Folding Whare

Deployable Shelter for the 21st Century.

Written by Callum Dowie

An explanatory document submitted in partial fulfillment of the requirements for the degree of, Master of Architecture (Professional).

Unitec New Zealand, 2009
ACKNOWLEDGEMENTS
This project would not have been possible without the help of a number of people. Jeremy Treadwell initially gave me the introduction to the Department of Conservation staff who took me to Raoul Island in April 2007. It was on this trip that I began thinking about huts. Jeremy subsequently supervised the study I undertook and was invaluably supportive of my many constructions. Professor Mike Austin, as my other supervisor, clued me on to some of the key moves which transformed a potentially dull hut into a delightful piece of architecture. Dr Reagan Potangaroa used his deep knowledge of disaster relief housing, to encourage me to think about how my structural system could benefit the most deserving of people. Jeremy and Reagan were responsible for writing the funding application without which a full scale prototype would never have been realised. Tony Van Raat our inspirational Head of School approved the requisite funding in concert with Leon Fourie, the Dean of the Creative Industries Faculty. The inexhaustible energy of Tom Whealan was essential as the driving force of the Architecture Department Workshop, (apologies for wrecking your back Tom). Tom also acted as banker for the project making the required purchases with Unitec’s money and keeping tabs on how much we’d spent. Graham Leach as the other workshop technician assisted in both manpower and with a few useful books. Thanks to Associate Professor Dave Strachan for having given me the confidence to think I could design, detail and construct an entire building, ‘closing the loop’ as Dave says. Thanks also to Dr Cristoph Schnoor for allowing me to design such a small building programmatically when the rest of the class were looking at things so much larger. Mark Southcombe of Victoria University Wellington who confirmed at just the right moment that of course it should be built full size. My sister Dr Megan Dowie helped by proof reading this document at rather short notice, though the editing was my responsibility alone so no mistakes were her fault. Many of my classmates contributed along the way and
particular mention must be made of James Dawe, my tireless sounding board, as well as Jack Darlington and Brad Balle for helping so much when it really counted. Also thanks to Jacob Hadler and Elizabeth Tryland the most attractive ‘photoshopped’ people an architectural model ever had.

Finally and most importantly a huge thank you to my parents, without whose moral and financial support I wouldn’t have been able to become even more passionate about architecture than when I began studying it. Cheers Mum and Dad.

Callum Dowie

Point Chevalier

Feb. 2010
ABSTRACT

Deployable Shelter
A hut. The simplest built shelter. From knowledge of simple shelters and the “hut” of architectural literature, a shelter is to be designed for rapid deployment in situations where existing housing has been destroyed. Prefabricated panels are arranged in an assembly derived from Maori traditions of binding and tensioning, to span a space and provide shelter. From the building of a full scale model, tests will be made of the firmness of the structural system and the utility of the building created. Observation of the prototype will determine by empirical evidence the success in detailing a system of parts which make transportation and assembly easy and efficient.
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1.0 INFLUENCES
INTRODUCTION

Deployable Shelter - How can shelter best be provided to remote locations with difficult access?

Through this study a new knowledge may be added to that already existing on pre-fabricated shelters. This new idea may be implemented to benefit a large number of people. The idea of understanding the simple, before tackling the complex, is not new in architectural discourse. The intention here is to learn from existing examples, and design something useful as well as learning how that design occurred.

Investigating basic shelters, often called huts, has been an important part of architectural discourse for a long time. Abbe Laugier stated in his *Essai sur l’architecture*, written in the 17th century, “let us never lose sight of our little rustic hut.”¹ The requirement for simple shelters is today as important as it ever has been. So the investigation into their making must therefore be as relevant also.

In the developed world, simple shelters are too basic to meet the demands of the general population. However swelling populations and an under supply of houses puts pressure on existing accommodation. This is seen in the conversion of garages and other out buildings to additional accommodation for extended families in South Auckland for example. Geographically isolated areas, such as the backcountry of New Zealand, will continue to be the main location of simple shelters in developed nations.

¹ (Laugier 1977 (1753) , 12)
Developing nations have a need for simple shelters also, as this type of building makes up the bulk of housing. Although many settlements on urban fringes are easily accessible, poor infrastructure can make the supply of even basic accommodation difficult.

The main circumstances requiring new shelters in remote locations are following a natural or manmade disaster. When existing housing has been destroyed or a population displaced from their traditional homes, a need for accommodation is created. The remoteness of these locations may be as a result of a disaster, or due to their geographic location, such as an island in the Pacific Ocean or high in a mountainous region.

The initial thinking in this project was concerned with the provision of backcountry huts such as those provided by the Department of Conservation. Huts are provided for trampers and staff undertaking field work. These are mostly existing huts built for the forest service 30 or more years ago. Popular tourist areas have newer purpose built huts.

Building in New Zealand has tackled the challenge of making shelter in remote locations for as long as humans have inhabited these shores. The islands of New Zealand are geographically isolated from the rest of the world. The earliest Polynesian and European emigrants to New Zealand arrived by sailing vessel. The ships they arrived in, whether multi-hulled waka in the 13th century\(^2\) or sailing ships from the last years of the 18th century\(^3\), were forms of ‘portable architecture’. The immigrants brought with them detailed knowledge of the making and repairing of sailing vessels. The sailing vessels employed the most up to date technology of

\(^2\) (King 2003, 48)
\(^3\) (King 2003, 118)
their time to improve their function. These boatbuilding skills lead to the construction on land, of houses which involved the builder’s traditional techniques.

The other longstanding tradition in the making of shelter in New Zealand important to acknowledge is the use of prefabrication. Early European emigrants shipped housing components and complete disassembled houses from as early as 1833. James Busby the first ‘British Resident’ (a sort of proto-governor) brought with him from Sydney “the pre-cut frame, fittings and most other materials” of the house we now refer to as the Treaty House at Waitangi.\(^4\)

The trade of prefabricated houses between New Zealand and the west coast of America began in 1849.\(^5\) The trade was in both directions with prefabricated houses sent to San Francisco first and later complete kits of bungalow parts exported to New Zealand.

Prefabrication within New Zealand was used in the making of large numbers of houses by the Railways Department from their factory in Frankton, Hamilton from 1919. Fletcher Construction also used some prefabrication in the building of their numerous state houses from 1937.

The most interesting use of prefabricated parts however was by Maori. This is known about mainly through archaeological evidence so the proposition that shelter parts were made in one place to be erected in another is not certain, but certainly seems reasonable.

\(^4\) (Toomath 1996, 2)  
\(^5\) (Toomath 1996, 80)
The Folding Whare design has used the preceding ideas to devise a system which allows a structure to be folded for storage and transport. It can then be assembled in a short period of time to provide shelter without requiring special tools or machines.

In spite of the common nature of the problem, no single solution exists. This is due to the range of environments in which different people live. The solution proposed by this project is not intended to work in all situations. It is however an appropriate way of sheltering people at short notice in a humane way.

Many architects have attempted to deal with the problem of providing simple shelter. The usefulness of prefabrication has occupied the minds of the greatest architects of the 20th century. Few of these visionaries’ ideas have been mass produced. In most cases it has not been for lack of inventiveness on the part of the architect but due to the bureaucratic challenges faced by those trying to implement grand ideas.

