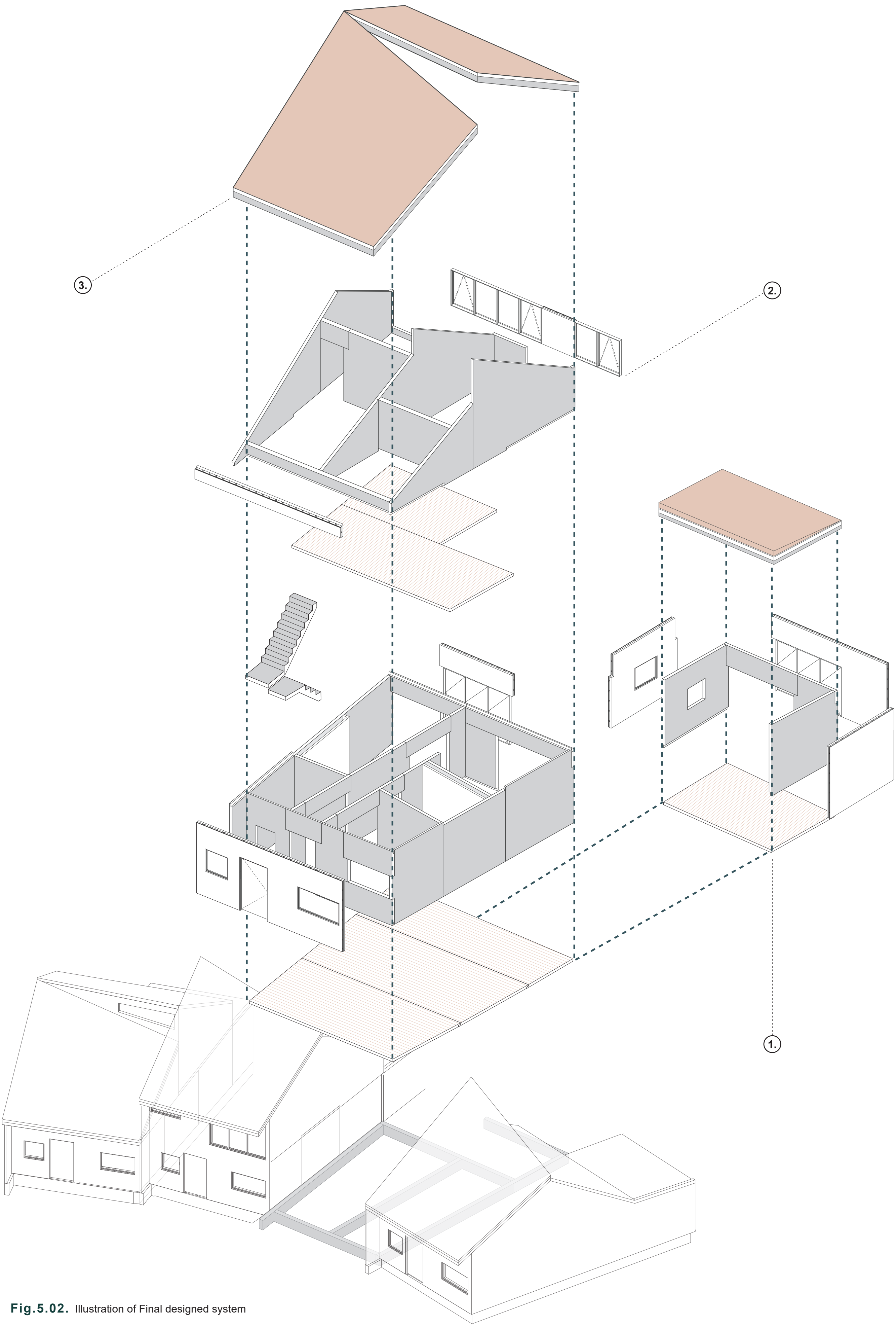
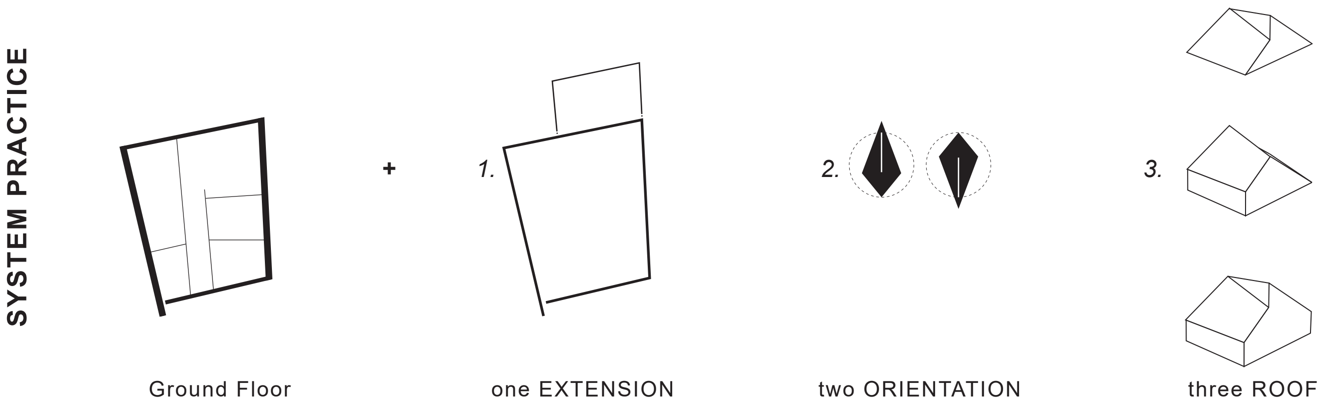


Fig.5.02. Illustration of Final designed system

Connected Wedge

Designed prefabrication system for medium density living in New Zealand



Designed System

Onsite assembly of the designed system involve the different layers of foundations, ground floor, ground floor walls, optional extension, staircase, first floor, roof walls, roof (see fig.5.02). The arrangement is communicated in setting at 132 Coromandel St, Wellington.

The system practice comprises of three steps (see fig.5.03). It begins with the assigned ground floor – programme for each space is determined using various ingress and the optional extension. Then it is orientation. This is a large decision that involves the final aggregate outcome, and it also plays a big part to how the unit is inhabited. The third step is the roof, which determines the complete spatial quality.

Fig.5.03. System Practice

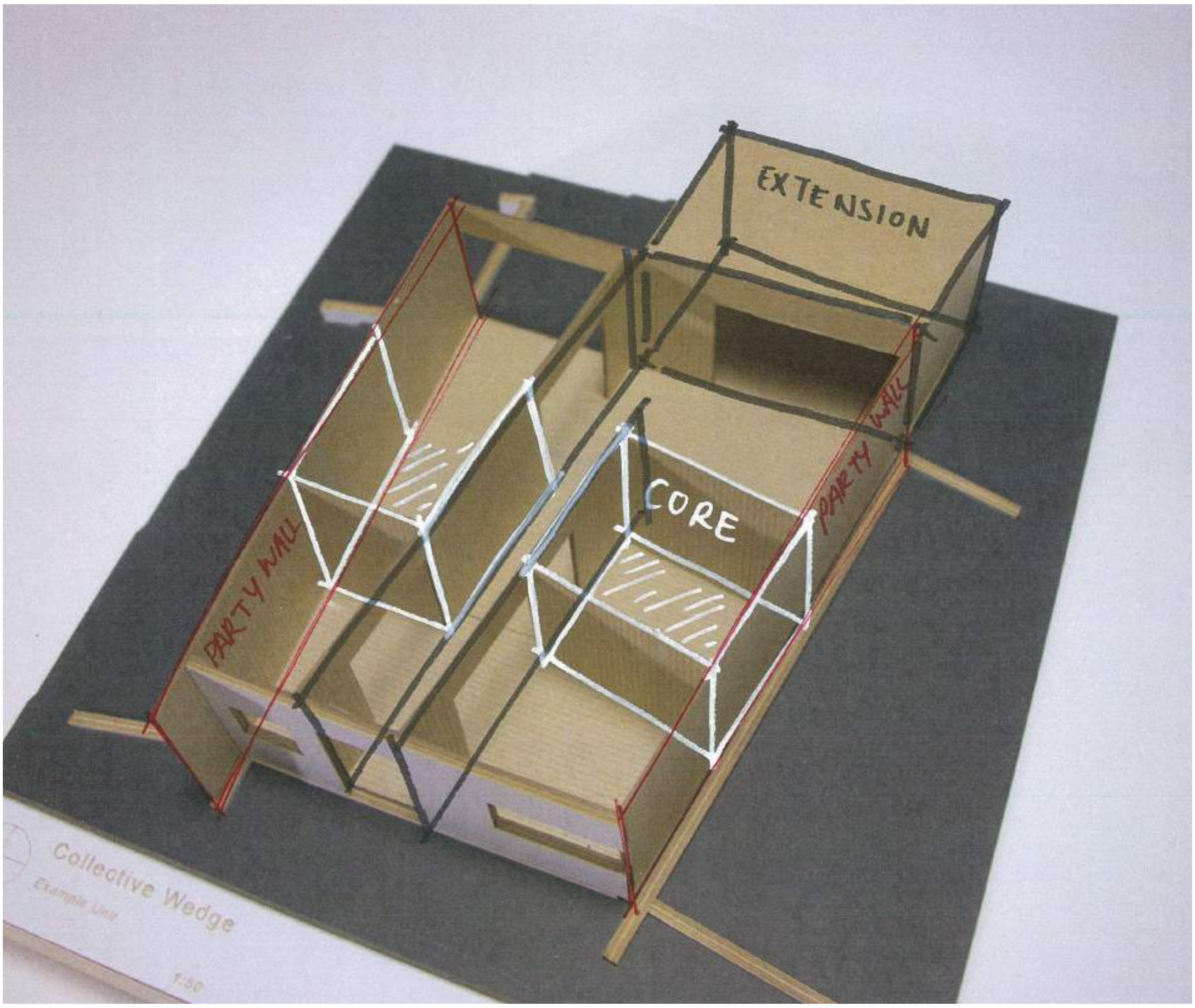
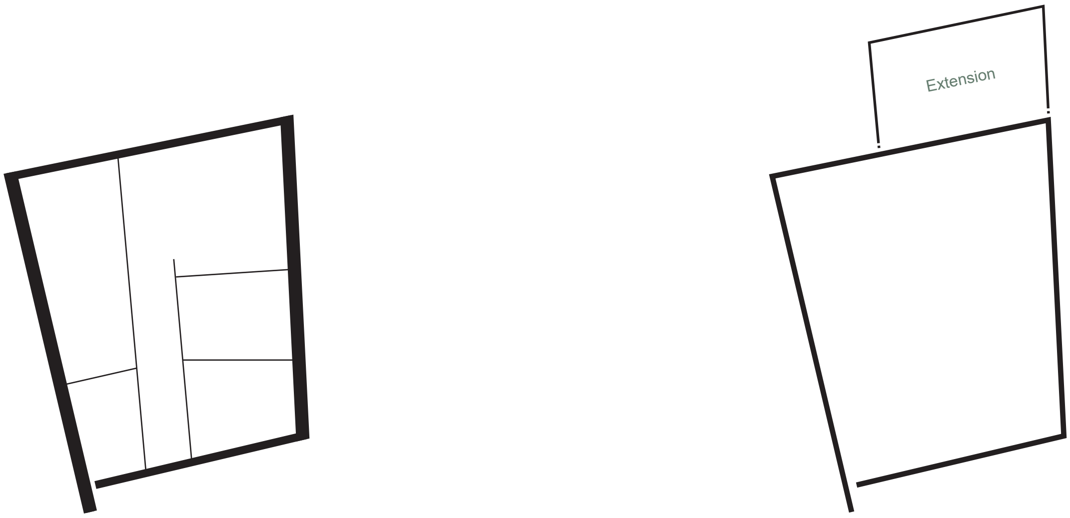


Fig.5.04. Over-sketch of unit model showing various zones

1. GROUND FLOOR + EXTENSION



ground floor + one EXTENSION

Floor Plan

The floor plan encapsulates standardisation. The overall form, bracing walls, and circulation, deliver a framework of rooms. However, assigned programme is yet to be determined. There the ingress influence the determination. This personalisation contribution involves the standardised element – the extension. This determined volume that can connect on to the large room.

Fig.5.05. System Practice

Fig.5.06. Floor Plan of established zones and potential programming

1. GROUND FLOOR + EXTENSION

Fig.5.08. Floor Plan of established zones and potential programming

Fig.5.07. Over-sketch on image of unit model breaking down zones of the floor plan

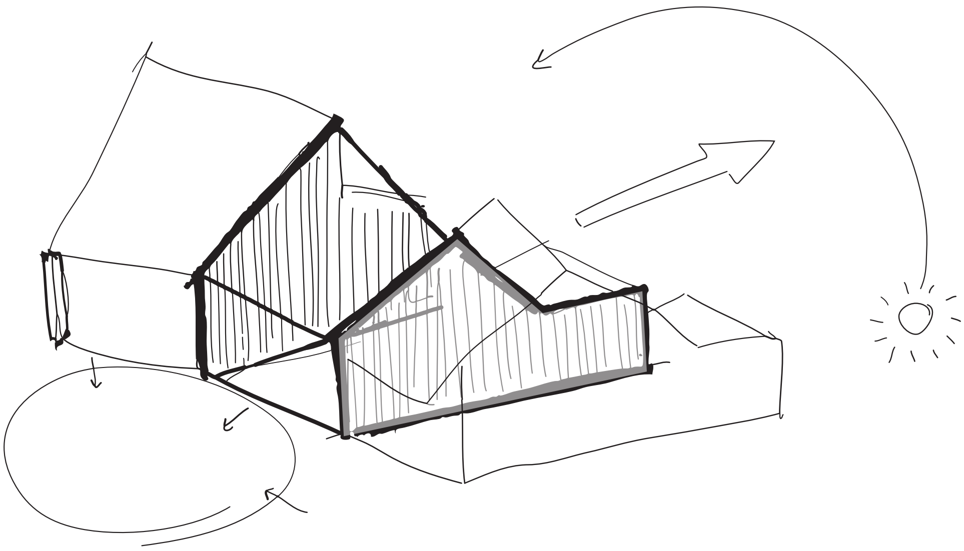


Fig.5.09. Physical models exploring the various physical arrangements possible with the designed ‘unit’

Orientation

To address the criteria of the designed unit to be repeatable but still suit the various residential programmes, sites, and topographies it is flexible with its placement alongside other units.

Uniform orientation creates the wedged shape that pinches in and opens out (see fig 5.09). Varying orientation creates different aggregate forms: curve, circle, straight, swiggle (see fig.5.12).

The involvement of orientation essentially amplifies the three roof types to six. Connections between only involve three extra façade pieces (see fig.5.15). With all the options the roof lines unites the individual units yet retains their independence (see fig.5.16.)

Fig.5.10. Physical models exploring the various physical arrangements possible with the designed 'unit'

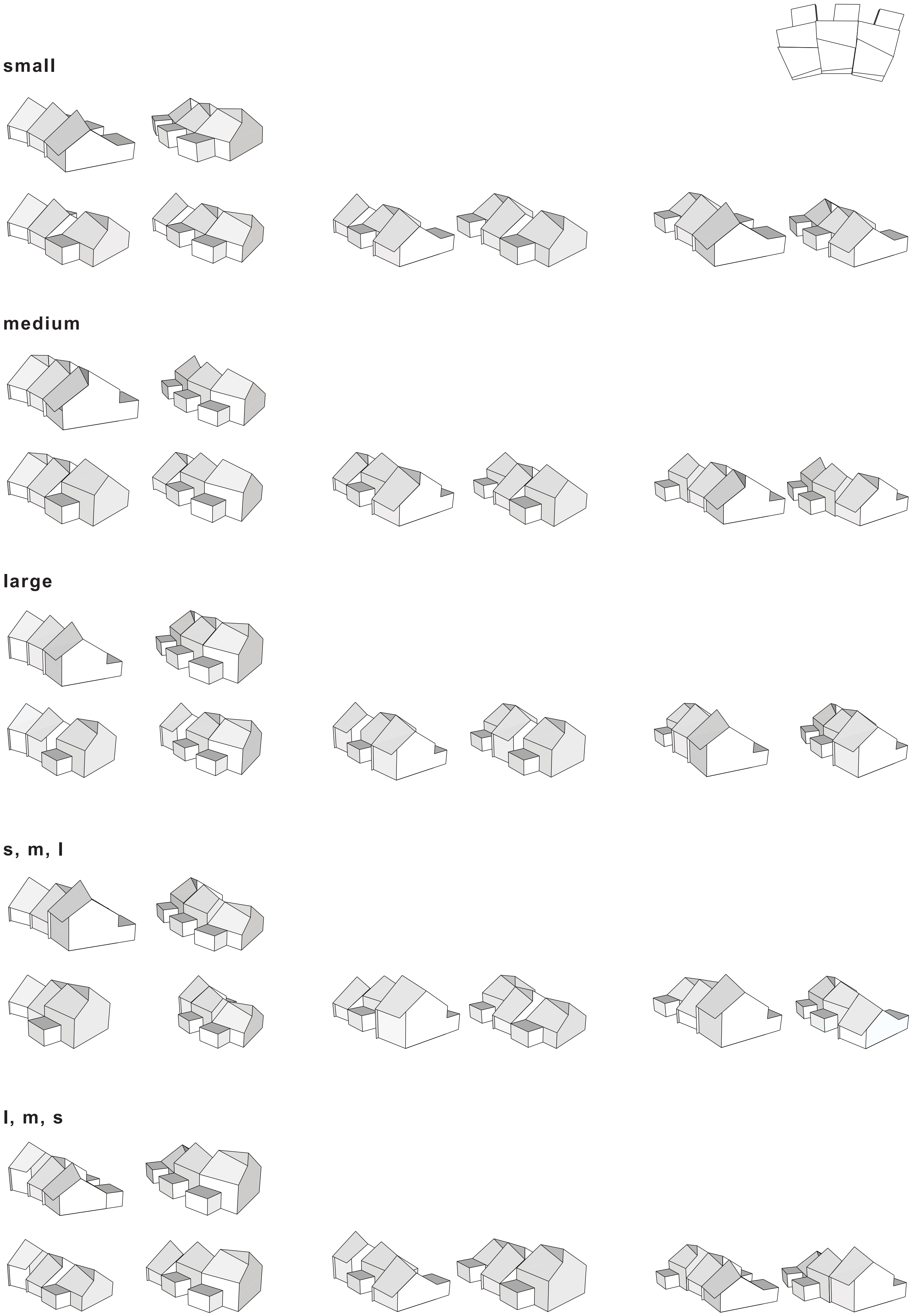
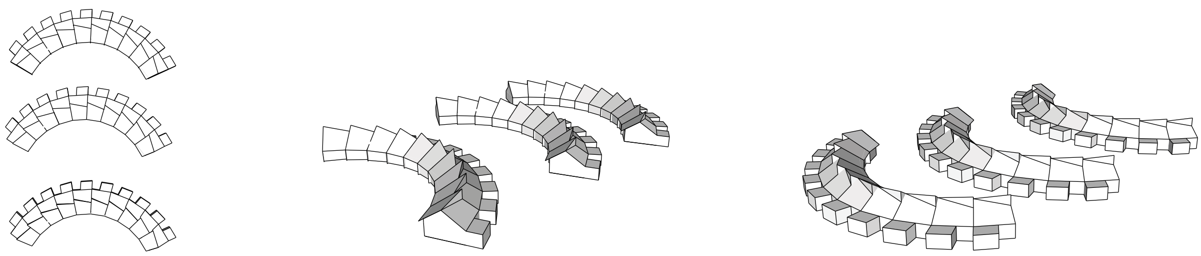


