KIWI PREFAB

COTTAGE TO CUTTING EDGE

PAMELA BELL & MARK SOUTHCOMBE

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PREFABRICATED HOUSING IN NEW ZEALAND

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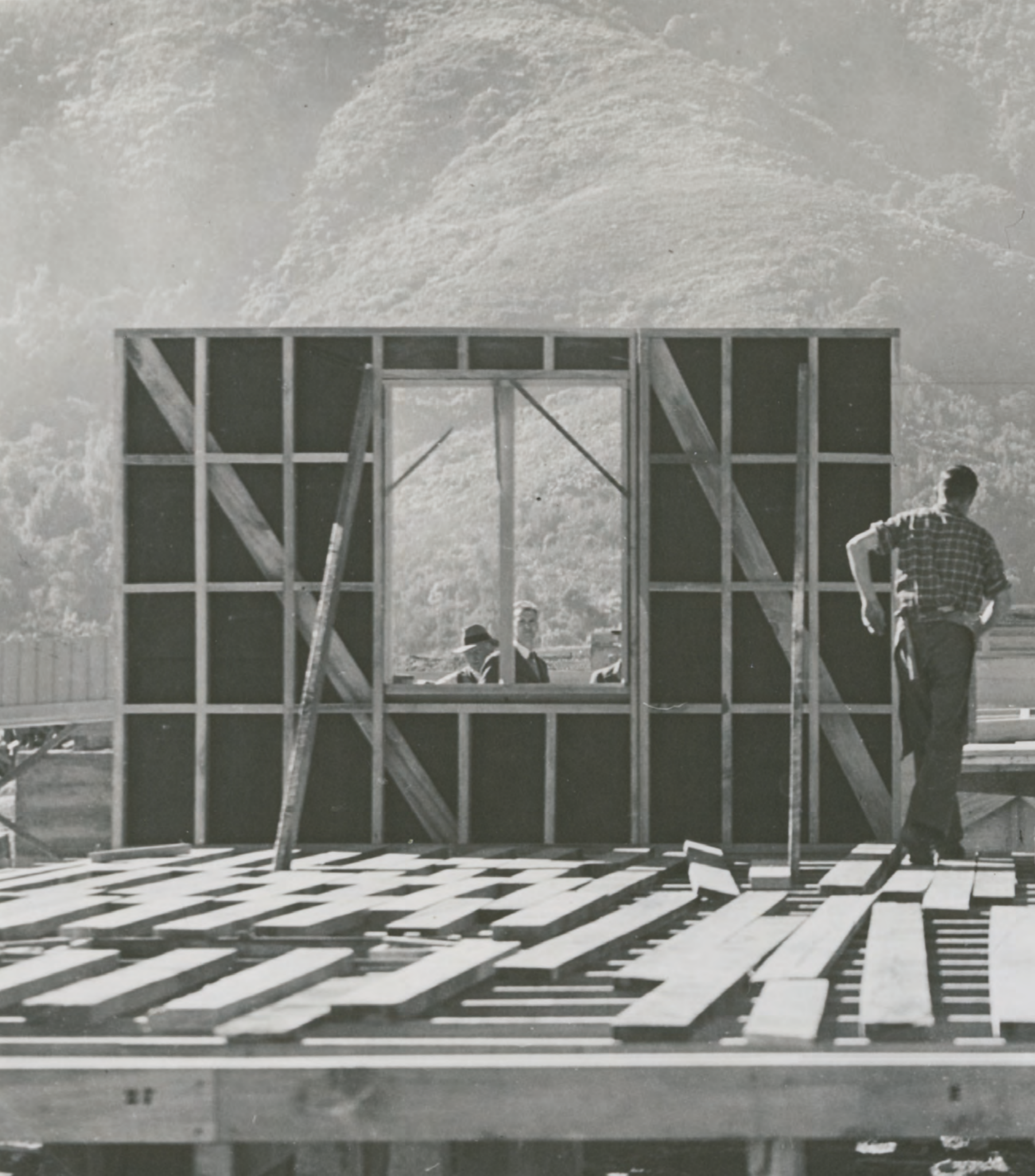


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CONTENTS

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Thank you to our esteemed guest essayists Barry Bergdoll, Peggy Deamer and Brenda Vale, and to the estate of Roger Hay for allowing the publication of his unpublished essay *Out of Time; IBS, an idea too strange for home.*

A heartfelt thanks to Puke Ariki and in particular Gerard Beckingsale for believing in the dream of a major New Zealand prefab exhibition and working alongside us to turn it into a reality. The *Kiwi Prefab, Cottage to Cutting Edge* exhibition has been a parallel project to this book, and research for the exhibition has informed the book as much as material for the book has informed the exhibition.

To the internal team, Puke Ariki staff, VUW colleagues, Dr Robin Skinner, our graphic designer Diana Curtis, proof-readers, and our families Tim, Sophie and Tessa Park, and Carolyn and Luke Southcombe who have lived this with us for the last few years.

We also aknowledge important precedents and prefab publications; *Dwell* magazine and the inspirational architects of the 'green modern prefab' movement, the Museum of Modern Art (New York) 2008 exhibition *Home Delivery: Fabricating the Modern Dwelling* and the 'Dwell on Design' Los Angeles conference, and Stephen Kieran and James Timberlake's *Refabricating Architecture* and *Loblolly House.*

Pamela Bell and Mark Southcombe September 2012

Re-fabricating Prefab

MARK SOUTHCOMBE

WHAT HAS changed today? Everything. Mass production was the ideal of the early 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 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 with 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.[1]

Kiwi culture has documented and revered the caravan, the tent and the shed and until now, the prefab home has been left out in the cold. This book was prompted by a lack of published information on prefabricated housing in New Zealand (NZ). We hope to pique your interest in Kiwi Prefab, to do justice to a rich NZ history of pioneering prefabs, to showcase contemporary prefabs, and to open up opportunities for increased integration of prefab into our collective future.

Until recently when New Zealanders thought of prefabs they most often recalled drab, cheap, temporary, poorly designed school classrooms. Prefab houses tended to be thought of in a similar way; as cheap, small, relocatable, standard homes. This perception is changing. Today's prefab home is design rich, high-quality, and readily customised to individual sites and needs. It is likely to be state of the art, an innovative blend of architecture, design, manufacturing and construction. The prefab sector of the New Zealand construction industry is one of the few places where the ageless craft based, bespoke nature of our construction processes and resulting architecture are changing. They are becoming better designed, more efficient, more productive, of higher quality. A broad interest in and uptake of prefab principles and practices is slowly but surely incrementally revising the construction industry. It is being re-fabricated from the inside out. This book aims to document and contextualise a history of kiwi (NZ) prefabrication, our prefab architecture, its present state, some prefab characters and characteristics, and emerging and possible prefab futures.

From 2007 to 2009, motivated by the potentials of collaboration between architecture design, manufacturing and marketing, Pamela Bell engaged in research into NZ prefabricated housing at Victoria University of Wellington (VUW). Pamela's research resulted in a Master of Architecture thesis titled *Kiwi Prefab: Prefabricated Housing in New Zealand.*[2] Pamela's research had significant conclusions for the New Zealand design, construction and manufacturing industries and has been the impetus for several initiatives since. These have included some academic papers,[3] a number of articles on prefabrication, and a multidisciplinary Kiwi Prefab educational symposium and workshop about prefabrication and its potentials in NZ. This workshop at VUW in February 2010 attracted a wide cross section of participants from Kaitaia to Wanaka. It deliberately facilitated cross-disciplinarity – that is communication, collaborations and partnerships between design professionals, industry and manufacturing as the necessary foundation for advancing prefabrication.

The Kiwi Prefab symposium resulted in the establishment of a new pan-industry body PrefabNZ, governed by a board of nine design, construction and manufacturing industry representatives. PrefabNZ was incorporated in July 2010, a few months before the first of the Canterbury earthquakes. The organisation

appointed Pamela Bell as chief executive officer and has been actively educating, promoting and demonstrating advantages and potentials of prefab in NZ ever since. PrefabNZ has a website, an online prefabrication directory, a monthly newsletter and has facilitated a number of broad industry events including site and manufacturing plant visits. These events led up to the establishment of the HIVE Home Innovation Village in Christchurch in April 2012. Pamela's efforts are an exemplary demonstration of applied research in action. Her research findings and their application in the time since have been the seed for much of the growth in interest and awareness of prefab that has occurred in NZ over the past five years including the development of her original research and its augmentation. Additional research on New Zealand prefab was funded by VUW. Through a partnership with Puke Ariki Museum the original research was able to be expanded further and material developed for a major exhibition and book both titled *Kiwi Prefab; Cottage to Cutting Edge*.

The exhibition documents past histories, present exemplars, and emerging future potentials for prefab in NZ. Through separate research funding VUW also supported several projects that are included in the exhibition and published in this book. These projects were the First Light House, Depth of Shadow, Jigsaw House, Creature, and included the publication of this book. The changing face of NZ prefab is exemplified by the design rich, low energy, sustainable VUW First Light House,

The changing face of NZ prefab. VUW First Light House.

visited by 20,000 people during three weeks on the Wellington waterfront before disassembly and travel to the USA and back. The book draws together and records the breadth and depth of New Zealand prefabrication.

The exploration of prefabricated housing continues to be one of architecture's most purposeful and enterprising pursuits. Attempts to reconcile singular artistic creation with mass production reflect on the role of the prefabricated dwelling as a critical agent in invention; in architecture, formal and material research, and sustainability.[4]

The history of prefabricated housing in New Zealand recorded here is based on historical and current research, and interviews with many prefabrication protagonists. It is drawn together and published here for the first time.

Our intention is to document key prefab challenges and accomplishments, and some emerging prefab potentials. For example the story of IBS, (Industrialised Building Systems) is a story of a NZ project that came close to revolutionalising the house building industry in Australasia. American experts saw IBS as having the potential to change the American housing scene on the same scale as Henry Ford, who through industrialised manufacture of cars changed America's social mobility. An important historic NZ unpublished essay *Out of Time: IBS an idea too strange for home* by Roger Hay, one of the IBS founding team members, is published in this book for the first time.

Essays by international academics Barry Bergdoll, Peggy Deamer and Brenda Vale give a wider context for the discussion the book initiates.

Barry Bergdoll, the Philip Johnson Curator in Architecture at the Museum of Modern Art (MoMA)in New York reflects back on the landmark exhibition *Home Delivery; Fabricating the Modern Dwelling* he curated at MoMA in 2008. Barry reflects on the challenges and opportunities that arise from the exhibition of architecture at MoMA, and on the lessons to be learned from prefab histories.

Peggy Deamer is a principal of Deamer Architects New York and a Professor of Architecture at Yale University. Her essay gives a theoretical context for a contemporary re-evaluation of prefabrication. It rethinks the onsite/offsite opposition between traditional and prefabricated building practices and astutely posits a reversal of some long held prejudices against off site design and fabrication, expanding the notion of site.

Professor Brenda Vale of Victoria University of Wellington is an international architect, pioneer researcher, writer and expert in the field of sustainable housing. Brenda's essay contextualises the claims for sustainability of prefab housing arguing there are relatively small potential contributions towards the design of a sustainable house that prefabricated construction is able to make. Brenda highlights the sustainability context with a comparatively large difference that factors such as services autonomy, energy generation, and energy use over a building lifecycle make towards a building's ecological footprint.

Four sections of the book written by Pamela Bell are an augmentation of her original Master's research and make up the body of the text. The first section is a prefab primer; a technical commentary that sets out key prefabrication typologies and clarifies some prefab language. This is followed by a brief overview of the international context for the following documentation of a New Zealand history of prefabrication. A cross-sectional survey of contemporary New Zealand prefab companies and homes then follows. Pamela's final section draws on her most recent experience as CEO of PrefabNZ. It considers some innovative emerging New Zealand prefab homes and exemplars.

The digitally fabricated futures section of the book documents and reflects on research-led design, digitally fabricated design, design-led research and teaching occurring in NZ universities. Much of this is applied architectural research and innovation that gives a glimpse into the future and the likely affects of emerging changes on future prefabrication practices.

Stories associated with prefabricated housing are diverse and particularly relevant to New Zealanders of all ages today as we experience a new wave of digitally generated, tested and machine-cut prefab elements and homes. Puke Ariki Museum exhibition curator Gerard Beckingsale reflects on the *Kiwi Prefab: Cottage to Cutting Edge* exhibition at Puke Ariki in New Plymouth from December 2012–April 2013, and associated events. The museum's role in the exhibition development and presentation in partnership with VUW is discussed along with its exploration of the role prefabricated housing has played in New Zealand.

The final section of the book is a summary of the context for NZ prefab and revisits some lessons that really do need to be learnt. It begins with a commentary on the current status of prefabrication in the light of Leaky homes, the Canterbury rebuild and Auckland's current housing shortage. It looks at the changing contexts for prefab and predicts some exciting future directions in kiwi prefab. These are relevant to kiwi homeowners, investors, tenants, architects and designers, architectural, engineering and construction academics, students of all levels, builders and construction companies, manufacturers, materials suppliers, regulators, policy makers and even politicians who have interests in or are affected in some way by *Kiwi Prefab; Cottage to Cutting Edge*.

The book presentation deliberately adopts an accessible manner to reach the overlapping audiences that have an interest in prefabrication. Its contents and the contents of the associated exhibition are a representative cross section of the research and available material and do not intend to be a comprehensive survey.

Concept design for the exhibition at Puke Ariki Museum.

[1] Kieran, S and Timberlake, J. Introduction to *Refabricating Architecture*,New York: McGraw-Hill, 2004, pg xii.

[2] Bell, P *Kiwi Prefab.Prefabricated Housing in New Zealand; An Historical and Contemporary Overview with Recommendations for the Future*, Unpublished MArch Thesis, Victoria University of Wellington,2009.

[3] Bell, P. Lessons from the Past: A Short History of Prefabricated Housing in New Zealand, *Cultural Crossroads; Proceedings of the 26th International SAHANZ Conference*, Auckland 2–5 July 2009, pg 14.
Bell, P. Prefabrication Potential: On the edge between academia and industry, *On the Edge: Proceedings of the 44th Annual Conference of ANZAScA*, Auckland 24-26 Nov 2010, pg 18.
Bell, P. Kiwi Prefab: Reframing Attitudes towards Prefabrication in New Zealand, *5th Australian Housing researchers Conference*, Auckland 17-19 Nov 2010.

[4] Bergdoll, B,and Christensen, P. Exhibition text *Home Delivery; Fabricating the Modern Dwelling Exhibition* Museum of Modern Art, New York July 20-Oct 20, 2008.

"Home Delivery (2008)" Prefabrication and Digital Fabrication in the Rear View Mirror

BARRY BERGDOLL

EVER SINCE its founding in 1929 New York's Museum of Modern Art has conceived the difficult art of exhibiting architecture as a chance not simply to showcase important work, past and present, but also to experiment in ways that architecture on display can open new thinking about architecture's prospects for both professional and general audiences. From its opening salvo with a manifesto to realign American architectural practice around the newly defined principles of an *International Style* in 1932 to Terence Riley's celebration of a new tectonics of transparencies in *Light Construction* in 1995, stylistic change was a frequent battle cry of a museum that sought to define, as much as to reflect, the vanguard. Since my arrival at the museum in 2007 I have sought to develop new types of exhibitions in which the stakes and not simply the formal results of architectural thinking are addressed, seeking at once to puncture some of the aura that has too often distanced contemporary architectural practice from the very public it addresses and to create new interdisciplinary conversations that can effect as much the tasks that are given to designers as the stylistic ethos in which they design.[1] Most recently this experimental format has taken the form of workshop residencies inviting interdisciplinary design teams to take on some of the most pressing issues facing the world today, but ones that are too rarely addressed in design terms: climate change and sea level rise, tackled in the workshop/exhibition *Rising Currents* in 2009 and *Foreclosed: Rehousing the American Dream*, of 2012.[2]

The first such experiment was the exhibition in 2008 *Home Delivery: Fabricating the Modern Dwelling.* This was an attempt to create a different kind of exhibition merging a historical survey of materials animated by film projections, a series of full-scale building prototypes outdoors that could be visited, and a website regularly built upon through blog posts and video clips that documented the process of conceiving of contemporary prefabricated solutions in real time.

Returning to the tradition of commissioning 1:1 scale exhibition houses more associated with building fairs than with museums, the mandate of *Home Delivery* in selecting five architects to present prefabricated houses out of doors in the summer of 2008, was to recapture the dual popular and professional appeal of model buildings in the long history of experimental building exhibitions.[3] *Home Delivery: Fabricating the Modern Dwelling*, presented in the temporary exhibition galleries on the museum's sixth floor as well as in the buildings installed on an adjacent vacant city lot was in certain measure an homage to the most popular displays in MoMA's eighty years history of architectural exhibitions[4] – the Houses in the Garden of 1949–55.

At the same time, unlike that series, which turned its back on the most advanced fabricating experiments of the post-war period, this set of prefabricated exhibition houses sought to advance current research into new materials and applications of digital fabrication to create diverse housing types from vacation homes to replacement houses for populations at risk, notably in a house designed for use in post-Katrina New Orleans.

The exhibition might be said to have been born of two opportunities: one the wealth of positions in current discourses on fabrication that have rapidly redrawn the lines between architectural creativity and manufacturing innovation, the other the unique availability of a large scale vacant site in midtown Manhattan. Unlike many exhibitions that seek to exhibit only a panorama of a single tendency, it was the curatorial intent to bring together practitioners operating in divergent milieux, both that they might be brought into dialogue – at the very least in the

Home Delivery: Fabricating the Modern Dwelling, installation view of the exhibition.

exhibition – and to explore their place in a larger historical spectrum of alliances between design and production which have often characterised the most fruitful moments in the history of architectural modernism for over a century.