To this end then the Folding Whare is a physical testing ground for new ideas. It may not provide a final solution to the problem of how to house people when existing housing stock has been destroyed. However by engaging with new technologies as well as traditional spaces and forms, a way of addressing problems and finding creative solutions has been developed. Tensioned folding structures and Structural Insulated Panels (SIPs) are variations on existing technology. The forms and spaces used are the result of the materials available and are familiar to most people (well, it’s a square room under a gable roof).

Some of the ideas researched and tested in the Folding Whare may be of direct practical use in the near future. Some developments may be useful first steps toward new disaster relief
shelters while others may be tested and discarded immediately. This is the nature of any research and the fate of many prototypes. The intention of building the Folding Whare prototype at full scale is to illustrate many of the ideas which have occurred this year and to evaluate them empirically.

Models and marquettes made as part of the process have given rise to a belief that a full scale version will overcome any deficiencies of smaller scale or incomplete assemblies. Deficiencies have included the flexibility of single sheets of plywood and the stretch of tension elements not made of braided wire. The full scale version will enable the most realistic testing.

Testing begins with the making of the panels. The panels are machined and hardware fitted to enable simple assembly. The building of the hut with a complete set of parts is the second phase of testing. The ease with which the hut can be built and the time taken to do so are the critical attributes to be evaluated from this. The next set of evaluations relate to practicalities of transporting the hut. The weight of the individual panels and the combined weight of the complete hut are important. The physical size of the disassembled hut and what, if any, packaging materials need to be determined.

An additional ‘test’ which can be made of the full scale model is the cost. As financing any disaster relief solution is important a total cost for the Folding Whare needs to be calculated. The expense of building the prototype as it stands will inevitably be different to that of a production model. In any future version, some parts will be added, others deleted or changed. However the final cost is a useful starting point for further development. The costing does not include labour as all operations involved in the fabrication of the hut are performed by the
author. Assistance in the construction from the workshop technicians also incurs no charge. Total man hours involved in the fabrication will be estimated.

A number of different areas of investigation have informed this design. These are explained in the following document. However this only describes a review of the most relevant reference material. In the course of this study, further reading has indirectly affected my thinking about architecture, shelter and construction. Books read are listed in the bibliography. Many websites and blog entries have also proved interesting and relevant, particularly with regard to the most recent of ideas and exhibitions. These however have not all been listed.
HUTS IN THEORY

“He was at first bare and out of doors; but through this was pleasant enough in serene and warm weather, by daylight, the rainy season and the winter, to say nothing of the torrid sun, would perhaps have nipped his race in the bud if he had not made haste to clothe himself with the shelter of a house.” H.D.Thoreau, Walden, or, A Life in the Woods, 1854

Hut describes the simplest type of shelter.

A hut can be similar to a cave or other naturally occurring protection from the elements.

A hut can equally be a complex arrangement of parts for the purpose of creating a habitable interior space.

As Thoreau said in the opening quote, the function of a hut is similar to an additional layer of clothing. The hut provides protection from the climatic excesses in which we live. Our bodies require constructed assistance to survive in most parts of the world. For this reason almost all indigenous peoples have a traditional type of building. The hut then is well illustrated by indigenous dwellings which exist around the world. These types of housing or shelter, as we also call them, exhibit the simplest definition of a hut. That is, a place to shelter from the elements. In each different location different requirements of shelters exist.

The main environmental effects people need shelter from are rain, sun and wind. These can encompass all forms of precipitation, including snow, hail, mist. It is important to negate the effect of excess sun in most hot climates, particularly where water is scarce. Wind is predominantly responsible for lowering temperatures and in many locations this could make human habitation impossible. Wind also causes rain and other precipitation to penetrate...
beneath roofs and through openings in a shelter’s fabric. Wind can also carry clouds of dust, sand or insects or could cause other unwanted debris to be brought in to a shelter. Some locations require the movement of air in order to make spaces cool enough to inhabit. In cold or freezing climates insulation is required and this can take many different forms. The use of a thermal mass such as adobe walls or floor, to stabilise temperature variations between day and night is also a traditional climate modifier in many cultures.

Huts provide examples of how humans can adapt an environment to suit their specific requirements. However the hut is not naturally occurring, but is constructed. It is of human making. Constructed shelters allow humans to live where they choose, and not just where the landscape provides readymade protection. Since the earliest civilisations shelters have allowed humans to live near sources of food, even if the climate has not suited our ill-prepared bodies. Huts then are closely tied to the earliest civilising aspects of human existence on this planet. The traditional housing of indigenous peoples throughout the world demonstrates an evolution from versions of a basic hut. From this we can tell that a hut is not one thing, not one type of structure or form, but is actually an idea of shelter which makes life possible.

The hut also exists both physically and metaphorically, as a place for thinking. The earliest recorded hut dwellers in this mould were two Chinese sages around 1000 B.C. Po-i and Shu-ch’i retreated from the reign of Emperor Wu Wang into the mountains and are remembered for the poetry they left behind. Centuries later, a string of reclusive thinkers beginning with Lao Tzu, inhabited huts, following the example set by the earlier monks. The building of huts in developed places, palace gardens etc. was seen by wealthy princes as a way of bringing the meditative calm of the cave or mountain hut to their gardens. Hand in hand with this was the
use of ceremony, particularly the preparation and drinking of tea. Japanese tea houses are the contemporary version of this hut usage. Huts used for Japanese tea ceremonies are also a source of architectural interest. Their simple form and defined use sit well with ideas of minimal architecture.

Huts have significance greater than their physicality might suggest. In religious ceremonies in many cultures huts are often built specifically for a particular occasion or annual event. Huts for this use are the oldest recorded. Joseph Rykwert in his book *On Adams House in Paradise*, writes “...rites [are] practiced by a number of peoples: Greeks, Romans, Jews, Egyptians, Japanese, in all of which a “primitive” hut has been built ritually - and at intervals - or deliberately in a “primitive” state for analogous ritual purposes.” Records of the use of such huts for rituals provide the oldest descriptions of what would otherwise be an overlooked building type. Grand temples, palaces and fortifications have far less difficulty enduring either physically or in writing through the ages, than the humblest of buildings, the hut.

It is interesting to note the parallels which exist between the most ancient of huts which Rykwert writes about and many of the huts which are to be found in New Zealand. The seasonally built hut for the ‘sacrifice’ of animals is a completely contemporary artefact in New Zealand. The duck shooting maimai found around many inland waterways are one example as are the shelters and structures associated with the catching of whitebait near many river mouths. The other hut type common found throughout New Zealand is the backcountry tramping hut, the majority of which were built by the New Zealand Forest Service for animal

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6 (Cline 1997, 3,4)  
7 (Rykwert 1981, 182)
control purposes. These huts are still used 40-50 years after their construction for the same purpose, the hunting of introduced animals such as wild pigs and deer. These New Zealand huts are also places for people to retreat to in order to escape the built up nature of the places they live. It is the simplicity offered by living in a hut which continues to make them a valued haven in the 21st century. As Rykwert states regarding ceremonial huts built millennia past, “They are all rites of urbanised or at least semi-urbanized peoples, implying a more permanent, more elaborate form of building against which the “primitive” hut provides a memento of origins.”8 This use of huts as places to seasonally or regularly inhabit as a way of marking time and gaining perspective on daily life is an established part of human existence which continues to be relevant today.