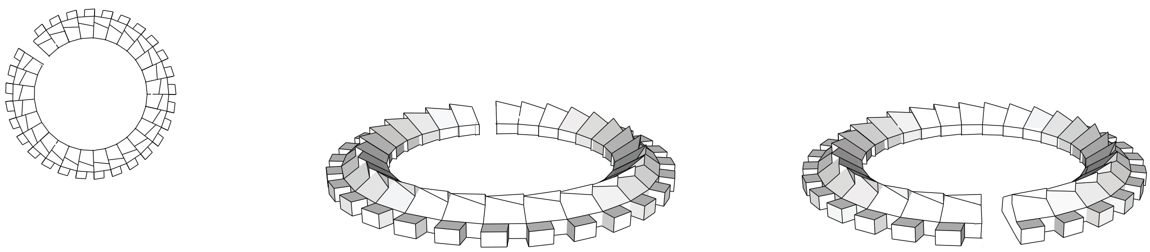
Fig.5.11. Physical models exploring the various physical arrangements possible with the designed 'unit'

2. ORIENTATION

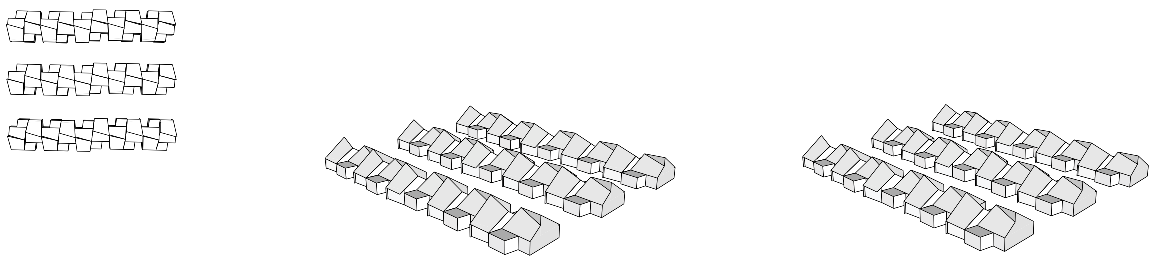
curve



circle



straight



swiggle

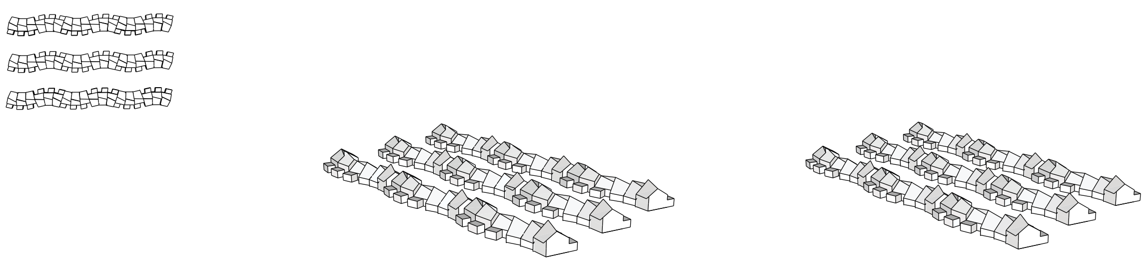


Fig.5.12. Physical models exploring the various physical arrangements possible with the designed 'unit'

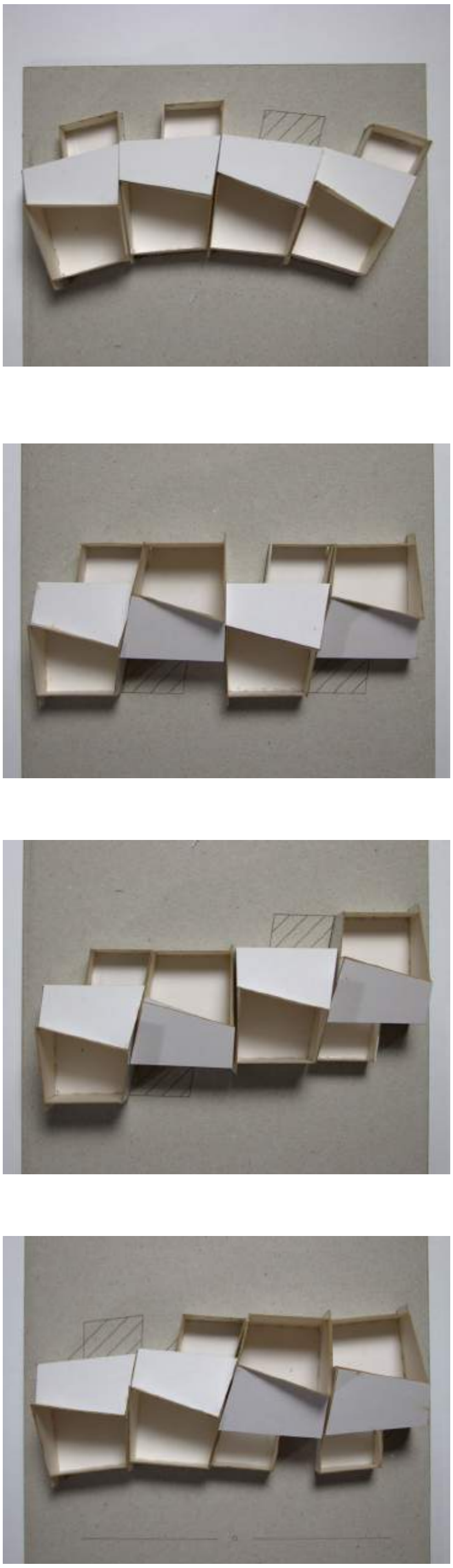


Fig.5.13. Physical models exploring the various physical arrangements possible with the designed 'unit'

2. ORIENTATION

Fig.5.14. Physical models exploring the various physical arrangements possible with the designed ‘unit’

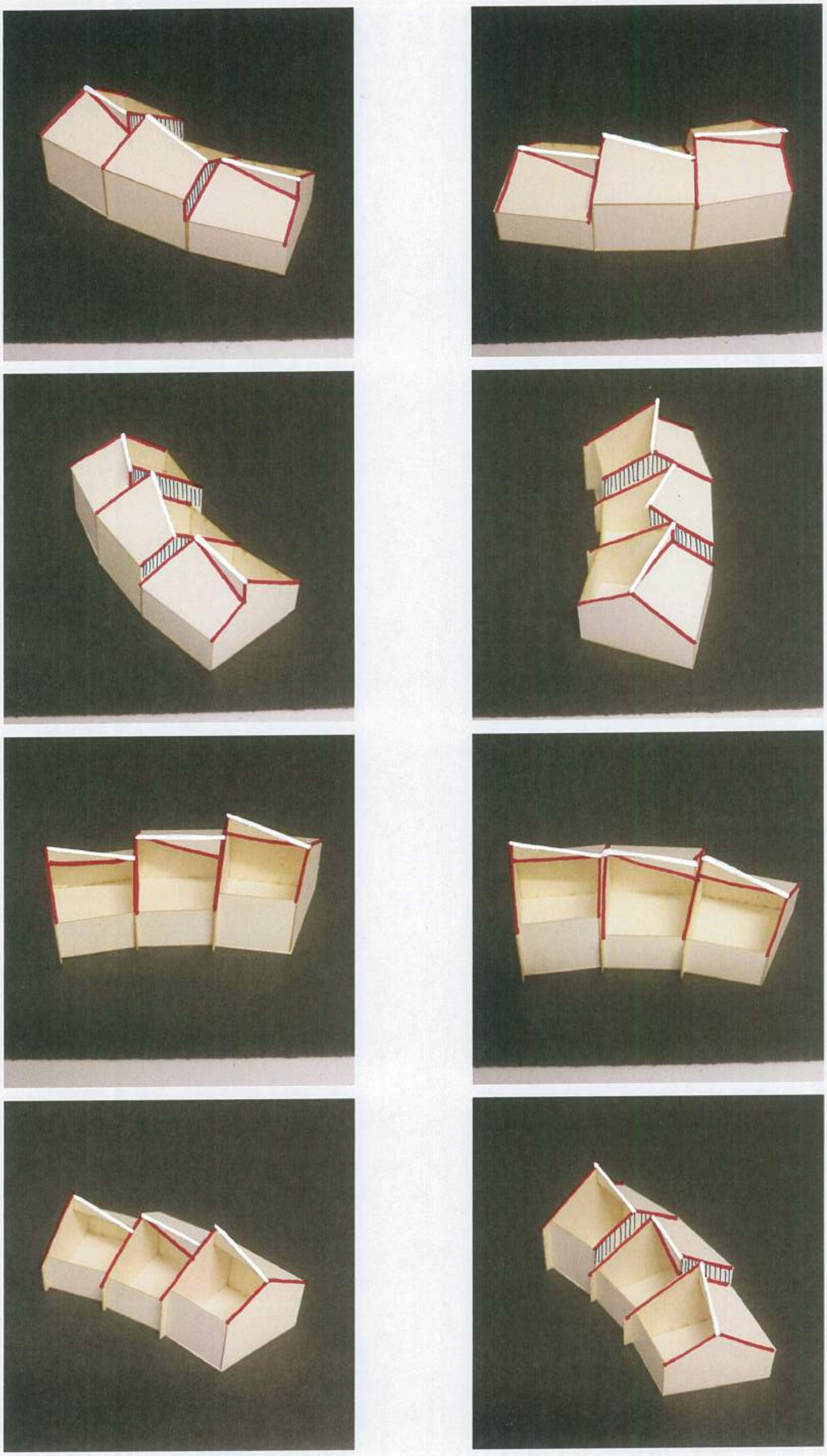


Fig.5.15. Physical models exploring the various physical arrangements possible with the designed ‘unit’

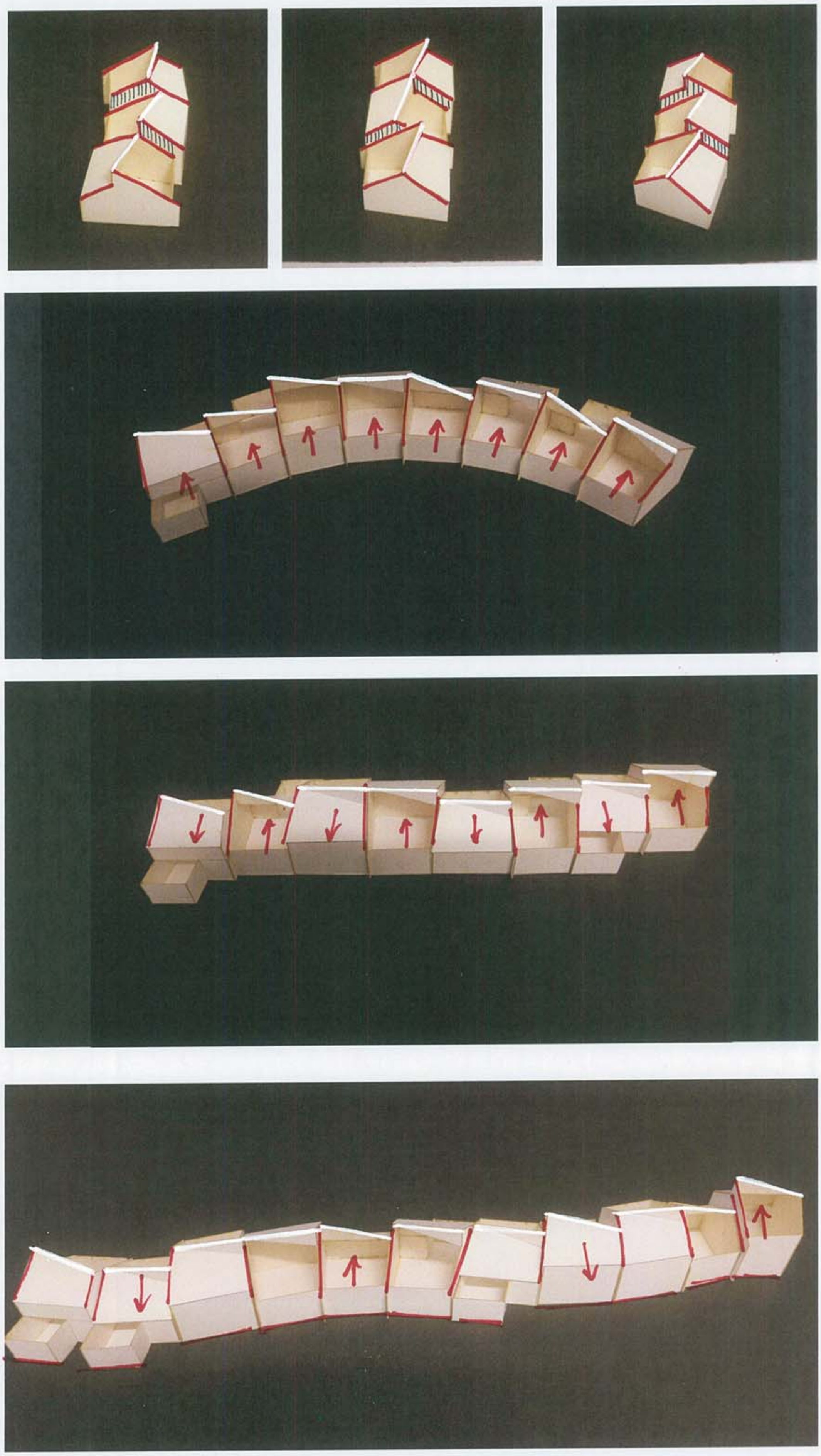
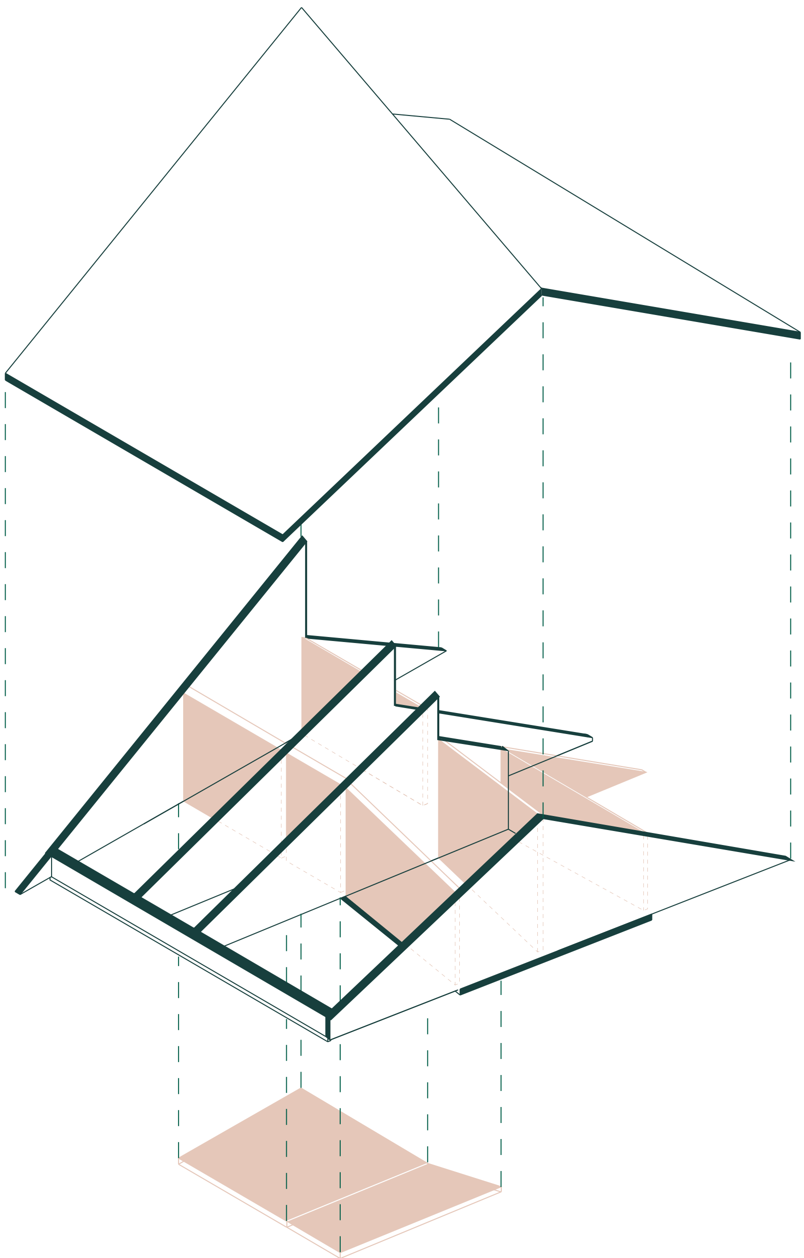


