Architectural Indicators.

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Architectural Indicators.

A 120-point thesis submitted to the Victoria University of Wellington in partial fulfilment of the requirements for the degree of Master of Architecture (Professional)

by *Jonathan James Hay*.

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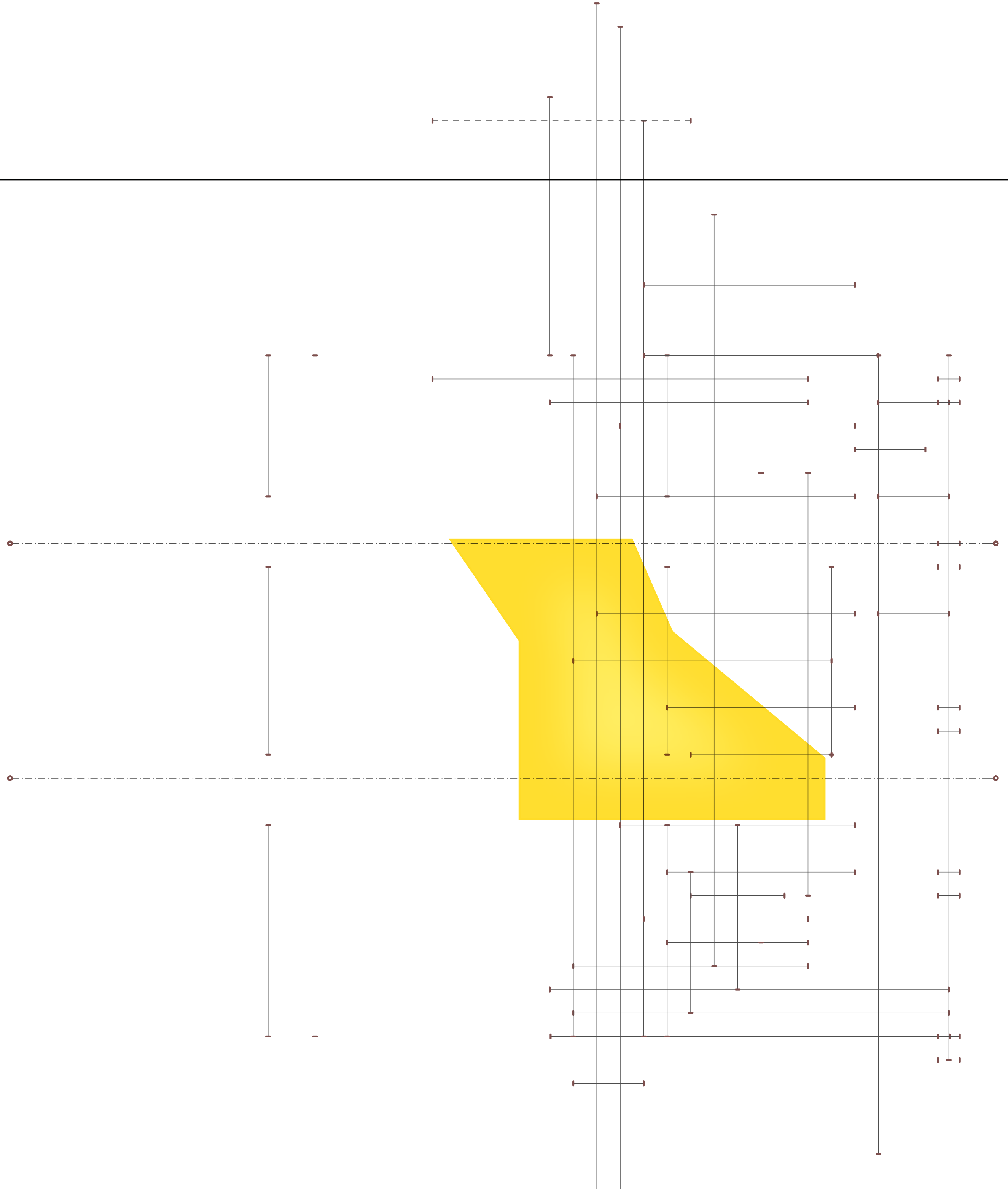
School of Architecture



ABSTRACT

A political crisis is currently underway in New Zealand with a critical lack of affordable well-designed housing. Due to the presence in New Zealand of such vast timber resources and our enviable global location for export shipping, there are great economic and industry opportunities for the production of prefabricated timber housing. However, the contemporary architectural position on prefabrication is often limited by the inability to evidence individuality, diverse detailing and robust habitability with a predetermined production 'formula'. This thesis argues that the anonymous open plan nature of prefabrication facilities is restricting prefabrication from achieving high levels of architectural design that evidence qualities of craft. This thesis argues that by using an interdisciplinary approach recognising qualities of shared authorship with prefabrication, this highly effective form of construction can satisfy a wider market while maintaining key architectural values of individuality (authorship), detailing (craft) and habitability (integrated technical functions, sustainability, etc.).

The design research explores how the design of a large-scale prefabrication facility can encourage craft and authorship within production processes. Similarly through design exploration the facility intends to provide a cohesive understanding and implementation of complex and specialised industry systems alongside production processes. The design also explores how the facility can provide an environment where this collaboration can be meaningfully encouraged, while also facilitating collaborative learning to resolve prefabrication design-related problems.

The site for the proposed new Trade Build Facility is on the border of Wellington's operational port of Centre Port, on the south intersection of Waterloo Quay and Cornwell Street, Pipitea, alongside a resource of raw logs with multiple national and international transport modes. The thesis proposes the experimental design of a facility that focuses on timber beginning with the processing of the raw log at the input end, through to the pre-fabricated housing units at the output end. This thesis proposes a production facility that also takes on the role of an educational design vehicle for both the architect and the architectural student to develop and engage the latest technologies of design and construction in the field of prefabrication, providing them with the foundation for entering the complexities of the current architectural design profession. It is intended that users will witness the actual creation of a system of architecture, in a setting explicitly designed to enable these conditions to transform and evolve in step with the latest industry developments. This results in a productive partnering between design and construction, production and education, architect and architectural student through the refined inclusion of craft and authorship in architectural design.

The thesis actively seeks a design solution that develops future design outcomes of prefabricated timber production facilities through an enhanced and responsive adaptability within the facility. The building design also encourages robust and cohesive collaboration by incorporating multidisciplinary specialists with the production and education processes of prefabrication. As a result this thesis argues that architects will be provided greater opportunities for exploring craft and authorship within the context of prefabrication. The problems addressed by the strategic design experiments are prefabrication focused; however the situation is emblematic of a greater problem in the overall field of architecture. Through a focused evaluation on the collaborative environment experienced in the production of prefabrication, valuable lessons are transferrable to all collaborative construction-based work environments, facilitating the ability to engender qualities of craft in an architecturally advanced industry.

ACKNOWLEDGEMENTS

To my parents Martin and Barbara,

who I'm sure are glad to see me finally finish this degree.

To the great 2012 class,

who have helped push each other through to the end.

To my supervisor Daniel K. Brown,

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for keeping me on track to the end.

Thank you.

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INTRODUCTION

As experienced throughout contemporary industries, technological developments have significantly contributed to production efficiencies, providing both economic and technical improvements. These developments have also shifted the way in which industry objectives and processes operate, re-defining interactions between people, materials, and the machinery or technology involved. In the case of the building industry, the specialized and compartmentalised nature of interdisciplinary relations has led to collaborative environments less able to adaptively respond to emerging alternatives, specifically in the field of prefabricated architecture. Identified challenges include the blurred distinctions between a diverse range of discipline responsibilities and the question of authorship under a collective cohort in prefabrication production facilities. The architect's role in this situation is important for a prefabrication production facility's ability to design and manufacture prefabricated architecture that augments qualities of craft through collaborative acts of conception that recognise qualities of shared authorship. It is through this change in scenario toward increased technological specialisations that collaborative environments require an alternative approach to design in order to readily implicate prefabricated architecture that is comparably well designed, yet more cost effective, to typical production approaches in the building industry. The benefits of prefabrication production include: efficiency of labour and time in a controlled environment, simultaneous production of multiple units, and the productive use of materials, all resulting in architecturally designed housing units at a reduced cost to typical production approaches and design build package homes. The design experiment aims to address the collaborative and diverse range of industry disciplines essential to achieving this desirable form of prefabricated architecture.

This thesis integrates socialist theory in parallel with traditional theory of craftsmanship through Richard Sennett, Professor of Sociology at New York University. Sennett's work provides traditional and historic understanding on where current industry roles and responsibilities are founded. This provides design research directives on the organisation of labour and design management techniques for a collaborative work environment. Physical manufacturing and production techniques are then critiqued through the work of French architect Jean Prouvé, who made comparisons between manufacturing based industries of automobiles, aeronautics and furniture design.[I] It is through these alternative production techniques and the integration of a module based system that the thesis investigates a balanced focus between technical and creative realms of the architectural discipline, practicing a 'design by making'[II] approach to the design and prefabrication production. This analysis provides a departure for design as an integrated thread embedded in traditional and contemporary discourse, which amalgamates contemporary industry roles through established principles of shared authorship resulting in qualities of craft to be engendered in the production of prefabricated architecture.

This thesis investigates the strategic design of a large-scale prefabrication production facility able to take on a responsive and adaptive role with the collaborative processes of production, to encourage prefabricated outcomes to evidence a high degree of architectural design representative of individuality (authorship), detailing (craft) and habitability (integrated technical functions, sustainability, etc.). It is through the three design themes implicated within the prefabrication facility beginning with focused authorship, articulated craft, and a cohesive collaborative environment of interdisciplinary specialists that the prefabricated outcomes can evidence a high degree of individuality, detailing, and habitability.

Through a synchronised integration of education and production processes within the Trade Build Facility, this thesis argues the collaborative environment will provide opportunities for responsive learning between the diverse and cohesive range of industry specialists. Similarly, the architectural design integrated with the production processes within collectively act as a catalyst for learning and testing of alternative approaches to the production of architecture.

The Trade Build Facility design experiment encourages diversity of collaborative experiences by facilitating designs at multiple scales examined from multiple directionalities within the progressive nature of production employed. This architectural approach encourages shared authorship principles through facilitating and reinforcing the collaborative design process. The approach begins with investigation of the joint, the detail, thereby evidencing how craft can be implicated through a collaborative approach to resolve design-related problems identified in the production of prefabricated architecture.

The site for the design research experiment is on the border of Wellington's operational port of Centre Port, on the south intersection of Waterloo Quay and Cornwell Street, Pipitea, where a significant resource (and production input) of raw logs is located along with multiple national and international transport (and export) modes. Due to the proximity of a logging resource and New Zealand's vast timber resources the new experiment for a Trade Build Facility is focused on timber, employing a boutique scale sawmill at the beginning of the production process. Due to the current political crisis in New Zealand relating to the need for affordable well-designed housing, the thesis challenges the design of prefabricated housing units at the output end of the production facility.

The thesis is structured around two sections. Part 1: Between the Background and the Millions, looks at the context and nature of the timber prefabrication environment within which the contemporary architect operates, alongside the architect's shared responsibility for the prefabricated architectural output. Part 2: Design and the Contributors, deals specifically with the design component of the thesis and design responses to the theoretical discourse and examined case studies on shifting industry approaches in the field of timber prefabricated architecture.

Part 1: Between the Background and the Millions

Chapter 1: Craft and Innovative-Technical Industry Approaches

The development of industry operations and the integration of technologically driven alternatives to timber prefabricated architecture reveals responsive opportunities for the architect, as well as adaptable approaches to design. Research is discussed relating to how traditional qualities of craft and authorship can be set within the context of critical theory relating to prefabricated architecture. Examining how technological shifts assemble through multiple specialist involvements of a collaborative industry through the lens of authorship, can provide insight into how the diverse roles and responsibilities can actively evidence qualities of craft in prefabricated architecture.

Chapter 2: The Future Potentials, Programme + Case Studies

Following the critique of prefabrication facility approaches to production, attention is shifted to how craft and authorship can be revealed and realised in prefabrication through the strategic design of a large-scale prefabrication production facility. Case studies examined contribute to the formulation of the dual design programme of synchronised production and education processes of the Trade Build Facility. Examining prefabrication factories, mixed typological projects, and modular and multiple scale production alternatives provides the fundamental prefabrication principles for the design to respond to and integrate with the educational facility.

Part 2: Design and the Contributors

Chapter 3: Site Selection

The chosen site for the Trade Build Facility invites the dual programme of a production and educational facility. Bordering on the threshold between dense urban residential and the busy economic industrial port of Wellington, the site provides an existing economically viable situation for the dual programmatic components proposed. Of primary site significance is the accessible location of the raw logging resource and global transport capabilities, in combination with the national and international supply and demand of materials and prefabricated architecture.

Chapter 4: Crafting Iterative Design

The departure for the design approach begins with the iterative design exploration of the truss, prior to integrating the complexities from all the internal and external contributors of programme, site, and theoretical thinking. The thesis argues that the joint represents the craft of the output, and the strategic design of the truss as a means of enabling high quality production is essential, both as an educational tool as well as a production element. This design methodology has been followed through the design of the prefabrication production facility, and it is envisaged as an essential operational element within the Trade Build Facility as the foundation to the educational curriculum and pedagogy.

Chapter 5: Truth is Beauty, Design Pragmatics

The architectural design of the Trade Build Facility as a design research experiment reveals how responsive and spatially adaptable production environments can engage collaborative design engendering qualities of craft in the prefabricated architectural outcomes. The design solution also provides opportunities for the architectural discipline and prefabricated architecture to actively adapt in response to emerging production alternatives and technological developments in the shifting contemporary industry environment.

This thesis directs design research to further develop outcomes of timber prefabrication production through an enhanced and responsive adaptability within the production facility. The design also encourages cohesive collaboration in an environment of shared authorship, which promotes an engendered presence of craft in the contemporary production of architecture.

[I] Jean Prouve: The Poetics of the Technical Object. p 137.

[II] West, "Thinking with Matter." p 55.

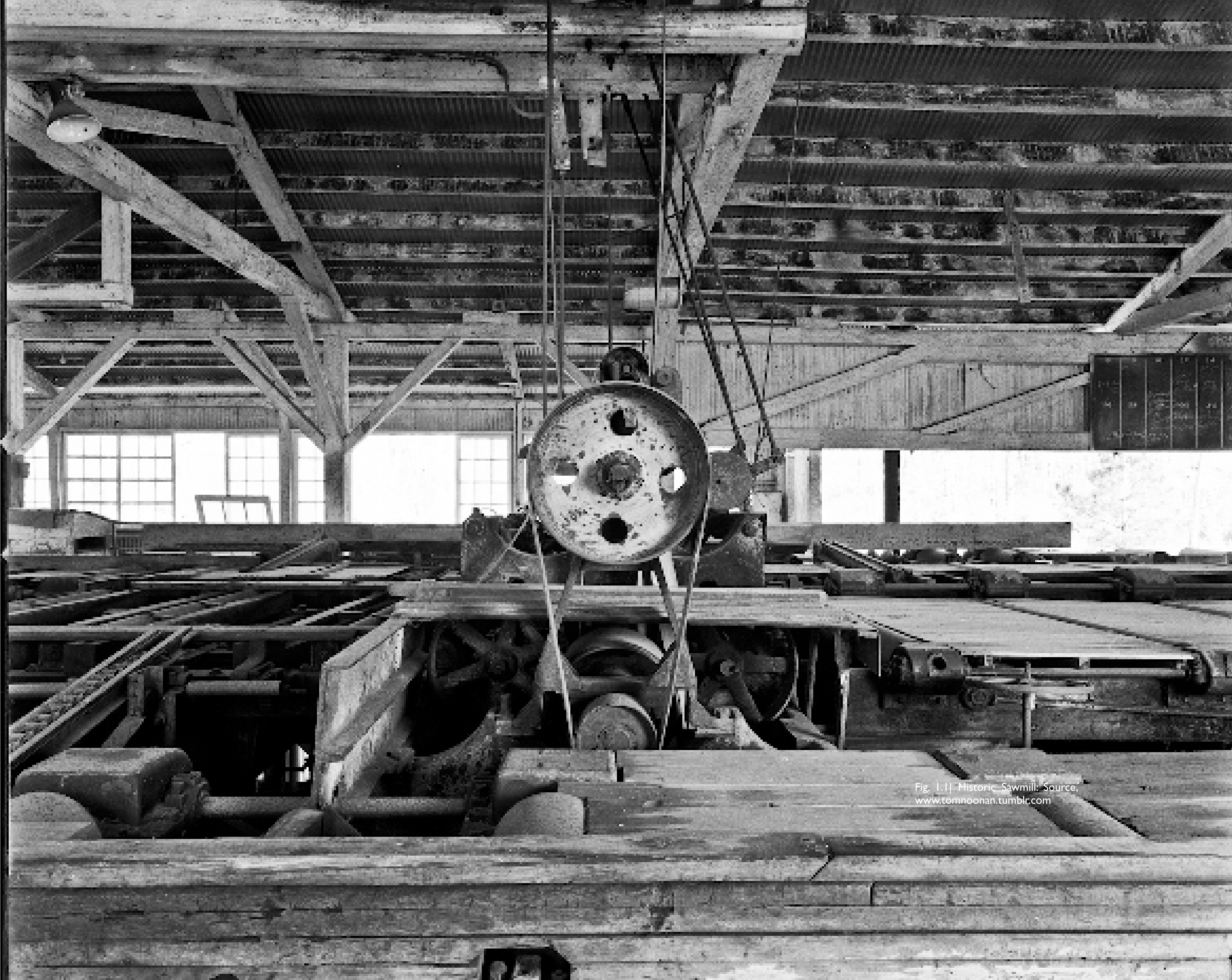


Fig. 1.1| Historic Sawmill: Source, www.tomnoonan.tumblr.com

PART 1

BETWEEN THE BACKGROUND AND THE MILLIONS

1 CRAFT AND INNOVATIVE-TECHNICAL INDUSTRY APPROACHES

This chapter highlights traditional qualities of craft and authorship, set within the context of critical theory relating to timber prefabrication. This dual thread of craft alongside architectural production in the collaborative industry environment, introduces the difficulties of a creative discipline in a scientific and pragmatic environment. This section of the thesis reveals traditional theory on authorship as essential contributory factors to the ability of design to evidence qualities of craft in architectural production.

In the modern environment notions of 'the collective' and knowledge sharing are paramount to the foundation of the building industry, which this thesis argues are further pronounced in the field of timber prefabrication. Collaboration between disciplines is the primary means of articulating design and construction outcomes in a technologically specialised industry focused on achieving high levels of architectural design, environmental control, and sustainable use of materials. It is the architect's ability to productively articulate these diverse contributions within three design themes of individuality, detailing, and habitability that provide timber prefabrication the opportunity to develop as a desirable alternative to typical production approaches of architecture. This thesis argues that the architect's ability to 'design' prefabricated architecture representative of these three themes is established through an integrated recognition of shared authorship that engages qualities of craft. This chapter examines historic definitions of craft and alternative approaches to architectural production, while simultaneously establishing the critical context required for evidencing an educational design solution (aimed at students, architectural practitioners, and representatives of all technologies currently implicated in architectural design) that allows an increased integration and understanding of collaboration, craft and authorship, in the field of prefabricated architecture.

1.1 Craftsmanship

The traditional thinking and understanding of craft emerged from the early centuries where trades had master craftsmen who led in their respective specialty. Skills were taught and thereby learnt from the master and the apprentices gradually understood the requirements and duty of the work, their craft. It is this method of education and apprentice learning that allowed individual roles to retain pride in their work through a sense of authorship to their task at hand. This historic understanding of craft and the craftsman is foundational but is not directly transferable in the modern building industry environment, which in contrast is significantly more diverse and technologically specialised. There are however defined areas of transferability and this thesis argues these borders could be productively widened through strategic design to enable prefabricated architecture the ability to engender qualities of craft, forming a pivotal position in the market of small-scale housing.

When defining the limits of craft in the contemporary environment of prefabricated architecture there is an important distinction between the pragmatic and creative realms of architecture; as Richard Sennett explains in The Craftsman: "art seems to draw attention to work that is unique or at least distinctive, whereas craft names a more anonymous, collective, and continued practice" [1]. It is important as contributors to the architectural profession, to recognise the shared influence from both the technical and creative threads of the discipline specifically in the field of prefabrication where the two are closely aligned.

This thesis frames craft as a tool for managing the architect's responsibility to the collective, establishing balance between pragmatic and innovative approaches in reference to architectural prefabrication. The true beauty of the discipline as exemplified by many notable architectural examples is the embodiment of and association between the technical and creative, and consequently the assemblage of multiple specialists. The potential for this dual nature to further develop and manifest in prefabricated architecture is prominent in the contemporary context.

1.1.1 Contemporary readings of Craft

The term craft has varied meanings but in the most basic form can be understood as a measure of quality or workmanship. David Pye, Professor of Furniture Design at the Royal College of Art in London, writes on the subject:

"Craftsmanship…means simply workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making." [II]

It is through this that the highlighted importance of the worker's invested interest and empowered responsibility to the task becomes important. The distinction between craft and authorship is important to identify; authorship is a subsidiary to craft but representative of individual contributions in a collaborative work environment in order to evidence craft. The workers' demeanour and enjoyment of the job at hand becomes paramount to the project's outcome. This reading of the workers and their involvement highlights the important focus of this thesis, where the responsive adaptability of the environment of prefabrication facilities, and how conducive the collaborative environment is, has a direct influence on the end product. This position by Pye however is limited by its directed focus primarily on the constructional 'worker', which divorces the design component from the ideally balanced design-to-construction continuum of prefabrication processes.

Through analysis of architect Renzo Piano, winner of the 1998 Pritzker Prize, and his position on craft, we learn of a clearer distinction that encompasses design and the systematic process that enables an even balance between both design and construction.

"Craft-The work of someone who does not separate the work of the mind from the work of the hand… It involves a circular process that takes you from the idea to a drawing, from a drawing to a construction, and from a construction back to idea." [III]

With Piano's reference to the fluid and responsive process that occurs through the design, the shared influence of both the mind and the hand are able to productively cooperate forming a crafted result or output. Additionally it is important to recognise the humanistic scale implied in these definitions, providing a level of authorship and responsibility often not prevalent in larger scaled work. In the context of both of these quotes, this thesis employs a strategic approach to the responsive adaptability of prefabrication production facilities that enable craft and authorship to manifest. It is through this engendered position on craft and authorship that allows a new approach to prefabricated architecture to emerge.

1.1.2 Craft in the Industry

In the contemporary architectural design environment craft is limited in actual practice, due to the highly collaborative nature of the industry. Contemporary discourse on prefabrication with the multitude of disciplines involved provides a step toward uncovering the reasoning for the weakened evidence of craft, experienced today. The common theme that emerges is that of authorship, critical when such diverse collaborative groups govern contemporary industry practice.

The significance of authorship in the field of prefabrication is tied directly to the diverse and specialised nature of roles and the compartmentalised structure experienced across the design-to-build continuum. The causes of the diminished identity of authorship are complex but include an imbalance between design and construction. The opportunity for design to establish a production environment inclusive of design and construction realms provides an opportunity for prefabrication production to reference – and encourage – craft through an integrated understanding of production authorship.

The recently published book Kiwi Prefab by Pamela Bell and Mark Southcombe aims to shift people's conservative preconceptions towards prefabrication. They discuss responsive and adaptable production environments that engage the public, to strategically evidence the increase in design control over the "repetitive" nature of prefabrication systems. Professor of Architecture at Yale University, Peggy Deamer, states in the context of the contemporary industry, "…the entire organisational process is being revamped to be more responsive to the various talents needed to produce a building." [IV] This is directly related to the prefabrication of architecture, determining the most productive and rewarding recipe of design and construction and showing the balance between the creation and execution of components. Through this responsive balance between the various components of the design and production, the outcome is much more likely to be highly individualised in its detail and its habitability.

1.2 Regulatory Environment

Regulatory building codes arguably become the safety net for the authorities; however the culture of the industry and the relation to the regulations is two-sided. Often consultants seem to view the codes as design-maximums; secondly they are ensuring that an appropriate level of safety and permanence is achieved.

New Zealand does allow 'Alternative Solutions' to be granted if there is sufficient information and testing undertaken to prove the alternative method will perform to the same standards required. This process is adequate although establishing the viability of an alternative solution for a project can be costly. In the context of regulations and workmanship a quote from Sennett summarises the qualitative and operational limits of a 'code of practice': "Since there can be no skilled work without standards, it is infinitely preferable that these standards be embodied in a human being than in a lifeless, static code of practice."[V]

The situation for prefabrication is notable as both design and construction are beneath the same roof, providing an opportunity for dynamic regulatory control that is more responsive to emerging alternatives. The evolutionary aspect demanded by technical and innovative fields in the prefabrication industry suggests the enabling of craft and authorship through production workflows could assist regulations in defined areas, allowing a more accommodative control structure to be implemented.

The issues discussed here are representative of the way in which the legislative process in the industry operates. The regulations are fundamental and the objectives are successful for improving the overall quality of the built environment. With modern technological developments and the broad introduction of fabrication and alternative production techniques such as timber prefabrication, there is the ability for verification of design to be achieved at different stages in the process, allowing a collaborative team to more fluidly approach achieving the regulatory performance criteria.

1.3 Production in Architecture

Questions such as 'What makes construction intelligent?' provoke alternatives to architectural production such as timber prefabrication, prioritizing the importance of a binary (production and education combined) and innovative approach to design and constructing. SHoP Architects, a New York firm at the forefront of technological and digital methods of collaboration and project control, captures a suggestive direction of where the prefabrication industry may exist in the future.

"The protocols of the construction industry, which are based on non-specific assembly-line production, have impoverished the fabrication of architecture. At the same time, a deliberate ignorance of construction technology on the part of architects has eroded the conceptual basis of design. By informing architectural concepts with the means and methods of making, architects can advance the art and science of design and construction."[VI]

Of particular interest to the field of prefabrication is the diminished conceptual and crafted basis of design, which has similarly been eroded by technical and specialised technological developments. SHoP Architects are clearly at the forefront of the industry and architectural discipline shift on collaborative and technological innovation; their experience presented in both design and construction realms, presents their signifying quality and recognition of authorship and craft. This quote highlights the importance of responsive and adaptable environments in production facilities, specifically timber prefabrication facilities. The technical pragmatics of architecture will remain the founding principles that allow creative and spatial mechanisms to be realised; furthermore each can productively cooperate in ways where innovations can fluidly advance one another.

Another example of alternative and collaborative approaches to the production of architecture is through Jean Prouvé [1901-1984]. One of the major achievements of Prouvé's career was his effort in translating the mass-production principles found in manufacturing industries to that of architecture. These industry principles were initiated in 1908 by Henry Ford with his reconceived approach to the production of the automobile.[VII]

Prouvé had the privilege of a diverse engineering and architectural background where he learned to combine structural and furniture design with architectural design. This helped him to pursue qualities of craft in his work, while questioning typical approaches to how architecture was actually produced. The role of the architect, for Prouvé, was a dual role of Architect-Constructor, the architect possessing creative instinct while the constructor obtained the technical competence allowing the conception of the works to be realised.

"...[T]he 'genius' of the architect lies essentially in transcending, in the cultural, technical and practical spheres..."[VIII]

Here Prouvé promotes the importance of working collectively and the shared authorship of skills across the industry. The specialisation of skills is inevitable in a developing technological world; however the risk associated with divisions of labour is the trend for the appearance of the specialist who "... knows everything about almost nothing." [IX] Prouvé viewed architecture through the lens of industry where he made comparisons between automotive and aeronautical fabrication with that of the complete customisation of buildings. Prouvé practiced using fabricating and mass-production methods in architectural production. The design process Prouvé followed was experimental and held significant importance for the role of the prototype. His comprehensive constructional thinking of the process of assembling the work allowed Prouvé to focus his effort on the fabrication and industrial make-up of the architectural elements, testing and refining the 'design' to a point of resolution.

In terms of translating the thinking and approach Prouvé practiced to current industry thinking, this thesis proposes a facility that develops the education of architectural students and multi-disciplinary practitioners alongside the production of prefabricated architecture. Through this binary of production with education, opportunities exist for the progression and advancement of timber prefabrication.

It is through analysis of the historical industry context and thinking on craft and authorship that opportunities for alternative approaches to contemporary prefabricated architecture exist through the incorporation of these terms. This thesis argues that the design of a multi-disciplinary prefabrication production facility will allow qualities of craft and authorship to be augmented with timber prefabrication through specialists' enhanced ability to collaborate in a cohesive manner. It is essential in the current industry situation for the architect to productively engage with the latest technologies in order to maintain an articulated and informed position that integrates complex specialists in the field of timber prefabrication. If design fails to maintain a presence through integrated developments and production processes, the result runs the risk of economic and environmental losses.

Through design research this thesis intends to develop prefabrication facilities that inspire an increased level of responsive adaptability, allowing prefabrication to develop with design and technological advances.

Within the defined context that deals primarily with timber housing units, it is essential for a balanced focus on creative and technical realms that engender qualities of craft and authorship in order for prefabrication to be productively adopted. This thesis proposes a production facility that also takes on the role of an educational design vehicle for both the architect and the architectural student to develop and engage the latest technologies of design and construction in the field of prefabrication, providing them with the foundation for entering the complexities of the current architectural design profession. It is intended that users will witness the actual creation of a system of architecture, in a setting explicitly designed to enable these conditions to transform and evolve in step with the latest industry developments. This results in a productive partnering between design and construction, production and education, architect and architectural student through the refined inclusion of craft and authorship in architectural design.

I Sennett, The Craftsman. p 66.

II Deamer and Bernstein, Building (in) the future. p 38.

III Ibid. p 67.

IV Bell and Southcombe, Kiwi prefab. p 22.

V Sennett, The Craftsman. p 80.

VI Speaks, Shop Architects: Out of Practice. p 279.

VII Harvey, The condition of postmodernity. p 125.

VIII Jean Prouve: The Poetics of the Technical Object. p 206.

IX Ibid. p 210.

2 THE FUTURE POTENTIALS, PROGRAMME + CASE STUDIES

The following chapter examines selected case studies as a means of determining a dual production and educational programme, including productive and innovative areas where the programmes can crossover. Through understanding the historic techniques on timber prefabrication in New Zealand and critically analysing their effectiveness, this allows an informed, adaptive design response that actively engages the prefabrication problem.

This chapter examines the current situation of timber prefabrication in the New Zealand building industry while introducing the design experiment programme. Through close examination of both production and educational case studies, design opportunities are evidenced that engage with emerging architectural production alternatives of timber prefabrication.

Due to the dynamic and dual nature of the production and education programmes there are three different types of case studies to be examined. Pre-fabricating and factory based case studies have been selected to evidence the technical pragmatics inherent in large-scale production buildings. Secondly, a similar mixed typology case study has been examined with respect to methods of integrating diverse programmatic environments in a generative manner. Finally, modular and multiple scale case studies have been chosen to distinguish different scales of operations transferrable between production processes and learning experiences.

Case studies appear in the below order, beginning with a building footprint analysis followed by more detailed examination within the three case study categories; Pre-fabricating and Factory Projects, Mixed Typology/Programme, Modular and Multiple Scale Production.

- Victoria University of Wellington's Faculty of Architecture and Design
- University of Tasmania / LARC Vocational Training Centre in Tasmania
- Frankton Junction Railway House Factory
- Stanley Modular
- C.A.S.T.
- Prouvé's Evian Water Pump Room
- Prouvé's Meudon Houses

This chapter researches case studies to determine the most effective programme alongside case studies to inform the design vehicle with the objective to integrate an increased and responsive level of adaptability in prefabrication production facility 'sheds'.

The thesis challenges the appropriateness of the existing conventional 'shed' typology for prefabrication facilities. The thesis argues that the conventional 'shed' can be further advanced to act as an educational facility for a diverse range of users, while also becoming an architectural exemplar that enables alternative approaches on prefabrication production techniques to manifest. The case studies were selected to provide greater understanding of the historic production and spatial arrangement techniques typically employed in prefabrication facilities. Through critical analysis of their effectiveness, a more informed design response that engages contemporary industry prefabrication is developed that progresses beyond the typical open plan nature of the prefabrication production 'shed'.

2.1 Programme

Historically, prefabrication of buildings has not been synonymous with qualities of individuality (authorship), detailing (craft), and habitability (integrated technical functions, sustainability etc.). Achieving suitable outcomes for these parameters is a key challenge of this research investigation. This thesis argues that architectural design of a facility within which prefabrication production occurs, can play a significant role in encouraging these parameters to be implicated. To encourage conventional prefabrication production approaches to be enhanced, the thesis investigates reinterpreting the standard open-plan production environment and the structure around how diverse disciplines work together in a common environment. The thesis argues for an alternative industry approach to the design of a responsive and spatially adaptable production and educational facility, specialising in prefabricated timber housing units. This design research provides a framework to facilitate alternative timber prefabrication production approaches.

The integration of typically opposed functions of a production workshop alongside an educational programme goes beyond the examined case studies and forms the basis of the diverse programmatic response. This allows for a programme that challenges and engages with alternative production systems of architecture, while establishing a responsive and adaptable production environment that facilitates the ability of architects to implicate craft and authorship in the production of prefabricated housing units.

Building footprint analysis on existing case studies include comparisons between; Victoria University of Wellington/ Faculty of Architecture and Design, University of Tasmania/ LARC Vocational Training Centre in Tasmania, University of Manitoba's Centre for Architectural Structures and Technology (CAST) and the first southern hemisphere facility of its kind the Frankton Junction Railway House Factory in Hamilton. This comparative analysis presents a large range of facility scales, critical to setting the scope and scale of programme for the Trade Build Facility design.

Initial programme volume estimates for the Trade Build Facility totalled an approximate gross floor area of 2700m2. Multiplied by a modest utilitarian design factor of 1.4 the anticipated net floor area is approximately 3800m2.