The hut has also been the site of regular and prolonged dwelling for the purpose of thinking and writing about existence. This practice in Eastern philosophy has been mentioned previously. Western philosophers have also appreciated the value of a simple place to think. Greeks philosopher Heraclitus9 recorded his thoughts in classical times from a simple hut.

In recent times, and for this reason more widely read, numerous books, on hut dwelling have been written. Henry David Thoreau wrote Walden, or, A Life in the Woods, in 1854 as an essay on how a more harmonious relationship could be had with the place in which one lived. He also recorded in great detail all he required to achieve his ends. This included many details about a hut which he built himself for a very modest budget. Thoreau’s hut was quite intentionally the

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8 (Rykwert 1981, 182)  
9 (Cline 1997, 5)
most simple and modest of dwellings. The utility and delight gained appears, from Thoreau’s writings, to be on a par with far more elaborate residences.

Martin Heidegger wrote in a hut he helped build for himself in the Black Forest from the 1920’s onward. This hut, a simple 3 roomed affair, without running water, is important as so much of Heidegger’s influential writing including *Being And Time*¹⁰ his paper *Building Dwelling Thinking*¹¹ were written there. Heidegger was a philosopher but his interest in buildings, particularly simple huts, has meant that his writings have had an impact on architectural theory in the later 20th Century.

Le Corbusier was a hut dweller also. His holiday accommodation at Roquebrune, Cap Martin in the south of France was a single room hut, clad externally in rustic split logs. Le Corbusier spent his annual summer retreat here. The Cabanon, as it was known, was a single room “measuring 3.66m x 3.66m x 2.66m high,... [and] was based on his Modular dimensions.”¹² The interior, in contrast to the external rough appearance, was a testing ground for various ideas of simple living within a machine designed for just such a purpose. The Cabanon had built-in furniture which efficiently used the space provided. Le Corbusier was not a complete adherent to the simple life, a water closet was in one corner and a door adjoined the neighbouring restaurant, where Corb ate all his meals.

In recent years a number of successful architects have turned their attention to the idea of inhabiting small spaces, and some with the particular challenge of accommodating those

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¹⁰ (Sharr 2006, 3)
¹¹ (Sharr 2006, 66)
¹² (Slavid 2007, 131)
removed from their regular housing for whatever reason. Australian Architect Sean Godsell spent many years developing his solution to the problem of relief housing. The Future Shack uses a standard shipping container as a base element. The container is insulated and lined with plywood, parts of which hinge down to form a table and two beds. The Future Shack is transported with a set of legs and a sun shading roof packed inside the container for deployment on site.13

Richard Horden is another architect whose work has impacted this project is. Horden’s work with small scale buildings, and leading edge technology, provides useful lessons on approaching architectural problems. Designing complete projects and then building them gives those investigating the problem, the most tangible educational benefit. This is why Horden teaches the design of the smallest (i.e. micro) pieces of architecture around. The original design which encouraged Horden to promote micro architecture as an investigative tool was the Ski Haus designed and constructed in 1991. Horden’s office, Horden Cherry Lee Architects collaborated more recently with Haack+Höpfner Architekten on the design of a self contained cube 2.6m in each dimension. A very 21st century hut. A set of Micro-Compact Homes (M-CH), were build in Munich as experimental student housing. In 2008 a Micro-Compact Home was sent to New York for inclusion in the Home Delivery Exhibition at the Museum of Modern Art. The use of a small scale project to test innovative ideas is exactly the intention the Folding Whare is designed to pursue.

The ideas Horden proposes regarding the use of technology and the importance of research to architectural progression, are similar in many ways to the recent work of Stephen Kieran and

13 (Godsell and Van Schaik 2005)
James Timberlake. Within their firm Kieran Timberlake Associates, is a dedicated research department. Their interest however doesn’t just lie in finding new materials to build with, but in new ways of making buildings. Kieran and Timberlake have authored a book promoting their ideas as well. *Refabricating Architecture* intentionally borrows from the rhetoric and structure of Le Corbusier’s *Toward a New Architecture*. However it is set firmly in the current century and promotes the use of leading edge technology and systems. *Refabricating Architecture* proposes no stylistic rules for the future but a new way of looking at the methods by which buildings are made. Of interest was a project designed and built for the Home Delivery Exhibition at the Museum of Modern Art in New York. The combined use of offsite fabricated parts and new materials enabled the building of a progressive piece of architecture. The project was not intended as a definitive solution of how to house people in the future but as a test laboratory which could be evaluated by anyone who attended the exhibition.

Figure 24: Cellophane House by Keiran Timberlake Associates installed at Home Delivery Exhibition MoMA New York.
KOHIKA - PRE-EUROPEAN MAORI SHELTERS.

From the making of objects and thinking about binding of structural elements came an introduction to the pre-European contact, Maori system of construction. This was used throughout the North Island but known about only through relatively recent archaeological excavations. The excavation of a pa site in the Bay of Plenty, in the late 1970’s, lead to a considerable increase in knowledge of pre-contact building techniques used by Maori. The accumulated research on the excavated pa site was published in 2004 in a book named after the pa site, Kohika edited by Geoff Irwin. The pa site of Kohika is located between Te Puke and Whakatane in an area of low lying land. Due to the submerging of timber elements in the peat marsh, parts of several Maori whare were well preserved and provide an insight into construction techniques long forgotten. As well as surviving structural timbers floor plans were in evidence, so the size of the different buildings of the pa could be recorded. The size of the buildings and their construction was also evidenced by holes in the ground which had previously housed posts and in some cases held remnants of these. An important finding from the excavation of the Kohika pa was the evidence on preserved timbers of how the various parts were held to each other and how their particular arrangement worked. This has provided an explanation of the previous gap in knowledge of how whare were constructed. In-spite of numerous descriptions of whare built before the use of European tools and materials, no description exists of how they were constructed. After steel tools and later corrugated iron roofing became available, the way in which Maori constructed the places they lived changed and over time the body of knowledge on construction techniques was lost. This was compounded by the hidden nature of the bindings which held the whare together. The
structural lashings were placed on the outside of the timbers supports and were covered by thatching to exterior of the whare. It has been proposed, based on the whare parts found at Kohika, that the construction method used in the making of ‘superior’ houses (houses made from squared timber elements) was a response to the colder climate which required thatching insulation, and was influenced by the type of trees available. The arrangement of parts and the way they were held together relates strongly to Polynesian canoe building technology. The hiding of structural bindings in a canoe is done to protect them from damage when the canoe is drawn up onto the beach. The use of a tensioned structure, not visible to the inside was an important idea in the designing of the Folding Whare. Another aspect of traditional construction which transferred to the new design was the idea of a set of parts which could be assembled and tensioned to make a shelter. Although it is not mentioned in the text about Kohika it seems reasonable that once carefully crafted parts of a traditional whare were made, they could be disassembled and transported by canoe along a river or coastline to a new site where they could be reassembled. This is where the idea for a set of reusable parts came from.
DISASTER RELIEF SHELTERS

