dynamic system
A DIGITALLY FABRICATED ENVIRONMENT
CUSTOMISED COMPONENT DESIGN

A Research Project submitted in partial fulfillment of the requirements for the degree of Master of Architecture Professional at Unitec Institute of Technology, 2013.

Part 2 of 3

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Fig 1 System logo.
Digitally designed and fabricated construction is continuously evolving, in its capabilities to produce elements that are susceptible to change. These parts, generated from digitally produced models are able to be made by machines in order to achieve the desired result in a three-dimensional environment. The implications of such processes that current technology offers, allows for greater levels of accuracy in detail and assembly, faster production times and finally a realisation of what were once only thoughts of the imagination. These can now be translated into three-dimensional forms that define our spatial environment.

Myself and my two colleagues intention is to pursue this thesis project in collaboration. As a team we believe that the combination of our individual areas of focus, we anticipate, will lead to an outcome of greater substance. Our intention is to bring the findings of our three points of focus and integrate them in an effort to produce a complete solution (three components that form a whole). The outcome of this research as a team is aimed towards investigating the relationship between architecture and construction through the application of digital technology, where we intend to produce a series of customisable, prefabricated modules from components that are able to be both joined together and taken apart.

Individually, my focus considers the relationship we have with our built environment, in the way structures impose or define our spatial boundaries. I intend to investigate how the design of a modular system may have an allowance to be completely customised and manipulated in a way that allows their forms to be modified by the designer; so that they meet the specific requirements of their intended program. This thesis forms one part of three. It presents a combined investigation into the digital design and manual fabrication processes involved with creating a ‘hybrid’ system; joining ‘cut’ flat sheet elements into components that form a larger habitable structure. A thesis on architecture; “the art or practice of designing and constructing buildings.”

"A proper building grows naturally, logically, and poetically out of all its conditions.” Louis Sullivan, Kindergarten Chats (Paraphrase)

adaptation
1. any alteration in the structure or function of an organism or any of its parts that results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment.
2. a form or structure modified to fit a changed environment.
3. the ability of a species to survive in a particular ecological niche, especially because of alterations of form or behavior brought about through natural selection.

This definition, translated for the purposes of outlining a DFE brief follows:
Design For Evolution
1. any alteration in the structure or function of [the architecture] or any of its [components] that results from [the design process] and by which the [architecture] becomes better fitted to [sustaining ‘place’] in its environment.
2. [a modified form thats customised structure is adjusted to] fit a changed environment.
3. the ability of [architecture to sustain its place in its locale context. Especially brought about by requirements for changes in: function, form, scale, style, services, economy or social character]

I would first like to acknowledge the contributions and continuous efforts put in by my colleagues over the development of the project; through hard work came many breakthroughs and it would have been much more difficult and a lot less enjoyable working to such a scale by myself. I appreciate your contributions in the areas of knowledge you brought forward. Cheers guys.

To the staff involved with our project and education over the years, thank you. I have enjoyed my time spent here under your guidance. All the studio assignments and trips abroad will not be forgotten. Thanks to David Chaplin for his support of all the masters students and helping to trigger solutions to our work; your comments were much appreciated. To Tony Van Raat, for his passion, support and encouragement of our work, enabling us to ‘make something real’. Simply put, ‘to create architecture’.

Finally, to my friends and family, the completion of this project means I got released from the asylum, yay! and ‘about time’ you will say. These last years have been both some of the most enjoyable and stressful moments I’ve experienced. Through your support, it has been made much easier and I thank you for your tolerance in being a part of the process (as an artist may say). To all involved, thank you.

JM
introduction

1. Research Question

With the development of digital software programming and evolving manufacturing capabilities, how do advances in technology influence the relationship between the processes of design and fabrication. What do we see in the architectural field that represents such progression. This explanatory document looks at:

1. Dynamic environments; the fabrication of customisable components & their ability to adapt to the programmed framework.
Digital Systems

The rapid development of BIM (Building Information Modelling) in recent years has allowed for much clearer communication of design information and more intelligent use of significant product information data that play a crucial part in the performance and analysis of any structure. It is the translation from CAD (computer aided design) to CAM (computer aided manufacture) that I am most interested in; this can take a digitally designed structure and digitally manufacture it.

In the past, the introduction of such technology was used all in the mass production of elements for prefabricated construction. Over time there has been a shift in mindset; induced by aspects of social construct, economy, political movement, climate, environment, health and education, though most prominently through the use of used computer programming. This shift has moved towards mass customisation, the design and fabrication of a range of often standardised parts, that are significant to their own design.

Our endeavour to produce a building directly from a digital model using a collection of cutting files will enable a greater translation and realisation of those forms we often find impossible to conceive in a physical realm. Additionally, through the processes of interaction between user and designer we may find that we become more aware of what it is that we produce, not only in architecture in relationship with people, place and culture, but also through the integration of our three individual focus areas that will lead to a significantly more cohesive result.

Implementing New Processes

The application of technology is not uncommon in today's construction, and there are many examples of where CAD-CAM processes have been applied. Though it is most often found that their use is limited to the fabrication of only a few elements that contribute to a final building, and they are employed to produce structures that are either used as display models or inhabitable installations that merely explore some theoretical design concept. To the contrary, I see that our projects importance lies in making use of all the available tools by taking their capabilities one step further, exploring digital processes at both the design and fabrication phases to produce a 'habitable structure' that is made complete from digitally cut components.

At this current time in the design and construction industry there are many who are interested in the research and development of such technology, and would be intrigued how our proposal could contribute to the future growth of such processes. The outcome, and accompanying documentation may be of relevance to many interested people. We hope that our proposal will be found to be far reaching in its application to the education and development of others that may have similar interests.

Aims & Objectives

1.2 Aims & Objectives

The predominant purpose of this project is to explore the relationship between fabrication and assembly, regarding the use of digital architectural applications and their abilities to produce components that allow for flexible operation. The architectural research problems we are predating to some extent involve many of the following: Exploring conceptual issues of habitation and interaction (non-digital) with structures, the evolution of buildings; allowing for the systems to develop throughout their life time by creating cooperative modules that consider adaptive design and DFD (design for disassembly) as essential parameters. Resolving issues around materiality, of both aesthetics and performance will be important.

Further issues include the communication of design and methods of fabrication; dealing with the technological implications of CAD-CAM software, the translation from CAD to CAM (computer aided design to computer aided manufacture), packaging digital information for digital output, fabricating structures with alternative connections and finally designing it to be easily assembled. The feasibility that may be tested is that digital processes will enable architecture to evolve over time, as customised structures are fabricated to be adaptable for intended requirements.

An Investigation

The rapid development of BIM (Building Information Modelling) in recent years has allowed for much clearer communication of design information and more intelligent use of significant product information data that play a crucial part in the performance and analysis of any structure. It is the translation from CAD (computer aided design) to CAM (computer aided manufacture) that I am most interested in; this can take a digitally designed structure and digitally manufacture it.
Individually, the aim is to break down the project into sub-topics to aid in methods of research and design, this will enable a greater focus on the key elements of the project. These sub-topics are consistent with the evolution of BIM (Building Information Modelling), DFD (Design for Disassembly), digital fabrication and communication of design data. As a group, we intend to work together, drawing on each other’s knowledge to produce the final outcome. The way in which we integrate ideas to form a solution will be discovered, with aid to such procedures coming from those with relevant experience. We intend to create a team brief that will be in place not only to summarise the relationships between our specific focus areas, but made to control how our ideas can be merged, so as to create a final solution.

There are grounds for a significant amount of research and development into the plan of producing customisable modules from digitally fabricated components. It is as a team that our collaborative approach will lead to a successful outcome in the documentation of the thesis and presentation of the design project.

1.3 Project Outline

1.4 Methodology
Lastly, at a more conceptual level, we can think of the site not merely as a physical but as a social construct. If the previous descriptions have emphasised the importance of the context in designing the architectural form: the network that brings together all the designers, makers and constructors is a new place of social relations. To think this way means leaving behind the idea that architects are responsible (only) to the owner/occupier in delivering a building; rather, it means seeing a responsibility to the entire team who help make the building. Ed Ford, in his book ‘Details of Modern Architecture’ has pointed out that “20th Century architecture, if socially motivated at all, is concerned with structuring/enhancing the life of the client, leaving behind the 19th Century concern for the maker.”

Today, we may be able to achieve both. “The architect, in thinking off-site, can construct an on-site that is physically provocative, environmentally responsible, and socially attuned to the labour network.”

First, a vast array of materials are on offer for their performative qualities. New applications of materials open up affordable alternatives in their response to site and design program. Furthermore, as one moves beyond CAD/CAM production, craft is heightened in two ways. Material choices move to the forefront of the design process, the properties of materials entering the machines need to be understood from the outset. CAD/CAM is a tool to bring this material exploration into the hands of the fabricator; their expertise allows for the production of complex building elements. Moreover, the entire organisational process is being changed to be more responsive to the various parties required to produce a building. If fabrication has directed our attention to a process that allows a better work environment and less waste (calibrating the most compact ways to cut pieces from a standard sheet and then collecting/recycling the waste), it initiates a whole new approach to re-crafting the design and build process. Building information modelling (BIM), by producing a virtual model that all involved collaborate in encourages all to take responsibility for their specific roles as ‘authors’ of both the model and the building. Likewise, integrated project delivery (IPD) goes further than the re-organisation of work in allowing all disciplines in a project to operate as a team sharing the goal of fewer costs, faster delivery periods, and a shared interest in producing quality buildings. Lastly, at a more conceptual level, we can think of the site not merely as a physical but as a social construct. If the previous descriptions have emphasised the importance of the context in designing the architectural form: the network that brings together all the designers, makers and constructors is a new place of social relations. To think this way means leaving behind the idea that architects are responsible (only) to the owner/occupier in delivering a building; rather, it means seeing a responsibility to the entire team who help make the building.

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Stephen Kieran and James Timberlake

Pamela Bell discusses in her book ‘Kiwi Prefab: Cottage to Cutting Edge’ that “the resistance to finance experimental factory produced architecture remains an obstacle, while in Japan where the assembly of houses is nearly as advanced as that of cars the issue here remains one of conservatism in the marketplace of anything produced in quantity. To a certain extent a changed economy brings a scaling back of people’s expectations about the size of housing and the exploration of customisation, including the re-thinking required in the wake of such disasters as the Japanese tsunami or the Christchurch earthquakes. It pushes the issue of fabricated structures, as a quick and inexpensive delivery of shelter. There is suggestion that there might be greater openness to well conceived designs beyond the niche market of a magazine such as Dwell.”

Further discussion states that there tends to be a fear of prefabrication. Today, production processes, of which fabrication is a small but visible and significant part, offers opportunities for the ‘on-site’ assembly on a number of fronts.

“Mass production was the ideal of the twentieth century. Mass customisation is the recently emerged reality of the twenty-first century. We have always customised architecture to recognise differences. Customisation ran at a cross purpose to the twentieth-century model of mass production. Mass customisation is a hybrid. It proposes new processes to build using automated production but the ability to differentiate each artifact from those that are fabricated before and after. The ability to differentiate, to distinguish architecture based upon site, use, and desire, is a prerequisite to success that has eluded our predecessors.”

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Fig. 4 Additive form - Fed Square, Melbourne, Australia
Fabrication refers primarily to a process, rather than a product. As outlined by Pamela Bell & Mark Southcombe, the definition for the types of prefabricated buildings are categorised as: component (stick and sub-assembly), panel (non-volumetric), module (volumetric), and complete buildings (box-form).

Component
Component-based prefab includes stick and sub-assembly prefabrication. This applies to pre-cut or pre-sized pieces of timber. Sub-assemblies are windows, doors, fixtures, fittings, and structural elements.

Panel
Prefabricated fabrication involves manufactured panels that are transportable via flat-packing. They are often categorised as pre-finished closed panels with doors, windows, claddings and linings. They can also be made as open sections, consisting of separate components.

Module
Module, three-dimensional fabrication refers to 3D assemblies manufactured off-site and combined with different components or elements to create a complete building. The distinct parts can be noted as volumes, modules, or sectional bays. They can be produced in a controlled environment, where services can be easily managed and both the interior and exterior completed prior to transportation to the intended location.

Hybrid
Hybrid fabrication is the term applied to integrated systems: e.g. hybrid module. These systems apply a mixture of components in construction. Hybrid construction systems provide a greater balance between efficiency in construction and the various requirements of the client.

Complete Buildings
These buildings are commonly known to be transportable or relocatable. A fabrication process where complete buildings are made under controlled conditions before being shifted to site and connected to foundations. These buildings are not restricted to the inclusion of prefabricated components, or common standard structural or finishing elements. The distinction between portable, transportable, mobile and relocatable in terms, as used in New Zealand. Portable buildings are lightweight, temporary and easily movable, transportable buildings are larger and can be shifted from the place of construction to a site, mobile indicates structures mounted on chassis which can be moved more than once, e.g. Caravans.

The advantages in prefabricating structures may offer more for less, quality vs time on site, more readily made to suit the outcomes, and greater opportunities for sustainable practices.

Quality
Maintaining quality control over manufacture and construction processes begins a greater outcome overall. This is undertaken by the close organisation of labour, material, and equipment within a controlled environment. Further work can be completed prior to the end product leaving the place of manufacture.

Rapid Delivery
A big advantage to using alternative fabrication methods is an increase in the speed of delivery. A structure can be manufactured off-site while site works can progress on-site. This can reduce the programme by between 30%-40% of a typical construction process. Although, a period of planning is needed prior to manufacturing as changes cannot be made once this fabrication process begins.

Economic Value
Cost savings occur from a faster delivery, reduced remedial periods and a shorter period of financial borrowing. Time frames and costs can be decreased by eliminating dependence on the weather, more efficient coordination of the trades, reduced demand for transportation, and price advantages in mass orders. Further savings can be reduced by decreasing the floor area and scaling down the size for reduced living / working needs.

Social Value
This includes the ability to construct within an endorsed space in variable weather conditions, lowering equipment in close proximity, and improvements in health and safety. It also has the ability to be less noisy, dustier, transportation and neighbourhood disruption through (traditional) build processes.

Material Sustainability
This includes reduced waste through efficient administration, construction taking place in an enclosed environment, preplanning, and precutting. In New Zealand, construction is the ‘forty percent industry.’ Our buildings consume 40% of the energy, 40% of the waste, 30% of carbon dioxide emissions, and 40% of raw materials. Fabricated buildings can be designed for disassembly and potential future reuse of materials and components. A sustainability drawback for modular sections, could be said, is the excessively engineered and additional material applied to brace for transport. However, this also makes the structure more durable and resilient once it’s assembled on-site.
and assembly is now a widely used practice. Customised digital cutting workshops. This technology also allows sheet configuration and many specialist prefab plants, joinery factories and university prototypes of components and assemblies to be made easily and on digital files allows complex component construction and pushing into the construction realm. Machine cutting based before it occurs by way of file-to-factory manufacturing is The virtual model, and its ability to simulate and test construction File-to-Factory Manufacturing (Bread & Butter films, 2011). Further descriptions are outlined through to page 142. 11 Bell and Southcombe, (Quest publications and Eames the Architect & Painter J Cohn & W Jersey J Cohn & W Jersey. Kiwi Prefab who aimed “to create the best to the most for the least.” Many architects have been motivated to make good design more accessible to people, in the manner of Charles and Ray Eames Willingness to Embrace Change. Customisation poses a threat to manufactures who are asked to provide different products for clients and site conditions. Alternative systems and manufacturing. When parts of a traditional site built houses are completed elsewhere the builder’s role shifts to one of assemblage and project management. Alternative systems require various building techniques and a continuation of education in practice. Customisation allows a firm to manufacturers who are asked to provide additional products to clients and site conditions. Manufacturing processes are most efficient when they are repeated without variation. Design requirements that stretch the capabilities of a prefabrication system may add a premium cost to reflect the additional time involved at set-up. Future Circumstances and Challenges As we move into an increasingly digital age, traditional building practices will be replaced with design and fabrication processes. Digital fabrication is being integrated into contemporary practices and this process will continue as efficiencies give advantages to early adopters. Clients will get an increased value based on the receipt of more quality over a reduced timeframe and lower costs. “A shift in construction methodologies is forthcoming, due to the implementation of digital technologies.” Transportation Panel and hybrid modules + panel systems minimise transport costs and add value to raw materials in a greater extent than components. Small modular systems that extend or connect at site to create larger sections may become more common. Panel and hybrid modules + panel systems minimise transport costs and add value to raw materials in a greater extent than components. Small modular systems that extend or connect at site to create larger sections may become more common. The Trade of Elements & Components A prefabricated building that grows and changes according to demand is one that may be seen in the near future. This idea requires a market for the storage and reassemblage of prefabricated parts. Currently, it occurs in New Zealand as a market for relocated houses removed from their original sites. It is just a small step from here before the establishment of an internet market for prefabricated parts, panels or modules. It’s already possible for someone to purchase a small prefab shed or other building from the website TradeMe. The Trade of Elements & Components A prefabricated building that grows and changes according to demand is one that may be seen in the near future. This idea requires a market for the storage and reassemblage of prefabricated parts. Currently, it occurs in New Zealand as a market for relocated houses removed from their original sites. It is just a small step from here before the establishment of an internet market for prefabricated parts, panels or modules. It’s already possible for someone to purchase a small prefab shed or other building from the website TradeMe. Resilience The results of recent earthquakes have brought into focus the short-term capital costs associated with the building industry. Engineers have designed buildings for clients to comply with minimum code standards with no consideration of future servicing or resilience. As a consequence, although most buildings survived and many are structurally stable, they are no longer serviceable. Thus, a mass of demolition and waste has resulted. This is not economically or socially sustainable. The ways that buildings fit together and the ways they are constructed may need to change. Flexible prefabricated elements can be part of the solution. Resilient design technologies in the building envelope are now more common in practice. As we move into an increasingly digital age, traditional building practices will be replaced with design and fabrication processes. Digital fabrication is being integrated into contemporary practices and this process will continue as efficiencies give advantages to early adopters. Clients will get an increased value based on the receipt of more quality over a reduced timeframe and lower costs. “A shift in construction methodologies is forthcoming, due to the implementation of digital technologies.”
Architecture can take a long time to produce. It requires a many resources, and so it is placed beyond the reach of most people.

Stephen Kieran and James Timberlake discuss in their book "Rationalizing Architecture" that an architect could compare their work to the progression being made in the design and fabrication of cars by industry and its customers. In industries where there is an advanced range in the application of material and fabrication techniques. Build time, production costs and waste is reduced, as the quality increases. The advancement in software requires the adoption of descriptive information as resulting forms are found to have no relation to any existing products.