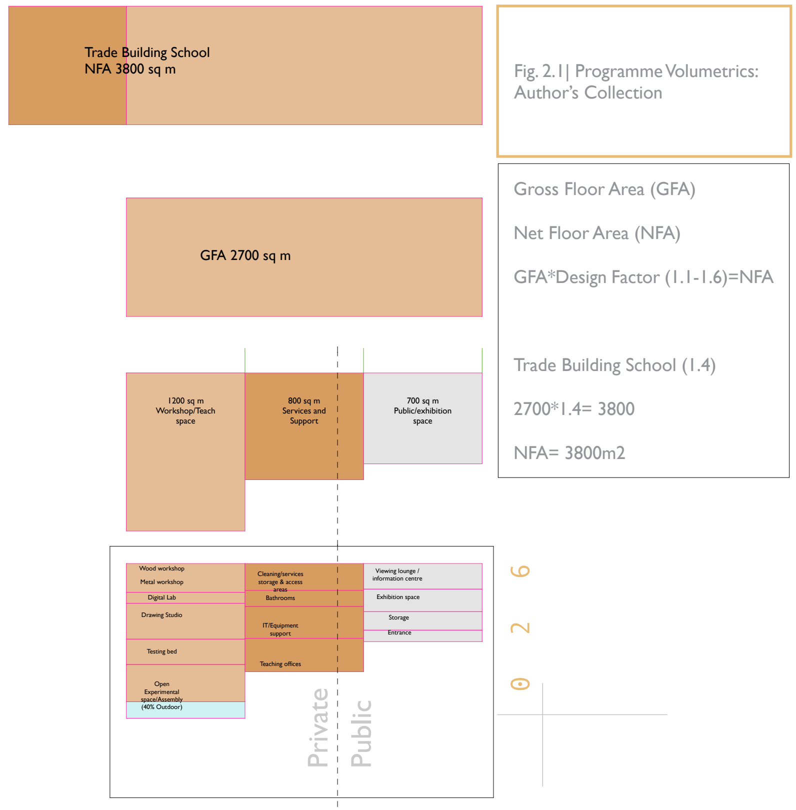


Fig. 2.1| Programme Volumetrics: Author's Collection

Fig. 2.2| Schedule of Spaces: Author's Collection

	Schedule of spaces:				m2			
#Sequence	**Trade Building School**				**Production**	**Exhibition/ Teach**	**Support**	**External**
INPUT	Log transport from yards				5			
2	Entrance/Foyer					120		50
3	Bathrooms						75	
4	Storage/access areas						200	
5	Timber milling				150		100	
6	Exhibition space: details/ presentations					400		
7	Teaching/Admin offices						200	
8	Air-drying of timber				75			75
9	Meeting Rooms/Conference					100	50	
10	Experimental making				50	200		
11	Plant Machinery (WOOD)				300		75	
12	Plant Machinery (METAL)				150		75	
13	IT/Equipment Support						100	
14	Studio space				100	280		
15	Kitchenette/common areas						150	50
16	Gantry hoist				15		50	
17	Observation deck					150		
18	Production Line				400		20	
19	Testing bed				75		80	
OUTPUT	Product: Staging area							300
								475
	Net Floor Area: 3800m2				**1266**	**1266**	**1266**	

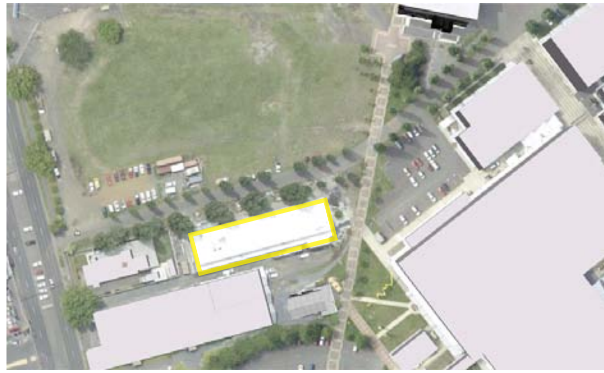
With this volumetric programme analysis the schedule of spaces include a diverse range of requirements; beginning with a boutique scale sawmill, then the main 'workshop' volume intends to be separated into three sections (material processing, experimental workshop, and assembly workshop), an integrated 'studio' space and the associated support/ancillary space.

Fig. 2.3| Programme Scale Analysis, Victoria University of Wellington-SOAD, University of Tasmania-LARC, University of Manitoba-CAST, Frankton Junction Railway House Factory: Author adapted from, Google Earth.

VUW SOAD

10,725 SQ M

3 FLOORS



UTAS Trade-school

270 SQ M

2 FLOORS

U. of Manitoba-Architectural + Technology Centre

510 SQ M

1.5 FLOORS

1920 Frankton Junction Railway Houses Factory

2,300 SQ M

1 FLOOR

2.2 Prefabricating and Factory Projects

The term pre-fabrication and the often perceived negative connotations this method of production attracts are significant to the analysis; focussing on historic precedent and primarily the operations and processes active within a factory environment the design intends to reinterpret the perceived view on prefabrication.

Frankton Junction Railway House Factory

New Zealand's North Island main trunk railway line was completed in 1908 and at the time it was the principal mode of domestic transport and communication. Maintenance and operation of the railway required a large staff that worked from railway depots along the line; however the influx of returning servicemen following World War I saw a great housing shortage for these workers. In 1922 the Railway Department required an estimated 1200 additional houses, alongside similar housing shortages experienced in townships and cities. This meant significant pressure was on private builders and carpenters, and the department realised there needed to be an alternative approach to meeting this need.

At this point the Railway Department utilised its internal resources of architects and access to indigenous forests and built a sawmill and house factory at Frankton Junction in Hamilton. It is here that a limited number of standard timber house designs were mass-produced at a cost of £635 per unit. Details surrounding the breakdown of modular units and how the houses were transported by rail are limited; however the simplicity in design and regimented planning provided a simple approach of pre-fabrication to achieve the desired outcome. This standard planning in combination with a kitset of pre-cut and numbered timber components allowed for easy assembly. The mass production of houses, producing components for one unit in a day and a half, in combination with skilled labour assembling the components on site led to a savings of 33% in labour and considerable time. [1]

The styles of housing units had different combinations of rooms and were identifiable by a small plaque on the top right corner of the street facing wall; this would be marked with the design style code, AB/296, AB/326, AB/1123 etc. Pictured below is a modest AB/296 unit with roof type A. It is clear how the design is driven primarily from the assembly and constructional point of view with structural symmetry and minimal large openings. Pile foundations support the house above ground level and therefore require an entranceway that mediates the level change. This would allow easy staging of work and essentially modules could be lifted directly onto the pile foundations ready for final assembly of the units.

Fig. 2.4| Frankton Railway House AB/296 with roof type A: Source, "The Railway House in New Zealand: a Study of 1920s Prefabricated Houses."

The housing factory that produced these prefabricated housing units was relatively modest given the intensive scope of processes that were integrated ranging from the timber-processing sawmill to the completion of units being transported by rail. Consisting of a large single-storey building of linear directionality, the building was approximately $2,300m^2$. The structure employed a typical industrial sawtooth roof design that repeated itself the length of the factory. This purpose-built industrial building provided large open plan space within the factory with extensive lighting from the south. The basic repetitive roof structure also meant the facility was easily extended as was done in 1924; [II] however information on the internal layout and the adaptability in response to production processes is limited. It appears an original building formed the start of the factory and the sawtooth sections were additions at each end.

Eventually the housing factory became the seed of its own demise when the 1600 housing units were produced and the level of output exceeded the demand, which led to the shutdown of the factory in 1930.[III] The Frankton housing factory is the only known case in New Zealand where prefabrication of housing units was a fully integrated operation with the existing railway company. Because of this efficiency and ability to satisfy the housing demands, the effectiveness is pronounced in comparison to earlier examples.

It is the complete production and delivery process of the Frankton house factory that is significant as it differentiates the manufacturing production from other standardised pre-fabrication production alternatives. The thesis investigation's proposed design of a large span prefabrication facility similarly argues for the importance of a full continuum of production from material processing across experimental alternatives and the primary assembly line. Secondly the full circle approach and integration of transportation channels adds a feasible and economic component critical to the marketing and public perception towards off-site timber prefabrication.

Fig. 2.5| 1920 Frankton Junction House Factory, Hamilton New Zealand, External photo: Source, "The Railway House in New Zealand: a Study of 1920s Prefabricated Houses."

Fig. 2.6| Stanley Modular Factory webcam series: Source, www.stanleygroup.co.nz/modular/liveview.php

Stanley Modular

Stanley Modular is a modern version of prefabrication employing a multiple scale, residential and commercial prefabrication model. It is a specialised division of the Stanley Group construction company which was established in Matamata in 2004 utilising the plant and factory originally of Carters Modular. This company provides productive contemporary insight into how factory layouts can determine and/or alter the constructed output.

The factory employs an open plan fluid layout that can be adapted with assembly tables and 'beds' depending on the manufacturing process required of the project specifics in relation to scale, typology and time or material constraints. As outlined by Stanley's Development Manager, Gary Caulfield, their basic workflow and management of construction follows these consecutive stages: [IV]

1. Plan the materials required for manufacturing;
2. Plan the construction process and the order of key stages;
3. Once the requirements for the construction process are understood planning is shifted to the factory layout, adapting this to suit the required processes of output/design;
4. Installation of specific "beds" or assembly tables suited to the process;
5. Usually a simple linear production process is suitable to most projects.

The key distinguishing factor for Stanley Modular is their production principle to focus on process over product; this promotes the importance of construction and the pragmatic requirements of production. The principle reason for process-based production is that there is simply not enough demand to keep the factory going if the process is converted into one of product as opposed to one of process.[V] Due to the limited demand of prefabricated architecture there is also limited scope for product differentiation, hence a tailored and adaptable production process is Stanley Modular's solution to the current industry situation.

It is envisaged the Trade Build Facility will similarly employ a process-based production process and will therefore adapt depending on the type of demand. Further to Stanley Modular, the Trade Build Facility and the integrated educational programme leads to active experimentation and development in production to occur, which may allow this production principle to shift to a product-based approach. The responsive nature of the Stanley Modular facility layout is a major strength that the thesis will incorporate into its design investigation, as the proposed design of a large-scale prefabrication facility demands architectural techniques that facilitate a responsive and adaptable production environment.

This constructional focus on the requirements of the production process is significant and reinforces the need for a productive partnership between designer and constructor, something that Stanley Modular fails to evidence. The thesis argues that the approach to design needs to become more integrated with production processes in order to facilitate further opportunities for the prefabrication of well-designed architecture. Important to both Stanley Modular and the design research of the thesis's prefabrication production facility is the ability for adaptive use and non-restrictive process outcomes to exist and mass customization to be further promoted. This primarily demands open floor space that is adaptable according to the Trade Build Facility's integrated design experimentation with production processes.

The design and planning for the thesis's prefabrication production facility poses architectural challenges where the building needs to accommodate adaptive programmatic responses while also productively engaging the architecture with the production processes within. It is this productive partnering between the architecture and the production processes facilitating a responsive and equal collaboration between diverse industry disciplines of the production environment, that allows the facility to move beyond the architectural typology of the Stanley Modular 'shed' while also actively engaging the current industry problem of production alternatives to architecture.

2.3 Mixed Typology / Programme

The Centre for Architectural Structures and Technology in Manitoba, Canada has been selected as a successful case study representing a mixed typology project that also combines a mixed programme of fabrication and education. It has been selected as a means of critically examining typical approaches of cross-accommodation with dual or multiple programmatic functions.

The Centre for Architectural Structures and Technology (C.A.S.T.)

The University of Manitoba is privileged to run a facility where students are given the opportunity to understand and experience the fundamental principles of making architecture. Technical and structural alternatives are explored and challenged at a 1:1 scale in an educational environment, combining a research unit and a teaching lab into one. This facility represents a successful case study that encourages building industry roles to be collapsed, allowing active collaboration to form new ways of thinking about the production of architecture. However the weakness of the C.A.S.T facility is that it fails to include a realistic component of industry viability and economic exposure within its institutional insulation. Its priority is education rather than production. The thesis argues that a prefabrication facility should equally partner education within an economic and productive model of production, a critical component required to present the industry with viable innovative, cross-disciplinary inspired options for timber prefabrication.

Founding Director Mark West promotes the C.A.S.T facility for students to explore structural properties of materials, while finding their own personal capacities for invention. West says, the physical act of making and breaking allows the essential playfulness required for creative innovation and new approaches to designing and making architecture to manifest.[VI] It is West's model that collapses the typical academic structure and presents 'design by making' principles, which the thesis's prefabrication production facility will be based on. The literal blend of raw industrial space integrated with an educational programme that the C.A.S.T. facility has achieved is considered a productive partnering between production and education programmes and the Trade Build Facility should similarly emulate this relationship.

The C.A.S.T. facility is a rather small space at just over 500m2 yet it provides an adaptable space for production where the workshop and production line accommodate one production space able to be reconfigured based on the production design focus. The typical institutional learning environment of clinical, transient and solitary rooms where the modern students are literally connected with their laptop or computer is reversed in the situation of C.A.S.T. The walls of the workshop are painted black and allow drawing in white chalk to take place amongst the raw machining and constructing environment, reinforcing the connection between learning and making. Comprised of predominantly open space and a raised loft area there are a range of precincts that are defined by specialist fabricating and equipment zones within the building, these allow for differing kinds of manufacturing work and teaching/learning to occur.

The industrial nature of the building houses and masks the machinery and materials in a raw state prior to the manufacturing and experimental constructing of designs, while the building exposes the completed units to the public environment the building is sited within. This technique provokes public involvement through controlled and obscure views of the interior production activity and draws the public attention to the exterior raised 'display shelf' of the completed outputs. This public engagement, through the viewing of the facility's activities and output, shifts the building from a primarily functional shed into an architectural exemplar representative of the production processes of architecture. The limitation of the C.A.S.T facility is the restrictive nature of the building being

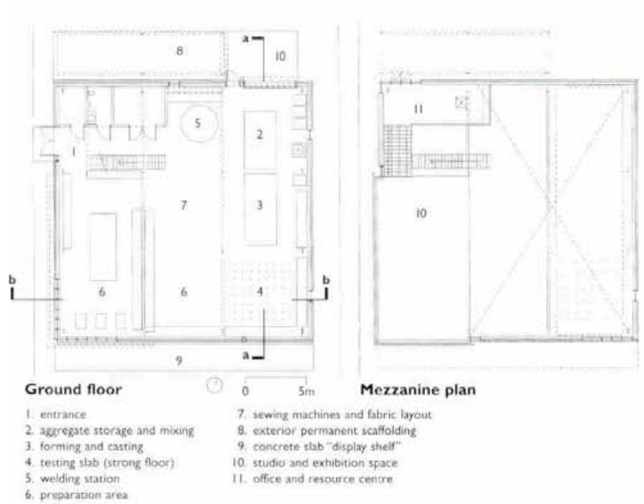
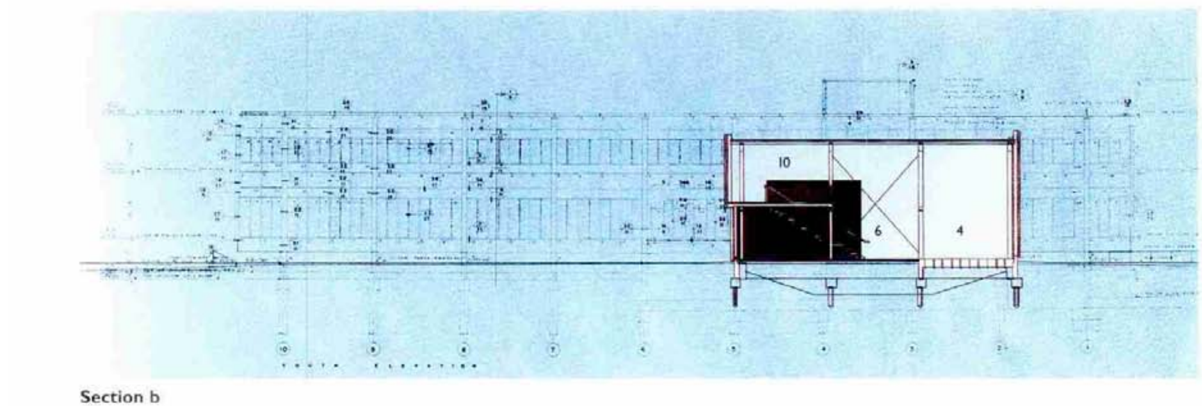


Fig. 2.7| The Centre for Architectural Structures and Technology, plans and sections: Source, "Thinking with Matter." West.



primarily for students where collaboration and multi-discipline involvements are less transferrable between the teachers and the students as the two main inhabitants.

It is the highly specialised collaborative nature of the industry environment today that represents a unique set of conditions characterising the 21st century; as such it is a fundamental research imperative for this thesis investigation on how the production of architecture should equally integrate both design and construction within a multidisciplinary production environment. The Trade Build Facility sees the opportunity to develop alongside this current industry environment, where the principal mandate of the design is an active production facility which will involve a diverse range of industry specialists alongside students in a collaborative design and construction prefabrication facility.

The non-standard approach to the spatial organisation of the C.A.S.T. facility, allowing the education programme and production-based industrial workshop to intertwine, is signatory to the architectural success. The Trade Build Facility intends to further advance this model through integration of a common architectural element that actively engages both production and education components while becoming a foundational component to the operation of the two. The thesis's prefabrication production facility will establish an integrated architectural language with the research and education processes, and the design and construction processes, as productive co-participants in the operation of the facility. It is this architectural partnering of the systems of operations within the production facility that the C.A.S.T. exemplar provides little opportunity for, which this thesis argues will provide a more adaptive and collaborative environment to manifest in the prefabricated architecture.

2.4 Modular and Multiple Scale Production

Many architects ranging from Prouvé to Herzog & de Meuron challenge architectural production methods and specifically prefabrication. With the current industry trend towards collaborative approaches it is particularly relevant to examine historic and contemporary manufacturing approaches to the production of architecture.

Jean Prouvé boasted a vast range of experience across architectural design, industrial design, structural design and furniture design revealing his diverse understanding of scale and physics evident through his work. With Prouvé's depth of practical hands-on knowledge and industry exposure he was determined to transfer industrial manufacturing technologies to architecture.

Two case studies of his architectural work have been selected each revealing multiple-scale approaches and the influence scaled components of physics and design can have on the end outcome. The Evian Pump Room provides insights into design beginning from the joint, enhancing the ability to perceive manufacturing form from multiple perspectives/ scales is important in alternative approaches to production. The Meudon House examined is based primarily on extreme efficiency and the simplicity of the structural system developed, a historic exemplar that challenges contemporary prefabricated architecture with sheer simplicity. Both projects have industrial production techniques as foundational bases that present efficiencies unprecedented in typical constructional approaches during their time.

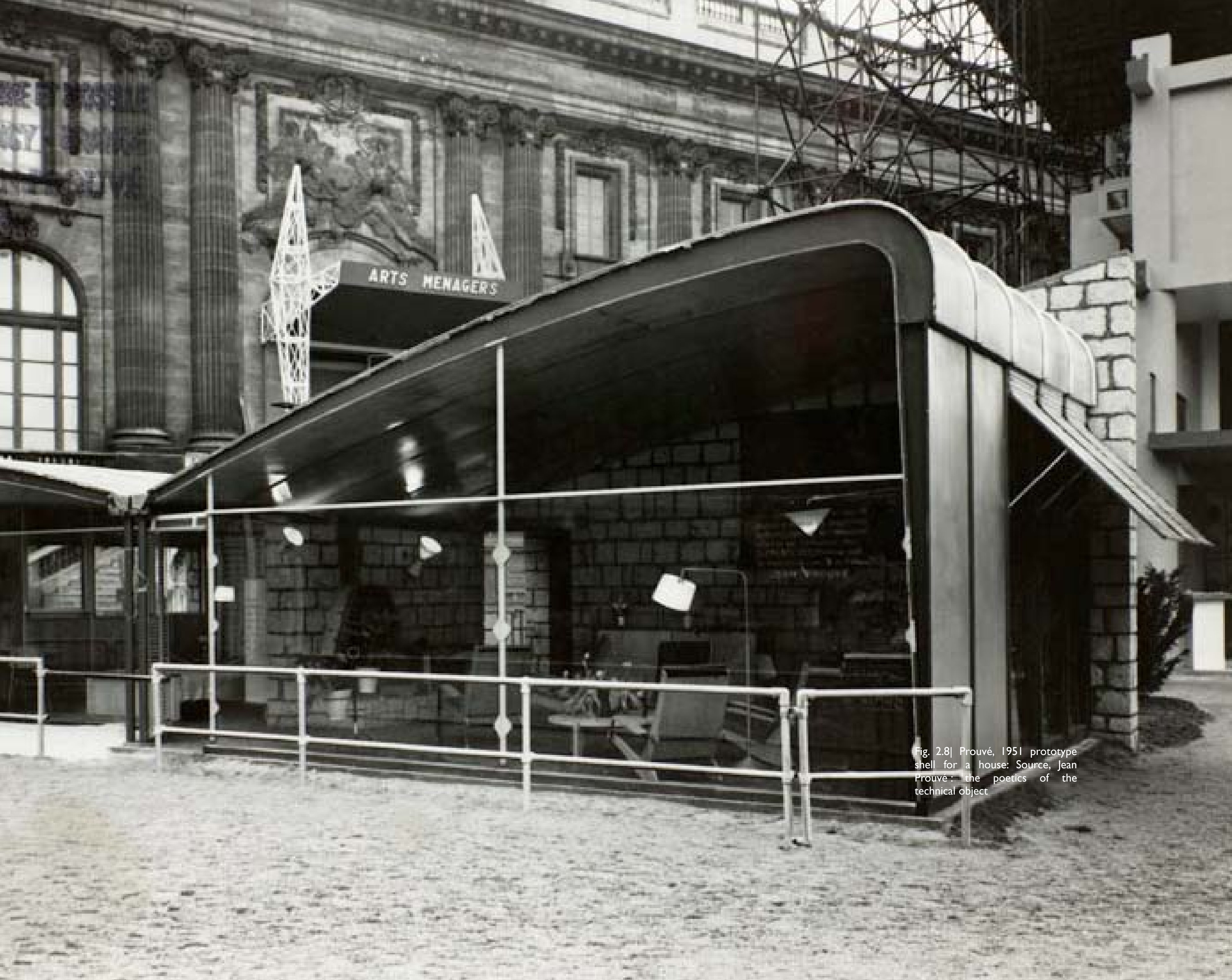


Fig. 2.8| Prouvé, 1951 prototype shell for a house: Source, Jean Prouvé : the poetics of the technical object

Fig. 2.9| Prouvé, Evian Water Pump Room view 1: Source, Jean Prouvé : the poetics of the technical object

Fig. 2.10| Prouvé, Evian Water Pump Room view 2: Source, Jean Prouvé : the poetics of the technical object

Evian Water Pump Room

Designed in 1956-57 the Evian Water Pump Room employs a transferrable structural language and style to some of Prouvé's table designs. The asymmetrical crutch forms the primary structural system supporting the responding roof plane; together these two components set a clear architectural tectonic which is in conflict with typical responses to vertical gravity loads. The forces acting on the structure seem in tension with the form which provides a dynamic relation between reading the outcome as an 'object', as opposed to a collection of components connected with the ground typical of architecture. This was a conscious decision where Prouvé made parallels to that of automobiles and aircrafts as objects that disregard typical gravitational forces, alternatively responding to the external forces of movement. Read alongside furniture projects, i.e. individual objects, it is more conceivable to understand this alternative approach to external forces, allowing the design to achieve a dynamic equilibrium between both diverse and collaborative disciplines and programmatic operations. Architecture that traverses this objective barrier achieves an experiential quality that is reflective of a construction-based and crafted approach that is accessible to the user.

The constructional mechanics of the design remain simple where alternative approaches to structural members and materials allow a somewhat complex product to be realised. The crutch that is the main vertical component doubles as a bracing element while also signifying the main form of the building. Secondary to the vertical crutch of the building the need to enclose the building envelope is achieved with a typical curtain wall system, which interestingly promotes the impact of the building form. It is such techniques, of dynamic but modulated approaches to objects, which begin to identify parallels with manufacturing industries.

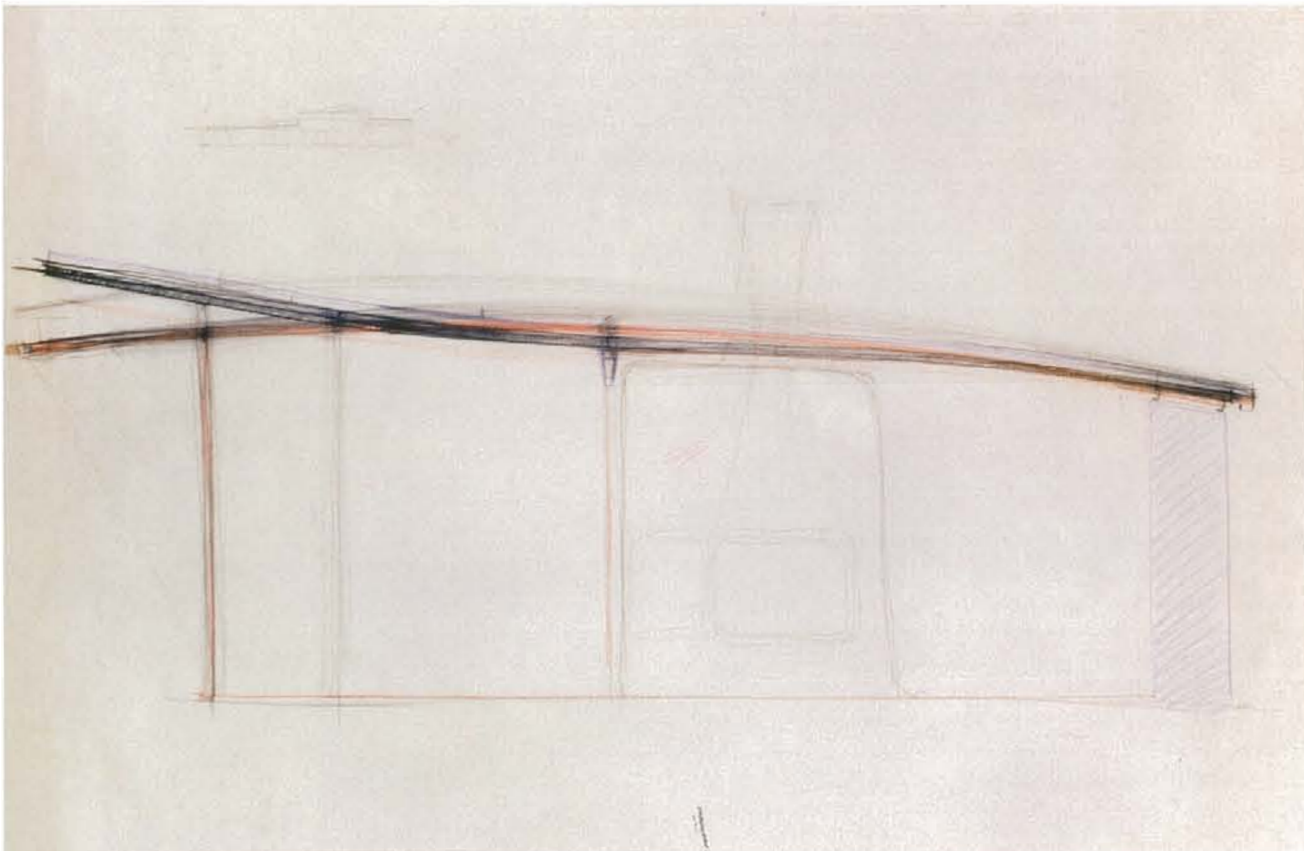


Fig. 2.11| Prouvé, Evian Water Pump Room architect drawing: Source, Jean Prouvé : the poetics of the technical object

This scaled and simplistic understanding of the physics and forces acting on the structure presented by Prouvé are transferrable to any type of structure. This thesis aims to present that design from this starting point of the joint, has the ability to implicate unique design opportunities alongside similar efficiencies at both prefabrication facility and prefabricated housing scales.




Fig. 2.12| Prouvé, Replication of the historic Meudon House including assembly stages: Source, Prouve_shed_transformation_ENG.pdf , http://www.tb-cms.org/data/article_downloads/171/Prouve_shed_transformation_ENG.pdf

Meudon Houses

Developed between 1944 through 1947, Prouvé designed a series of 14 experimental emergency houses at the request of the French Urban Development Minister. The primary aim was to allow easy transport and assembly in order to accommodate refugees from the Second World War. Prouvé welcomed the challenge and it provided the main opportunity for full integration of manufacturing principles with architecture. "I am ready to fabricate machine-made houses assembly-line style, as Citroën did as early as 1919 for the automobile industry… With metal, one can build quickly and solidly."[VII]

Continuing his interest in steel as a primary building material Prouvé developed a simple structural system that used basic steel trusses that spanned from a central 'tuning fork' support. This supported the simple low pitch roof that employed the same structure as the floor. A series of nine different spandrel panels were available for the exterior cladding, each providing different levels of transparency dependant on client preference. Construction of the units was with a factory assembly-line production creating the components to be delivered to site. In total the process from production through to assembly took three days, while retaining the ability to evidence a high degree of design individuality and control. This project presents an efficient production process that represents an adaptable prefabricated outcome able to apply mass-customisation principles, additionally able to be applied to multiple scaled outcomes depending on the demand.

2.5 Augmented Programme

The selected case studies presented have used multiple programmes specifically related to production, while also contributed to specific design opportunities. The proposed thesis design research experiment of a prefabrication production facility will incorporate a production workshop drawing from the positive attributes of Stanley Modular and the Frankton Junction Railway House Factory, following a production process that is inclusive of material processing through to assembly stage. The educational component of the design research experiment will draw from C.A.S.T. where the high level of integration with manufacturing allows crossovers to inform and alter approaches to the production of architecture. The thesis design research experiment will challenge the typical typology of prefabrication 'sheds' by incorporating responsive and adaptable spatial arrangement with the collaborative environment conducive of an architect's ability to productively design and deliver architectural exemplars of prefabricated timber housing. The proposed Trade Build Facility experiment shifts beyond the examined case studies establishing a specific prefabrication typology for the facility and the potential production output, along with an integrated educational programme in the current industry context for prefabricated architecture.

The Trade Build Facility proposes an educational curriculum that integrates systems of production founded in principles expressed in the C.A.S.T. case study. This allows an integrated and collaborative production and education system to be evidenced within the extensive binary of design and construction processes experienced in the current prefabricated architecture industry.

This analysis of case studies in the field of prefabrication has focused on three points of view: firstly of existing prefabrication production 'sheds', secondly mixed typology projects, and finally modular and multiple scaled production approaches, each facilitating varied views on the requirements of a prefabrication production 'shed'. The selected case studies cumulatively provide a departure point for a strategic and innovative approach to the design of a prefabrication 'shed' that goes beyond providing only an open-plan environment. The design experiment will need to engage a responsive spatial adaptability that integrates the multiplicities of design, construction, education, production and public engagement within the timber prefabrication context. These multiple components provide a productive situation for prefabricated architectural design to develop on existing production approaches, including utilisation of multiple efficiencies compared with typical industry approaches.

The architectural problem of generic production spaces that limit the innovation and quality of prefabricated architecture has been critically examined in the above case studies, providing insight into approaches for adapting this large-scale 'shed' typology to engage a multiple and diverse range of spatial, programmatic and production demands. The most effective Trade Build Facility design will incorporate production and delivery systems following the Frankton Junction Railway House Factory model as a successful case study evidencing how this can be achieved. Frankton Junction House Factory also developed an early version of mass customisation, which is important to this investigation; this case study also provides guidance on area requirements for a timber prefabrication housing facility.

This thesis also argues that the most effective design solution needs to be able to address multiple scales of prefabrication, Stanley Modular is an exemplary and successful case study across multiple scales. Stanley Modular also evidences how factory layouts can determine and/or alter the constructed output using an open-plan and fluid layout that adapts and changes according to the production demand.

The most successful and productive Trade Build Facility design should incorporate production with an active educational component; the presented C.A.S.T. facility is a successful case study that includes means of learning, drawing, etc. within an active production environment. This thesis argues that this is important to encourage active collaboration to form new ways of thinking about prefabricated architecture. Through examining the C.A.S.T. case study it reveals that the collaboration is limited by being mainly for students; contrary to the Trade Build Facility which will be primarily for production, it will be filled with various engineers and industry specialists, which will invite even more collaboration than C.A.S.T. This case study also provides area requirements for the educational component of the prefabrication facility.

It is with these developments that the thesis challenges and moves beyond the examined case studies, establishing the merged dual programme and design of a Trade Build Facility in response to the current situation of the housing and prefabrication industry in New Zealand.

I L. Kellaway, "The Railway House in New Zealand: a Study of 1920s Prefabricated Houses" (MArch Thesis, University of Auckland, 1993). p 46.

II Ibid. p 62.

III Ibid. p 23.

IV Gary Caulfield, "Stanley Modular: Development Manager" Email, November 20, 2012.

V Ibid.

VI Mark West, "Thinking with Matter" p 55.

VII Museum of Modern Art (New York, N.Y.), Home Delivery: Fabricating the Modern Dwelling (New York: Museum of Modern Art, 2008). p 145.

PART 2

DESIGN AND THE CONTRIBUTORS

3 SITE SELECTION

The CentrePort logging yards and the vacant site on the south intersection of the Wellington Tranz Metro freight railway lines and Waterloo Quay, Pipitea, Wellington, provide a large-scale site that incorporates on-site material resources, existing global and domestic delivery systems, and industrial processes transferrable to the production of architecture. The existing delivery systems of goods and materials arriving and departing from the port, provides a constant 'global' demand for prefabricated architectural components on an economic level. This site provides the thesis research experiment design of the Trade Build Facility the ability to utilise on-site materials efficiently while also integrate with sea, rail and road delivery systems for prefabricated home delivery.

This chapter introduces the site as a productive vehicle for design development in response to examined background research, theories, and case studies. Located in Wellington, the capital city of New Zealand, the site borders the city's port, CentrePort, alongside a proposed Business Park in the northern commercial and industrial precinct of the city. Directly adjacent to the CentrePort logging yards and south of the Wellington Tranz Metro freight railway lines and Waterloo Quay intersection, the vacant site (currently used for parking cars) presents the departure for the thesis research experiment design of the Trade Build Facility.

As presented in the previous chapter, selected case studies revealed specific production and education programmatic requirements along with unique implications of design, these projects also require specific site conditions. The below conditions have been highlighted in these case studies and are all implicated and further developed in the selected site:

- a site that invites both production and delivery advantages (Frankton Junction Railway House Factory);
- a site on the threshold between industrial and residential zones to facilitate public engagement and the addition of a successful educational component (C.A.S.T.);
- a site that enables a large open-plan footprint (with ease of vehicular access) to encourage multiple scales, fluid layouts and adaptability (Stanley Modular);
- a site at a junction of opposing grids, to offer the design opportunities for engaging multiple orientations and alignments.

The site is characterised by shipping containers being stored and loaded/unloaded for export and import purposes while it is also a major recipient for forestry logs primarily for export purposes. This natural timber resource is the beginning point of production processes where the Trade Build Facility transforms the raw logs into prefabricated architectural housing. The immediate surroundings to the site consist of mainly large-scale industrial sheds, including multiple transportation movements in and around the proposed building platform. Additionally, the site is at the distribution end of export markets and multiple sea, rail, and road transport modes providing a sustainable and efficient method for prefabricated component/home delivery options.

Wellington City Map 1842

Wellington City Map 1877

Wellington City Map 1880

Wellington City Map 1890

Wellington City Map 1891

Fig. 3.1| Historic plans, 'City of Wellington': Source, Plan of the City of Wellington and Surrounding Districts, Plans held with Wellington City Council (WCC).

3.1 Historic Wellington

The two main geographic edge components of Wellington's urban context consist of the steep restrictive topography that borders the city, opposed by a more defined edge with the harbour. The harbour can be thought of as the city's principle outlook. The harbour edge was altered by the 1855 earthquake uplift, along with multiple reclamations over history due to the limitation of suitable flat land for development. The effect of the 1855 earthquake was significant, the highest magnitude 8.2 ever recorded in New Zealand forced the Wellington shoreline originally below sea level, upward by approximately 3-4metres. This lift and tilt of land to the west of the fault spread to the southern end of the Rimutaka hills and to the southern coast of Wellington totalling approximately 50,000 square kilometres. [1]

"Blocks of the city's central business district now occupy land that was below sea level before 1855. The newly exposed strip of shoreline between Wellington and the Hutt Valley offered a safe road and railway route – parts of the coastal road had previously been impassable at high tide." [II]

The selected site is located where the edge of the original 1840 shoreline[III] joins the reclaimed land that forms CentrePort. A current day trace of the historic shoreline is Waterloo and Aotea Quay that wraps around the Westpac Stadium and heads north towards State Highway 1. It is through this historic wavering edge that the urban fabric reveals the joint between the junctions of lands, further reinforced by the vast scale of the stadium that now operates as a large turntable to the northern precinct beyond Wellington city. The subject site becomes a key component to this part of the built fabric, reinforcing and highlighting the contemporary 'trace' of lands while presenting the importance of the industrial contributors (port) to the city.