The need for shelters to accommodate people after natural or manmade disasters is increasing. The reasons for this are; firstly that there are more people on earth than ever before, and populations continue to multiply. This is leading to larger numbers of people being affected by each event, be it war, tsunami, bush fire, flood or famine, or any other such catastrophe, displacing them from their houses. The second reason for additional shelter requirements is the increasing frequency of severe cyclones and rising sea levels. Both of these are a result of increases in the earth’s temperature. Higher sea levels may also require the movement of coastal dwellings such that a shelter which is relocatable is of benefit. The use of prefabricated parts will enable the production of shelters before they are required and allow storage without occupying excess space. The transportation of a set of parts for deployment in a disaster zone is current practice however currently the parts assemble to form only a tent which is susceptible to wind damage and provides no insulation. The lifespan of a tent is also limited although it should be acknowledged that the ease of distribution in the short term is hard to beat. The intended use of the Folding Whare is as interim shelter between tent accommodation and permanent new housing. The use of the Folding Whare as disaster relief shelter was not the initial intention. The design began its evolution as a set of parts for supply to difficult to access locations such as mountainous areas of New Zealand or areas with no road to them, such as New Zealand’s out-post on Raoul Island. The idea was to be able to supply a set of parts of low weight to enable helicopter conveyance to the site. The parts then need to be assembled in a short space of time, without specialised tools, by people without professional building skills. It became obvious that these criteria were very similar to the
requirements of second phase disaster relief shelters. As previously mentioned the first phase of disaster relief is the provision of tents to shelter people in the short term, immediately following a disaster. The Folding Whare is ideally suited to the following phase, providing shelter for the medium term while infrastructure is rebuilt and permanent housing is replaced.
PRE-FABRICATION AND TECHNOLOGY

The importance of engaging with new technologies has been in the minds of architects since the industrial revolution. Technologies were and are often developed for industries other than the housing of people. Architects skilled at adapting and further developing materials and structures have had an important impact on our built environment. Joseph Paxton’s use of glass-house technology for the Crystal Palace in 1851\(^\text{14}\) was a transfer of technology from an industrial, functional use, to the housing of an exhibition. The use of standardised prefabricated parts also highlighted the efficiencies which could be achieved by industrial processes.

Barry Bergdoll begins his essay on prefabrication in the book, *Home Delivery, Fabricating the Modern Dwelling* with an acknowledgement that the off-site fabrication of buildings and an architectural culture of prefabrication are distinct from each other.\(^\text{15}\) This is illustrated by quotes from Le Corbusier and Walter Gropius, two of the most influential 20\(^\text{th}\) century architects. Ideas of how prefabrication could be used to produce houses in an industrial way were central to modernist architectural discourse. The modernist interest in new materials and techniques and their effect on building forms has had an undeniable influence on this project. Architectural thinkers of the early 20\(^\text{th}\) century took inspiration from indigenous building forms in many parts of the world. The Folding Whare takes technological and formal cues from traditional pre-European contact, Maori buildings of New Zealand.

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\(^{14}\) Wilkinson 1996 (1991), 1
\(^{15}\) Bergdoll and Christensen 2008, 12
While modernists, particularly Le Corbusier, were enamoured with the production line and the cars that were produced on them, in the 21st century the objects which epitomise technology are manifold, a great number of them virtual and the result of miniaturisation and ever increasing speeds information distribution. This shrinking and speeding up of tools, toys and appliances is difficult to apply to housing and building. People are getting bigger and the space required to house all the ‘stuff’ modern life supposedly needs, increases too. The rate, at which building technology increases in comparison to say computer technology or the modernists’ favourite, car technology, is very slow. This is influenced by the cautious attitudes of regulators and a lack of spending on new technologies. The Folding Whare is an attempt to try several new technological ideas. These are not intended to be definitive solutions to the problems faced, but as a means to learn from the new materials and processes involved. A way of thinking which is open to experimentation is used in the design of the Folding Whare. Testing the untried without the fear of failing handicaps much contemporary architectural design. Because the Folding Whare fits into the “core theme of modernist architectural discourse and experiment, born from the union of architecture and industry... and exploration of new materials and techniques”\(^\text{16}\), it can be viewed as a descendant of the architecture of the mid 20th century.

Perhaps the most interesting modernist to explore prefabrication was Jean Prouvé. Although not a trained Architect Prouvé was responsible for the design of an astounding array of objects throughout the 20th century. These ranged from school chairs and desks to facade systems and complete housing assemblies. Prouvé used his knowledge of metal working techniques to design systems of housing. Houses were prefabricated off site and transported by truck or in the case

\(^{16}\) (Bergdoll and Christensen 2008, 12)
of the Maison Tropical, by airplane, to the intended site for rapid erection. Some of these houses ended up as far from their place of fabrication, France, as Algeria, Congo and Niger. Work on prefabricated housing systems began with the design for Demountable Barracks Units for the French Army in 1939. The production of these was curtailed by the German invasion. Importantly the construction time for these units was only three hours. Prouvé developed innovative systems of housing after the end of the Second World War, however only a limited number of these were completed due to costs higher than that of conventional housing. A system of housing Prouvé designed in the 1950’s has been influential on the Folding Whare Project. The ‘Maisons Coques’ or Shell Houses were designed for car maker Citroën. “The buildings Prouvé proposed were meant to be economical and prefabricated and able to be assembled over the weekend by the users themselves.” Just the qualities the Folding Whare is aiming to achieve. Another similarity with the Folding Whare was “...the construction principle...based on the idea of a roof and wall forming a single building part.” The idea never got beyond a prototype stage because the management at Citroën thought the design was too Modern.

17 (Peters 2006, 56)
18 (Peters 2006, 56)
2.0 PROCESS
PORTABLE WHARE - DESIGN PROCESS
The process employed to design the Portable Whare involved a number of distinct stages. The earliest phase of the design was not specific to any particular part of a building although possible uses are included in the descriptions. The objects produced dealt with a set of limitations in terms of materials used and the type of assembly made. The second phase takes this idea of producing objects without obvious function and adds technology derived from traditional Maori construction techniques. These objects were then combined to make a structural system, which were later tested in various arrangements. The third phase was a set of details modelled at full scale in order to demonstrate how different parts of an actual hut might be configured. The final phase of the Folding Whare’s design evolution was the production of the full scale prototype. The construction of a complete building, like any construction project big or small, raised a further set of design challenges. These challenges were overcome with a combination of the design skills already established and the pragmatism required to complete a construction project on time and within a budget.
INITIAL JOINING DETAILS

Figure 27: Arrangement for the connection of a table leg or furniture structure detail. - eucalyptus saligna, meranti plywood, stainless steel screws, washers and nuts. Natural preservative oil finish.