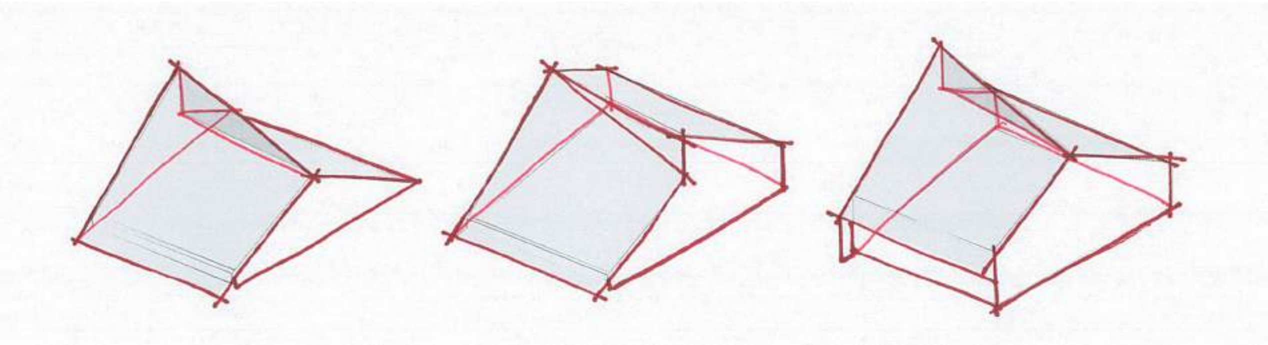
Fig.5.16. Physical models exploring the various physical arrangements possible with the designed 'unit'



ROOF - Small

With 9 independent panels - 7 vertical, 2 horizontal - there are 362,880 variations using 'Roof Small'. Realistically there are 6 inhabitable options.

Fig.5.17. Drawing illustrating how roof small can be sectioned off to create various volumes. Pink represents options, dark green reps determined

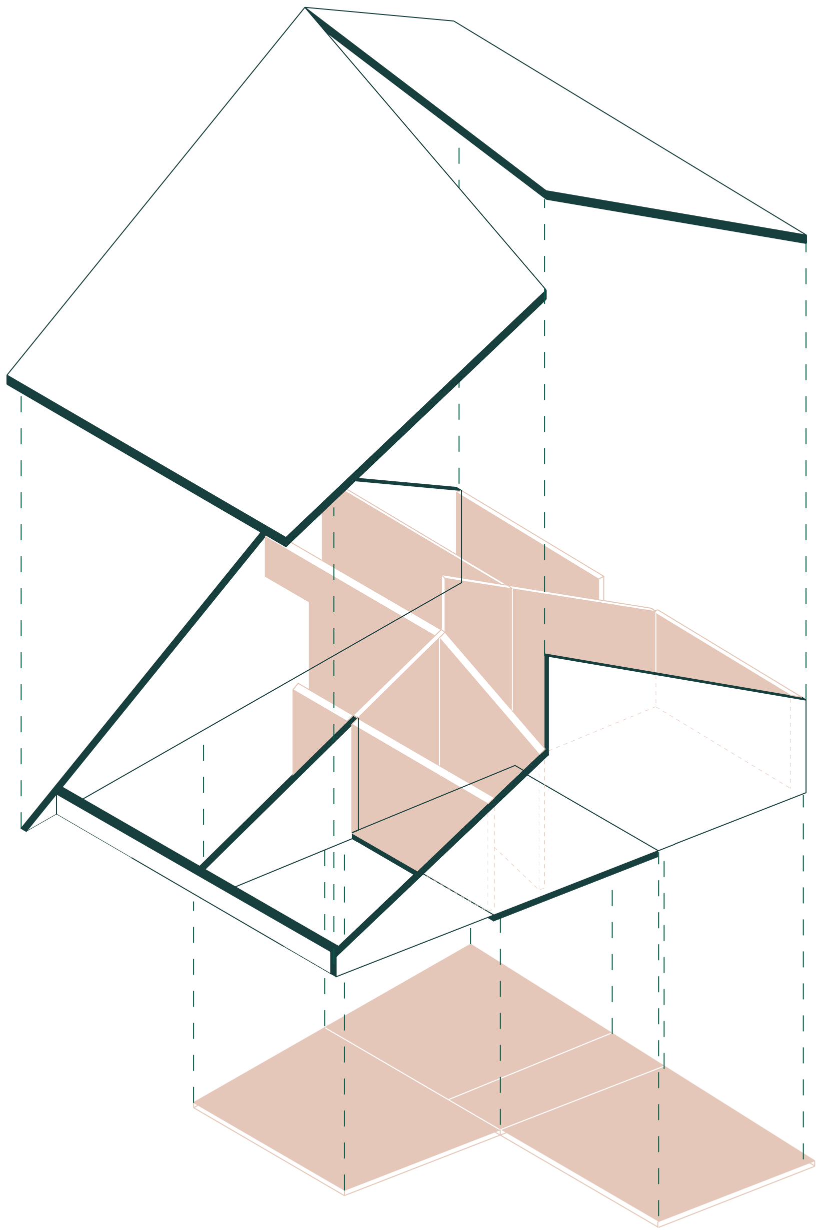


ROOF small ROOF medium ROOF large

The Roofs

The three roof sizes (see fig.5.18) provide a depth of personalisation. Each roof volumes has determined structural members, with supporting qualities of the roof panels and bracing qualities of the unit. From here different wall and floor panels can be inserted to create different volumes – involving both the ground floor and first floor. Along with the two party walls, internal bracing walls, and additional division wall, there is a set floor panels that act as the ceiling for the bathroom contained below.
As an example the small roofs optional configuration is communicated (see fig.5.17)
See fig5.21. for a matrix of optional configurations explaining how the inputted panels in the roof determine everything.

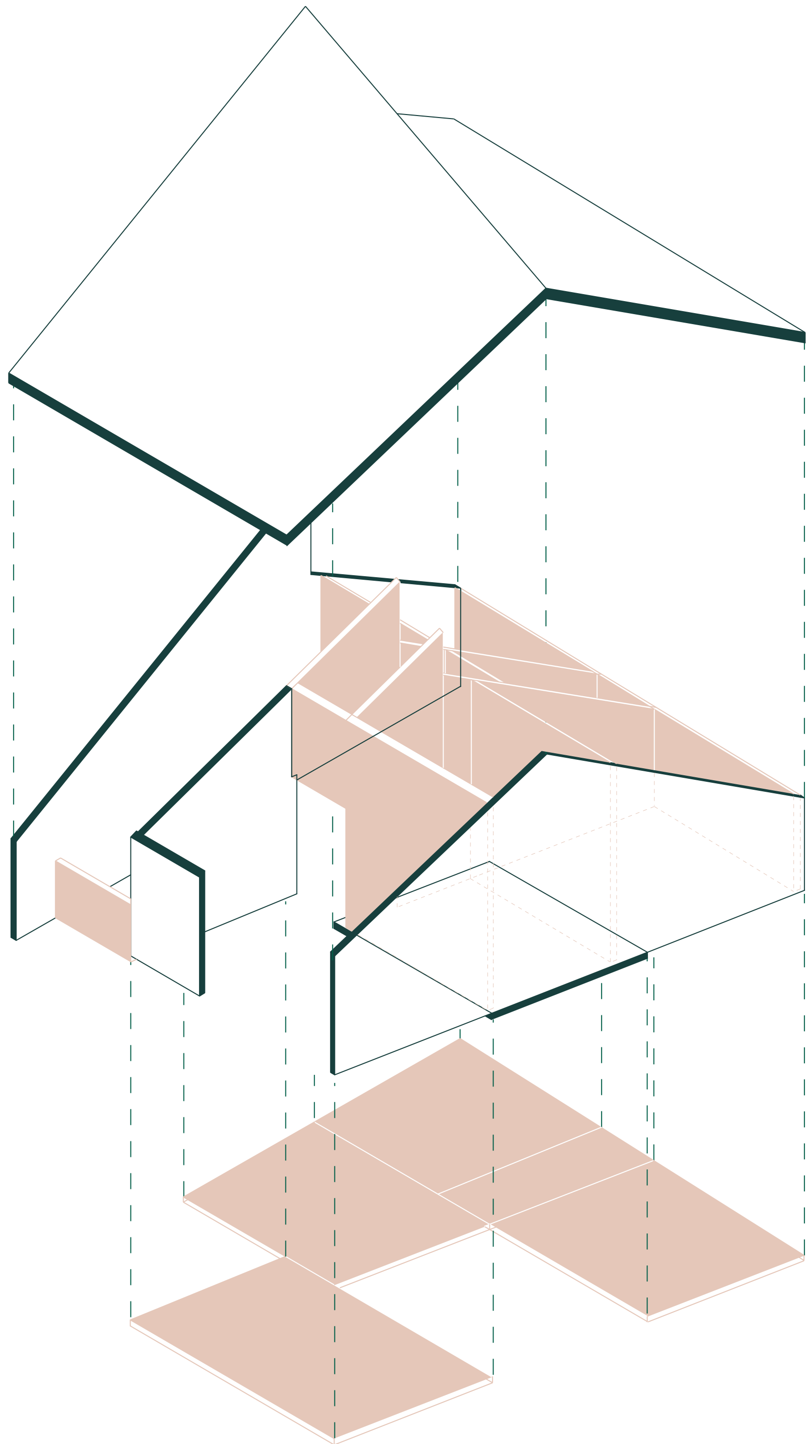
Fig.5.18. Diagrams of the three sizes of roof units



ROOF - Medium

With 14 independent panels – 10 vertical, 4 horizontal – there are 8.72x10e variations using 'Roof Medium' Realistically there are 8 inhabitable options.

Fig.5.19. Drawing illustrating how roof medium can be sectioned off to create various volumes. Pink represents options, dark green reps determined

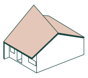


ROOF - Large

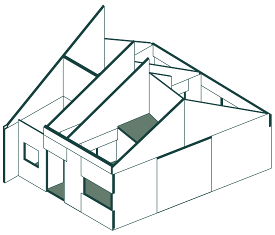
With 18 independent panels – 13 vertical, 5 horizontal – there are 6.4x15e variations using 'Roof Large' Realistically there are 8 inhabitable options.

Fig.5.20. Drawing illustrating how roof large can be sectioned off to create various volumes. Pink represents options, dark green reps determined

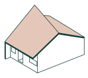
Small Roof



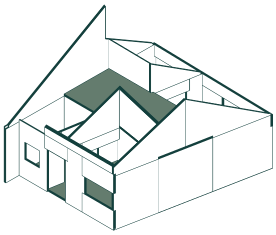
Unit 1a



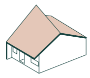
58 sqm
One Bedroom



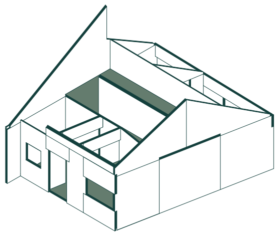
Unit 1b



76 sqm
One Bedroom

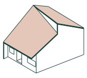


Unit 1c

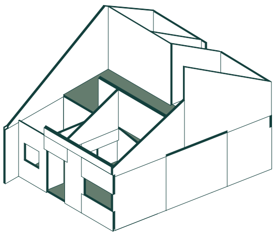


76 sqm
Two Bedroom

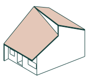
Medium Roof



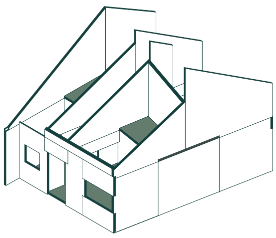
Unit 2a



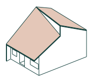
76 sqm
Two Bedroom



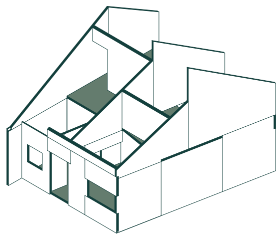
Unit 2b



72.5 sqm
Two Bedroom

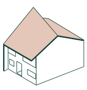


Unit 2c

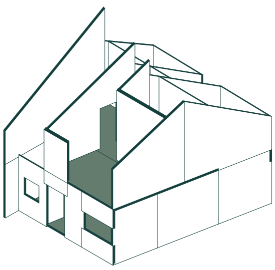


87 sqm
Two Bedroom

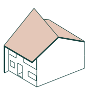
Large Roof



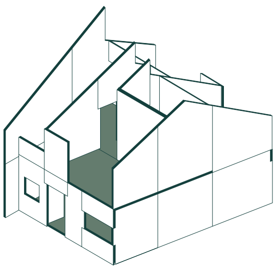
Unit 3a



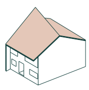
87 sqm
Two Bedroom



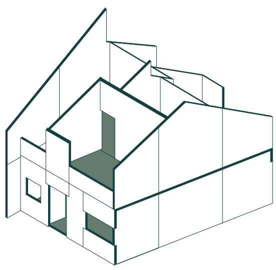
Unit 3b



98 sqm
Three Bedroom

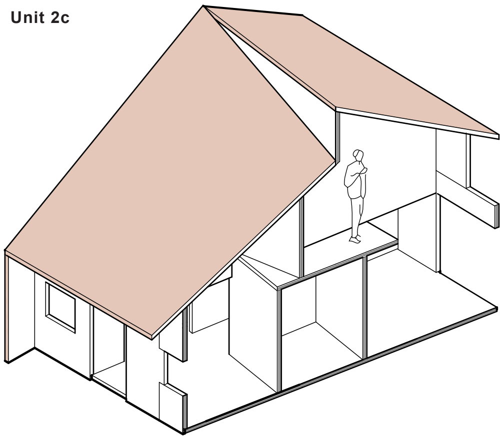


Unit 3c

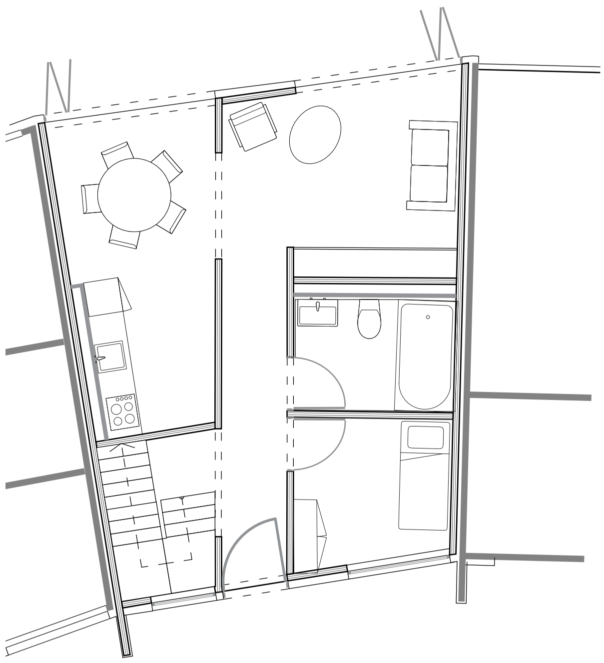


98 sqm
Four Bedroom

Fig.5.21. Visual example of volume variances with applied roofs



87 sqm
Two Bedroom



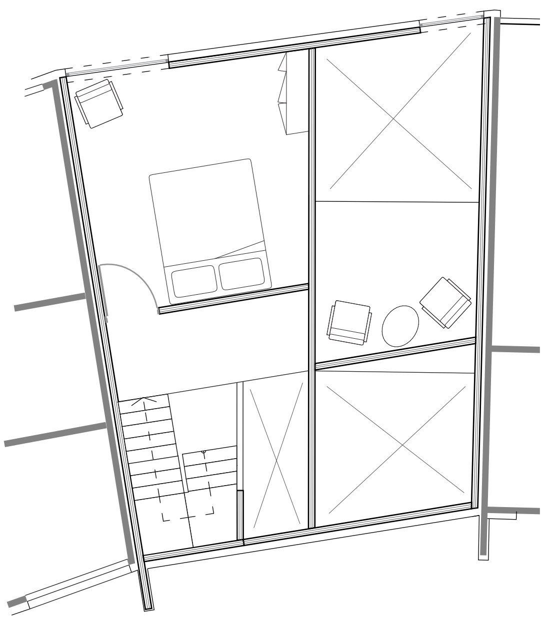
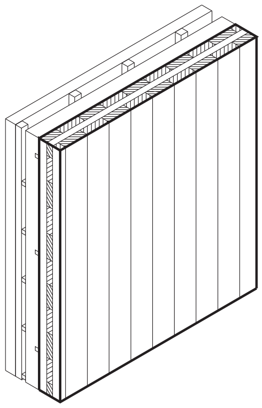
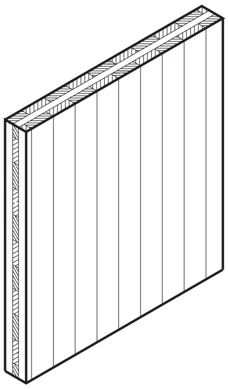