The announcement shortly after my arrival as Chief Curator of Architecture in Design in January 2007 that MoMA was close to concluding a deal with developer Gerald Hines to sell the vacant lot spanning the midtown block between West 53rd and West 54th Streets immediately to the west of the Museum (it is now slated for redevelopment as a mixed use skyscraper design by Jean Nouvel) made the moment more than ripe, and the exhibition became unwittingly a chance to test prefabrication's claims to accelerating the process of construction by staging processes traditionally sequential as simultaneous and separate undertakings, notably site preparation and building assembly. This gritty urban asphalt lot – quite different from the outdoor gallery setting of the sculpture garden used by Marcel Breuer and Gregory Ain in 1949–50 – would make possible the display of full-scale prototypes of recent or new prefabricated housing types, types both urban and suburban.

With the explosion of research into digital fabrication at all scales, notably at several American architectural schools which feature prominently in the commissions (MIT, Columbia, University of Pennsylvania), the moment seemed ripe both for creating opportunities to scale up that research to the prototyping of entire buildings or components of building systems, adding therefore program to the exploding research in parametric design. From a survey of nearly three hundred firms curatorial assistant Peter Christensen and I selected twenty-five to draw up proposals either to deliver an example of a current or projected house or to prototype a new one with implications beyond the specific iteration to be displayed.

A jury, which included Max Risselada from the Netherlands, Kenneth Frampton from Columbia University, and other museum curators, chose five of these firms to take the projects to execution: Kieran Timberlake of Philadelphia, Larry Sass of MIT, Oskar Leo Kaufmann of Dornbirn, Austria, Douglas Gauthier and Jeremy Edmiston of New York, and Richard Horden of London and Munich. Horden, for instance, delivered one of his Micro Compact Houses to the site from its place of fabrication in rural Austria, the others were all newly created for *Home Delivery*.

These houses, chosen for their immediate realisability, were juxtaposed with three newly commissioned experiments in digital fabrication, by Reiser + Umemoto (New York), Marble Fairbanks (New York), and Ali Rahim and Hina Jamelle of Allied Architecture Practice (Philadelphia), all of which served as spatial dividers in the exhibition space and stood as fragments of possible future architectures. These were integral parts of the interior exhibition, juxtaposed with historical fragments of prefabricated structures by Jean Prouvé and of the American Lustron House system, both of 1949, as well as numerous other designs that offered a highly selective survey of the history of modern architecture's fascination with developing a replicable house design from the horizons of industrial production.

Both the continuities and the differences between earlier prefabrication (too readily relegated to a stereotyped failed mass standardisation) were conceived of as valuable contexts for understanding both the precedents and the new stakes for factory produced architecture in a period of direct communication between a designer's software and the machinery of fabrication. Much of the greatest promise for unleashing the potential of the research into digital fabrication, beyond the sheer abundance of possibilities often explored for their own sake in architectural school settings, comes from sets of new conditions in the world of global manufacturing that have profound parallels with earlier moments of rapid change in industrial techniques with their consequent discrepancies between different parts of the globe. Larry Sass's house for New Orleans, for instance, exploits a difference in centres of technology for design and centres of handwork for assembly that can as easily be applied between Cambridge, Massachusetts and New Orleans, for instance, as between Dhaka and rural Bangladesh, Bangalore and rural India, or between Beijing and rural China.

By underscoring this the untapped potential for prefabrication, nascent or implicit in several of the projects given full-scale demonstration in the American summer of 2008 *Home Delivery* set out to deliver more than simply brilliantly conceived and styled new additions to the growing popularity of prefabrication in the niche market of neomodernism as represented in life style magazines such as *Dwell*.

To make process as much a part of the theme and the display as product we enlisted a whole range of media not as frequently associated with architectural exhibitions as drawings, blueprints, photographs and other static imagery. Historical and new film footage, digital animations, and computer simulations illustrated the process of fabrication, delivery, and assembly, so that the architecture can be understood as the result of a process not only of design but of integral making. The new commissions were documented at each stage, and that documentation, a kind of joint fabrication log, was posted in real time to the exhibition's website, (today archived at www.momahomedelivery.org,) which opened to viewers three months before the official opening of the exhibition and was updated daily, thus creating a sense of real time and process in an exhibition that follows the process – and as recalled in its title – the delivery of the houses from five different places of fabrication to a single site. Although no longer active as a site of dialogue, the site is archived and available as a permanent archive of the exhibition. The curatorial team joined the architects once a week in blogging on the premises and means of realisation of the exhibition, making the exhibition itself another experimental project, both illustrative of and parallel to the great energy of experimentation going on in architecture itself.

The exhibition closed in October 2008 in a vastly different context than it had opened a few months earlier. In the wake of the near meltdown of the global financial markets over the course of late August and September of that year and the ensuing escalation of the subprime mortgage crisis that rocked the housing markets in the United States, Ireland, Spain, and Iceland and beyond, the issue of the prefabricated home took on a whole new set of valences. While several of the buildings found new homes, none found the immediate resonance of say Marcel Breuer's 1949 House in the Garden built just as the post-war residential building boom was escalating.

Still the research launched continues, easy to track in the case of say Kieran Timberlake whose research continued to push parametric logics as an integrated form of building research, rather than mere formal research, an important counterpart to the more frequent search of formal experiment for the simple pleasure of pushing algorithms to new heights in so much so-called parameticism.[5] Only the beginnings of a cross fertilisation of concerns and terminology has begun to take place, and the latent possibilities remain enormous.

The most potent research prospects it seems lie less in pushing the issue of mass customisation, CNC cutting, and the like that were the obsession of the first euphoria of the digital revolution, than in getting over humps that have historically plagued prefabrication: the integration of secondary systems of plumbing, heating, and the like and the search for the simplest number of parts that don't turn each new system into a technology that can be assembled only by specialists like certain high end sports cars. The integration in particular of smart materials has a potential only suggested in the houses on display – for instance the smart wrap of Kieran Timberlake's lateral facades – and the integration of even the lessons of the Passive House movement which has thus far been largely associated with painstaking stick built architecture into prefabricated components would be promising. In the United States the tremendous variation between building codes in different cities and towns as well as the resistance to finance experimental factory-produced architectures remains an obstacle, while in Japan where the assembly of houses is nearly as advanced as that of cars the issue remains primarily a conservatism in the marketplace of anything produced in quantity.

To a certain extent the down scaled economy which brings with it a scaling back of people's expectations about the size of housing and the fad for customisation for customisation sake, as well as rehousing needed in the wake of such disasters as the Japanese tsunami or the Christchurch earthquakes make the issue of prefabricated housing, and the quick and inexpensive delivery of shelter all the more urgent and suggest that there might be greater openness to well conceived prefabricated dwellings beyond the niche market of a magazine such as *Dwell* or of the house by Kengo Kuma offered for sale, until recently, by Japan's Muji Store.

Many have said that the history of prefabrication, even in the age of digital production and mass customisation, is always a history of the next best thing, yet it is too wasteful to discard the lessons of over a century of experimentation in attempting to reap the benefits – ecological, economic, and in terms of better working conditions for building workers – in the ongoing exploration of prefabricated buildings and components.

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[1] This article is based upon, and updates, an earlier account, Barry Bergdoll, "Plein-Air Prefab," in *The Skira Yearbook of World Architecture Y08*, 2007-2008. Milan: Skira, 2008, pp. 88-89.

[2] See Barry Bergdoll, "The Art of Advocacy: The Museum as Design Laboratory," *Places 09/16/11 http://places.designobserver.com/feature/the-art-of-advocacy-moma-as-design-laboratory/29638/* See also Barry Bergdoll, *Rising Currents; Projects for New York's Waterfront*. New York: The Museum of Modern Art, 2010 and Barry Bergdoll and Reinhold Martin, *Foreclosed: Rehousing the American Dream*. New York: The Museum of Modern Art and the Buell Center for the Study of American Architecture, 2012.

[3] Beatriz Colomina, "The Exhibitionary House," in *At the End of the Century: One Hundred Years of Architecture*, ed. Russell Ferguson, Los Angeles, Museum of Contemporary Art, 1998.

[4] See Barry Bergdoll, "The Museum of Modern Art: 75 Years of Architecture at the Museum of Modern Art," in *A+U 451* April 2008, 66-78.

[5] *See Stephen Kieran and James Timberlake, Cellophane House* ™. Philadelphia: Kieran Timberlake, 2011. Contrast with Patrick Schumacher, Parametricism – A New Global Style for Architecture and Urban Design, in: *AD Architectural Design – Digital Cities*, Vol 79, No 4 July / August 2009, guest editor: Neil Leach, general editor: Helen Castle.

Offsite/Onsite

PEGGY DEAMER

IN THE onsite/offsite dichotomy, architects have certain preconceptions regarding what constitutes the site sensitive built object; buildings built on and for a specific site are good; buildings built away from and indifferent to the site are bad. Critical Regionalism plays a large role in instantiating this preconception. It criticises the local neutering of the international style and promotes the value of the 'near-by': materials should be found, natural substances; the workmen should be steeped in the local craft of building; the architecture should engage the land in a bodily, tactile manner. Critical Regionalism takes as its ideal the Heideggerian models of place-making: the clearing in the forest (a subtractive activity) and the Greek temple of rearranged stones found in situ (an additive process). But for all that is profitable in a promotion of the 'local' and the insights of Critical Regionalism, conceptual doors are shut to materials, techniques, and spatial deployments that are not threats to site sensitivity but expand our notion of 'site' beyond the merely physical.

To help set the framework for rethinking the value of the 'off-site' for the 'on-site', it is helpful to re-examine many of the same19th Century theorists evoked by Critical Regionalism for their interest in craft. Struggling to make sense of the implications of industrialisation for craft, a number of these thinkers, while arguing for craft, did not equate sensitive making with localised production. Gottfried Semper, in *Der Stil* (1863), proposes that architecture finds its motivation in the technical, not spatial arts. His four procedures – textiles, ceramics, tectonics (carpentry), and stereotomy (masonry), and his four materials that these procedures are identified with, pliable (fabric), soft (clay), elastic (wood) and dense (stone) – describe a condition in which labour was simultaneous, nonsequential, and dispersed. Indeed, in his suggestion that enclosure (textiles) precedes structure, the disengagement of the textile making from its eventual place-to-be-hung emphasises process over space/place.

Likewise, in the hands of Otto Wagner, a disciple of Semper, this dispersal of work became a dispersal over time as well. He realised, with the introduction of steel and the consequential necessity of cladding, that the discrepancy between work which was heavy and took a long time and work which was light and could be mounted quickly, would polarise the different trades and fracture what had previously been a single construction industry. Each trade would be working at its own speed, and until the end, in its own locations. While he neither promoted nor lamented this procedural realignment, he was primarily responsive to the type of work that the new builder/makers were faced with and wanted to capitalise on the new formal rigour offered by the changes in building production.

Adolf Loos, also establishing the importance of accepting the reality of builder/maker's craft in producing quality architecture, suggesting that the true threat to quality work was the domination of the builder/maker by the architect/designer. Liberated from the dictatorship of the architect (and the unnecessary traditions of the past) the craftsman would naturally make things 'in the modern spirit.' If this sounds like a reinforcement of a traditional notion of craftsmen who know how to build better in their own cultural context than the overly abstract architect, it is not. Loos argues against Josef Hoffman – and implicitly, before him, John Ruskin and William Morris – who promoted the reintroduction of local individuality to insure the 'joy of labour.' Hoffman's contention was that this joy depended on working with ones hands and, more importantly, also guaranteed unique and unrepeatable objects. Loos, in opposition to this, claimed that craftsmanship is essentially impersonal; that any evocation of a craft tradition would acknowledge its repetitive, system-like essence. Regarding the carpenter, he writes *straight lines, right-angled corners: this is how the craftsman works who has nothing in front of him but his materials, his tools and his predetermined objective.*[1] The 'natural' approach to work was not what nature yielded up but, rather, the appropriate deployment of available technique with the given material.

These authors are probably not needed to justify the value of the off-site for the on-site; we are embedded in the midst of industrial standardisation of products – the shape of I-beams, the lengths of 100x50s; the standard 1200x2400 sheets of plywood or gypsym plasterboard – that make contemporary building processes possible. But they do remind us that the fear we have of prefabrication – that the process precludes sensitivity to indigenous culture – should have been digested and discarded over a hundred years ago. Industrial production and cultural authenticity can go hand in hand. Today, those production processes, of which prefabrication is a small but visible and significant part, offer opportunities for the 'on-site' on a number of fronts.

First, a vast array of materials are on offer for their performative qualities. I think about this as a backpacker with a tent trying to camp responsibly in the wilderness; we are not piling up stones or cutting down the trees found at the campsite, but sitting on the land as lightly as possible and exploiting the advantages of synthetic materials. New materials open up affordable and/or formally dexterous alternatives to the standard wood, glass, steel, or concrete and in doing so, respond to the site in various ways. Polymers and polyurethane resins, fibre-based composite materials, rubber and foam all open new interior and exterior possibilities. Glass itself extends its viability through different sandwiching techniques that filter light, scatter sun rays, disperse heat or function structurally. Fibre-optics and dichroic glasses, light emitting diodes (LEDs) and liquid crystal displays (LCDs), offer enclosures of varying opacity, colours and intensity. Polarising, fresnel lens, photochronic and electroluminescent films (among others) change the behaviour of glass, making it more environmentally responsive.

Fisher Island House by Thomas Phifer and Partners. A light modular steel and glass pavilion with major components built off site.

Fisher Island House, by Thomas Phifer and Partners New York. Side view.

Wood composites, be they of sawdust, laminates or veneers, not only offer the advantages of recycling, but combine with glass and fibres to yield luminous effects and occupational changes. Each of these participate in a growing industry of smart materials that, as Michelle Addington writes in her *Smart Materials and Technologies*, respond in real time to local, activating events and register more than one environmental state.[2]

Second, as one moves to the factory or, beyond that, to CAD/CAM production, craft is heightened in two ways, both having to do with the fact that material choices move to the front end of the design process; the properties of materials formed by and entering into the machines need to be understood from the outset. CAD/CAM, on the one hand, simulates the outcome in a virtual model, making experimentation vastly more predictable and economically viable. On the other hand, CAD/CAM brings this material exploration into the hands of small, independent firms which connect with and utilise fabricator expertise to produce sophisticated and complex building elements. It is DIY at a most sophisticated level.

Third, the entire organisational process is being revamped to be more responsive to the various talents needed to produce a building. If prefabrication has directed our attention to a process that allows a better work environment (in the heated factory, on the floor, not hanging from rafters in the open air) and less waste (calibrating, for example, the most compact ways to cut desired pieces from a standard sheet and then collecting/recycling the waste), it is only the tip of the iceberg for recrafting the design/build process. Building information modelling (BIM), in constructing a virtual model that all players collaborate in producing, encourages the fabricators, normally (again) at the back end of the process, to contribute to the design from the earliest stages. They and the general contractor, the structural engineer and the mechanical engineer are all 'authors' of both the model and the building. Likewise, integrated project delivery (IPD) goes farther than the work reorganisation leveraged by prefabrication and allows all disciplines in a construction project to operate as a single entity sharing the goal of lower cost, faster delivery time, and mutual interest in quality. The single purpose entity (SPE), which precludes lawsuits and shares profits, responds to the main tenant of the 19th Century authors discussed above: the happier and more appreciated the players, the better the work.

Fourth, with regard to site, the physical and conceptual rethinking brought by 'off-ness' is profound and varied. Physically, this means letting the building act as a datum against which the site is read. The building doesn't disrupt the site, it reinterprets it. It also means that an environmentally responsive building – one using off-site technology and smart materials – will remind us that the site is not just the immediate one of property and view range, but the larger regional ecosphere that shapes and is shaped by weather, wind, sun, water and soil ecologies.

And finally, at a more conceptual level, we can think of the site not merely as a physical but as a social construct. If the above descriptions have emphasised the importance of the work context in crafting the architectural object, the network that brings together all of the designer/makers/constructors is a new 'site' of social relations. To think this way means leaving behind the idea that we architects are responsible (only) to the owner/occupier in delivering a building; rather, it means seeing our responsibility to the entire team who help make the building be its best and share in the preservation of the site and the larger environment. Ed Ford, in his *Details of Modern Architecture,*[3] has pointed out that 20th Century architecture, if socially motivated at all, is concerned with structuring/enhancing the life of the client (how can the architecture produce/support the 'new man'?) leaving behind the 19th Century concern for the maker (how will industrial production yield satisfied builders?). It seems today, in the 21st Century, we have the means 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. We are, after all, all citizens of the wide world.

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[1] Adolf Loos, "Hands Off," in *Samtliche Schriften*, 1917, 342–47, quoted in Benedetto Gravaguolo, *Adolf Loos*, New York: Rizzoli, 1982, 61.

[2] See for example, *Mutant Materials in Contemporary Design*, Paula Antonelli, The Museum of Modern Art, New York, 1995 and *Smart Materials and Technologies* by Michelle Addington and Daniel Schdek, Architectural Press/Elsevier, Oxford, England, 2005.

[3] Edward R. Ford, introduction to *Details of Modern Architecture*, Cambridge, MA: MIT Press, 2003.