This is a pair of the same junction attached to opposite sides of a piece of thick plywood. The junction uses a version of a cam fastened bolting detail common to furniture construction. The mechanical advantage of this junction is in the amount of torque which can be applied through the stainless steel screw to the ‘leg’. The load is spread over the area of one side of the hole by the cam removing any point load and meaning that a greater jointing force can be applied. The arrangement becomes an example of excess since the size of the load which can be applied is greater than that required to perform the function. The finished object is intentionally not of any use other than as an experiment and although interesting to look at has no obvious use although it could be considered visually appealing.
Figure 28 & 29: Arrangement for the connection of a table leg or furniture structural detail - radiata pine plywood, radiata pine, 100mm flat head nails, 100mm right and left handed galv. wire dogs.

This arrangement of elements was an attempt to achieve the same functional end result as the previous assembly but using the crudest of connection hardware, the wire dog. It is to show a lineage to the previous assembly that the ends of the ‘legs’ are cut at an angle and are joined to opposing sides of the plywood. In order for the wire dogs to function as they are intended to do, that is around a corner, with legs nailed perpendicular to the plywood faces, the ‘legs’ are attached to the corners of the plywood. While this certainly changes the end form of the assembly there is still a clear relationship with the preceding arrangement. The use of the inferior timber, soft cheap pine vs. the more expensive hardwood eucalypt, was intentional as a further illustration of the cheapness and minimal efficiency of the wire dogs. The timber is left unfinished since it is not valued to the same degree as the earlier assemblies. The most striking effect of the use of wire dogs to secure the ‘legs’ is that they read as tension elements tying or binding the timber together. This was the first link to the idea of binding junctions to make them fast.
Figure 30 & 31: Arrangement for the support of a rafter or where a post could meet the ground- radiata pine, finger jointed pine, galv. wire staples.

As a result of the previous assemblies I had made I became interested in using a simplified palate of materials to display intentionally crafted joints. The use of wire staples as the ‘crudest’ jointing mechanism and trying to form an aesthetically pleasing joint was the aim. An intentional move was made to reflect the Auckland’s place in the South Pacific. This was done with the use of the fanning arrangement of the struts. Wire staples effectively illustrate the joining of elements by binding them. The staples do not actually bind the elements continuously but do tie them together.
Figure 32: Arrangement for the junction of a post and rafter - radiata pine, galv. wire staples.

The elements in this arrangement are intentionally placed to give the feeling of binding the timber elements together. The wire staples are overlapped to imitate the strengthened nature of a binding made by tying in offset directions to resist forces applied at different times / under different conditions.

Figure 33 & 34: Arrangement for the junction of a post and rafter - radiata pine, galv. wire staples

The elements in this arrangement are placed half housed onto one another, that is, the post is rebated into the rafter half way. The effect of this is that post and rafter are better able to resist vertical twisting between the two elements. The arrangement is held secure by the use of two wire staples each side. The staples are placed to reflect the binding nature of their effect. The staples look like stitches ‘sewing’ the structure together.
Figure 35: Arrangement for the junction of a post and rafter - radiata pine, galv. wire staples

This arrangement looks back to traditions of timber joinery, particularly the Japanese obsession with precision dovetailing etc. The notch cut into the rafter is far more complicated than the typical ‘birds-mouth’ type made in traditional New Zealand carpentry. The effect of this joint is that it locates the timber elements more securely, preventing them from moving relative to each other in most situations. The junction is held fast by wire staples which are located centrally and through the corners of the junction diagonally. The arrangement of the staples is functional and also represents the binding of a joint as typically done in indigenous constructions.
As a result of the type of objects I had been making, I was introduced to some traditional Maori construction techniques which involved binding. These techniques were known about through archaeological excavations and I was shown photos of a half scale frame-work which had recently been built. Due to my limited knowledge of these constructions and the few photos I saw I misunderstood the complete structural arrangement. This turned out to be a fortuitous mistake as my attempt to produce similar arrangements resulted in a folding structural system which exhibits an interesting new idea.
TIED JUNCTIONS

Figure 39 & 40: Arrangement for the junction of a post/board and rafter - pine plywood, garden twine, hardwood, doweling.

The materials chosen for this assembly were intentionally low tech. This was done in order to test the feasibility of such a system when constructed using materials and technology which represent those available in New Zealand around 600 years ago. The first of this series uses a junction notch one third the width of the timber members. The initial attempt at tensioning the joint failed as a result of a lack of angle between the boards and the tension members. The illustrated version uses a hardwood bar, which represents a sort of purlin in a complete building, to hold the tension element, the twine, away from the joint. The joint works when the timber elements are folded toward each other, the twine comes into tension resisting the folding action.
Figure 41 & 42: Arrangement for the junction of a post/board and rafter - pine plywood, garden twine, hardwood, doweling

The second in this series again explores methods of joining essentially the same parts with twine. This assembly has a more complicated junction being in 2/5 joining to 3/5 on the timber edge. The advantage of this is a more even spread of the forces on the teeth/fingers of the joint. The twine has its path prescribed by the teeth/fingers of the joint, although the arrangement of those tension elements is the same as before. The advantage of keeping the tension parts of the structure to the outside of the arrangement is that the internal faces, and hence the interior of the building are kept free of complicated and messy bindings. The internal walls and rafters are more easily decorated as a result.
Figure 43 & 44: *Arrangement for the junction of a post/board and rafter - pine plywood, garden twine, hardwood, doweling.*

The third assembly used the same basic set of parts as the first two but with the teeth/fingers in a $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{4}$ arrangement. The method of securing the elements with the twine is refined in this third iteration, the tension exerted on the assembly is much higher due to the use of doubling back and tying-off in such a way as to increase tension throughout the system at each stage of its tightening. The resulting assembly is successful enough to be worth replicating and arranging into a complete structure.
TIED ASSEMBLIES

Figure 45,46 & 47: Arrangement of posts/boards and rafters into a portal frame - pine plywood, garden twine, hardwood, radiata pine, steel screws, doweling.

The combination of a series of tensioned junctions similar to those assembled earlier produces a portal frame when the posts are attached to a base made of 100x50 timber representing the ground. The post-rafter junction is the most important connection in this arrangement. The apex/ridge intersection is in fact only holding the two sides of the portal frame together. The gravity (vertical) loadings are resisted by the tension elements simultaneously. Wind or earthquake (horizontal) loadings are resisted by the tension elements of one side of the structure at a time. The advantages of using such a system of construction are; it has high strength to weight ratio, it can be disassembled and reassembled in a new location without damaging the parts so this operation could be performed numerous times. The parts are of a scale which can be manoeuvred by human effort alone, no machines required, or only very simple ones. Through their reusability/long lifespan the parts can become more than just elements of a building, but objects worth preserving and cherishing. Their ability to shelter and protect adds to their metaphorical importance. This particular arrangement abstracts the placement of posts into footings in the ground by attaching them to the 100x50 base plate. This creates a situation of cantilever action on the posts reducing the importance of the tension elements, the structure will actually stand up to vertical and horizontal loads with no tension elements at all. A limitation of this arrangement is the small amount of tension the twine can apply to the system. Even with the elaborate tying system employed, the mechanical
advantages are not enough to resist forces in the system effectively. The twine stretches after loading and needs retightening. The effectiveness of the system is warrants further investigation. It is important to note at this stage that this arrangement of elements is different to the recreation of the pre-historic structure shown in the earlier photos. The difference is that the ridge post used previously has been omitted. The reason for this is that the structure shown below was built from memory of a brief viewing of the earlier photos. As such it was by accident that it was omitted, not design.