3.2 Urban fabric and influence

A notable site quality is the significance of the two bordering and very distinctly opposed urban conditions. Firstly dense urban residential wraps the intermediary topography bordering the natural green belt and the industrial transit zone of the railway station and the rail yards heading north. At this buffer point of transits incorporating shipping, rail and road linkages, the fabric shifts to the large-scale industrial grain of the Business Park and operational container and logging port. The port's composition of containers versus logs is directly market dependant; currently due to increasing demand in the building industry logs have a considerable return resulting in a high demand for logging storage.

These diverse bordering urban conditions converge on the selected site, and provide productive design opportunities. The design experiment aims to engage these two grid conditions with the dualities of production and educational processes within the building, aligning technical and creative components in an accordingly adaptable nature. It is this dynamic convergence of urban surroundings and transportation movements that offer opportunity for public engagement with the responsive and adaptable design of the Trade Build Facility.

3.3 Port Operations

At the immediate junction of the site, there are a series of urban grain shifts, firstly the coarse grain in response to the harbour and railway line to the north, followed by an acute shift towards the Westpac Stadium and finally perpendicular to Waterloo Quay. These grain shifts and opposing grids converge at the junction of the selected site, and therefore the design will be afforded opportunities for engaging with these multiple grid orientations. This thesis argues that this might be useful in furthering opportunities for fluid layouts and adaptability in the production facility.

Existing port infrastructure and car parking exists on the southern side of the warehouse adjacent to the Trade Build Facility. This is accessed off Hinemoa Street and is incorporated with the proposed Business Park plans. The principle access to the site is from the Business Park and 'public' area of the port, while there is provision for pedestrian access directly from Waterloo Quay onto the northwestern corner of the site. Similarly, the transportation and storage of the extensive log resource would be available to the design experiment as the primary material for production purposes.

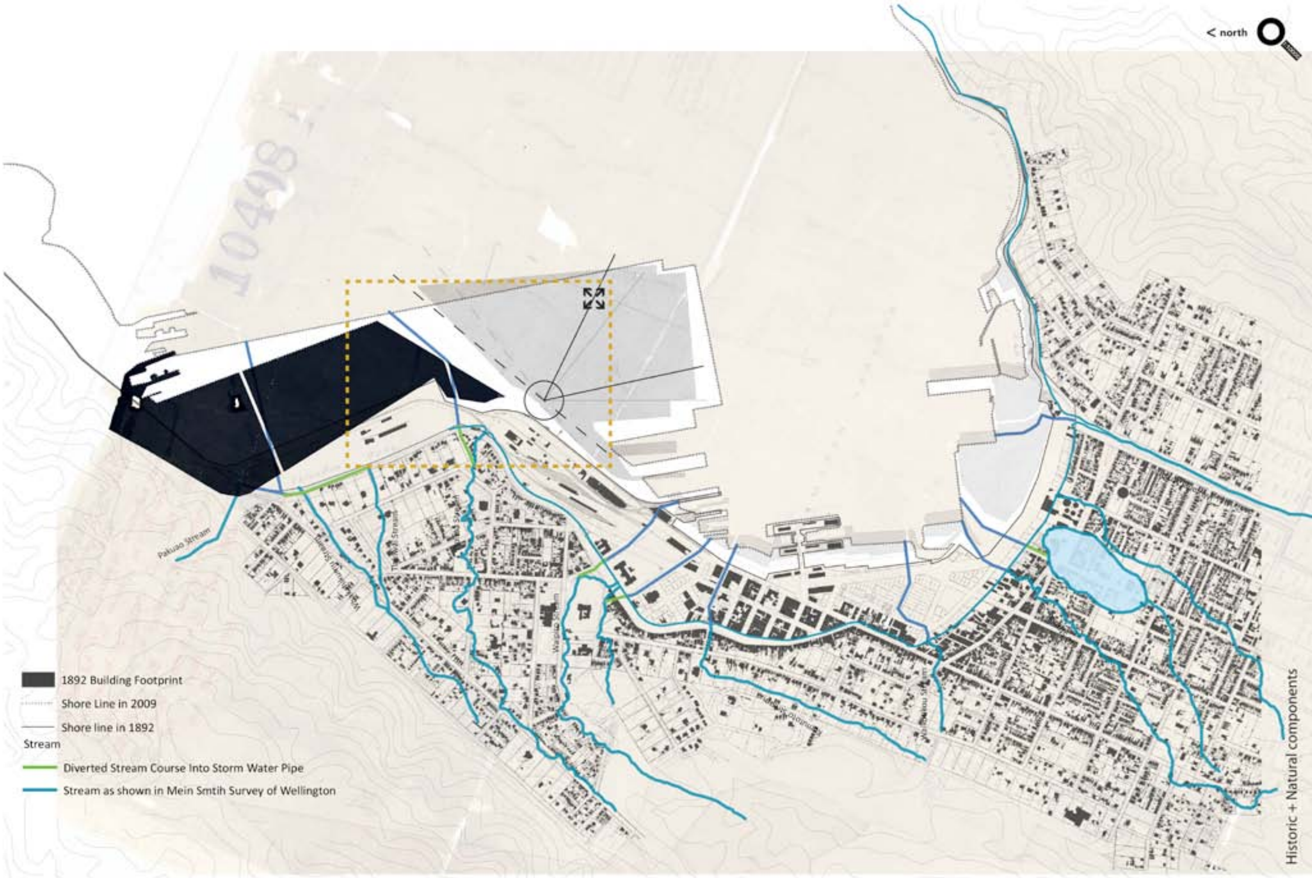
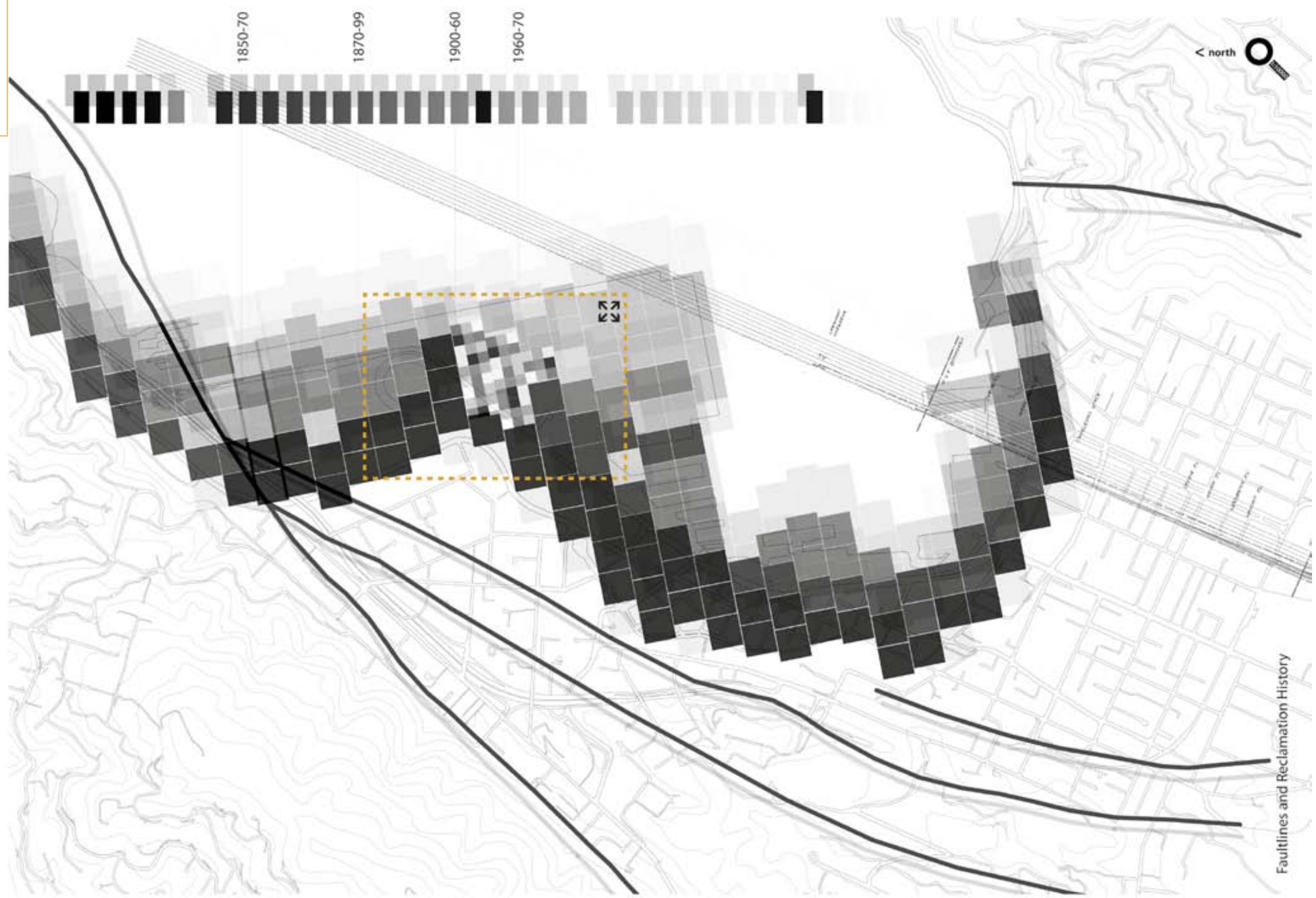


Fig. 3.2| Historic and Natural Site mappings: Author adapted from; 1892 City plans-Plan of the City of Wellington and Surrounding Districts, Plan held with Wellington City Council.

Fig. 3.3| Faultline and Reclamation Site mappings: Author adapted from; 'Primary roading layer' WCC Morphology Study, Working Paper 5.



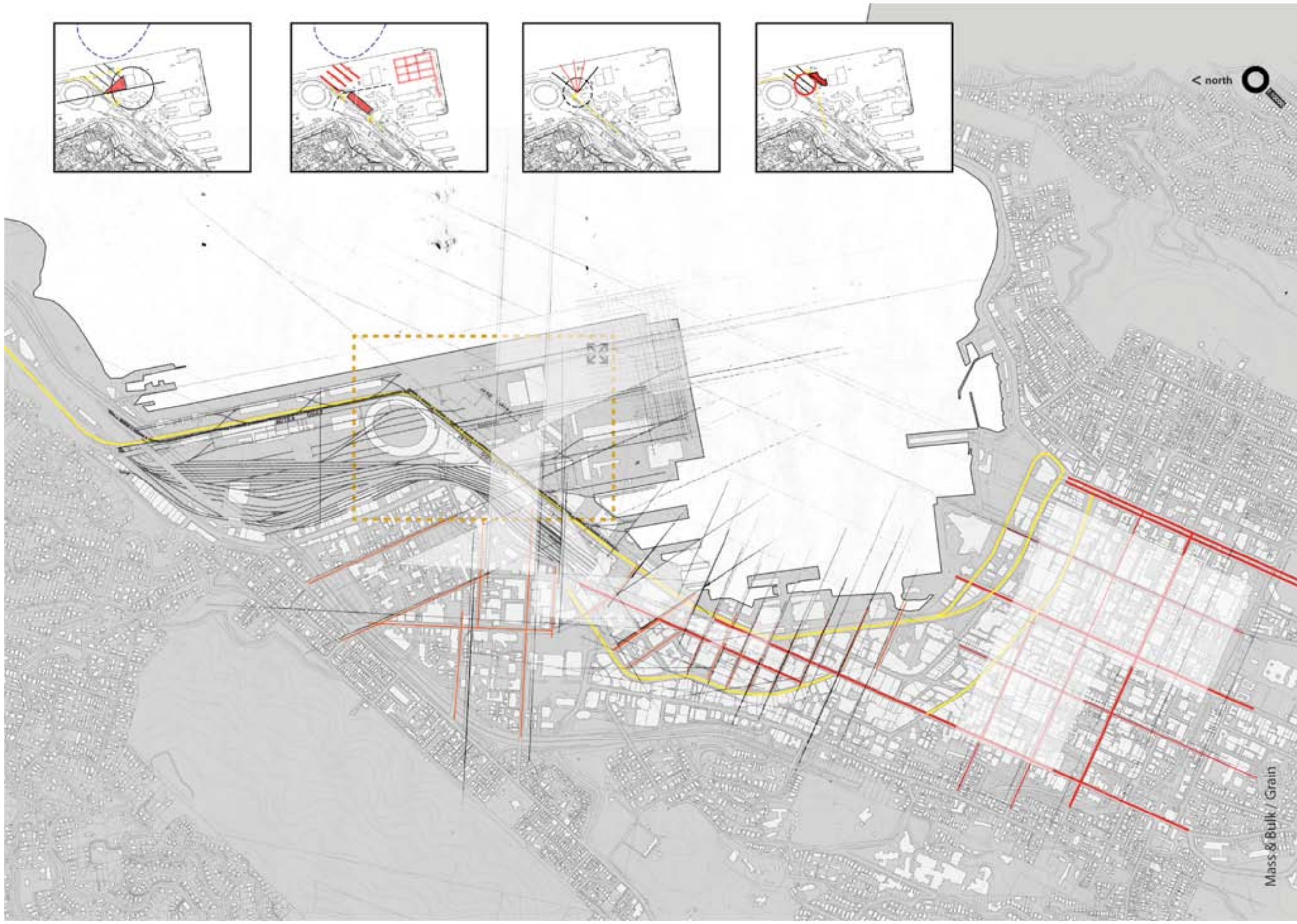
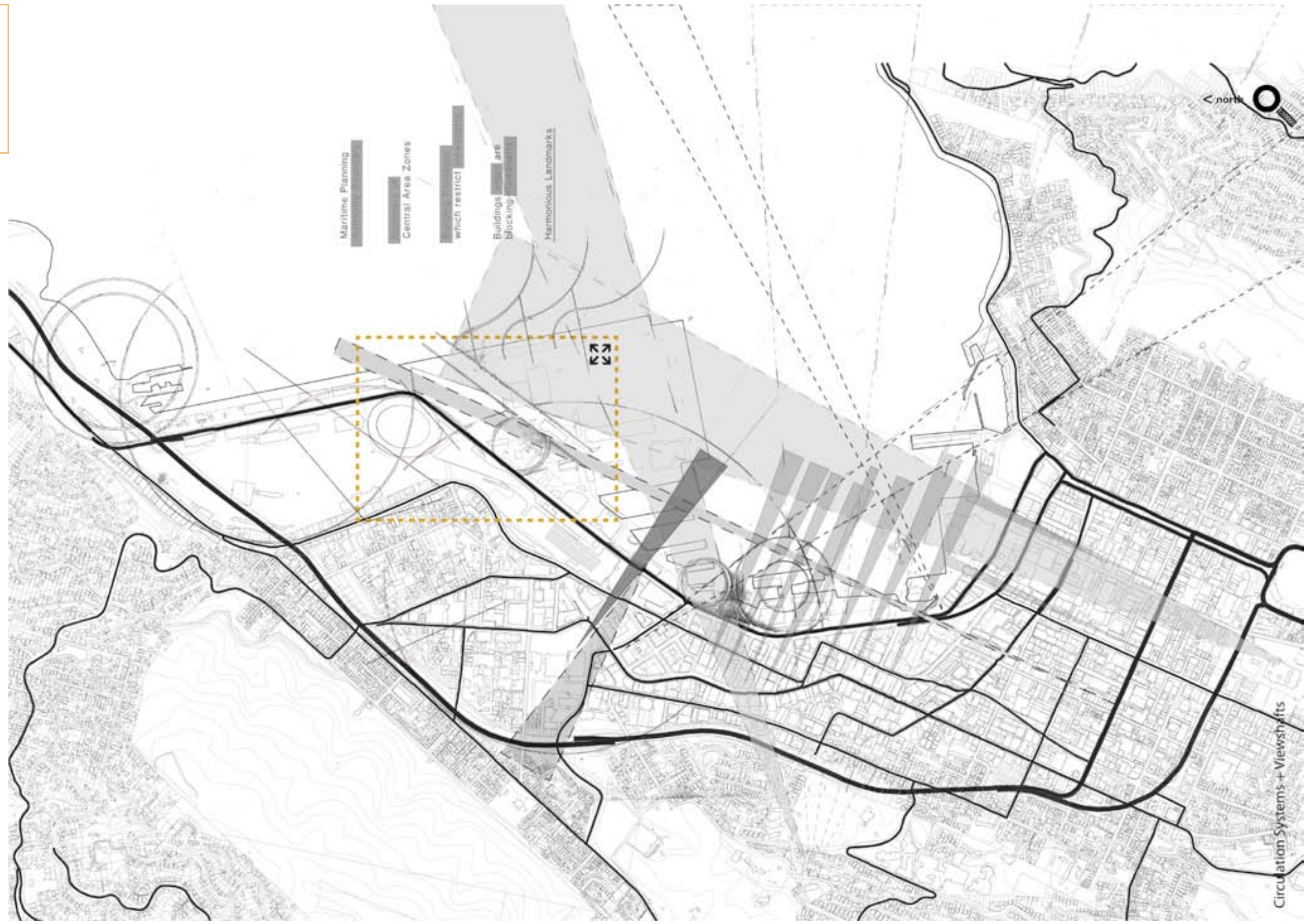


Fig. 3.4| Mass & Bulk/Grain Site mappings: Author adapted from; 'Latest Building Footprints' WCC Morphology Study, Working Paper 5.

Fig. 3.5| Circulation Systems and Viewshafts Site mappings: Author adapted from; Wellington Harbour Maritime Planning Authority.



Currently this area of the waterfront is not open to the public and as such obstructs waterfront access to the north of the city. With the incorporation of an educational component to the Trade Build Facility there is opportunity for design to become a driver to bring more public into this previously restricted area of the operational port.

Fig. 3.6| Site Panoramic from Westpac Stadium Concourse: Author's Collection

Fig. 3.7| Logging Yard Photograph: Author's Collection

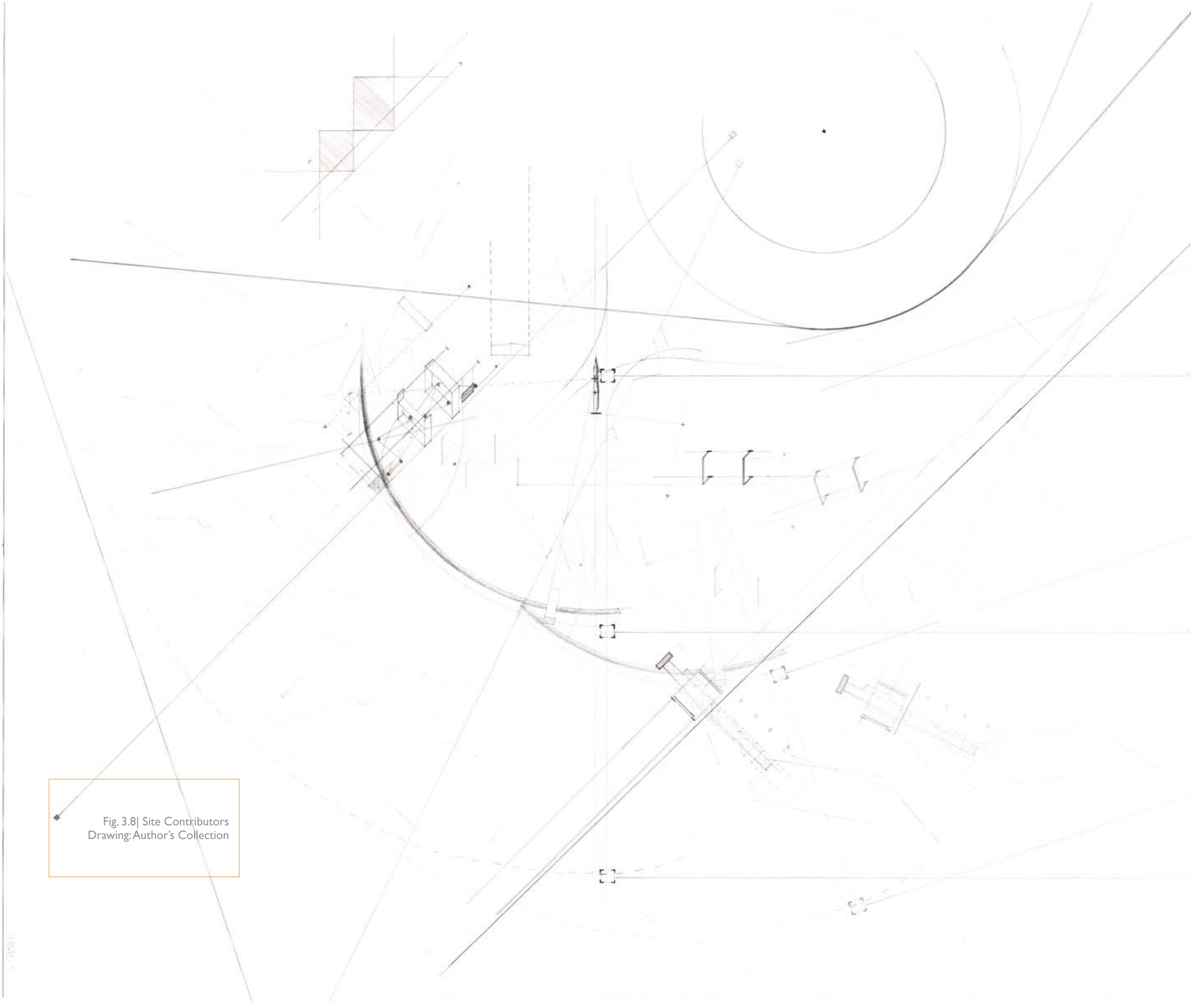


Fig. 3.8| Site Contributors
Drawing: Author's Collection

3.4 Site Contributors:

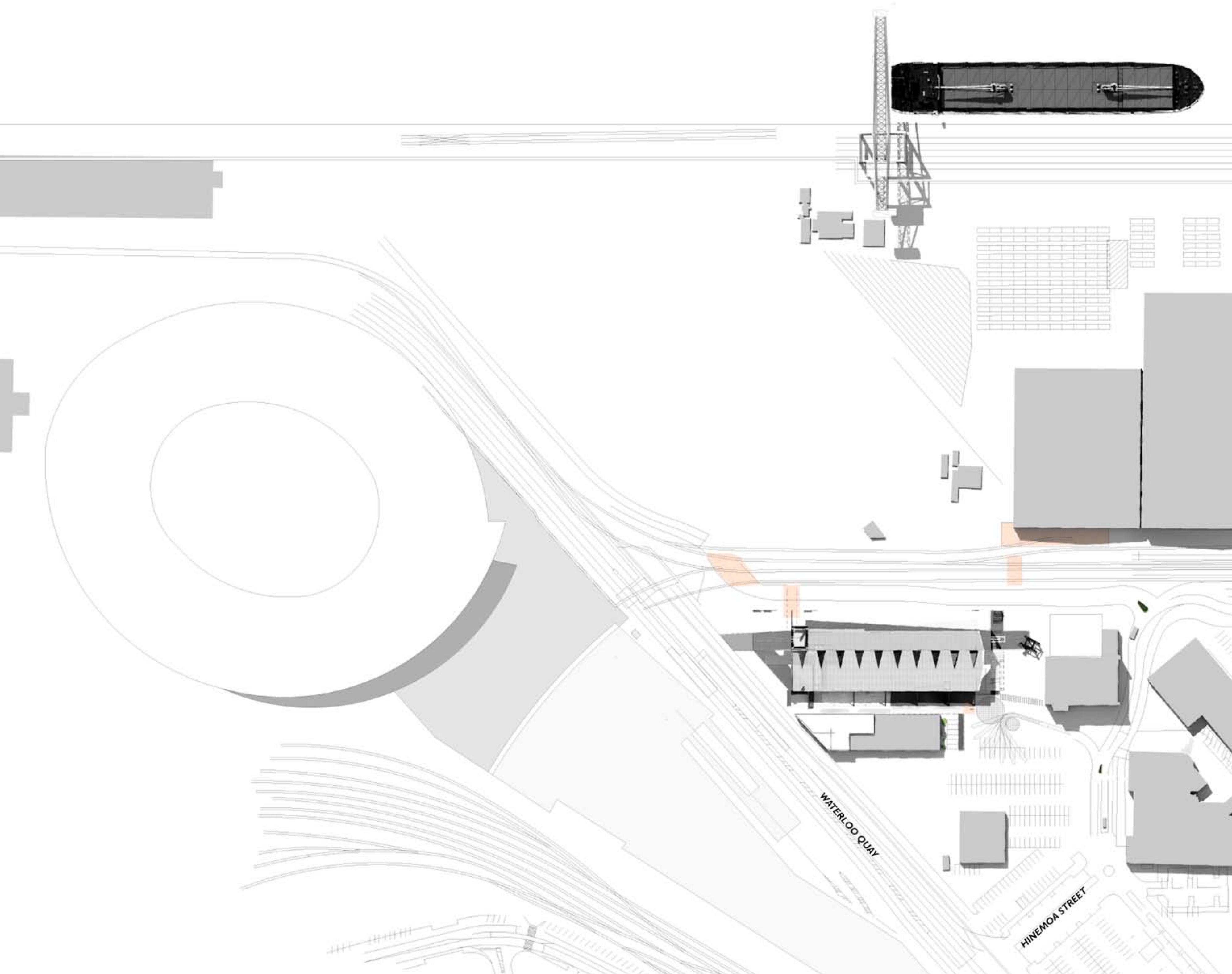
This drawing reveals the assemblage of multiple site contributors from a contextual point of view combining port operations, transport links, the greater urban contribution, and finally the production operations of the proposed design research experiment. Sited on the liminal edge between the dense urban/residential boundary and a functional economic port, the drawing reveals the tension between the two expanding halves.

The drawing titled Site Contributors captures current and historic elements of the site context, allowing the design to activate these alongside the programmatic requirements of the proposed design research experiment.

3.5 Architectural Mandate

The design research experiment aims to engage the urban and industrial processes of influence at a macro scale, while strategically integrating the operations of the port with the prefabricated production at a micro scale. This provides economic diversity to both the design research experiment and the port, while also facilitating a productive and economically viable situation for establishing an exemplary public facility on prefabricated architecture.

The close analysis and mapping produced, reveals the site aspects that are influential and that will impact the design. Firstly the production operations of the port provide existing pragmatic systems required for large and industrial based production programmes such as will be required by the design research experiment. Secondly the dual residential and industrial conditions contribute and enable a productive situation for the prefabrication facility to operate within. They also contribute to the two different grid alignments that provide the opportunity for design to facilitate responsive adaptability through the building design.


WATERLOO QUAY
HINEMOA STREET

The site was selected because it offers a suitable context for a complex and demanding innovative programme that exists in an intermediary urban and industrial site. From the case study research the thesis discovered how infrequently the architecture of prefabrication facilities actively encourages innovation. Current architectural models for large-scale production facilities miss this vital opportunity for furthering responsive adaptability through the proactive architectural design of the production facility. This thesis argues that the site can be an active contributor to achieving those objectives. Meaningful architecture is informed by and responsive to context, so strategic site selection can be a positive contributor to the success of a design solution. The selected research site for this design research experiment, set between the Wellington Tranz Metro freight railway lines and the CentrePort logging yards, offers the design experiment strategic opportunities to actively incorporate:

- production and delivery systems;
- multiple scales of prefabrication;
- fluid factory layouts that contribute to adaptability and diversity;
- engagement in an urban/industrial setting with active educational components and public participation;
- engagement in an industrial setting with a diverse range of engineers and technical industry specialists;
- architectural systems derived from industrial vocabulary that invite multiplicities of diverse production application.

This thesis challenges a new approach to the strategic enabling of responsive adaptability when engaging timber prefabrication. By strategically conceiving architectural design to enhance the adaptive responsibility of such facilities, further opportunities will arise to engage craft and authorship during the process of prefab production. The site is a major contributor to this imperative.

The following chapter introduces the argument for beginning the design experiment with the design of the truss, a technique that allows detailed design to progressively develop and eventuate to engage with the greater complexities of a large-scale production facility.

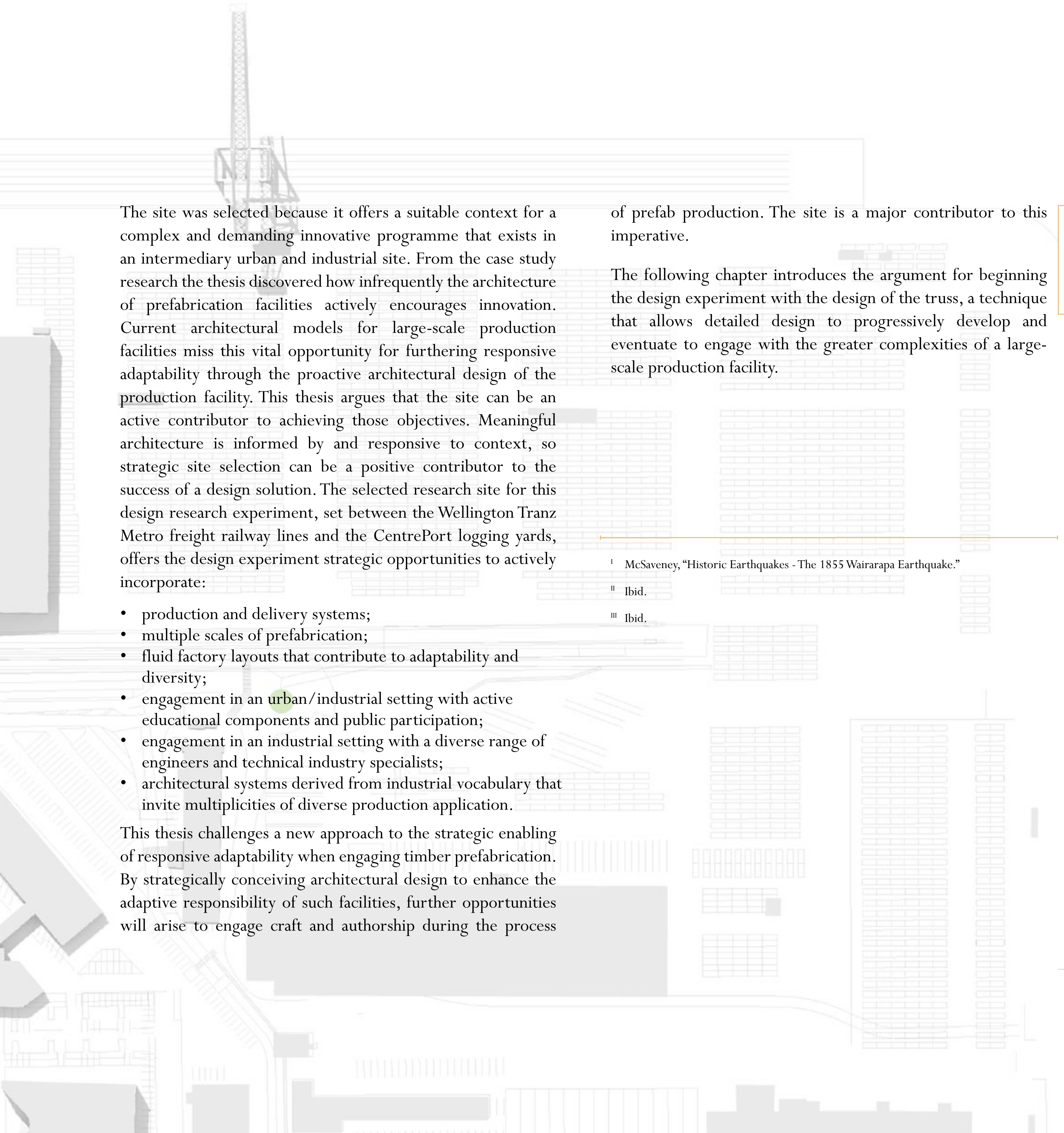


Fig. 3.9| CAD Site Plan: Author's Collection

I McSaveney, "Historic Earthquakes - The 1855 Wairarapa Earthquake."

II Ibid.

III Ibid.

4 CRAFTING, ITERATIVE DESIGN

This chapter focuses on the adaptive process of space and object making at a structural and didactic level; the established methodology approaches design from the detail, in this case the truss. The design by making process begins with the truss, investigating both design and construction principles this methodology produces the structural truss. This section of the thesis argues that design beginning with this small scale, developed with principles of shared authorship, resulting in engendered qualities of craft that are more easily transferrable to larger scaled components of design. This forms the basis of the design methodology that develops individual components of the prefabrication facility, to be later assembled and merged within a greater system of design based on programmatic and production functions, an assemblage of parts in the field of timber prefabrication.

Fig. 4.0| Joint making explorations, Ernsting inspired: Author's Collection

In this chapter the design methodology begins initially with the truss, this thesis argues this develops both design and construction understandings while furthering the capability of the prefabrication facility to engage responsive adaptability. The primary design imperative for this research experiment is that a prefabrication facility that evidences responsive adaptability will allow collaborative production environments to engender qualities of shared authorship, to actively pursue innovative outcomes of prefabricated architecture that evidence qualities of craft, while they are comparably well designed, yet more cost effective, to typical contemporary production approaches. Based on the previous literature review, case studies, and site analysis, this thesis argues that:

1. A large open floor plan alone is not a totally satisfactory design solution for engaging meaningful prefab timber design; the means of adapting this open floor to multiple challenges, however, is; i.e., the architecture itself should be designed so as to strategically enhance responsive adaptability capabilities beyond only providing large open floors;
2. This approach can enhance the ability to implicate craft and individuality within the production of timber prefab units;
3. This approach can enhance the collaborative innovation capacity of the large number of specialists now involved in the building industry;
4. Responsive adaptability can be strategically evidenced by the prefab production facility as a learning tool for young architects wanting to maintain design control over architecture designed as a prefab "repetitive" system.

Additionally through careful site selection and site analysis the selected site for the design research experiment invites the active and strategic incorporation of:

- Production and delivery systems;
- Multiple scales of prefabrication;
- Fluid factory layouts and geometries that contribute to adaptability and diversity;
- Engagement in an urban/residential setting with active educational components and public participation;
- Engagement in an industrial setting with a diverse range of engineers and technical specialists;
- Architectural systems derived from an industrial vocabulary that invites multiplicities of diverse production application.

With the above principals and design research imperatives the departure for design establishes a strategic methodology to integrate the diverse range of components within the Trade Build Facility. The experimental 'design by making'[1] process is important as it maintains an even balance between design and construction, a critical and visible characteristic of prefabricated production processes. With this in mind the design begins with the joint/truss, a design approach specifically focussed on engendering individuality (authorship), detailing (craft) and habitability (integrated technical functions, sustainability, etc.) in prefabricated architecture. This approach aims to enable the prefabrication facility design experiment the ability to possess these qualities through a practical and applied understanding of both design and construction in the field of prefabrication, initially at a smaller, modulated, and easily accessible scale. Later in this chapter this process begins to assemble the facility components within a greater system of operations and functional requirements.