Fig.5.22. Visual example of volume variances with applied roofs



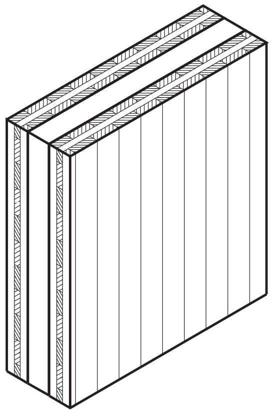
a1 -
External Wall

105mm Cross Laminated Timber
3 layer
90mm Solid Insulation with battens
Waterproofing Membrane
20mm Battens Vertical/Horizontal
40mm Cladding Timber/Steel



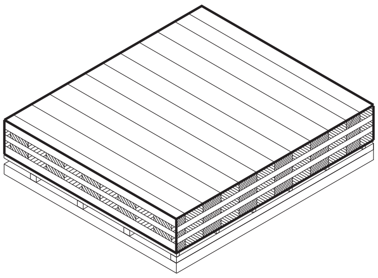
a2 -
Internal Wall

105mm Cross Laminated Timber
3 layer



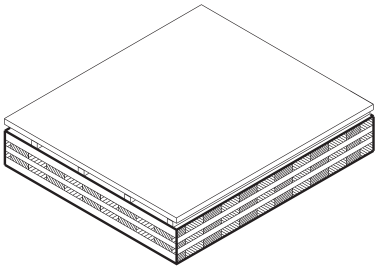
a3 -
Party Wall

12mm GIB Lining
105mm Cross Laminated Timber
3 layer
90mm Solid Insulation with battens
105mm Cross Laminated Timber
3 layer
12mm GIB Lining



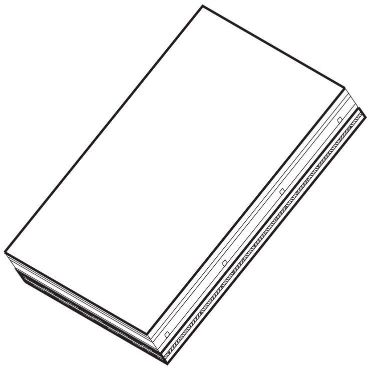
b1 -
Ground Floor

105mm Cross Laminated Timber
3 layer
90mm Solid Insulation with battens
Waterproofing Membrane



b2 -
Internal Floor

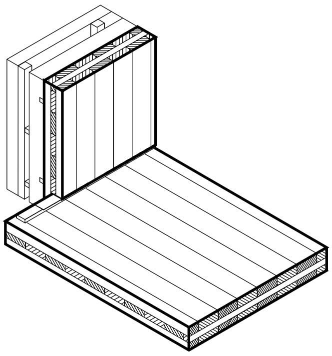
Carpet
Underlay
105mm Cross Laminated Timber
3 layer



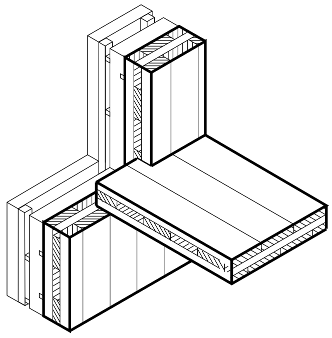
c1 -
External Roof

105mm Cross Laminated Timber
3 layer
90mm Solid Insulation with battens
Waterproofing Membrane
Netting
Battens
Roof Steel

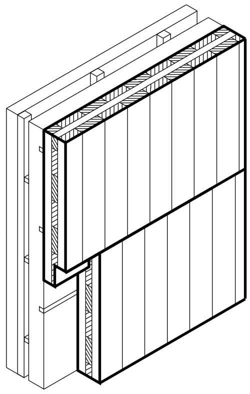
Fig.5.23. Visual example of volume variances with applied roofs



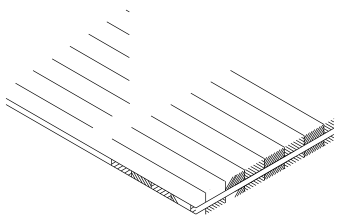
d1 -
External Wall / Floor



d2 -
External Wall / Floor / Wall



d3 -
External Wall / Wall



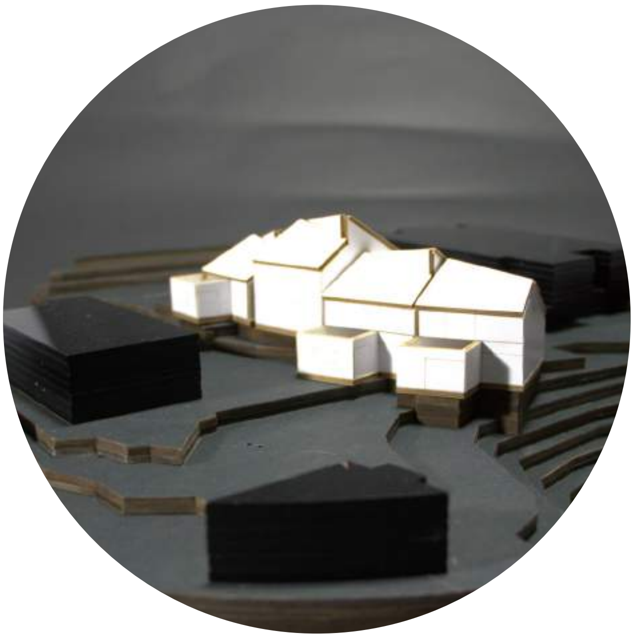


Fig.5.24. North West perspective of final design
Fig.5.25. South East perspective of final design

Developed Design

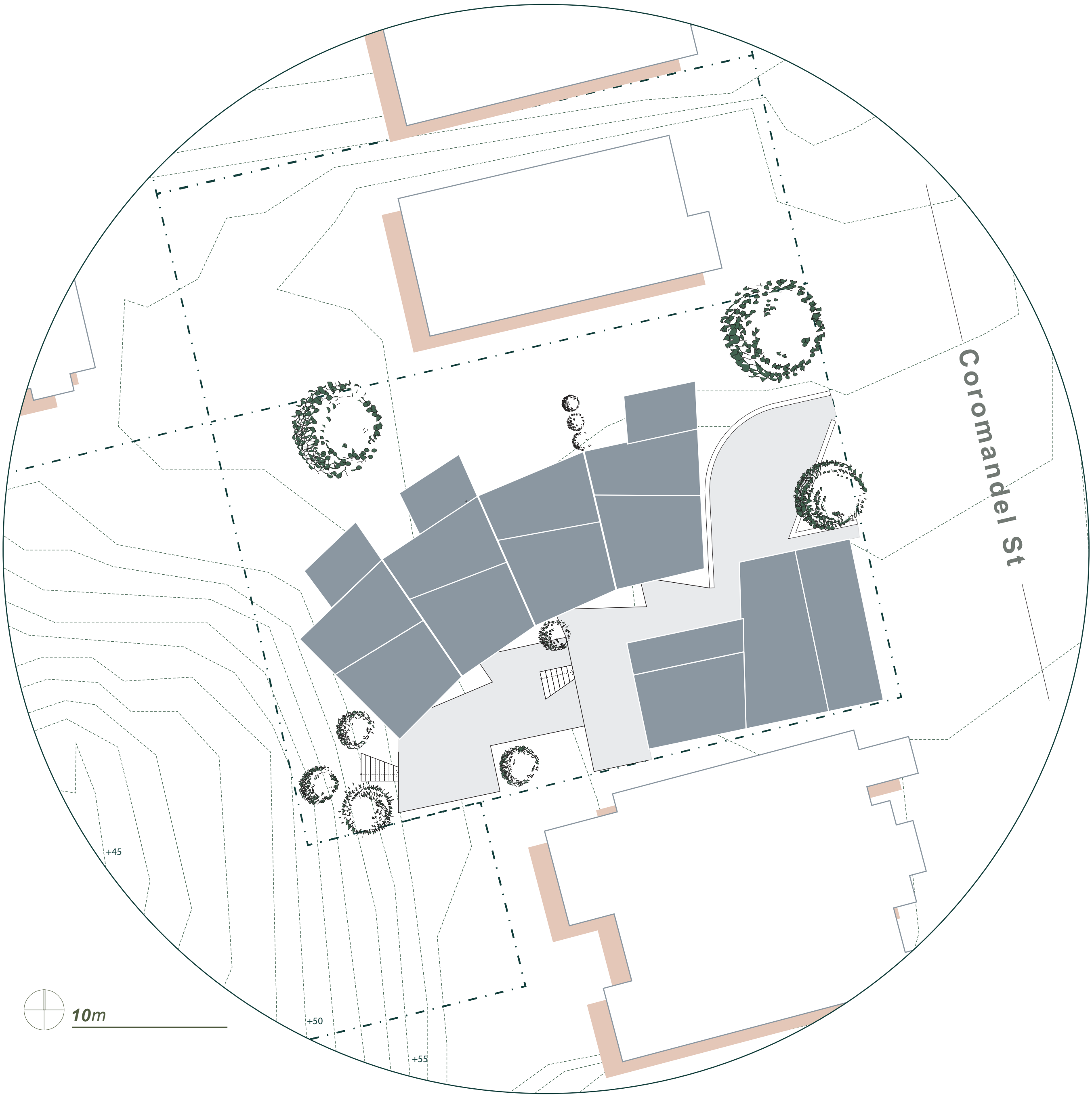


Fig.5.26. Photograph of final design in site model

132 Coromandel St

'Stage two' applies the learnings from 'Stage One' involving the development of both the design and the system using a Newtown site. With the system established, the final design is reviewed with the opportunity to analyse the outcome. The site provided neighbours, weather, and topography to address whilst meeting the design requirements. They are a shared positive social environment. With expansion out to outdoor personal space. Celebrates small New Zealand living. Meet the sunlight requirements. Make an individual but aggregated form.

Fig.5.27. Photograph of final design in site model

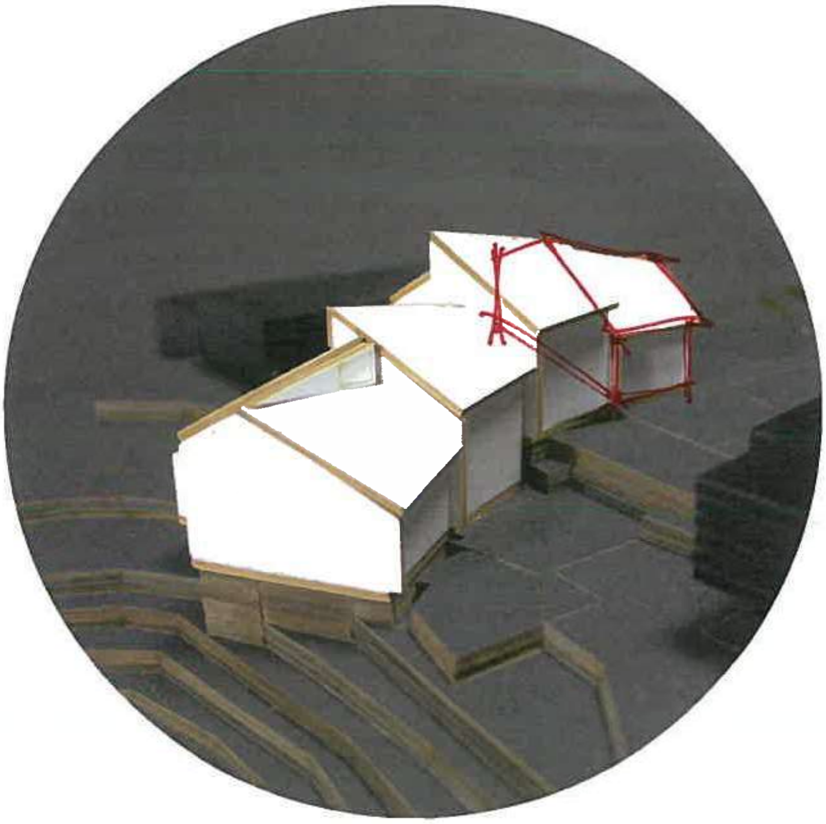
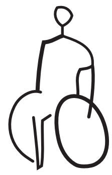


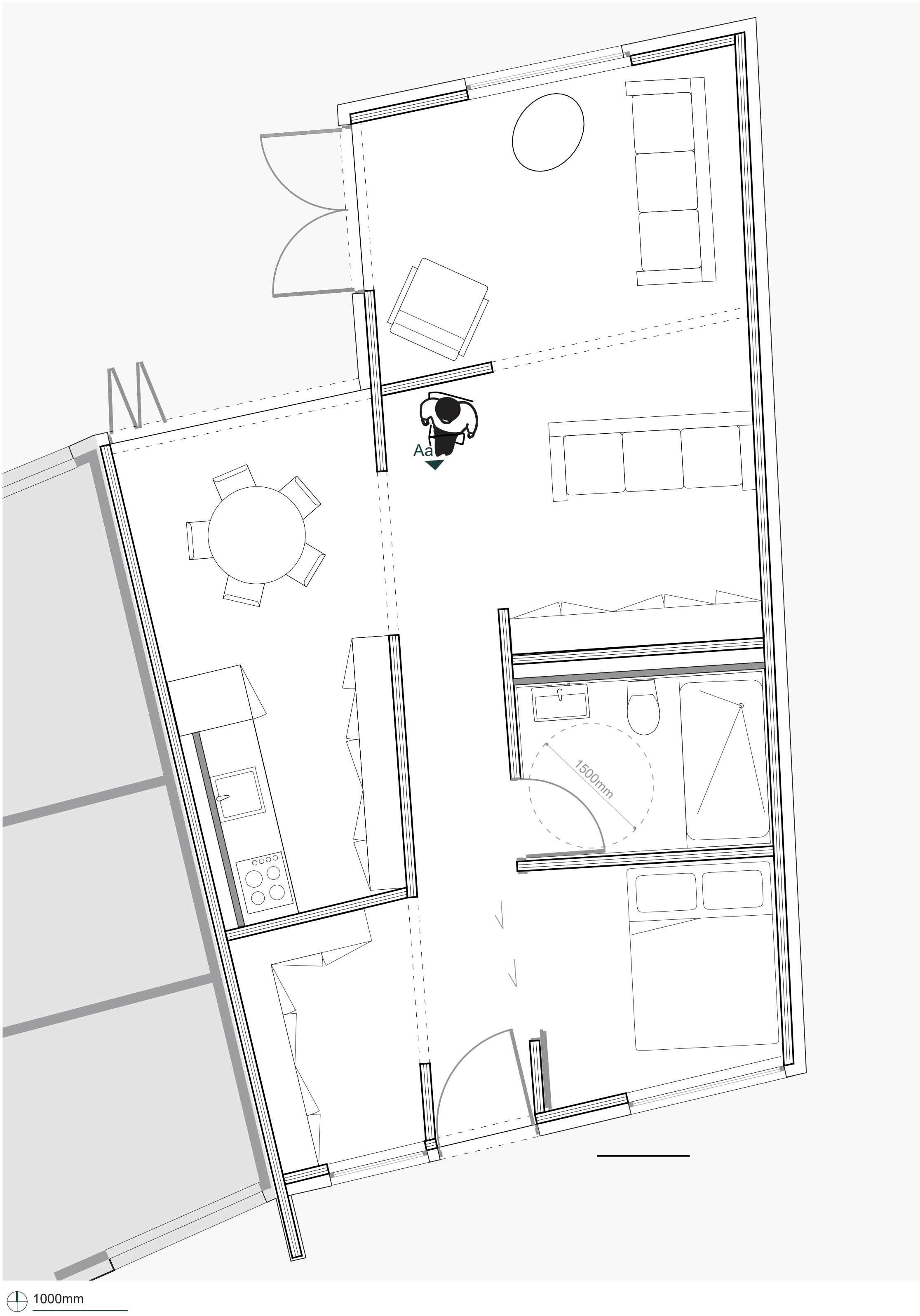
Fig.5.28. Unit A indicated in physical site model

UNIT A

Homeowner Downsizing
66sqm

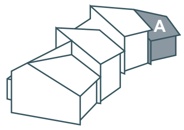


This unit explores how the floor plan can accommodate universal design practices. The result is the addition of the extension and the use of the small roof. The bedroom is placed in a south facing room with the window looking towards the Southern Belt. The entrance is arranged as part of the bedroom with the hallway annex acting as a large walk in wardrobe. The kitchen is in the core of the plan with the dining room connecting it to the courtyard. The extension builds on the existing lounge to expand the living zone (see fig.5.31. and fig.5.32.)
At 66sqm this plan is the largest ground floor design. With the occupant wheelchair bound, the mezzanines have been built up and out to create the desired spaces for the ground floor and to leave opportunity for storage or additional living if desired.
The roof relates to the rooms with the skylight drawing light into the back bedroom and the kitchen holds volume (see fig.5.30.)