Prefabs and Sustainability

BRENDA VALE

RGR BEATSON, better known in New Zealand as the editor of *Home and Building*, submitted his thesis on the prefabricated house for NZ[1] (and went on to build a partially prefabricated house in Takapuna[2] and a prefabricated bach on Lake Rotoma.[3]) The first page of this forgotten document describes housing in the 1860s, housing that has many of the attributes of sustainability: it was small and made of wood (which grows on trees); heating was localised to where it was needed and came from burning wood (including hot ashes in warming pans for the beds); water was rain stored in a tank; lighting was daylight or homemade candles (using tallow); and the lavatory was an outhouse a distance away where 'nature' did the recycling of human waste to nutrients. Housing was thus sustainable because it only used renewable resources and sought to return any wastes, such as sewage, back into natural cycles. Beatson goes on to describe a modern house (in 1939) and the technology it draws on to maintain this improved standard of living, such as electric light, heated water and the telephone. For Beatson prefabrication was a way of keeping the cost of this improved housing within the means of the average New Zealander. However, his descriptions also make the point that housing in New Zealand has moved from a sustainable position to one in which many more nonrenewable resources are now required to supply the same human needs in a family dwelling. This article is concerned with how prefabrication can (or cannot) contribute towards making modern housing more sustainable.

One of the most famous in a long line of prefabricated house prototypes is Dymaxion 1 designed in 1927 by Buckminster Fuller and exhibited as a model in 1929. This house addressed housing sustainability issues in a number of ways, some potentially more important than others. Buckminster Fuller designed the house to be autonomous so that it was independent of mains services. Bruce and Sandbank maintain that this was one of the designs around that time that brought prefabricated houses to the fore, especially at a time when conventional construction was booming.[4] The house was 'autonomous' by having a septic tank and diesel fuel tank at the bottom of a central mast from which the lightweight floor and roof structures were hung.[5] The roof was covered by a further lightweight structure to form a covered roof terrace. Water was collected off this and channelled down the mast to be stored in a further tank. The walls of the house were made of 'insulating' transparent casein plastic, insulation being in the form of a vacuum created between two skins. The house was sealed and Fuller saw this as being a means for the same design to be used anywhere in the world. The house was also to be rented not owned and because of the single masted design could be set down anywhere (by Zeppelin).[6]

Autonomy has been associated with sustainability because a house designed to be independent of mains services would have to collect resources from its own site. However, these were seen as the renewable resources of rain, sun and wind 'falling' on the plot. Wastes would also be processed on site.[7] For a big enough site, a septic tank would qualify for this, especially if the sediment was composted on site. However, Fuller's diesel generator would not be viewed as autonomous in sustainability terms because it depended on a fossil fuel. Alongside this, the fact Dymaxion 1 was designed to be independent of climate goes against housing sustainability principles where the aim is first to reduce the need for resources and then supply the minimal remaining resources from renewable resources alone. This suggests design must be in accordance with local climate conditions, something that might work against the more universal approach of prefabricated design. Resources might have been saved by making a very lightweight house, for example Fuller estimated Dymaxion 1 at 3 tons against 150 tons for a brick house.[8] However, the materials Fuller used, duralumin and steel, are materials that have a much higher environmental impact than some other heavy materials, like rammed earth,[9] so weight alone is not necessarily a signal of being sustainable. Fuller does not discuss waste in relation to Dymaxion 1 only likening its production to the automobile industry.[10] This is curious as McKinsey and Company's research suggests the North American automobile industry wastes US$10-12 billion a year through poor planning and co-ordination, a figure they estimate could be reduced by $8 billion.[11] For 2005, the year of their article, 16.3 million cars and trucks were produced,[12] meaning there is waste of $736/car. If the average vehicle costs $28,000[13] this is 2.6% of cost as waste. Comparing this to a timber frame house, in Connecticut the Department of Energy and Environmental Protection state that 3.0–5.2lbs/ft^2 (0.126–0.219 kg/m^2) of waste are produced when a house is constructed.[14] If a typical single storey USA timber frame house with its foundations weighs 200lbs/ft^2 (8.43 kg/m^2),[15] then the construction waste is 1.5–2.5% of total, marginally better than the car industry. Obviously these figures are very rough but they do show, as common sense suggests, that the existing nonprefabricated house building industry knows how to build houses. What should be questioned is not the rate of waste production but the size and numbers of new houses, which will push up the total waste going to landfill. This is a social rather than a design problem.

A prefabricated cottage at Lake Rotoma by R G R Beatson. The cottage was prefabricated in sections at Takapuna, transported to site and erected in 14 hours.

To see the contribution of prefabrication to the sustainable house, and particularly to the sustainable house in New Zealand, it is necessary to consider what the elements in a house are that have the highest impact over its life. The first thing to emerge is that in terms of overall environmental impact, operating energy over the 50 year life of a house is a very much larger component than the materials that go into making and maintaining it.[16] This means that the prefabricated sustainable house must be designed to minimise the energy required to heat it and run its lights and appliances, with the preference being for making a zero energy house. This is where the problems start. Prefabrication tends to be associated with use of materials that are easy to transport and so are light in weight, rather than with the creation of the insulated mass passive solar building more usually associated with zero energy house design.[17] As long ago as 1846 J.C. Loudon recognised that a conventional English cottage with 230mm brick walls and a tile roof would be too hot in summer and too cold in winter without expenditure on scarce and expensive fuels, recommending walls of 610mm of earth and a 305mm roof of thatch or heather as a design which would be comfortable in winter "almost without fire."[18] The earth sheltered zero energy houses for the Hockerton Housing project in the UK consisted of 300mm of concrete with 300mm of insulation on its outside face, then waterproofing membrane and earth. Mass and insulation are thus the key to achieving comfortable indoor temperatures and no operational energy use. Although prefabricated Structural Insulated Panels (SIPs) are well insulated some mass is required, perhaps in a floor slab, for their use to come close to achieving the zero energy building.[19] The heavier the prefabricated building to achieve the goal of zero energy, the more difficult it will be to transport. This is borne out by the history of prefabrication where the complete Hobart all steel welded prefabricated two storey house was only produced in small numbers[20] and could only be delivered via wide streets.[21] Transport has also been an issue in one of New Zealand's prefabrication successes, the Railway workers' houses. These were produced in a factory in Frankton and shipped to settlements along the main trunk line in the North Island. In the 10 years the scheme operated over 1300 houses were produced, along with other buildings for the railways, such as huts.[22] The approach here was mass production of a small number of fixed designs. What is more significant is that despite having a saw mill at Frankton and a means of transporting the houses immediately to hand, it was still not economic for NZ Railways to ship their factory produced houses to the South Island, where the price of timber was lower. Railway workers' houses in the South Island were made locally to the standard plans.[23]

As mentioned above, the sustainable house is normally viewed as one that works with the local site resources (and skills) and climate rather than a universal solution. Prefabrication could achieve this by customising each house for factory production using CAD/CAM technology but this is not a cheap road and tends to serve the higher end of the market. The 180m^2 Kieran Timberlake Cellophane House with its two bedrooms[24] is typical of such architecture, as most people building that much floor area would expect to have a family house with probably four bedrooms. However, the Cellophane House is designed to be demountable and to grow and change as its family grows. This has two potential implications; either housing is temporary which runs counter to the human need to build and maintain communities, or there has to be a system whereby the house plot is large enough to cope with the changes, and there is somewhere to store unused house parts, both conditions that will require the use of more land, not less, for a human population that is already living beyond its biological income means. The simple sustainable solution is to build small houses that last a long time on sufficient land to promote low environmental impact living. The design of these houses will minimise the need to use fossil fuels and will probably also allow for some onsite water collection and treatment, and some on site food growing, what is finally done being dependent on the local site conditions and climate. This is something that can be achieved without prefabrication.

In fact prefabrication has little to do with making a house zero energy, autonomous or sustainable. Looking at prefabricated sustainable houses, such as those that appeared in the 2011 US Department of Energy Solar Decathlon in Washington[25] it is not the prefabrication that is significant for their sustainability. It is their use of design to make the most of the microclimate for heating and cooling, followed by their use of prefabricated energy generating equipment, like photovoltaic panels and solar water heaters, combined with their use of very efficient appliances. It is these elements that are vital to the sustainable house, however it is first constructed. However, equally important is how the occupants live within their sustainable house, in terms of choosing to live a life that has a low impact on the environment (through daily use of public transport, buying organic food, not flying to holiday destinations etc).[26] Together this suggests that the sustainable house is something much more complicated than prefabricating its parts.

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Out Of Time: IBS, an idea too strange for home (1983)

ROGER HAY

THE STORY of IBS, Industrialised Building Systems, is the story of a New Zealand project which very nearly revolutionised the house building industry in Australasia. American experts saw it as having the potential to change the American housing scene on much the same scale as Henry Ford had changed America's social mobility. It was born in 1968, through the extraordinary vision of a Palmerston North land developer, Keith Clark, and died in 1978, when, having spent $2.5 million on the project, his financial resources collapsed.

Designscape issue 50 1975. IBS and sunburst. A new era in housing dawns.

Prefabrication of houses is not a new idea: the Pilgrim Fathers took prefabs to the New World, and settlers brought them to New Zealand. Mass production of building components on an assembly line is not a new idea either: Joseph Paxton's 1851 Crystal Palace was assembled out of cast-iron mouldings. But 'industrialisation' of the building process was something more than either of those techniques: the common dream was use of in-factory assembly line techniques to produce a kitset of major components which could be fitted together on site by relatively unskilled labour, to get around the growing shortage of skilled tradesmen, and avoid delays caused by weather and slow delivery of materials. Most of this century's pioneering architects had dabbled with the concept, at one stage or another, while the patent offices of the world are stacked with the stillborn ideas of backroom geniuses. By the 1950s, British architects had produced some efficient and intelligent systems for building schools and high rise housing blocks, and the Russians were making entire apartment units in precast concrete, craned into position. But the ultimate dream of the completely factory finished house, ready to use on delivery (like a car, or a refrigerator) seemed, to architects and the building industry generally, an impracticable idea.

It was Keith Clark, frustrated by the difficulty of transporting pre-built houses over narrow roads to the new town of Turangi, who saw that the answer was being provided by a new American industry that had no connexion with the accepted concept of 'building'. This was the outgrowth of the holiday caravan, called the 'mobile home'. Mobile home production in the USA had grown from 63,000 units in 1950, through 163,000 in 1960 to over 400,000 in 1970. These ticky-tacky boxes, built from stapled-on plywood interior linings, and aluminium sheathing, on a flexible steel chassis (with a set of tyres that lasted a thousand miles, or one year) were less than a third of the cost of conventional housing, and were meeting an immense demand. By 1973 they accounted for 48% of all new housing starts in the USA; 69% of all houses under US$30,000; and 91% of all houses under US$20,000. About 800 factories each produce one model (the models changed annually) at a rate ranging from two homes a day to twenty nine, selling them to dealers' yards who then sold and delivered them to the customers, on hire purchase; 95% of them were sold fully furnished, down to the cutlery in the kitchen drawers, pictures on the walls, and plastic flowers in vases. Delivered to a rented plot in a 'mobile home park' and connected to water, power and drains, they were instantly usable. And, not least, this was the best performing industry on the stock exchange, and totally debt free.

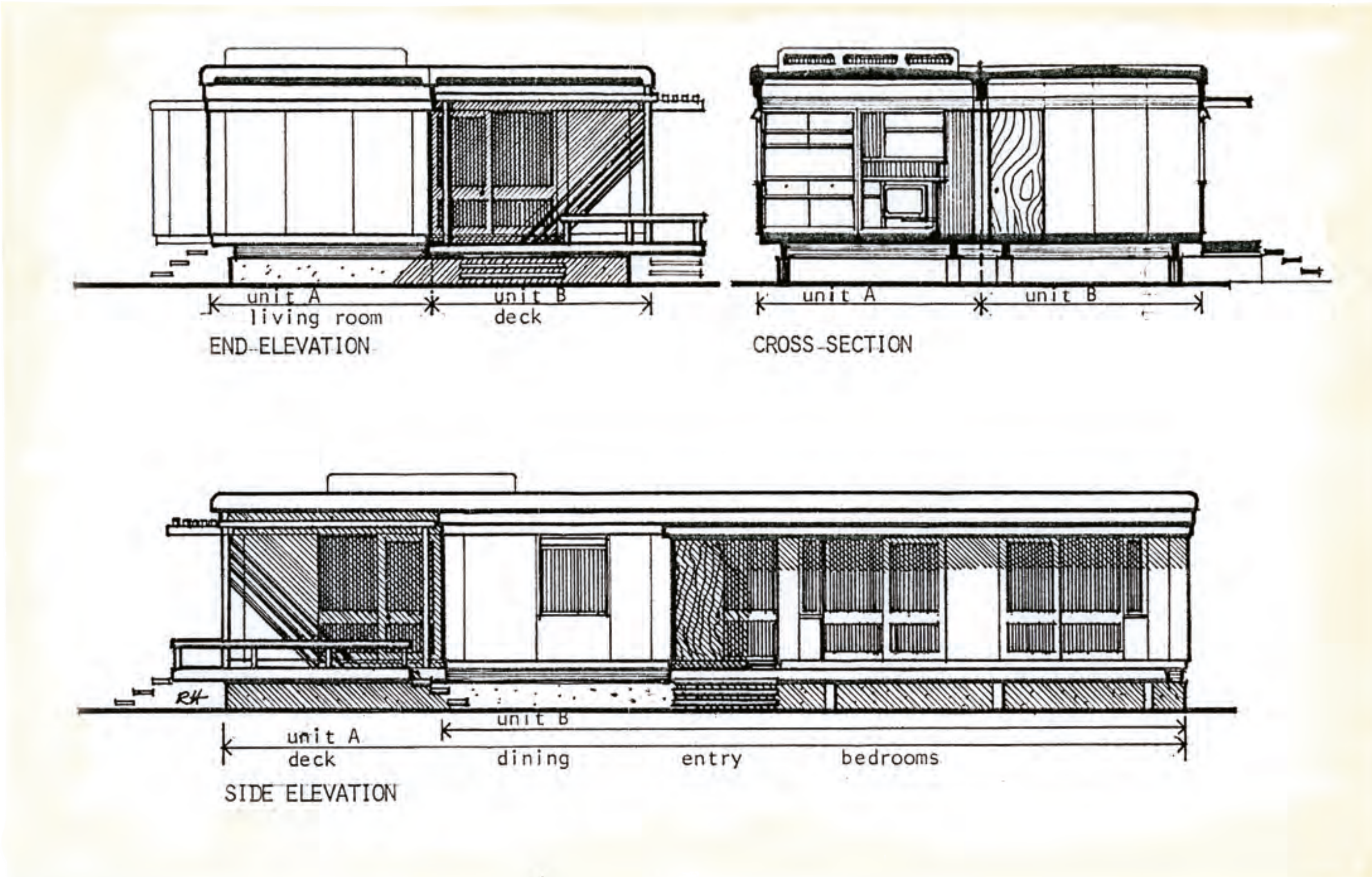
But they had a reputation for producing instant slums, and had their own peculiar aesthetic which set them apart from conventional housing. Nor did they comply with normal construction standards: it was alleged they 'self destructed' in ten years. So Keith Clark asked Auckland architect Ivan Juriss whether it was possible to take the best of the idea, and redesign it in a form which would be acceptable in New Zealand. After a tour of the USA industry, they came back to New Zealand, set up a small research and development team (architects, planners, draughtsmen, a production manager who was a magician with wood and glue, plus a circle including consulting engineers, cost analysts and industrial designers) and set to work.

Ivan Juriss as the last member of Group Architects, enterprising pioneers of rationalised house construction, and a craftsman in timber, when confronted by the scale of the American dream, was initially reluctant to take up the challenge of designing a 'better' version of the mobile home, for New Zealand. Keith Clark's enduring aim was a system which could produce the equivalent of 1000 full size houses a year, selling at no more than 75% of the cost of conventionally constructed houses.

Double-wide American mobile home.

Model of IBS 'managed estate' with trees.

The IBS project arose from the example of that peculiarly American phenomenon, the mobile home. Basically an overgrown caravan, too big to be towed by the family car, it is produced in vast quantities, at about a third of the cost of conventional housing, and sold through dealers' yards. Up to 18m long and 4.2m wide, of fairly flimsy structure on a steel chassis, its tunnel-like space can be extended sideways with clip on extras in the same idiosyncratic aesthetic. As their popularity grew, 'double-wides' dominated the classier end of their market, providing a home of much the same size as a conventional house, with an appropriately refined image. The brick skirt is not a peel-off: most mobile homes, once delivered to their site, never move again.



Ivan Juriss line drawing: elevations of first IBS housing model.

Having started as nothing more than affordable accommodation for low income, semi-itinerant workers, about half the mobile home parks in America fall into the 'instant slum' category. But the other half conform to design and management standards laid down by the Mobile Home Manufacturers Association, with some rising to standards of glamour and exclusiveness that make them sought after by well-to-do retiring couples, keen on the lavish communal facilities provided.