Figure 48 -52: *Arrangement of posts/boards and rafters into a portal frame -pine plywood, nylon webbing, steel ratchet mechanism, steel hooks, hardwood, radiata pine, steel screws, steel hinges.*

This assembly directly translates the earlier one tensioned with twine. In this new version the tension is created by proprietary ‘ratchet tie-downs’. These were used as they are inexpensive, commonly available, and are able to excerpt far higher tension loads than the twine. The possibility of combining the ‘tie-downs’ in a variety of configurations also allowed a rapid testing of different tension arrangements. The parts required to make the portal frame can be broken down for transport and storage.
It is important to note that for this arrangement of parts the cantilever action of the earlier portal frame is eliminated by the use of a hinged joint between the post member and the base plate. This requires the tension system to do all the work of holding the arrangement in position and resist all loads acting on it. The testing of different configurations revealed several ineffective ways of combining the parts. The first was with a single tension element over the whole portal frame. This worked to a limited extent under gravity loads, but under horizontal loading, such as would be experienced due to wind, one side becomes slack as the other side tightens so the whole assembly falls over. Although plenty of tension is exerted on to the joints the transfer of loading from one joint to another under load prevents the arrangement from holding up. The second arrangement tried was to use two ‘tie-downs’ which cross from the middle of one rafter over the ridge junction and rafter wall junction to the wall opposite. This worked far better than the first set-up but the length of the ‘tie-down’ and the flex of the timber elements meant that the amount of movement and flex in the frame was still considerable.

The third arrangement used three ‘tie-downs’ each of which isolated only one of the junctions. The benefits of this are that the total length of each tension element is as short as practical, the joint will not be affected by changes in loading to other joints in the system and the joints at rafter and wall can be tensioned/made rigid independent of the rest of the arrangement. This leads to benefits in the assembly of the portal frame as the two sides can be tensioned and then brought together. This arrangement exhibited by far the best resistance to vertical and horizontal loading, to the extent that it seemed feasible as a possible system for the assembly of a building.
Figure 53 & 54: Arrangement of posts/boards and rafters into a portal frame - pine plywood, nylon webbing, steel ratchet mechanism, steel hooks, hardwood, radiata pine, steel screws, steel hinges.

As a way of visualising what a complete building made using such a system as tested previously would look like. The scale is approximately 1:10. The tension elements are not to scale but are arranged to produce enough tension to hold the building together. The hinge (pin joint) at the connection to the ground is continued from the previous versions. The tension joint at the ridge has been replaced in this version with a hinge (pin joint) this is possible since the ridge junction is only required to connect the two side assemblies, transferring loads from one to the other, but not itself resisting any. This arrangement resisted vertical and horizontal loads well, as expected. The form created by the wall and roof elements proved worth further investigation although the space created inside looked like a particularly habitable volume. The major deficiency evident from this assembly was the difficulty in trying to waterproof/weatherproof the junction between the roof and the walls.
JUNCTION DETAILS

Figure 55 & 56: Arrangement for posts/boards and rafters - meranti plywood, hardwood, steel pin.

As an initial attempt to solve the problem of weatherproofing the wall/roof junction, the type of intersection between the two elements was identified as the main problem. The first possible solution was the movement of the pivot location from the outside of the junction to the inside. Doing this removes the need to create an angle between the tension element and face of the wall and roof elements. The faces of the wall and roof can now be made flush with each other or could even be made to overlap in one direction.
Figure 57, 58 & 59: Arrangement of posts/boards and rafters/roof - plywood, colorsteel, piano hinge, stainless steel machine screws and nuts, steel ratchet mechanism, galv. Steel wire, stainless steel screws

As a refinement of the previous assembly an attempt was made to model the weatherproof junction between the roof and wall elements. This model also converts the crude ‘hinge’, of hardwood and steel pin, to a conventional hinge. The type of hinge used is a section of piano hinge this was intentional as a long hinge spanning the width of a module, 1200mm, seems an ideal way to achieve good fit and spread stresses evenly along the junction. The use of stiffening ribs is made in this model in the line of the tension members. The tension is created by the same ratchet mechanism as in the earlier models however in this version the nylon webbing is replaced by a length of wire. The wire does not stretch like the webbing. The ratchet could easily be substituted in a further or final version by a typical fence strainer and the wire scaled up to fencing wire. This is an intentional reference to vernacular farming tectonics. The cladding of the plywood with flat sheet steel (0.55mm) is a reference to deer culling huts built by the forest service in the 1950’s-80’s. These huts were regularly clad in flat tin (steel) dropped in to the bush by planes or helicopters and cut to length on site then nailed into place. The plywood is thickened at the junction for several reasons. The first is to allow the rib to run right to the end of the sheet, the second to allow the screws sufficient depth. The most important reason however is to provide distance between the pivot point (hinge pin) and the tension wire. This offset is required to cause the tension wire to hold the arrangement in place. The angle at the touching ends of the plywood elements is intentionally cut to prescribe the roof angle, the wall angle being vertical.
1:10 FOLDING DETAIL

Figure 60-63: Arrangement of walls and roof - plywood, piano hinge, stainless steel screws, galv. steel wire.

This assembly is primarily an illustration of how a complete portal frame/arch would be put together. The wall and roof elements are 1:10 scale of 1200x2400 sheets typical of many common building materials. Hinges (pin joints) are used at the apex/ridge and also at the ground connections. The wall to roof junction is hinged to show how it can be folded for storage and transport, then folded into position on site and secured as part of the erection process. The walls are fixed to the ground from the beginning. The wall and roof elements are fixed together to form a single unit. The two sides are lifted into position and held together by the addition of the ridge pin. Owing to the scale of this model the wires tensioning the sides are not ratcheted tight but simply wound round a screw and then screwed fast. This model shows the shift from a set of parts to a complete portal. The addition of further portal modules adjacent will create a room. The possibility now occurs that the number of modules might not be a definite four, three to enclose the room and an additional one to cover the porch, but may in fact be added to, to make long rooms to accommodate many people.
1:50 MODEL OF COMPLETE HUT

Figure 64: Northern elevation 1:50 model.

Figure 65: North west perspective 1:50 model

Figure 66: North east perspective 1:50 model

This model was made to illustrate how a complete set of parts would look arranged into a hut. The wall panels are shown clad in sheet metal and sky lights are included in the steep section of roof. The front wall, on the porch, includes a window and door as well as clearstory windows above. The hut is supported off the ground on a three legged frame which would be levelled more quickly than a conventional sub-floor structure. The proportions of this model include long roof elements of 3m and short roof elements of 1.5m.
Figure 67, 68 & 69: Arrangement to illustrate wall and roof junction - plywood, 0.55mm coloursteel, high density polyurethane foam, piano hinge, stainless steel screws, hardwood blocks, hardwood wedge.