In those fields, the processes of the engineers have won, while in building the architect, at times, can be focused on the aesthetic, disregarding the functional or performative aspects. As connections are made within the junction between an array of elements. The joints arise in the formation of the joint. The connection is a craft in resolving the size of materials. As thermal expansion and contraction of style. The repetitive appearance of elements are no longer essential for off-site fabrication. Mass customisation is replacing repetitive forms. The designer can develop alternatives from the engineer's focus towards regarding functional provisions and connection to place as drivers for design. There is also a notion of the 'master builder' being the only creator, an architect can integrate with other disciplines through the construction industry. Architects and connection to place as drivers for design. There is also a development of lightweight systems increase economy: transport efficiency, reuse, and waste of all which contribute to savings in a life-cycle. Architects, fabrics, clients and users all benefit from a more sustainable architecture. Developments of lightweight systems increase economy: transport efficiency, reuse, and waste of all which contribute to savings in a life-cycle.

Today, architects can utilize methods of information sharing to integrate skills, again becoming the 'master builder' of the design. An architect can combine the knowledge of a material supplier, product designer, engineer, occupant and client to create a more informed outcome. Architecture can be more affordable and accessible to all, a resource and social benefit the designer, maker and inhabitant. The amount of time and energy required in the utilisation of tools that control information we can both split the design and assembly process into pieces: modules, components and individual parts. As connections are made, the utilisation of tools that control information we can both integrate with other disciplines through the construction industry.

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The mental strain here is immense. Each point of connection can be a problem. The designer must produce a solution that integrates within the constraints around it, it may effect adjacent elements. The customisation of the work is then developed, whose fundamental methods in correcting are created. However, the amount of modifications required is 'just-in-time'. As time is an expensive factor to consider, there is a focus on splitting the design and assembly process into pieces: modules, components and elements. Manufactured away from their final assembly point, the process of change does not disappear. What may initially be seen as a very complex process can be broken into smaller, less complicated ones. Design can be more focused, and the processes more straightforward. The focus turns on the production and connection of the modules, including their relationship to the components and individual parts. As connections are made, the utilisation of tools that control information we can both integrate with other disciplines through the construction industry. Architects, fabrics, clients and users all benefit from a more sustainable architecture.

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Fortunately, through the application of today’s modes of controlling information in the processes of design, we can manage the stages of fabrication and assembly through virtual simulation. We can now model elements to simulate their interaction, assembly and fabrication for future disassembly, progression, Pamela Bell said “prefabrication of design focuses on connection, assembly and fabrication for future disassembly. Immediate adaptation, and the sustainable reuse of parts.”

Adaptation involves the management of the elements that make up a structure. James Douglas, in his book Building Adaptation: says “it is based on the premise that buildings are not static; in a use or condition over their [lifetime]... The level of activity or functional purpose is unlikely to remain the same over the building’s entire existence.”

This change has presumably been fuelled by the advancement of technology. Developments in manufacturing processes and the fabrication of components, as well as the diverse application of materials are a few of the influences on the design and construction industries.

As displayed in James Douglas’ publication ‘Building Adaptation’, modifications to future systems may include some or all of the following points; to allow the evolution of their systems to continue:

**Spatial Modifications**
- Adjusting the size of modules.
- Vertical or horizontal arranging of a large structure into smaller modules.
- Combining spaces.
- Providing additional space.
- Expanding existing space.
- Increasing accommodation.
- Improving accommodation.
- The provision of space for new or specific activities.
- Adaptation for the elderly or those with disabilities.
- Re-configuration of internal spaces.
- Altering the function of spaces.

**Structural and Fabric Conditions**
- Change is classifying to improve the resilience to the weather, the aesthetic, accurate and thermal performance of the envelope.
- General repairs and improvements to demand proofing and timber preservation.
- Major works that enable the provision of additions, jettison and substitution of modules as required, functional, spatial and aesthetic improvements.
- Inserting new components for strengthening or improved load-bearing capacity.
- Repairing defective or substantial structural elements.
- Change in cladding to improve the: resistance to the weather, the aesthetic, accurate and thermal performance of the envelope.
- Improving accommodation.
- Reducing construction tolerances and lower energy use during occupation.
- Efficient production with work off-site and on-site occurring simultaneously, significantly reduces the overall time spent on site and construction can proceed through the environmental conditions within a factory or similar enclosed space.
- Sustainability gains arise from waste minimisation, reduced construction tolerances and lower energy gain during construction.

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- Sustainability gains arise from waste minimisation, reduced construction tolerances and lower energy gain during construction.

Shorthands in trades are considerable. The reason why, though most commonly associated with working conditions and safety. Shorthand helps to provide improvements to such conditions: e.g. by building indoor, could make it more appealing to people without experience. Over time, education and training can provide them with the skills to further their careers, working in specialised positions. There, increasing productivity, health, safety, and the spirit of all involved. The automotive industry displays such methods well, in the support and collaboration with their employees, contractors and clients.

We desire the choice for the ability to self-expression in design. Mass customisation offers a way to design and assembly this type of architecture. The notion that one design for all, working for all projects: regarding clients, users, and sites is simply not going to be the case. Architects will proceed to develop through the continual implementation of alternative schemes, designs, systems and materials applications. It will continue to progress into areas that are currently unexplored.

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19 Ibid., 117.
20 Kiwi Prefab, 140.
21 Architecture will proceed to
At a time where the conventional role of the architect is evolving due to changes within the building industry, we see the architectural drawing as a catalyst and a driving force for change in the form and character of a structure. Architecture is no longer a static entity; it is a dynamic system that can be designed, constructed, and modified in real-time. The ability to create digital models represents a new frontier in the design and construction process. The virtual environment enables a more rigorous approach to the process of design and assembly.

In a virtual model, the building is merely a representation of the end product. It is the reference to a real structure. The features of a virtual model can be developed and communicated through the forms of drawings that can be made. "Drawings" that can be made.

The architect and user can visualise space in a way that a conventional two-dimensional perspective drawing cannot. Three-dimensional virtual environments provide the details needed to build a structure. Design decisions can be made in real-time, allowing for changes to be incorporated to enable extensive research and design. The ability to create digital models represents a significant change in the way that architecture is produced. Changes to projects can be tracked and recorded. The virtual environment enables a more rigorous approach to the process of design and assembly.

In 'research by design' the act of computing operations such as rendering through code and design manipulation through rotation, mirror, stretch and crop can have an impact on design and research. The ability to create digital models represents a significant change in the way that architecture is produced. Changes to projects can be tracked and recorded. Numerous designs can be produced, accurately and rapidly to support further options and amendments to a scheme. The ease of access and operation of the available software programs will increase the potential for the realisation of dynamic or complex architecture.

"BIM is a technology, combining data normalisation with geometric projection. BIM is a methodology which supports efficient integrated project delivery. But BIM should not be construed as a philosophy of design. It is not the reason for designing a building in a particular way."26

The process of making is no longer so straightforward as it once was. Collaboration plays a major role in the development of virtual models. Production becomes part of the design process through the stage of construction it provides the details needed to build a structure. Design decisions can be made in real-time, allowing for changes to be incorporated to enable extensive research and design. The ability to create digital models represents a significant change in the way that architecture is produced. Changes to projects can be tracked and recorded. Numerous designs can be produced, accurately and rapidly to support further options and amendments to a scheme. The ease of access and operation of the available software programs will increase the potential for the realisation of dynamic or complex architecture.

"If the designer is to be able to make drawings of buildings, it is necessary to be able to make drawings in real-time as designs develop... Never before have we known so much about a building before any work occurs at site."27

The architectural form is a derivative of the programme. Sets spaces and creates plans for the connections between areas. The form is a result of the design of elements through to larger components before being conceived as a whole. A complete system.

"What an architect is and what they are capable of providing. The architect forms a proposal derived from the programme. Sets spaces and creates plans for the connections between areas. The form is a result of the design of elements through to larger components before being conceived as a whole. A complete system.

Digital communication has changed the way we work. Drawing boards have been replaced with computers that include a range of software programs. In the simulation of buildings they are incorporated to enable external research and design. Today, the inclusion of data in 3D models can be made, otherwise be a complex and confusing abstract space. An "architecture: with more control and quality in improved design. It is the reference to a real structure. The features of a virtual model can be developed and communicated through the forms of drawings that can be made. "Drawings" that can be made."

"The tools for representation of information allow for connections and end users. Kieran and Timberlake discuss in 'Refabricating Architecture: with more control and quality in improved design. It is the reference to a real structure. The features of a virtual model can be developed and communicated through the forms of drawings that can be made. "Drawings" that can be made."

"Robin Evans wrote that 'architects do not make buildings; they make drawings of buildings'. Twenty years on, there has been an unprecedented development in the way architectural ideas can be developed and communicated through the forms of drawings that can be made."

"Research by design is a philosophy of design. It is not the reason for designing a building in a particular way. The virtual environment enables a more rigorous approach to the process of design and assembly.

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"When the aspirational pushes beyond simple ability of building to architecture, it is the architect who pushes the assemblies and their joints by measuring, shaping, surfing, and profiling."

22 This being implemented through

26 Bell and Southcombe, ‘Refabricating Architecture: with more control and quality in improved design. It is the reference to a real structure. The features of a virtual model can be developed and communicated through the forms of drawings that can be made."
Does craft matter in the digital age? Some say that it only matters for certain things, like installations or a fruit bowl and other special objects. Steve Jobs disagreed. At Apple, craft is considered in every product made; the design was informed by the user experience. Together, architects and engineers can determine how the design must be executed. Time is an important consideration for craft as does the designer in the process of production. Craft can be precluded by both the programme and the fabrication process. The digital coachman can have a varied process on different days. The value of craft is found in the perceived connection to the maker. The user may derive from this for original works, or similar. We seek out craft, as it continues to have a diminishing presence. We place more value on the ‘artisanal’ custom, tailored work. So, in the act of relating the maker to the user, we can decrease the distance between humans in the environment of production.

Guy Horton conveys in his article “The Maker’s Craft” in the Digital Age that using digital tools in research and production does the designer in the process of production. Craft can be prescribed by both the programme and the fabrication process. The ‘digital’ craftsman can have a varied process on different days. The value of craft is found in the presumed connection to the maker. This may derive from our desire for original works, or other special objects. Steve Jobs disagreed. At Apple, craft is considered in every product made; the design was informed by the user experience. Together, architects and engineers can determine how the design must be executed.

Computer generated 3D models provide the necessary information on elements, as required for their fabrication. The application of CNC (computer numerical control) production processes deals with the computer-based control of cutting and milling operations to be performed on a machine. The door to new types of building components, structural elements could be fabricated in a factory with the use of CNC machines. The data transferred is the control of the machines using CNC (computer numerical control) production processes. CNC operations that take place in the desired profiled elements. CNC commands are essentially coded computer scripts that instruct the machine what to do. The prescriptive code is usually assigned with the letter ‘G’, thus (G-code). Nick Dunn, author of Digital Fabrication in Architecture explores the code as directed into a series of commands that dictate the cutting paths, speeds and depths; resulting in either profiles (shallow, abraded marks), cuts or holes... The term 'Routing' is specific to the digital cutting of architectural elements from flat sheet materials. Operating on three axes, X and Y being the horizontal, and Z being the vertical plane, CNC machines. This process becomes a challenge, to design and manufacture utilizing such systems. To enable the assembly of systems expands the 'craft' matter in the digital age. CNC routing refers to the process of machining wood with a router tool. In architecture, the potential lies primarily in the multi-dimensional objects from flat sheet materials. In the case of, wood, the digital work is the material of choice. This data set is the program controls the cutting of the digital data set into a series of commands that dictates the cutting paths, speeds and depths; resulting in either ‘profiles’. The paths can be simulated on screen, to check if the cutting lines will be processed correctly. The CNC operations that take place here use the methods of either CNC Laser cutting or CNC Router cutting. The setup for these procedures differs, in required setup for these procedures differs in setup.

The most accessible and commonly used method to fabricate parts is through ‘cutting’. The most common techniques consist of laser and routing methods. They essentially produce ‘jigsaw’ shaped elements form flat sheet materials. Operating on three axes, if Y is being the vertical (cutting depth) the subtractive procedural cut material to result in the desired profiled elements. CNC machines are essentially coded computer scripts that instruct the machine what to do. The prescriptive code is usually assigned with the letter ‘G’, thus (G-code). Nick Dunn, author of Digital Fabrication in Architecture explores the code as directed into a series of commands that dictate the cutting paths, speeds and depths; resulting in either profiles (shallow, abraded marks), cuts or holes... The term 'Routing' is specific to the digital cutting of architectural elements from flat sheet materials. Operating on three axes, X and Y being the horizontal, and Z being the vertical plane, CNC machines. This process becomes a challenge, to design and manufacture utilizing such systems. To enable the assembly of systems expands the 'craft' matter in the digital age. CNC routing refers to the process of machining wood with a router tool. In architecture, the potential lies primarily in the multi-dimensional objects from flat sheet materials. In the case of, wood, the digital work is the material of choice. This data set is the program controls the cutting of the digital data set into a series of commands that dictates the cutting paths, speeds and depths; resulting in either ‘profiles’. The paths can be simulated on screen, to check if the cutting lines will be processed correctly. The CNC operations that take place here use the methods of either CNC Laser cutting or CNC Router cutting. The setup for these procedures differs, in required setup for these procedures differs in setup. The term of tolerance in architecture has become more pronounced as digital fabrication has progressed. Fabrication methods are advancing, as there is a reduction in the allowed tolerances for assembly and reassembly that mass customization in architecture will become commonplace. The precision that the processes enable, allow for greater complexity and control. The process has sharpened the understanding of the relationship between digital presentation and the actual product. Robl Stoutie defines in an article The Depreciating Value of Form in the Age of Digital Fabrication that the word ‘tolerance’ is commonly found to be a measurable variable, among components for achieving a desired structural accuracy. Design is influenced by a variety of factors including and possibly most importantly, the manufacturing process employed. As students we don’t have to face the full restrictions of a ‘real-world’ process. Thus, we have the opportunity to explore new realms of architecture where the task of fabrication is through a process of work for an unforeseeable future.
2.5 Precedents

Fig. 10 Concept sketch for Dunescape by Shop Architects.

Fig. 11 The dynamic structure was up for only 6 weeks.

Fig. 12 People enjoy the poolside atmosphere.

Fig. 13 The dynamic shell was set up for only 5 weeks.
2.5.1 Dunescape

A project by Shop, a multi-disciplinary practice based in New York, the United States.

The urban beach installation, manipulated ideas relating to a promenade to blur the distinction between art and the viewing public. Visitors could lounge, socialize, sunbathe, wade in pools, or be cooled by a spray of mist. These occupying the space, could be considered “in display” as part of the installation.

The installation was configured as a landscape in which structure, programme, and enclosure were compacted into a singular form, expressed by triangulated frames consisting of over 6,000 individual twenty-two-inch cedar sticks. The position of each frame expressed changes in surface and use. Typical architectural drawings could not represent such complex work for construction. As outlined in the practices publication ‘Shop architects - out of practice’ "full-scale colour-coded templates were created by exporting the information directly from a digital model. The frames were cut and assembled directly on template sheets. They were then joined with screws and erected to bring life to the growing structure." 37

Shop implemented digital technology not only to generate such a complex form, but to simplify the manufacturing and assembly process. The digitally produced axonometric drawings facilitated the assembly of the structures components at site. Those working on the assembly were impressed, as “there was no measuring or cutting. The construction documents for the Dunescape project were characterised by a lack of dimensioning; instead, full-scale colour-coded templates translate directly to the actual built work” 37 while maintaining a complex and intriguing aesthetic.

This exploration of creating a continuously growing structure from digitally defined elements is a great example of the creative possibilities of utilising computer programming in methods of construction. The definition, control and execution can be strategically managed. In this case, the elements were all hand-cut by a team that worked effortlessly with the aspiration of seeing the architects vision for a unique public structure. In this precedent the process of incorporating digital manufacturing is not evident. Though the initial stages of development and processing will be influential to our design thinking, in how we conceive taking a conceptual idea through to a completed structure.

shoparchitects.com

Fig. 13 Colour coded cutting templates.

Fig. 14 Dunescape under construction.
Wellington architect Chris Moller of CMA+U has developed a building system called Click-Raft. A CNC cut, plywood structure that could be compared to Meccano, in the way it clicks together to form a lattice like structure. Moller’s wider vision is for it to be “tuned in” to the environment. That the components would act as “evolving cells, capable of learning new information – rather than simply being fixed prefab materials.”

The flexibility and capability of the system to extend longitudinally allows for it to be applied to a variety of situations. Through customisation, fabrication, flat-pack transportation and a process of assembly it results in a cost-effective solution.

The plywood pieces identified as “click-leaf” and “click-beam” frame a networked lattice from standardised panels which click together to form the floor, walls and roof. The Y frame part pan to integrate service and adducts to both the formed interior spaces and finished envelope. There is mention of the ability for the system to integrate parallel concrete or steel beams and SIPs (structurally insulated panels) for roof and wall cladding. An additional skin can be added to aid in environmental control and to provide an increased area for the installation of solar panels.

The system has said to have been professionally engineered. It has also been “produced to respond to the challenges of global warming by incorporating materials from renewable resources, in the support and replenishment of architecture and landscape.”

The system’s flexibility allows “open ended configurations” to enable changes to be made according to site, environmental and programmatic functions. However, this is yet to be seen. As the designs have not been built to such completion, the intended outcomes have not been fully realised. Although a structure has been built at full scale, it has been left un-insulated, un-clad and not serviced or closed-in to encapsulate the ideas of “low impact habitation”. Alternative cladding options are not clarified, with it being predominantly depicted as unfinished; missing both internal and external finishes. There is also presumed difficulty in the lattice systems ability to facilitate access for servicing and additions.

The current structure developed has not addressed supporting additional levels or moved away from the longitudinal linear arrangement, to shape alternative forms in differing directions. Its viability could be questioned as a suitable proposal for many projects, though it is making progress with smaller scaled work in schemes that cover: pavilions, garages, small houses and education facilities.

The ‘Minimal Unit’ (Click-Raft 02B-M01) is proposed to be a disaster relief shelter. The 10m2 unit provides a small living space for multiple scenarios. Optional variations could be created; where applicable, a warmer environment may mitigate the need for such concealment of the structure / a reduction in insulation and plywood cladding. Instead “a waterproof fabric could be pulled over the structure.”