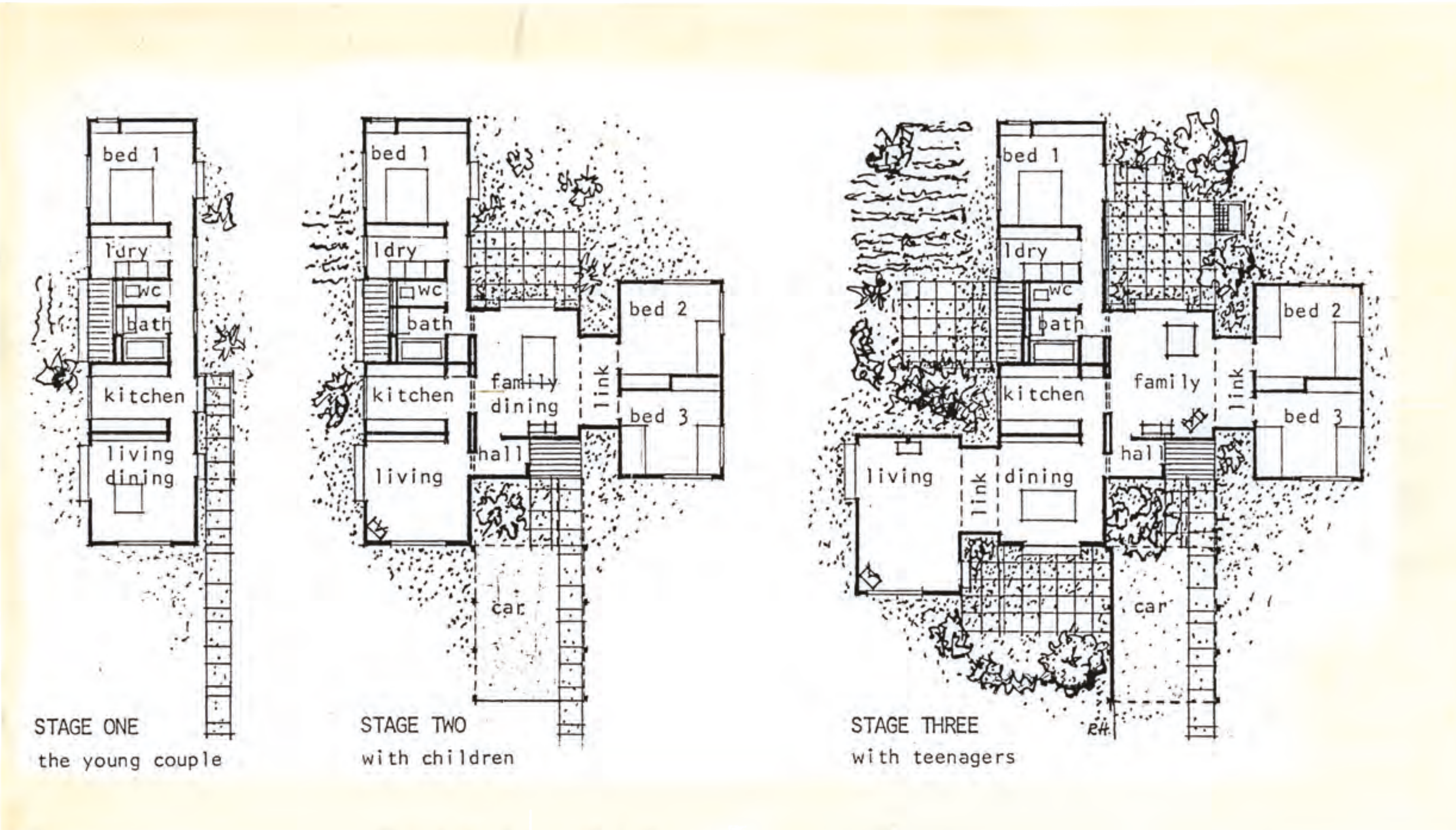
The IBS development of this idea, in the form of a 'managed estate', was one of the most significant losses of the IBS collapse.

By arranging houses for individual privacy and sun, on communally owned land, rather than by reference to boundaries rules by surveyors, it is possible to achieve a far more compact use of land, at less cost without reduction in amenity.

The first Juriss image for IBS: a highly sophisticated 'double-wide' with a moulded fibreglass/foam plastic sandwich forming both roof and ceiling. Modular wall panels were of more common sheet materials, but also sandwiched around foam plastic. The central spine was a double wall, one half for each of the two adjoining units.

Although technologically impracticable, in terms of New Zealand industry at least, most of the aesthetic discipline (except the roof line) carried through to the second stage development: notably the continuous line of window and door heads; the curved exterior corners; and the inset foundation.

It was in the planning that Juriss made the



most significant breakthrough. Realising that, if a 'single-wide' could be extended to a 'double-wide' it followed that further lateral extensions were possible, he produced the basic concept of the 'house that grows'.

Stage 1 is the basic house for a young couple, at minimum cost – just like a mobile home. Later, with a growing family, and some capital gain, stage 2 can be added. And then, later still, stage 3, with more living space to provide escape from noisy teenagers.

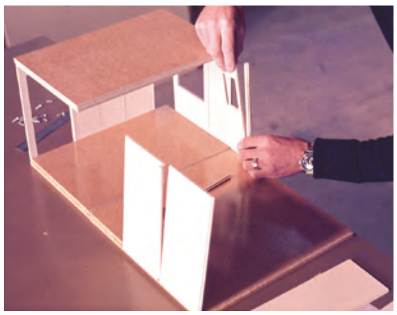
The unique design innovation that enabled this lateral expansion is the small 'link unit' with its ceiling at door-head height: an architectural device that not only solved the problem of how to join the roof surfaces, but also made a very pleasant articulation of interior space. A whole book of plan variations, based on the initial single-wide unit was produced.

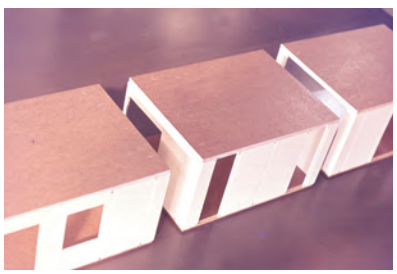
The first technical hurdle was overcome by developing a wall panel jointing system, and a rationalised range of panel sizes, which enabled the elimination of the double wall between adjoining units, and a host of other problems. It also enabled the mass production of a kitset of wall components. The next was the development of a surprisingly strong lightweight 'slab', 3.6m wide and up to 7.2m long, which formed both the floor and the ceiling. The entire system was made of timber-based sheet materials, glue-bonded together: lightweight, extraordinarily rigid, and versatile.

But the major breakthrough was when it suddenly became apparent that the new system

Line drawing: Three plans of IBS extendable house.


Row of panel components.


Assembly of a model, using panels.


Row of room modules, in model form.


IBS 'Block Game'.


Test rig.

allowed production of a range of 'room modules' on an assembly line basis. IBS was now ten years ahead of American mobile home technology, and the international prospects were exciting.

The IBS 'block game' was the customer eye view, IBS's most significant gift to the building industry's market. Each plastic block represented a 'module' containing one or more rooms, with one key module containing the 'service core' of bathroom, laundry and kitchen. In the patented form (never made), the blocks would have been made with interlocking keys which automatically gave the rules for combinations. Within those rules, any customer could design his own house (or other type of building) and the stages of its growth, knowing the cost of each part. Also, within each module, wall panels could be interchanged for windows or doors, not just at the initial design stage, but at any stage in the life of the building, opening up a future of flexible response to changes of lifestyle or user needs. It was a silver-plated answer to the cries of sociologists who had been demanding consumer involvement with the design of mass housing. But it went even further: because modules could be taken away as readily as they could be added, it became possible to shrink a house as children left; the perfect answer for housing authorities embarrassed by elderly couples rattling around in overlarge units. It was even realised, half jokingly, that a divorcing couple could – quite literally – divide their house between them. It looked as though IBS was providing the seeds for major social changes.

At the peak of its endeavour, the IBS research and development programme was founded on an intensive programme of appraisal and testing of both materials and components, and of costs and ideas, which has probably never been paralleled in the construction industry in this part of the world.

Initially, until the designers learnt, from hard experience, to distinguish between the limitless scope of theoretical problems, and the finite facts of real problems (such as those imposed by the poverty of New Zealand's industrial resources, in both technology and entrepreneurial verve), IBS made some expensive mistakes.

One example was the cost and time spent on developing an elaborate 'environmental test chamber' – a crank beast that caused enormous trouble, and was never used because the problem it was designed to evaluate could be eliminated by intelligent design. On the other hand, after spending time on simplistic tests of some of the 'magic' materials they had hoped to use, the designers found that there was one equally simple test that proved most of them to be totally unsound. But the same test revealed potentials of other materials that are still unrecognised by their unimaginative manufacturers, a decade later. As the choice of materials and design of components narrowed down to the few that were readily available, the testing methodology and research scope became decidedly more pragmatic and simpler.

The essential thing was to show that it all really worked: so the IBS team rolled up its sleeves and set about making the bits and pieces for three prototype buildings. Wall panels were manufactured by subcontracting firms, but the big roof and floor panels were assembled, glued and pressed on a clumsy looking but highly efficient home-grown press which occupied one whole end of the IBS workshop. In next to no time, the whole space was filled with room modules in various states of completion, with everybody hammering and drilling and painting. By the time we had rolled and lifted the completed sections onto trucks, the team had a feeling of pride and assurance.

Prototype house emerging from factory.

Aerial view of house on site.

The acid test of the whole idea was to show that the buildings could actually be put together on the site in a quick and simple manner. After all, the system was by now far more elaborate than just another 'mobile home' equipped with 'one-way' tyres. Perhaps mistakenly, IBS had opted to use ordinary flatbed trucks, and cranes; whereas the nearest parallel in the American industry had developed special low trailers, and sliding systems for pushing their 'sectional' houses onto their foundations.

Transporting and effecting the first few modules was a distinctly untidy business, but by the time it came to pulling the last of the three prototype buildings out of the factory, the IBS team was confident enough to make use of the crazy, tricycle-based, extendable width trailer that it had built in the early days, when it did not really know what it was doing. By the time the prototypes were erected, IBS was able to show off its expertise by repeatedly demonstrating (for the benefit of

Kitchen.

Bathroom.

television, and overseas dignitaries) how the 'motel' unit could be craned up off its foundations, plonked on a truck, driven down the road, and then returned to its site – with all furnishings intact – all in a matter of an hour or two. But that was only a single module: the real problem was showing that a full size house could be handled as easily. In spite of a series of nail-biting crises, (intrinsic to innovative development), it worked. It was photographed from on high, as only the sky seemed to be the limit.

Finally completed, the interior spaces were remarkably pleasant, with most of the credit due to Ivan Juriss's skill as a designer. None of the stream of visitors and potential customers seemed in the least concerned by the discreet lines of the wall-panel joints, the lack of wallpaper. The view into the living room, from the dining room, in the large prototype house, with the dropped ceiling of the link unit between, adding a grace note previously unknown in the dour images of industrialised building.

The model kitchen, by industrial designer Bruce Woods, was an exemplary exercise in the flexibility possible through intelligent use of modular fittings, combined with ergonomic good sense. All the underbench units were interchangeable, so that, for instance, the oven could be located on the right or the left, or a cupboard exchanged for a dishwasher. This sort of repositioning was made simple by a horizontal duct (visible as the white band above the bench tops) which not only contained all the electrical wiring, but also the complete array of switches and power points, in a form which made alterations and additions a simple task.

The laundry also excited admiration, because Bruce Woods had set out to solve the problem of the most neglected area in New Zealand housing. He not only provided drip-drying racks, and a rack of handy moveable 'tubs' (under the bench) for such things as sorting washing and soaking nappies, but also the splendid device of a lipped bench, with its own drain, on which to dump wet clothes, or clean football boots, or shell oysters, or cope with similar messy activities for which the normal house provides no facilities.

The bathroom, elicited the most lavish praise. But in fact, its gleaming mock plastic surfaces, with innovative designs for both bath and hand basin, was an expensive folly, concealing a host of unresolved difficulties in both the planning and the plumbing. That, and its accompanying toilet, which together represented the core of the vital aim of cutting costs through industrialisation, proved to be the most intractable problems that IBS attempted to tackle. In retrospect, Juriss's first idea, indicated in the line drawings of the extendable house, might have been more fruitfully developed.

But in the end, there was one major problem. It did not seem to concern anybody who strolled around the 'single-wide' holiday house, perhaps because its single-pitch shed roof was balanced by a typically generous Juriss verandah, complete with a low cost version of his favourite Japanese style balustrade. Nor was it readily visible when the larger house was viewed from under the pergolas around the living area, through the luxuriant foliage of Michael Burton's splendid landscaping. Where it showed was when the roof line was most visible. Although the real estate salesmen were enthusiastic, and the hordes of potential customers who traipsed through, eager to buy, never said a word about it, the grey suited financiers objected to the roofline. It did not look like a 'real' house: and they stolidly maintained that only if IBS could prove at least 25% less cost than conventional housing would it be a commercial proposition – unless the roof was changed. But the low-pitched roof was an essential feature of the system: without it, the modules would be too high to transport along the roads: and the cost analysis could only show 12% less cost, at that stage of development.

This is where IBS finally began to collapse. Frustrated by the lack of enthusiasm of Australasian financiers, the hollowness of political promises and a suddenly declining housing market in New Zealand, the IBS team turned to America. After all, an executive of the Mobile Home Manufacturers' Association, excited by the system, and its potential in the American market, had advised: 'If they don't like the appearance, just put in another $200 worth of furniture.' And there was a huge gap in the American market, centred on the middle income group who could afford to buy something only a bit more expensive than a mobile home, (which they refused to live in) but could not afford to buy a conventional house, at three times the cost.

Ivan Juriss outside IBS show home in 1972.

IBS had a chance. But the IBS market research consultants came back with the advice: 'They won't buy an IBS house unless it has a fairly steep-pitched roof. Anything low-pitched is synonymous with mobile homes'. In desperation, the IBS team completely redesigned the system as a two storey house with attic bedrooms. In the process, they abandoned the versatile wall-panel system, and the whole concept of the expanding house. (A pitched roof freezes a plan into one limited form). They even dreamed up extravagances of form which made nonsense of the whole idea of assembly line production. Ivan Juriss lost interest, and went off to take up market gardening. And then the source of funding for the whole exercise began to run dry. Four or five forgettable two storey houses were built: and then it all stopped.

Primer: About Prefab Housing

PAMELA BELL

TODAY, HOUSES are constructed on their sites using bespoke building processes that vary little from those of a hundred years ago. Construction processes that occur away from the building site are known as prefabrication, or prefab. These prebuilt parts can be manufactured from any material and in a variety of sizes, from precut pieces to an entire building.

Prefabrication requires a close link between design and business. It is an opportunity for architects and designers to make architecture as accessible, affordable, and sustainable as the most technically sophisticated consumer products available today. Prefab is not a new idea. Early prefabricated housing arrived in New Zealand with European settlers at the turn of the 19th Century. Over the years it has also been referred to as kitset, panelised, modular and transportable housing.

Prefab Terminology

Prefab, short for prefabrication, refers to any building part that is made (fabricated) before (pre) it is assembled at the final building site. Prefabrication typically occurs off site in an enclosed building, a factory, or a controlled construction yard. Increasingly the term offsite is used interchangeably with prefab. Other terms used include offsite manufacture (OSM), modern methods of construction (MMC), nontraditional construction, ready-made and innovative construction. Yet more terms include prebuilt, preconfigured, predesigned, preplanned and preassembly. To simplify matters we have adopted the original terms, prefabrication and prefab throughout this book. Prefabrication refers primarily to a process, rather than a product. It is first and foremost a way, an approach, a system, that does not necessarily lead to a single product outcome. The term prefab is also used to describe

Lockwood EcoSmart
Home Series Gullwing
show home in Rotorua.

Pre-cut light-gauge steel components assembled as house framework.

Timber panels assembled as house structure.

Modular volumes being set into position on site.

buildings made using prefabricated systems. This confusion has contributed to perceptions of prefab being at times low-quality, flimsy and standardised. These misperceptions have been an impediment to consumer acceptance and commercial success. Adding to this problem prefab homes have also been confused with mobile, portable, standardised or industrialised housing.

Prefab buildings are wide ranging. They can be temporary or permanent, cheap or expensive, all the same or all different, small or large, with traditional or modern aesthetics, and well designed or badly designed. Prefab housing can be categorised according to the size of its parts. The five main types of prefabrication are: component (stick and subassembly), panel (nonvolumetric), module (volumetric), hybrid (module+panel) and complete buildings (box-form).

Component

Component-based prefab includes stick and subassembly prefabrication. Stick refers to lengths of timber or steel which are precut, presized or preshaped puzzle-type pieces brought to site. Subassemblies include windows and doors, fixtures and fittings, and structural members such as prenailed roof trusses and wall frames. The use of prenailed components has become an accepted part of the traditional construction process by the full range of home building companies in New Zealand. A common form of component-based construction is known as kitset housing.

Panel

Panelised, nonvolumetric or two-dimensional prefabrication comprises manufactured panels that are transported as a flat-pack. They can be classified as closed panels, complete with doors, windows, services, cladding or lining, or be open panels, made up of framing components.

Some architects refer to closed panel systems as cartridges or cassettes.