Throughout the design process there was particular attention made to collaborate with industry specialists at key design stages – as would be experienced in practice. Industry practitioners who were approached during this thesis investigation include, Ben Miller-Structural Engineer with Harrison Grierson, Tristan McDonald-Project Manager with RCP, Gary Caulfield-Modular Development Manager with Stanley Modular, and Steven Peng-Building Consent Officer with Wellington City Council. Their views and insights proved indispensable for realizing components of the design. Additionally the thesis research objectives and related industry problems had a strong resonance with practitioners, clearly a significant developing problem for the industry to deal with.

4.1 Design Methodology

It is through the dynamic processes of iterative design that collaborative strains of design and making have been threaded together; reflecting refined and technologically developed end products. Similarly the progressive joint design focussed on the truss, possesses structural and architectural qualities that are responsive to the forces acting on the structure. The process of design, which focuses on specific components sequentially, ensures the quality of the result is continually at risk and is therefore refined and becomes progressively crafted.

The building evolves from the programmatic requirements through the collaborative assemblage of parts that both the function and construction demand. The design has employed the expressed nature of the joint/truss as a representation of the collaborative industry in contemporary contexts of timber prefabrication. This somewhat reversed approach to the design process begins with the micro components and detail ensuring a high-level of design is achieved that can then be further represented and developed in the greater system of design. This approach allows a staged design system to be developed early on, resulting in an adaptable design that is responsive to programmatic and production requirements.

4.2 Processes

The framework discussed here focuses specifically on the detailed and component based approach progressively establishing a set of structural components that the spatial and programmatic system then engages with, articulating the assemblage of components that collectively form the design experiment. The below stages within the framework are in the linear order of prefabricated production beginning with material input and culminating in the final outcome. The stages of the production process within the Trade Build Facility represent both the design process followed, but also the simultaneous production and education curriculum that operates within the Trade Build Facility.

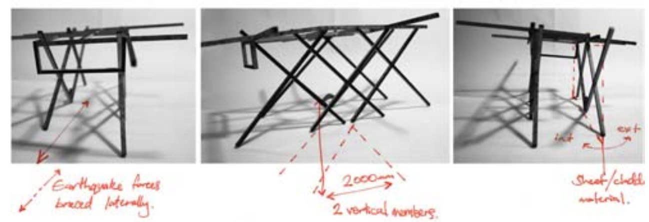


Fig. 4.1| Model photographs: Author's Collection

Fig. 4.2| Model photographs: Author's Collection

Inputs

Highlighted through the research investigation it became evident that the processes involved to deliver a basic useable timber material and especially contemporary manufactured timber products, were relatively unknown and could potentially provide productive insight into innovative prefabrication processes. A range of local sawmills and timber manufacturing plants were visited and examined. The Davis-Featherston sawmill provided an understanding of the material altering processes the raw log goes through to become a useable timber member. This understanding was crucial, reinforcing the importance of exposing the construction process from the very beginning, the producing of the material, to the educational programme within, providing learning opportunities about the extensive capabilities of timber and how prefabrication can potentially better utilise this resource. Contemporary manufactured timber material plants including Juken New Zealand LTD in Masterton and XLam New Zealand Ltd. in Nelson were also examined. Both these timber plants provided insight into the extensive range of alternative timber products available. With products such as CLT[1] that are structurally stable and ideal for flooring, alongside high quality finish materials that use waste timber as the substrate (predominantly exported to Japan), there are multiple opportunities within prefabricated architecture primarily providing alternatives to typical construction techniques. This reinforced the primary focus on timber for prefabrication purposes, which led to incorporating a boutique scale sawmill at the beginning of the production facility.

1 XLam CLT-Cross Laminated Timber, is very strong and has spanning capacity in both directions. The principal strength lies in the direction of the outer layers. The number of layers will vary typically between 3 and 7 depending on use, loading and span as a floor, wall or roof. CLT panels can be manufactured in any size up to 15.3m x 3.2m and thicknesses up to 250mm or more. CLT panels may be utilised as individual building components or as a complete factory-prepared construction system."XLAM New Zealand Ltd."

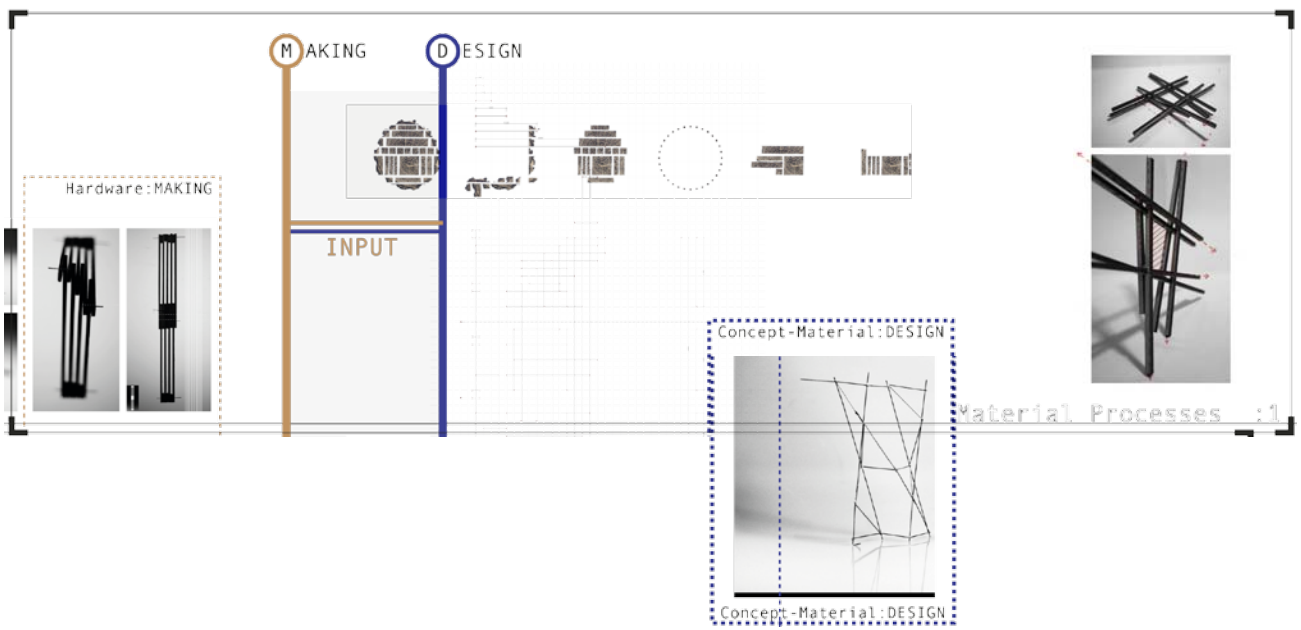
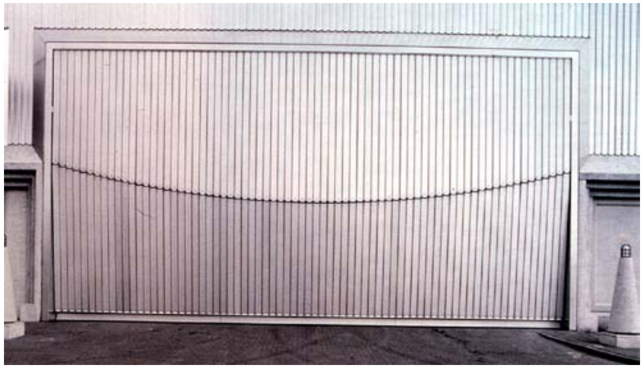


Fig. 4.3| Design Methodology illustration Part 1:Author's Collection

Experimentation

Fig. 4.4| Calatrava's Ernsting Warehouse doors closed/open: Source Creatures from the Mind of the Engineer, The Architecture of Santiago Calatrava

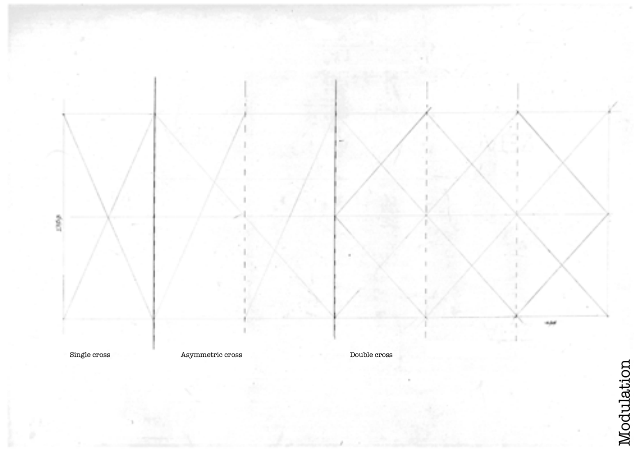


Because of the large span required for the design research experiment of a Trade Build Facility, the truss became the first and principal design problem including an opportunity for early design differentiation. This introduces the requirement for enhancing adaptability that the large industrial scale production facility demands in order to innovatively respond to the detailed human scale of prefabricated outputs. Through the design process which alternated between design and making explorations these responsive and adaptable dualities were able to manifest and facilitate design representative of extensive collaboration across design and construction.

The primary design driver was the investigation of the tectonic forces acting on the long span truss in order to enable a responsive and adaptable collaborative environment. The grid alignments of the site encouraged multiple alignments for design of the truss to engage with. As seen in the first series of models this formed a sculptural twisted form truss element that was not structurally sound or efficient. Investigative experiments were developed until the joint and truss productively influenced the adaptable ability of the programme and became responsive to the site components. These have been reflected in the truss design, allowing the bottom and top chords of a typical roof truss to break away from the perpendicular nature of typical production 'sheds' and concertina the length of the building.

The common component in each truss iteration was the multiple reference planes formed by the truss, each responding to site, programmatic and tectonic contributors. Each of these truss design developments became implicated in the next, increasing the responsive and adaptability capabilities from the one before.

Santiago Calatrava's Ernsting Warehouse doors[II] provided inspiration for experimentation focused on moving joints. The basis to Calatrava's door design was that it incorporated the most simple hinge available but used in succession with multiple slats of differing lengths it developed an impressive result representative of the gravitational force on the doors. This method of design that is responsive to the forces and loads acting on the component evidences efficiency and presents opportunities for innovation through simple and adaptable uses of typical components. An architectural technique also practiced by Prouvé, influenced the 'bowed' bottom chord of the truss, which is responsive to the gravitational forces experienced in the long span of the design research experiment truss.



Modulation

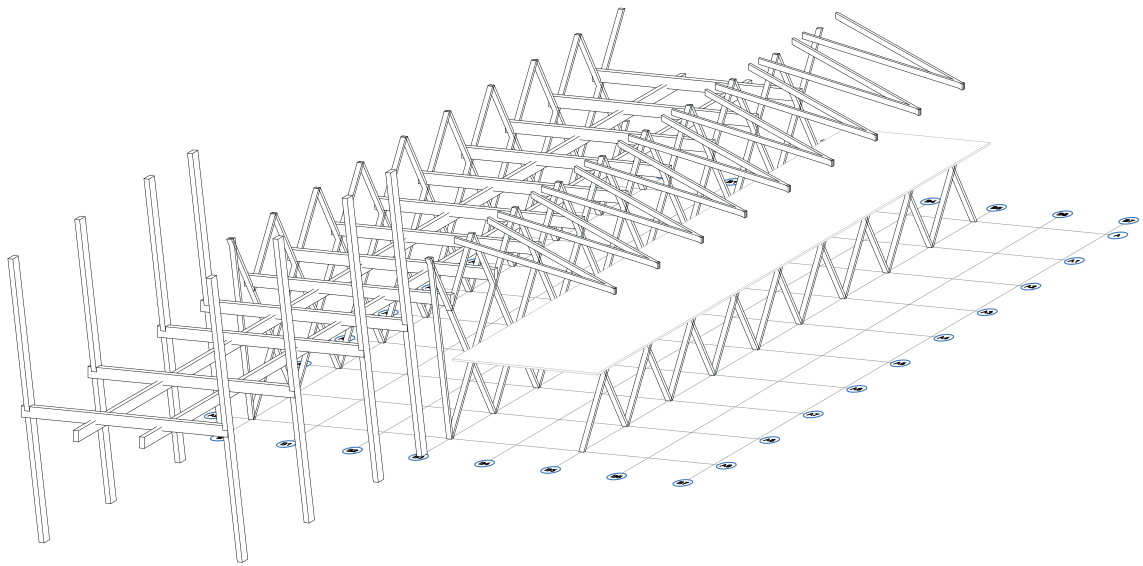
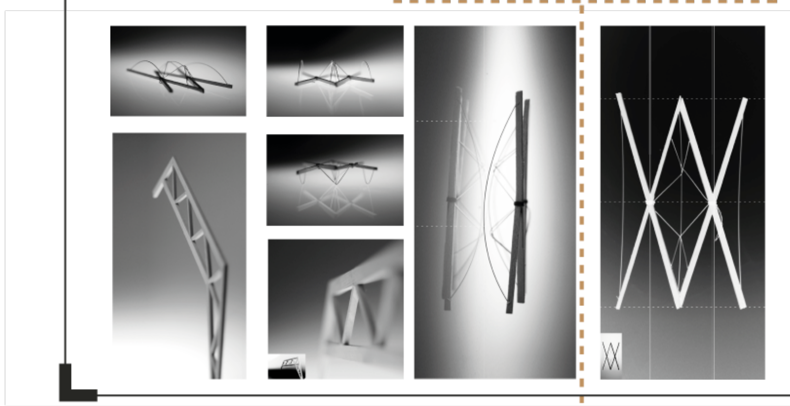
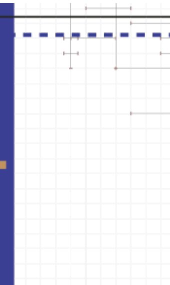


Fig. 4.5| Early design iteration & drawings, modular structural concept: Author's Collection

Component:MAKING

Modular:MAKING





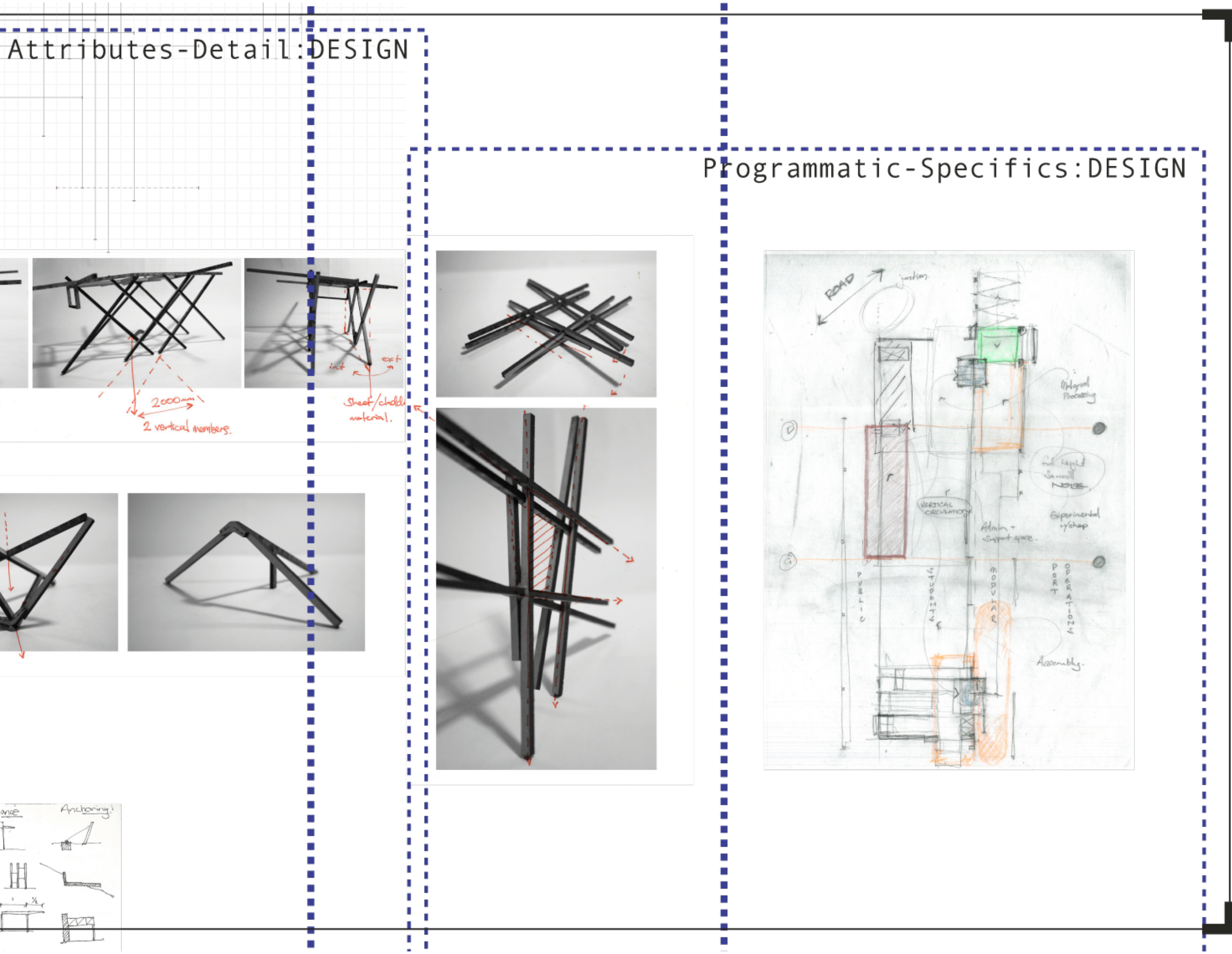
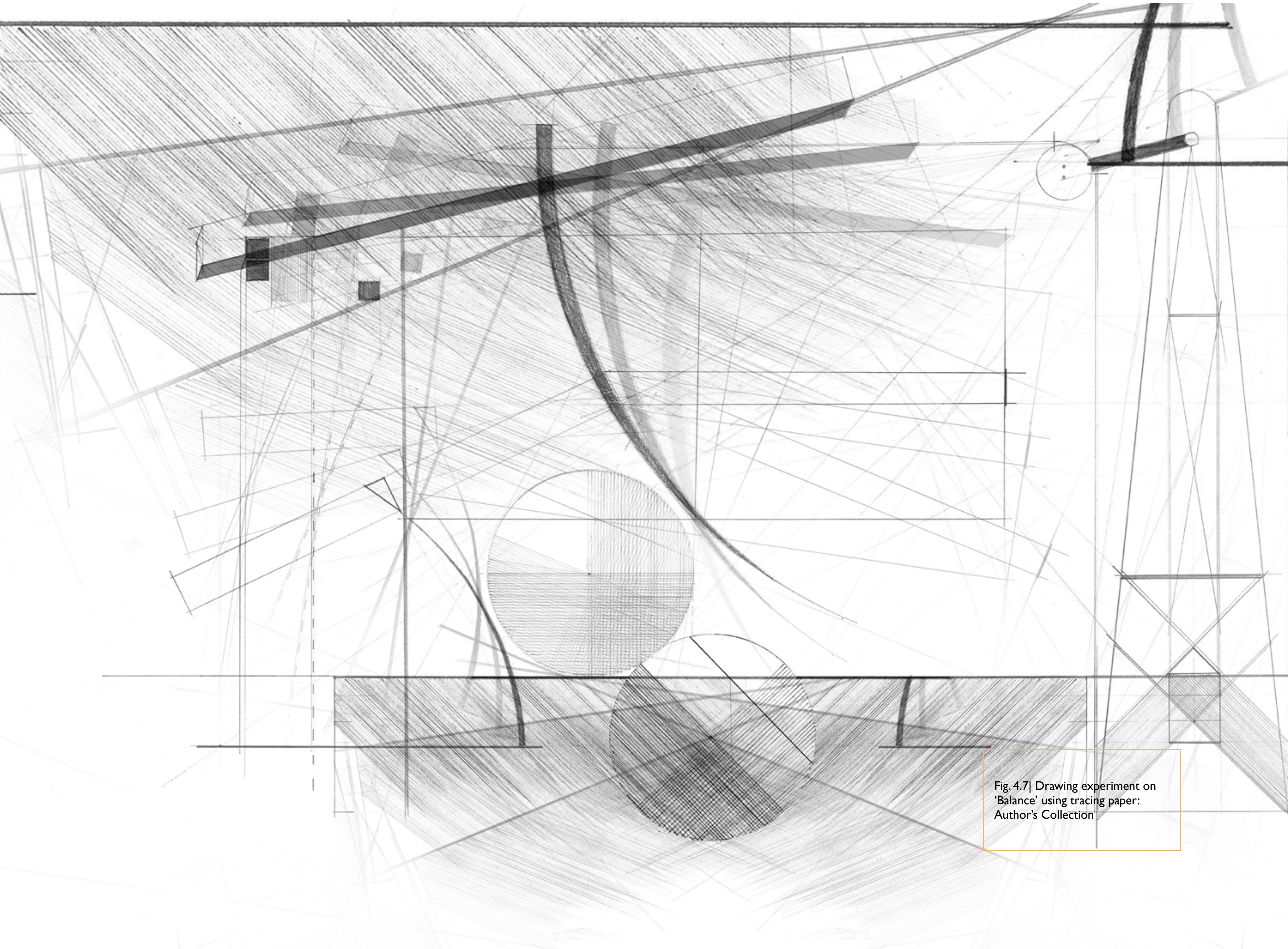


Fig. 4.6| Design Methodology illustration Part 2: Author's Collection



balance.

Fig. 4.7| Drawing experiment on 'Balance' using tracing paper: Author's Collection

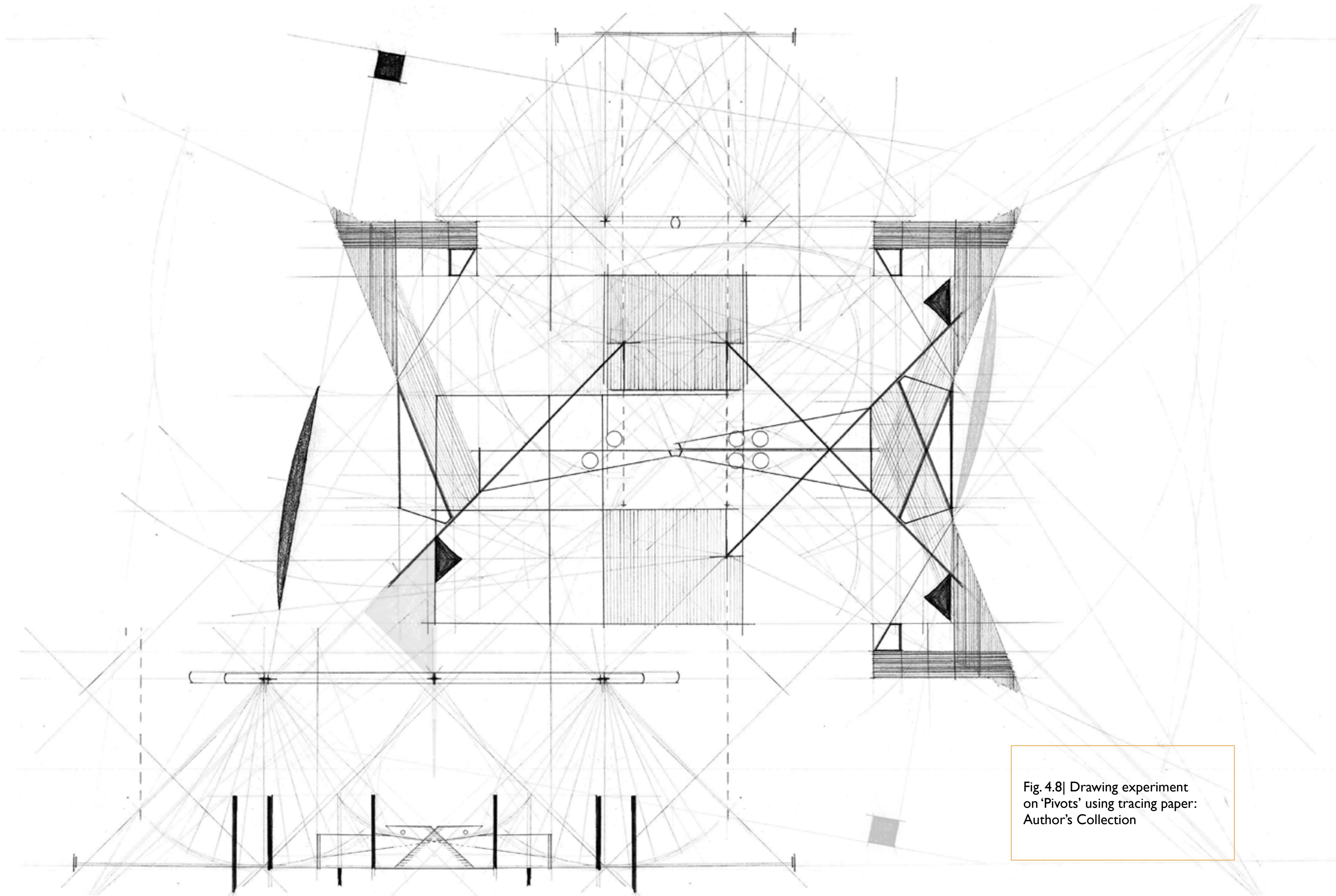


Fig. 4.8| Drawing experiment on 'Pivots' using tracing paper: Author's Collection

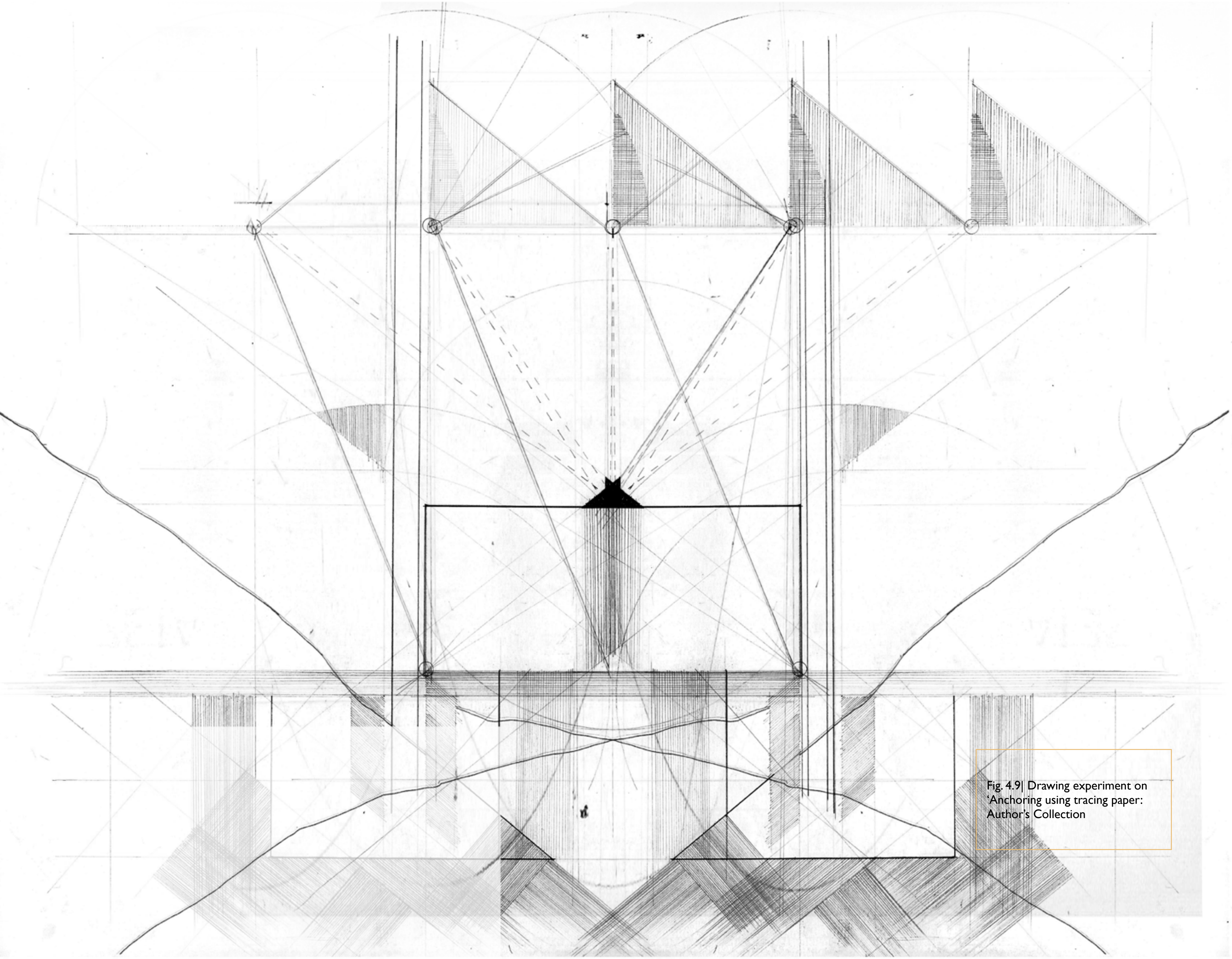


Fig. 4.9| Drawing experiment on 'Anchoring using tracing paper: Author's Collection

Fig. 4.10| Davis Sawmill, Featherston, Log movement between splitter and planer: Author's Collection

Analysis

Collaboration with structural engineer Ben Miller followed, where specific focus on the truss design allowed a conceptual structure to be visually analyzed. Of particular focus was the structure's ability to expose the forces that it was resisting and to be responsive to the laminated veneer lumber (LVL) timber material employed. The shape and form of the truss in particular needed to be responsive to the production processes within and highly efficient, while also educational through revealing its function with the adaptive production processes operating within the Trade Build Facility.

Three themes of structural moment resistance were adopted and represented through different stages of production: anchoring, pivot and balance, each represented in the drawings below. This helped to determine the structural action being resisted and provided suitable approaches to the design of the main structural truss right down to the detail of the joint.

Represented through theses responsive components is the building's ability to be perceived as a united assemblage of parts that are all interdependent and signatory of the production techniques operating within. Design of this responsive and educative nature adapted this prefabrication production position.

Application

Through further development alongside the structural engineer this truss concept was able to rely completely on a structural space-frame principle, meaning each modular unit (truss) was not structurally stable alone and relied on the adjacent units for stability and strength as a total system. In keeping with the fundamental production principles intended for the design research experiment there needed to be a modular unit capable of being fabricated, demanding a structurally independent unit that participates as part of an overall working system.

At this point in the design the truss evolved to become a 3-dimensional truss, arguably a space-frame, however split into smaller and structurally independent units. The form still retained the concertina truss chords; however the lower chord was adapted to align with the typical perpendicular grid of the building envelope. It is with the lower chord that the readability of didactic tectonic systems of the truss are achieved, with the majority of the weight in the truss at the top and a slender bowed lower chord connected to the top chords at each end of the truss unit.

The vertical supporting structure employs LVL columns that in combination with the truss units establish a moment resisting frame. It is through this developed and responsive truss design that a large clear span can be achieved while also facilitating an adaptable production environment within.

Processes

The design processes and micro-based detail experimentations used to develop the structural system engaged the truss as the departure point. In reference to Calatrava's Ernsting Warehouse doors, it is the dynamism of perceived 'movement' that the truss establishes as the link between the architectural armature and the production processes within, rather than integrating the internal operations into a larger construct that masks them. This expressive tectonic formed initially by the truss is carried through the assemblage of parts in dynamic equilibrium of the overall spatial and programmatic system.

This also ties in the theoretical link where shared authorship across collaborative environments, proposed as the industry 'equilibrium', allows prefabricated design and construction innovative alternatives responsive to user and market demands. Arguably the architect is no more appropriate than other disciplines to orchestrate the dynamic and collaborative contributors to this 'equilibrium' where design and construction actively contribute to each progressive stage of prefabrication production.

The production processes required by prefabrication are not definitive and the basis of this thesis argues against standardized open plan space for production facilities as this limits the ability for architectural design to innovatively adapt with the developing and technologically advance industry.

Output

This framework of processes enabled a developed structural system that is adaptable for integration with the programmatic and spatial systems as required. Additionally the structure has integrated dual directionalities and scales that will allow responsive interactions with the production and education processes engaged within.

As highlighted in the site analysis chapter the opportunity for the site to become a joint in the greater urban fabric reinforced the principle design initiatives. The design development manifested as a truss, signatory of the collaborative nature within the proposed new Trade Build Facility. This sense of design connectivity with the internal production processes is also linked with that of the Trade Build education programme, which reveals the processes of constructing, primarily evidenced in

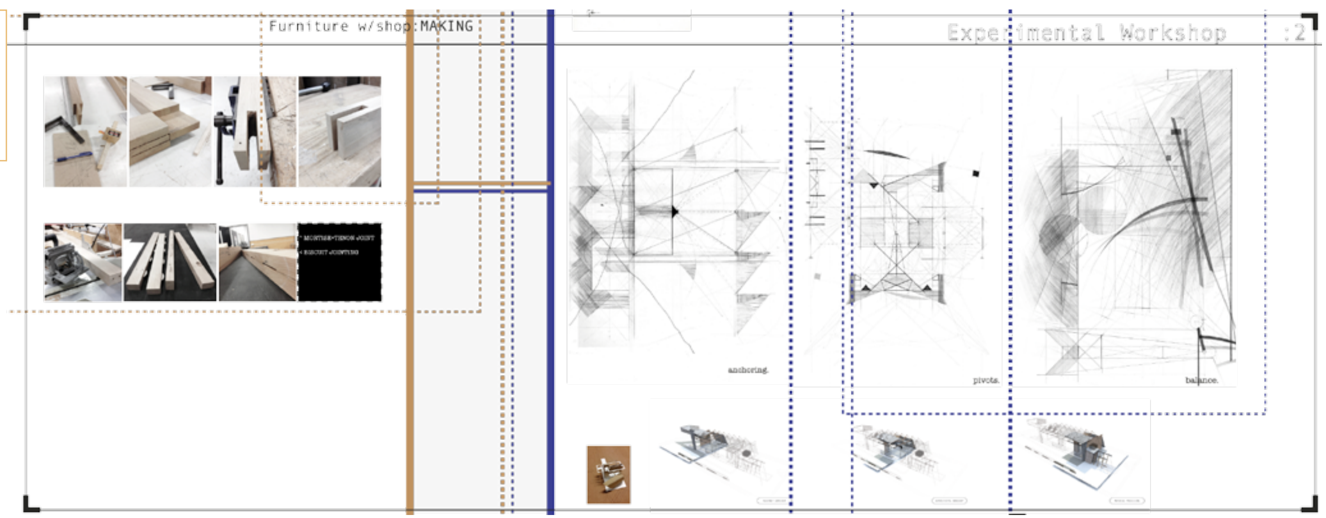


Fig. 4.11| Design Methodology illustration Part 3: Author's Collection

joint/truss (physical) and details (drawn). It is with this in mind that the layers of design evidenced operate a similar didactic to the production and education operations within, inheriting mechanical qualities from the prefabricated production and offering learning opportunities to the educational programme.

4.3 Education Curricula

It is this unique 'design by making'[III] process-based approach to prefabrication facilities that suggests an alternative approach to prefabrication production, in combination with educational opportunities for a collective base of industry specialists to simultaneously witness this alternative approach. The final and 'external' educational component to the design of the proposed new Trade Build Facility is the opportunity for the design to act as an exemplar of prefabricated architecture, enabling collaborating specialists, architectural students and the public opportunities to perceive prefabrication production from a new perspective.