The purpose of this assembly was firstly to show a shift from a steel clad plywood wall material to a thicker composite sandwich. In this case the wall panel would be 62mm thick. 50mm foam insulation, 12mm plywood a steel cladding to the outside of the building would give a durable exterior as well as being a structural part of the wall panel without adding excessive weight or mass. A panel of this type of construction does not exist commercially at present. The most similar proprietary wall/roof cladding panels are made with steel cladding to both faces. This gives advantages in calculating the structural properties of the panels. The hardwood blocks placed in the ends of the experimental arrangement would not be possible in proprietary panels although extruded aluminium and folded steel end-caps are readily available. The second major thing exhibited by this assembly is the effect of using the thickness of the panel to shift the pivot point in, away from the outside surface where the tension element is located. This appears to be a successful result of thickening the panel, the advantage of this thickness being used for insulation is significant. Thicker panels offer higher load bearing potentials and better insulation properties, but are bulkier to store and transport and more expensive. The interior of a hut made from panels with steel to both faces would not be as aesthetically pleasant as a hut lined with timber or plywood. For this reason it is to be investigated how a plywood lining could be installed and used productively e.g. for furniture or as a surface to fix to.
1ST SHEET OF DRAWINGS FOR FOLDING WHARE. FIGURE 70

Demountable disaster relief hut 1:50  
callum dowie 08/09
Figure 70: *Sheet of pen drawings on butter paper. Reprinted here not to scale.*

The drawings on the preceding page show a version of the Folding Whare which was the earliest to take into account the possibility of use in a disaster relief situation. The suggested application was after a tropical cyclone had struck a Pacific Island nation. Since then the Tsunami has affected Samoa and so it is reasonable to think of this situation as the potential use of such a shelter. This version was designed with a recycled billboard skin as the roof membrane; the skin is shown tensioned down to polyethylene bearers with sealed ends and valves attached. These could be filled with water to provide mass to resist overturning due to wind. When empty the bearers could act as skids so that the hut could be dragged short distances to serve other functions within a village at a later stage. The idea of protecting the ridge and roof-wall junctions with a stretched tarpaulin was abandoned. Instead of using the tarpaulin for its intended purpose, it would most likely become another temporary shelter and the folding hut would be left exposed.
Figure 71: Arrangement to illustrate alternate SIPS panel. 12mm shadowclad plywood paint finished, pine blocking.

The purpose of this assembly was to show how a panel made with plywood on both sides would look and to evaluate its composition at full scale. The use of wooden skins for SIPS panels is not a new idea however it is not used in New Zealand. The production of panels in other countries is predominantly of Oriented Strandboard (OSB), but plywood is also a proven facing material. In New Zealand the composition of SIPS panels is almost exclusively steel facings and these are used most commonly for cool stores and freezers. Some portable buildings such as construction site offices are also made from steel faced panels. Steel faced panels do not in most cases create an environment in which people are comfortable inhabiting. The use of plywood is potentially cheaper and provides a far more pleasant, tactile interior.
Figure 72 & 73: 1:10 structural bay model and detail.

Version of a structural bay made of stressed skin plywood panels. The purpose of building this model was to illustrate structural panels made from plywood skins bonded to timber studs/rafters. A continuous polystyrene interlayer was not modelled. The main problem shown by this model was the difficulty of penetrating the gutter and roof edge flashing with the tension wires. Overcoming the challenge of detailing this junction became one of the main focuses later in the design stage. The model roof form is made up of a scaled 3m long panel and a 1.5m short panel. The reason for these sizes was that plywood is the preferred facing material and the longest commercially available lengths of ply is 3m. 1.5m being half of one of these long sheets seems an economical way of using the material. From researching costing of the readily available steel faced SIPs panels and their alternative, timber faced panels, it was discovered that the timber panels are cheaper to construct. The use of timber in this case plywood (although orientated strand board is more commonly used overseas), is preferable since steel production is an extractive process and the energy embodied in the steel is large compared to any wooden products. It is important to acknowledge that prefinished steel sheeting does have advantages in durability and requires lower amounts of maintenance however for the purposes of this investigation which is a prototyping exercise low cost is more important than overall durability. The model illustrated is of stressed skin panels. These panels are made of two layers of sheet material in this case plywood bonded to a timber structure. The sheet material needs to be glued and mechanically fixed. The two sides of the panel act in a similar way to the flanges if an I-beam with the timber structure acting as the web. The strength of the panel is greater than the sum of its parts. The action of a SIPs panel is the same but with a continuous interlayer of foam (polystyrene, urethane etc.) instead of the timber.
structure. This model and the structural bay model which preceded it both are arrangements of 2.4m wall elements, a 3.6m floor and a roof 3.0m on its long side and 1.5m on its short. These sizes have been amended to use more commonly available plywood lengths.

The process to select the revised proportions was a combination of CAD drawing and hand drawing. It was only after a number of iterations that the final version was selected. A large number of combinations of differing length panels were arranged in Archicad (see fig.? above) To test the relationship of them. The available sizes of plywood being paramount in determining what was possible, no panel could be longer than 2700mm and panels of sizes

Figure 74: Screen grab of Archicad file showing different roof configurations.
other than full or half sheets while possible, would lead to material being wasted. So the selected sizes of panel (lengths) are 2400mm, 2700mm and 1200mm.

Figure 75: Sheet of pen drawings on butter paper. Reprinted here not to scale.

The second sheet of drawings of the folding hut, on the following page, shows a move back to the external tension wire method of structure. The panel sizes have been revised to represent available plywood sheet sizes. The hut now rests on traditional timber bearers and these are shown on light weight screw-in plies. The floor plan remains as before. The ridge is covered by a polycarbonate flashing to enable light to enter the space from above. The gap at the ridge allows stale air to escape in addition to daylight ingress.
2nd SHEET OF DRAWINGS FOR FOLDING WHARE. FIGURE 75.

demountable disaster relief hut 1:50 callum duvie 09/09
Initially the panels were arranged in a similar order to the earlier models and sketches. This is seen above on the right. On consideration the steep pitch of the roof in the earlier version was lost and the section felt too static. A rearrangement of the same sized panels was made in order to create a more dynamic section. This new sectional form on the right above was drawn up in the same way as the earlier versions and a final comparison could be made.

Figure 76: Screen grab of Archicad file showing different roof configurations.
3rd SHEET OF DRAWINGS FOR FOLDING WHARE. FIGURE 77.
Figure 78: 1:10 Structural bay model.

Figure 79: 1:10 Model showing folding furniture.

Version of a structural bay made of proprietary steel faced Structural Insulated Panels (SIPs). This model was made to show ‘off the shelf’ cool store type panels, which are commonly made in New Zealand, assembled into a structural arch. The interior of this arch is clad in plywood with the intention of improving the internal aesthetic; powder coated steel walls not providing the most pleasant environment.

Further to the idea of using proprietary ‘cool store’ panels the use of an additional lining inside the hut was justified by using the ply lining as furniture which could fold from the walls. A model was made of the interior showing how furniture could fold from the walls. This model revealed that although it was possible make furniture which did fold out it was very difficult to achieve this and also keep the parts of the hut modular such that they would fold into the required set of parts.