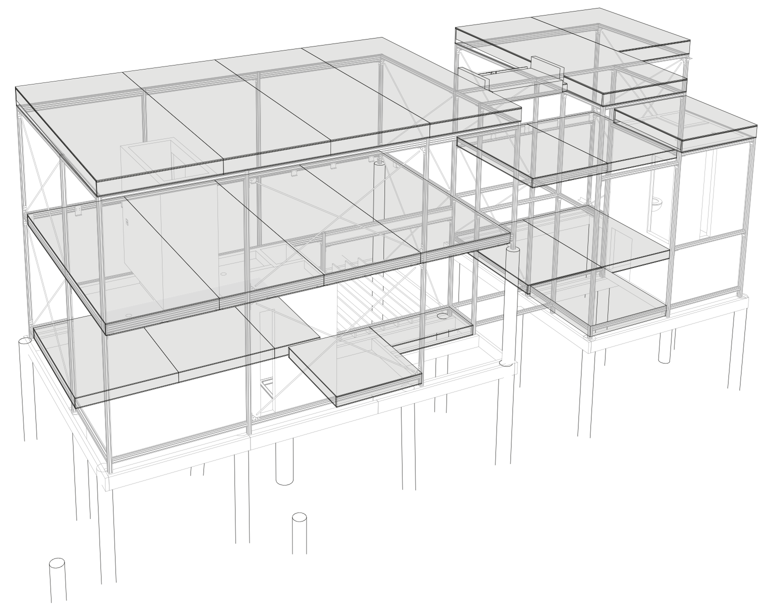
Module

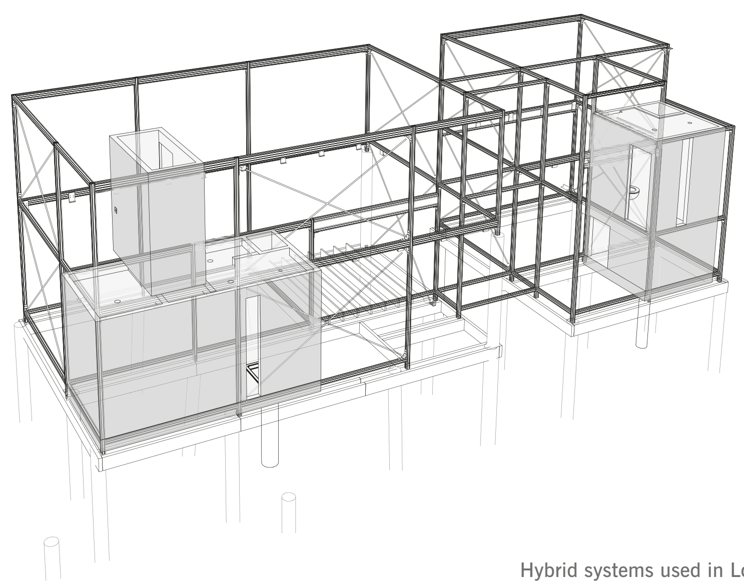
Modular, sectional, volumetric or three-dimensional (3D) prefabrication refers to a 3D structural unit made away from site and combined with other units or systems at site to create a whole dwelling. These prefab elements are referred to as volumes, modules, or sections. By contrast, cores and pods refer to nonstructural volumetric units often used within conventional buildings. Modular units are manufactured in controlled conditions with a high degree of services, internal finishes and fit out installed in factory prior to transportation to site. This approach is particularly suited to highly serviced areas such as kitchens and bathrooms, which have a high added value, and cause disruption and delays on site.

The modular home term came into common usage in the 1970s US modular housing industry. These homes are a type of building that meets building codes, are factory assembled in three dimensional units and then fixed onto permanent foundations on site. It is a more permanent type of building than chassis-based mobile or manufactured homes which also gained popularity during that era.

Hybrid

Hybrid prefabrication is a term used for combinations of systems, such as hybrid module+panel or semivolumetric systems. These systems use a mixture of volumetric units for the highly serviced areas such as kitchens and bathrooms and construct the remainder of the building using panels or by other means. Hybrid prefab systems combine the benefits of two prefab construction systems, balancing construction efficiency with flexibility and consumer choice.





Hybrid systems used in Loblolly House with panel elements highlighted above and modular elements highlighted below.

Prefab can offer more for less Chart.

Complete Buildings

Box-form or complete buildings are commonly known as portable, relocatable or transportable dwellings in New Zealand. They are a type of volumetric prefab where entire buildings are constructed in a factory or yard and then moved by a heavy haulage vehicle to site where they are attached to permanent foundations. These buildings may or may not incorporate prefabricated components, and standardised framing and sheet elements. There are subtle differences between portable, transportable, mobile and relocatable terms as used in New Zealand. Portable refers to small temporary buildings that are light and easily moved repeatedly such as toilets or site offices; transportable refers to larger buildings that are moved once from place of construction to a final site; mobile indicates towable caravan-like structures on a permanent chassis which can potentially be moved repeatedly; and relocatable describes buildings that are designed to be moved several times during their life cycle.

A completed building arrives at site on the back of a truck.

Prefab Advantages

Prefabrication can potentially offer more for less: more quality for less time at site, more known outcomes and less unknowns, and potentially more energy efficiency for less resource use.

The value of tangible outcomes in cost, quality and time frame are evident to the consumer through visiting prefab show homes to evaluate prefab systems, design options and material samples. Observation of factory manufacture, and the house arriving at the building site are also prefab consumer advantages. Technical, social, economic and sustainability merits will also be discussed below.

Quality

There is a common perception that prefab will primarily deliver a more cost-effective housing solution. However, the main advantage is increased control over manufacturing and construction conditions, creating a higher quality solution. *Improvement in quality is regarded as the principal advantage of prefabricated housing.*[1] This higher quality is achieved through closer coordination of labour, materials, machinery and subtrades in controlled conditions. Quality control and resulting remedial work can be carried out before the product leaves the factory floor.

Speed of Delivery

After quality, the second major advantage to using prefab is increased speed of delivery. A house can be manufactured offsite while foundations are prepared on site. This can reduce the programme between 30–60% of a traditional construction process. It is estimated that each week of timesaving on a housing project equates to a cost saving between $1,000 and $1,600.[2] At a commercial scale, the savings are increased dramatically. A difference is that a period of planning is needed prior to prefab manufacture and changes cannot be made once fabrication processes commence. This presents a cultural shift from traditional linear-sequenced construction.

Technical merits

Technical merits include tight workmanship and material quality control, and the ability to test systems and prototypes within a controlled factory environment. Testing, together with greater planning, accuracy and minimised tolerances, reduce the level of mistakes and subsequent remedial work postoccupancy. This results in less stress for the home owner and less costs for the contractor, a win-win situation.

Social merits

These include being able to work under cover during inclement weather, having tools and amenities close at hand, and improvements in health and safety. Investment in machinery and training can also lead to longer term employment stability. At site, there is likely to be less noise, dust, transportation and neighbourhood disruption than a traditional build. Prefabricated homes are often indistinguishable from conventionally constructed homes and can be individually customised to be aesthetically dissimilar from each other.

Economic merits

Economic merits include the cost savings to customers and developers from a faster delivery, reduced remedial periods and a shorter period of financial borrowing. *Given the cost savings inherent in the construction technique, a prefabricated shell will generally be less expensive than a site built structure of exactly the same specifications, configuration, and quality.*[3] Time frames and costs can be decreased by eliminating dependence on weather for site-based construction, more efficient coordination of subtrades in-house, reduced transportation, and price advantages from bulk ordering. Costs can be further minimised by reducing overall floor area. Often a prefab home design is efficient to minimise transport demands, a scaled down size for scaled down living needs.

Off-site undercover construction.

Sustainability

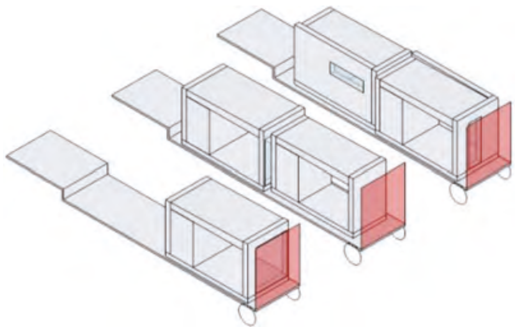
Sustainability merits include reduced material waste through efficient ordering, indoor construction protection, preplanning and cutting. In New Zealand, construction is the 'forty percent industry.' Our buildings are responsible for 40% of energy consumption, 40% of the waste stream, 35% of carbon dioxide emissions, and 40% of raw material use. The United Kingdom's (UK) Waste and Resources Action Programme (WRAP) reported that up to 90% of construction waste could be reduced in the use of a variety of prefab manufacturing methods. US projections are similarly optimistic, with claims that construction industry energy consumption can be reduced by 50% by using prefab methods. The final building also benefits from the reduction of defects, and closer tolerances for tighter thermal and acoustic performance leading to better energy efficiency and lower heating bills. Prefab buildings can have a reduced carbon footprint through minimised transportation to site and lower energy use over its life cycle. Deliveries to site can be reduced by 60% for modular construction. Process benefits are from a safe, healthy and controlled environment for workers, as well as savings in labour productivity and material efficiencies. Traditionally, work at site can fall up to 50% below potential, and an estimated 13–18% of materials delivered are wasted from not being used properly.[4]

Prefab holds the promise of delivering a greener home in less time and perhaps even less money, but it is only as green as the designer and the builder.[5] In its greenest form, prefab buildings are designed for disassembly and potential future reuse of materials and components. One prefab sustainability drawback for modular units is in the over-engineering and subsequent additional material used to brace for transport however this also makes the house more durable and resilient once it is assembled on site.

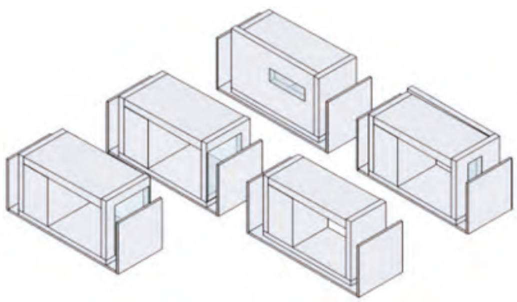
Together, prefab advantages can help tackle construction industry challenges such as a low-skilled construction workforce, increasing market demands for higher quality housing, and increasing industry regulation.

Prefab Challenges

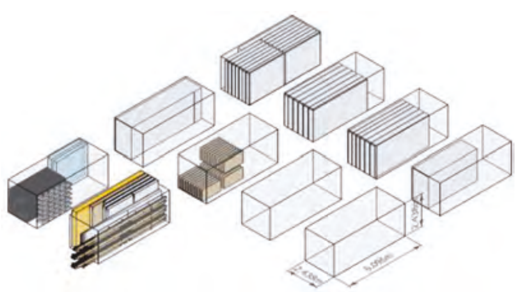
There are challenges to greater prefabrication uptake in New Zealand. The commercial success of prefabricated housing has been inhibited for reasons ranging from prohibitive start up costs and limited market size, to ongoing financing issues and macroeconomic conditions. There are continuing challenges for designers around differing site conditions and transport box limitations. All prefab parts must fit on the back of a truck or in a shipping container, and for export markets both.



First Light House test design for transport by flatdeck truck.



First Light House test design for transport by sea freight on flat rack.



First Light House test design for transport by shipping containers.

Misperceptions

By far the greatest challenge is from social perceptions, or rather misperceptions of prefab. These can be grouped into historical, quality, aesthetic and sociocultural issues and are held by the design and construction industry, and the wider NZ public.

Historical issues

There appears to be a good deal of misconception about prefabrication, in as much as it has been considered by many people as being a cheap substitute for conventional building. It is, in fact, merely another way of building.[6] As New Zealanders, our historical perceptions are based on our experiences going to school in temporary prefab classrooms that remained permanently in place, mass-produced kitset homes and transportable baches and cribs.

Quality issues

In 2001, the British still associated prefab with the poor material quality and bad design of temporary prefab homes, and the multistorey concrete structures of the 1950s and 1960s. Despite the longevity of the post-World War II temporary prefab programme, there were negative perceptions of prefabrication from that era. *People have got the idea that [prefabrication] means jerry-building, tumbledown shacks, caravans, shoddy work, ribbon development, draughts and leaks and everything that is bad in building.*[7] US citizens judge prefab housing as similar to mobile or manufactured homes, with connotations of being light, flimsy, temporary and cheap 'little boxes of ticky-tacky.' Low-cost manufactured homes are perceived as low-quality. A widely accepted myth about manufactured homes is that they are not well built, yet they are structurally reinforced to withstand lengthy road transportation.

Aesthetic issues

The common assumption that prefabrication results in repetitive outcomes has caused aesthetic misperceptions. It has lead to an association of the prefab term with standardisation. *Prefabrication does not necessarily imply either mass production or standardisation. In fact none of the three terms necessarily implies the other two. Standardisation is not essential and mind-numbing monotony is not inevitable.*[8]

Innovative prefabricated housing has also been thwarted by a public perception that equates unconventional appearance or materials with inadequacy of performance. Most people understand traditional housing vernacular of a pitched roof and horizontal linear cladding. By contrast, prefabricated housing that travels as a complete building on the back of a truck will be more likely to have a low or flat roof. This has been perceived as nontraditional and even worse, something to be afraid of, *psychologically, mass production is considered an attack on individuality.*[9]

Sociocultural issues

A key barrier to prefabrication in the UK is the sociocultural perception of the home as an economic investment, rather than a consumer good. This is echoed in New Zealand, where the concept of the family home as a primary investment and indicator of economic wealth is a dominant part of the national culture. In the late 1970s and early 1980s, an influx of material and component options entered the New Zealand construction market resulting in a proliferation of consumer choice. This emphasis on choice and individualisation has become intrinsic to the home buying process today. This poses a challenge to prefab uptake because perceptions that prefabs are standardised remain dominant, and standardisation can be seen as an assault to personalisation.

Contemporary prefabricated housing businesses attempt to subvert problems caused by misperceptions around the prefab term by using other names such as offsite, prebuilt, preconfigured or preplanned. The misperceptions explained here are changing, but they continue to affect the uptake of prefab housing today. They also provide the perfect platform from which to step off into the future, towards high-quality, architect-designed, permanent homes with sustainable features, delivered to consumer expectations on time and on budget.

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Prefab panels arrive on back of truck for on site assembly circa 1940s.


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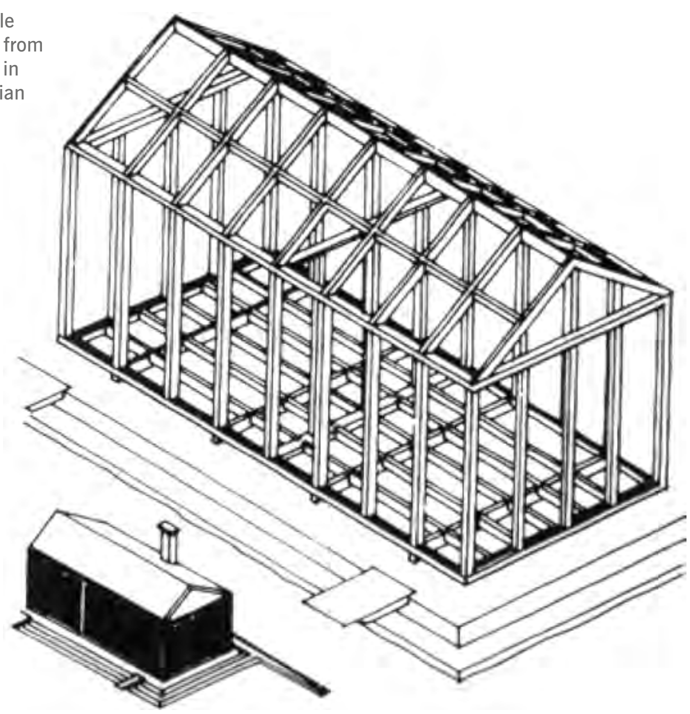
Prefabs Past: A History of New Zealand Prefabricated Housing

PAMELA BELL

BEACHSIDE BACHES, portable classrooms, and state houses are all part of the history of prefabrication in New Zealand (NZ). Prefab houses occupy our coastlands, our rural hinterlands and our suburban subdivisions. They are an integral part of our architectural landscape and our cultural heritage. The history that follows draws on the first hand experiences of NZ prefab housing pioneers and innovators. These examples illustrate the role of prefabrication as a vehicle for experimenting, testing innovative materials and system technologies. Historical exemplars provide the opportunities to learn about what remains relevant to prefab housing today and for the future.



Manning's Portable Cottage: Drawing from an advertisement in the South Australian Register 1837.

International Historical Overview

The Museum of Modern Art (MoMA) in New York paid homage to historical prefabricated housing in a landmark 2008 exhibition curated by Barry Bergdoll and Peter Christensen titled *Home Delivery: Fabricating the Modern Dwelling*. The exhibition included full-scale structures as well as construction drawings and architectural models of over 100 artefacts of prefabricated housing, stretching from the 1800s to today. This was an important retrospective for its depth, complexity and acknowledgement of the current resurgence of interest in architect-designed prefabs. The historical summary here draws on highlights of that exhibition text[1] and other key references on prefab housing listed in the Selected Bibliography section at the end of this book.

The history of prefabricated housing begins with migrants from the United Kingdom. H. Manning of London exported a range of pre-cut housing kitsets to Australia and New Zealand from 1833.[2] Manning used pre-cut timber posts, roof trusses and panelised timber cladding bolted together at the site without any need for joints, cutting or nailing. By the early 1900s American Henry Ford was manufacturing cars on an assembly line and Sears Roebuck and Company had begun their successful US mail-order housing catalogue. They sold a staggering amount, over 100,000 timber balloon-frame kitset homes between 1908 and 1940. Frank Lloyd Wright designed a ready-cut series of American System-Built Houses, but despite a marketing campaign the houses failed to gain market attention. Le Corbusier developed the patented Dom-ino building system in 1914 as a standard structural unit and basis for mass produced housing. It consisted of pilotis: perimeter load bearing columns, and concrete slab floors

Wichita House by R. Buckminster Fuller 1944–46.

Maison Tropicale by Jean Prouvé 1949-51 (New York 2007) The Maison Tropicale house was auctioned by Christies for nearly US$ five million in 2007.

Case Study House Eight by Ray and Charles Eames 1945–49 Los Angeles.

and roof planes allowing an open-plan interior, horizontal ribbon windows and roof terraces. He went on to patent this proto-architecture. Its standard structural system was a major influence on 20th Century architecture.

Richard Buckminster Fuller was a prolific and future oriented designer with a focus that included sustainability and marketing. His 1927 Dymaxion House and later Wichita House both enclosed a maximum amount of space with a minimum amount of material and expense.

The 1944 Wichita House realised in association with the Beech aircraft company facilities is perhaps, the most important prefabricated house design of the 20th Century. The circular structure was assembled top down on a tensile frame supported by a central mast which meant it could be erected on any sloping site. It cost approximately half the cost of a conventional house and received 37,000 unsolicited orders in less than a year. The houses never entered production because of Buckminster Fuller's fanatical determination to retain complete personal control of the project, eventually leading to financial disaster.