2.5.2 Click - Raft

![Click-Raft 02B-L01 View](image1.png)  
![Click-Raft 02B-M01 Assembly](image2.png)
Fig. 17 KIWI Prefab Exhibition in New Plymouth, New Zealand

Fig. 18 Click-Raft model on display. A lattice structure.

Fig. 19 Assemble your own Click-Raft model.

Fig. 20 Click-Raft structure 1:1

Fig. 21 Cross-lapping woven elements provide strength.
WikiHouse has been developed in recent years as a new method for building dwellings. The aim is to simplify the construction process further enabling people access to smaller, smarter more economically viable dwellings. The project was founded by British architects Alastair Parvin and Nick Ierodiaconou of London based practice 97. The project has been made available to anyone willing to contribute: www.wikihouse.cc

A WikiHouse structure can be assembled within a day, by people that don’t require any previous experience in design or construction. A completed timber frame is required to be enclosed with cladding, fitted with associated services, insulated and then to finish the interior. Currently, there are no completed WikiHouse projects being occupied. Only mock-up frames, small prototype models, and furniture objects have been produced. As a guide, the current typology for a full scale structure is a timber framed dwelling assembled from modules that measure 550mm x 3600mm, with an overall floor area of approximately 16m². Further information on the development of WikiHouse can be found online at: http://www.gizmag.com/wikihouse-print-your-own-41

2.5.3 WikiHouse

Wikipedia, encyclopaedia, “WikiHouse” 17 Dec 2013, accessed 04 March 2014. Gizmag Pty Ltd. The project has been made available to anyone willing to contribute: www.wikihouse.cc...
Fig. 23 Cutting files of building elements

Fig. 24 Parts can be produced through a CNC machine.

Fig. 25 WikiHouse developers assemble their work.

Fig. 26 The future concept for WikiHouse: A completely fabricated building.

Fig. 27 Assembly for all ages.
Additive Architecture was developed by architect Jørn Utzon in a description of his architectural work that focused on patterns of growth. It was reported that the term arose in 1965, in Utzon’s office. His colleague Mogens Prip-Buus said he wrote “Additive Architecture” on the wall.

"We saw it as part of an additive world where both natural and cultural forms contributed to additive systems and hierarchies."

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"We saw it as part of an additive world where both natural and cultural forms contributed to additive systems and hierarchies..."
Fig. 29: Examples of additive plantypes

Fig. 30: Jeddah Stadium, Saudi Arabia, 1967

Fig. 31: The composition and components of the 'Espansiva' system

Fig. 32: The human dimension; a measure of space

Fig. 33: Sequential modulation
As the building is to be designed and manufactured through digital processes, the selection of the appropriate material and its performance will need to be considered when it is exposed to the phases of manufacture and assembly. The standard requirement for selected materials is that they are able to be cut by CNC (Computer Numerically Controlled) machines. The tooling process will be able to manipulate the material into the desired components for modular construction.

A few aspects that were considered when developing the scheme below:

**Concept**

The concept for the scheme involves the production of a variety of modules that facilitate different functions. Each module may provide a change in service, depending on functional and spatial requirements. As the final building may range in complexity and scale, the structure will be broken into modules, with each module being fabricated from a series of digitally manufactured components. It is once they are assembled that the digitally produced design can finally come to fruition.

With my focus considering the relationship we have with our built environment, in the way structures impose or define our spatial boundaries. I propose that the design of such modules have an allowance to be completely customised and manipulated in a way that allows their form to be defined by their user. That interaction design will have an influence on the fabrication, thus allowing for DFD (Design for Disassembly) to educate and stimulate ones awareness of those structures in our built environment.

**Spatial**

Each module is completely customisable to its intended function. This results in a variance across all modules, depending on their intended use. Larger spatial requirements may be catered for by connecting multiple modules of a smaller, standardised size, or may be produced by fabricating a larger 'bespoke' module that is fit for only one purpose. The overall volume will be a series of connected modules, each made of elements that allow for flexible adaptation in their use over time, occupancy and operation.

Closing the loop between designer and user should enable architecture to evolve into not only products of the imagination but rather structures that are sustainably produced to meet the precise needs of their user. This may be through form, function, performance, spatially or aesthetic desires.

**Function**

The dynamic relationship between fabricated modules is through their formed connection to one another. In this process, all elements will be bound together. The configuration may vary in time, whereas it will allow for additional modules to be added with others removed and dismantled. This would be defined by the intended spatial or functional requirements.

**Style**

The collaboration between designers and end users will always influence the characteristics that make each design unique. Closing the loop between designer and user should enable architecture to evolve into not only products of the imagination but rather structures that are sustainably produced to meet the precise needs of their user. This may be through form, function, performance, spatially or aesthetic desires.

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As the fabrication of the modules are dependent on their digitally produced form, the customisation of the components will display the variations in production. The resulting outcome is not intended to be style specific, though such processes could propose that the style be defined as "Parametricism, the great new style after modernism".47 The collaboration between designers and end users will always influence the characteristics that make each design unique.

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3.11 Processing Architecture

Research is focused and achieved through the processing of architecture. The design processes and implementation of the methodology is represented through both theoretical study; drawn concepts, developed models, detailed designs and the fabrication of information into ‘real’ material. The research material is analysed and transferred through diagrams that aim to communicate the design, fabrication and assembly of the outcome. The individually accumulated knowledge obtained from the investigation is integrated to present a proposal.

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**Style**

Style can be endlessly reviewed, especially as the aesthetic is at the designers discretion. The design is focused on its functional merits as much as the aesthetic. The outcome is intended for habitation rather than another sculpture that makes no contribution to the architectural profession. Where many works are merely fabricated expressions; the application of creative skills used to generate imaginative works that are appreciated primarily for there beauty or emotional power. Although interesting, they are rather pointless.

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Our intention to pursue this thesis project in collaboration, as a team means we endeavor to bring the findings of our three points of focus and integrate them to produce a complete solution (three components that form a whole). The three stage process combines to form the resulting outcome. A customisable and adaptable structure formed by components that are digitally manufactured and easily assembled. The craft in the fabrication of connections provides a humanistic context; the link between the virtual and real.

The design process at this stage is predicted to revolve in a circle from person to person, taking the scheme through further stages of development. The communication ‘web’ between the three of us will enable further analysis and critical suggestions about the projects development and feasibility.

Predicted lines of communication:
1. Culture in crafting architecture: Azmon, Simba & James
2. Digitally generated form: Simba & James
3. Digital fabrication: James
4. Interactive assembly of components: James & Azmon
5. The craft in jointing the structure: Azmon & James
6. Analysis of assembly process: James & Azmon
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The nature of the project meant we needed to outline our individual roles in creating work that could be merged effectively in collaboration. The process of defining such settings is outlined below.

Framework; 'a basic theoretical structure underlying a system, or concept'

STAGE 1 - Simba
Parametric Framework; a process of applying specific parameters as spatial constraints to an environment.

STAGE 2 - James
Dynamic Environments; the fabrication of customisable components & their ability to adapt to the programmed environment.

STAGE 3 - Azmon
Cultural Connection; the craft in the detailed design and assembly of digitally fabricated elements.

Frame of reference - a basic theoretical structure underlying a system, or concept

"All right, stop. Collaborate and listen." - Vanilla Ice; 'Ice, Ice Baby'.

Undertaking a project as a team initiates a process of collaboration. A process that may change the way we approach and resolve our work. The three key points to define the are outlined by Blair McKolskey:

Communication: "The exchange of information between key people.

Collaboration: "The process of shared creation: individuals with complementary skills, interacting to achieve a common goal that none could have come to on their own. Collaboration creates a process, a product or an event."

The opportunity here, is for a collaborative effort between team members. As the array of skills combine with different backgrounds and knowledge of technology, the design process will explore alternative methods to propose an outcome that is as strong as the individual parts.

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Our intention to pursue this thesis project in collaboration, as a team means we endeavor to bring the findings of our three points of focus and integrate them to produce a complete solution (three components that form a whole). The three stage process combines to form the resulting outcome. A customisable and adaptable structure formed by components that are digitally manufactured and easily assembled. The craft in the fabrication of connections provides a humanistic context; the link between the virtual and real.

The design process at this stage is predicted to revolve in a circle from person to person, taking the scheme through further stages of development. The communication ‘web’ between the three of us will enable further analysis and critical suggestions about the projects development and feasibility.

Predicted lines of communication:
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Works that follow include but are not limited to the conceptual development of form; taking an abstracted form and translating it into a structure that may be achievable of actual construction. From sketch to computation to model. A plan to develop a system that enables components to be adapted according to desired changes. The fabrication of elements for the assembly of an open-ended system will not be fixed but allow for modification.

Finally, there will be the connection of a structural system with influences from a traditionally pacific context; methods of jointing and tensioning the system. Allowing manual processes to be incorporated.

We are undertaking a thesis on fabrication and assembly; with the intention of creating a structure entirely from CNC cut elements. The outcome of our research as a team is aimed towards investigating the relationship between architecture and construction through the application of digital technology. We are producing designs for the assembly of a pavilion; a temporary building or structure that is used for a specific function, i.e. trade displays, summer houses, shelters & art installations, etc. In this case, a small studio.

The challenge lies in the process of producing a structure through a collaborative method. Though through such an exercise we may find that we become more aware of our contribution to real world practice, not only in construction but also in architecture's relationship with people, place and culture.

The intention is to produce a series of customisable, prefabricated modules from components that can be both placed together and taken apart. Our endevour to produce a built structure directly from a digital model involves a complex process.

On display there will be the first full scale structural prototype. The module will represent a middle bay from the ‘core’ five (11 bay) structure. Its intention is to explore the fabrication process through manufacturing and assembly. The connections are all tests; they're to aid in the development of further modifications. As the project can be deemed a construction ‘work in progress’ information was made public to allow for interested parties to make contact, in the hope that they may provide partnership to the project development. We invited anyone interested to join us, with the hope that they could contribute their products and services or provide their knowledge and expertise, that may be beneficial to the success of future developments.

3.1.3 A Work in Progress

Fig.37 Spatial model
Through practice, the design process aims to implement innovative applications in technology, to deliver a project that encompasses the vision of the collective involved.

The initial design process began by incorporating the early stages of research with conceptual ideas to develop a theoretical strategy. The combination of researched literature, precedent survey and conceptual studies, were explored to represent such work; this was undertaken in the form of sketching, writing and modeling work.

The process allows you to explore an idea, a possible proposition to a problem. Without doing this you will not reach a point of progression.

The first sketch was a play on the process of creating a sequentially modular and adaptable structure. This was later found to be an important concept for the development of further work.

Dynamic Process in Architecture
'The design and fabrication of various components, digitally customised to enable future adaptation through disassembly.'

Key points were made from the definition of ‘experience design’; applying terms of an interactive collaboration to the process of an architectural system. These points aided the design process:

1. Ergonomics and spatial concept as applied to both user and site.
2. Functional requirements as applied to the design of components.
3. Digital processes; building an information model.
4. Documentation; fabrication and assembly.

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Jane Anderson discusses in her book 'Basics Architecture: architecture design that ...'

Construction design problems are complex and require creative solutions. Although architects often make explicit judgements, architectural projects are seen as 'formal' ways to design. Architectural experiences, influences and innovative ideas and concepts are central to the making of work, but each person makes their own judgements. Ultimately, the moment of design springs from the individual: imagination, no matter how collaborative the circumstances that prompted it.

Design can be seen essentially as an individual act. If it is where the simplicity of the task must be broken down and understood internally in the mind of the individual and their interpretation of the problem expressed.

"There is no such thing as one right answer in architecture."14

The device that architecture in the observation of the one right answer is the ability to make critical judgements. This way of thinking helps in the decision making process to solve problems. It is a core task, to be able to question your own decisions and compare them with other possibilities.

"It's delicate. We don't force whatever's emerging. On the contrary, we try not to keep it in the peripheral vision for as long as possible and try to let it acquire its own qualities and its own momentum. It's such a delicate thing and if you try and look it down into a crude, over-presented way, that is an absolute anathema to the way that we work."15

- Steve Tompkins, Haworth Tompkins

Jane Anderson continues to state that ...

It is a process that is reflective, conscious, contextual and pragmatic. Its strength is its ability to adapt to the ever-changing nature of any given architectural problem. The design possibilities can seem endless. The architect needs to find ways to stimulate or create new ideas. The design process is important as a stage for playing with ideas. Design decisions are made in a constant feedback loop while the model is being crafted. Design is a way of finding from the creative possibilities of craft and the art of making. Ideas can be explored by ‘happening accidents’. Making and reflecting enables you to acknowledge the possibilities and limitations of your own process.

"The willingness of architects to use their critical judgement and creativity to challenge assumptions, coupled with the freedom of knowing that there is no one right answer, means even the most difficult design problems are seen as an opportunity for creative thought."16

Every architect follows their own process.

"There is no such thing as one right answer in architecture."14

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Ideas about creating digitally fabricated elements through the implementation of CAD/CAM processes were considered with early sketches of elements and how they may fit together. The idea of creating a much simpler frame as the core structure was explored. This was to allow for easier servicing capabilities. The notion of creating a linear frame as the base structure would allow for the internal and external environments to be further explored through more dynamic means. Profiled sections on each side would achieve this.
Fig. 56 – Exported template for laser cutting

Fig. 57 – Undulating interior surface

Fig. 58 – Dynamic modulation (hand-cut) elevation 1

Fig. 59 – Dynamic modulation (hand-cut) elevation 2

Fig. 60 – Sectional study model; (hand-cut) perspective

Fig. 61 – Detailed model: elevation, perspective view
The next stage involved the beginning of an integration of ideas with Simba. This involved a process of discussion and development to figure out how to turn an original, conceptual piece of work into a realistic structure made from separate components. Sketches explored the ideas of how we could translate models into such a structure. Further concepts incorporating alternative programs were explored. As we continued this work it became imperative to start to model these forms on the computer as this would be a required step in future developments.

A survey of a range of software programs was undertaken. Methods of modelling was processed in varying packages to test if and how we could make such work. Each program had its benefits however the combination of their inability to process certain data and inaccuracies in modelling techniques, plus the limited knowledge and experience in their operation resulted in a decision that would mean incorporating multiple programs: Rhino, SketchUp, Adobe Illustrator and Auto-CAD were the selected few. ArchiCad was omitted on grounds that its 3D modelling methods and lack of direct 2D exporting was unachievable. The BIM software Revit was the least known program by all three team members, so was additionally excluded. The additional features and ability for communication between the selected programs would prove to be beneficial in future work.

Other software programs of note are: Vectorworks, MicroStation, Bentley Components and CATIA.
The process of turning a shell surface into a modelled structure was complex. Translating the organic form into digital components was tested in CAD. Additional plug-ins were used to aid in the selection, sectioning and cutting of the generated forms. At this stage of the scheme’s development these processes were found to be difficult to achieve, especially in controlling the accuracy of work.

The solution was to produce framed profiles in a 2D layout and tilt them on their axis to simulate a portal section. Panelled elements could then be incorporated, slotting into their respective housings. This was a much closer representation of Simba’s original models, the application of dynamic form and patterned surface.

Fig.76 – Patterned surface model
Fig.77 – Division of the original form
Fig.78 – The structural lines of such a proposal
Fig.79 – First attempt at digital modelling
Fig.80 – Digital extrusion of a modular frame
Fig.81 – Breaking up a frame into smaller sections
Fig.82 – Framing slots for connecting modules
Fig.83 – Developed concept for a dynamic, modular / patterned mass
Fig. 84 - Refined concept adhering to planning requirements

Fig. 85 - Axon. A dynamic modular structure

Fig. 86 - Illustration of the proposal, in context
Fig. 87 – Exploded axonometric drawing of panel to portal assembly.

Fig. 88 – Illustration outlining the parts to a sectional ‘bay’; slotting into the portal frame.
Architecture is about designing spaces for habitation: to facilitate experience through occupation. Function is first, though efficiency in production and fulfillment in living can’t be achieved without the implementation of spatial dynamics. The ability for spaces to adapt to requirements over time. Designing for evolutionary structures that implement a system of continuous development.

The system involves the process of taking a digital file from conception through development and into fabrication. The digital module holds all the elements that will be manufactured for construction. The built form is an exact representation of the virtual realm. All modeled data is fabricated to become real material. As the model is adapted and developed over time it allows for future growth of an architecturally fabricated environment.

Designing a "dynamic system" facilitates evolutionary development: the system speeds up the construction process; makes the creation of an "idea" an achievable exercise. There is an increase in the variety of forms. It enables these rather explorative concepts to become real and habitable. Environmentally it uses less man made material, reduces waste and lowers costs in the manufacturing process. It allows for people with less skill and experience to build and be a part of strengthening their community.

The next stage in development gave rise to the injection of parameters that would define the form of these modules, in how they would create habitable, functional spaces of experience. Sketches were produced in exploration of possible configurations, displaying an array of activities that may be included in an individual module. The relationship between each module would prove as an imperative consideration in the development of the overall programme and aesthetic.

Explorations of volume and dynamic form were further analysed for the ways in which they could communicate and service an applicable function or activity. These included elements that provided a definition of space: for seating, storage and work.
In collaboration with Simba, a set of parameters were discussed and developed to service a scheme for a studio space that included provisions for the tasks of artistic works, display, and presentation. A 15 bay (modular) concept was developed to represent this. Its form varied in scale, heights, widths and shaping of profiles were all variables to the programmed space.

Fig. 92 – Various functional provisions that a module could provide.

Fig. 93 – Section of an envelope that integrates functional interior fixtures.

Fig. 94 – The deployment of flat-pack furniture; from within the wall space.

Fig. 95 – Moulding the environment to emphasise the spatial qualities of an interior.

Fig. 96 – Conceptual planning of a 15 bay modular studio.

Fig. 97 – The separation and connection of modules to ensure a design programme.
The theory to the profile developments were conceived through the process of creating a ‘ring of adaptive points’. These control points would be moved to provide the starting positions to a profile. Elevational studies depict this. Customisable modules defined by adaptive components was the definition. The requirement for flexibility was controlled by the setting of four key points, they would be preset to the scalable limitations of structural material. Then the secondary, adaptive points would be free to manipulation. They would be changed as required in order to meet the aims of the programme: functional, performative and spatial requirements. These was predominantly data based on ergonomic relating to heights and widths, which may impact on the spatial experience of the end user.