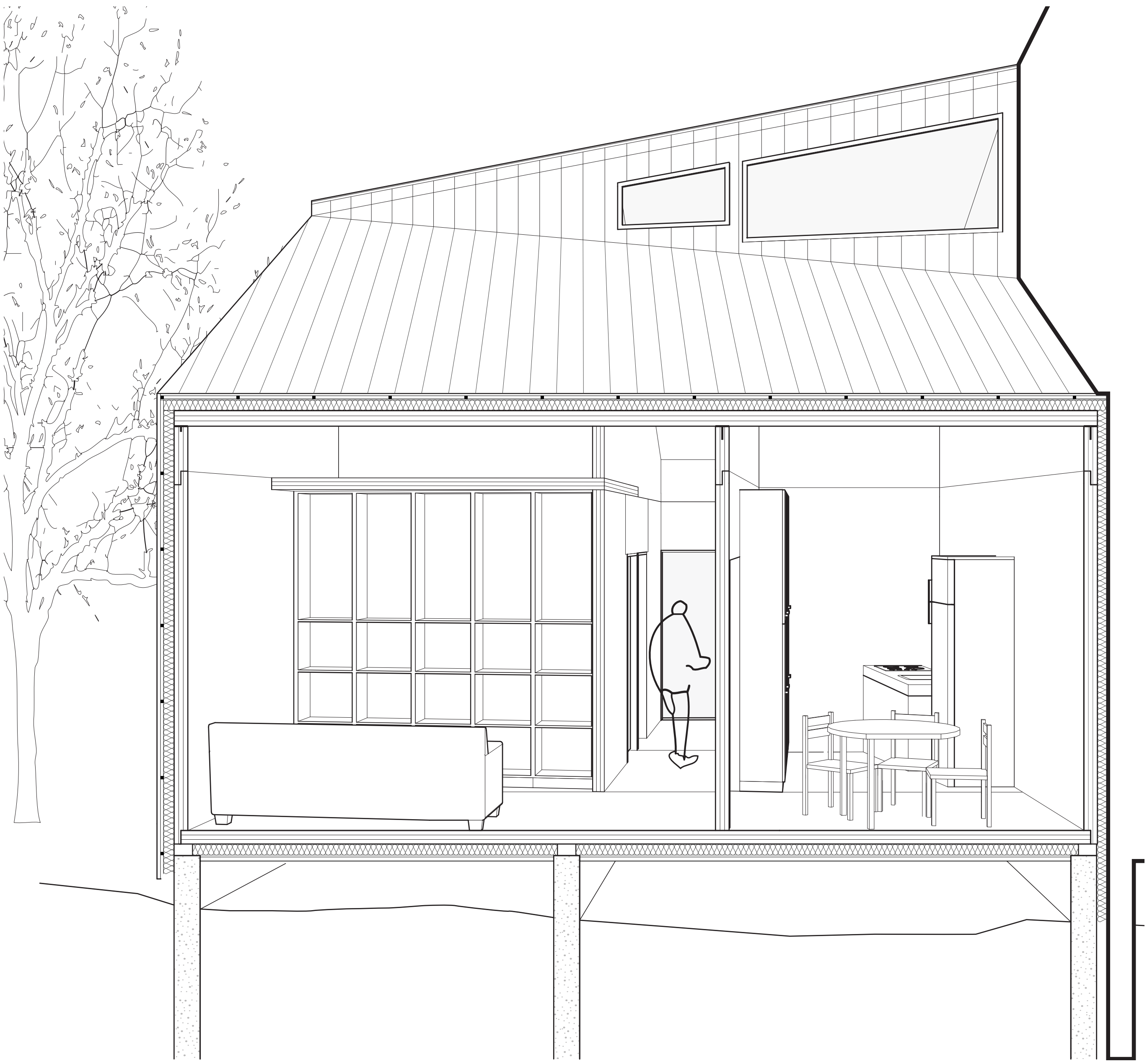


Ground Floor Plan

Fig.5.29.



UNIT A

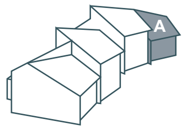


Section Aa

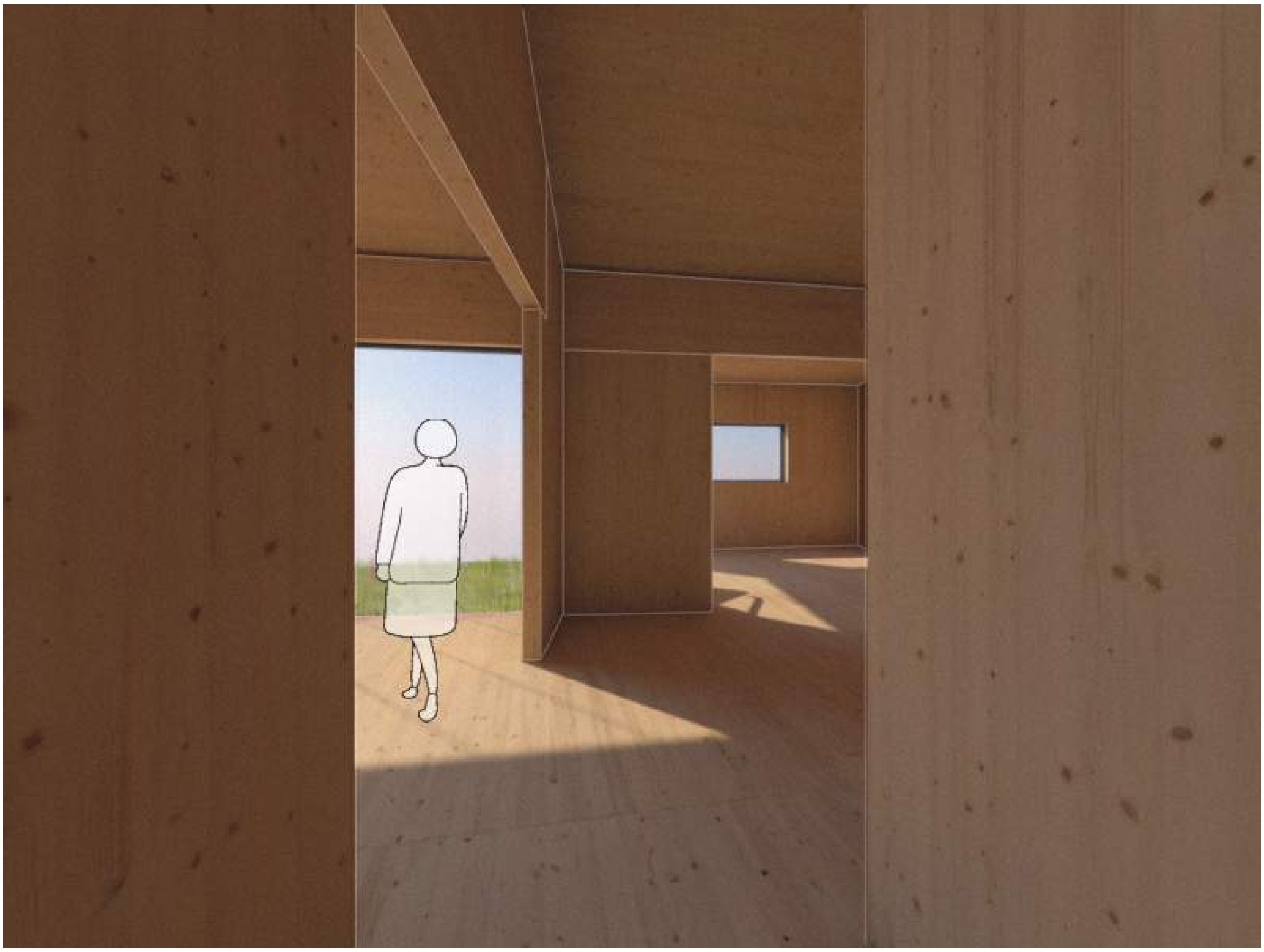
Fig.5.30.

Looking through public living spaces

Fig.5.31.



UNIT A



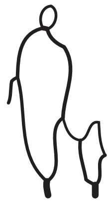
Looking down and out hallway

Fig.5.32.

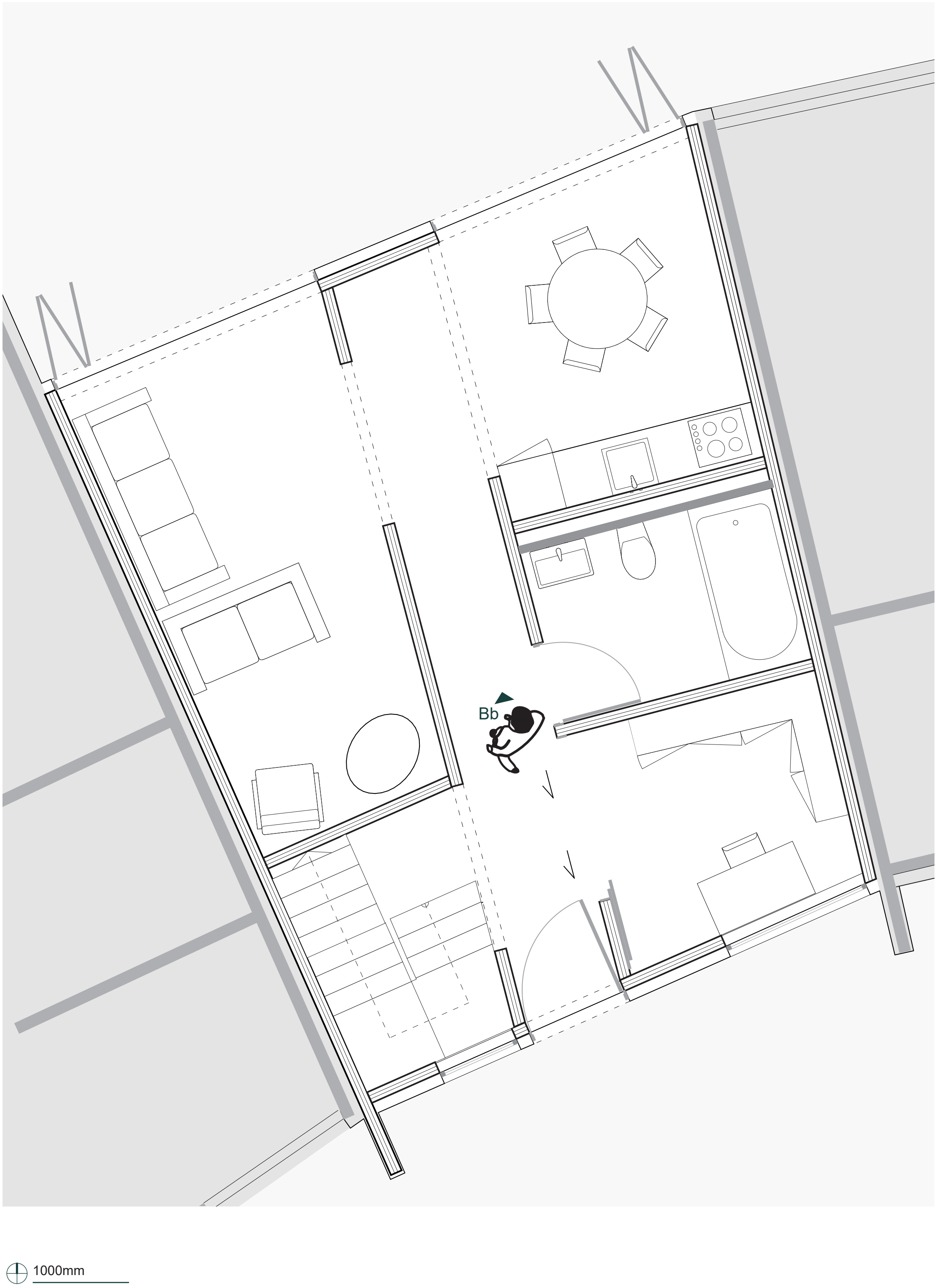
Fig.5.33. Unit B indicated in physical site model

UNIT B

First Home Buyer
137sqm

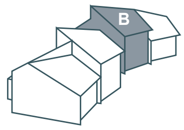


This unit explores programme within the largest roof type. The lounge and dining room open directly to the north facing garden with the kitchen/dining room holding double height adding depth to the public living quarter (see fig.5.37.) render. The downstairs room as a study with direct contact to the communal courtyard.
This plan displays the hallway annex as vertical circulation to the first floor. The first floor is not completely built up and results a double height space for the kitchen/dining room. This level was concerned with of providing sufficient bedroom sizes. The use of the 'Roof Large' means that they skylight draws northern light in down through the circulation to the hallway creating a sense of openness (see fig.5.38.).

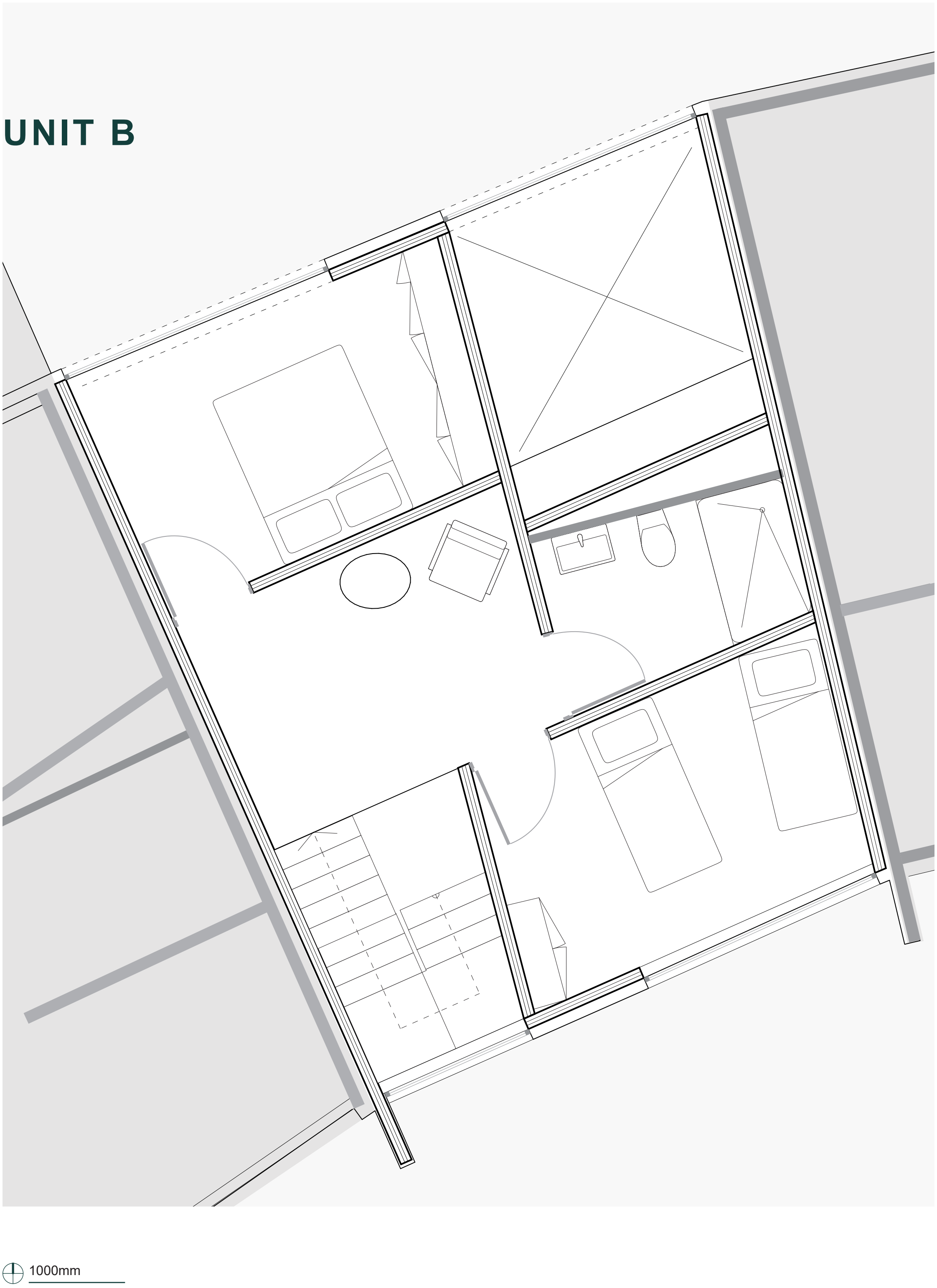


Ground Floor Plan

Fig.5.34.