Buckminster Fuller produced some of the earliest utility pod designs, such as the innovative one piece Dymaxion Bathroom originally in copper in 1936, and later in fibreglass in Germany in the 1950s. This idea was taken further with the design of the Mechanical Wing project in 1940. Electric hot water, reserve water tank, and cooking and sanitary facilities were combined in a caravan-like form which could plug-in next to a cabin or tent. His ideas and designs were provocative, future focussed and well ahead of mainstream consumer thought and acceptance. He believed that the construction industry had a 50-year time

Nakagin Capsule Tower by Kisho Kurokawa under construction in 1972.

lag between idea inception and idea take-up. Sadly Fuller didn't live long enough to see his Dymaxion House finally achieve critical acclaim as a design masterpiece in 2001.

There was a surge of post-World War II prefabrication activity spurred by housing demand and the opportunities afforded by postwar technical and industrial abilities and factory capacity. Jean Prouve shipped his Maison Tropicale series to French colonies in the Congo; Marcel Breuer's House in the Museum Garden was displayed at the Museum of Modern Art in New York; Ray and Charles Eames' Case Study House Eight was completed in Los Angeles; and the all-steel Lustron Westchester house model was in full production.

In the United States, the Walter Gropius and Konrad Wachsmann Packaged House or General Panel System generated a detailed panel-plus-connector system, a factory and a single prototype before succumbing to bankruptcy. The system's demise was another example of relentlessly tight design control at the expense of business acumen.

Around this time, large scale standardised housing developments such as Levittown in Long Island, Pennsylvania and New Jersey tainted the image of prefabrication for generations to come. Despite good intentions of widespread home ownership, the repetitive cookie cutter aesthetic earned them the nickname 'little boxes made of ticky-tacky.'

The 1960s was an exuberant and experimental period with work of the Metabolists and Archigram featuring meta or megastructures containing plug-in living pods. Kisho Kurokawa's Nakagin Capsule Tower and a handful of other provocative projects, such as Moshe Safdie's Habitat 67, were built in the mid 1960s. Habitat 67 was built of 158

Futuro BNZ bank branch at Christchurch Commonwealth Games in 1974.

Marmol Radziner Prefab
Desert house.

interlocking concrete modules as part of the World Exposition at Montreal in 1967 and is still standing. The iconic Capsule Tower was demolished in 2009 in order to build a more intensive development on the high value site.

Another provocative design was the flying-saucer-like Futuro by Finland's Matti Suuronen (1968-78). It was also made in New Zealand under license and featured as a Bank of New Zealand (BNZ) branch at the 1974 Commonwealth Games in Christchurch. There are just 60 of these left in the world and New Zealand is home to 12 of them. Most ended up as beachside baches or garden follies and are now sought after by collectors of modern design.

By 1960, chassis based mobile homes made up 15% of the United States housing, but the postwar rush to build them resulted in poor design aesthetics, a perception that persists today. The early 1970s witnessed a further rise of the manufactured home as well as modular housing in the United States, before an economic slump which contributed to the consolidation of the wider prefabricated housing industry by the end of the decade. By 1980, manufactured home residents in the United States were estimated at over eight million, and manufactured housing was established as a major housing alternative.

The 1980s and 1990s were relatively bare in terms of prefab activity, as the industry focused on bespoke luxury dwellings. A few examples emerge from the mainly British high-tech school of architecture, such as the Almere House by Benthem Crouwel and the Yacht House by Richard Horden. Waro Kishi's Kim House, Shigeru Ban's Furniture House, and Heikkinen-Komonen's Touch House are good examples of one-off architect-designed prefabricated homes from Japan and Scandinavia respectively. Prefabrication today is being addressed by a number of United States architects such as Michelle Kaufmann, Adam Kalkin, Teddy Cruz and Greg Lynn. They are focused on contemporary sustainable prefab, containerisation, disaster housing, and the potentials of digital design. A green modern prefab movement is spearheaded by United States architects Leo Marmol and Ron Radziner, Michelle Kaufmann, Jennifer Siegal, Charlie Lazor, and Rocio Romero, who began their businesses by designing and building prototypical homes for themselves. This prefab revival is publicised through the pages of San Francisco based *Dwell* magazine and popular websites such as Inhabitat and Treehugger.

A New Zealand Prefab Housing History

As the rest of the world was busy innovating, experimenting and manufacturing, New Zealanders looked on, adapted and applied prefab methods as they became available. Pre-1800s Maori used traditional techniques for raupo house construction. These involved bundling or clumping of six to eight raupo (bulrush) stems into 300mm wide vertical panels with flax strips.[3] These were then bound prior to attaching to an independent timber-framed structure, which enabled a very orderly and fast fixing technique and construction. This is an early application of prefabricated processes.

New Zealand shares its prefabricated housing origins during colonial settlement with the rest of the world. The first recorded European prefabricated house was a gift to the Ngapuhi chief Te Pahi from Governor King of New South Wales, Australia. Te Pahi had visited Governor King in Sydney in 1805 and returned home by ship to the Bay of Islands with gifts that included iron tools and 'a small house in frame.'[4] The house was used by Europeans visiting the area until 1809, when it was burned down by European whalers during a raid on Te Pahi's village. Settlers in the 1800s were encouraged to bring their own housing components from England. These were purchased

Local Maori constructing housing of raupo for European settlers on the banks of the Whanganui River.

Treaty House by
J. Verge Sydney 1833.

The Railway House in
New Zealand. A typical
elevation from the Railway
Housing scheme.

from firms like Cottam and Hallem, and Manning Portable Colonial Cottages. The Manning kitsets were made in London and sold to British colonies in Australia and New Zealand from 1833 through to the 1850s. They were commercially successful and offered a variety of types to meet diverse customer needs. These imported houses provided a good start for some settlers, but sometimes they didn't arrive intact, were too difficult to assemble, or proved unsuitable for local conditions.

There are a number of well-known colonial cottages that arrived by ship to our shores. New Zealand's most familiar colonial house, the Treaty House, was brought by James Busby from Sydney to Waitangi in 1833 as a pre-cut frame with fittings and most materials. Other notable early prefabs include the Auckland Governor's house, Chief Justice Martin's house at Judges Bay and a number of ready-made houses that were shipped from England and France to Canterbury.

In the mid 1800s, prefabricated Kauri cottages were made in the Bay of Islands and shipped to California for their goldfields. Around this time, seven houses were shipped to Australia from New Zealand. By 1870, pre-cut building components were being widely manufactured by local timber mills and were transported to the gold rush settlements in the Coromandel. By the early 1900s United States pattern-books had spread populist designs to New Zealand. The Victorian style gable-and-bay villa had a consistent system of interchangeable, designed elements. Plan-books laid out options for basic structural shells that were made on site before being accessorised by factory produced ornamental components such as cornices, eaves, veranda posts and gable ends.

In the early 1900s, the New Zealand Railways Department was the first and largest producer of prefab housing. They used standard planning, together with a kitset of pre-cut and numbered timber components. The familiar Railway house design was a modest bungalow cottage with variations to the principal facade treatment. A factory was established in the early 1920s at Frankton, the largest rail junction in the country. This factory could produce components for a house in a day and a half, which were then transported by rail around the North Island for assembly at site by just two people in two weeks. South Island houses were made at site due to difficulty with transport between the islands. A saving of 33% in labour resulted because of the process and the skill of the men on site. The efficient means of prefabricating eventually led to its own demise in 1930 when the scheme was abandoned after the supply outstripped the demand.[5] The Railways Department had produced almost 1,600 houses over a six year period. Today, the Railway House remains a part of our social fabric. It offers a cute and slightly quaint cottage aesthetic that still responds well to personalisation through changes in paint colour, decorative elements, verandahs and landscaping. They can be found in groups around former railways workplaces in the North Island, such as Railway Row in Ohakune and amongst residential suburbs such as in Ngaio, Wellington.

The Railways programme overlapped with the 1925 introduction of the Hutt Valley Lands Settlement Act to address the needs of returned First World War servicemen. This scheme involved houses from the Railways Department, land servicing by the Lands Department, and targeted loans from the State Advances Corporation, to make a complete housing package. This total state responsibility for every aspect of housing development is seen as a precursor to the Labour government Public State Housing Scheme which was officially launched in 1937 when the First State House was opened in Miramar, Wellington. State Housing used a standard range of house parts and construction details, window and door sizes and internal fittings, including baths, washbasins and cupboards. A single specification document was used to cover over 100 house plans.[6] A varied schedule of colours was used for claddings, roof tiles and plasterwork to ensure each neighbourhood had an interesting and harmonious grouping. Large contractors such as Fletchers also supplied pre-cut framing and unlined wall panels. Over 400 housing designs were commissioned and although a standardised planning formula was followed, no two houses in the same area were exactly alike.

The World War II years (1939-45) saw factories dominated by military construction activities. Over 30,000 prefabricated huts were fabricated offsite, along with tent floors for temporary buildings

Returned soldiers headed by trained builders construct panelised state houses in the 1940s.

and transportable buildings for military camps. Most of these structures were destined for camps at Cornwall Park, Hobson Park, Victoria Park, Western Springs, Mangere Crossing and Avondale in Auckland. In Wellington, temporary settlements at Paekakariki, Pauatahanui and McKay's Crossing demanded over 4,000 buildings and huts. Some of the buildings for the Paekakariki camp were prefabricated in the South Island.

In the 1940s, returned World War II soldiers joined small construction gangs headed by a trained builder to assemble prefabricated wall panels as part of a state housing programme. The panels came complete with external cladding from joinery factories and were trucked to site.[7] These prefab panel techniques were originally introduced with the hope of speeding up construction and saving costs but the panel house failed to achieve either of these aims. In 1953 use of the timber panel-type house system stopped, as the houses needed level sites, had limited plan options and incorporated expensive additional joinery. The combination of pattern-book designs, use of unskilled labour and pre-cut prefabrication techniques enabled the State Housing Scheme of the 1930s and 1940s to become one of the most successful public housing schemes in the world.[8]

In 1942, Andrew Fletcher of Fletcher Construction presented information from a research trip to National Homes in the United States, to the Director of the Department of Housing Construction.

Shortly afterwards in 1943, Chief Architect Gordon Wilson proposed a government led prefab design competition to produce practical modern data on prefabrication in home building. The Department invited local architects to compete in the design of prefab dwellings, which resulted in the selection of eight house designs by R.S. Walker and Paul Pascoe, three of which were built in Christchurch.

It would seem that pre-cutting and partial prefabrication will be the immediate answer. Standard construction will be followed to the floor, with the exterior walls, interior partitions and roof trusses prefabricated.[9] Roof trusses and open wall framing pre-engineered and pre-nailed away from site, with moisture barriers, insulation and exterior claddings applied at site are the mainstay for traditional construction methods used today. Wilson's vision in the early 1940s can be viewed as close to reality 50 years later. This is in line with Buckminster Fuller's thinking that there is a 50-year time lag from idea to inception in the construction industry.

By mid 20th Century prefabrication techniques were gaining popularity in Britain, the United States and Australia. The New Zealand government also invested in research and experiments with prefab wall sections, multistorey concrete construction, and imported housing technologies from Sweden, Austria and the United Kingdom. In 1943, in Naenae Wellington, five houses were built using prefabricated wall panels. From 1945–7, in Petone Wellington, five blocks of terrace flats were built using prefabricated concrete panels, and in 1947, in Wadestown Wellington, a single house imported from Sweden was constructed using prefabricated wall panels, complete with window and door joinery.[10] In 1948, two houses imported from England were erected temporarily in Wellington using aluminium components. Direct importation of prefabricated housing was not pursued any further at that time due to high transportation costs and quality defects.

In the 1950s, the government embarked on several low-cost housing initiatives. Responding

Government-backed show homes open to the public as part of a popular Parade of Homes in the 1950's.

to public outcry on the postwar housing shortage 500 pre-cut houses were ordered from England for Auckland, and 500 from Austria for Titahi Bay.[11] This initiative made the government unpopular with the local building industry which was concerned about losing work to imported products.

By the mid–1960s, the cost of regular repainting and replacement of rotting window sills, mullions and porches highlighted the pitfalls of imported timbers and products. Sixty years on, despite the drawbacks of this additional maintenance, the houses have outlived their original 20–year life expectancy and remain structurally sound. As a result of this experiment, the immediate housing shortage was partially addressed and the construction industry gained skilled workers from Austria, however the government did not import any more of these houses.

A government Part House Scheme was set up in 1952 combining notions of partiality, prefabrication, the temporary, and the use of labour from ex-servicemen. The small basic plan houses were fabricated in a factory near Rotorua and transported to site, complete with financing and plans for later additions. The reduced plan was indicative of a time when the postwar government placed restrictions on importing building materials, planning house areas and building of structures deemed to be luxury items, such as garages and baches.[12] A single storey, three bedroom house could not exceed an area of 1,600 ft^2 (149m^2), and childless couples were restricted to a single storey home not exceeding 1,150 ft^2 (107m^2).

A national housing conference in 1953 spawned government initiatives for the National Housing Council (NHC) and the Group Housing Scheme.

De Geest factory interior with prefab homes under construction 1970s.

Hydro scheme township of Twizel in 1970.

De Geest factory exterior
with prefab homes under
construction 1970s.

This Scheme encouraged speculative building through a government guarantee to purchase houses built in groups of six or more that were unsold two months after their completion. These Group home builders frequently used state house plans. The Scheme promoted the use of pre-cut elements in house construction. Beazley Homes and Neil Housing went on to become dominant housing suppliers in the 1960s.

The NHC was a forum for the government to promote prefabrication construction techniques, focus on housing targets, and encourage cooperation amongst the construction industry and related professions. By 1963 the scheme had lapsed because the government perceived the housing shortage was over. The sponsorship of parades of homes to showcase new house designs and stimulate housing sales to the general public was an NHC marketing initiative. These were well received, with their popularity being next to racing and football amongst New Zealanders according to one newspaper reporter. The parade of homes clearly shows New Zealanders' growing infatuation with housing. In 1956, the government had set up a technical committee investigating new methods of construction. Two designs from the Experimental Component House Scheme were built in Porirua when Cabinet approved a budget ten years later. These houses were test beds for precast concrete load bearing wall panels and prefabricated timber roof trusses. Both of these elements are now commonly used in construction.

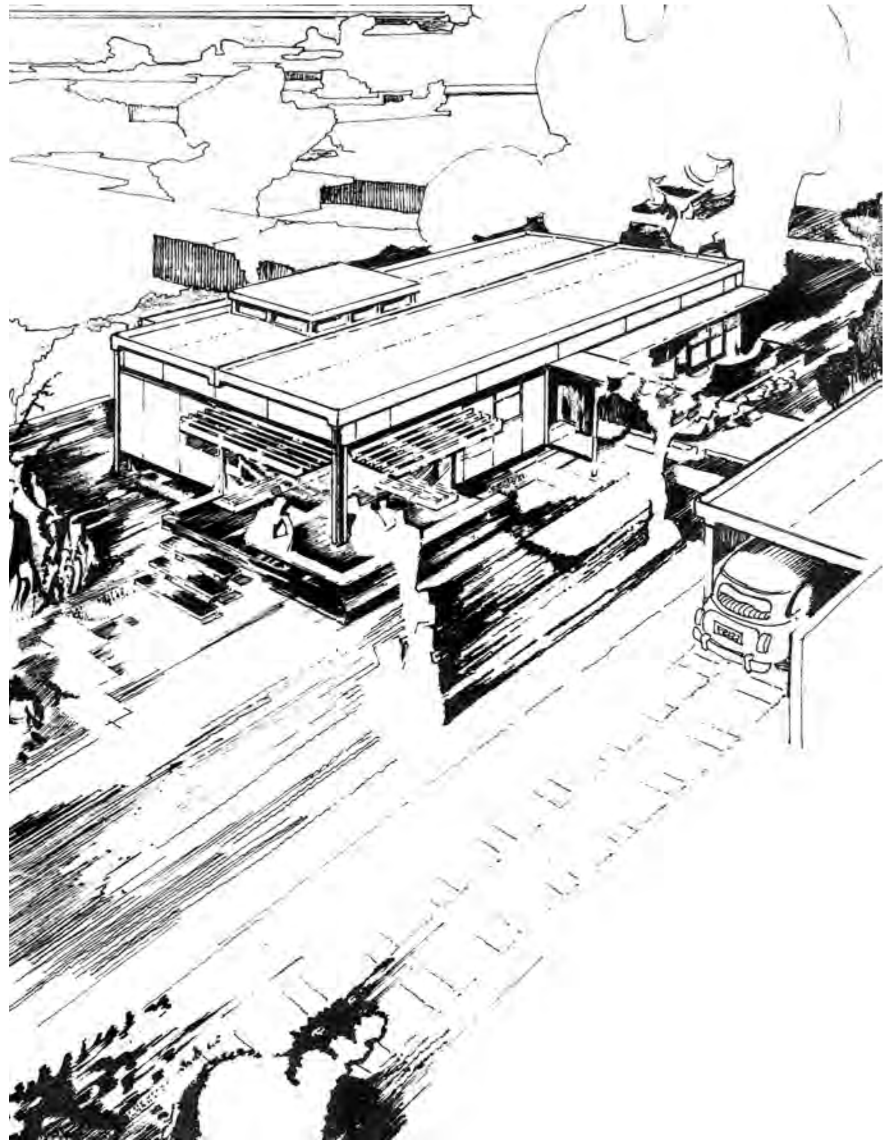
Nationwide hydroelectric schemes used prefabrication techniques to easily erect and shift worker housing from one scheme to another, or in areas with housing shortages. Combinations of construction, transportation and relocation were used throughout the 1940s and 1950s for the North Island Waikato Hydro Scheme and in the 1960s and 1970s for South Island towns such as Otematata and Twizel. The Ministry of Works set up a carpentry workshop at Otematata to build 250 houses on a production line. Other housing was provided by contractors such as Keith Hay Homes Christchurch, Martin Homes Timaru, and De Geest Brothers Construction of Oamaru. De Geest constructed 549 complete houses for Twizel and 350 componentised houses for Cromwell from their purpose-built factory.[13]

The 1950s to 1970s was a period of rapid population growth after World War II. A number of prefab housing businesses were established during this time, such as Keith Hay Homes, Beazley Homes and De Geest Construction. Barry Beazley founded his house building business in Tauranga in 1953. It was a very significant and successful business in those days and was bought by Fletchers in 1973 to be later consolidated under the Fletcher Homes umbrella in the early 1990s. In its heyday over 1,200 component based and complete dwellings were produced a year by 80 accredited builders. This occurred in the late 1960s and early 1970s for markets in New Zealand and offshore. They developed large scale use of pre-cut housing in New Zealand, supplying pre-cut components including window and door joinery and plumbing fittings for their network of builders throughout the country. This was supplied from their yard at Mt. Maunganui which had its own rail siding.