This process could be termed as ‘the crafted system’. Through the utilisation of CAD software, a series of dynamic modules were created from Simba’s set spatial parameters. The conception of 10 controllable components within one module is broken down to many elements, that piece together in assembly. The collection of components are then placed in position to be securely connected and tensioned through the crafts of Azmon’s developed assembly methods. The ten parts in a profile are made up of one in the floor, three in the roof and three in each wall, six in total.
Study models were produced by digital craft, in the exploration of shaping profiles. We examined the ways in which we could manipulate a profiles edge to create a particular aesthetic. The digital processes at this stage were explored through the creation of a surfaced model in the software program Rhino. This allowed for more dynamically accurate forms to be generated. Control points in elevation were set as the spatial parameters. Line-work was then looped through or stuck to the points to create the overall mass. The range of profiles were converted to become a surface before being sectioned to acquire the modular profiles. The 2D sections were exported for further development.

Fig.108 – The wireframe process of constructing a digital model
Fig.109 – A resulting form illustrated as a realistic proposal
Fig.110 – Perspective displaying the panelled envelope between frames
Fig.111 – Profiles being modelled to set spatial parameters
We laser cut models that displayed the organic nature of the structure. Consisting of variable profiles such as:

- Curved Interior and Exterior [1]
- Linear Interior and Curved Exterior [2]
- Curved Interior and Linear Exterior [3]
- Linear Interior and Exterior [4]

The last model was selected as the most suitable for reasons that include ease in modelling and fabrication processes, functionality of internal space and provision for a constructible envelope. A curved exterior profile is an alternative option, where covering may be achieved through the use of a ‘fabric’ system. However this option was not pursued further as it was too costly and prohibitive in terms of allowing our project to progress.

Fig.112 – Profile 1  Fig.113 – Profile 2  Fig.114 – Profile 3  Fig.115 – Profile 4  Fig.116 – A study of the possible spatial experience
Each module was required to be flexible to the programme. So a set of three definitive bays were created as platforms for the growth of the structure, one set in the middle and one at each end. The data that informed their character was derived from collaborative studies on the dimensions required for each space. The three selected were placed at a distance apart, contained within an allocated footprint of approximately 40sqm. This was the allocated floor area for a temporary structure. The additional modules were then needed to slot in between them, bridging the gap and creating an architectural space within.

The spatial experience catered for the transition of movement through a smaller threshold into a larger habitable space that was more adept at servicing the outlined programme. The back end of the studio featured a partition to provide a smaller enclosed workspace for individual study. The larger central volume being allocated as a space for larger works: discussions, meetings, and presentation of work. Thus, a linear profiled wall element was selected to enable the display of work.
Fig.123 – Proposed elevations. NTS

Fig.124 – Proposed section and external form. NTS
It was at this stage of the design process where details started to emerge as to how the envelope would be assembled. In previous modelling work, a panelised system was slipped into cut sections of the framework. They overlapped one another like patchwork to deal with the notion of shedding water. However, in such a method there would still be issues with mitigating damage to the frame itself, as the profiles were exposed to the elements. So an envelope that enclosed the structure was developed, in the instance that it could be propped up with rails, a bracketing system, to follow the form of the modules. The waterproofing system would be placed behind it as commonly found in traditional timber framed structures.

This method would allow for open compartments, allowing the inclusion of window components in each individual module. However, after discussions with an industry professional about the possibility of producing a scheme with such complexity, it would prove costly and rather ambitious. As to the panelled nature of the modules, with variable angles at each step, the railing and bracket system required to fit the design would be extremely difficult to design, control and manufacture. At every point of differentiation customised brackets and lengths in railing would need to be produced. The consultants stated; “they had worked with architects on many projects, but never something as complicated as this.”

An additional hinderance to the method of the proposed envelope was that it would work considerably better if the edges of each panel were chamfered to provide a more accurate and secure junction between elements. This we found, would not be achievable with the available machinery. The CNC Router is a 3-axis machine, not 5. Thus cutting elements at an angle would prove to be unattainable.

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INTERNAL LINING
12/15MM PLY
NOG. 90MM CAVITY.
SPANNING 550MM ‘BAY’
BATTEN SCREWED TO INT. PANEL. SLOTTED INTO PORTAL
EXTERNAL CLADDING ON BATTENS, SLOTTED INTO CHECKED OUT CUT (CNC)
CAPPING OVER END OF EX. CLADDING
BATTENS OVER WRAP FOR 100MM OFF-SET BETWEEN PORTALS
INTERNAL LINING
X2 18MM PLY PORTALS @ 550-600 CRS.

SERVICES CUT-OUT

EXTERNAL CLADDING ON BATTENS, SLOTTED INTO CHECKED OUT CUT (CNC)
CAPPING OVER END OF EX. CLADDING
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SERVICES CUT-OUT

Fig.132 – Envelope construction diagram 1
Fig.133 – Envelope construction diagram 2
From progressive discussions within the team and consultation with supporting staff, we agreed that we needed to make adjustments to the system to allow for it to be easily produced and assembled, while retaining many of the definite characteristics.

Work started on the exploration into creating by digital means. The output was to come from the computer in order to maintain the control and desire of production. This would prove to be critical to the future stages of fabrication and assembly.

The research into the developments by WikiHouse proved to be beneficial to such work. As we had been working with the consideration of their systematic developments and methods of producing structures from CNC cut plywood. We decided to utilise their work that’s available through a Creative Commons [CC]. We could download, analyse and adapt if it was required. We aspired to produce something new. We were informed that our processes were over complicating things and we needed to exercise restraint in our methods. That we should take the existing knowledge, adapt it through collaborative development and share it again with the community; allowing for further progress to be made.

So, with the use of WikiHouses generative script that allows for components to be exported to flat cutting sheets, with the click of a button. We implemented this as part of the process, with the aim of fabricated building elements. There are restrictions in the process of designing elements for export. As the parts are configured in a sheet with dimensions measuring 2400mm x 1200mm, anything made oversized would not be produced. This was a consideration, though it was found not to be a problem, as the method of breaking the frame into separate components reduced the size of the resulting elements.
The modelling began with the development of a floor section, comprising of five separate components; three footings and two fin sections. A selected model from the WikiHouse online library was downloaded, pulled apart and assessed for feasibility. Taking note of the ongoing work by others developing the system, decisions were made to improve the arrangement of parts, the design of their profiles and the way they fit together. All the elements had, to hold them in connection, were a series of pegged slots and wedges that relied entirely on their own resistance and gravity to not pop out and collapse.

The exploration conceived of the creation and development of seven models; these would be produced from 2D/3D modelling methods within the software program. Actions made included: dragging, slicing, exploding, deleting, pushing, pulling, offsetting, grouping, identifying, labelling, and tagging elements in the creation of components.

Model 1: This was the WikiHouse floor section taken from an existing model, with the fins pulled towards the center to create a more even diaphragm. It consisted of components from two connected 550mm bays. The S-joint was evident, where there were no additional connectors resulting in a very fragile junction. The elements were exploded and data was deleted to extract the 2D profiles, enabling further analysis and editing.

Model 2: The second model was produced from the existing profile. This time changes were made to the secondary connectors that ran at a crossroad to the section. The amount of unnecessary connections were reduced by removing the pegged elements from the middle two rings. This reduced the number of elements to be cut and assembled. They were replaced with a stronger and simpler method of cross-lapping.

Model 3: The S-joints in this model, straightened the line-work of the profiles. They were previously at angles to each other for a connection that prevented collapse. However in modelling this method is tricky to control and makes the process more complicated.

Model 4: Taking the process a step further the S-joint was squared off to become a simple lap joint. This would not hold by itself, thus a twin-peg was inserted to secure each element together.

Model 5: This time the lap joint was extended and an additional peg was added to provide supplementary strength.

Model 6: The scarf joint was now re-established for its lateral performance in reducing the overall ductility of the section. The pegs were modified. They became larger and were rotated 90 degrees to connect the separate floor elements.

Model 7: Adjusted the placement of the sections elements in a more accurate model overall. The only addition here was the inclusion of an additional modified twin-peg to secure the associated junction. This model was then saved to an older file format, exploded for exporting and fabricated by hand.

Models produced in SketchUp PRO-13 had to be saved to an older version, SketchUp-8, as the plug-in for exporting components only worked in that package.
Physical Modelling Results: Floor & Wall Details

The first fabricated structure was procured from the ‘virtually’ simulated floor section. The exported data is delivered as an .SVG (scalable vector graphic) file, which was incompatible with other CAD software programs available. This meant that it had to be opened in Illustrator to be visible. Here it was found that not only were the exported parts arranged in an inefficient arrangement, the cutting sheets scale was wrong; it wasn’t 1:1. The file was exported as a .DWG (Auto-CAD drawing) file where it was opened and rescaled. The outlines of the cutting sheets were then generated and the parts arranged in a less wasteful pattern.

We chose to laser cut the model as our endeavor to fabricate was hindered by numerous factors which included: our knowledge of the CNC machine’s CAD/CAM software and its omission from the schools computers meaning any work we did create we couldn’t save. Lastly there was a lack of availability in using the Router as there was no technician employed at Unitec, to operate the equipment.

The modelled parts were scaled down to 1:2 to enable an assembly process that utilised 9mm ply and to fit on a cutting sheet that measured the dimensions of the laser cutting bed; approximately 900mm x 600mm.

As the density of the marine grade timber was too great to be cut through completely we chose to etch the modelled line-work and cut out the individual elements in the workshop. This proved to be a lengthy process taking a whole week to create, from file to fabrication.

The fabrication of the floor model at 1:2 was as much about seeing how the elements connected physically as it was about testing their ability to be produced directly from a digital file. A test of whether or not the data imbedded in the virtual simulation would be retained in the process. Thankfully it all worked as planned. What we learnt was that any miscalculation or error made in the digital process would be transferred to the fabricated model. This was seen in the misalignment of connectors in the floor, as their adjustment was missed during the design phase.

The process of making the model is further explained in the following chapter.
The next addition to the physical modelling was a 1:1 wall detail. It was produced in order to test the tolerances of the slots in which the elements connect to one another. All the corners of the elements featured ‘dog bone’ indentations, to accommodate the circular head of the router tool. The tool leaves rounded corners, therefore an indentation 5mm deep and 10mm long was required to attain a flush intersection.

In collaboration with Azmon, we worked on making additions to the frame, to make a component that could be easily connected. We added struts between the elements in provision for the process of tensioning the joints. Squared tabs were added to act as hooks, to prevent the elements slipping in ‘shear’ stress. Grooves were also incorporated in the exterior face of the ‘nogs’ as an allowance for the inclusion of a tension cable. Post fabrication, we discussed how the addition of further struts would allow for the bracing sheets to be secured.

This was going to be our first cut on the CNC Router. A technician was found: a first year architecture student with the relevant skills and experience in operating the machinery. I worked through the stages of making the files required for the manufacturing process to begin. Through exporting the AutoCAD drawing as an older and more compatible .DXF (drawing eXchange format) file into V-Carve Pro (CAM Software Program) we arranged and setup the profiles for cutting.

It was a worrying step in the phase of development, as I was unsure whether or not the parts were going to be replicated accurately. However, the cutting proved to be perfect. Produced to the millimetre in terms of accuracy. If it was to go wrong, it could have resulted in the ‘make or break’ of the project.

The aim was to test how differences of up to two millimetres in each cross-lapped junction would perform post assembly. The three different fins were given additions in 1mm increments. The results and findings are documented in the following chapter.

**CUTTING + OFFSETS**

**IN MODEL AS CUT**

10mm

5mm

Dogbones

To allow for different sizes of milling piece (typically between 6mm and 9mm) put in dogbones to allow full internal 90 degree angles. Curves tend to be memory intensive and slow, so just draw 10mm x 5mm rectangles and the CNC machine will infer the rest.

**Offsets**

In computer world, two connecting pieces are infinitely close to each other. Reality, obviously doesn’t work like that – tolerances are needed, and are put in by offsetting edges inwards. Eventually this should be automated, but for now it is necessary to do it manually. Offset amounts vary depending on material and climate, but 0.1mm-0.3mm offsets are typical. Too tight, and the structure will be very hard to put together. To test your offsets, download and adapt the Wikihouse test cutting / calibration piece.

![Fig.150 – The smooth ‘Dog bone’ cut by a router head as the tool passes around sharp lines](image)

![Fig.151 – CAD model of a wall detail made to test tolerances in cross-lap junctions](image)

![Fig.152 – CNC machine cuts profiles from a 18mm plywood sheet](image)

![Fig.153 – Alternative methods for connecting components](image)

![Fig.154 – Accuracy in fabrication: parts measured to match the digital file.](image)
Design Process

The design of the interior is influenced by the experience of the place that it is to inhabit. The practice of designing an interior is an intricate process of satisfying the needs of the user, while balancing this with considerations of context and place.11

Definition of the Interior

Graeme Brooker and Sally Stone outline in their publication Basics Architecture: form + structure that...

Elements for Organising Space

The strategy for organising space informs the plan or layout of the building. It is the elements within the space that give the space its feelings. The components are made up of the individual elements of the building, the separate details. They are an expression of the use and character of the program. It is these elements that distinguish or make different one design from another. The elements give character; they define the quality and provide the features of the structure. It is the calculated placement of them that gives the space its individuality. The whole building can be understood through the reading of the details. The arrangement and juxtaposition of form and lighting can be discussed through the arrangement and juxtaposition of form and lighting.

Thresholds establish the physical and visual relationships between components and spaces. They include the exit part of the journey and become a reminder of things already experienced. The thresholds is not intended to interfere with the experience of the journey, as there is the intention for a seamless transition.

The views of inserted elements provide focus to the space, facilitate and encourage movement, supply rhythm and balance, and provide clarity and direction. The texture of elements describe the materials that are fabricated. It is the stuff that is touched, felt and handled. The application of materials and finishes imparts character; the surfaces establish a direct relationship between human contact and the building. It is not only provides ergonomic and environmental strength where necessary, it also signals personality and craft in assembly.12

3.5 Proposed Module

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Further developments took place through discussion amongst
the team, sketching and modelling a future direction. After
consultation with staff it became imperative that we wanted
to further simplify the scheme if we aimed to build a portion of
it. The theory was now to simplify, simplify, simplify whenever
feasible.

In refining the developed concept, we strengthened the brief
to guide our process. The proposed structure was to be more
constrained in its footprint and service to the studio space;
through the integration of internal formwork and structural
elements. It was to be the creation of a seamless interior inside a
cleaner, linear formed container.

Supplementary information to the outline can be found in the
following chapter.

3.5.1 Refined Concept

Sketches of changes to the profiling depict these modifications
to form and function. Working through this process, there was
a continuation of adaptation for the components to generate
a form. Reducing the severity of angles would make a built
resolution more attainable.

Dynamics in form were still considered, though it was to
be fashioned in a more restrained manner. One side of the
structure being adjusted or a surface being manipulated through
decorative means; the deployment and shape of cladding battens
and building features.

A variety of finishes to the envelope were explored and
developed as options for a possible outcome.
The form of the buildings’ profiles and spatial plan were further refined to meet the objectives of the program. Establishing a plan for the proposal of the core structure enabled the internal framework to be developed in collaboration with Simba. The integration and connection of elements was developed in conjunction.

The proposed outcome is for an 11 bay, modular structure, consisting of 5 enclosed modules at the core and open additions at each end. They can be detached at any time. Its development considered the stages previously stated in the process of design, with the overall shape addressing conditions of site, programme, experience and aesthetic. A new laser cut card model depicts the new volume. Similarities can be seen in its relationship to earlier work.

The finished core was then used as a platform for the integration of the morphed interior framework being simulated by Simba. The inclusion of such elements was omitted from the fabricated structure that followed. A morphed model was created from sectioned contours in Rhino. This study model provided a useful method of communicating how the final interior may be perceived.

**Fig.171 – Internal view of the digital structural model**

**Fig.172 – Illustration of the return to an earlier concept**

**Fig.173 – Laser cut model / view 1**

**Fig.174 – Laser cut model / view 2**

**Fig.175 – Individual sectioned profiles extracted for cutting**

**Fig.176 – Virtual model containing moulded interior forms**

**Fig.177 – Laser cut ‘profile’ study model / view 1**

**Fig.178 – Laser cut ‘profile’ study model / view 2**
The computer model for the prototype was started from scratch. This process began by creating the outlining profiles to the form, turning them into a solid surface, breaking the planes into elements to suffice as compatible building components, there was the addition of methods for connection at critical junctions, slots in each element for seamless jointing and grouping of compatible components to enable duplication and adaption. The resulting structure, a core module derived from the central five was then exploded into sections and groups for the staged process of export. This was done to rectify issues with the WikiHouse script; as attempts to export the whole model resulted in many missing elements. Further to this, the smaller components were not recognised by the plugin. Therefore they had to be drawn in Auto-CAD and copied in multiples to mirror the designed work. This software is still in its early stages; to contribute to its growth you can provide your services as a developer or make a donation by visiting the WikiHouse website. Finally the building had become a hybrid system; a modular arrangement of panel and stick elements. An open system that allows for a combination of parts to be incorporated into future work for support of the functional program, mechanical servicing, or finished aesthetic.

“Wood is just a one-syllable word. But behind it a world of beauty and wonder is concealed.” Theodor Hess (1884 - 1963)

Gerald Staib, Andreas Dorrhofer and Marcus Rosenthal, Components and Systems Modular Construction (Munich: Birkhauser, 2008)
**Architecturally the program (use) of the space is informed by a particular dialogue / language.** This dialogue will be used to identify the desired prototype. Through a process of research material, an investigation of different spatial qualities through modelling, drawing, and testing will reveal what the final outcome can be. This will be worked on individually then collaboratively. The chosen form must adapt, change and become flexible enough to be configured in different arrangements. Ways to do this will be through testing various methods in which an internal layout is fitted. The architecture will be formed by the spatial qualities of the structure; most importantly it will determine how the spaces can be used. Continuous feedback from the team members and staff will ensure that this process is dealt with appropriately.

**Fourth Stage - Construction**

**Azmon Chetty - Connection**

"the action of linking one element with another"

Works include the research and modelling of various joints, lashing methods and tension systems that are suited to this prototype. A physical catalogue of models is produced for discussion as team members decide what joints, lashing and tension system will perform to the best measure. Further developments through more modelling, or changes during application of the building process may be made.

The development of each component is not set, provided changes may be made upon completion of the built prototype. Load testing the structure will uncover the performance of each component, (the joint, lashing and tensioning system) each component will unveil both the weak and strong points of the structure. Further developments may be proposed for the prototype to increase its structural stability. The fabrication process utilizing digital and manual techniques provides an opportunity to evaluate both component joints, and lashing and tensioning systems on the prototype. Following this the variations of each component will be recognised and compared to those being tested within the structure. The results will give indications as to which connections may need manipulation to strengthen their performance.
Architecturally the project has a responsibility to address the contextual conditions: site, climate, culture, people, shelter, material, and projected fabrication costs. These and many more factors are considered in the process and adhered through differing methods of design and assembly. As the work can be customised according to requirements, the proposed system is open to modification; a change in use or location.