Through the design investigations' of this thesis, collaborative workflows proved invaluable and therefore the education curriculum is aimed at all building industry disciplines, enhancing the adaptable and collaborative nature of the production environment within. It is envisaged both students and practitioners will have the option to choose from a variety of courses ranging in length and integrated detail, the principle component being the ability to witness the entire process of prefabricated production, from material processing through to final assembly with integrated design throughout.

It is this design research framework presented that provides the foundation for the curriculum and architectural pedagogy of the proposed new Trade Build Facility. The dynamic relation between design and construction through production techniques

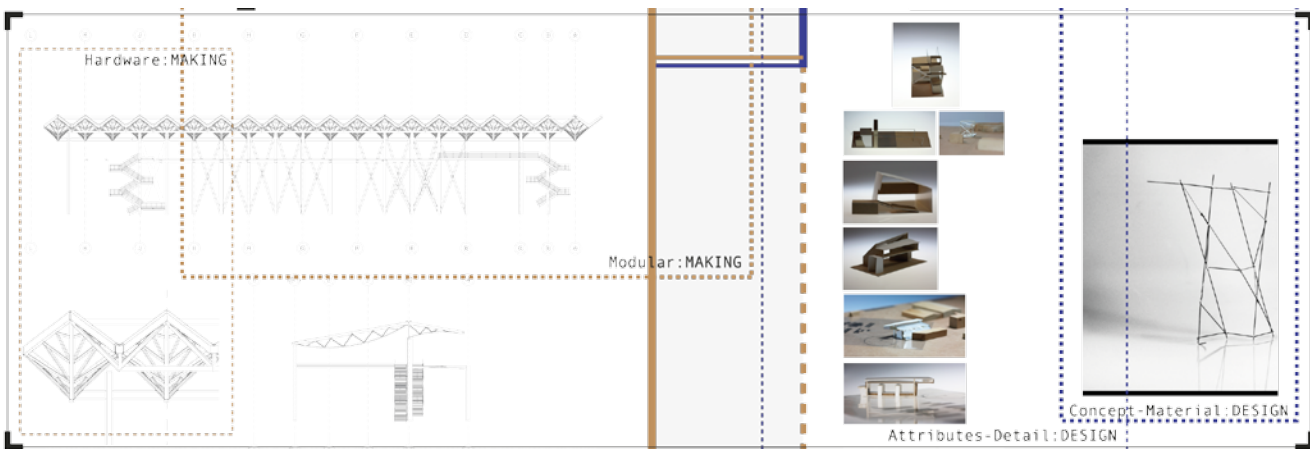


Fig. 4.12| Design Methodology illustration Part 4: Author's Collection

offers an informed understanding on prefabrication qualities of craft and authorship, facilitating an adaptive apprentice-based pedagogy.

The operation of the Trade Build Facility where the production and education of prefabricated architecture operate simultaneously must incorporate open research and experimental channels to ensure productive influence between the two operations. This is essential to the responsive adaptability of the prefabrication facility that advances as alternative techniques and technologies emerge.

Through this methodology, each design component has a high-degree of architectural design, allowing a large-scale prefabrication facility to evidence design qualities typical to

Fig. 4.13| Truss design schematic: Author's Collection

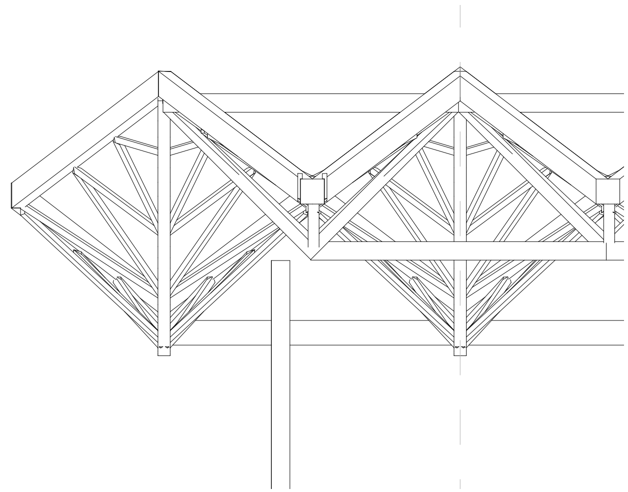


Fig. 4.14| Design Methodology illustration Part 5: Author's Collection

that of smaller scale prefabricated examples of architecture. The thesis argues this is critical to determining an environment within the Trade Build Facility that promotes detailed creative thinking to a diverse range of specialised disciplines that collaboratively operate within the field of timber prefabrication.

The design that began with the truss developed into the primary structural component enabling long uninterrupted spans to be achieved in the facility. Through the truss experimentations, the ability of a component to address multiple scales, loads, orientations, 3D observation, narrative processes and cross-disciplinary observations were explored. It is this multiplicity of processes and systems that are essential to the responsive adaptability of the production facility. The truss design presented is one representative component in this system, which is a part of the greater system of the Trade Build Facility.

4.4 The mechanics of the building

The building as an assemblage of parts is an important theme that governs the design process of this research experiment. The architectural challenge is to convey prefabrication of the assembled components, integrated with the complex and diverse pragmatics required of the prefabrication and educational productions within, as a cohesive whole.

Important to the nature of production are the input and output (arrival and departure) termination points. The building identifies these significant points at one end with the industrial sawmill lift, balanced by the 'control room' which houses the boardroom at the southern end. These two points embrace the stages of production ranging from the Material Production to the Assembly Workshop, while providing responsive limits to the production processes within.

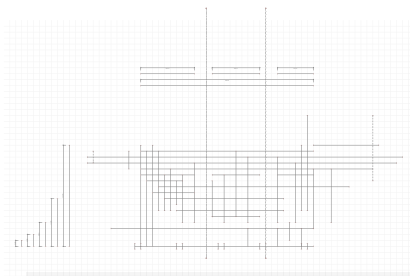
In returning to the established and developed definition of craft from Chapter One- Craftsmanship and technical industry thought:

"Craftsmanship…means simply workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making." [IV]

This allows the design experiment, the Trade Build Facility, to assume the overarching role of care to the prefabrication within, it's duty is to the production environment to enable a high quality of workmanship while constantly managing the risk of design and construction throughout the process of manufacturing. It is this motive that demands a production environment that evidences responsive adaptability. As a result of this alternative approach to production environments, the workers' vested interest and empowered responsibility to the task become of paramount importance.

An important distinction to identify: authorship is a subsidiary to craft but is representative of individual contributions in a collaborative work environment. The static nature of the building (symbol of what is taught) is countered by the dynamic and diverse activities operating within (evolving with time), collectively challenging typical approaches to the production of architecture (output) while providing responsive experiences that manifest conjoined qualities of design and construction, established through shared authorship and collaborative activities. The integrated partnership between the design of the Trade Build Facility and the programme within enable collaborative work processes to articulate alternative approaches to prefabrication production.

Material Proc



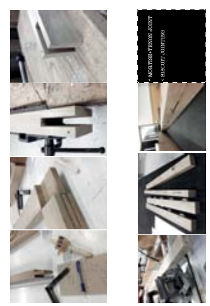


Fig. 4.15| Design Methodology illustration Full: Author's Collection

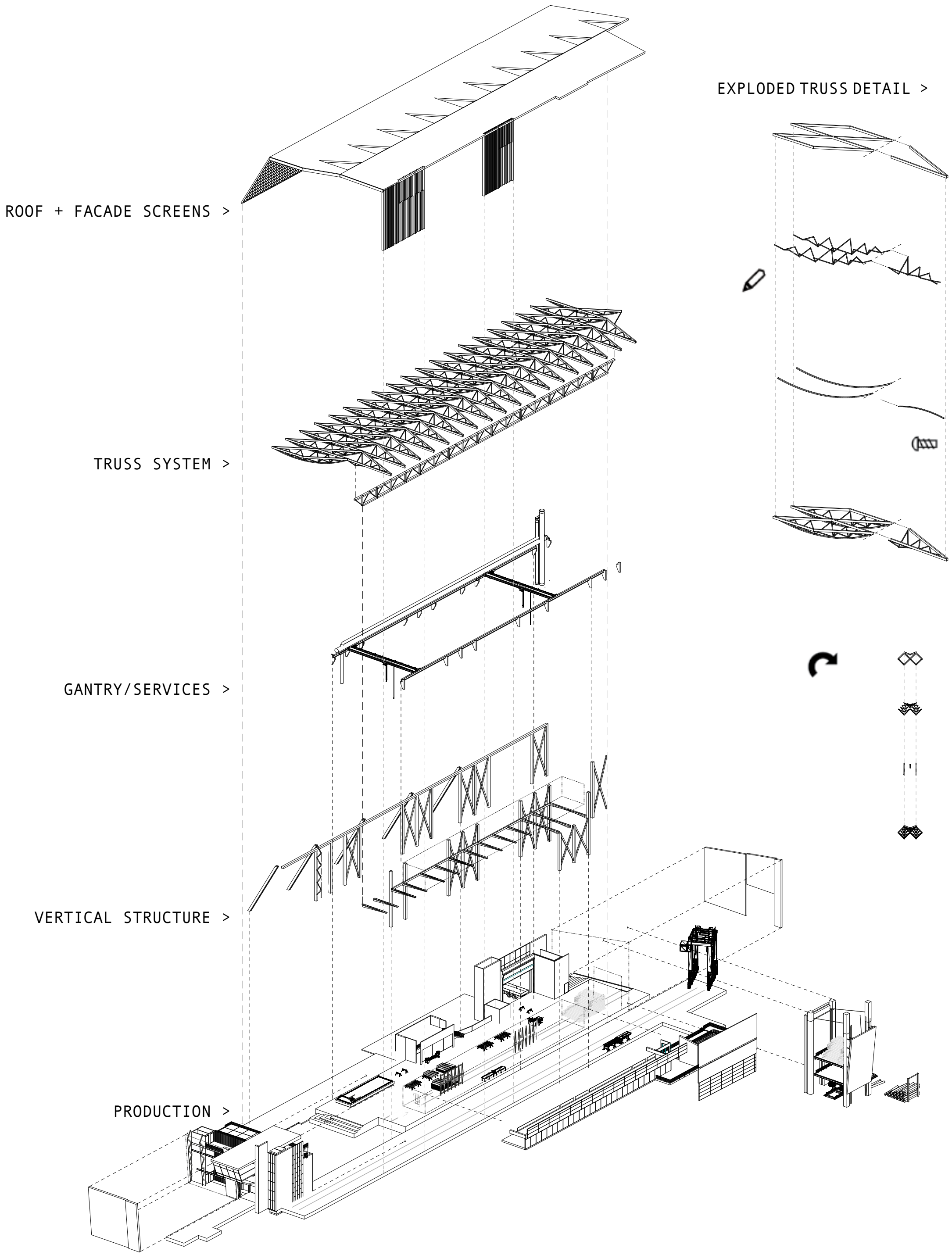


Fig. 4.16| Exploded Axonometric, Design mechanics: Author's Collection

The structural truss sets the system of design for the building, while also transforming it from a shed to a dynamic and responsive educational example of architecture using prefabrication production approaches. This structural system is the backbone to the design and integrates more typical building elements convincingly while retaining the sense that the truss and programmatic operations govern the building tectonic and outcome.

The facades of the building are important in uniting the vast range of components while controlling the exposure of the production to the passerby and the main roadway that traverses the site. These are intentionally 'dis-engaged' from the structure and give the feeling that they can peel back from the building to reveal different stages of the programme within. For example the southern façade that is completely disengaged and pulls away from the building revealing specific components, that together provide a dynamic response to the production operations within. Similarly on the interior of the building, facades are employed in combination with specific programmatic spaces that are presented as separate administration volumes within the main building. This allows the assemblage of parts and the collaborative nature of the production processes to become apparent through the experiences of the users.

It is through these architectural techniques and established theories evidenced, that the typology of the 'shed', what the programme initially demanded, is shifted and transformed into the Trade Build Facility – a spatially adaptable and responsive facility, which allows alternative approaches and technological developments to be evidenced in the cohesive and collaborative prefabrication production environment.

[I] West, "Thinking with Matter." p 55.

[II] Harbison, Creatures from the Mind of the Engineer, The Architecture of Santiago Calatrava. p 87.

[III] West, "Thinking with Matter." p 55.

[IV] Deamer and Bernstein, Building (in) the future. p 38.

Fig. 4.17| Model photographs:
Author's Collection

5 TRUTH IS BEAUTY, DESIGN PRAGMATICS

The design mediates programmatically between iterative micro-based design experiments and constructional developments. This approach to design allows the qualities of micro-scaled design to manifest through larger programmatic and site based pragmatics. The simultaneous production and education processes operating within are incorporated with the spatial organisation required for two opposed and diverse programme combinations. This chapter reveals the operatives within the prefabrication facility that allow an educative programme to co-accommodate an extensive industrial based fabrication facility that begins with the log and delivers prefabricated timber housing units at the completion end of the dynamic collaborative processes within.

In this chapter the outcomes of the investigative design process on the joint-based 'design by making' approach that resulted in the design of the large span truss, become implicated within the greater systems of the design. This is in response to the identified prefabrication problem where this thesis argues design of prefabrication production facilities need to:

1. Strategically enable spatial adaptability capabilities that are responsive to emerging alternatives of timber prefabrication.
2. Facilitate the ability of the prefabrication facility to act as an educational facility for different specialists to simultaneously witness and participate in prefabrication processes.
3. Evidence the ability of the prefabrication facility as an architectural exemplar that provides a productive learning tool for architects wanting to maintain design control over architecture designed as a prefabricated "repetitive" system.

Within this design context the proposed new Trade Build Facility explores developing a system of design that integrates production and education processes through a collaborative environment of multiple and diverse range of industry specialists. The prefabrication facility establishes spatial organisation relations that productively engage the ability of design to evidence a high degree of individuality (authorship), detailing (craft) and habitability (integrated technical functions, sustainability, etc.) in prefabrication production principles. Additionally the final design transforms the typical prefabrication production 'shed' typology, offering suggestive insights into contemporary education and industry relations in the field of prefabricated architecture.

Primarily the proposed new design for a Trade Build Facility exposes the processes of production through the transformation of raw material (beginning with the log) and experimental investigations to the final output of prefabricated housing units. The architecture operates as a functional and educational component to the system of production, allowing responsive learning opportunities from both the building and the programmatic functions within. This allows the Trade Build Facility to be presented as a signature of the production techniques and developing approaches to prefabricated architecture that manifest within.

5.1 Typology

This thesis argues that the existing production facility 'shed' typology is a significant limiting factor to the contemporary context of prefabrication. The design of the proposed new Trade Build Facility tests design approaches to shifting beyond this 'shed' typology by integrating spatially adaptable process-based

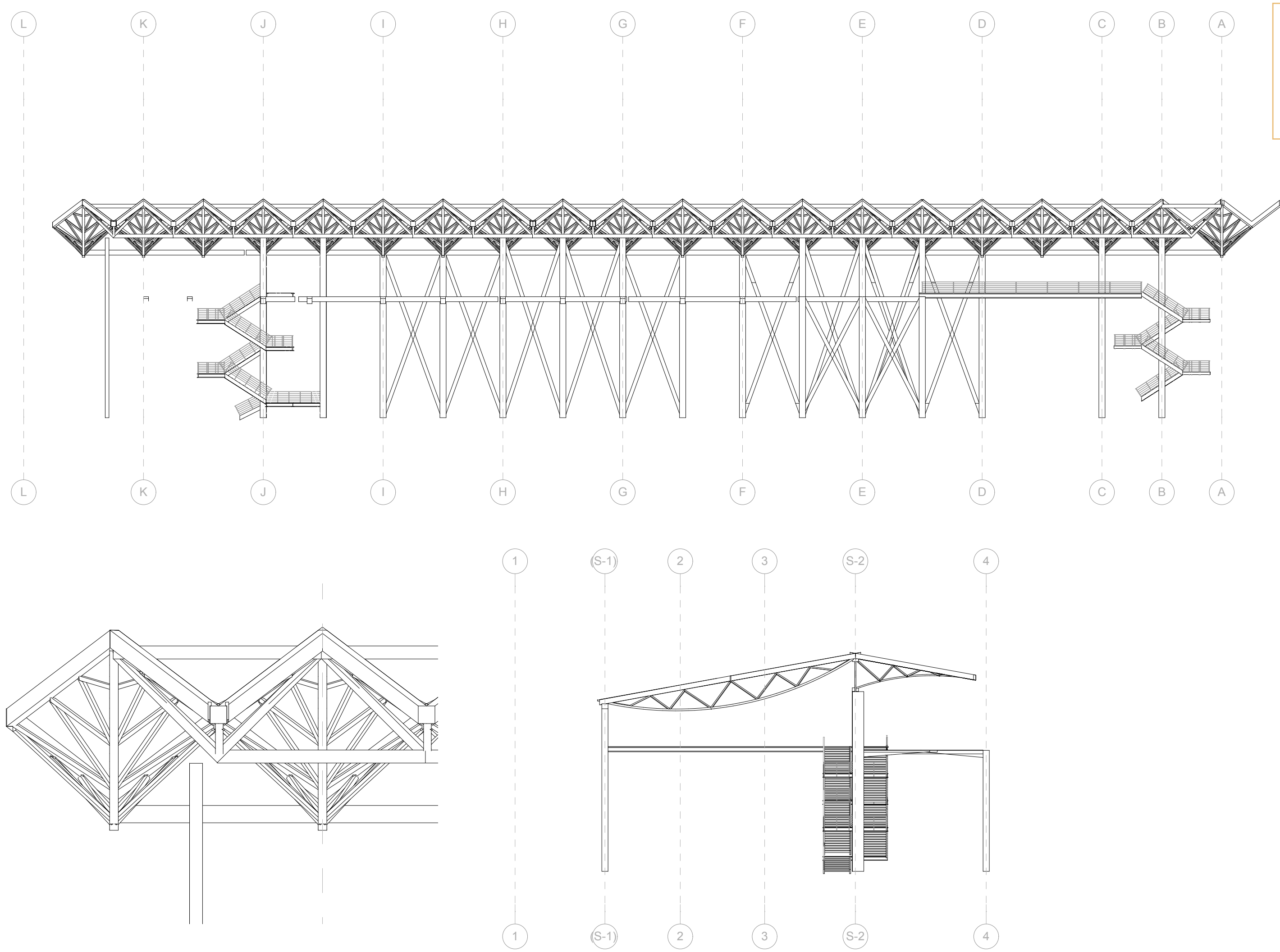


Fig. 5.0| Structural Sections:
Author's Collection

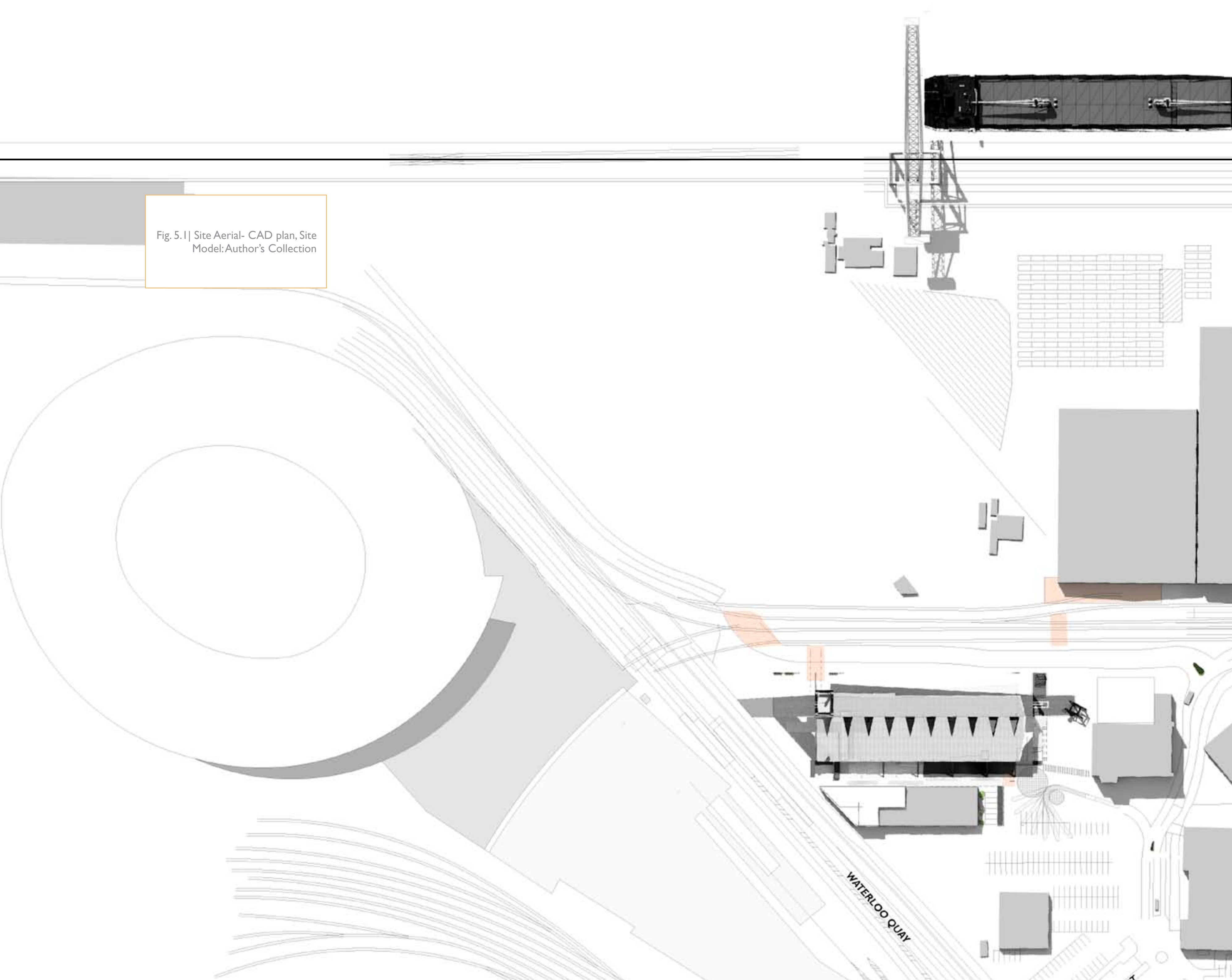
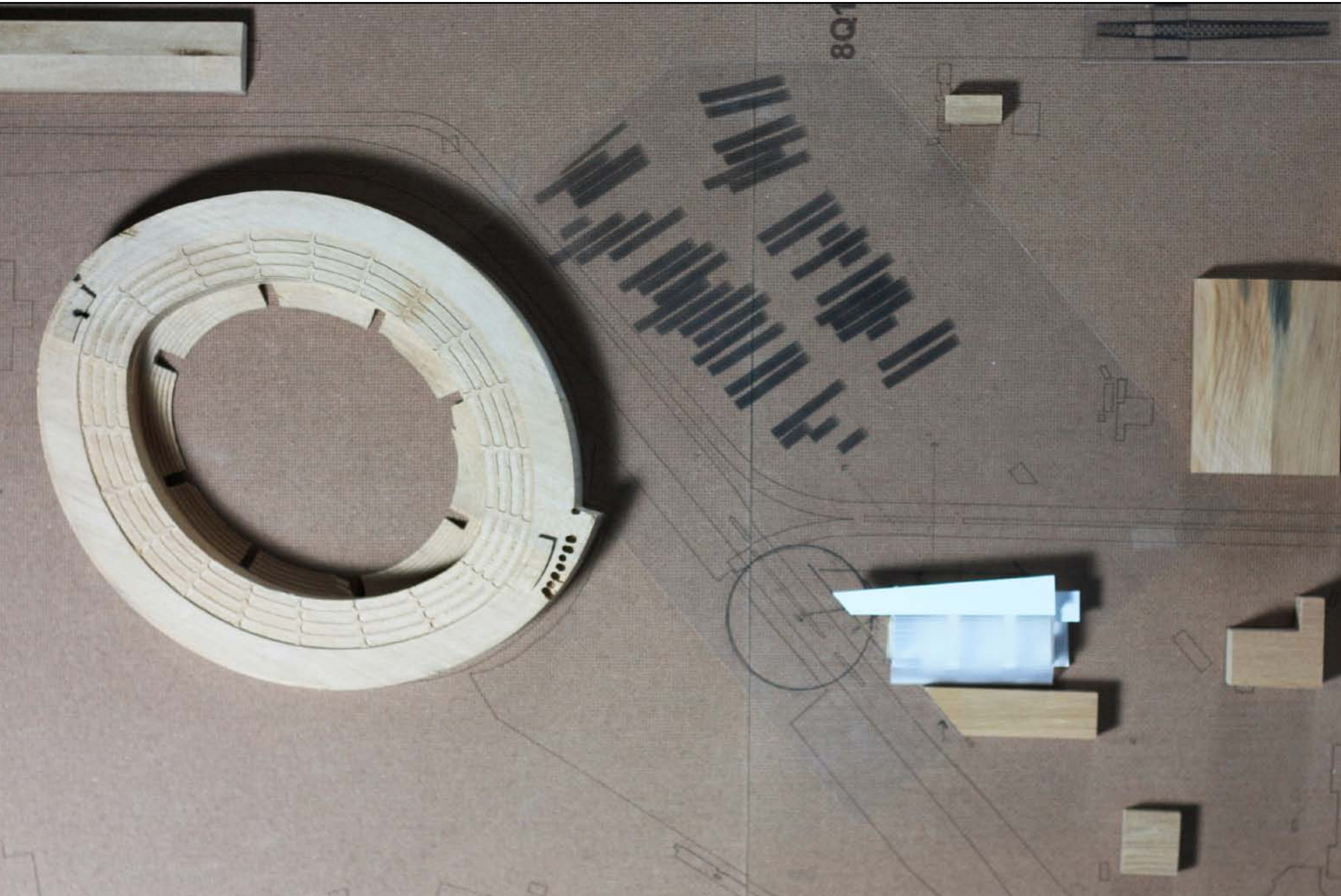
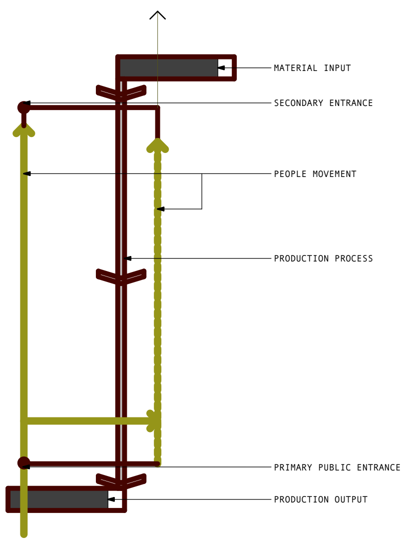
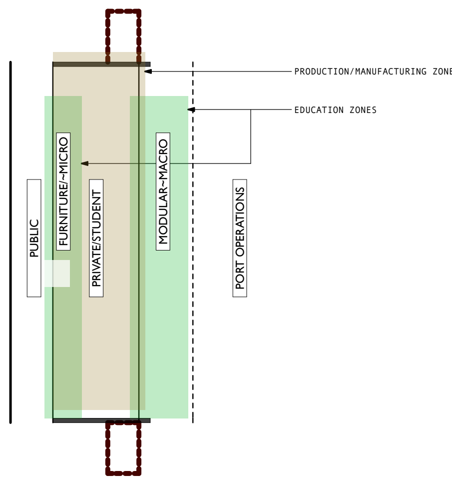


Fig. 5.1| Site Aerial- CAD plan, Site Model: Author's Collection

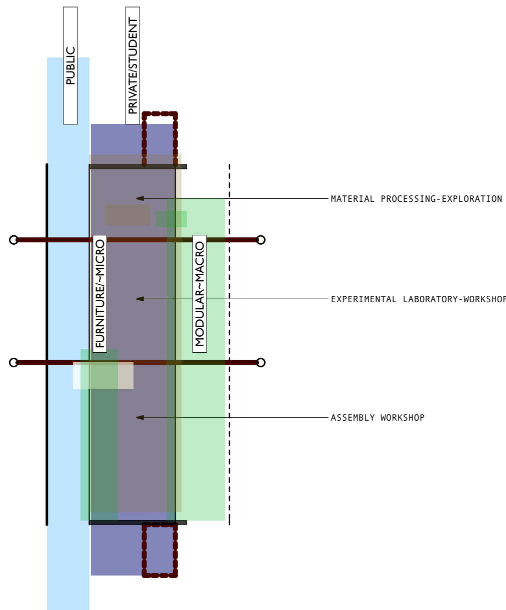




SITE ORGANISATION



PROGRAMME ORGANISATION



PROGRAMME-PRODUCTION INTEGRATION

Fig. 5.2| Design Diagrams, Site Organisation, Programme Organisation, Programme-Production Integration: Author's Collection production, with developing technological and production alternatives incorporating emerging material technology alongside innovative design. Similarly this allows a cohesive collaborative environment that enables learning opportunities through strategic witnessing of production processes and exposure of prefabrication that is founded in contemporary principles and understanding on craft and authorship.

Due to the industrial scales of both the site and the programme including the shifting notions of transport of the adjacent port, the design demands a large-span infrastructural typology; in the immediate vicinity of the site this is typically a shed.

The design challenge is to engage the architecture so as to strategically enhance responsive adaptability capabilities of the production facility, beyond only providing large open plan floors. This approach enhances the ability to evidence multidisciplinary innovative design within the production of prefabricated timber units that move beyond predetermined repetitive and utilitarian based outcomes. The prefabrication production focus on timber immediately changes the typological perception of the 'shed'.

The concluding solution is the design that follows and how this transgresses the 'shed' typology to facilitate an architectural design that promotes a cohesive collaborative environment that is responsive and adaptable. This thesis argues that this enables the Trade Build Facility to challenge typical production approaches through innovative, detailed construction, and technologically advanced production in the contemporary field of prefabricated architectural housing units.

5.2 Movements

The operational port allows rail cargo to be transported on tracks parallel to Cornwell Street along the northeastern side of the building, establishing boundaries that restrict public access to the port. It is this cargo rail line along with the main road, Waterloo Quay, that form the boundaries to the site footprint. The programme will produce additional vehicular and industrial movements that engage with these surrounding movements: firstly, the movements of physical materials and deliveries required for production; and secondly, the presence of people and pedestrian observation of the Trade Build Facility.

The structure of the building employs the new experimental truss to enable internal gantry operations that also engage dual orientations of the site in order to provide more adaptive production layouts, while providing a long span that allows the linear process of production to stretch the full length of the building uninterrupted. The primary objective of the structure is to encourage greater responsive adaptability of movement within, allowing different systems to be suspended from this truss along multiple orientations, zones and scales of production.

5.2.1 Materials

Beginning with the program and spatial configuration for the sawmill component, there are two main material inputs: raw logs and manufactured timber product deliveries. Manufactured materials enter the building into the material processing stage at the northern end, while raw logs enter the boutique scale sawmill also at this northern end but restricted to an outdoor section of the front quarter of the facility.

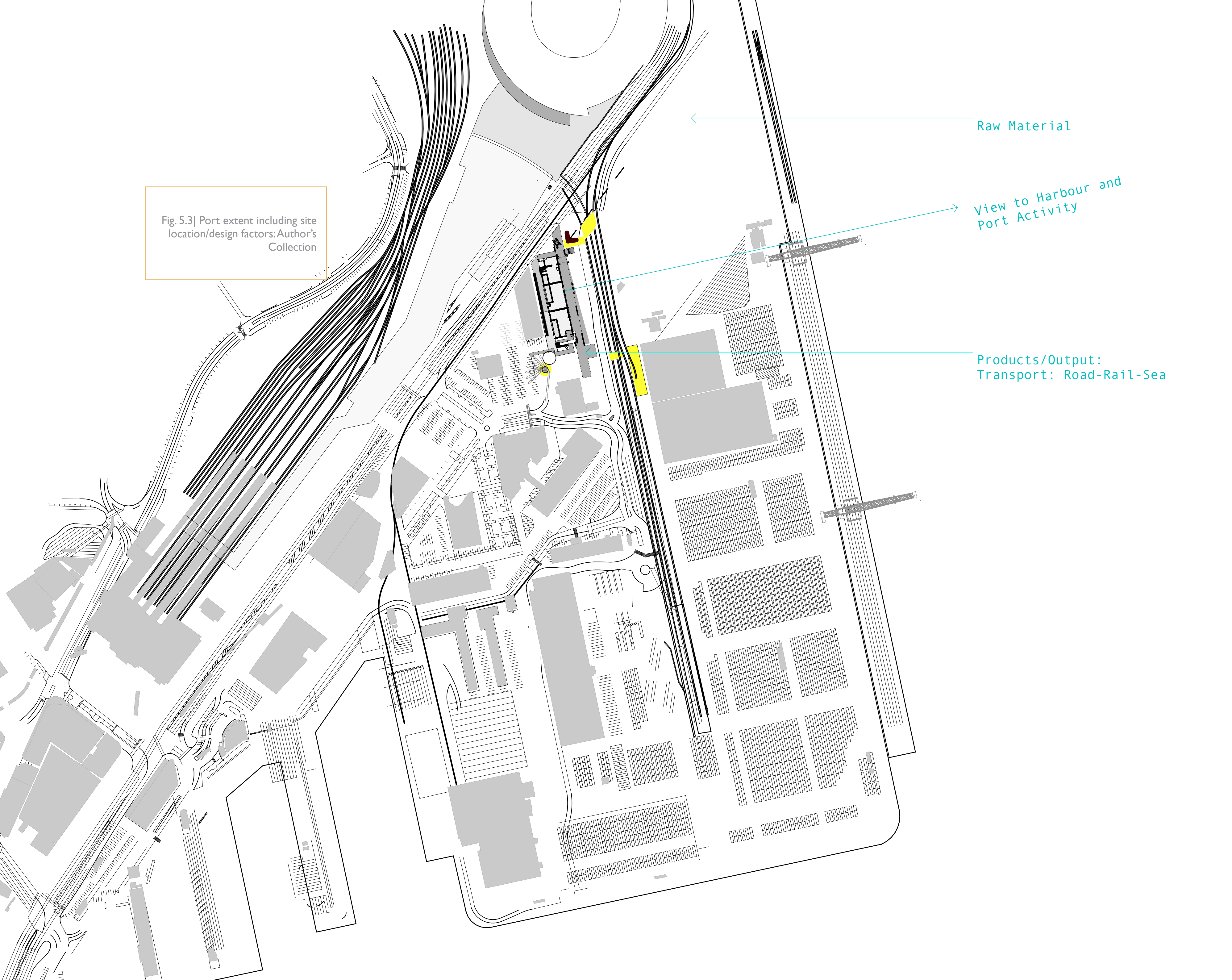


Fig. 5.3| Port extent including site location/design factors: Author's Collection

The log is transported directly to the small-scale processing boutique sawmill from the adjacent yards and then it is machined and ripped down into timbers appropriate to the current prefabrication demand. At this point the sawmill, which employs vertical processing requiring much less space, is open and transparent. Through this specific design technique the individual processing stages of a sawmill are considerably prolonged and visually exposed to both levels of the prefabrication facility. This is an important component and fundamental concept to the incorporated educational programme.