The cost of the cool store panels was also determined to be too expensive to be practical for a prototype. After visiting a manufacturer of the steel-polystyrene-steel panels it was decided that a plywood faced panel system would be easier to work with and by manufacturing them ourselves we would be able to customise the panels for specific roles within the building. Typically this meant the inclusion of additional blocks of timber to allow secure fastening for the various hardware required to assemble the hut. The use of plywood faced panels made the need for additional internal lining irrelevant and the folding furniture idea was scraped. A further reason for not pursuing the use of cool store panels was the cost. Panels are priced at
a per square metre rate, the retail for a typical 1200x2400 panel being just under $300 (see appendix 1). The projected cost for a plywood faced panel was $143 (see appendix 2). Because it had been decided that building a full scale prototype of the hut was the best way to evaluate the structural system and detailing, the lower cost made this more achievable. The cost of making the plywood panels did not include any allowance for labour cost or specialised equipment. The labour has all been done by the author with the assistance of the workshop technicians and all equipment has been available through Unitec.
It was realised early on that the junction of the wall and roof was the key detail to be resolved. In the earliest assemblies no allowance was made to weather proof this intersection.

In traditional structures the outer layers of thatch insulation/weatherproofing effectively covered the wall-roof junction. This is not possible in the Folding Whare. Later versions of
externally tensioned assemblies began to deal with this problem by moving the pivot point to the inside of the junction. The problem which remained was how to collect water from the roof. Collection of water in either a remote location or after a disaster, so that it can be stored and drunk when needed, was viewed as an essential function of the hut. The problem which existed was how the tension wires could act around the wall roof junction without penetrating the gutter or any flashing, causing a weak point in the weather skin. This is shown in an earlier illustration. The solution which has been used was arrived at after a workshop looking specifically at this junction. A detail drawing at 1:1 was made and then a prototype model constructed, as shown in the illustrations.
Figure 85 & 86: Assembly of the wall and roof junction. - plywood and polystyrene panels, steel compression ring, Galv. steel wire, fence strainer, piano hinge, screws.

A section of SIP panel was made to test the glue to use, to bond plywood to polystyrene. A moisture cure urethane glue was employed for the test and worked very well. It did not melt the polystyrene as a solvent based adhesive would have and due to its foaming action while setting, it penetrated approximately 10mm into the polystyrene this could be seen when the panel was subsequently cut. The panel created was divided into parts and two of these were arranged to form a typical roof wall junction. This model is at full scale and is intended to show how all the parts of a typical junction would fit together. The interior is intentionally free of structural elements (apart from the top wire anchor point, which would be moved in a full length panel). It is also intended that the wire strainer (tensioner) should be mounted from the lower edge of the panel; this will be possible when the panel is connected to the floor, and will prevent it from pulling out while still giving clearance for the moving parts. This prototype was successful in showing that the proposed arrangement would work to protect the intersection from rain, collect water and be structurally rigid enough to cause the wall and roof panels to act as a single element as one side of the three pined arch. Form this detail prototype it was realised that additional blocking would be required before the end of the roof panel to accept the piano hinge screws. The fence strainer worked well at generating tension although its fixture and location will need modification in the final version. The bolt securing the compression ring was mounted on the wall. The effect of this is that when the load is applied to the wire, the ring tends to roll down the wall. To overcome this problem the fixing bold is to be located into the end of the roof so that it is only loaded in tension, which it will more easily resist than shear forces.
Figure 87-90: 1:2 Assembly of complete structural bay. - plywood, steel compression ring, Nylon webbing, Ratchet tensioner, piano hinge, screws.

A half scale version of the final arrangement of panels was made to test the proposed method of assembly and erection. The tests were successful enough to make building of the hut at full scale a reasonable proposition. The biggest negative of the half scale version was the flimsy nature of the single sheets of plywood used, which prevented a complete structural arch from looking convincingly stable. The hardware used to make this version is appropriate to a half size model. The amount of tension exerted by the straps is sufficient to ‘pull’ the arch in to position, and to lock the wall and roof panels into a single part. The single sheets of plywood were used because that was what was at hand. This prevents a maximum tension being applied as the plywood bends distorting the shape of the arch. The half scale model has been assembled a number of times now ad not only continues to work but has become easier to operate. It is hoped that the erection time for the full scale version will be under two hours from arrival on site. This will be determined after all full scale parts are made and fitted, and a suitable location found.
3.0 PRODUCTION

Photos of full scale Folding Whare prototype under construction.

Figure 91: Floor Frame laid out on assembly table.

Figure 92: Urethane glue foaming out from floor-floor frame junction.

Figure 93: Polystyrene infill sections glued up for insertion into the floor.

Figure 94: Wall and roof panels after being glued and vacuum formed.

Figure 95: making the vacuum bag. Plastic film is taped round the assembly table to form an airtight seal.

Figure 96: First wall panel in the vacuum bag. The front edge of the bag is taped closed around the suction pump inlet.

Figure 97: As air is removed from the bag the panel is pushed flat on to the table.
Figure 98: Completed panels showing additional blocking to accept hinge screws.

Figure 99: Panel ready to be glued. Additional support blocks can be seen.

Figure 100: Panel awaiting glue. Blocks to support ridge hinges can be seen.

Figure 101: Steel compression rings, drilled and grooved ready to galvanised.

Figure 102: Butt hinges welded into double hinges. Awaiting grinding and zinc plateing.
4.0 CONCLUSION

From the preceding writing it can be seen that the simple shelter or as it is also known the hut, is both the simplest architectural structure but also a comprehensively studied object.

The architect’s obsession with making shelter is ongoing. As different generations of architects test ideas at a micro scale they educate themselves in the most basic of built forms. Each new group of architectural explorers is indebted to all those who have preceded them. We owe a debt also, to the technologists and philosophers who have added to the body of knowledge, of what it is to inhabit this place.

The Folding Whare is not a commercial product. It is not the result of an industrial design process, or product design. It is however a prototype and investigates a number of ideas of how we might provide shelter in the future. The ideas are not in themselves new, but in combination they certainly display an original system for the assembly using simple equipment of a shelter. The shelter will provide its occupants with a place in which to live their life for a finite period of time. The intention is not that the Folding Whare is a permanent house. This is the reason services, as expected by residents of a developed country, are absent. Potable water can be easily gathered and stored, gravity in concert with a roof and gutter system collect and transport the water without any assistance and storage vessels can readily be made or sourced. This would be particularly important where other sources of drinking water may be polluted or simply remote from the site of the hut. In situations of abundant drinking water provision, the system can simply be omitted.

It is from thinking about these things as well as the pragmatic problems of ‘how to make’, that has led to the Folding Whare as an example of a 21st century hut. Many examples of
architectural hut have been built. Even more have been designed. Very few, if any, have been produced in large numbers, even when this was the express intention. The Folding Whare is an additional step in the development of responses to one of the true architectural challenges of our age. Hopefully further research and design will lead to even more refined solutions.

At the time of writing the Folding Whare hut prototype, at full scale, has not been completed. This is due to occur before the final exam presentation.
BIBIOGRAPHY