The modularity and assembly of the structure allows for the system to be deployed in areas needing adaptive development: such as disaster struck regions, social aid zones, districts of residential growth, and commercial ventures. Globally it may be made accessible through a creative commons enabling others to contribute in further developments.

The proposal, like many has its theoretical elements. This investigation considers the relationship between architecture and construction; through the craft in fabrication and assembly. Therefore a built component must take its place to represent the intended scheme. The representation of structural components and methods of connection takes place through the digital fabrication of scaled elements. Additionally, manually made models will be produced, displaying methods of connection with influences deriving from Japan and the Pacific regions.

The setting for our work is Auckland, a city of a temperate climate. The selected construction material consists predominantly of flat sheet plywood. The plywood succeeds in similar works for its structural performance, appearance, ease in workability, assembly and control in the fabrication process.

The materials are locally sourced where applicable and are stored in a controlled environment (under sheltered conditions of the workshop). The workshop where the CNC machine is located is where the manufacturing and fabrication of the structure will take place.

The levels of fabrication being plans during the project are subject to: availability of facilities, support staff, our design intentions, work rate, skill level, material supply and the relative costs with funding this work.

4.3 Site

The scheme is intended to be non-site specific. As the proposal considers the design, fabrication and assembly of an architectural system as the primary focus. This is the driver for design, with ‘making’ at the heart of the project. The conditions of alternative sites and climatic conditions have become secondary in the design process. At times they are acknowledged where applicable as we endeavour to propose alternative adaptations; though this is not the main concern.

We set additional limitations to control the projects scale by implementing the building under a non-consent classification: a temporary dwelling; positioned away from significant buildings, boundaries and other important structures. The footprint is to measure no more than ten square meters; this is the core five modules of the structure, with the additional six modules making up the ends, functioning as a detachable deck and pergola like components. The larger allocation of forty square meters is too large and unnecessary for representation of our intended proposal.

The location selected for the positioning of the full eleven-module structure is a grass-covered plinth, a slightly elevated level outside and adjacent to the Masters of Architecture studios, on site at the Unitec Institute of Technology (1 Carrington Road, Mt Albert, Auckland, New Zealand) (fig. 184 - 188). This site is an ideal area to display the built works, and functionally suitable for the intended occupants.
4.1.4 Design Program

The design program for the proposed structure has been set as a single space for operation by two to three students. A small studio, where collaboration between peers and presentation of work can take place. The provision of desk space is of primary concern for achieving this purpose. The spatial environment is a condition of note, as its functional features are moulded from the framework of the structure. The framework consists of elements that are seamlessly related to the structure, keeping the aesthetic and functional value. This will allow for a unique spatial experience, engaging the senses of the inhabitant. The space is intended to propose a notion of a greater awareness of our built environment through the display and connection of the structure itself. The aim is to fabricate a structure that people find both intriguing and useful; giving an opportunity for discussion around the proposed alternative methods of fabrication and assembly.

4.1.5 Brief

As a guide to the development of the project, the brief to the scheme consists of requirements that would best suit the different focus areas of our research. The commonalities between our individual works form the background for the proposition. The aim is to produce a design proposal for a modular system that allows for 1. Ease of assembly and 2. Can be disassembled to allow for expansion and reduction.

It must express fabrication processes to showcase the craft and culture in the digital and manual construction techniques. Ultimately, it must propose a structure that is capable of permitting habitation. It cannot be simply a sculptural model, which is often seen in other projects that lack considerable purpose.

Technically, the structure must be designed so that it adheres to the limitations of the available CNC machines capabilities. The being the parameters guiding the process of manufacturing from flat sheet materials; cutting plywood elements at variable scales and thicknesses. The depth of the modules is to range between 500-600mm and the width to be within the vicinity of 3600mm. The scope to these settings is derived from the WikiHouse precedent, (refer), along with the restrictions of both the digitally influenced CNC processes and our own manual skills in piecing together such a range of components.
4.2 Design & Construction
4.2.1 Floor Model 1:2

The floor model was conceived as the end product of the computer file conversion. It was more of a trial basis to see what the initial processes would be to get a computer file uploaded into the laser cutting software and then cut and joined together. Not all file types are compatible with the software used by the laser-cutting machine. Issues with scale were the biggest factor. There was often rescaling of the design and checking measurements to see if they were correct.

The laser cutting machine was capable of cutting certain materials, however it was not capable of cutting others. The model was specifically made at 1:2 scale to deal with limitations of the laser bed and material dimensions as elements for a full scale model would not have fitted.

The majority of the time was spent on testing the file conversion across multiple programs to find a fully functional model that was compatible. It was clear that the computer modelled components had to be perfect. Otherwise any incorrect or off-scale line increments would be cut by the machine resulting in pieces not fitting together properly.

In terms of time and cost, the etching process was more efficient (fig. 237). Having the components etched onto the plywood meant having to cut the pieces out manually.

Issues faced when hand cutting the pieces - the cutting was tedious and repetitive as the scale of many component pieces were so small. Hand cutting and chiseling proved to be time consuming and it was difficult to operate the bandsaw effectively.

The cutting has to be accurate so the components will join and slot in properly. Pieces had to be adjusted through sanding and air grinding. Care is needed when doing this; constantly checking the fit. Taking too much off could mean a loose fitting which is not ideal when no permanent fixings or glue is being used. With our project we are using interlocking joints for accuracy in cutting which is key as any tolerance too big or small in the joint could result in too much flex when testing the structure. When tension is applied the joint could move too much through the alignment of the components resulting in pieces such as the cladding stubs moving out of alignment with the bracing sheets.

Hand cutting brought to light and further reinforced that manual cutting is not as precise as cutting done via machine such as laser cutters or CNC machines (fig. 192). This could be due to a number of factors such as hand speed, control, state of mind (being cautious of workplace accidents), machine capabilities and calibration of its accuracy. Manual cutting is simply not an option for us, due to the number and size of the components. If the final structure is to be used in a disaster situation, i.e. Cyclone relief, it has to be cut quickly and efficiently so production can be quick and easy. Manually cutting and preparing the floor model took one week with two people, while utilizing a CNC machine we expect to complete this process within one day.

In tandem, manually cutting the pieces means the final product is rough; tends to get uneven surfaces, with big splinters of wood (fig. 193). The manual craftsmanship of the model required using an air diment machine, files, and hand held sanders to get a higher level of finish on the components (fig. 193). Compare this to the finish of the CNC machined elements which have clean sharp cuts leaving only small splinted edges that can be easily smoothed off with a sanding block.
Fig. 190 - Component pieces ready for assembly.

Fig. 191 - Azmon using the air dime grinder to sand down the rough bits.

Fig. 192 - No.193 - Roughness of manually hand cutting the component pieces.

Fig. 193 - Simba cutting out the shapes on the etched sheet of plywood.
The idea for the wall detail was to test what tolerances would work; one or two millimetres out would make a significant difference in the tightness of the joint. There was no tolerance given to the scarf joint (which has been tweaked to be more square, to allow room for the pegs to pass through (fig. 195)).

No tolerance was given to any of the vertical members as their joints needed to be tight. Any loosening could mean deflecting the cladding slots once the joint is under tension. Tolerances were given to the horizontal nogs, all three slots for the cross lap joints were given different tolerances ranging from 18mm (fig. 196), 19mm (fig. 197), to 20mm (fig. 198). The result being; the 19mm and 20mm tolerances were too loose, causing them to slip out easily without much friction holding it in place. The 18mm joint performed the best as there is some friction in sliding the fin in and out. This friction allows the nogs to stay in place, so when the structure is compiled the joint will come under compression in further reinforcing the friction in the cross lap joint, which is aided by the cladding at the open end.

Essentially, the clinch knot makes up for any looseness in the ‘loop phase’, as it binds and pulls the rope and joint together.

The issues that came to light from the lashings were associated with the size of the rope and not having any notches on the struts. 0.5mm ‘hemp’ rope, was used to lash the joints together (fig. 205, 206), too much strain from tensioning or surface friction (rubbing of the rope) would lead the rope to snap; this joint was not under maximum tension. The size of the rope dictates how much friction is being placed on the joint, thinner rope means more surface coverage for less loops (fig. 206), more allowance for strain which equals a tighter joint. In this case, smaller rope, 0.3mm, means more loops are required to cover the same surface area as the larger rope (fig. 206); which all leads to less strain and a weaker joint.

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Fig. 196 - 18mm, zero tolerance given in the cross lap joint.

Fig. 197 - 19mm, 1mm tolerance given in the cross lap joint.

Fig. 198 - 20mm, 2mm tolerance given in the cross lap joint.

Fig. 195 - Squared oblique scarf joint.
Fig. 199 - Unitec CNC machine in the process of cutting the component pieces for the wall model.

Fig. 200 - 18mm Plywood loaded onto CNC machine.

Fig. 201 - Second phase cut.

Fig. 202 - Racking the sheet so all the pieces fall out.

Fig. 203 - Tapered pegs are too short, not locking the joint sufficiently.

Fig. 204 - No internal pegging allows the joint to slide inwards on the strut.
Fig. 209 - Clinch knot lashing.

Fig. 210 - How to do a clinch knot lashing: step 1, peg the rope and loop it under the bottom strut.

Fig. 211 - How to do a clinch knot lashing: step 2, on completion, loop a second time (clinch) around the first, apply tension with every rotation.

Fig. 212 - How to do a clinch knot lashing: step 3, pull the clinch tight, either peg or knot the end.

Fig. 205 - Figure 8 lashing.

Fig. 206 - How to do a figure 8 lashing: step 1, peg the rope and loop it under the bottom strut.

Fig. 207 - How to do a figure 8 lashing: step 2, loop it over and around the top strut.

Fig. 208 - How to do a figure 8 lashing: step 3, pull the rope back and under the bottom strut. Keep repeating the process.
The technician then reconfigured the cutting sheets and brought the components closer together in order to get maximum use out of each sheet.

The next step was to set up cutting passes for each individual sheet. The passes dictate the quality of the finished cuts and the time it takes to make those cuts. The machine could either cut the components in one pass, meaning a 19mm deep cut on an 18mm plywood sheet or multiple passes, cutting in 6mm increments, in a three pass process. Less passes means poor quality and less time consumption, more passes means high quality and more time consumption; therefore we had to weigh in what was to be compromised.

After the cutting had commenced we manually measured the cut components, discovering that the machine had added up to an extra 2mm on one axis, mostly on the larger elements. The machine had somehow calibrated itself incorrectly which lead to the boundary line moving up to ‘two millimetres out’ on one axis. This was no fault of the computer files or the technician, but simply an error in the CNC process. The technician had no knowledge of how to recalibrate the machine to fix the problem so we had to persist. The affected pieces were first shaved back using a bandsaw then either hand sanded with a sanding block or an air die grinder. This issue would be minor as the edges were to be shaved back manually, the resulting finish quality isn’t as sharp or straight edged as what you would get from an initial CNC tooled cut.

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After the cutting had commenced we manually measured the cut components, discovering that the machine had added up to an extra 2mm on one axis, mostly on the larger elements. The machine had somehow calibrated itself incorrectly which lead to the boundary line moving up to ‘two millimetres out’ on one axis. This was no fault of the computer files or the technician, but simply an error in the CNC process. The technician had no knowledge of how to recalibrate the machine to fix the problem so we had to persist. The affected pieces were first shaved back using a bandsaw then either hand sanded with a sanding block or an air die grinder. This issue would be minor as the edges were to be shaved back manually, the resulting finish quality isn’t as sharp or straight edged as what you would get from an initial CNC tooled cut.

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Fortunately the smaller pieces were the last components to be cut on that sheet. Once all the cutting was finished we had enough free space left over on the previously cut sheets to cut the smaller pieces on. This time the technician had upped the cutting passes and configured wider margins between the pieces. He also left small tabs (fig. 218), on the final cuts so that the piece would not shift when cutting its way around. These were easily sanded back on the table belt sander.

When testing struts to see if the pegs would slot into the holes in the struts we had noticed that the peg holes were varying in size. The holes had been programmed to cut after the strut had been cut, so the stubs holding the strut were not effective in stabilising it when the peg holes were being cut, allowing the strut to move around. This didn't affect the final model structurally because the pegs were tapered. The effect was only seen aesthetically when tapping in pegs with varying heights (fig. 219).

The quality of the plywood did create some problems down the line because we had opted for the cheapest in the market. Choosing BB grade - 18mm sheets for fifty dollars each, manufactured in China, we compromised quality for cost. The quality was poor and this was first displayed when the pegs would burst while the CNC machine was cutting them, due to the cheap glue used to make the plywood. At the end, extra pegs had to be cut as back up if anymore were to burst when the assembly phase had begun. When hammering the pieces together the edges would start splitting under pressure (fig. 220), which didn’t compromise the structure but left an uneven and rough edge plain.

A significant issue that occurred was when cutting the pegs and struts. As these were such small pieces the technician thought he could cut them quicker by lowering the number of passes. The larger pieces were being cut at four passes (4mm, 9mm, 13mm, 18mm), this was then taken back to two passes (9mm, 10mm) for the smaller pieces. The technician didn’t factor in the amount and size of the accumulating sawdust. More passes created smaller amounts of the sawdust (fig. 216), which is easily sucked up by the dust extractor attachment, less passes meant larger flitter clumps of chip and dust which is harder to extract (fig. 217). Usually an air gun is required to blow out the cutting channels of any excess clumps that weren’t sucked up by the extraction.

The smaller pieces had been laid out quite closely to each other on the cutting sheet so when cutting the tool jammed, which made the whole sheet shift resulting in it losing its datum point. The reduced number of passes and the faster cutting rates of the spindle had combined to jam on the sheet. The debris heavily blocked up the cutting channels (fig. 217), which the dust extractor couldn’t remove. This lead to the tool bit pushing the dust along so it was cutting at a point where the dust got compressed that either the tool or the sheet had to give. Fortunately the resulting damage was to the plywood sheet and not the CNC tool bit, which would have proven costly. Damage to the tool bit would set the cutting schedule back by a week or more.
A further discussion took place between the group team about what would be the easiest method to assemble and erect the structural frame.

Option 1: Build the frame bottom to top whilst it is free standing:

The advantages of this method is that the frame itself must be picked up and slid into place. The disadvantages of this method is the frame could tip over (fig. 223, 224), or buckle without any support from either side, making it hazardous for the people around it or building it. The joints will be flimsy on their own; this will allow the joint to have too much movement while the structure is being erected. The movement would cause the frame to break up if it was to tip over because it is not one solid frame but a number of elements joined together to make one whole module. This would cause arms of the scarf joint to rupture and snap.

Option 2: Build the whole frame entirely in four portions (fig. 223, 224), the advantages of this is that a majority of the lashing and joining can be done on the ground. This option would also minimise ladder use as it would require the person lashing or hammering to be on a ladder for long periods of time; when banging the nogs into the cross-lapped slots.

The disadvantage of this option is that the weight of each portion, when erecting requires a lot of man power to lift and hold the components into place. Once the portion is in place it needs to be held up while the other portion is slotted into place. Manpower can be replaced by mechanical power but we did not have access to a crane or pulley system. Even if we did we could not have got the crane up to the second storey of the studio space and the rafters were not certified to take such loads using a pulley system.

Figure 221 - Fixings; from left to right; hook turnbuckle, ring screw hook, crimp, eye strap, hemp rope, jute twine and wire rope.

Keeping an eye on the amount of components was crucial for us, as we did not have access to the CNC machine once the cutting was done due to the schedule that we were working to; as this prototype was being made for presentation. The large pieces were easy enough to track but the smaller pieces took the most time to count up (all 202 pegs). Keeping track of these pieces became harder because there was a number of people that handled them after they had been cut. Pegs can be manually cut on the band saw but the size of these tiny components were too complex to be cut manually.

Half a day was spent gathering up the fixings (turnbuckles, ring screw hooks, crimp, eye strap, hemp rope, jute twine and wire rope) (fig. 223). We were fortunate to find a shop that sold most of the fixings and rope required for the build. Just under $120 dollars was spent on getting most of these fixings as we had managed to source turnbuckles and wire rope from the Unitec Institute of Technology, Architecture workshop. If the model were to sit outside and be exposed to the elements the cost of fixing would double because stainless steel fixings and wire would be needed to stop rust from occurring. In this instance we opted for the galvanized steel option as the structure was going to be built in a fully enclosed, indoor studio space.

The entire range of component pieces were moved to the studio space once they were prepped and sanded (fig. 222). The individual elements were then matched and stacked (four identical elements) so it was easy to locate the elements when placing together the structural building frame. The stacks were then moved to the area where the frame was allowed to sit on the floor. This gave us an appreciation of how much space the structure required in the allocated area.
After our experience of this scenario, it was decided that the third option was most appropriate; due to the location of the build and what assembly options would best suit alternative locations.

Option 3: Completely build the frame on the ground and lift it up. The advantage being the whole structural frame is built on the ground and the majority of the prework is done in the ground, thus minimizing the use of a ladder. Once the frames are built up and placed side by side, the nogs can be slid in to join them together making a bay. Once the second frame is up the structure can support its own weight and be freestanding without additional assistance. The biggest advantage of this option is once the frame is built up the frame compresses the joints which aids in the lashing process so the joint is already under a certain amount of compression.

The disadvantage of this option is that the frame is freestanding without support. Unless it is tied back to something that can hold the frames weight or there are people holding it, there is nothing to stop it from tilting and falling over. The nogs must be removed, then slotted back in each time another framed module is erected, as the nogs span multiple bays; the length and quantity of these elements are dependent on the completed scale.

After our experience of this scenario, it was decided that the third option was most appropriate; due to the location of the build and what assembly options would best suit alternative locations.

The first frame was pieced together on the floor using a rubber mallet (fig. 226). The struts were slotted in to the larger pieces first. Once the strut was in place the component pieces were then elevated allowing the arms of the scarf joint to line up and slot into each other (fig. 227, 228). The large pieces had to be manually held in place to allow for the pegs to be hammered in. The pegs locked the joint completely, thus keeping separation, allowing us to move on to the next joint. This process was repeated all the way around in the making of an enclosed frame.