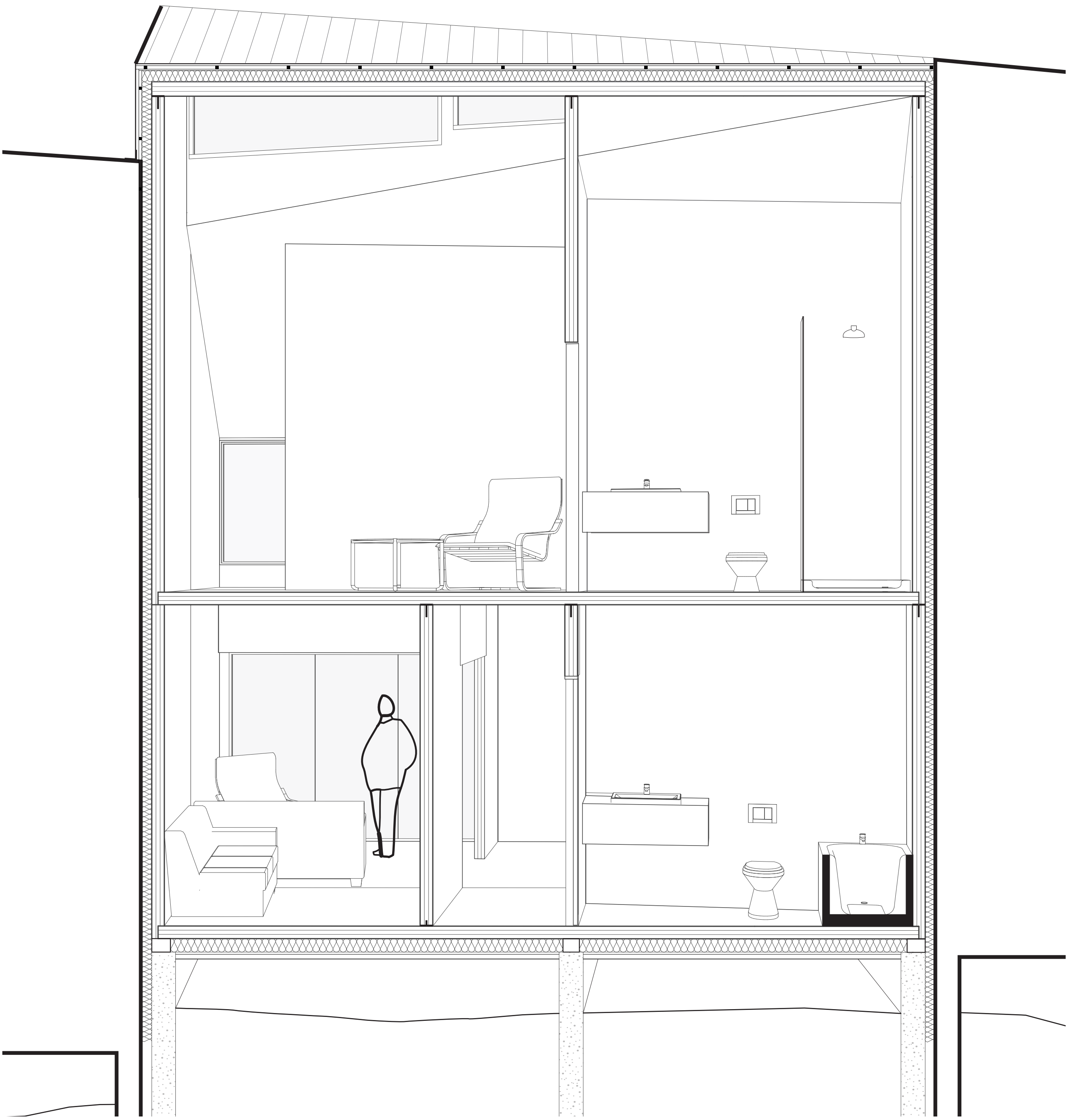


UNIT B



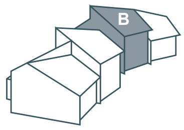
First Floor Plan

Fig.5.35.



Section Bb

Fig.5.36.



Dining room and kitchen

Fig.5.37.

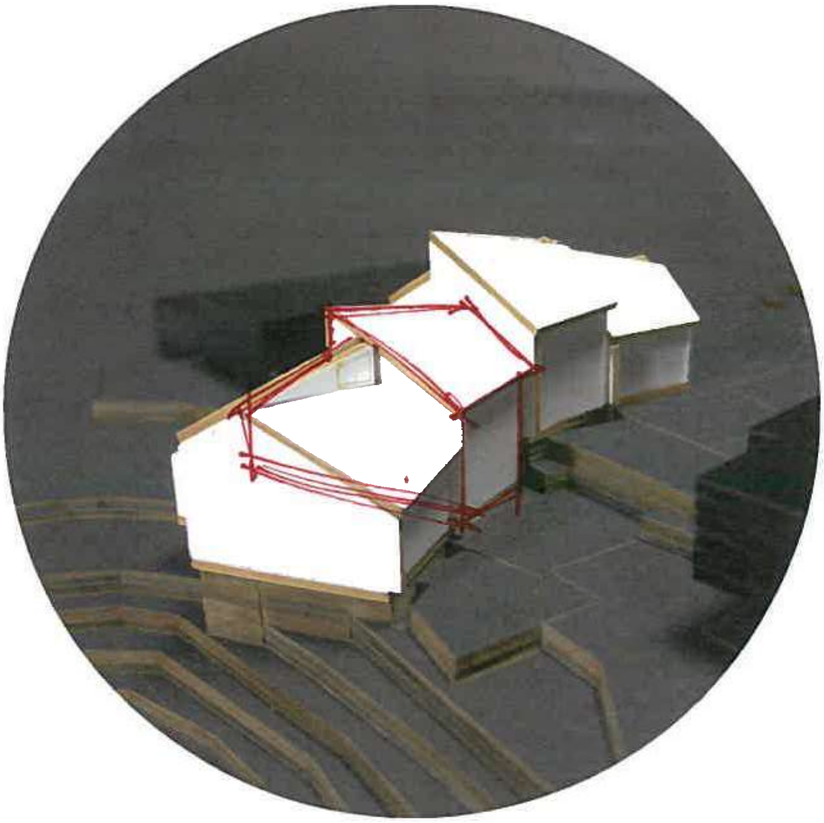
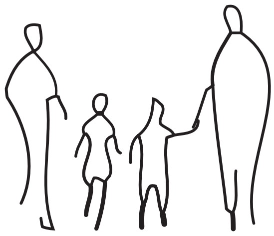


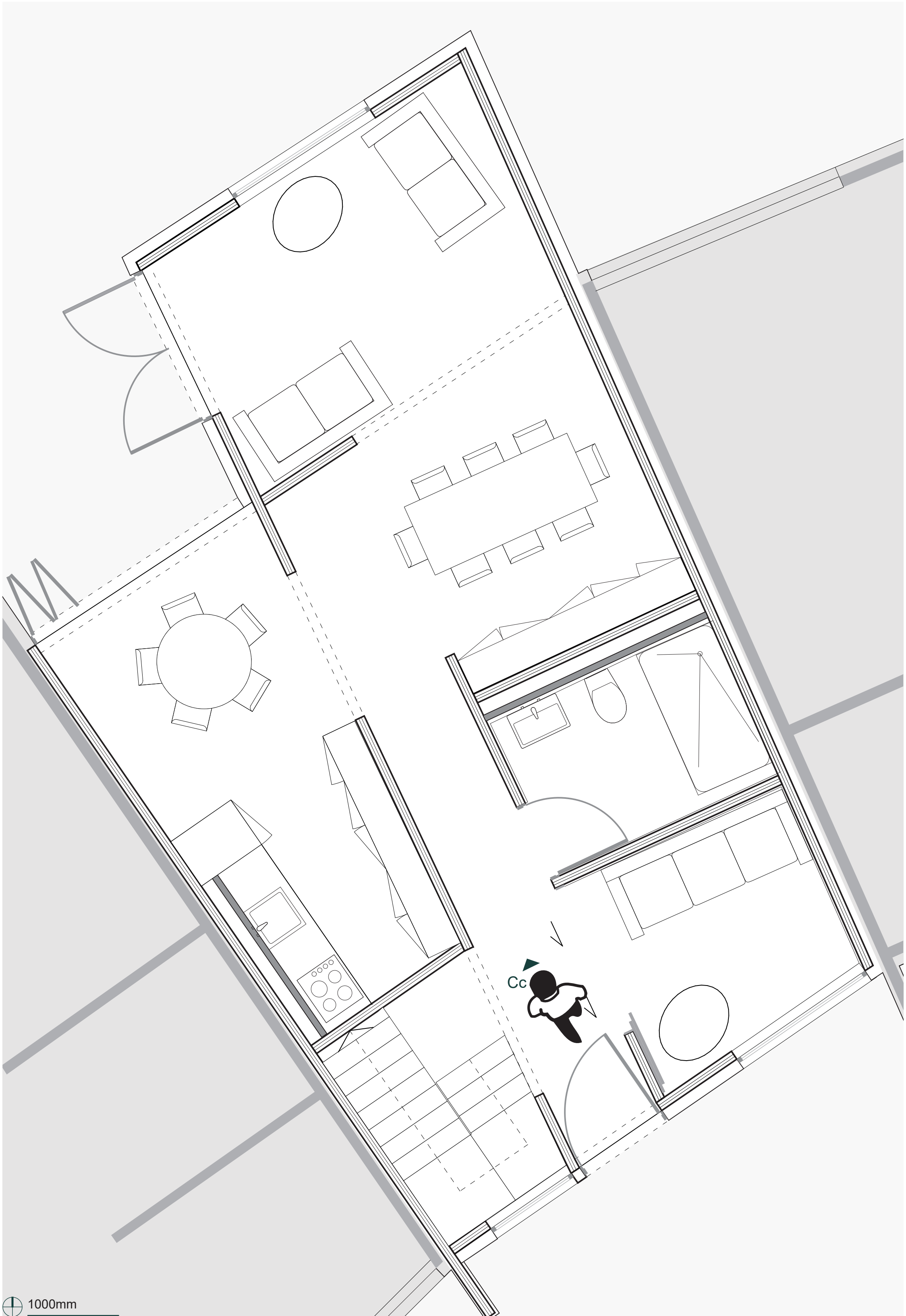
Fig.5.38. Unit C indicated in physical site model

UNIT C



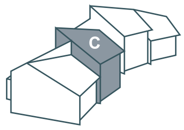
First Home Buyer
148sqm

This unit is the largest built out area of the design. This uses the large scaled roof and the extension. This is the unit at capacity with the opportunity of integrating four bedrooms. However, with consideration, the use of the ground floor room facing the central courtyard is best to contribute to the public living spaces (see fig.5.39.).
The public living zone has treated each programme generously. The kitchen is located in the core of the plan in an accessible, social location. It has a balance of public/privacy for entertaining and everyday living. The dining room then connects it to the lounge. This is an internal room that breaks down the direct north light experienced by the kitchen and the lounge.
With uniform ground floor room heights, the first floor landing is an open spill out zone. Depth is added to this area with the skylight in the roof drawing in direct light from the North (see fig.5.41.) section.



Ground Floor Plan

Fig.5.39.



UNIT C

First Floor Plan

Fig.5.40.

Section Cc

Fig.5.41.

UNIT C

First Floor Landing

Fig.5.42.

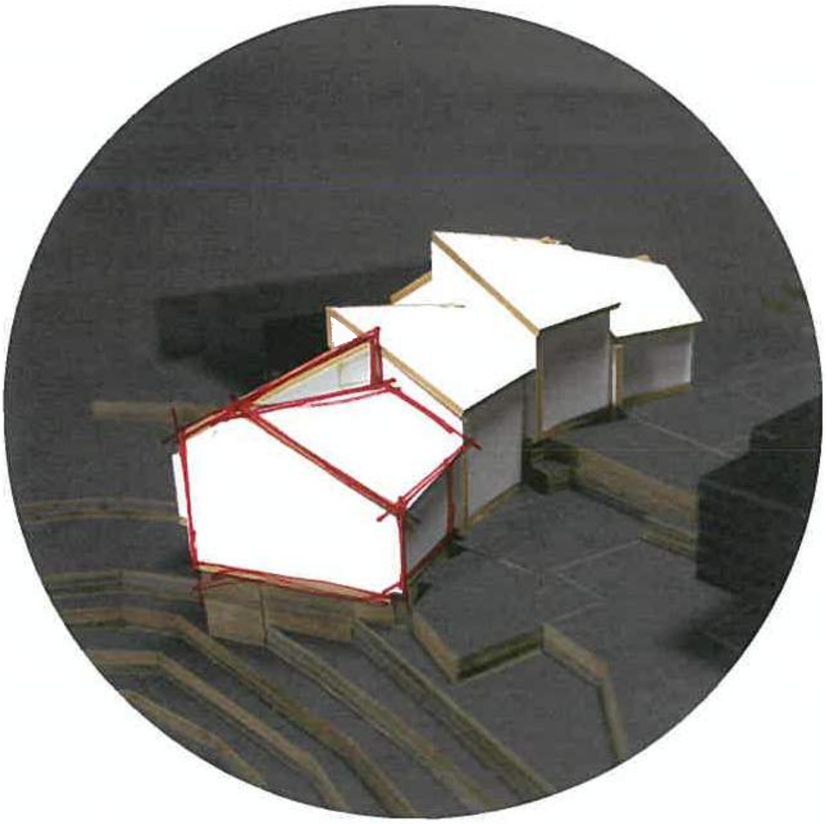
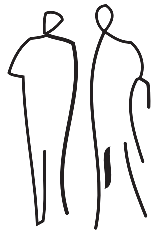


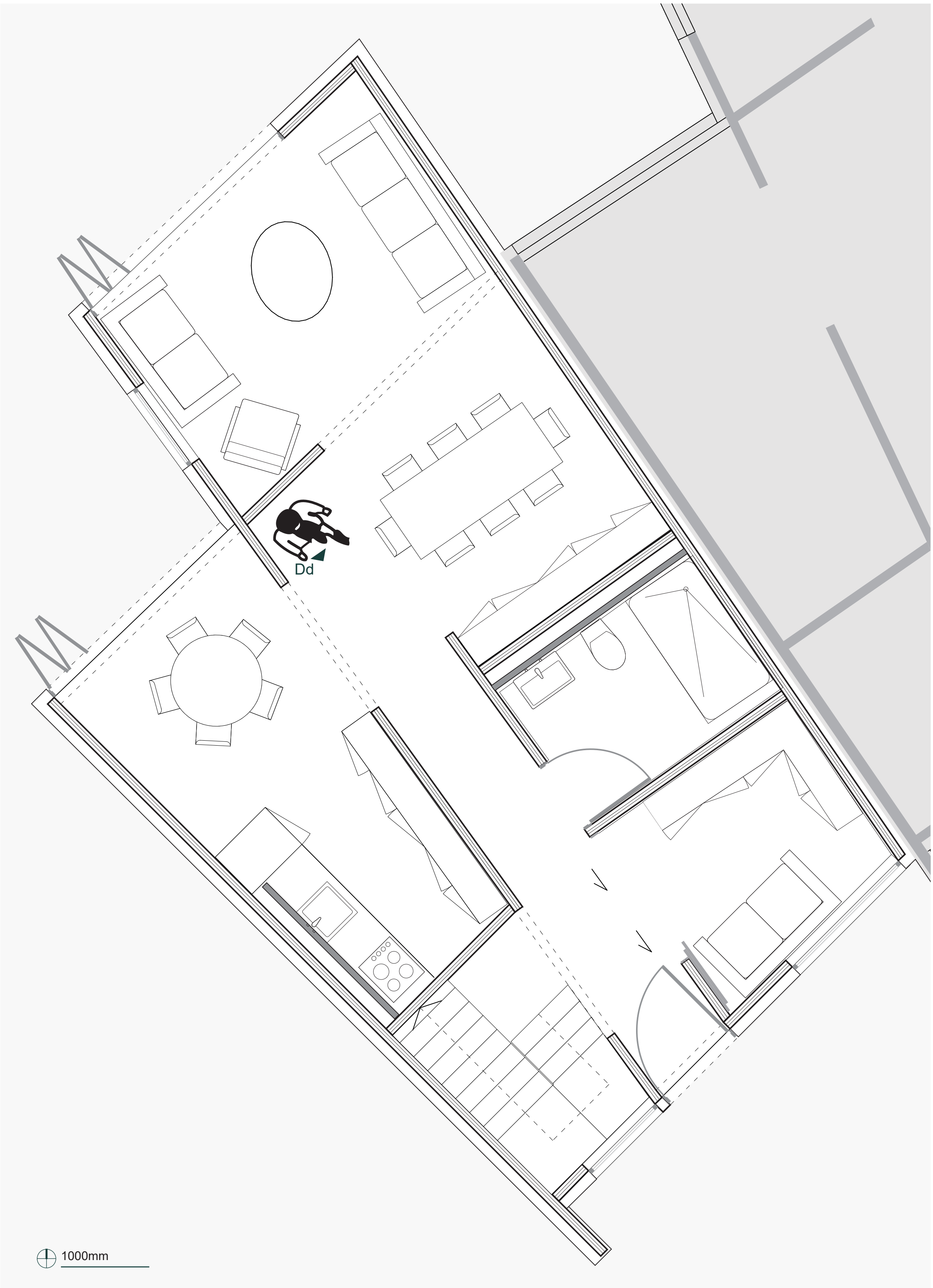
Fig.5.43. Unit D indicated in site model

UNIT D

Home Owner Downizing
128sqm

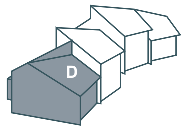


This unit maximises on the generosity of programme for a small occupancy. It has formed designated rooms per public living. The kitchen is tucked in the floor plan core to achieve the desired private/public balance wanted for socialising. A fourth public living zone is in the room looking onto the shared courtyard. It can be imagined as a study, storage, office, or guest bedroom (see fig.5.44.).
The first floor is then arranged for generous spaces. This has resulted in the removal of the second bathroom, and in place is a mezzanine space that is suited to a second study, adding to the atmosphere of the dining room below (see fig.5.46.). Again this has happened above the ground floor study to add depth to the space. The result is a private double bedroom facing North.