The supplementary and manufactured timber product is delivered onto a large rolling bed that moves the material from the north loading dock into the building out of the weather. Typically the delivered timber will consist of Laminated Veneer Lumber (LVL) and manufactured sheet products not able to be replicated on site, but will change with technological demand; for example Accoya Pine[1] will be heavily investigated in the near future.

These materials then traverse through the adaptable production processes of the building on a rail system that carries customised fabrication beds. Additionally the main volume of the building has two full-width gantries that crawl the length of the building altering the sequence of single or multiple production processes as required.

1 Free hydroxyl groups adsorb and release water according to changes in the climatic conditions to which the wood is exposed. This is the main reason why wood swells and shrinks. It is also believed that the digestion of wood by enzymes initiates at the free hydroxyl sites - which is one of the principal reasons why wood is prone to decay. Acetylation effectively changes the free hydroxyls within the wood into acetyl groups. This is done by reacting the wood with acetic anhydride, which comes from acetic acid (known as vinegar when in its dilute form). When the free hydroxyl group is transformed to an acetyl group, the ability of the wood to absorb water is greatly reduced, rendering the wood more dimensionally stable and, because it is no longer digestible, extremely durable.

5.2.2 People

In the Trade Build Facility production moves from the north and shifts through experimental production transformations until it exits the building at the southern end as prefabricated housing units. The intention is for production to be in constant operation with refinement and learning opportunities at each significant stage of production. The experience and collaboration between the design and the construction processes is diagonally bi-directional, as per the truss orientations, which forces active collaboration. Spatially there are developed zones that define areas for public observation of the production versus the collaboration between users. The main pedestrian entrance is from the southern end while there is a secondary pedestrian entrance from Waterloo Quay; however there is no provision for parking on this street.

The workshop was elevated 1200mm in order to allow the public zone that borders the west side of the building to have an increased visual connection with the components (and the act of making) evidenced on the workshop floor.

A mezzanine floor was added along the eastern side of the facility in order to replicate this visual connection between the 'studio' spaces with the main workshop/production space. Vertical circulation comprising two mechanical lifts and two stairways provide access to the mezzanine floor suspended over the main workshop space. In combination with the mechanical sawmill and the vertical circulation core at the opposite end of the building, these cores establish a system of tectonic anchors to the structure and signify the start and end of the production processes within.

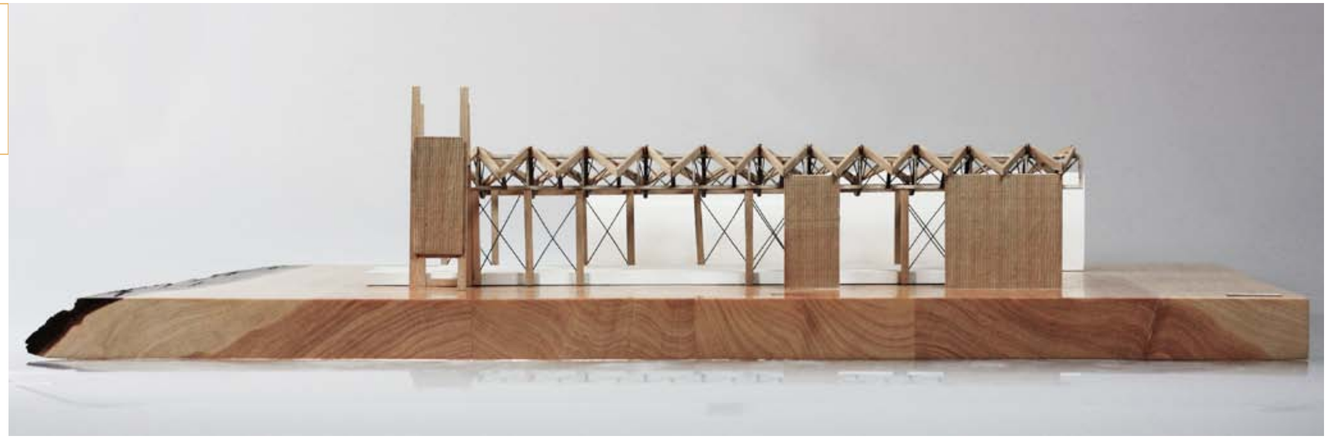


Fig. 5.4| Model photographs: Author's Collection

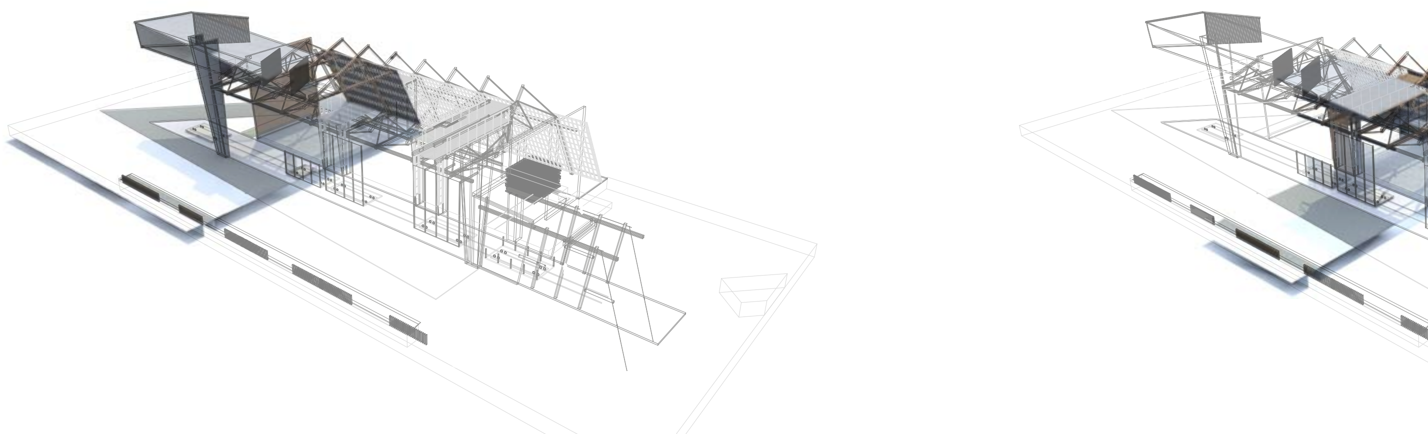


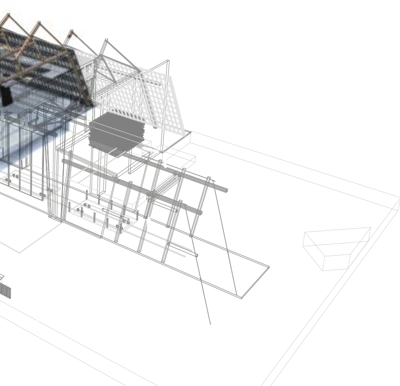
Fig. 5.5| Staging Diagrams: Author's Collection

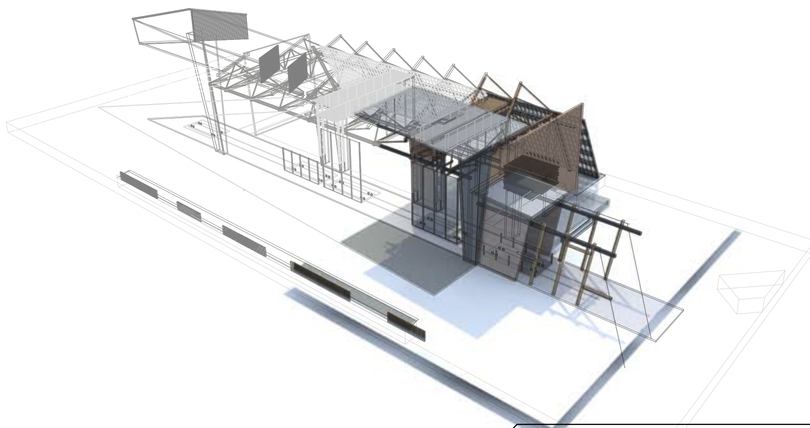
5.3 Production

The assertion of the dual movements facilitated by the truss design and experienced through production is emphasised by the integration of people and material movements, allowing points of confluence to evidence and define specific learning opportunities, while also defining the stages of the production into:

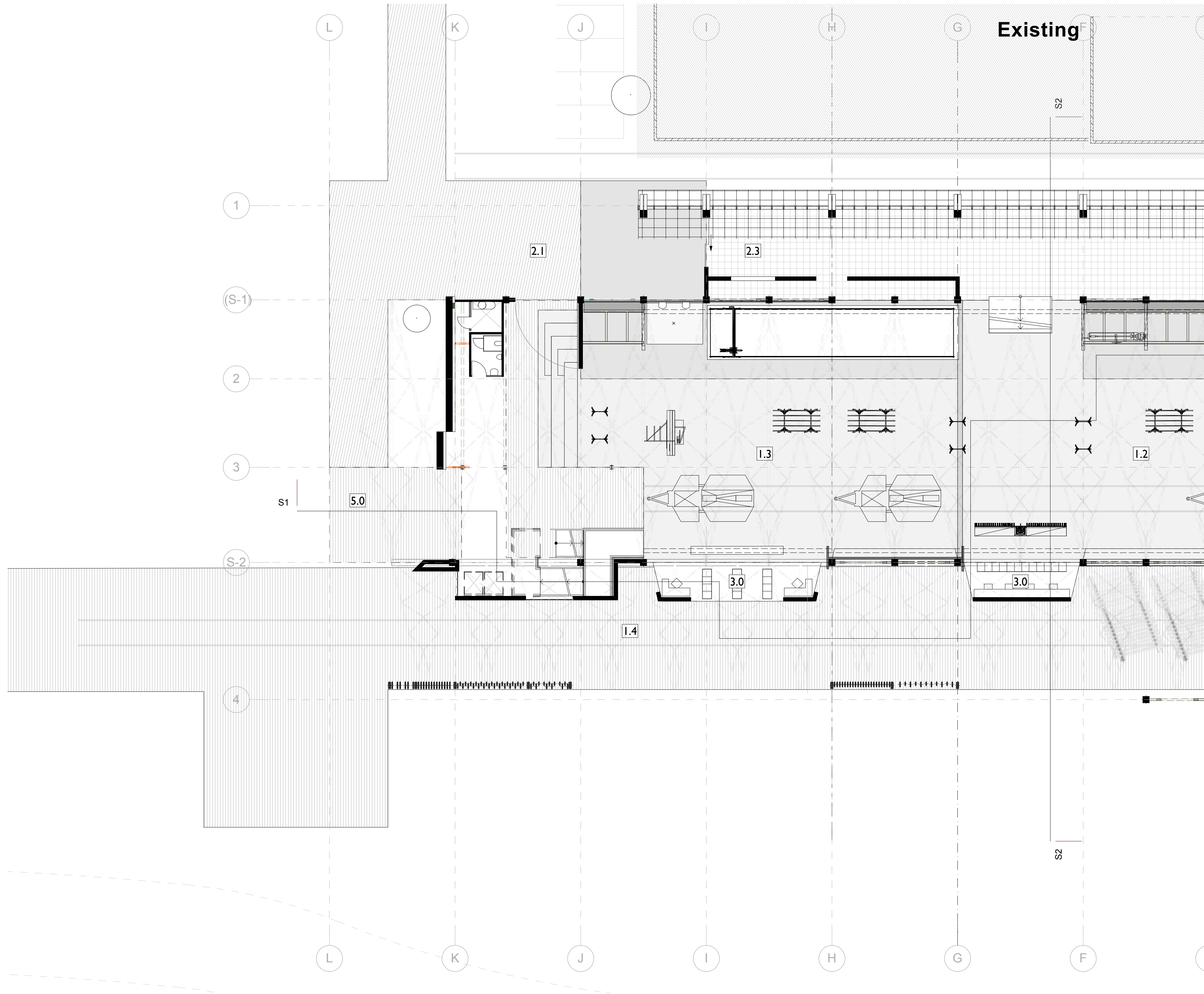
1. Material Processing-Exploration
2. Experimental Laboratory-Workshop
3. Assembly Workshop
4. Studio

It is at these defined stages where particular lessons of collaboration and practical hands-on design-construction explorations are reinforced and emphasised throughout the synchronised production and education processes. At these defining points for both production and education, the traditional understanding of authority is challenged allowing the production environment to transition to a position of collaboration.





STAGING DIAGRAMS



Existing
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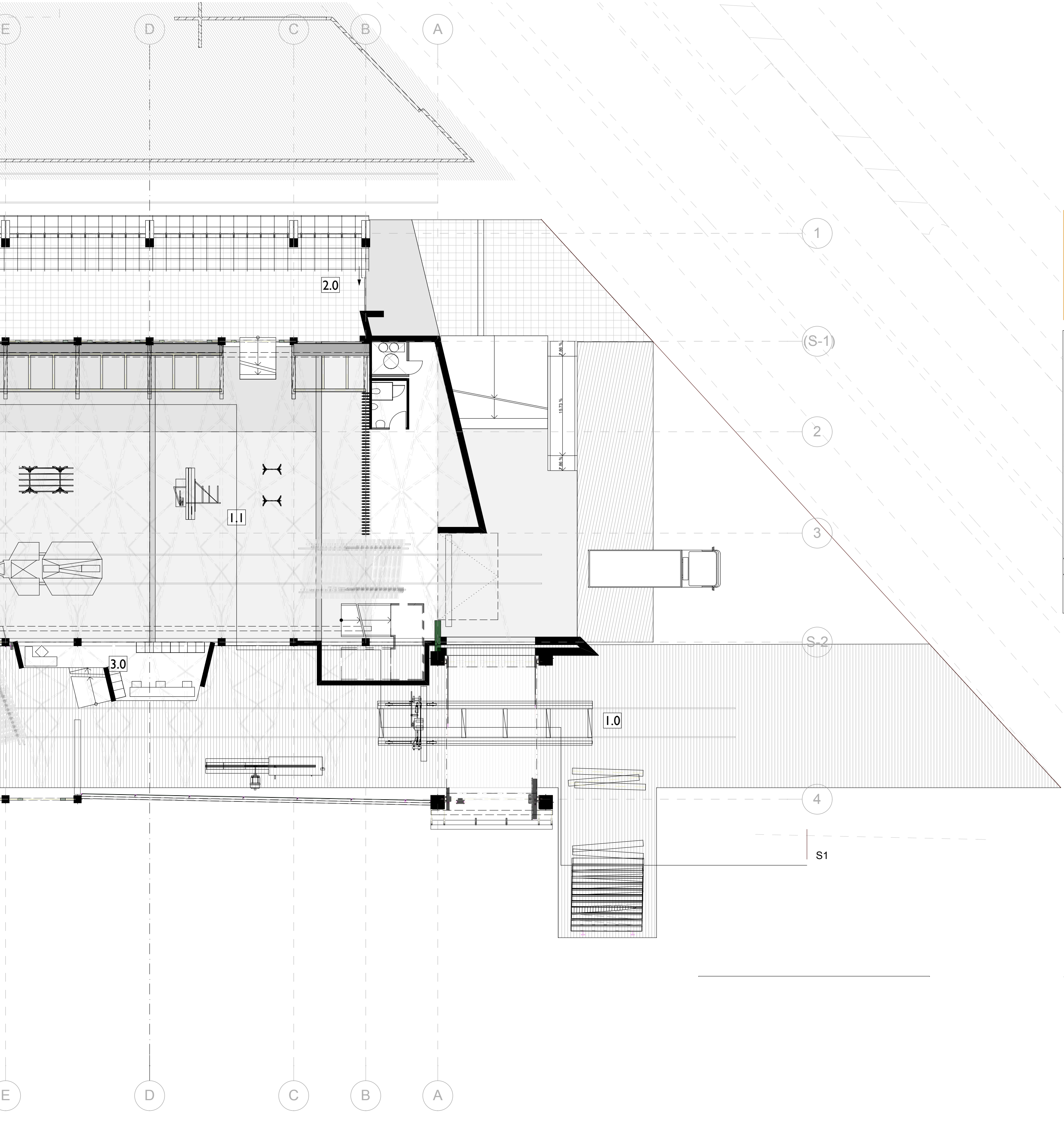


Fig. 5.6| Design Ground Plan: Author's Collection

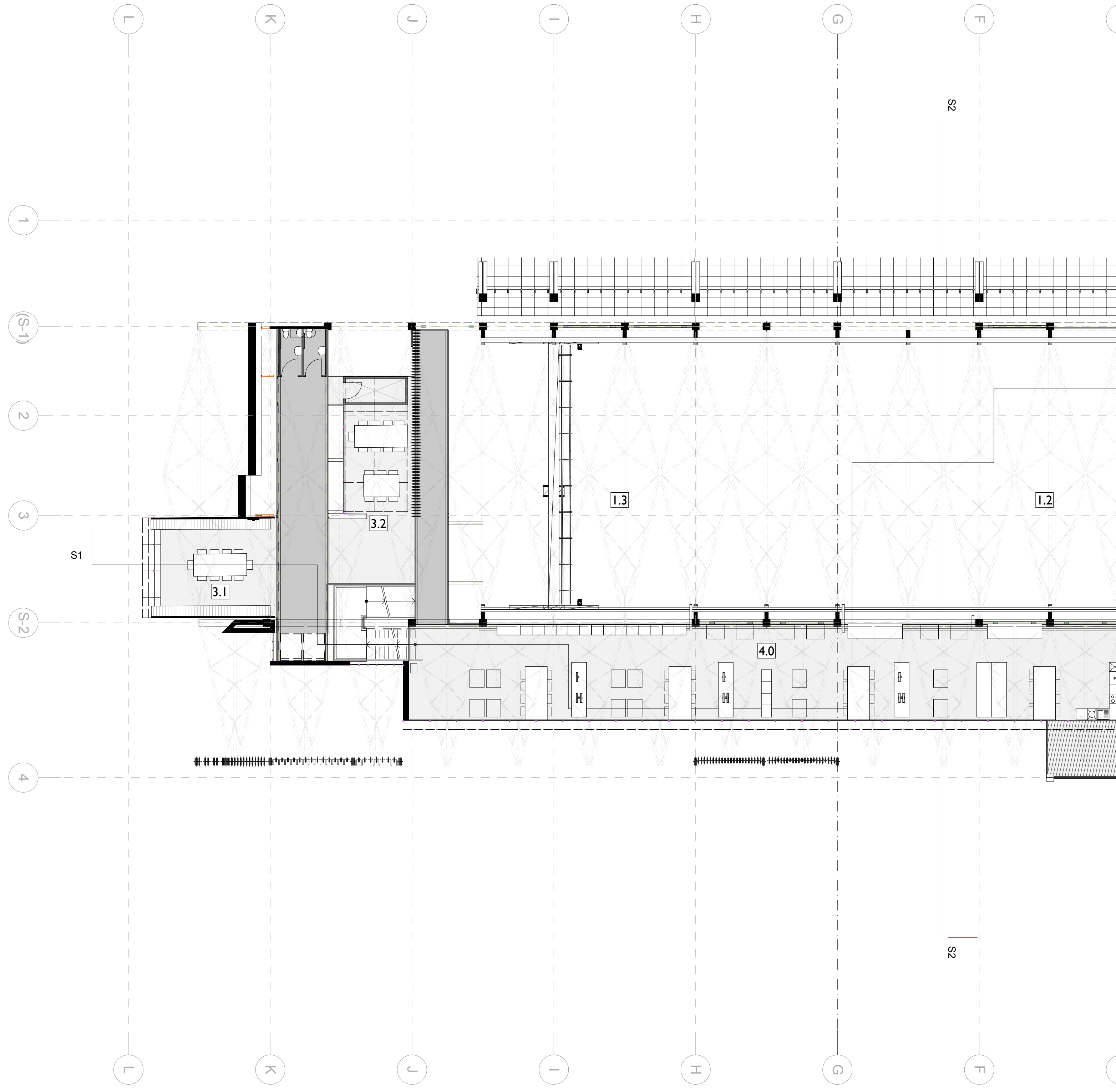
1.0 INPUT
1.1 Material Processing
1.2 Experimental Workshop
1.3 Assembly Workshop
1.4 Component Storage/Transport

2.0 Public Entrance/Gallery
2.1 Student Entrance/Courtyard
2.2 Cafe/Servery Kitchen

3.0 Staff Offices
3.1 Conference room
3.2 Informal meet/presentation

4.0 Digital/Analogue Studio
4.1 Kitchenette + Deck

5.0 OUTPUT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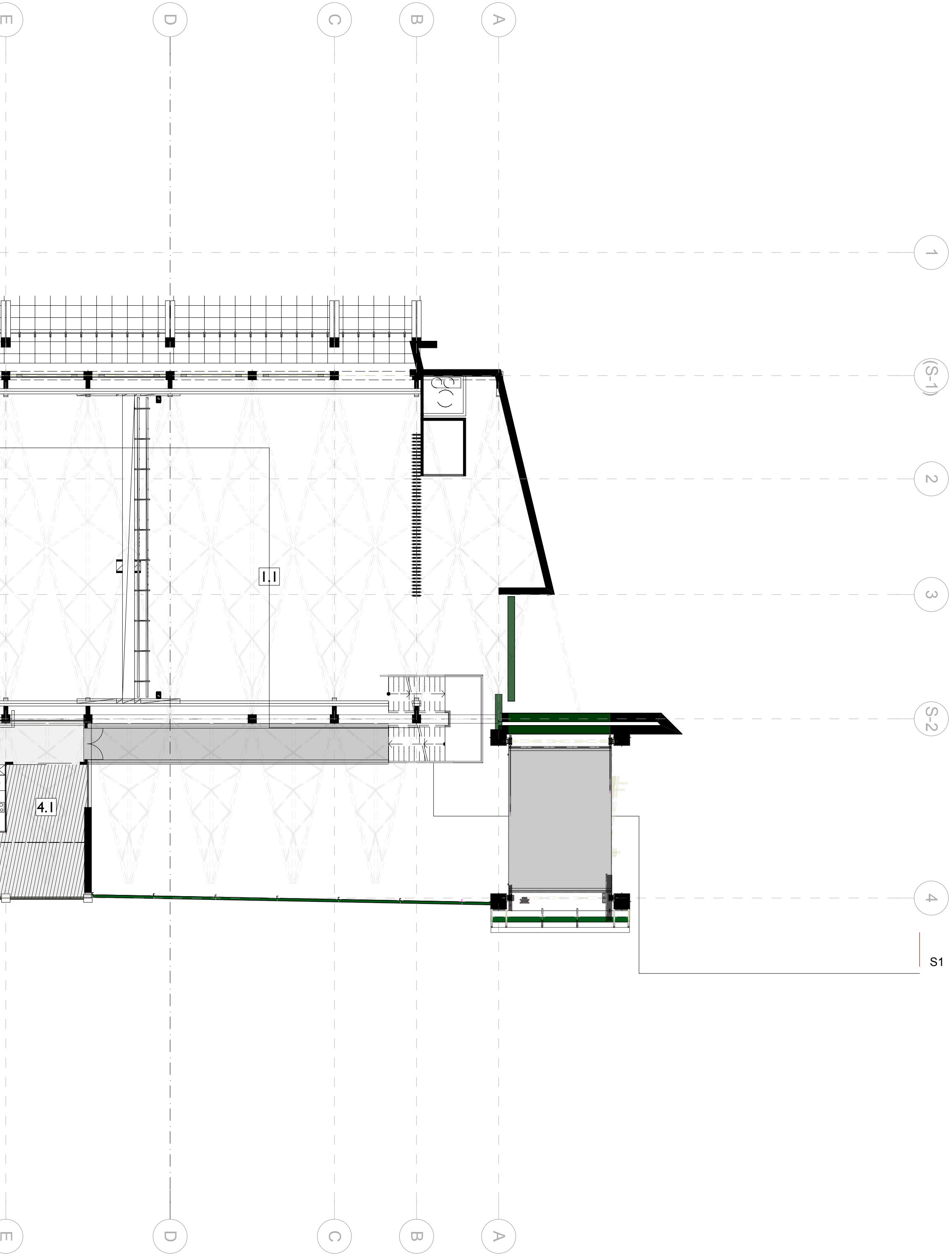


Fig. 5.7| Design Studio Plan: Author's Collection

1.0 INPUT
1.1 Material Processing
1.2 Experimental Workshop
1.3 Assembly Workshop
1.4 Component Storage/Transport

2.0 Public Entrance/Gallery
2.1 Student Entrance/Courtyard
2.2 Cafe/Servery Kitchen

3.0 Staff Offices
3.1 Conference room
3.2 Informal meet/presentation

4.0 Digital/Analogue Studio
4.1 Kitchenette + Deck

5.0 OUTPUT

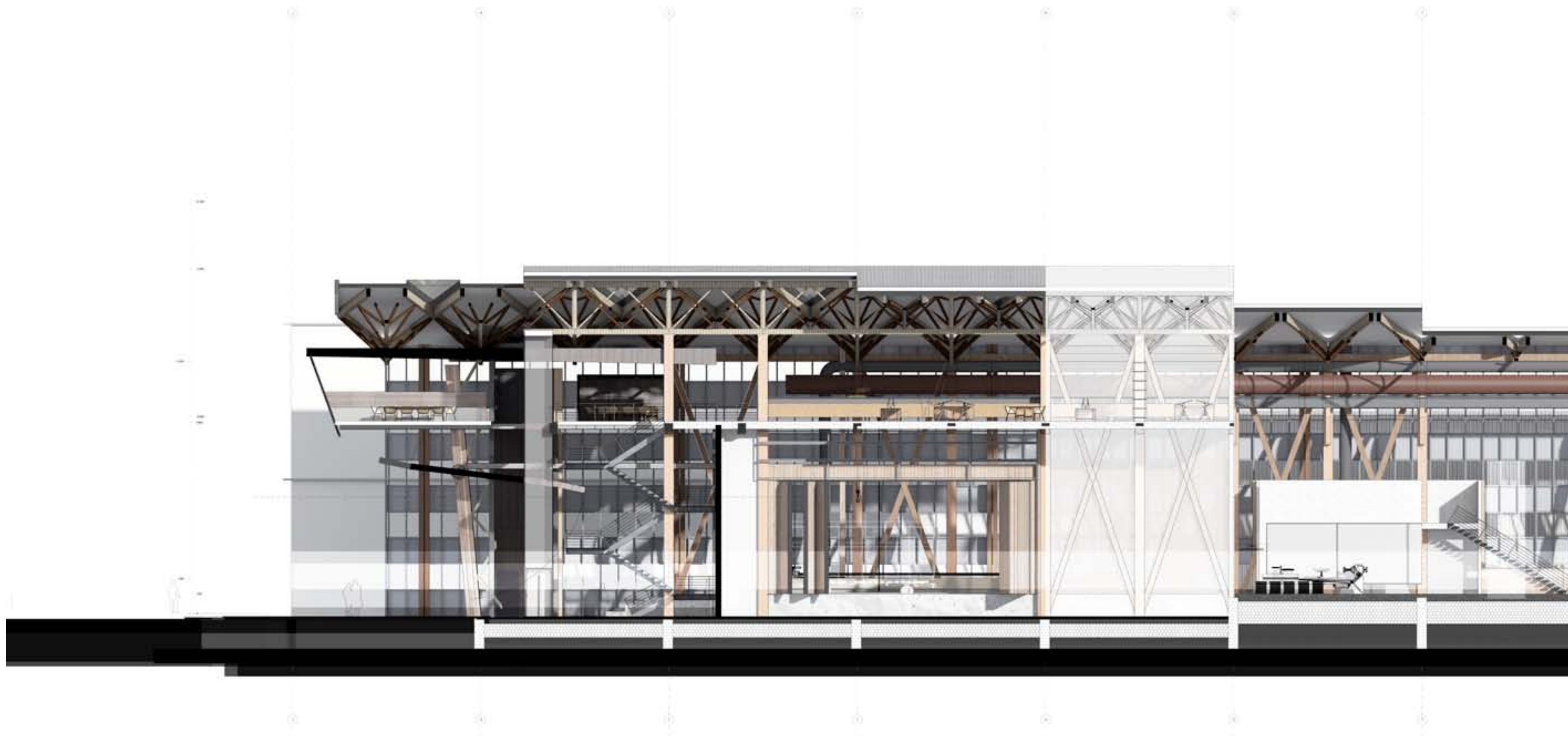


Fig. 5.8| S1 Longitudinal Stepped Section, rendered: Author's Collection

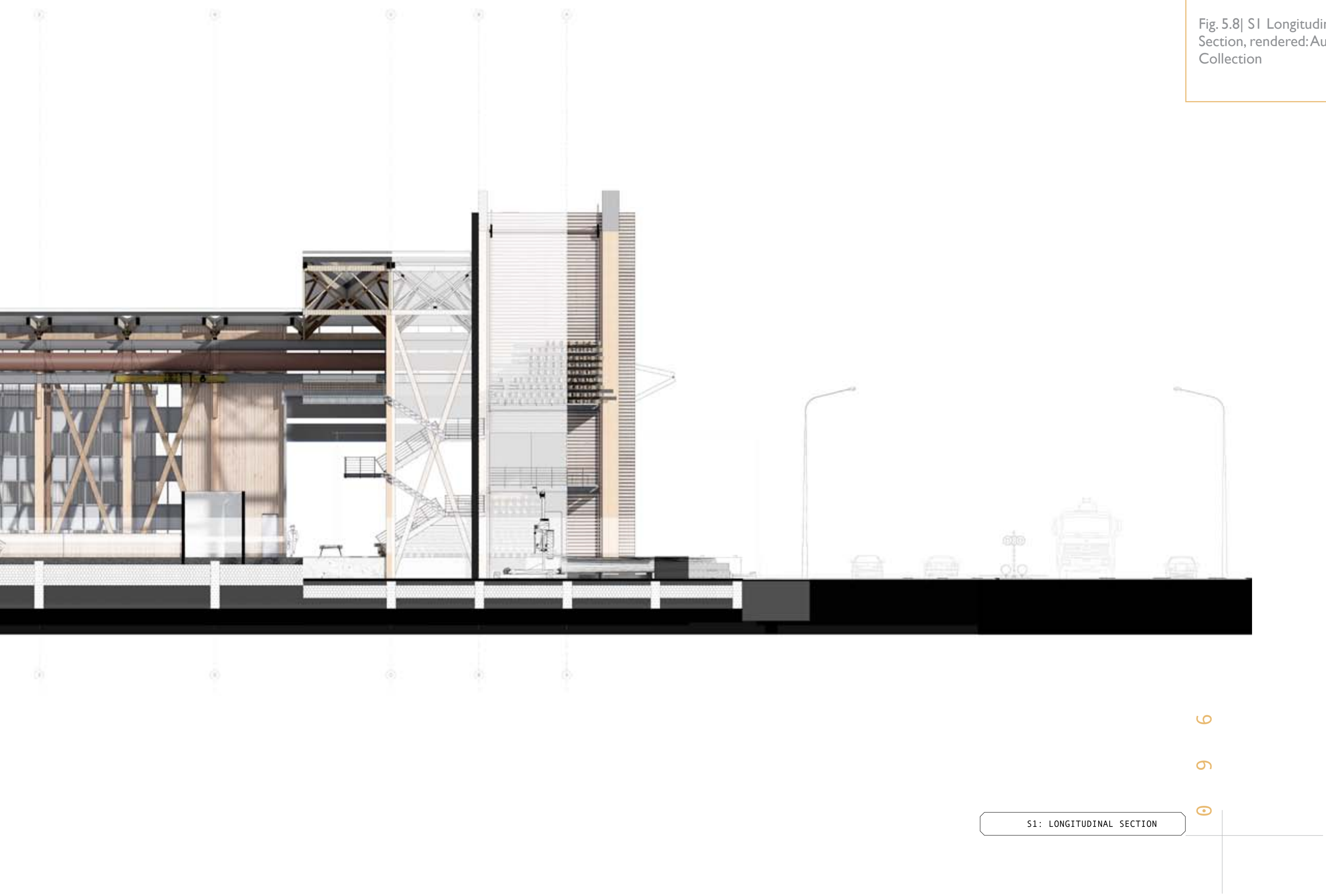


Fig. 5.9| North end, Log/Material Entry: Author's Collection

Design of a Trade Build Facility that is responsively adaptable to industry developments and technological advances allows a collaborative shift, primarily allowing shared skills to drive the operation of the spaces and prefabrication production. Summarised by Sennett, the architecture aims to return the driving force in production to further align with the design and/or construction qualities demanded by the subject of production. His writing also supports the architectural pedagogy proposed where an open-ideas apprentice based approach allows partnered and responsive production and educational systems that respond to emerging prefabrication approaches.

"A more satisfying definition of the workshop is: a productive space in which people deal face-to-face with issues of authority. This austere definition focuses not only on who commands and who obeys in work but also on skills as a source of the legitimacy of command or the dignity of obedience. In a workshop, the skills of the master can earn him or her the right to command, and learning from and absorbing those skills can dignify the apprentice or journeyman's obedience. In principle."1

The spread across the spectrum from industrial and raw inputs to highly refined outputs of production provides a dynamic and adaptable environment for architectural design and construction. Production begins with the Material Processing stage, where raw logs are processed, progressing into the Experimental Workshop and concluding at the Assembly Workshop where the completed and refined output is then transported to the site. The architect's understanding of this all-inclusive production process is pivotal in cementing their role that successfully orchestrates integrated specialists in a collaborative environment in prefabricated architectural production.

Fig. 5.10| Interior view from Material Processing floor to exterior Sawmill: Author's Collection

5.3.1 Material Processing

The importance of timber and the processing of the raw log to the production of the Trade Build Facility is founded in practical principles that facilitate the collaborative design and construction specialists to witness all stages of prefabrication production beginning with the material processing. This thesis argues that this approach contributes to activating an individual and/or collaborative understanding on unfamiliar stages in the production of architecture. The design of the boutique sawmill and vertical lift allows this to be realised and foregrounds the important notion of education amongst a diverse range of technical processes incorporated through architectural production techniques.

Due to the large and complex range of operations typical of a full-scale sawmill the main functions have been simplified into a smaller scale boutique sawmill. This scale aims to reveal the range of processes step by step, rather than being determined by efficiency targets and mechanised processes evident in operational sawmills. Utilising vertical production with an industrial service lift, individual steps of the milling process are elevated and become visible to the production facility. Once green timbers are cut, these are stored and dried using the cable lift, which is uncommon to conventional sawmills. The control over what type of timber is produced can vary according to the production demand; additionally manufactured timber and materials can supplement if required.