Once the frame was completed it needed to be stood upright and moved away to make space for the assembly of the second. We quickly found that three of us alone would not be enough to lift the structure into position. There was a possibility the frame would buckle under its own weight due to the flex occurring on parts of the frame that were not supported; (fig. 229), when tilting it up the unsupported distances between the three team members were too great. The frame would bend inwards where there was no support. The pressure while lifting it upwards in three positions would cause immense strain on the unsupported parts. Commonly referred to as the ‘bending moment’. The frame consists of multiple elements and if the bending moment occurs near where these pieces are joined (fig. 230), the pressures could buckle the components without notice, causing significant damage to the scarf joint.

Additionally, any pre-wrapped lashing would have become loose because they wouldn’t have been processed while the frame was under compression. This option may have been the weakest and slowest possible way to work and place the portions together. In any other situation, either a crane or pulley system would be beneficial.

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Fig. 226 - Assembly: layout of framing elements on the floor.

Fig. 227 - Oblique scarf joint separated.

Fig. 228 - Oblique scarf joint connected.

Fig. 229 - Scarf joint bending inwards.

Fig. 230 - Frame bending inwards.
During the assembly of the second frame the team members heard a creaking noise which seemed to be getting louder. As they turned they noticed the frame that was previously upright was on its way down. It ended up landing on top of the frame that was being built on the ground (fig. 232, 233). Luckily the team moved to the centre when the frame was falling around them. No one was injured. It was again evident, the grade of plywood was poor as the frame had incurred major damage as one of the larger elements had split; (fig. 234), but not to the point where it had broken away completely. The upside to this incident was that the frame had maintained its shape when it had fallen over, giving us an indication that the connections were doing their job and sustained the impact of hitting the ground.

The fallen frame was tilted upright after it had been rigorously checked over for any other damages. As four people braced the frame to stop it from falling over, discussion and survey took place on what the frame could be tied back to. The frame was situated in a tight space where it could not be moved to another part of the room.

Once the upright frame was braced securely work recommenced on the secondary frame on the floor. Building the frame the second time was faster as we improved our assembly methods. This was from the knowledge and techniques we picked up from assembling the first frame. The base of the finished frame on the floor was dragged closer to the frame that was already upright. This meant less time moving the frames around when trying to get them closer upon erection. By moving it closer it would allow us to quickly tie the two frames together using the nogs, meaning the two frames could support and brace each other without us having to manually support it.

The secondary frame was tilted up (fig. 235), manually by six men, whilst two men were still required to brace the first frame. Once the frames sat side by side the nogs were hammered into their housing joints which combined both frames to make one bay. Once combined the structure had doubled in width (a bigger footprint). The larger footprint allows for better weight distribution throughout the structure thus allowing the structure to be more stable under its own weight. During the design phase we knew weight distribution was key for structural performance as the connections are free of glue at any permanent metal fixings. Even weight distribution allows for even compression of the structure. The module may fail if one connection is under significantly more pressure (fig. 236), than another (fig. 237), in the same frame. The joint that has less or no compression can cause a loose joint that can affect the whole bay by having too much movement. Take the scarf joint: if the element was to slip out it would make the frame lean slightly to one side; this would throw the alignment out for the cladding, interior components or any other key element.
Through the findings of research we managed to apply two other forms of compression to the joints and the structure if the weight alone could not compress the structure evenly. The first step was to place the structure under controlled compression through tensing by using wire cable’s fitted with industrial strength turnbuckles (fig. 238). These would force the structure to compress, hopefully putting the structure back into alignment if it was out. Second, was to put struts on both arms of the scarf joint then lashing in-between to pull the joint together. This time placing compression and tension on each individual connection (fig. 252, 256). Using these methods ensured the structure has three lines of defence, so if one was to fail, there are two systems backing up that work at an easy to fix the one that had failed.

In the meantime, the rope for the lashing was measured and prepared for the next day. After the preparation we decided to have a test run, which would determine the length of rope used on one connection. This helped to gauge how effective the thicker hemp rope would be before tensing down the structure with wire cables. It was good practice to have the trial before the first phase of the build commenced as it provided an extra day in advance to resolve any issues that arose from it.

The trial run would help identify a couple of issues with the lashing: originally the plan was to crimp the rope around the strut. However, a problem occurred with the metal crimp that would cut into the rope, possibly causing it to snap under tension. The other issue with crimping the rope was when the crimp was too small to slot the rope into. When trying to thread the rope through the crimp, the rope fibres split apart (fig. 239), making the rope lose its shape; which leads to the rope losing strength.

Bigger crimps were available but around the channels that the rope is fed through they couldn’t close enough to stop the rope from sliding inside the crimp. This would cause the lashing to lose tension over time.

As the lashing junctions were being connected, a solution that would eliminate crimps and hold the rope in tighter was brought to our attention. This process required the inside pegs to be hammered out to allow the rope to pass through the hole. Once the rope was through, with 20mm over hanging, the peg was hammered back in, locking the rope in place (fig. 240). Once the rope was locked in, three people pulling on the rope applied tension. This resulted in the whole bay moving but the rope did not slip or snap at any point. As a result of this, the joint was completely tensed to gauge how much tension could be applied to the connection. The issue was that tension was being lost through a grip in the process when looping the rope around the strut after a few attempts, the technique that was employed for lashing to achieve tension failed, when the rope had been looped around the strut and no maximum tension was gained. This was due to the rope trenches locking themselves into the channelled edges (fig. 241) of the strut, where there was no allowance for any further movement.
The rope was to be treated with tarring, but this process is very labour intensive. Eventually the hemp rope was replaced by Manila hemp (no relation to the Hemp plant) which is more durable, flexible and water resistant. The option to use hemp rope was based on the site of the assembly (indoors). In a water proof area the rope can be used affectively. If the site was to be located outdoors, Manila hemp would be used, as precaution, as the tarring would be protected from external conditions by a selected weather skin.

During the trial run, two different types of lashing methods were applied. A ‘figure of eight’ (fig. 245), and a ‘clinch knot’ (fig. 246).

Both lashing selections performed as expected. The clinch knot being the stronger of the two as it withstood the pressure under tension and held its shape once the ends of the rope were pinned in place. With both lashing types in place the rope was numerous times around the position of the scarf joints; that had been under tension from the lashing. This was undertaken to see if gaps would appear where one face of the join met the other. We were more than satisfied the lashing had compressed the joint to the point where it didn’t open up at all, when jolted or pushed.

The next day, the housing slots on the nogs where shaved back for the last time and after the same three white pegs were cut in case any roof bralt in the final phase of the build. The remaining pegs were driven into place for the structural frame. Once the nogs were in place the structure was deemed safe to move by the exhibition coordinator and workshop technician. It took a group of six people to move and position the structure in its final resting place for the event (fig. 247). During the move the frame held firm as it was solid paying. After the move the frame was checked to see if the joints and pegs had deflected. The top half of connections near the roof had moved by 1-2mm, this was because there was nothing breaking the top during the move, the move was extra fast as they wanted to be lakend back to the exhibition area early to be packed away. The bottom half of the frame was more than satisfied the lashing had held firm. After positioning the structure, prep work commenced on the wire cables so that the structure could be tensioned to the ground before the lashing could start. cloves wire was then unravelled and straightened to check for any defects. One end of the wire was then fitted with a galvanized hook and turnbuckle. Once the wire is passed through the turnbuckle ring-head, it has to be folded back where it is then threaded back through the eye of the metal crimp. A large hand operated crimper is used to crimp the wire into place; once the wire has been cramped it can’t be taken apart unless the wire is cut. An alternative method of crimping the wire would be to use wire rope rings. They are more efficient as you loosen them to adjust the lengths of the wire without having to cut them. We opted to stick with the metal crimpings to see how they would perform and adjust the lengths of the wire without having to cut them.

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In other events, centre points were marked out in the floor cavity space of each frame. The mark was set back from the building edge so that tensioning mechanisms did not hinder the cladding brace performance. After drilling holes, stainless-steel ring screw hooks were secured down. The turnbuckle hook and eye piece (fig. 238) were adjusted before hooking them into the ringed hook on the floor. The wire was then thrown on top of the structure where it was aligned and slipped into the tracks cut for it, on the edges of the nogs. At this point, another person measured and bended the wire to where it needs to be cut. The turnbuckle is fixed once the wire has been cut and cramped. Hooked onto the ring screw the turnbuckle is left un-tensioned as the same processes are repeated on the frame next to it. The turnbuckles are tightened on all four sides (fig. 238); all four turnbuckles having the same amount of turns to apply equal pressure over the whole structure.

Lashing the connections commenced once the structure was under tension from the turnbuckles. The frames featured two types of lashing. One frame had the ‘figure of eight’ and the other had the wrench knot. During application, the lashings completed on the top half were noticeably harder to apply because the person had to stand higher on a ladder to undertake the lashing. Stability was difficult to maintain when doing the lashings in such a position. The rope needed to be pulled and tightened to gain the maximum amount of tension, this was difficult when attempting to balance on the ladder while trying to achieve maximum leverage on the rope. Employing a scaffold system would have been ideal as无论是 for a stable footing on a wider and longer platform.

The last phase of the build was connecting the cladding panels (12mm ply brace sheets, fig. 248), in terms of their alignment, the holes on the cladding panels didn’t align with the connecting stubs on the structure (fig. 249). The fault was again due to the turnbuckle on the CNC calibration. Some edges had more than two millimetres taken off them. Manually the slots were increased with the use of chisels to remove excess material. Additionally, it was under tension that we found the structure had shifted a few millimetres, further offsetting the cladding in some places. The frames had to be pushed and pulled to align the cladding boards with their fixing points. Once aligned the boards were tapped on with rubber mallets. As the boards were being fixed we noticed that the structure had started to re-align itself because the boards were shifting the alignment to where it should have been. Lashing the boards to their allocated struts was abandoned due to time constraints prior to exhibiting the work. Yet the boards proved to all security on their own without anything holding them back to the frame (fig. 250). Similar issues with alignment were faced when putting the floor panel down. The same process was taken to mediate the problem and eventually it slotted into the housing slots without any problems.
4.3 Structure - Load Testing

4.3.1 Testing Equipment

After the assembly discussions took place with Dr Regan Potangaroa (structural engineer at Unitec) on what methods and equipment were required to test the structural loading on the single-module prototype (fig. 260). He indicated that a tension / compression load cell (fig. 251), and tension kit with converter brackets (fig. 252), spring cylinder jack with hand pump (fig. 254), steel tie downs (fig. 255), jack push frame (fig. 259), and load cells (fig. 295) would all be required for testing to take place. Unlike dirt, did not have load cells, jacks, or the load cell. Eventually they agreed to purchase the proposed list of equipment after a proposal from the School of Architecture that considered the beneficial use of the equipment and operation in future work.

From the outset a tension / compression load cell was desired by the engineer. This would be the best option in testing deflection. It allows you to test tension and compression while other load cells only work in compression. As the frame is to be tested in a lightweight structure only a small load cell was selected; it has a loading capacity of ten tons. The staff’s aim is to future proof this by opting for a fifty-ton cell, which is much larger and heavier.

The load cell purchased currently is in compression only. Like most load cells, it needs to be closed on which allow the cell to be used for testing tension. The kit brackets are fitted with round eye rings, which are lined with ball bearings to allow the cell to be used in a flexible environment where it can be twisted or placed at odd angles. These brackets did not come with the load cell as they are made to order items as load cells are commonly used for compression only in weight testing.

An electronic weighing meter is required for any testing as it plugs into the load cells and gives the operator the readings and any analytical data coming from the testing process. The indicators setting have to be calibrated to the specific load cell that is being used. Each load cell has different weighing capacities that have to be programmed on the indicator. A high spec indicator had to be purchased for this load cell as it needed to be capable of reading tensioning data, as a result, the calibration of the meter took a lot longer.

A decision on what jack to purchase was dictated by the loading capacity of the load cell, on its was deemed pointless by the engineer and workshop technician to not have a jack that couldn’t apply the maximum loading capacity of the load cell. A heavy-duty fifty-ton low profile spring cylinder hydraulic jack was chosen. This proved to be just as heavy as the purchased load cell. The jack is detached from the hand pump as only a heavy-duty pipe connects the two, a safer option due to the loading capacity and the overall weight.

The floor of the bay model needs to be securely fixed to the ground, not allowing for movement in the floor when the frame is being pushed by the jack. Steel tie down frames where selected by the engineers as they prove to be stiffer than timber (fig. 303) when put under strain from load testing; invalidating and complicating any deflection results. The steel components for the tie downs needed to be sized and fabricated by the workshop technician as none of the team members have experience in welding. The tie down frame is made up of a 100 x 50mm C-channel beam, 16mm threaded rod, DynaSet drop-in anchor, high tensile screw nuts and circular split washers (fig. 304).

After the assembly, discussions took place with Dr Regan Potangaroa (structural engineer at Unitec) on what methods and equipment were required to test the structural loading on the single-module prototype (fig. 260). He indicated that a tension / compression load cell (fig. 251), and tension kit with converter brackets (fig. 252), spring cylinder jack with hand pump (fig. 254), steel tie downs (fig. 255), jack push frame (fig. 259), and load cells (fig. 295) would all be required for testing to take place. Unlike dirt, did not have load cells, jacks, or the load cell. Eventually they agreed to purchase the proposed list of equipment after a proposal from the School of Architecture that considered the beneficial use of the equipment and operation in future work.

From the outset a tension / compression load cell was desired by the engineer. This would be the best option in testing deflection. It allows you to test tension and compression while other load cells only work in compression. As the frame is to be tested in a lightweight structure only a small load cell was selected; it has a loading capacity of ten tons. The staff’s aim is to future proof this by opting for a fifty-ton cell, which is much larger and heavier.

The load cell purchased currently is in compression only. Like most load cells, it needs to be closed on which allow the cell to be used for testing tension. The kit brackets are fitted with round eye rings, which are lined with ball bearings to allow the cell to be used in a flexible environment where it can be twisted or placed at odd angles. These brackets did not come with the load cell as they are made to order items as load cells are commonly used for compression only in weight testing.

An electronic weighing meter is required for any testing as it plugs into the load cells and gives the operator the readings and any analytical data coming from the testing process. The indicators setting have to be calibrated to the specific load cell that is being used. Each load cell has different weighing capacities that have to be programmed on the indicator. A high spec indicator had to be purchased for this load cell as it needed to be capable of reading tensioning data, as a result, the calibration of the meter took a lot longer.

A decision on what jack to purchase was dictated by the loading capacity of the load cell, on its was deemed pointless by the engineer and workshop technician to not have a jack that couldn’t apply the maximum loading capacity of the load cell. A heavy-duty fifty-ton low profile spring cylinder hydraulic jack was chosen. This proved to be just as heavy as the purchased load cell. The jack is detached from the hand pump as only a heavy-duty pipe connects the two, a safer option due to the loading capacity and the overall weight.

The floor of the bay model needs to be securely fixed to the ground, not allowing for movement in the floor when the frame is being pushed by the jack. Steel tie down frames when selected by the engineers as they prove to be stiffer than timber (fig. 262) put under strain from load testing; invalidating and complicating any deflection results. The steel components for the tie downs needed to be sized and fabricated by the workshop technician as none of the team members have experience in welding. The tie down frame is made up of a 100 x 50mm C-channel beam, 16mm threaded rod, DynaSet drop-in anchor, high tensile screw nuts and circular split washers (fig. 304).

4.3.1 Testing Equipment

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A strong and sturdy frame is needed for the jack to push off (fig. 258). The frame is to be fabricated from steel as it will provide a stable and strong surface that can take the impacts of the load. Ground surface condition is key for the testing process, as it must provide a stable and strong surface that can take the impact of the load. Due to the considerable weight because of the large steel sizes specified by the engineer it would need a small crane and may be unfeasible. As the frame is very flexible, a large force impacting the side is likely to shift and collapse, hindering any deflection results. The type of joint at these points; braced by struts, pegged and lashed will be under considerable stress. Although joints between components will most definitely be the areas of concern. The type of joint at these points, braced by struts, pegged and lashed will be under considerable stress. Although ground surface condition is key for the testing process, as it must provide a stable and strong surface that can take the impacts of the load. The workshop was chosen as the location for the test as it is an enclosed building with a covered floor space. Rain cannot damage any electrical gear or cause any slip in the jack. The workshop was fixed to the floor so that it doesn’t flex or fall back, releasing any pressure during the test. Failure of the frame could result in invalid and complicated deflection results. It could also lead to damaging gear, if the frame were to fall over.

Rope

It took approximately four weeks to acquire the gear due to the process that is set in place by Unitec to purchase such equipment. The loading and unloading of the equipment was performed by DAM Engineering. The equipment was collected by a truck and placed in the Unitec workshop. The roof of the workshop is 10m in height and large enough to manipulate the equipment. The workshop was chosen as the location for the test as it is an enclosed building with a covered floor space. Rain cannot damage any electrical gear or cause any slips in the jack. The workshop was fixed to the floor so that it doesn’t flex or fall back, releasing any pressure during the test. Failure of the frame could result in invalid and complicated deflection results. It could also lead to damaging gear, if the frame were to fall over.

Concrete Pad

The workshop was chosen as the location for the test as it is an enclosed building with a covered floor space. Rain cannot damage any electrical gear or cause any slips in the jack. The workshop was fixed to the floor so that it doesn’t flex or fall back, releasing any pressure during the test. Failure of the frame could result in invalid and complicated deflection results. It could also lead to damaging gear, if the frame were to fall over.
4.3.3 Test Setup

The process required us to find a suitable area to test the frame. The workshop was the most suitable location; with the appropriate facilities and protection from external elements. After carefully selecting the position we set up the structure accordingly. (Picture of the layout of on the floor). Once the frame was laid out on the workshop floor, we had to adjust the angles of the frame to allow people to pass through the adjacent space, to carry on with their work.

The following steps were taken prior to the event:

- We would no longer push off the concrete block wall of the workshop, as the wall may not take the impact of such a loading capacity.
- The components of the module were pieced back together to form the original frame of the presented prototype. Polyethylene sheets (fig. 260), were slid under the frame to mitigate friction upon impact.
- Holes were drilled into the concrete floor, in specific locations for the positioning of the DynaSets (fig. 261). The steel rods would slot securely into these.
- The C-channel profiled steel lengths were cut with holes drilled into them for alignment with the M16 threaded steel rods. This frame locked together with the Dynasets would clamp the structure together.
- The base was bolted down using nuts and washers (fig. 262).

Tension cables were pulled around the frame and tied to the eye-ring hooks; fixed to the 100mm x 100mm bearers of the base (fig. 238). The turnbuckles were tightened until the entire structure remained rigid.

The inaccuracies of errors in the CNC process led to the nub holes on the brace panels having to be further chiselled out for the slots to align with the frame. These sheets were lashed back into the ‘specifically positioned nogs’ to provide bracing for the structure.