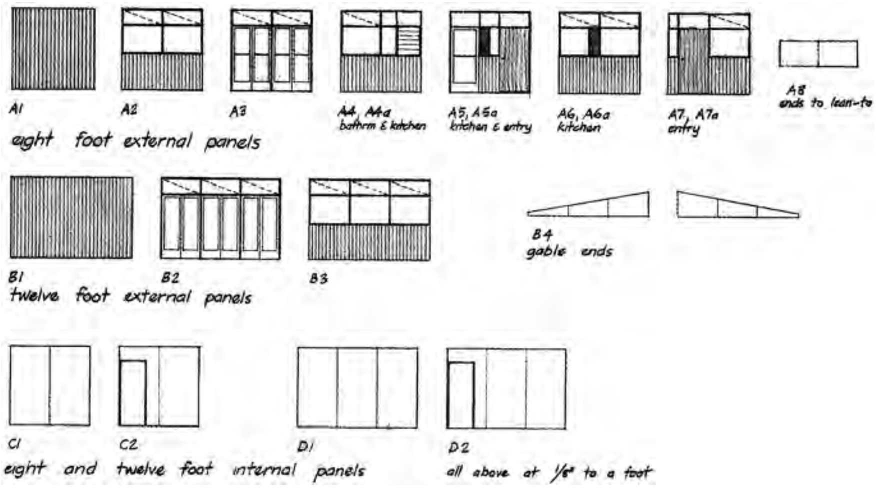
During the late 1970s, Beazley successfully exported housing construction services to Australia, Papua New Guinea and Noumea, as well as a site-hut building to Saudi Arabia and Iraq. This transportable building was constructed in their factory on steel frames and shipped as a flat-pack with complex kitchen cabinetry as built modules. Export success was later hindered by the dominance of Canadian and United States operations, as well as high ongoing running costs including marketing and sales staff offshore. In the early to mid–1980s, the proliferation of small locally based pre-cut manufacturers spelt the end of the business.

A diverse range of prefab housing was produced commercially in the 1950s to 1970s including several innovative, yet commercially unsuccessful, systems such as Solwood and Industrialised Building Systems. In the early 1950s, Napier architect Guy Natusch, of Natusch and Sons, founded the Solwood system of solid timber construction at a time when several other suppliers were also working with solid wood components. Sixty millimetre thick tongue and groove boards were used to create wall and ceiling panels that functioned as both interior and exterior linings. The adoption of pine (Pinus Radiata) was innovative at a time when architects were specifying native timbers. In 1953, the Solwood house won the construction section in the National Housing Conference. An exhibition house built in Napier was received enthusiastically by the public and was widely thought to be a new opportunity for State House design.[14]

Several challenges led to the demise of the Solwood system in the late 1950s: Napier City Council was reluctant to grant permits, the Carpenters Union felt threatened and refused to participate, the State Advances Corporation would not approve loans for the homes, and New Zealand Forest Products were unwilling or unable to provide timber of a quality and quantity that met Solwood's specifications. Modulock, Solwood, Putaruru Timber Yard, Conecta, Lockwood and Fraemohs were other solid wood component systems established in the 1950s–70s era. The latter two systems are still in production today with head offices in the North and South Islands respectively.



Perspective view of IBS Double-wide prefab home.



Group Architects' 8 and 10 foot wall panel system 1952.

In the late 1960s, Industrialised Building Systems (IBS) began under the leadership of entrepreneurial Palmerston North property developer Keith Clark. The IBS team ambitiously planned for three separate consortia in New Zealand and six in Australia with each factory forecast to produce 1,200 homes per annum, or 25 per week. Architects Bill Wilson, Ivan Juriss and Roger Hay were part of the team that designed the IBS system of additive room modules. In the 1950s both Bill Wilson and Ivan Juriss were also members of Group Architects whose collaborative work focused on efficient lower cost housing solutions, modular planning and mass production techniques. Group Architects' forays into prefabrication began in 1952 with the design of a series of houses utilising a panel based system with eight different plan variations. The All-Pine prefab was the prototype realisation of this work in 1953. It was an exhibition house erected at Western Springs over a ten day period and was published in NZ Home and Building. Another design exercise by Group Architects for Fletcher Construction in 1956, and Ivan Juriss's work with IBS in the 1970s continued the development of the earlier work in this area with similar results.[15]

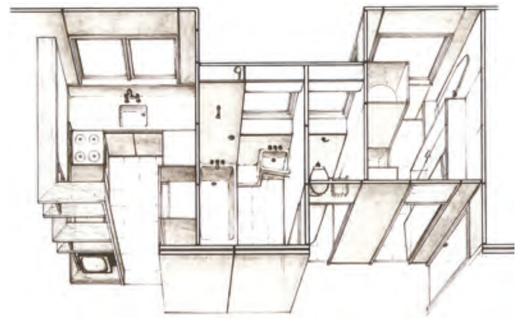
A prefabrication system where parts would be resold back to the factory, additional ones bought, and worn out ones replaced was envisaged by the IBS team. The walls and floors were made of a triple layer stressed-skin sandwich panel, together with a specialised jointing system. This rigid Ribsel panel was developed and patented to provide a strong and precise platform to withstand the stresses of loading, travel and installation. By 1972, a 1,400 ft^2 (130m^2) family house, a motel unit and a weekend home were built in the IBS factory at Avondale and exhibited nearby. Stage Two of IBS was the creation of Xibis (pronounced Zy-biss), a house consisting of ground floor modules, with steeply pitched roof panels installed at site to create a second storey. The Xibis system was taken to the US for further market development. Despite considerable interest from customers in New Zealand, Australia and the United States, IBS collapsed in 1978 as a result of a number of factors including funding constraints due to the wider economic recession. It left a legacy of enduring innovations, one being the creation of the first one piece fibreglass showers, a product that remains in production today. The Xibis combination of modules plus panels is one of the first examples of hybrid prefabrication design in New Zealand prefab history.

The modular influence was clearly popular during this time as several other experimental businesses were launched based on this theme. Light Modular Construction (LMC) and Modulock used modular language, although both were panel based prefab systems. Architect Roger Walker was at the time using standardised planning and a kit of architectural elements in his Vintage Homes business, and the government experimented with modular design in 1974 with a ten unit project in Paraparaumu carried out by Kielich Modular Concepts.

Light Modular Construction began operating in an enclosed factory in Whanganui in the late 1960s, became a subsidiary of Gemini Pepper Construction in the early 1970s, and was purchased by independent owners in 1977, but closed a year later. The LMC system consisted of load bearing closed wall panels that were pre-wired, fully fitted with doors and windows, lined with particleboard and clad with vertical board and batten. Pre-nailed roof trusses completed the precision-built system. After building 20 houses a year in its heyday, mounting financial problems in the mid–1970s were due to low consumer demand as a result of the recession.

The Modulock system began in Auckland in the early 1970s and was bought by Lanwood Industries from receivers in 1981. It consisted of a panel and postgrid-based system with solid timber vertical shiplap interior and imported plywood on the exterior, topped with a skilion roof made of a rebated beam and sheet system. At its peak, it achieved production capacity of 500 houses per year, an export deal with Australia and houses supplied to the Pacific Islands.[16] The business encountered difficulties when the Structex cladding on their homes experienced material failure in the late 1980s.

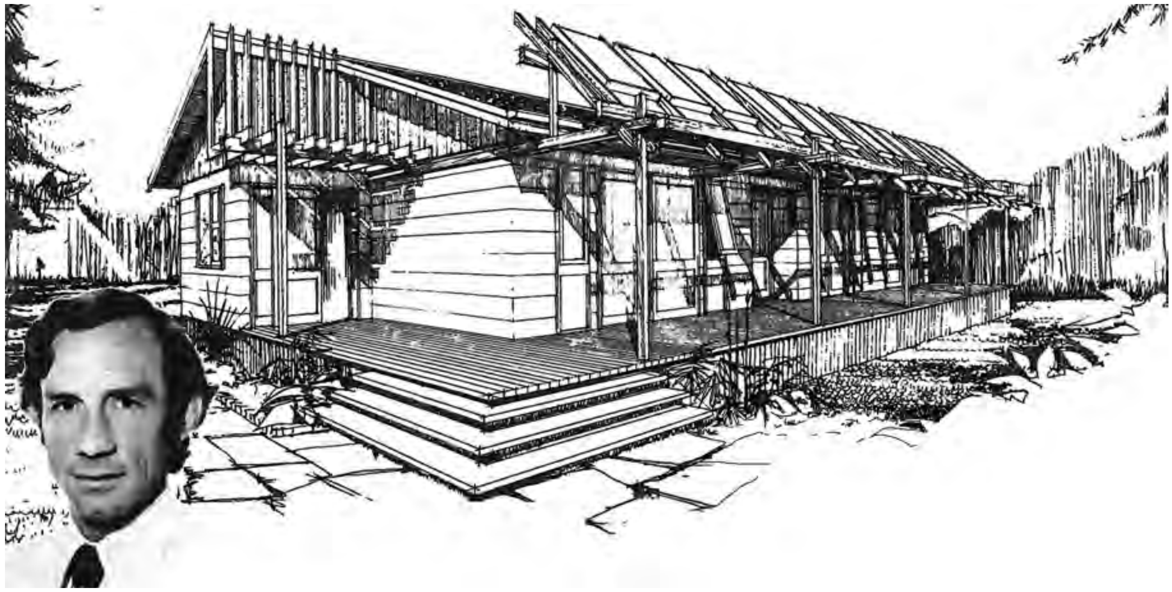
The business never fully recovered from the adverse publicity and legal bills, despite repairs being made at the cost of the material provider. In an effort to save the company, they rebranded as Pacesetter and Finemark Homes and offered a different selection of exterior cladding options. Despite supplying offshore markets and a large 100 unit housing project for the 1990 Commonwealth Games in Auckland, the mid–1990s housing



Perspective of IBS bathroom, kitchen and laundry service core.

Light Modular Construction panel corner joint detail.

Light Modular Construction panel assembly.



Keith Hay Energy saving Telethon home and Prof Harold Marshall, early 1980's.

Typical Vintage Home with standardised neo-Gothic dormer windows.

market downturn dried up consumer demand and Lanwood closed its operations. Lanwood's John Lockwood suggested that the success of any housing product is a function of marketing in the first instance rather than innovation and technical expertise. Today Modulock Portable Buildings are rudimentary site units made by Lanwood in Palmerston North from steel insulated panels that bear only the brand name in common with the original housing product.

Wellington architect Roger Walker began Vintage Homes in 1974 as a way to make architect-designed homes more affordable to a wider range of clients. They were inspired by Colonial and Gothic forms and underpinned by rational construction, a standardised planning system and repeated design elements. Walker was successful in producing a number of iterations, but an inability to adequately cover overheads led to the company downfall. Walker with architect Delisa Lovie went on in 2004 to explore Triboard panel construction in a business partnership titled Pod that resulted in a custom designed Queenstown home. In 2008, Walker continued his interest in prefab housing designing several plans for Strawberry Homes to make in their Napier factory using Metrapanel reconstituted timber panel construction.

Keith Hay Homes, McRaeway Homes and Lockwood Group were three companies that survived the late 1970s economic recession into the 1980s, an era of proliferating consumer choice and a slower period for prefab housing as the market turned its attention to larger and more luxurious dwellings. Keith Hay pioneered Keith Hay Homes (KHH) in 1949 when he began relocating second-hand buildings after a foray into caravan building. Construction of complete houses began in the controlled environment of their Morningside yard where Hay used pine instead of native timber to speed up production processes, as well as cutting labour costs, and incorporating new plastics and other innovative materials.

Through the 1960s and 1970s KHH became established through the supply of housing for the South Island hydroelectric schemes. Today, KHH, managed by son David Hay and employing third generation family members, continues to offer a range of commercial and lifestyle transportable or traditional site-built buildings aimed at the low-cost end of the market.

McRaeway Homes was started in 1965 by Ian McRae and supplied the Upper Waitaki hydro scheme with 250 pre-cut and pre-nailed kitset garages from its Timaru facility. In the late 1960s, an A-frame housing business was bought and turned into a kitset that sold over 2,000 homes. Subsequent housing kitsets sold over 3,500 houses around the country until the mid 1990s when customers demanded more customisable home packages.

In 1992 McRae's daughter Raewyn became director and sales manager, initiating a period of 20 years of exploring alternative options to the kitset or complete building. McRaeway Homes experimented with a modular joint venture in West Auckland and conducted a research trip to the United States looking at 12 modular building companies that had converted from kitset. An exploration into architect-designed housing ranges occurred to help dispel market misperceptions of transportable housing being cheap and poor quality. In 2008, the business envisaged that architect-designed prefabricated housing, would be their core business within the next ten years. However a change of ownership in 2011, saw the direction shift away from offsite construction towards traditional construction, for the first time in the business' 50 year history.

Lockwood emerged in the 1950s as a solid timber component based system and gained international exposure in the 1970s as the construction system for the New Zealand World Expo Pavilion in Osaka. With nationwide coverage through franchises and strong marketing through show homes, together with architect inspired ranges, they have established themselves as New Zealand's longest serving prefabricated housing providers. Today, Lockwood is specialising in upmarket secondary and lifestyle homes as discussed in the next chapter.

McRaeway A-frame home.

Since 2000, the international 'green modern prefab' movement has also reverberated in New Zealand with a wave of emerging prefab products boasting a neo-Modernist aesthetic and sustainable design features. Resurgence in interest in prefabrication is buoyed by popular publications from Europe and North America and magazine style websites.

A New Zealand business born during this revival era was Alpinehaus. From 2003 to 2005

Alpinehaus dwelling being positioned for lowering at site.

Alpinehaus produced eight homes together with house transporters Clutha Homes of Balclutha. Their aim was to be affordable and simply designed, drawing on the vernacular of the bach or crib. They used standard plans built by traditional means which were then transported to site as a complete building. They gathered a lot of market interest via their website and word of mouth, but went out of business when the consumer market demanded larger customised homes, that put them into direct competition with established design-and-build networks with greater economies of scale.

Architect Andrew Patterson designed the Relax Series for Architects Homes, resulting in 15 custom prefab homes built between 2002 and 2006. Patterson's own bach provided the prototype for these transportable homes. The eventual demise was attributed to high transport costs, infrastructure issues and lack of a sufficient consumer market. Several significant contemporary architect-designed prefab projects never made it off the drawing board in the last decade. In 2003, a team of architect Stuart Gardyne, branding specialist Ray Labone, industrial designer Peter Haythornthwaite and furniture designer Humphrey Ikin collaborated on the design of a panel based housing system that could produce infinite design variations when used with a series of components. The team was design heavy but lacked investment backing to produce a prototype. The group intended to target the international market with a quality housing system, but were faced with challenges from differing geographical conditions, cultures and construction compliance. They pledge the project can be resumed if research and investment issues are addressed.

In 2004, Wellington based Herriot Melhuish Architecture (HMA) began working on a range of modular transportable accommodation dwellings for a site in Marehau, near Nelson. Architects John Melhuish and Max Herriot chose prefab due to the site isolation, flood plain restrictions, and cost advantages of factory production. Decking, linking volumes, and an ablution block were planned to be built at site to complete the development. The project did not proceed due to a lack of client financing, impacted by higher site services costs than were originally anticipated. Several exemplars such as the internationally recognised bachkit did make off the drawing board into prototyping and production and are introduced in the following chapter.

On Prefabs Past

There are very few examples of historical prefab housing systems still in production and prefab housing companies that remain in business today, despite many heroic attempts. There are three main reasons for this; macroeconomic factors such as the 1978 recession, design and manufacture shortcomings that didn't allow for enough customisation to meet changing client demands, and sociocultural issues around communication and marketing. An overall lack of financing, marketing and customer awareness has caused the demise of many prefab businesses and the loss of many innovative systems to the construction industry and wider public.

Enduringly successful businesses are the ones that we are familiar with today, such as Lockwood Group, Keith Hay Homes and De Geest Construction. Lockwood is a great example of a business that has understood the cross-disciplinary character of prefab right from the outset. Prefab exists at the intersection between marketing and building, communication and innovation, design and business. Some of the key lessons are the potential use of unskilled labour under guidance of a trained professional to assemble prefab homes – as used in the State House panel programme, government led research and development influencing long-term industry uptake of technologies – as in the introduction of pre-nailed roof trusses and wall frames, and the success of collaborative marketing efforts – such as the popular 'parade of homes' and show home events.

It is also clear that New Zealand architects are very interested in pursuing prefab building solutions. There will be countless other prefab housing schemes carefully filed away in architecture and design offices around the country. This overview is intended to bring some hidden gems into the light, where they can be acknowledged for their contributions to our rich legacy of innovation, invention and intrigue.