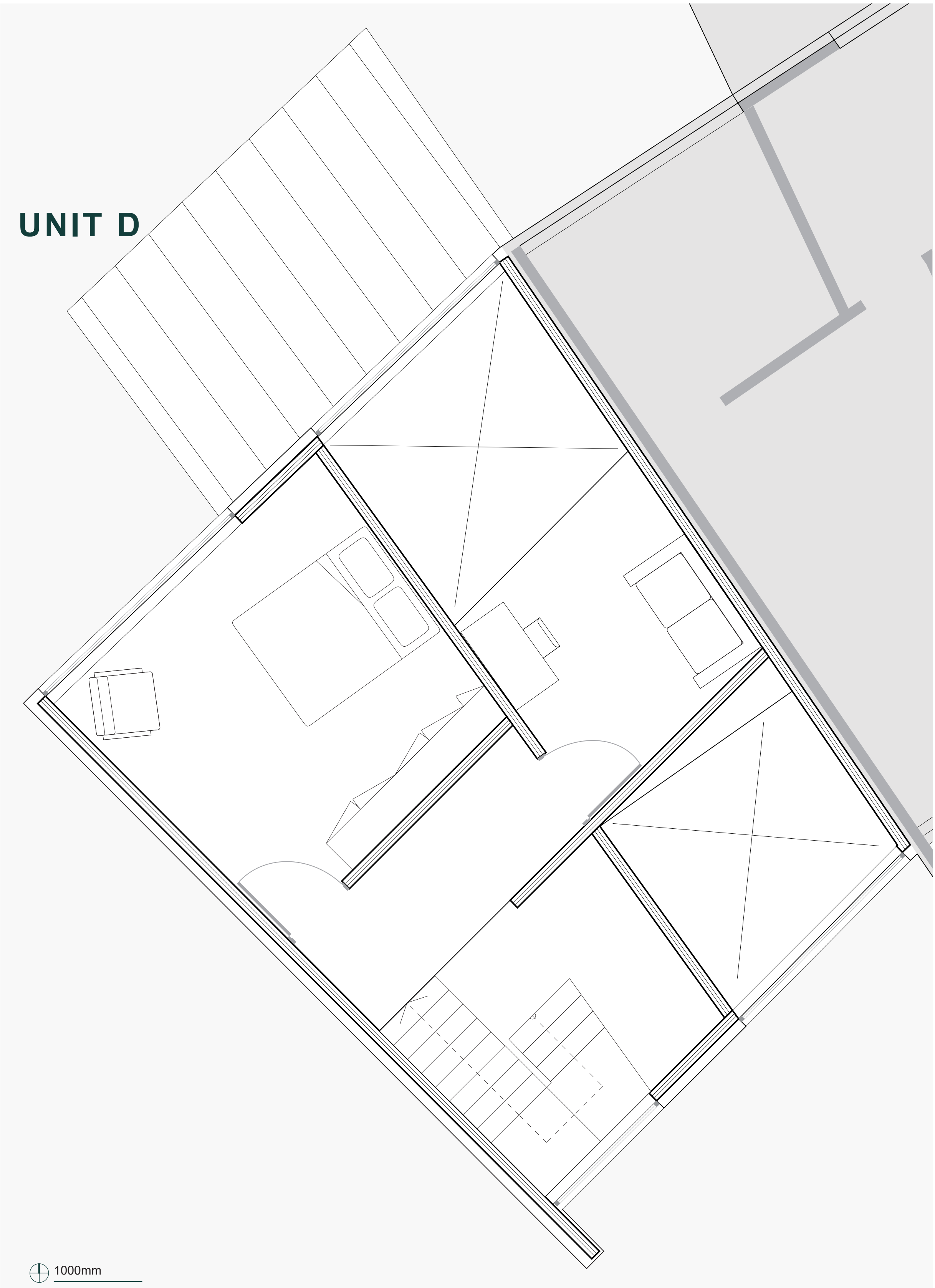


Ground Floor Plan

Fig.5.44.

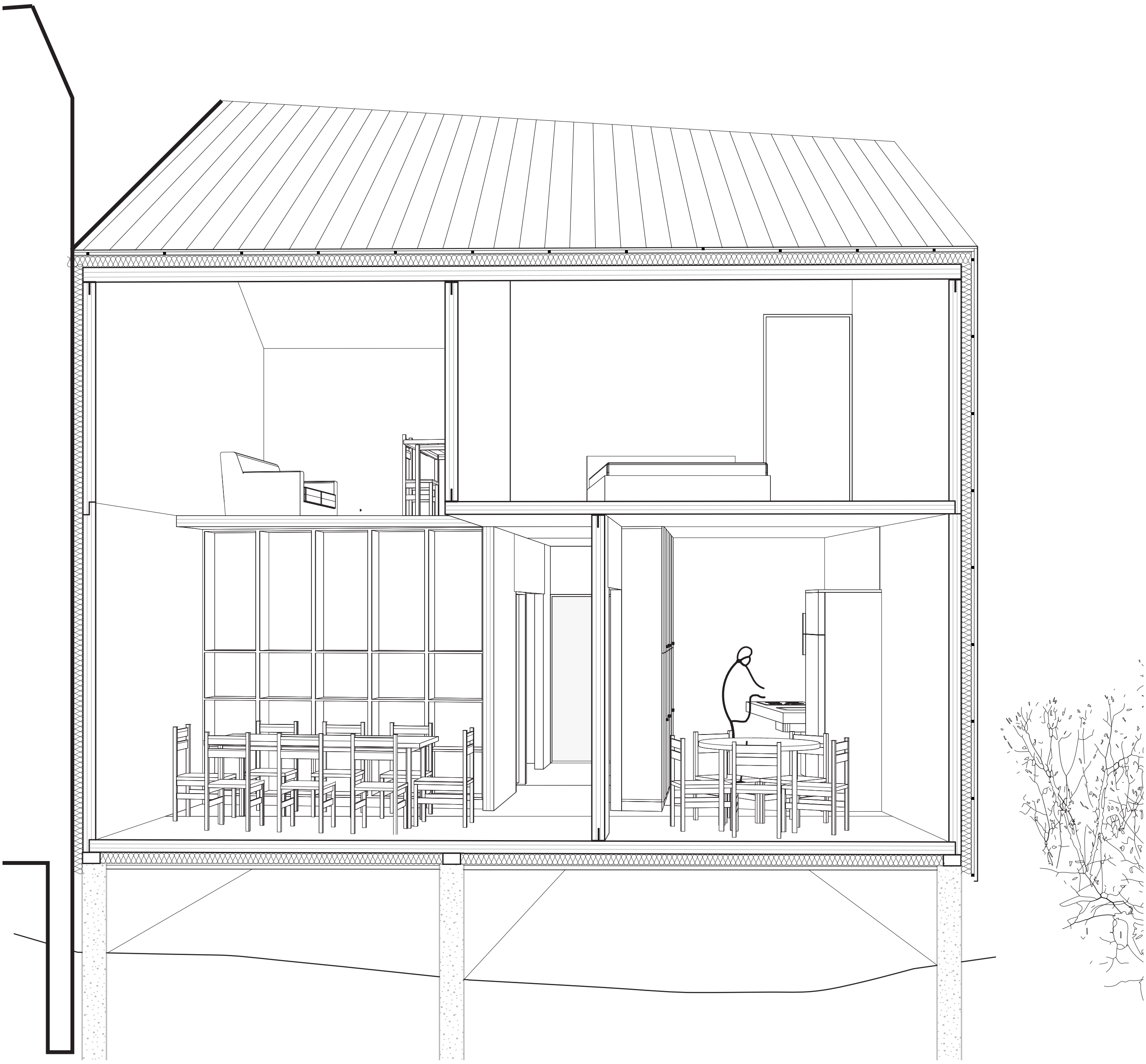


UNIT D



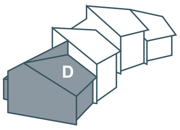
First Floor Plan

Fig.5.45.



Section Dd

Fig.5.46.



UNIT D

Mezzanine down to dining room

Fig.5.47.

132 Coromandel St
View of courtyard from garage

Fig.5.48.

132 Coromandel St
External view of aggregate form

Fig.5.49.

Morning light on landing
Unit B

Fig.5.50.

Afternoon light in bedroom
Unit C

Fig.5.51.

6. Conclusion

Reflection

As all historical texts summarise: the aspiration of industrialised housing manufacturing to reduce costs has never led a business to succeed, yet the ambition for efficiencies and high quality has. This is reinforced by the common idea that applying the prefabrication method to the genesis of the design process is integral to the overall outcome. It is important to design the construction method through the design process to ensure an appropriate manifestation of the system, and consequently a quality finish.

Summary

Adopting prefabrication for a project can help develop a design. The restrictions that are intrinsic to the construction method can create a framework for the design process to follow. With the research directed to the future living typologies in New Zealand, the outcome has provided a new identity for prefabrication. It has related the final outcome to the construction process and the design process. The final design meets the intended programme and embodies the three principles in a concise and balanced manner.

Design-led research is not a common approach when exploring a pragmatic topic like prefabrication. Yet it is important to address the qualitative nature of gathered knowledge. As stated in BRANZ and Pamella Bell's thesis, for New Zealand to adopt prefabrication commonly the empirical outcomes of the research must be investigated. This research has built from the lessons learnt from the past as encouraged by Pamela Bell. The research question is answered with the provided framework of the three principles. Instigating designing to the assembly as the aim, unite the construction process with the design process, so that a quality design develops from the restrictions. This is explained in the context of medium density living in New Zealand.

Founding Literature

This design led research builds on the approach discussed in Refabricating Architecture. The design impetus must acknowledge and assume the demands of the offsite construction method. This allows the development of the design and the processing to compliment one another, resulting in a higher quality outcome. Moreover, Ryan E. Smith's discussion in Prefab Architecture supports this. In accordance with the New Zealand context of a suburb in Wellington providing MDH, the research and discussions that Pamela Bell has on this construction method originating from her thesis also align.

The interrelationships of the founding literature gave confidence in the extracted design strategy. The generated prefabrication definition respected the provided dialogues and cross-checked with New Zealand's motivation for prefabrication – quality building. The same strategy was used to develop a methodology of applying the 'designing to assembly' ideology. The fact that these three principles have not been formally researched as a collective before offers a fresh perspective. The fact that the three principles were gathered from supporting texts proves that this perspective is suitable for the issue.

Design Process Shift

This research contributes to New Zealand developing prefabrication design dialogue by reflecting on two prefabrication design strategies: the component vs. the unit. 'Stage One' researched the viability of components - a common strategy for an industrialised prefabrication system. This supported maximising the applicability of the design. However, on reflection, this technique removed the element of design, due to component configuration only accommodating the programme by following the framework. The outcome 'Stage One' was not efficient due to the lack of party walls, too many corners and various roof lines. As has been written about IBS, 'Stage One' proved that the industrialisation motivation with 'arrangeable' components saturates the factor of design. Thus 'Stage Two' shifted the system strategy and integrated a specific site.

The site brought more constraints to the designing. Overall this provided a true scope for the design to progress within and positively added the perspective of contribution to the surrounding context to be addressed. Omitting a physical context in 'Stage One' is ironic. As seen in 'Stage Two' the incorporated site allowed the design system to develop suitably so as to ensure it was applicable to all scenarios.

The change in system strategy was that it was now one unit which could be tailored to different occupancies and arrangements was developed. It clarified the interrelationships and extents of the three principles appropriately. This shift in design strategy was inspired by the MUJI vertical house, and is a strategy that could revitalise the image of prefabrication in New Zealand.

On reflection the developed framework allowed the efficiencies of prefabrication to be augmented whilst not being detrimental to the quality of design. This can be attributed to the learnings of the two design stages. That control must be given to the depth of each principle. 'Stage One' developed an understanding of the principles of interrelationships that was applied to 'design stage two' to direct the design process more accurately. Suitable further research would be the address of this developed framework in other scaled prefabrication projects. Exploring more in depth the validity of the term.

Suitable further research would be the iteration of the detailing, and how the physical connections for the onsite assembly affect the quality of the design.

Outcomes

The outcome is an understanding of the limitations that come with a flexible, adaptable system. With options comes a resultant reaction that in turn becomes a secondary priority or compromise made. With the site, the aggregate design is determined, which can determine the orientation of some units, in turn affecting some internal programmes. Additionally with the option to build in a roof or leave it open is a question of providing the desired programme and adding spatial depth.

The designed system address the intended programme of future occupancies of MDH in New Zealand. The designed system can create solutions for different topographies, site sizes, and a scale of demographics. However, this is with the compromise of restricting the quality of the units. The freedom to address one factor is balanced with the direct impact to another factor. Theoretically when the system is applied to various sites with their intrinsic constraints it will create a quality aggregate design. This design subsequently determines the orientation of the units. However, if the site is not too constrained there is consequently a level of freedom with the placement of the units which gives a degree of control over the whole design. For example, four units on one site, can have 384 potential arrangements. Additionally the freedom for personalisation, with the changing of the programme per unit to the direction of the occupancy comes at a cost. Building in a 'Roof Large' completely results in the ground floor rooms to not be possible to be double height. This balance of flexibility with one decision comes at a cost of another decision. Addressing the programme in one part of the unit, will affect the spatial qualities of another part.

The design is interesting with how each unit contributes to the overall form. For example if half the units determine a switched orientation, then the aggregate design becomes either a swiggle, or a straight line.
As this research addressed a select programme of future MDH typologies in New Zealand, it is worth exploring the applicability of the design research to other project types. If successful, this would allow it to contribute further to the prefabrication and design relationship conversation.

Limitations

The outcome is an understanding of the limitations that come with a flexible, adaptable system. With options comes a resultant reaction that in turn becomes a secondary priority or compromise made. With the site, the aggregate design is determined, which can determine the orientation of some units, in turn affecting some internal programmes. Additionally with the option to build in a roof or leave it open is a question of providing the desired programme and adding spatial depth.

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Figure List

Unless otherwise states all figures are Author's own.

fig.2.01. External Aspect of House R -
Griffiths, A. (2017, December 31). Nilsson Pflugfelder's prefabricated wooden house is designed to maintain owner's privacy. Retrieved from dezeen: https://www.dezeen.com/2017/12/31/house-r-nilsson-pflugfelder-prefabricated-wooden-house-windows-maintain-owners-privacy/

fig.2.02. Internal View of House R
Griffiths, A. (2017, December 31). Nilsson Pflugfelder's prefabricated wooden house is designed to maintain owner's privacy. Retrieved from dezeen: https://www.dezeen.com/2017/12/31/house-r-nilsson-pflugfelder-prefabricated-wooden-house-windows-maintain-owners-privacy/

fig.2.03 Entry Foyer of House R
Griffiths, A. (2017, December 31). Nilsson Pflugfelder's prefabricated wooden house is designed to maintain owner's privacy. Retrieved from dezeen: https://www.dezeen.com/2017/12/31/house-r-nilsson-pflugfelder-prefabricated-wooden-house-windows-maintain-owners-privacy/

fig.2.05. Volumes Pre Onsite Assembly of BBB
ArchInform. (2018, November 21). Danish Office for Architecture. Retrieved from ArchInform: https://www.archinform.net/arch/3338.htm

fig.2.06. External Aspect of BBB
ArchInform. (2018, November 21). Danish Office for Architecture. Retrieved from ArchInform: https://www.archinform.net/arch/3338.htm

fig.2.07. Internal Aspect of landing in BBB
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fig.2.09. External Elevation of Dalsland Cabin 2.0
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fig.2.10. Internal Aspect of Dalsland Cabin 2.0
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fig.2.11. Internal Aspect of Dalsland Cabin 2.0
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fig.2.13. External Elevation of Muji Vertical House
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fig.2.12. Internal View of Muji Vertical House
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fig.2.13. Internal View of a kitchen in Muji Vertical House
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fig3.01. Treaty House Image
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fig.3.02. Portable Colonial Cottage
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fig.3.03. State Housing
Ministry for Culture and Heritage. (2014, July 21). Early Workers Dwelling - State Housing in New Zealand. Retrieved from https://nzhistory.govt.nz/media/photo/early-workers-dwelling

fig.3.04. Working Mens Huts in Otira
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fig.3.05. Unit of an Industrialised Building System

fig.3.06. Beazley Home Construction Factory
Fletcher Challenge Archives. (2010, March). Beazley Homes factory. Wellington. Retrieved from https://teara.govt.nz/en/photograph/24192/beazley-homes-factory