A timber beam (4x4) was then bolted and screw fixed onto the roof sheet (fig. 263).

Reference points were allocated at different points of the structure to measure the deflection.

- Timber off-cuts were (Dyna) bolted to the floor. Nails extruding through them and the structure acted as the reference points (fig. 264).
Fig. 268 - Data analysis sheet: showing increments and weighing force.

Fig. 269 - Graph showing the performance of the structure. No flat line in the graph meant the structure could not hold the load; bending meant it failed the test.

When testing commenced, the results of each push had to be recorded at every 10mm interval (fig. 268). As mentioned earlier, the jack only extruded up to 60mm, at load 7, a transition had to be made to allow for the reset. One side of the structure had to be clamped while this transition was carried through. While the loading carried on at load 7, the structure was starting to show the impact of it. The floor joists started coming apart (fig. 270), whilst the lashed joints tightened (fig. 271), and held the bracing sheets together. When the structure was in compression, there was a lot of bearing and bending which resulted in the structure getting affected at parts that were not predicted to be points of failure (fig. 270).

As the pushing carried on, there was a lot of deflection and this was due to the looseness in the junctions of the joints. Although there was an impact on the structure, it had to go through the 'slack' of which the system had made. This had an impact on the readings as it became apparent the structure was very flexible. At load 11, another transition had to be made. By load 13 there was a lot of creaking and noise as the structure was showing signs of giving in (fig. 272, 273). As the lashing held the bracing sheets on and the components together, the floor area was starting to show signs of the impact. At load 15 another transition was made. Another two readings were made until there was enough to plot a diagram of the results; of how the structure performed (fig. 268, 269).

After the loading tests were complete, the data from the findings was calculated. More tests had to be made to make an understanding of where the structure was going to fail. This was important because it would allow us to know the exact points of failure and how these connections could be improved.

4.3.4 Testing Procedures

The entire structure managed to get 61kN of force (fig. 322, 323), which is a small figure when compared to the amount of force (500kN) that is allowed for a standard NZS3604 wall system with steel bracing. The entire structure managed to get 61kN of force (fig. 322, 323), which is a small figure when compared to the amount of force (500kN) that is allowed for a standard NZS3604 wall system with steel bracing.

Fig. 322 - Joint and reference point locator: joints A - J; reference points and direction: 1-4.

The entire structure managed to get 61kN of force (fig. 322, 323), which is a small figure when compared to the amount of force (500kN) that is allowed for a standard NZS3604 wall system with steel bracing.
Fig. 270 - (b) Wall joints coming apart at the 7th push (initially, this was not predicted to be a point of failure).

Fig. 271 - (b) Wall joints coming apart at the 7th push.

Fig. 272 - (g) Floor joints coming apart at the 19th push (the missing floor steel made significant movement; this was expected).

Fig. 273 - (b) Wall joints coming apart at the 13th push.

Fig. 274 - The floor started to bow from the pressure at the 15th push.

Fig. 275 - (g) Floor joints coming apart at the 19th push (this was the most severe damage found in testing).
The plywood did not suffer significant damage, to the point of it failing as a suitable material for construction. Although, there were areas of flaking at the points of compression. The tension cables did not fray, stretch or snap to the point of needing replacement, though a higher gauge wire may be proposed for additional security in future. The turnbuckles & hooks performed well, keeping the tension across the frame. Under compression the amount of stress affecting the cable resulted in the hook being pulled out of position. The bearer, a soft wood, gave in to the pressure and allowed the hook to shift. Finally, there was no sign of damage to the lashing, as all components were held stable in loading.

4.3.6 Improvements to a Future System

As stated earlier, the application of an appropriate structural material would drastically improve the overall performative quality of the framing. A better graded timber that is approved for quality adhesives and strength would be desired. Although, the test showed as predicted what was successful and what went wrong. Ignoring the damage at the point of impact, which was expected from the outset, we learnt that the areas of the structure to be improved were those located around the floor, where the pegging alone did not prove sufficient in a case of undue stress. The resulting issues may be fixed in future prototypes through redesign of such elements as the floor components; with a lashed connection being implemented to increase flexibility under both tension and compression. The nogs may also be made deeper for additional stability. Further suggestions to improving the overall frames performance would be an upgrade to the fixtures and systems used for maintaining tension. A higher gauged cable (synthetic) would provide additional strength across each module, with a similar selection in ‘rope’ for the process of lashing. Additionally, longer threaded hooks may be used for connecting to bearers. What we learnt from this process, we intend to take into the development of the next prototype, and share with those interested.
Limitations in the knowledge of software and the implementation of ideas proved difficult at the outset. This hindered initial plans and changed our perspective on what was possible. The application of the selected structural material added to this barrier. We found this disconcerting at first, though the addition of further obstacles to the process assisted us to clarify a direction and set a brief for the proposed program.

Pen to paper was always the best mode for design. The temptation to use CAD was deterred by the limitation of creating only what we were capable of, from experience, or what the software could sufficiently produce. The sketch work was more relative to generating ideas compared with using a computer where you tend to chop and change as you go, moving away from the intended concept. It was also faster to draw by hand, to quickly go through ideas as they surfaced. The motif of 'organic' form, a subject of debate by many is an aesthetic that is usually intended to mimic nature, fluidity and beauty. It was steered clear from in the structural sense. We found it difficult to calculate, control, manufacture and assemble; with our acquired knowledge. Though we did make the profiles asymmetric at one point, which became messy. We found linear profiles to be more manageable in development and executable in manufacturing.

The process continued to display a reoccurring theme, to simplify, simplify, simplify, wherever possible. That's not easy, to say the least. We found that we should not be attempting to 'reinvent the wheel', instead we should be focusing on the research, adaption and sharing of work. We discarded the complicated whilst we managed the complex. It was a process of refinement and delivery.


The process of undertaking a project as a team, consisting of three members, all with different opinions and knowledge made for an interesting experience. While there were obvious benefits there were also many difficulties. As an example these included issues such as: a confusion in the understanding of each other's terminology; clarity in the communication of work, lack in communication of what we were working on individually and spending extended periods of time on tasks, that could have been overcome through earlier discussions. As everyone works at different speeds and each person experienced short-off periods it became difficult to manage. Though we worked through it by taking the lead. Defining a methodology in our paths of communication meant we each had our role to play. Simba and I worked on the underlying idea and form, before I took the abstracted concept and turned it into constructive elements that could be fabricated. I then worked in collaboration with Azmon to implement the system of connection.

The three sub-theses provided the platform to our collaborative work. We aimed to work together for 75% of the time and individually for 25%. I worked on the explanatory material: 25% collaboratively and 75% individually. We worked on two documents in conjunction. One of these being the 'team process' chapter for the design & build.

conclusion

5.1 Analysis

5.1.1 Collaborative Process

Teamwork is the ability to work together toward a common vision. The ability to direct individual accomplishments toward organizational objectives. It is the fuel that allows common people to attain uncommon results."
- Andrew Carnegie

5.1.2 Design Process

If I had tackled this project by myself, without the support of Azmon & Simba I may have 'pulled the plug'. At this stage of our education it would have been far more difficult to pursue by oneself. Although the project was long and strenuous, with intensely repetitive processes making tasks mentally draining. The experience of working as a team, running it like a practice where we shared ideas, with the collaborative goal of making something real was beneficial to our learning. We were required to work in the future. We were not 'paper' architects, in the way we were able to produce the whole product of our exploration. Looking back to any theories before the project it has changed the way I think and the profession, how the building industry works, where it's heading and how we may be practicing one day.

5.12 Design Process

Limitations in the knowledge of software and the implementation of ideas proved difficult at the outset. This hindered initial plans and changed our perspective on what was possible. The application of the selected structural material added to this barrier. We found this disconcerting at first, though the addition of further obstacles to the process assisted us to clarify a direction and set a brief for the proposed program.

Pen to paper was always the best mode for design. The temptation to use CAD was deterred by the limitation of creating only what we were capable of, from experience, or what the software could sufficiently produce. The sketch work was more relative to generating ideas compared with using a computer where you tend to chop and change as you go, moving away from the intended concept. It was also faster to draw by hand, to quickly go through ideas as they surfaced. The motif of 'organic' form, a subject of debate by many is an aesthetic that is usually intended to mimic nature, fluidity and beauty. It was steered clear from in the structural sense. We found it difficult to calculate, control, manufacture and assemble; with our acquired knowledge. Though we did make the profiles asymmetric at one point, which became messy. We found linear profiles to be more manageable in development and executable in manufacturing.

The process continued to display a reoccurring theme, to simplify, simplify, simplify, wherever possible. That's not easy, to say the least. We found that we should not be attempting to 'reinvent the wheel', instead we should be focusing on the research, adaption and sharing of work. We discarded the complicated whilst we managed the complex. It was a process of refinement and delivery.
Starting from scratch, it was definitely a learning experience: collaboratively, technically, and realistically. That whole work is tough. There were obvious limitations in the operation of facilities, time allocated to build, the budget for materials and our own skills in execution.

There was always going to be difficulty in implementing such work as so many factors were subject to it becoming a reality. These included: designer and client intentions, industry support, the desire for innovation in design, and a generally negative view of self-build projects. Predominantly from those who are afraid of change, where it may have a negative affect on their careers and livelihood. Additionally, the costs involved with manufacturing currently limits this type of work. In the case of a community environment, a significant amount of money would need to be raised to pay for such processing.

What we learnt was that it doesn’t always go perfectly to plan. There was no room for error when working to such tight tolerances, as components didn’t necessarily fit in the order we thought they would. Mapping the construction process in your head as you design didn’t always work out. However as we worked on it, it became simpler. We found an effective method that worked and as we followed it, we were able to complete assemblies more efficiently. This process when communicated effectively will enable anyone, regardless of previous experience to easily partake in the assembly of such structures.

Unlocking Locked Design

Richard Garber discusses in his AD article ‘Optimisation Stories: The Impact of Building Information Modelling On Contemporary Design Practice’ that current architectures ‘structural’ systems are fixed and don’t allow for adaptation through future additions, it is rather demolition and renovation as the adhered method. Structures that incorporate elements of DFD, do so in a very restrained manner; allowing for disassembly, though not considering the ease of fabricating further additions. These systems employed are often standardised and mitigate options for particular design changes, i.e. there is an allowance for Shipping Containers to be both removed and attached through their ‘bolted hinge’ connections.

Such a system is successful through connection, though is limiting its ability to allow for adaptation; changes in: form, scale, direction, material finish and performance of future additions.

Through Design for Evolution we can enable continuous change and development over time. A system can grow as required. Through ‘Design for Evolution’ we can enable continuous change and development over time. A system can grow as required. Thus allowing for modules, components or elements to be both added and removed. The project successfully explored this and there is the resolution that through the application of digital technology, there can be a greater relationship between architecture and construction.

In summary, the scope of the design process covered changes in design practice; the opportunities for optimisation and CNC fabrication. Rather than concentrating on the exact term BIM, the intention was to demonstrate through application, how making can benefit the practice of architecture. “As designers use tools to better produce, optimise, and test their ideas, we may soon see further proposals and built works that are not only integrated and precise, but make improvements to the process of architectural production.”

The completion of the project in its current state represents a further stage in the evolution of architecture: design, fabrication and assembly. The open-ended scheme allows for its development to be continued by both ourselves and the wider community. The sharing of the presented information further extends the process of such work. The proposed methods presented may be found relevant to those considering undertaking similar works in the future. Having access to this material may help them with their work, especially as a reference as to how we operated; the things we learnt through application, that we wouldn’t have known prior to the initial proposal. It provides a platform for additional architectural research and design.

The combination of explanatory material and design documentation, may be made available publicly through university libraries and as an online resource or downloadable reference to aid in further or similar research. The information discovered may lead to supporting the future production of conference presentations, information pamphlets, research papers and general film or media articles. The research may be used by members of the community, students or design professionals that may apply it to further the education of themselves, their employees and partners in practice.

As a team, we envisage that there lies an opportunity to take our collaborative methods to market, where the process could be further explored to produce designs for a series of architectural typologies such as housing, education, temporary dwellings, creative spaces, community facilities and commercial enterprises that includes hospitality and professional industries. We see that the project will initiate a process of discussion and collaboration amongst the community and design profession. The outcome displays how the presented processes can further contribute in architecture’s ability to be more accessible to the community, encourage interaction, promote design efficiency and be sustainably adapted as required.

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5.3 Future Directions

5.3.1 Where to now?

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5.3.2 Creative Commons

WikiHouse Creative Commons [CC]

I would like to see the necessary adjustments be made to the proposed design so that it can be uploaded to a creative commons library. Enabling people across the globe to access, download and modify it as desired. I have confidence that the non-standardised design process can initiate more dynamic schemes from what is currently available. There should be an aspiration for greater architectural substance where habitation and fluidity of both form and process is of the upmost importance. The most intriguing development to see in the future would be the completion of a full scale, enclosed and inhabited dwelling that employs a similar methodology. Such work is beginning and I would like to contribute to its innovative development.
It is easier to ship recipes than cakes and biscuits.” — John Maynard Keynes


Fig. 279 – WikiHouse creative commons

Fig. 280 – The team: Simba (left), Azmon (center), James (right) in the workshop
"Technology is so much fun but we can drown in our technology. The fog of information can drive out knowledge." - Daniel J. Boorstin

Table: Pricing Schedule for Materials

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Materials Schedule - Approximate / Estimate from Work on Prototype

The Approximate Total Build Cost for an 11 BAY Modular Structure =

$ + 10% for additional timber, fixings, sealants, hardware and finishes

7. Appendix

7.1 Presentation Drafts

7.2 Materials Schedules & Catalogues

Unknown pricing was found in data from materials schedules & catalogues

Appendix
Spatial Definition

The design program for the proposed structure has been set as a single space for operation by two to three students. A small studio where collaboration between peers and presentation of work can take place. The provision of desk space is of primary concern for achieving this purpose. The spatial environment is a condition of note, as its functional features are molded from the framework of the structure.

The framework consists of elements that are seamlessly related to the structure; keeping the aesthetic and functional value. This will allow for a unique spatial experience, engaging the senses of the inhabitant.

The depth of the modules is to range between 500-600mm and the width to be within the vicinity of 3600mm.

Programme

The space is intended to propose a notion of a greater awareness of our built environment through the display and connection of the structure itself. The aim is to fabricate a structure that people find both intriguing and useful; giving an opportunity for discussion around the proposed alternative methods of fabrication and assembly.

Interior Quality

Much of the space is dynamically formed, due to the nature of the building this allows the user to be more aware of their surroundings; while the poetics of the space is realised through the articulation of spatial arrangements.
Furniture Variations

A natural flow between the furniture and the structure allows for an effortless transition between seating and desk. This particular furniture variation is articulated and variated to allow the user to engage with the spatial qualities of the space.

The furniture flows from exterior seating to internal workspace; a space for students to work collaboratively on projects, in a stimulating environment.

Section Perspective AA

Digital Anatomy

The elements of the building are exposed. The structure’s joining system together with the furniture are reveal how the building is put together. Architecturally this allows the user to be aware of how the entire structure is pieced together. The furniture variations can change and alter to suit the requirements intended for the building.

Architecturally the project has a responsibility to address the contextual conditions: site, climate, culture, people, shelter, material, and projected fabrication costs. These and many more factors are considered in the process and adhered through differing methods of design and assembly. As the work can be customised according to requirements, the proposed system is open to modification; a change in use or location.

Section Perspective BB

Fig.306 – Examination presentation: Simba // sheet 3

Fig.307 – Examination presentation: Simba // sheet 4
An Adaptive System

Architecture is about designing spaces for habitation; to facilitate experience through occupation. Function is first, though efficiency in production and fulfillment in living can’t be achieved without the implementation of ‘spatial dynamics’.

The ability for spaces to adapt to requirements over time. Designing for evolutionary structures that implement a system of continuous development.

**A. Linear frame:** symmetric form. Regular modulation.

**B. Organic frame:** asymmetric form. Irregular modulation/covering.

**C. Linear Dynamic:** flexible frame adaptable to desired framework.

**Design for Evolution**

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
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<tbody>
<tr>
<td>B1</td>
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<td>B3</td>
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<tr>
<td>C1</td>
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<td>C3</td>
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Additive Modulation

Designing a ‘dynamic system’ facilitates evolutionary development: the system speeds up the construction process; makes the creation of an ‘idea’ an achievable exercise. There is an increase in the variety of forms. It enables these rather explorative concepts to become real and habitable. Environmentally it uses less man made material, reduces waste and lowers costs in the manufacturing process. It allows for people with less skill and experience to build and be a part of strengthening their community.

The building is a hybrid system; a modular arrangement of panel and stick elements. An open system that allows for a combination of parts to be incorporated into future work: for support of the functional program, mechanical servicing, or finished aesthetic.

1. x1 Ten Component Ring
2. x4 Rings form One Module
3. Struts & Pegs create secure Component Junction
4. Nogging Fins create diaphragm; maintain dimensional strength
5. Bracing Sheets added as underlay to building envelope
6. Connectors enable additional modules to be attached

**Dynamic Environments**

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<thead>
<tr>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>M6</th>
</tr>
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<tbody>
<tr>
<td>M7</td>
<td>M8</td>
<td>M9</td>
<td>M10</td>
<td>M11</td>
<td>M12</td>
</tr>
</tbody>
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Building Information Model

The system involves the process of taking a digital file from conception through development and into fabrication. The digital model holds all the elements that will be manufactured for construction. The built form is an exact representation of the virtual realm. All modeled data is fabricated to become real material. As the model is adapted and developed over time it allows for future growth of an architecturally fabricated environment.

A. Frame Elements
B. Connection Struts & Pegs
C. Module Cross-lap Fins (Nogs)
D. Brace Sheets
E. Flooring Underlay
F. Module Connector
G. Furniture Railing

Customised Components

Manufacturing Parts

WikiHouses generative script allows for components to be exported to flat cutting sheets, with the click of a button. We implemented this as a part of the process, with the aim of fabricated building elements. There are restrictions to the process of designing elements for export. As the parts are configured to fit a sheet with dimensions measuring 2400mm x 1200mm, anything made oversized would not be produced.

1. The ‘Plugin’ allows individual elements to be exported to cutting sheets. These parts can be tagged and nested for efficient use of material and ease in assembly processes.
2. The parts can be ‘printed’ from sheet material such as plywood. A CNC machine can mill each part, resulting in a mass collection of puzzle pieces.
3. These cut parts can be set out on the ground in their intended arrangement; joining together to form larger components and a complete module. The system is open to all skill levels.