Signified by the large mechanical lift that anchors the beginning of the production process, the portion of intensive processing is external to the main building but remains visible both externally and internally. At the foreground and significant to the north end of the building is the industrial mechanical lift. This lift allows

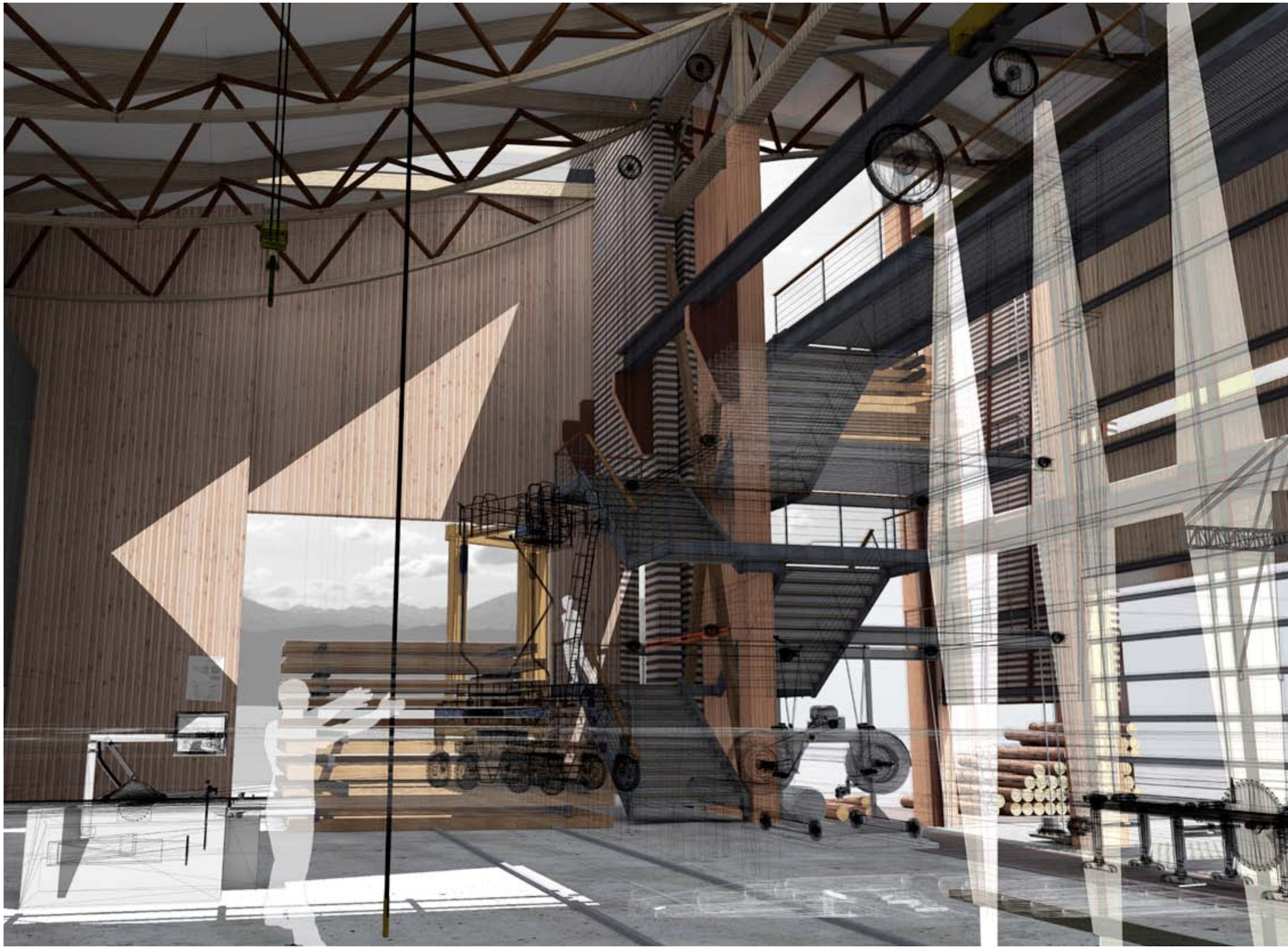


Fig. 5.11| Interior view through Material Processing floor and outward to the north of the building: Author's Collection

the extensive range of sawmill operations to exist in a confined space allowing the timber and logs to be lifted vertically, providing additional space and air-drying of green timbers. It is this architectural component that introduces the machine based system of the design that incorporates the required range of components as architectural devices operating within the designed system of production of the Trade Build Facility.

Timber has a grain. The different parts of the log reveal all the different potential uses for any piece of timber; it is predetermined from when it begins to grow. The architecture facilitates the ability for users to witness the systems that manipulate and define what the log becomes. Famously said by visionary architect, Louis Kahn, "'What do you want, brick?' Brick says to you, 'I like an arch.'"2 ; Similarly, this building invites the log to contribute to the final prefabricated design outcome. It is the building that allows the hi-tech collaborative world that we are engaged in and consumed by to understand these fundamental basics that without, our technology is useless. This establishes the responsive adaptability required in production facilities evidencing the ability for prefabricated architecture to represent innovative design approaches in the contemporary technologically driven industry environment.

It is this first of three production stages where the didacticism between the production and education processes becomes evident. This didactic relation is also referenced in the design experiment structural truss that represents the forces being resisted with selected specific timber members, primarily from the 'heart' of the log. By allowing responsive and dynamic experiences to manifest between the users and in this case the log, beyond what typical production facilities achieve, the Trade Build Facility facilitates the ability for dynamic prefabricated designs to be realised.

5.3.2 Experimental Workshop

The Experimental Workshop is the central zone of the Trade Build Facility where the majority of investigative experimentations on alternative production and design approaches develop. The main floor of the building that the Experimental Lab is centred on becomes the focal area to both the public portion of the facility and the educational mezzanine floor of the Studio, which both occupy the spaces on either side of the main production volume.

Flanked on the western side beneath sheet storage racks, the workshop provides a zone focused on medium scale (furniture) design-making production. This iterative making component at different scales of production is productive and transferable, allowing the established ergonomics to directly translate design directions of larger building-scale decisions through the assemblage of multiple components. The layout of this Experimental Workshop allows opportunity for design focus at this scale to influence larger more primary housing-scale production processes immediately adjacent, while also being adjacent to the Material Processing and Assembly Workshop on either side. The influence of the prefabrication facility truss design is important for its adaptability offered for multiple configurations of production while also the unique form created by the multiple members promotes innovative design and prefabrication approaches to be attempted.

The main experimentation and larger scale production occupies the central part of this primary production stage, where components can begin to be assembled on the manufacturing tables that traverse between the three areas of specialisation. Production and design experimentation tested at this stage is important educationally but also ensures responsive production

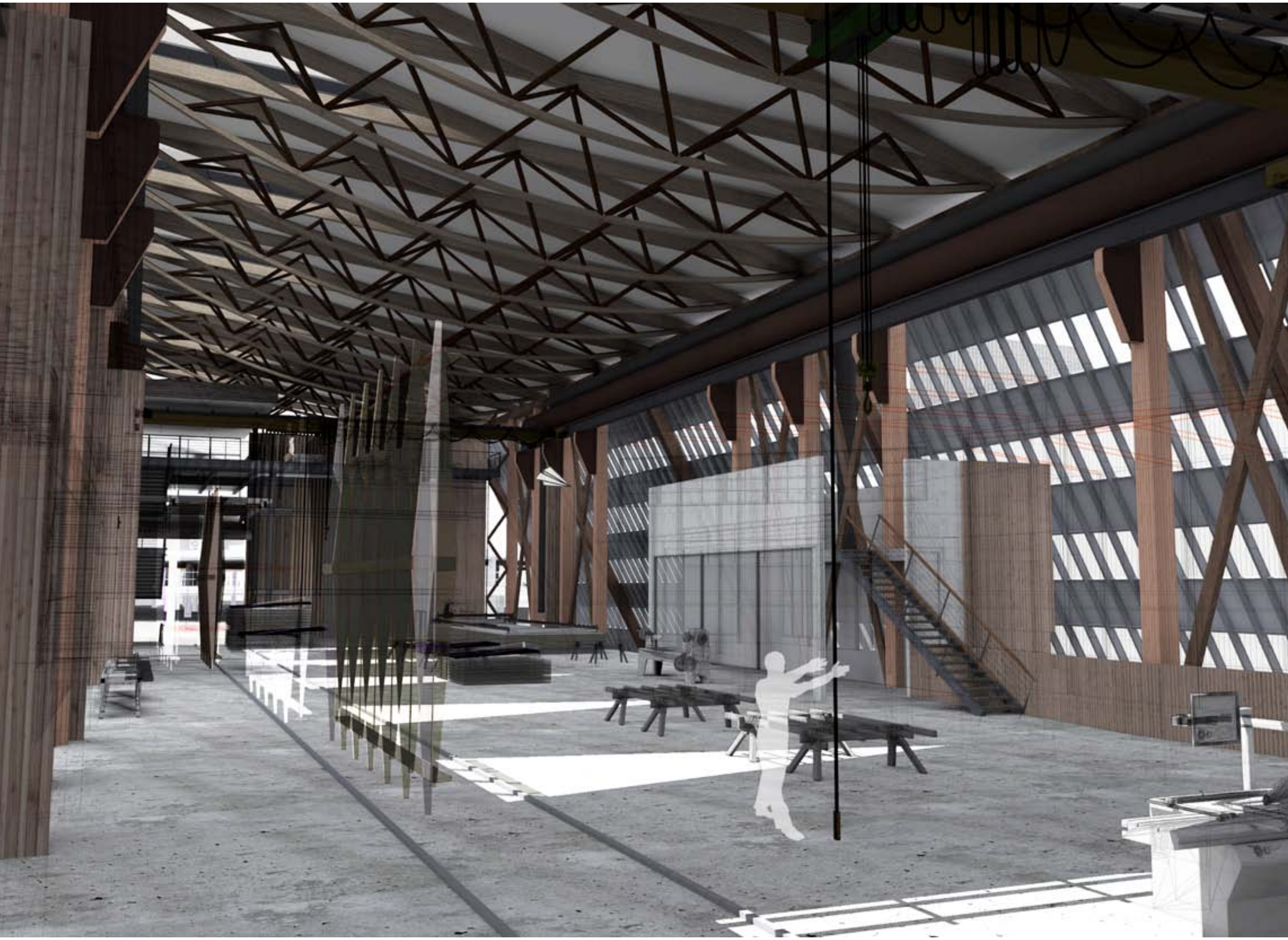


Fig. 5.12| Interior view along the production line southwards, looking through the Experimental Workshop to the Assembly Workshop: Author's Collection

outcomes referencing challenged and tested alternatives to prefabrication approaches.

Technological equipment providing complex digital manipulation of material includes a long 12m run CNC router along with a CNC lathe, and typical workshop equipment including drill presses, table saws, mechanical press, mitre saw and associated hand tools. Both pieces of CNC machinery are critical in achieving new constructional techniques and methods of assembly. The element of control achievable with this technology also allows qualities of craft to manifest in contemporary form, referencing the risk to the quality of the outcome through the continuous process of both design and construction. The detail becomes the primary driver in any design solution, as this design presents in this thesis.

An interesting tension between the disengagement versus the engagement of the detail arises through the assemblage of multiple components. The truss design of the Trade Build Facility evidences this engagement of the detail. Conceived based on a series of detail experimentations and subsequently establishing the overall system of design, the detail became fundamental to the application of the programme and functional requirements. The building evidences this friction as a positive response that is required to realise designs from an informed constructional point of view while retaining an engaged and detailed level of design.

5.3.3 Assembly Workshop

The Assembly Workshop is the culmination for multiple constructed components, while also the final staging area where the collaborative contributors congregate and review the production. The contributed inputs are unveiled revealing the refined innovative prefabricated product, representing the diverse range of disciplines and collective skills evidenced in the prefabricated architectural output.

This third and final stage of production includes the gateway and final information transfer point in the production process; the building in response leans away the end facade in anticipation of the output delivery. This also reveals the mechanics of the prefabrication facility where the structure and incorporated internal spaces are independent from the end façade, allowing architectural design driven techniques to be achieved. The space above this gateway at mezzanine level incorporates informal meeting rooms and a boardroom directly above the exit of the output, representative of the control room this space is where strategic responsive decisions on the direction of the Trade Build Facility are moving.

Located at the end of the production processes, output is adjacent to the main entrance providing opportunities for active interaction with the public while also allowing viewing of the final transformation point in the process, assembly or disassembly, before being crated and transported by ship, rail or road to its first application or use.

To graphically present the progressive transition of production processes evident in the Trade Build Facility, the Meudon House of Prouvé has been included as an exemplar prefabricated house. Illustrated throughout the assembly line the rendered views of the design references the Meudon House as a historical example of prefabrication. Exploded into the series of components the design exists in a disassembled and assembled state at each end of the assembly line.

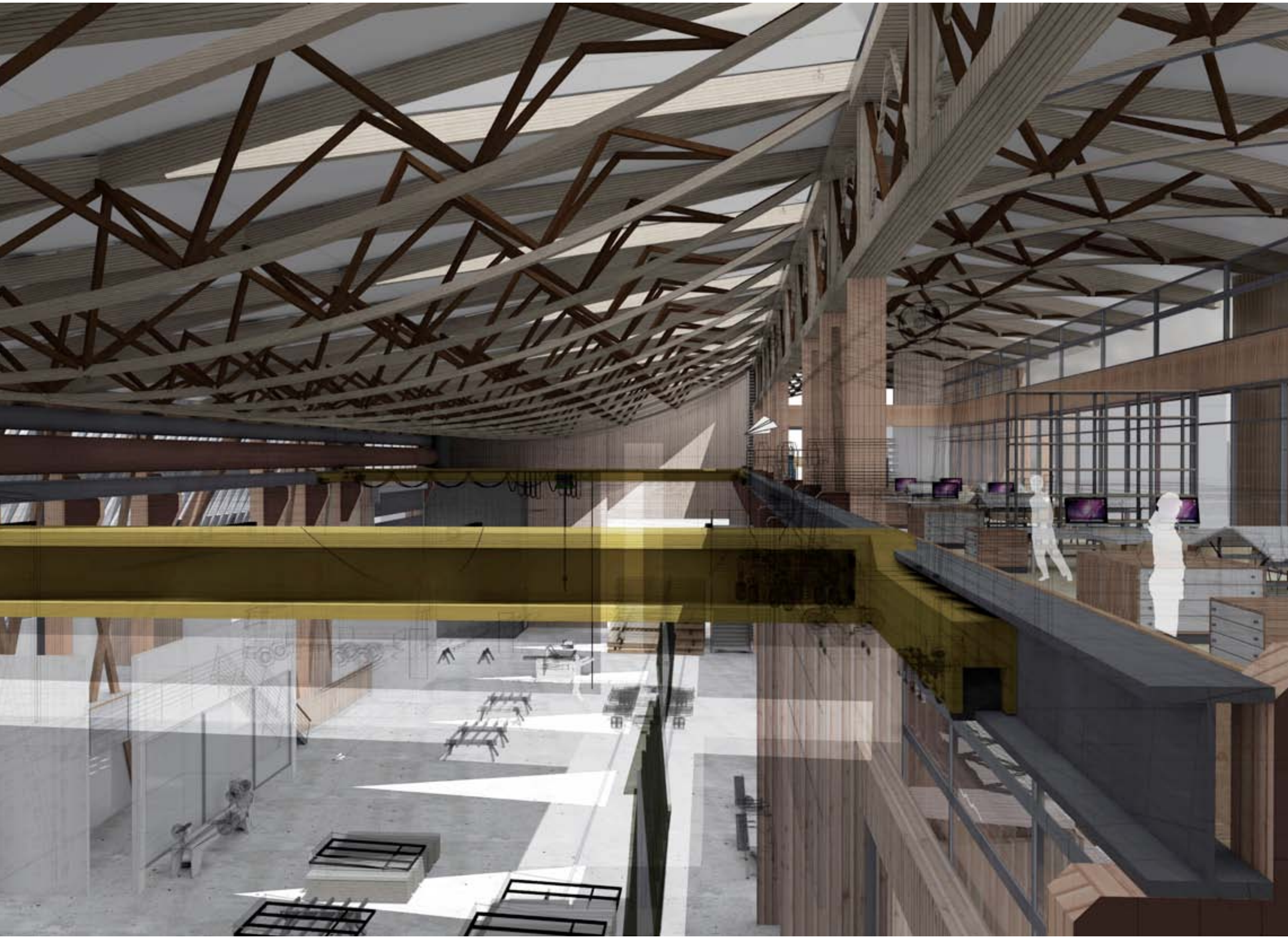
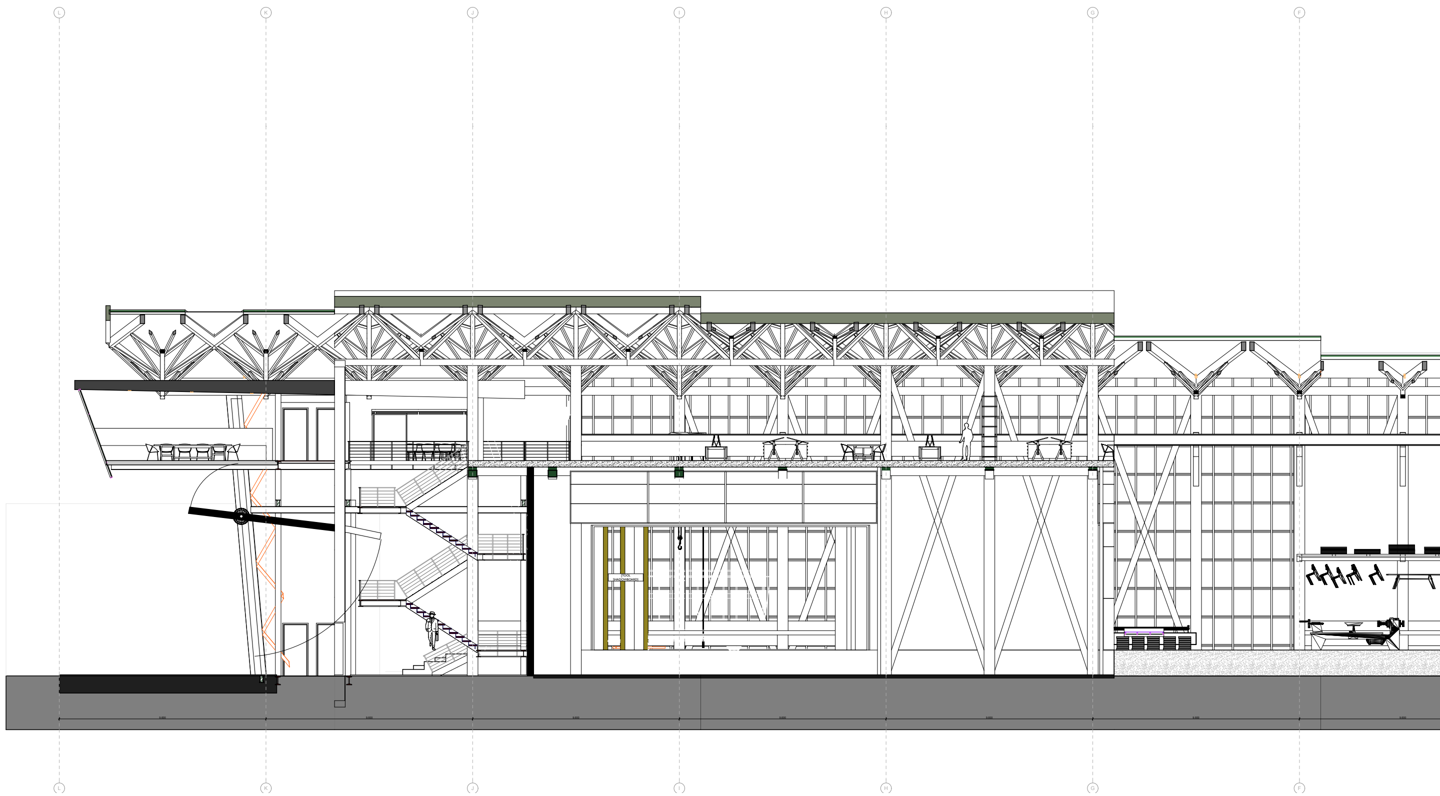


Fig. 5.13| Interior view from Informal Meeting Area (3.2), down the main production volume with raised mezzanine Studio space: Author's Collection



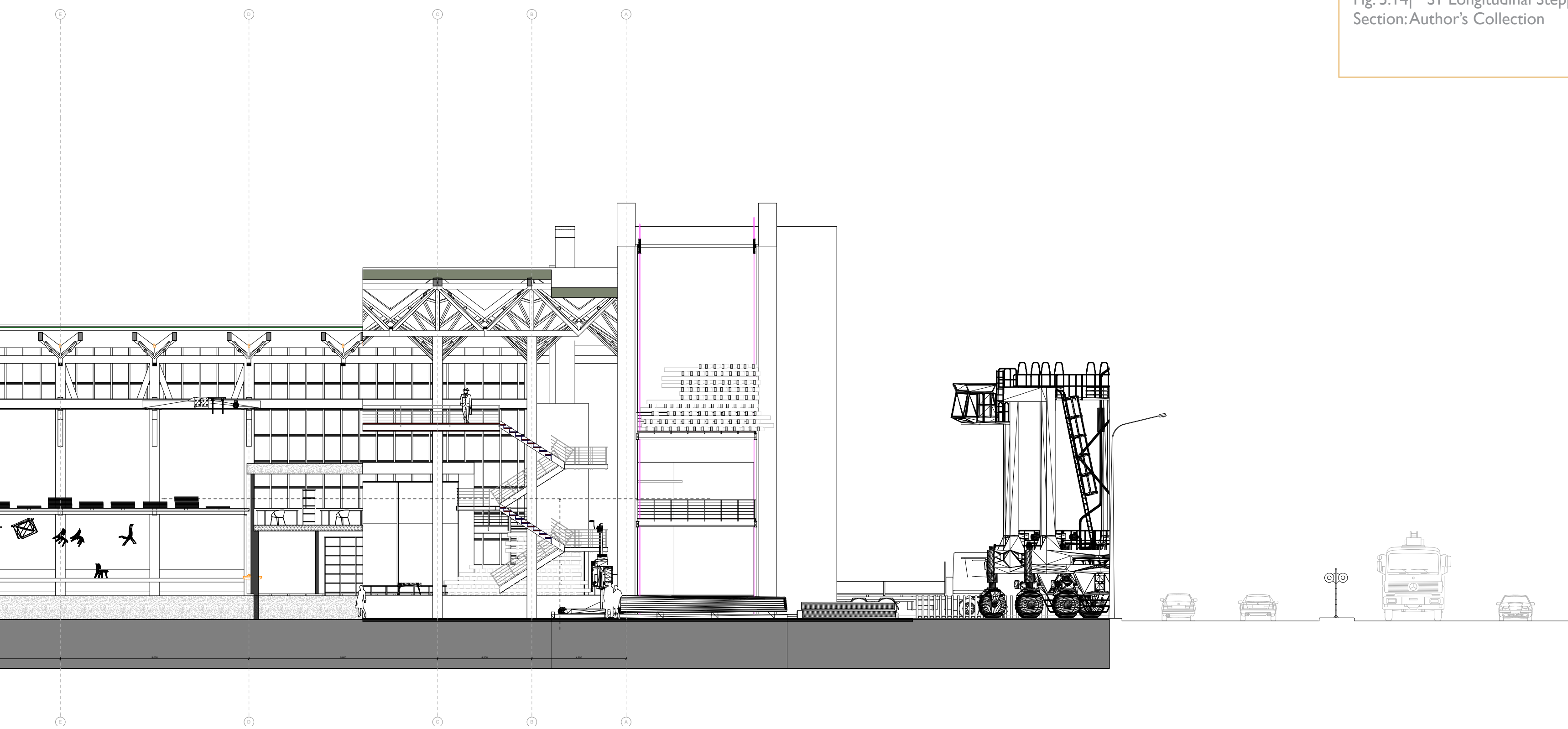
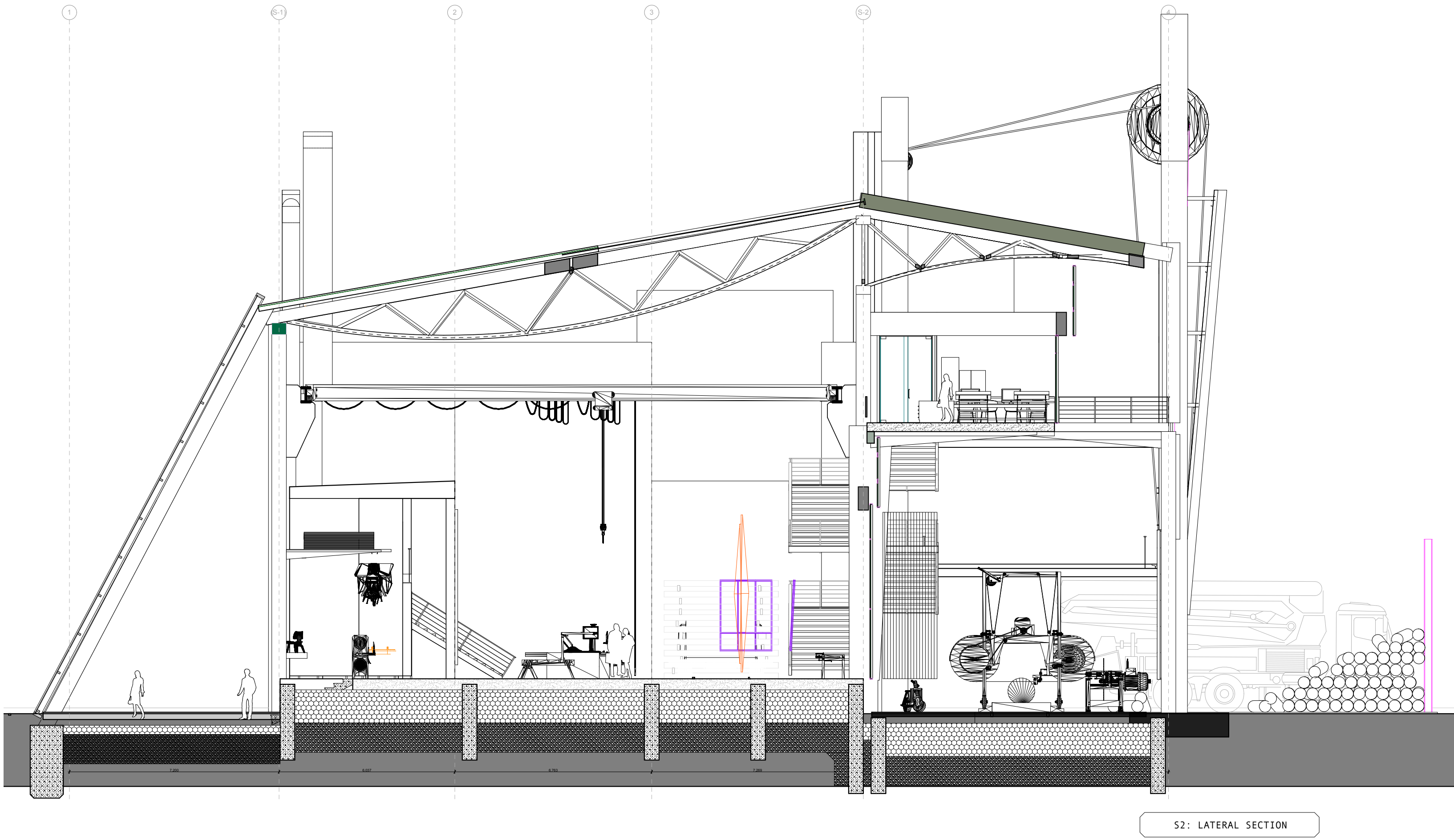


Fig. 5.14| S1 Longitudinal Stepped Section: Author's Collection

Fig. 5.15| S2 Lateral Section:
Author's Collection



5.3.4 Studio

The secondary zone to the main workshop area of the facility is the mezzanine suspended above the ancillary offices and support space while overlooking the production processes below. Architecturally the influence of the truss design to the Studio space involves a finer grain of truss. By inverting the triangulation to that of the primary long-span unit, the truss cantilevers with the mezzanine volume. This enables the architecture to traverse the objective design barrier typical of the discipline, where it achieves an experiential quality that is reflective of a constructional approach to design that is also accessible to the user.

This separated Studio space, the primary educational zone, allows climatic separation from the immediate operations and processes of the main production spaces, aligned more towards the creative realm albeit still retaining a sense of technical pragmatics.

The Studio space introduces a third scale of production iterations focused on the hand scale of tactility. The focus on the upper mezzanine level is scaled handcraft, in contrast with below where the body and machine scales are the focus. Between the different approaches and range of scales, all have transferable design opportunities that build on the experiences encountered through the design build continuum of prefabricated architecture.

5.4 Spatial Planning

The main workshop space was developed as a singular open volume. This in combination with the truss design allows adaptive space that can be integrated with the dynamic and technologically challenging state of industry. In addition to future based industry opportunities and developments the design invites the education realm of the building industry to productively challenge conventional approaches alongside the engagement of prefabrication with the public. The design location along with exposure of the production processes to the public through; the structural truss system utilised, raised floors and a programme that activates multiple engagements within the field of prefabrication, provides the premise for the spatial layout of significant ancillary and educational spaces.

Strategic symmetrical shifts in the plan that interact with the production stages and structural truss allow the size of the building to be broken into manageable and more conceivable parts. Divided principally through the middle the planning also references symmetrical characteristics to the adjacent Material Processing and Assembly Workshop stages, each setup on secondary axis. The spatial planning allows the facility to provide:

- An environment that accommodates spatially adaptable capabilities for design that are responsive to emerging alternatives of timber prefabrication.
- Facilitate the ability of the prefabrication facility to act as an educational facility for different specialists and architectural students to simultaneously witness and participate in prefabrication processes.
- Evidence the ability of the prefabrication facility as an architectural exemplar that provides a productive learning tool for architects wanting to maintain design control over architecture designed as a prefabricated “repetitive” system.

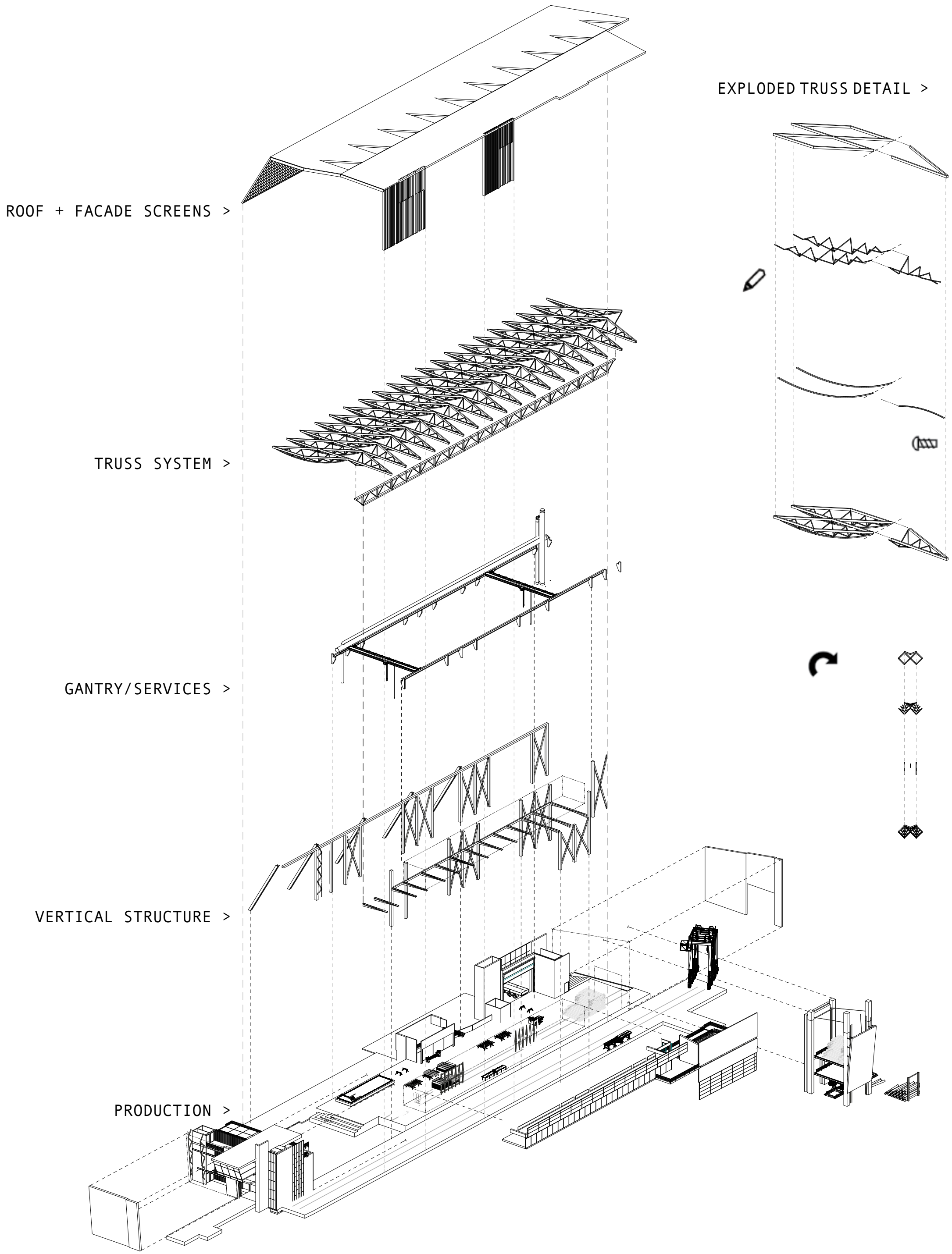


Fig. 5.16| Exploded Axonometric, Design mechanics: Author's Collection

The three points highlighted each reveal dynamic qualities while also providing a tectonic language that is represented in the responsive dual nature of the truss. Additionally these outcomes provide a logical arrangement system for the support spaces that incorporate: offices, tool and machinery storage, technician rooms, refreshment zones, staff and student areas and meeting rooms. These outcomes integrate aspects of the programme while reinforcing the dynamic nature of production and the opportunities for education in emerging approaches to the prefabrication of architecture. This is a way of fully engaging the processes within, while also allowing the pragmatic requirements to occur and exist with the building opposed to simply within.

5.5 Integration of Production and Education

The curriculum proposed to operate within the Trade Build Facility is intended to model the iterative design research process undertaken in this thesis. Principally it is a dynamic process where dualities between design and making, collaboration and authorship, craft and the machine develop through the interplay of design from the detail and component outward. The proposed curriculum incorporates students from all building industry disciplines along with practitioners and distinguished 'masters', similarly diverse, which make up the adaptive apprentice-based pedagogical structure.

With this adaptive approach, neither production nor education exists alone, allowing a unique combination of programmes in partnership with the building to become the main learning operatives.

It is through the defined stages of production and the junctions between the production stages parallel to the truss, that specific points of interaction occur between modes of design and construction. These junctions are the principal points where knowledge and information is transferred, providing productive learning experiences through hands-on 'design by making'3 principles.

As a means of closing the loop and further reinforcing the integration between production and education, selected educational outputs in the form of wall panels, stairs, handrails and so forth will be applied to the architecture. This process ensures the facility adapts and retains a leading presence into the future, while allowing the experimentation to respond with the architecture that becomes the Trade Build Facility.