fig.3.07. The Meridian First Light House
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fig.3.08. Motu Kaikoura
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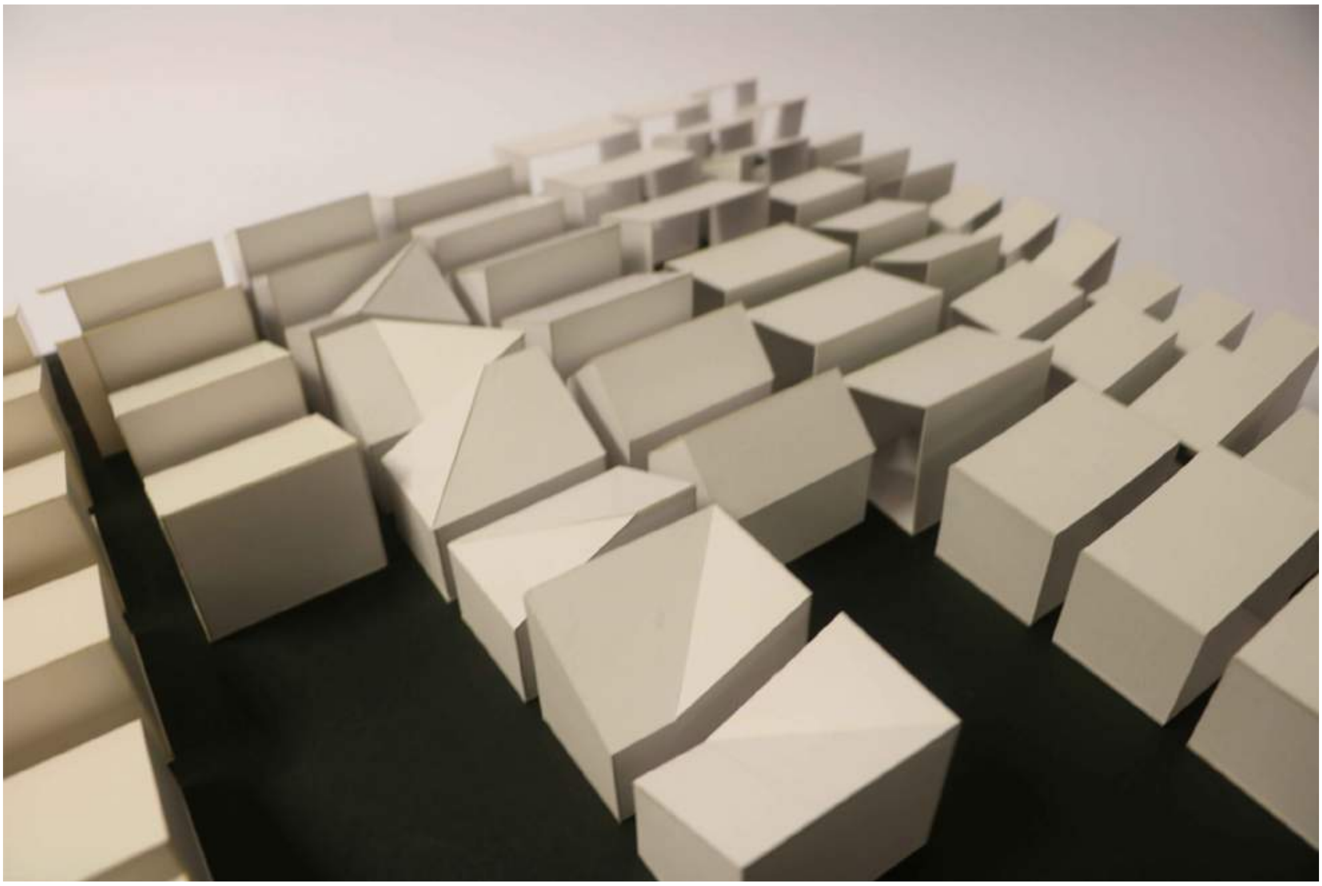
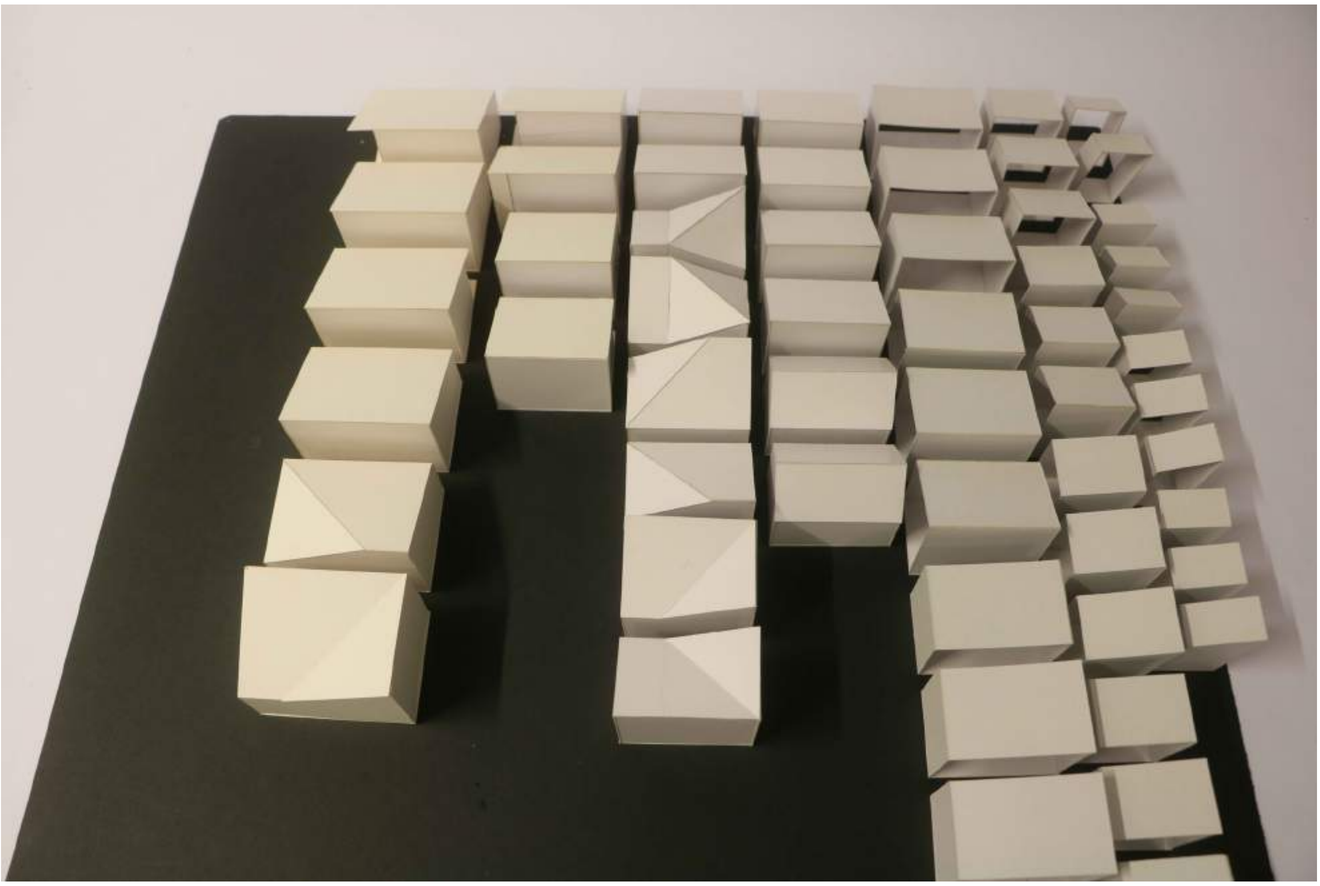
Appendix A - Projected NZ living

Dataset: National household projections, by household type, 2013(base)-2038 update						
Projection		Medium B				
Measure		Family households	Other multi-person households	One-person households	Total households	Average household size
Year at 30 June						
2013		1187200	68600	392700	1648500	2.6
2018		1306100	78700	438600	1823300	2.6
2023		1393600	79900	481600	1955100	2.6
2028		1458700	80300	523300	2062300	2.6
2033		1515800	81500	563400	2160600	2.5
2038		1563000	82100	599400	2244500	2.5

data extracted on 17 Nov 2018 04:32 UTC (GMT) from NZ.Stat

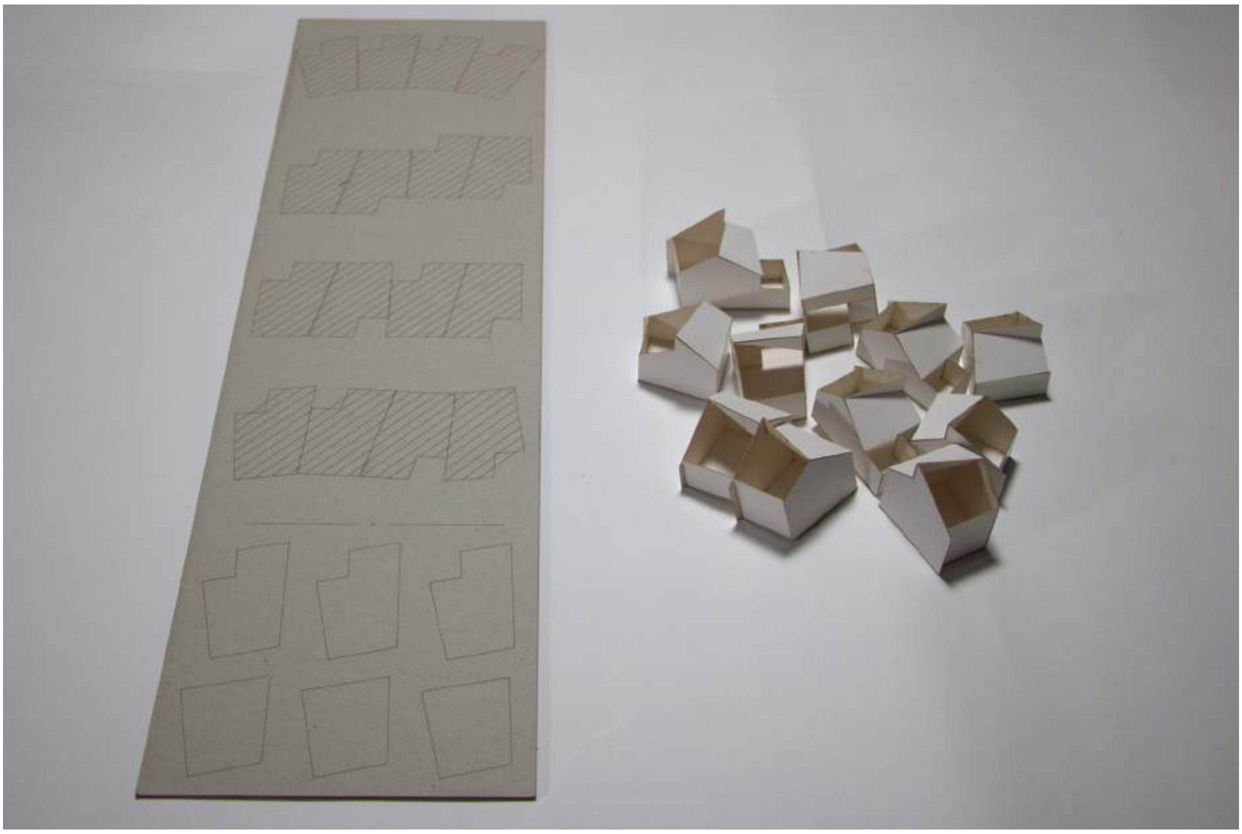
Appendix B - White Card Models

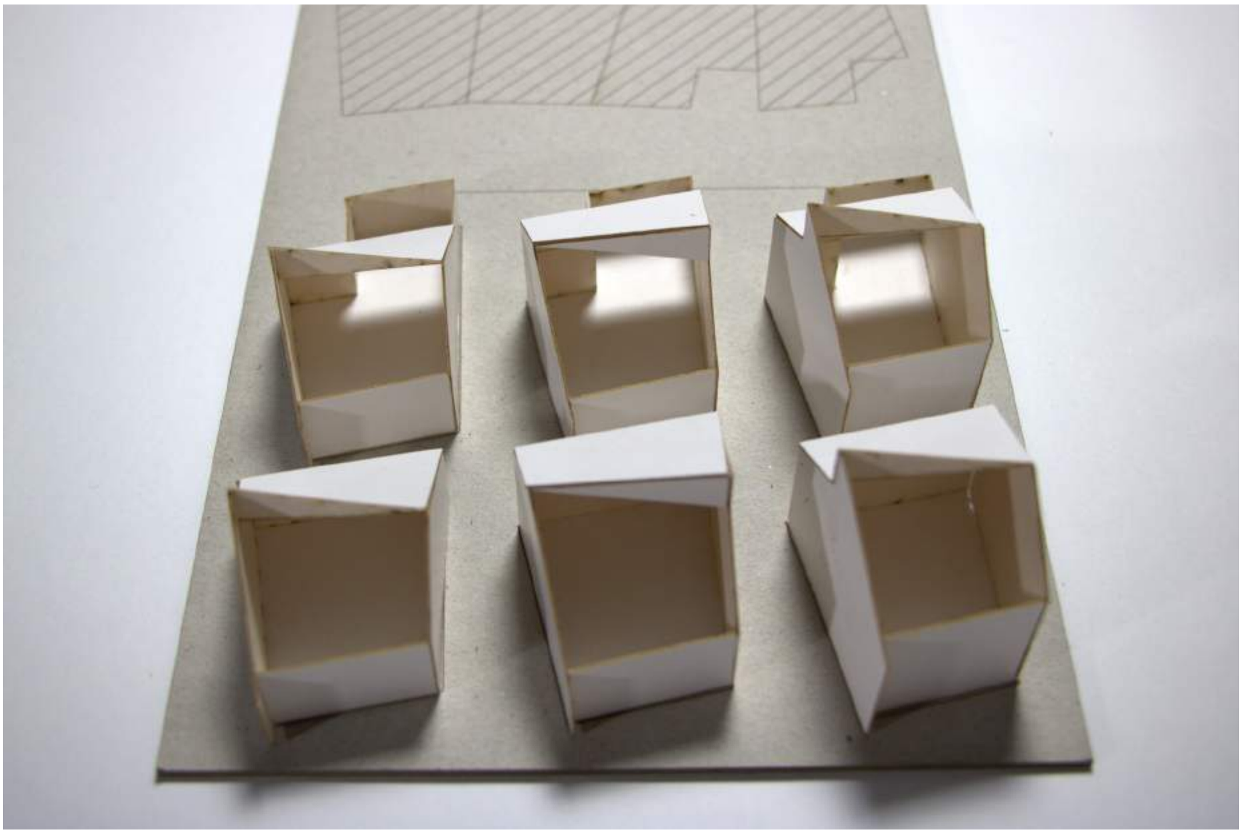




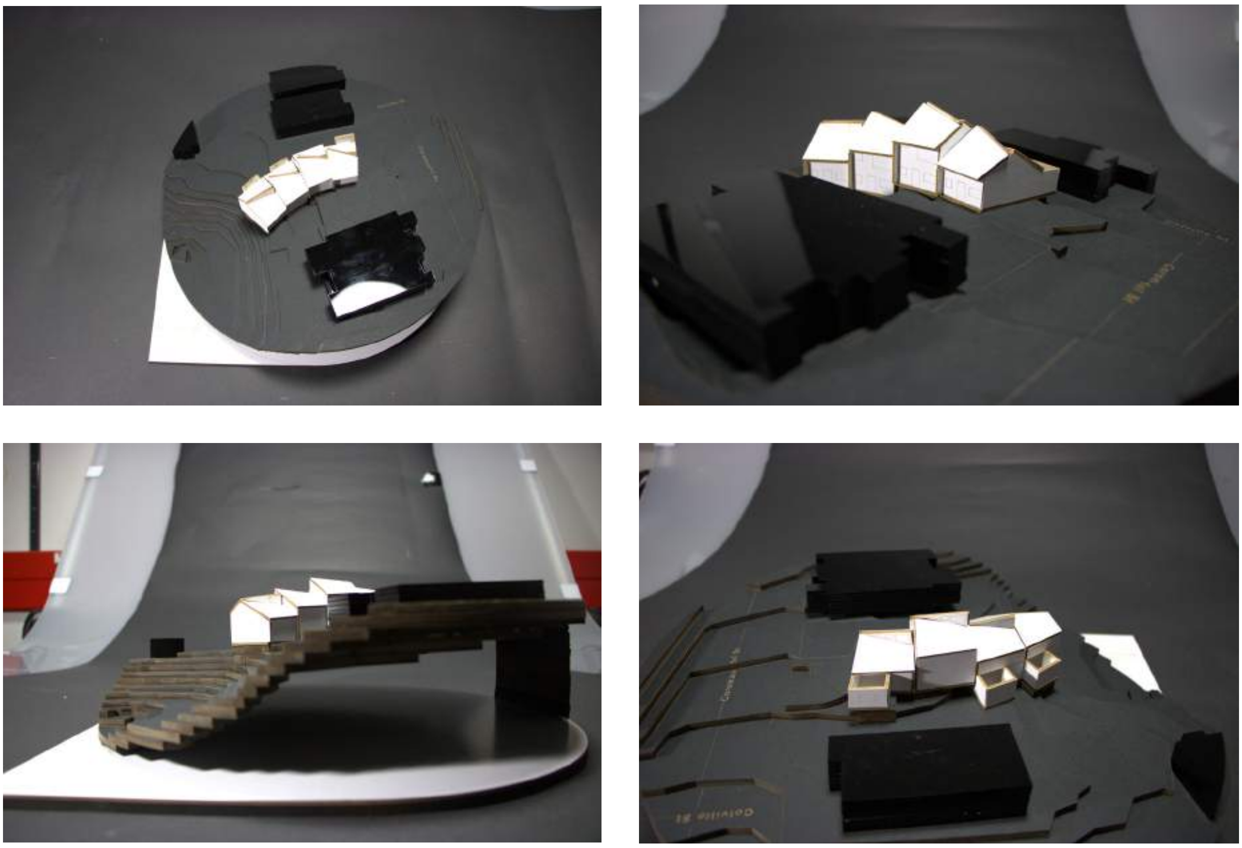
Iterated Components

Appendix C - System Modles





Models to explore relationship of models



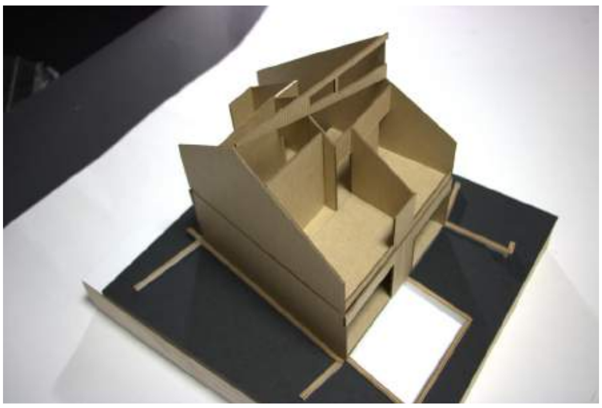
Designed Site Model

System Unit Model - Ground Floor







System Unit Model