Fabrication Process

1. Layout
2. Cut
3. Assemble
Variation of the Oblique Scarf Joint (square version)

- 2 stuts, 8 pegs, 1 lashing
- 4 stuts, 16 pegs, 2 lashing

Wall Detail

- e. 4 stuts, 16 pegs, 2 lashing
- f. 4 stuts, 16 pegs, 2 lashing
- g. 4 stuts, 16 pegs, 2 lashing
- h. 4 stuts, 16 pegs, 2 lashing

- 1. Female half of the oblique scarf joint, 18mm plywood (x2)
- 2. Male half of the oblique scarf joint, 18mm plywood (x2)
- 3. Tapered interlocking pegs, 18mm plywood (x 8)
- 4. Cross struts, 18mm plywood (x2)
- 5. Figure 8 lashing, 4mm hemp rope cut at 1.5m lengths (x1)

Variation of the Dovetail Joint

- 2 stuts, 8 pegs, 1 lashing
- 3 stuts, 12 pegs, 2 lashing
- 4 stuts, 16 pegs, 2 lashing
- 6 stuts, 24 pegs, 3 lashing
- 2 stuts, 8 pegs, 1 lashing
- 2 stuts, 8 pegs, 1 lashing

Floor Detail

- a. 2 stuts, 8 pegs, 1 lashing
- b. 2 stuts, 8 pegs, 1 lashing
- c. 2 stuts, 8 pegs, 1 lashing
- d. 3 stuts, 12 pegs, 2 lashing
- e. 3 stuts, 12 pegs, 2 lashing
- f. 4 stuts, 16 pegs, 2 lashing
- g. 6 stuts, 24 pegs, 3 lashing
- i. 2 stuts, 8 pegs, 1 lashing
- j. 2 stuts, 8 pegs, 1 lashing

- 1. Male half of the dovetail joint, 18mm plywood (x2)
- 2. Female half of the dovetail joint, 18mm plywood (x2)
- 3. Tapered interlocking pegs, 18mm plywood (x 8)
- 4. Cross struts, 18mm plywood (x2)
- 5. Figure 8 lashing, 4mm hemp rope cut at 1.5m lengths (x1)
**Cladding Junction Detail**

- 18mm plywood
- Prefabricated aluminium "H" channel with 40mm housing
- "O" compression rubber gasket. When compressed, it creates air locks in the join.

**Lashing/Cladding Detail**

- Figure 8 lashing, Hemp rope, 1.5m
- Clinch knot lashing, Hemp rope, 1.5m

**Tension System & Load Testing**

- Wikihouse oblique scarf join, 7th push, 23kN of pressure
- Oblique scarf join, 7th push, 23kN of pressure
- Wikihouse oblique scarf join, 13th push, 43kN of pressure
- Oblique scarf join, 13th push, 43kN of pressure
- Wikihouse oblique scarf join, 16th push, 50kN of pressure
- Oblique scarf join, 16th push, 50kN of pressure

**Tension System**

- Turnbuckle hooked and tensioned to the 100 x 100 bearer
- Fixings: from top to bottom; hook turnbuckle, ring screw hook, crimp, eye strap, hemp rope, jute twine, and wire rope.
- Each bay is tensioned twice
- Illustration of the tension system at 50kN of strain during load testing
NOTE: All drawings and images are of my own production, unless otherwise stated in the following list of figures.

Figure 1 – System logo.
Figure 2 – Team stages of process (symbols).
Figure 3 – Process Architecture symbol.
Figure 4 – Additive form - Fed Square, Melbourne. Australia
Photograph by James McNicholas, 2013
Figure 5 – Port-a-bach by Atelier Workshop, on display in New Plymouth. New Zealand
Photograph by James McNicholas, 2013
Figure 6 – Dynamic form. Interior of Baker D. Chirico Melbourne. Australia
Photograph by James McNicholas, 2013
Figure 7 – DFD.
Reproduced from: http://shelleycreativetech.wordpress.com/tag/submission-b/
Figure 8 – The assembly of parts.
Reproduced from: a stock image, Google images. 2013
Figure 9 – CNC Router.
Photograph by James McNicholas, 2013
Figure 10 – Concept sketch for Dunescape by Shop architects
Figure 11 – The dynamic structure was up for only 6 weeks.
Figure 12 – People enjoy the postcard attractiveness.
Figure 13 – Colour coded cutting templates.
Figure 14 – Dunescape under construction.
Figure 15 – Click-Raft 02B-L01 View
Figure 16 – Click-Raft 02B-M01 Assembly
Reproduced from: http://click-raft.com/minimal-unit-click-raft-02b-m01
Figure 17 – Kiwi Prefab Exhibition in New Plymouth. New Zealand
Photograph by James McNicholas, 2013
Figure 18 – Click-Raft model on display. A lattice structure
Photograph by James McNicholas, 2013
Figure 19 – Assemble your own Click-Raft model.
Photograph by James McNicholas, 2013
Figure 20 – Click-Raft structure 11
Photograph by James McNicholas, 2013
Figure 21 – Cross-linking cross-section provide strength.
Photograph by James McNicholas, 2013
Figure 22 – Niin tukkula’s (left) and Vander Poot’s (right).
Reproduced from: http://www.batterdishesarchitectureandperformance2012-04-16/Wikihouse-workshop/
Figure 23 – Cutting files of building elements.
Reproduced from: http://www.wikihouse.cc/about-step-make
Figure 24 – Parts can be produced through a CNC machine.
Reproduced from: http://www.wikihouse.cc/about-step-print
Figure 25 – WikiHouse developer assemble first such.
Reproduced from: http://www.batterdishesarchitectureandperformance2012-04-16/Wikihouse-workshop/
Figure 26 – The future concept for WikiHouse: A completely fabricated building.
Figure 27 – Assembly for all ages.
Reproduced from: http://labuenanoticia.com/casas-libres
http://24.media.tumblr.com/tumblr_lui67gNLbO1r0mtljo1_1280.jpg
Figure 28 – Additive patterns in the Sydney Opera house. Australia
Reproduced from: http://ft.blogs.nytimes.com/2013/05/13/birds-eye-view/5v4x.jpg
Figure 29 – Examples of additive plantypes.
Figure 69 – Conceptual development 1c
Figure 70 – Conceptual development 2a
Figure 71 – Conceptual development 2b
Figure 72 – Conceptual development 2c
Figure 73 – Conceptual development 3a
Figure 74 – Conceptual development 3b
Figure 75 – Conceptual development 3c
Figure 76 – Patterned surface model
Model by Simba Mtakwa, 2013
Figure 77 – Division of the original form
Figure 78 – The structural lines of such a proposal
Figure 79 – First attempt at digital modelling
Figure 80 – Digital extrusion of a modular frame
Figure 81 – Breaking up a frame into smaller sections
Figure 82 – Framing slots for connecting modules
Figure 83 – Developed concept for a dynamic, modular / patterned mass
Figure 84 – Developed concept adhering to planning requirements
Figure 85 – Axon. A dynamic modular structure
Figure 86 – Exploded axonometric drawing of panel to portal assembly
Figure 87 – Exploded axonometric drawing showing the parts to a modular ‘bay’ adding into the portal frame
Figure 88 – The ‘dynamic’ makeup of connected modules
Figure 89 – Refined concept planning to sections of a modular studio
Figure 90 – Sectional study, Alternative internal configurations
Figure 91 – Section of an envelope that integrates functional fixtures
Figure 92 – The deployment of flat-pack furniture form within the wall space
Figure 93 – The separation and connection of modules to service a design programme
Figure 94 – Developed design planning 1
Figure 95 – Developed design planning 2
Figure 96 – Developed design planning 3
Figure 97 – Developed design planning 4
Figure 98 – Developed design planning 5
Figure 99 – Developed design planning 6
Figure 100 – Developed design planning 7
Figure 101 – Developed design planning 8
Figure 102 – Developed design planning 9
Figure 103 – Developed design planning 10
Figure 104 – Developed design planning 11
Figure 105 – Developed design planning 12
Figure 106 – Developed design planning 13
Figure 107 – Developed design planning 14
Figure 108 – Developed design planning 15
Figure 109 – Developed design planning 16
Figure 110 – Perspective displaying the parallel envelope between frames
Figure 111 – Photoframe being modelled to set spatial parameters
Figure 112 – Photoframe
Figure 113 – Profile 2
Photograph by James McNicholas, 2013

Figure 114 – Profile 3
Photograph by James McNicholas, 2013

Figure 115 – Profile 4
Photograph by James McNicholas, 2013

Figure 116 – Study of the positive spatial experience
Photograph by James McNicholas, 2013

Figure 117 – The 3 defining spatial sections

Figure 118 – The linked sections form the resulting shape

Figure 119 – Initial digital model with parameters set for 'heights' within the space

Figure 120 – Parameters considering 'width' shift the volume closer towards a final form

Figure 121 – x15 bay laser cut model representing the developed physical form
Photograph by James McNicholas, 2013

Figure 122 – Plan for the proposed studio. NTS

Figure 123 – Proposed elevations. NTS

Figure 124 – Proposed section and external form. NTS

Figure 125 – Panel detailing for an enclosed envelope

Figure 126 – Integrating serving into the framing

Figure 127 – Capping to protect the exposed edge of the frame

Figure 128 – The junction that requires a complex weatherproofing solution

Figure 129 – Envelope section diagram

Figure 130 – Envelope construction diagram 1

Figure 131 – Fabricated external elements must connect to form a protective envelope

Figure 132 – Envelope construction diagram 2

Figure 133 – Envelope construction diagram 3

Figure 134 – The WikiHouse plugin can be downloaded from their creative commons website.
Reproduced from http://www.wikihouse.cc/about#step-download

Figure 135 – To further efficient modelling processes, parts can be identified and tagged with data
Reproduced from http://www.wikihouse.cc/guide/standards

Figure 136 – The plugin features a script that can export modeled parts to 3D profiles for fabrication

Figure 137 – Floor model 1

Figure 138 – Floor model 2

Figure 139 – Floor model 3

Figure 140 – Floor model 4

Figure 141 – Floor model 5

Figure 142 – Floor model 6

Figure 143 – Floor model 7

Figure 144 – A look into the CAD model for the floor assembly

Figure 145 – Chiseling the laser etched elements from plywood sheets
Photograph by James McNicholas, 2013

Figure 146 – The individual parts grouped in piles ready for assembly
Photograph by James McNicholas, 2013

Figure 147 – Twin-peg connection
Photograph by James McNicholas, 2013

Figure 148 – Floor section completed, a 1:2 scale study model

Figure 149 – Errors in modelling lead to issues in fabrication and assembly.

Figure 150 – The smooth ‘Dog bone’ cut by a router head as the tool passes around sharp lines
Reproduced from the "WikiHouse Design Guide" v3.0, May 2013
Figure 151 – CAD model of a wall detail, made to test tolerances in cross-lap junctions.

Figure 152 – CNC machine cuts profiles from a 18mm plywood sheet. Photograph by James McNicholas, 2013.

Figure 153 – Alternative methods for connecting components. Drawing by Azmon Chetty, 2013.

Figure 154 – Accuracy in fabrication: parts measured to match the digital files. Photograph by James McNicholas, 2013.

Figure 155 – Prototype stage was on public display at Unitec’s ‘Grad-Fest’. Photograph by James McNicholas, 2013.

Figure 156 – Trimming plywood pieces on a band saw in the workshop. Photograph by James McNicholas, 2013.

Figure 157 – Sketching alternative envelope systems.

Figure 158 – Component development.

Figure 159 – Envelope and section design.

Figure 160 – Dynamic cladding concept.

Figure 161 – Various internal definitions.

Figure 162 – Conceptual modular planning.

Figure 163 – Key component junctions.

Figure 164 – Further development of the concept.

Figure 165 – Framing concept.

Figure 166 – Cladding concept.

Figure 167 – Batten to frame detail.

Figure 168 – Trim/Reinforced connecting to structure.

Figure 169 – Internal seat element: connection concept.

Figure 170 – Internal view of the digital structural model.

Figure 171 – Laser cut model / view 1. Photograph by James McNicholas, 2013.

Figure 172 – Laser cut model / view 2. Photograph by James McNicholas, 2013.

Figure 173 – Laser cut model / view 3. Photograph by James McNicholas, 2013.

Figure 174 – Laser cut model / view 4. Photograph by James McNicholas, 2013.

Figure 175 – Virtual model containing moulded interior forms.

Figure 176 – Laser cut profile study model / view 1. Photograph by James McNicholas, 2013.

Figure 177 – Laser cut profile study model / view 2. Photograph by James McNicholas, 2013.

Figure 178 – Laser cut profile study model / view 3. Photograph by James McNicholas, 2013.

Figure 179 – Virtual space containing all modelled material.

Figure 180 – Complete structural module with bracing sheets.

Figure 181 – Expected outcome in cutting sheets.

Figure 182 – Labeled with their identifying ‘tag’ for placement within the module.

Figure 183 – Team design process.

Figure 184 – Building site location, front yard of the UMS Master of Architecture building. Reproduced from http://www.aucklandcouncil.govt.nz/EN/propertyvaluation/propertyinformation/GIS_maps/RegionalKno...aspx.

Figure 185 – Building site location, North perspective. Photograph by Azmon Chetty, 2014.

Figure 186 – Building site location, South perspective. Photograph by Azmon Chetty, 2014.

Figure 187 – Building site location, West perspective. Photograph by Azmon Chetty, 2014.

Figure 188 – Building site location, East perspective. Photograph by Azmon Chetty, 2014.
Figure 249 - Cladding alignment. Photograph by Azmon Chetty, 2014

Figure 250 - Cladding strut between the lashing. Photograph by Azmon Chetty, 2014

Figure 251 - Vetek: 50 ton compression / 24 ton tension load cell with cable - nickel plated steel. Photograph by Azmon Chetty, 2014

Figure 252 - Vetek: Kit to convert the cell into a 24 ton tension load cell. Photograph by Azmon Chetty, 2014

Figure 253 - Vetek: Weighing indicator multi-function with battery. Photograph by Azmon Chetty, 2014

Figure 254 - Durapac: 435kn capacity-stroke 60mm single acting low height cylinder. Durapac: 2 speed hand pump-700cc usable. Photograph by Azmon Chetty, 2014

Figure 255 - Steel tie downs. Photograph by Azmon Chetty, 2014

Figure 256 - Timber tie downs. Photograph by Azmon Chetty, 2014

Figure 257 - Steel tie down components, left to right: 100 x 50 C-channel beam, 16mm threaded rod, DynaSet drop-in anchor, high tensile screw nuts and circular split washers. Photograph by Azmon Chetty, 2014

Figure 258 – Steel jack push frame. Drawing by Simba Mtakwa, 2014

Figure 259 - Testing location, concrete pad in the Unitec Architecture workshop. Photograph by Azmon Chetty, 2014

Figure 260 - Tom Whelan checking the alignment of the push frame and load cell rig before Dyna bolting the frame to the floor. Photograph by Azmon Chetty, 2014

Figure 261 - Simba drilling he holes for the steel tie downs. Photograph by Azmon Chetty, 2014

Figure 262 - Steel jack push frame. Photograph by Azmon Chetty, 2014

Figure 263 - Timber 4x4 beam bolted onto the roof piece. Photograph by Azmon Chetty, 2014

Figure 264 - Reference point. Photograph by Azmon Chetty, 2014

Figure 265 - Tom Whelan constructing the rig for the load cell and jack. Photograph by Azmon Chetty, 2014

Figure 266 - Tom Whelan checking the alignment of the push frame and load cell rig before Dyna bolting the frame to the floor. Photograph by Azmon Chetty, 2014

Figure 267 - Joint and reference point locator: joints, j - l; reference points and direction, 1-4. Drawing by Regan Potangaroa, 2014

Figure 268 - Graph showing the performance of the structure. No flat line in the graph meant the structure could not hold the weight and representing one which creates a failed result. Drawing by Regan Potangaroa, 2014

Figure 269 - Analysis data sheet: showing increments and weighing force. Drawing by Regan Potangaroa, 2014

Figure 270 - (g) Floor joints coming apart at the 7th push (this was not predicted as a fail point). Photograph by Azmon Chetty, 2014

Figure 271 - (g) Floor joints coming apart at the 13th push (this was not predicted as a fail point). Photograph by Azmon Chetty, 2014

Figure 272 - (g) Floor joints coming apart at the 19th push (this was not predicted as a fail point). Photograph by Azmon Chetty, 2014

Figure 273 - (b) Wall joints coming apart at the 7th push. Photograph by Azmon Chetty, 2014

Figure 274 - The floor started to bow from the pressure at the 15th push. Photograph by Azmon Chetty, 2014

Figure 275 - (g) Floor joints coming apart at the 19th push (this was not predicted as a fail point). Photograph by Azmon Chetty, 2014

Figure 276 - (b) Wall joints coming apart at the 19th push. Photograph by Azmon Chetty, 2014
Figure 277 - The joint had to be cut apart as it would not separate after testing.
Photograph by Azmon Chetty, 2014

Figure 278 - The 1:1 prototype on display.
Photograph by James McNicholas, 2013

Figure 279 – WikiHouse creative commons
Reproduced from: http://www.wikihouse.cc/guide

Figure 280 - The team: Simba (left), Azmon (center), James (right) in the workshop.
Photograph by James McNicholas, 2013

Figure 281 – Pricing schedule for project materials

Figure 282 – Project website screenshot 1
Website by James McNicholas, 2013

Figure 283 – Project website screenshot 2
Website by James McNicholas, 2013

Figure 284 – Project website screenshot 3
Website by James McNicholas, 2013

Figure 285 – Project website screenshot 4
Website by James McNicholas, 2013

Figure 286 – Project website screenshot 5
Website by James McNicholas, 2013

Figure 287 – Project website screenshot 6
Website by James McNicholas, 2013

Figure 288 – Examination presentation: Model interior
Photograph by James McNicholas, 2014

Figure 289 – Examination presentation: 1:2 scale, x2 connected modules
Photograph by James McNicholas, 2014

Figure 290 – Examination presentation: Under floor of one module
Photograph by James McNicholas, 2014

Figure 291 – Examination presentation: Presentation sheets
Photograph by James McNicholas, 2014

Figure 292 – Examination presentation: Presentation material after exam 1
Photograph by James McNicholas, 2014

Figure 293 – Examination presentation: Presentation material after exam 2
Photograph by James McNicholas, 2014

Figure 294 – Examination presentation: Simba // sheet 1
Figure 295 – Examination presentation: Simba // sheet 2
Figure 296 – Examination presentation: Simba // sheet 3
Figure 297 – Examination presentation: Simba // sheet 4