Fig. 5.17| Top view, Model photographs: Author's Collection

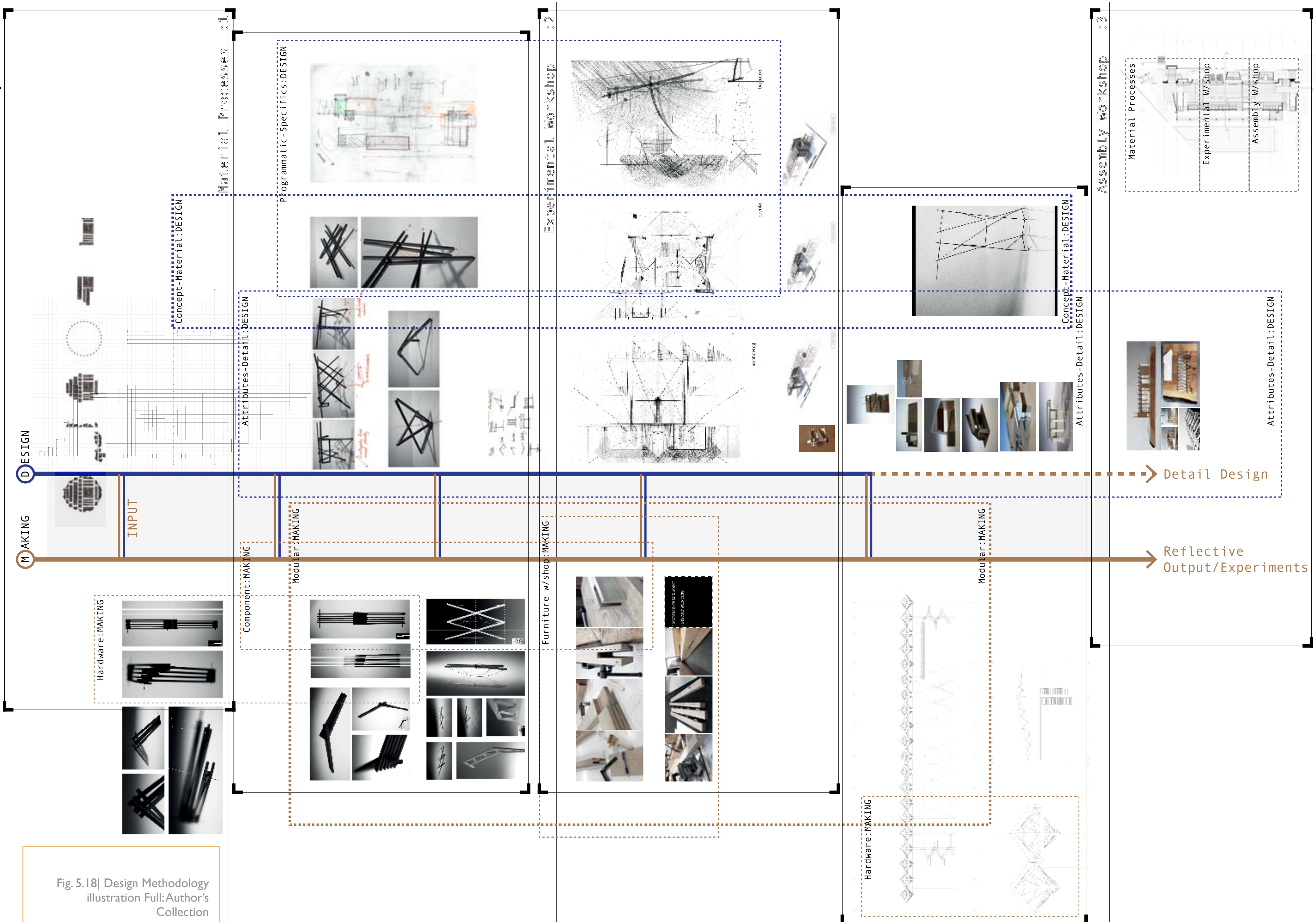


Fig. 5.18| Design Methodology illustration Full: Author's Collection

Through the design research process as a precursor to this final design, collaborative design experiences representative of multi-disciplinary inputs have manifested piece-by-piece, resulting in the assemblage of components of the Trade Build Facility. Implicated within the greater system of design pragmatics and spatial arrangements of production and education processes, the design progresses beyond the typical production 'shed' typology. The diverse range of processes operating within the facility engage the strategic adaptable design of the truss, while providing a responsive environment able to adopt changing production approaches and technological advances. The collaborative and adaptable environment created for prefabrication production provides architects the ability to evidence a high level of design individuality, recognisable detailing and extensive habitability in prefabricated architectural housing units.

I Sennett, The Craftsman, p 54.

II Kahn, What Will Be Has Always Been. p 89.

III West, "Thinking with Matter." p 55.

Fig. 5.19| North end, Log/Material Entry: Author's Collection

Fig. 5.20| Southeastern view towards the Westpac Stadium: Author's Collection

CONCLUSION

Due to the defined scope of architectural prefabrication that focuses on timber, one of New Zealand's most prevalent building materials, this design experiment has provided suggestive insight into why prefabrication as a production alternative to timber housing is not positively adopted. The contemporary timber prefabrication production facility 'shed' typology is restrictive and forms a compartmentalised working environment, typically separated from material sources and more importantly design. This thesis argues that the typical architectural design of production environments is less responsive and spatially adaptable to emerging developments and alternative approaches, contributing to the systemised and repetitive nature of prefabrication output. Furthermore, the need for a collaborative environment between the diverse ranges of specialists is not being met by these typical approaches to production facilities. This has in part contributed to the diminished evidence of shared authorship in collaborative environments through design and construction processes, resulting in fewer qualities of craft in prefabricated architectural outcomes. In the context of prefabricated architecture this thesis recognised that these qualities are critical and needed to be integrated within cohesive work environments of prefabrication facilities. This is essential in order for the architect to produce outcomes that are representative of a high degree of design individuality, integrated detailing and contemporary technical functions of habitability; this enhancement also contributes to furthering craft and authorship in the context of prefabrication.

As a result of improved technological developments in combination with tougher economic and technical demands of the building industry, the efficient and cost-effective alternative of prefabrication becomes more and more important to the building industry. Typical prefabricated outputs of repetitive and utilitarian character, however, are not reputable market alternatives.

The design research addressed the prefabrication problem through an investigative design approach for a responsive and adaptable production facility. This approach was aimed at developing a framework for a prefabrication facility that facilitates the specialised and collaborative building industry to cohesively engage qualities of craft through design, challenging standard approaches to prefabricated architecture.

Selected case studies explored a range of attributable situations; beginning with the Frankton Junction Railway House Factory which incorporated material processing and delivery advantages, the Centre for Architectural Structures and Technology which incorporated public engagement with a primarily educational base of production, the Stanley Modular facility which successfully incorporated multiple scales and adaptability through fluid layouts, followed by Jean Prouvé who provided historic examples of progressive production techniques. A common theme between the selected case studies was a specific focus on process over product, a link emphasising the importance for integrated construction processes alongside design processes. This thesis extends this design focus even further, by using the detail-based approach beginning with the truss as the catalyst for the entire design inception.

The responsive and spatially adaptable nature demanded of a production facility was the defined focus for the design approach. An equal balance between design and construction was required to ensure a veritable level of adaptation was achieved. In order to achieve this level of adaptation including a feasible level of production a large-scale building was essential.

This posed a design problem where the economic viability was under question and site requirements were extensive.

The industrial based programme required a large-scale site located within the public realm, allowing an educational interface between the architecture, the production within, and the public to manifest. The primarily technical and pragmatic requirements of the facility required transportation, firstly of material, raw and manufactured, and consequently the transportation of the prefabricated architectural output. The site located on the border of Wellington's port provided an economically viable situation for educational innovation of prefabrication to manifest. Located within an operational port the industrial environment commanded an industrial style building, parallel with the scale of operation specified by the programme. The movements of the port operations including on-site materials and facility outputs, have been employed as design contributors that ground the design as a part of the existing industry operations, infrastructure, and public engagement. One of the main advantages the site location provides is the reconciliation between industrial and public environments; architecturally these dualities are continued through the partnering of education with the production processes within the facility.

The C.A.S.T. facility discussed by Mark West[I] provides a building where the principal component collapsing the distinction between design and construction is limited to curriculum. The architecture provides a public interface with the functions within; however, the productive association between the building and the educational and production processes is subliminal. The Trade Build Facility develops beyond the C.A.S.T. case study and incorporates the stages of production actively with the architecture; the integrated two productively provide educational opportunities to the range of students and practitioners within.

Through Richard Sennet's theoretical research on the notion of craft, the importance of "…progressive learning techniques, that do not separate the work of the mind from the hand." [II] are highlighted. This becomes an important theme through the dual programmes promoting cross-accommodation in a dynamic and responsive industry environment. Additionally, through the exposure of the production processes the architecture allows accessible learning through each progressive stage, consequently providing both the users and the public insight into the creative and pragmatic components of prefabricated architecture. This interface with the public is also present in the analysed C.A.S.T. facility.

The thesis initially employs the design process as an adaptive learning tool that forms the basis for the education curriculum and the operation of the dual spaces within. Architectural techniques establishing multiple scales, directionalities, and productive partnering of the dual programmes with the adaptive architecture allowed the two typically opposed programmes to productively coexist. Additionally through specific design and making explorations testing the contemporary understanding of collective skills and shared authorship, qualities of craft were allowed to manifest in the structural roof components with these becoming further implicated in the greater system of design. This provided opportunities for the building to influence the learning and production within, through emphasising the need for a productive partnership between design and construction in an empowered environment. Spatially the primary educational zone which focuses on hand crafted fabrication is separated from the main production workshop hall, suspended as a volume within the greater volume of the design; it is representative of the finer timber grain and the micro scale of production. This differential in scale between the volumes continues the dual design conditions foundational to the research solution.

The conflicting nature and standard conditions typical to the two opposed programmes potentially introduces an incompatible environment. The design experiment mediates this in two ways, including the separated space of the mezzanine, along with integrated space managed by the education curriculum through the main production workshops. Similarly the expansive and ambitious range of production processes proposed may present operational issues in a commercial capacity.

Due to primarily pragmatic issues of noise and ventilation demands, the design has provided two main volumes with specific climatic conditions ideal to each of the programmes, however the two merge and share operational components. In response to the vast range of processes implicated and the operation of these in a commercially viable capacity, the Trade Build Facility would need to manage the educational income against production costs in order to operate a cost neutral production component of the facility. The educational benefit does however utilise the production as the primary base of the curriculum.

The architectural proposition to design a prefabrication production facility that is responsive and adaptable in order to maintain a cohesive and technologically advanced position, that is similarly able to engender qualities of craft in the design of emerging prefabricated architecture, is emblematic of the greater conventional architectural situation in the contemporary industry.

As evidenced through the production case studies, which operated at a time of crisis, the housing shortage currently experienced in New Zealand and pronounced in Auckland provides a suitable and comparable situation to the Trade Build Facility. Key Indication Rates (KIR) for the month of December 2012, present an average rise in national housing costs of 5.7%[III] along with a significant imbalance between the high demand and a shortage of supply. Along with rising construction costs these two factors of national economic significance in relation to a housing shortage provide major opportunities for a reinvented form of prefabricated low cost well designed timber housing.

In conjunction with this housing shortage the likelihood of architects contributing to this housing demand is minimal. Based on international statistics architects involvement is estimated to be between 5-7%[IV] of newly built houses; this has significant potential to increase.

Through changing perceptions on prefabricated architecture with an established integration of craft in the design and construction processes, it is envisaged that a high degree of architectural individuality, detailing and robust habitability will be represented in the prefabricated outcomes.

With opportunities for a contemporary take on prefabricated production approaches, there are significant and sustainable opportunities for a model of production as presented through the Trade Build Facility. Additionally, the industry has an opportunity to integrate this prefabrication approach, establishing a low-cost architecturally designed alternative in the housing market. Similarly this opportunity provides options for implementing architectural design to a wider audience, through an essential adaptation of typical production approaches. As an architectural graduate close to entering the industry, it is exciting to possibly become a part of a more responsive and adaptable work environment producing architecture that is widely accessible.

There is opportunity to advance prefabrication production approaches further. The design research presented in this thesis is focused specifically on small-scale housing units and only suggestive of how this may be implicated in larger-scale designs. The same framework of production and educational processes could be applied to larger-scale and more complex designs, assuring authorship in collaborative workflows that actively encourage qualities of craft to be engendered in the architectural outcome.

This thesis has explored alternative prefabrication production environments incorporating responsive adaptability in the collaborative work environment as a means of evidencing craft in architecturally designed prefabricated architecture. Adoption of the approach and principles presented on alternative production environments allows an opportunity for prefabricated architecture to shift, becoming a desirable alternative, as opposed to only a cost-effective alternative.

I West, "Thinking with Matter." p 55.

II Sennett, The Craftsman. p 124.

III Department of Building & Housing, Key Housing Indicators.

IV Moore, "Factory Direct"; LaBarre, "Truth in Numbers: A Look at the Origin of Architecture's Motivational '2 Percent' Statistic—and Why It's Wrong." p 31.

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LIST OF FIGURES:

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VICTORIA
UNIVERSITY OF WELLINGTON

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Fax 0-4-463 5209
Email Allison.kirkman@vuw.ac.nz

MEMORANDUM

TO	Jonathan Hay
COPY TO	Daniel Brown
FROM	Dr Allison Kirkman, Convener, Human Ethics Committee
DATE	4 October 2012
PAGES	1
SUBJECT	**Ethics Approval: 19462 Architectural Indicators**

Thank you for your application for ethical approval, which has now been considered by the Standing Committee of the Human Ethics Committee.

Your application has been approved from the above date and this approval continues until 15 December 2012. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Allison Kirkman
Human Ethics Committee

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Consent for the use of information in the thesis:
'Architectural Indicators'

Investigator: Jonathan James Hay
Supervisor: Daniel K. Brown. Program Director Interior Architecture
T. [+64 4] 463 6129
E. Daniel.Brown@vuw.ac.nz

This form is to confirm that I ..Ben Miller....... give **Jonathan Hay** permission to use facts, information and advice discussed at our sessions in his thesis named **Architectural Indicators** as a part of Jonathan Hay's Masters of Architecture (Prof) at Victoria University.

I consent to the use of the information, facts and advice discussed to be published under the following terms:

a) The use of such discussed facts and information will be quoted and referenced to the undersigned.
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c) Sections of the thesis that contain the information discussed will be given to the undersigned to read prior to publication, and changes will be made to suit the requests.
d) No liability lies with the undersigned for the facts, advice and information discussed in meetings, and will only be used on an academic basis to aid in the theoretical thesis Architectural Indicators.
e) The technical information, facts and advice will not be used outside of the theoretical basis of the thesis.
f) At any point the participant has the right to withdraw, this is allowed up to the 15 November 2012.

Signing Page

I ..Ben Miller..... consent to the terms discussed above.

Signed ______________ Date 20/11/12

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Signing Page

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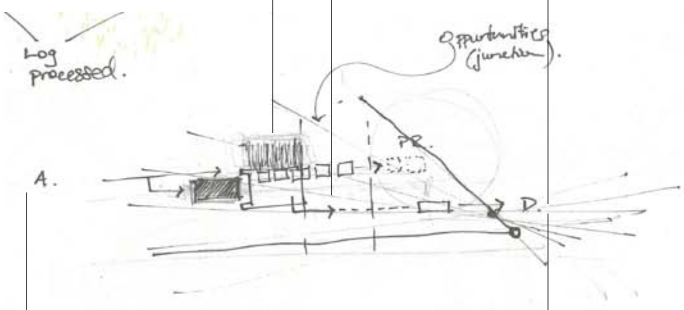
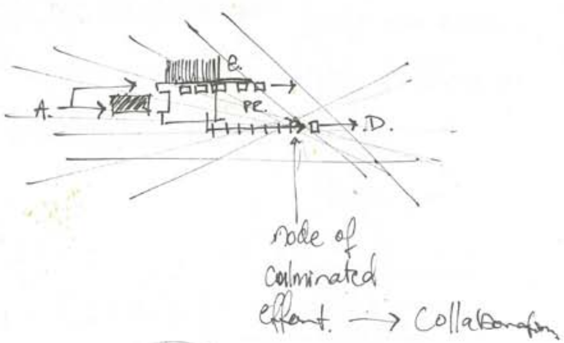
Signed ______________ Date 29.10.12

IV explorations

: Crafting- iterative jointing and making







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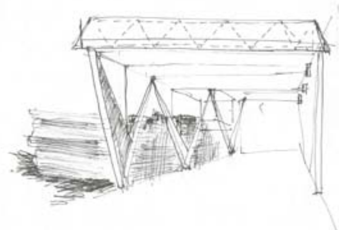
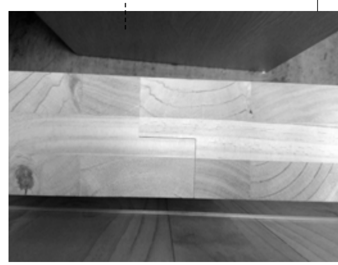


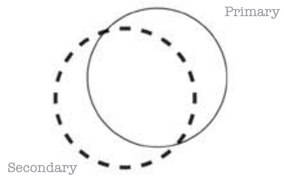
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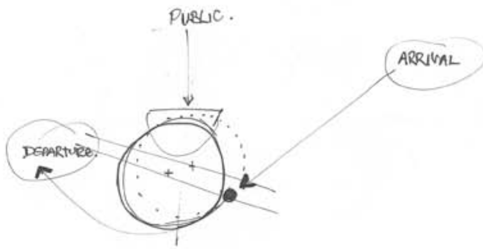
Secondary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ARRIVAL
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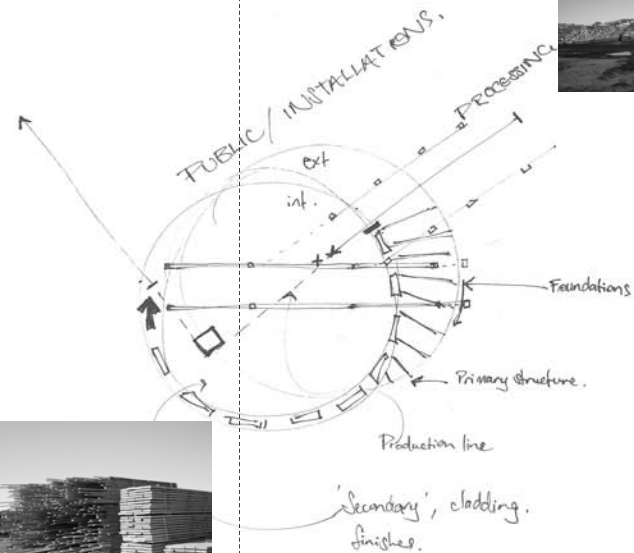
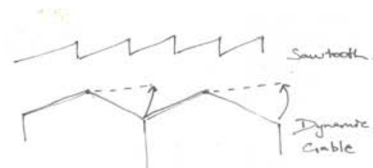

PUBLIC / INSTALLATIONS.
PROCESSING
ext
int.
Foundations.
Primary structure.
Production line
'Secondary', cladding.
finishes.

RADIAL


DESIGN
CONSTRUCTION
INDUSTRY FLOW
Disjointed, not aligned.
site axis.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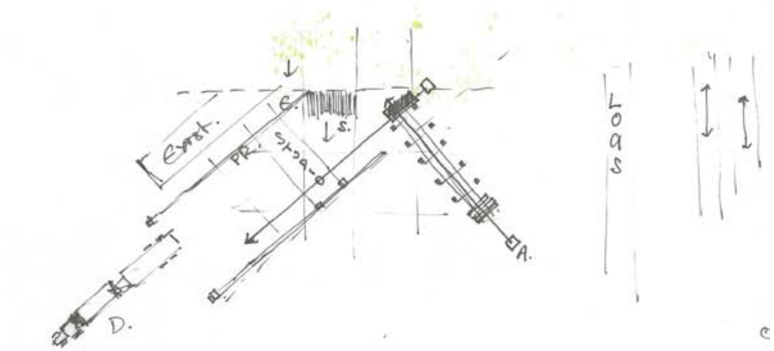
Dynamic Gable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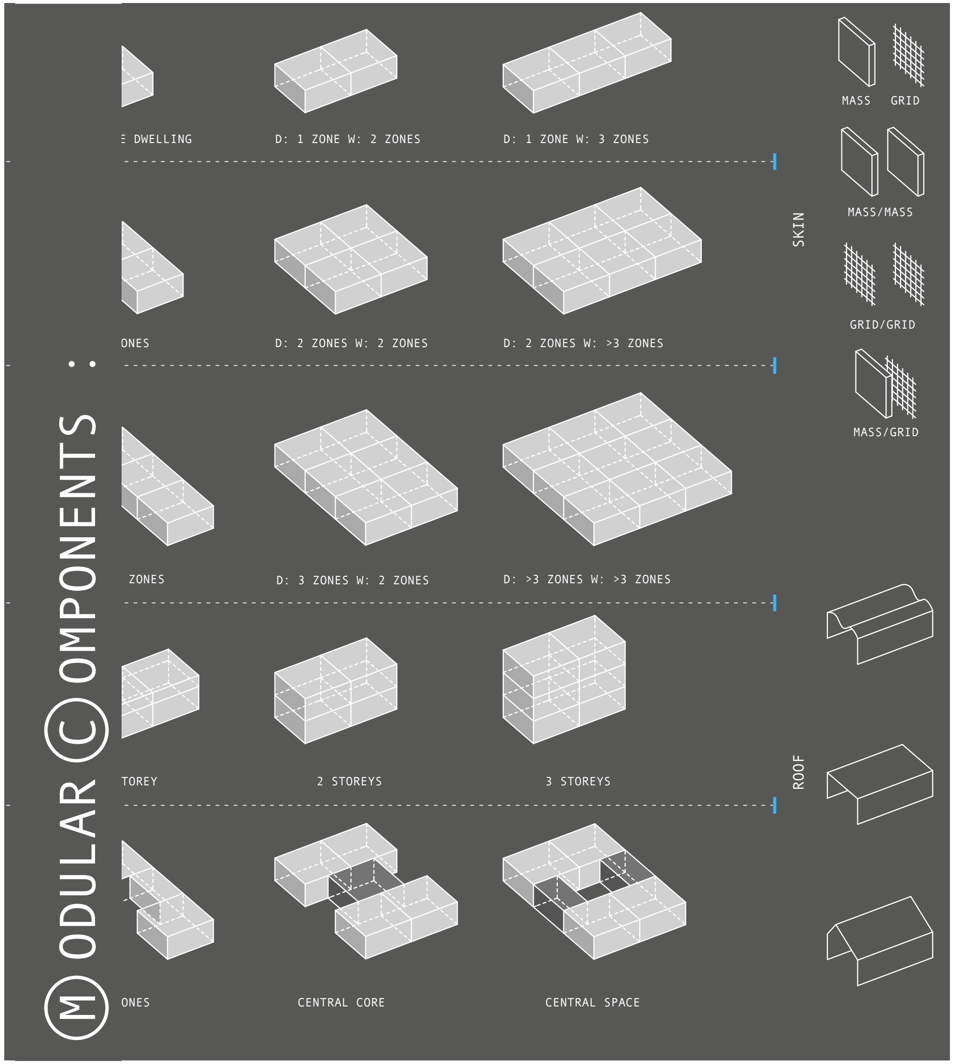
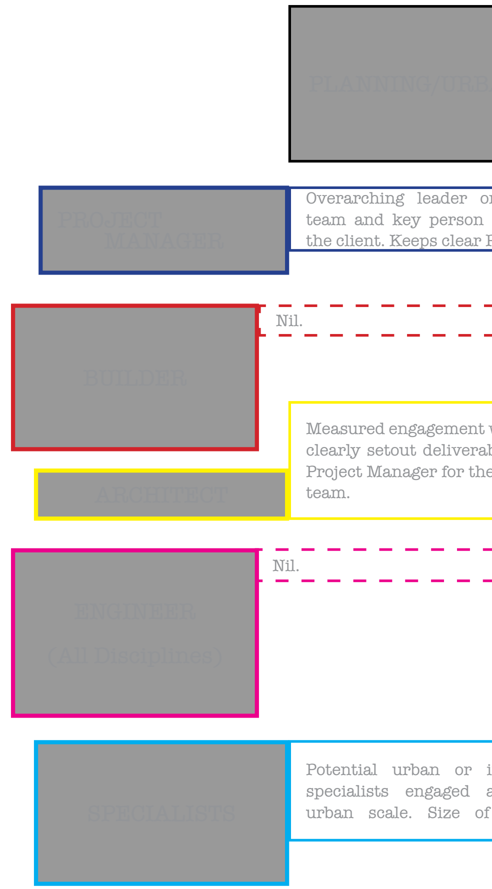
Logs
A.
D.

AXIAL



CURRENT PRACTICE/ENG



AGEMENT MATRIX

AN SCALE	CONCEPT DESIGN	DEVELOPED/PROTOTYPE	CONSTRUCTION/ IMPLEMENTATION	POST-OCCUPATION
n the project responsible to PCG objectives.	Monitors costs and helps to align the design with the available budget.	Directs the entire project team and ensures all logistics for construction, consents, and delivery are realised.	Manages all aspects of the construction, running site, PCG, and client meetings. Reports to the client on all aspects. Controls the information flow between all parties.	Defects period and follow up construction work.
	Nil.	Tendering process for Main contractor to complete and deliver the project to a defined budget and time schedule.	Reports to the Project Manager and follows a formal information flow. Single contract to the client through the contract engineer (PM), with subcontractors below.	
with the client, oles set by the e entire project	Critical design stage where the client needs to be more involved to ensure the design direction is on-track. Major design decisions signed off prior to developed design phase. Key areas requiring specialists arise.	Documentation phase and increased design detail developed. The longest phase of the project. Also includes material and finishes, further developing the concept and aesthetics of the design.	Observes site progress and designs further details/alterations if required.	
	Provide structural and design feedback alongside the architect at a high level stage.	Complete detailed design and construction documentation including associated producer statements required for Building Consent, and construction.	Nil.	
nfrastructural at a master/ development	Project Specific.	Project Specific.	Project Specific.	

PROPOSED PRACTICE/EN

PLANNING/URI
SCALE

PROJECT	Overarching leader o team and key person the client. Keeps clear l
BUILDER	Nil.
ARCHITECT	Measured engagement clearly setout deliveral Project Manager for the team.
ENGINEER (All Disciplines)	il.
SPECIALISTS	Potential urban or i specialists engaged a urban scale. Size of

GAGEMENT MATRIX

BAN E	CONCEPT DESIGN	DEVELOPED/ PROTOTYPE	CONSTRUCTION/ IMPLEMENTATION	POST-OCCUPATION
n the project responsible to PCG objectives.	Monitors costs and helps to align the design with the available budget.	Directs the entire project team and ensures all logistics for construction, consents, and delivery are realised.	Manages all aspects of the construction, running site, PCG, and client meetings. Reports to the client on all aspects. Controls the information flow between all parties.	Defects period and follow up construction work.
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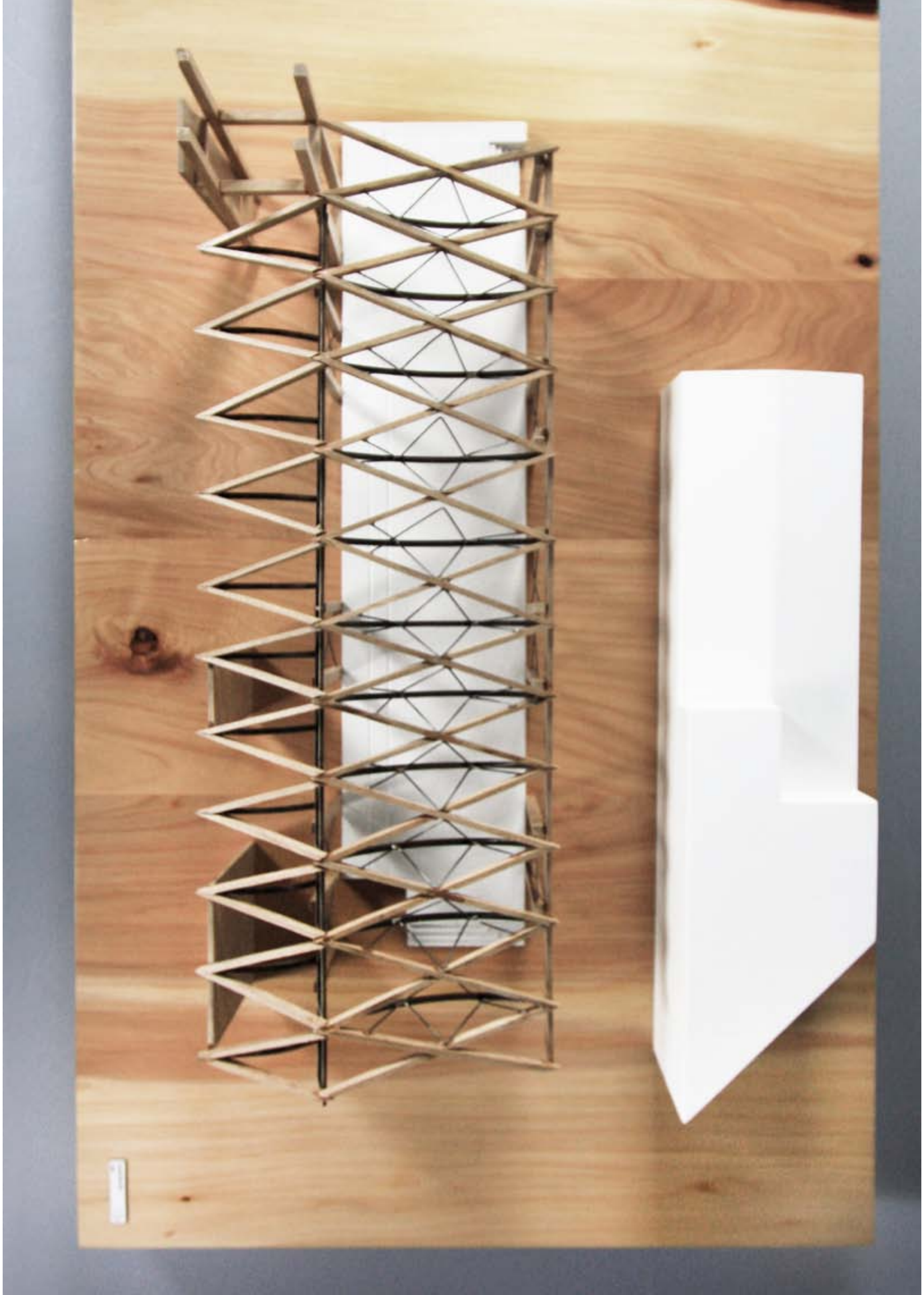
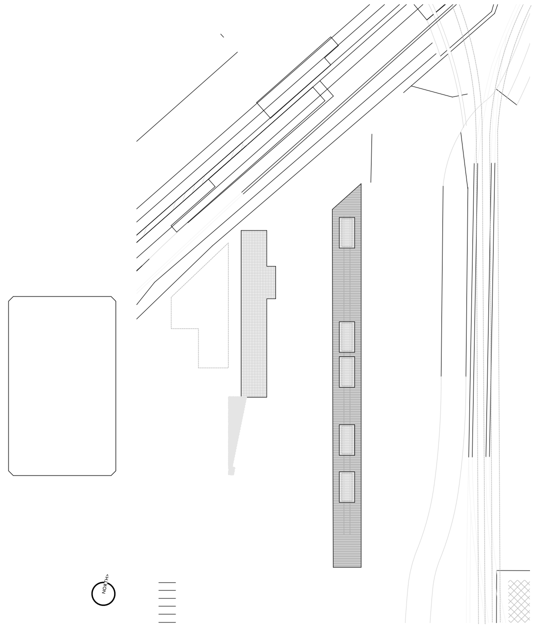
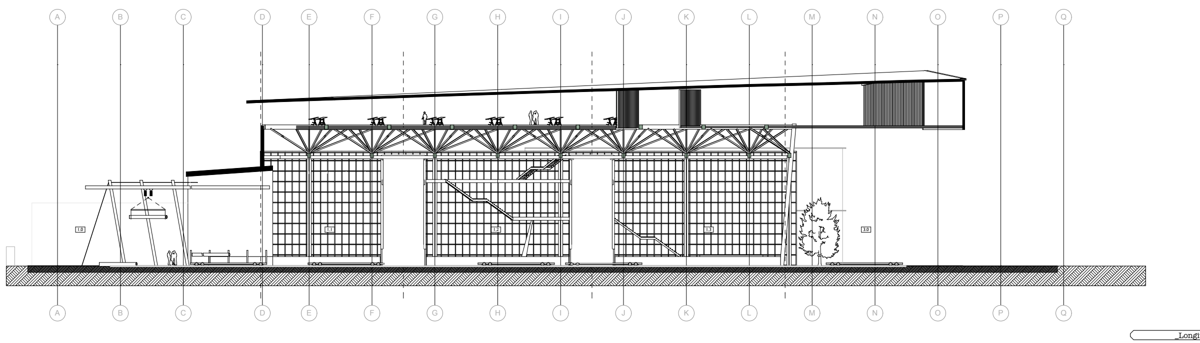
nfrastructural at a master/ development	Project Specific.	Project Specific.	Project Specific.	



INTERIM DESIGN (MID-YEAR)





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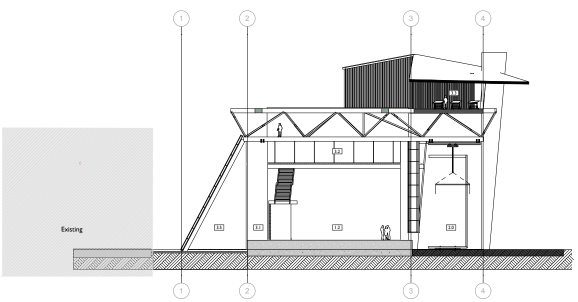

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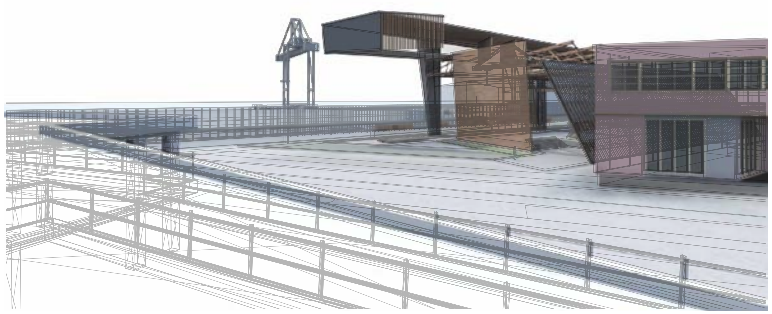
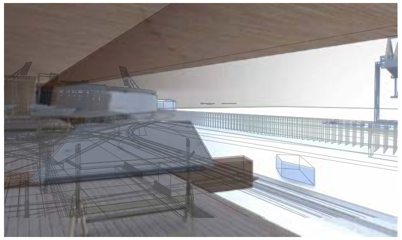
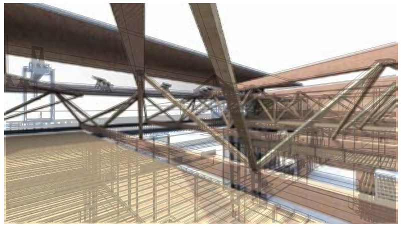


_Public Entrance

INTERIM DESIGN (MID-YEAR)

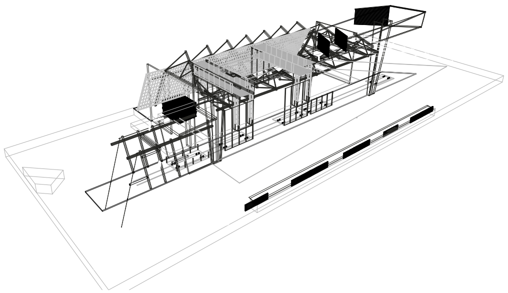


_Drawing Studio



_Truss walkway

_Production Entry



_Assembly-Production