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Kiwi Prefabrication Today

PAMELA BELL

'GREEN MODERN prefab' as it is known by many in the international design community, refers to the contemporary prefabrication renaissance. This has come to describe an aesthetic style of smaller, more energy efficient prefabricated housing characterised by open and flexible spaces. The renewed interest and optimism for architect-designed prefabs has been dubbed both a movement and a miniphenomenon. The starting point of this renewed interest was in 2001 when *Dwell* magazine published an article on prefab housing. Then editor Allison Arieff described the subsequent reaction as a prefab frenzy. The same year here in New Zealand, the refined design of the bachkit heralded the start of a local resurgence of interest in architect-designed prefab homes.

Dwell cover February 2009 issue.

The international prefab revival has been fuelled by rising consumer expectations and digital-based technology that has enabled the delivery of high-quality customised housing solutions. In the United States where there is an established manufactured (formerly known as mobile) and modular housing market, it has been estimated that as many as a third of all new single family houses built are either modular or manufactured homes.[1] Worldwide, architect-designed prefabs are growing their market share, making up 10% of the United States 6.5 billion dollar modular home market in 2004. Most recently tight macroeconomic conditions are proving to be challenging and reducing the output of new housing in many countries, including our own.

Contemporary New Zealand prefabrication is associated with stories of adversity and persistence – the great kiwi battler. These are also stories of the regions from Kaitaia to Timaru, Matamata to Wanaka and everywhere in between. Small towns may not have the consumer demand that urban centres have, but they have ingenuity, space, and time to rustle up a good idea or two. The following case studies are grouped according to their prefabrication typology or the size of their prefab parts, whether component, panel, module, hybrid or complete building.

Component-based Prefab

Component and stick housing packages are commonly referred to as kitsets and have been used for years by design and build businesses. Typically, these systems have been assembled by either the house owner or a contracted builder. This market is changing due to the recent 2012 Restricted Building Work (RBW) legislation which means only Licensed Building Practitioners (LBP) can design and build homes.

Pre-engineered, precut and prenailed roof trusses and wall frames are components used in an estimated 98% of new residential construction.[2] This extensive use is not commonly acknowledged as prefabrication, due to the widespread misperception in NZ that prefab is confined to modular or complete building typologies. Prenailed frames and trusses are supplied by large national networks of timber suppliers, such as Carters Manufacturing, PlaceMakers, ITM and Mitre 10, as well as small independent local manufacturing facilities. The pre-nail industry is dominated by two intensely competitive nail-plate manufacturers, Mitek (with 91 fabricators) and Pryda (with 40 fabricators). Both manufacturers provide engineering software to design components and direct machinery, as well as supplying computer hardware, plant and machinery, advice on factory layout, plant audits, best practice guidelines, ongoing education, certification and association support.

Not all roof truss and wall frame components are made of timber. Roll-formed precut light-gauge steel is gaining popularity for residential structural systems, with several house building companies experimenting with establishing steel framing in the NZ housing market. Suppliers of precut lightsteel components include Roll-forming Services, Rezlab, Frametek, FrameCAD and Zog.

Custom architect-designed homes account for about 5% by volume and 11% by value of new houses in New Zealand. Almost all utilise prefabricated components such as laminated timber joists and beams, structural steel frames, cabinetry built away from the site, window and door joinery systems or precast concrete technology. Custom prefab architecture has recently been designed by architects such as Assembly, Jasmax, Studio Pacific, Herriot Melhuish, Geoff Fletcher, Gerald Parsonson, Tennent+Brown, and Wilson & Hill. There are also predesigned component-based residential systems such as Box Living by Auckland architect Tim Dorrington and Ekokit by Hybrid Homes in Nelson.

CNC machinery cutting timber for frames and trusses, at PlaceMakers.

Carters Manufacturing

Carters Manufacturing is a division of Carter Holt Harvey (CHH), New Zealand's largest privatelyowned company employing 9,000 people across 130 locations in NZ, Australia and Asia. It is the biggest earner of NZ wood product exports which are collectively worth over three billion dollars. CHH is one of two major timber retailers, the other being PlaceMakers owned by Fletcher Construction Company. The CHH Wood Products group manufactures structural timber, plywood, laminated veneer lumber (LVL), medium density fibreboard (MDF) and particleboard.

Carters Manufacturing is an example of a facility that fabricates prenailed timber roof trusses and wall framing using engineering by Mitek with

Component-based pre-nailed roof truss and wall frames.

Gang-nail foldedsteel jointing components. The measurement and cutting of timber lengths is coordinated using extremely accurate computer numerically controlled (CNC) machinery. Final assembly into trusses and frames is by hand held nail-guns on table-top jigs, before stacking and wrapping to await delivery. Work flow is coordinated by Carter's Batch-cut program to produce on a just-in-time basis. Until 2008, the Carters 600m^2 Rotorua factory employed up to 18 people and was capable of producing framing for a 220m^2 house in a single day. They also produced laminated veneer lumber (LVL) window lintels, beams, floor joists and fruit-bins in an effort to even out cyclical construction demand.

A large network of frame and truss makers nationwide produce similar products. The Frame and Truss Manufacturers Association (FTMA) has about 60% of these fabricators under its umbrella and gives quality assurance branding to complying products. Carters Manufacturing Rotorua was supplying almost half of its production to design-and-build businesses, and the remaining half to small local residential and commercial contractors. Their prenail operation's greatest challenges were from consent compliance

RIGHT: Bachkit floor to ceiling glazing slides away to bring the outdoors inside.

Bachkit 'complete' floor plan option.

Bachkit north view to outdoor room with roof 'woggle' eliptical cut out.

costs, inclement weather affecting yard work and the cyclical nature of the building industry.

Bachkit

An adroitly worked example of architecture as commercial product.[3] The bachkit is an architectural product designed by Andre Hodgskin in 2000 with input from Holmes Consulting engineers, communication and marketing firm Mandela, graphic design company Seven, and construction company Maddren Homes. Replica Architects bought the bachkit housing system in 2001 to add contemporary low-pitched design to their selection of traditional pattern-book homes. An architectural design and project management company, Replica went on to sell a number of bachkit iterations to clients in New Zealand, Australia and Tahiti.

The bachkit design is based on standardised planning with five additive models starting from the basic pavilion and extending to a full version complete with deck and studio pavilion. The system consists of precut, preformed and premade components delivered to site as a kitset. These include steelwork, subfloor timber, wall framing, doors and shutters, track system, roof ellipse and flat-pack internal cabinetry. Replica tried to extend this current level of prefabrication by investigating an aluminium-frame system with plywood and plasterboard infill. In 2010 Replica investigated containerisation of kitset elements for inaccessible sites, as well as a modular prefab approach.

Bachkit's simple pavilion is reminiscent of mid–20th Century Modernist architecture, complete with a roof 'woggle', an elliptical-shaped cutout that gives it a distinct aesthetic as New Zealand's most recognisable contemporary architect-designed prefab. Its slick marketing image generated a lot of media interest, but to date this has not been backed up by the extent of sales. The bachkit's prefabrication process has been fraught with difficulties, failed research and development alliances, weak market demand, public misperceptions, and costly regulatory processes. These have caused Replica to look offshore to export markets in the Pacific and to establish a distributorship in Australia. The evolution of bachkit is of note for its separation of initial design and product creation from the ongoing fabrication and market supply, a willingness to explore further prefab typologies, and the search for an offshore focus to increase market size.

Lockwood system: joint and section of insulated board.

Lockwood

Dutch émigrés Johannes La Grouw and John Van Loghem started Lockwood Homes in 1954. La Grouw brought experience in construction, design and Dutch prefabrication methods, which complimented the sales and marketing background of Van Loghem. Together they established a factory in Rotorua near the pine forest industry and began producing five holiday homes a week. In the 1960s they developed a national franchise network which

now enables the Lockwood Group to build up to 500 houses per year, a total of over 40,000 houses by 2008. Several of these have been to overseas markets, such as Australia, Pacific Islands, Russia, the Middle East, Peru and Japan. This is as a result of international exposure and sales initially gained when Lockwood built the New Zealand Pavilion at the 1970 World Exposition at Osaka, Japan.

The Lockwood patented component-based system is made up of polyester-resin coated aluminium sheeting pressed into solid pine boards that then interlock with each other on site to make walls. These walls are joined by aluminium jointing profiles at junctions. The resulting wall system is robustly attached to foundations below and roof above with vertical steel tie-rods. The overall assembly process takes about half the time of a traditional stick-built house. More recently, Lockwood has integrated closed-cell polyethylene foam insulation, either within the board itself or within a new 'Super Wall' system.

The success of the Lockwood brand is the result

Lockwood's EcoSmart architect-designed prefabricated housing.

Interior of Lockwood's EcoSmart showhome, Rotorua.

Trower Panel internal wall system, with honeycomb structure and plumbing revealed.

of over 50 years of consistent marketing through show homes, plan-books and advertising. The brand has been supported by a franchise system where the Rotorua factory supplies materials, components and marketing to franchisees that are responsible for their own show homes, processing design plans and site-based construction. The Lockwood plan-books act as conversation starters between clients and sales agents, rather than as standard design templates. Lockwood attests that no two homes produced have been exactly alike.

The Lockwood Group has recognised the marketing benefits of architect-design and aligned its products with high profile architects through the 2003 Pete Bossley and Associates range and the 2008 EcoSmart Home series by architect Dave Strachan of Strachan Group Architects (SGA). The sales of these homes are a low percentage of total sales, however they are a drawcard to get people to come and investigate, and recognise the potential for architect-design. The show homes are popular – over 10,000 people visited the EcoSmart show home in Rotorua during its opening in 2011.

The longevity of the Lockwood business has been challenged by competitors, cultural shift, and consent compliance. The Lockwood Group experienced a cultural shift in the 1980s when the market reacted against perceptions of standardisation. This was at a time when the construction market swelled with an increasing range of options; together with economic prosperity and an increased desire for individualisation in housing. In more recent years, Lockwood Group has joined with competitors, Fraemohs and Intalok as well as Organic Building NZ, to form the Solid Wood Building Initiative.

Lockwood's recent strategic focus is to move past precut components and panels towards modular construction, to incorporate more CNC technology, update processes and systems, and introduce new manufacturing machinery. In mid–2009, they invested over six million dollars to upgrade the Rotorua headquarters and develop a timber processing machine which could increase productivity from 300 houses a year to 3,000. Lockwood plans to send these machines to offshore markets and set up franchises on the ground, rather than continuing with housing kit export. The Lockwood Group was headed by Jo La Grouw (Junior) until 2011. It remains one of New Zealand's foremost prefabricated housing companies, with 28 franchisees nationwide, and a line of affordable transportable housing under the Initial Homes brand.

Panel Prefab

Prefabricated panels in New Zealand are created in a number of ways; compressing layers of timber, lining and cladding a structural frame, sandwiching insulation between wooden or steel substrates, or casting concrete in panel forms. Juken New Zealand's Triboard and Fletcher's Metrapanel are two examples of a three layer compressed-timber panel system. Metrapanel was developed by Fletchers in 1996 at The Laminex Group plant in Taupo, and the rights for re-manufacture have changed hands several times, currently held by Metrapanel in Huntly. Over 250 Metrapanel-based homes are built each year through their network of 30 builder/installers. Their Black Heart sandwich panel system comprises two layers of 36mm Metrapanel on each side of 170mm polystyrene insulation, with an overall insulating value of three times the standard wall value.

Frame-plus-board panel systems

Grove Lifestyle Homes and Trower Panel are examples of businesses that manufacture frame-plus-board panel systems. Grove Lifestyle Homes are supplied from a Porirua factory making prenailed and preclad wall panels together with traditional truss and frame-based construction. Matamata's Trower Panel specialises in interior wall panels made of reduced timber framing with a glue-pressed honeycomb cardboard core. The interior walling of a 200m² house can be installed at the building site in just a single day. Trower Panel's main factory was established in Matamata in 1967 by Tony Trower and is now run by his son John. During the construction boom of the late 1970s and early 1980s they supplied up to six house lots a day.

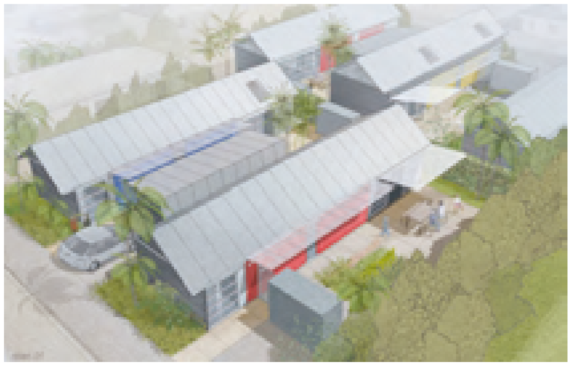
Solidwood panel

A solid timber panel system Touchwood is screw-fixed to conventional floor and roof construction with a variety of exterior cladding options. It was started by Corgi La Grouw, the son of Lockwood's founder, after working for 35 years at the Lockwood Group and selling his shareholding to brother Jo La Grouw in 1998. The family operation includes Corgi's son Brooke and is aimed at a lower priced market than Lockwood, with Touchwood house prices starting at $150,000 dollars ex-yard. The Auckland-based firm, like the Lockwood Group, has a nationwide network of assemblers and a Rotorua manufacturing facility.

Structural Insulated Panels (SIPs)

Sandwich panels of either metal sheeting or timber composite board with a rigid polystyrene or polyurethane filling are known as SIPs. They are typically used as a cladding material, most often in metal for cool-stores and industrial buildings but also have long span structural capacity. They are supplied by companies such as Bondor, Lanwood, and Kingspan. Levin's Thermawise Homes use paint finished or texture-coated metal exterior SIPs and

Touchwood wall panel assembly and wall panel assembly completed.



Competition entry by Geoff Fletcher Architects for Starter Home competition 2009 using metal SIPs panels as roofing.

Building a High Performance House using SIPs.

Metrapanel interior walls for housing they supply within New Zealand and the Pacific Islands. Several architects have experimented with one-off houses, using metal SIPs as walls or roofing for example the Architecture Workshop Seymour House of 1995, Geoff Fletcher Architects' own house, Strachan Group Architects Unitec Studio 19 house, and Irving Smith Jack's Fridge House.

SIPs panels for floors, walls and ceiling/roof structure can also be made of a magnesium oxide based building board (MgO board) with insulation infill, such as those made by MagRoc. The panels come in standard sizes or can be manufactured to order to include preformed door and window openings, roof pitch rakes and bevels and power and lighting outlets. A typical 200m^2 plus home on a prepared floor can be closed in and weathertight in 2–3 days.

Timber Structural Insulated Panels (SIPs)

These have been available for half a century to European and North American manufacturers but the technology is only just becoming available in New Zealand, despite Juken New Zealand (JNL) manufacturing oriented strand-board (OSB) that is used for facings of SIPs panels overseas. According to the United States SIP Association, the panels are extremely strong, energy efficient and cost effective as smaller heating and cooling systems are required, which reduces life cycle running costs.

Currently, a locally made SIPs product is being developed for market. Other businesses have chosen to import SIPs panels, such as Kingspan Tek-panels from the United Kingdom, and Premier SIPs from the United States. The High Performance range of houses by Salmond Architecture includes a SIPs house, and several SIPs homes have been built recently in the Central Otago region.

Cross Laminated Timber (CLT)

Essentially jumbo plywood, CLT is made up of timber boards. It can perform as floor, wall and roof panels, and can function as a complete structural system for a wide range of building types. The first CLT panels in the southern hemisphere were made on a European vacuum press in early 2012 at the XLam factory in Nelson. The XLam panels are profiled by CNC machine to meet specific project requirements, with surfaces and edges precisely cut, grooved, slotted, routed, or drilled to receive other structural components, connectors or services. CLT is very strong and has spanning capacity in both directions. Compared with concrete, the light weight of CLT construction and increased spanning capacity of floor panels can substantially reduce foundation costs. CLT performance is the same as solid timber and thermal insulation increases with thickness.

Precast concrete panels

Manufactured in factory conditions, these differ from tilt-up panels which are made at the final building site. Precast panels offer higher quality and time savings, as well as a wide range of finishing options and interesting texture possibilities. The residential sector only uses about 1–2% of the NZ manufacturing output, the rest being used by commercial construction. The houses that are being built using precast are high-quality architect-designed homes due to additional costs for individual panel custom design. Recent material advances include light-weight precast panels that use pumice as aggregate, such as Wilco's Litecrete.

Sandwich-panel systems

These panels consist of a thick structural internal concrete wall tied to a thin exterior concrete wall using high-strength nonconducting glass-reinforced-plastic anchors across polystyrene insulation filling. The insulated thermal break ensures temperature stability, reduced condensation and lower life cycle costs. Thermomass is an example of a concrete sandwich system.

Light gauge steel based composite

Panel systems from light gauge steel were developed between 2006 and 2009 through the Composite Structural Assemblies (CSA) programme. This was led by the Heavy Engineering Research Association (HERA) in collaboration with industry and tertiary research providers, under a Foundation for Research, Science and Technology (FoRST) grant. The key outcome was the development of a light weight, load bearing, composite panel using alternative filler materials such as concrete or polyurethane foams. The panels were intended for use as cost effective walls, roofs and floors in commercial and residential housing applications.

Precast concrete panels assembled in residential construction.

When the research period ended, New Zealand and Australian patents were sourced. The concept proved cost competitive, but the capital investment required to set up large-scale production proved prohibitive in a constrained economic environment, so the industry partners suspended the panel's further development.

Triboard

Japan's Juken Nissho (JNL) purchased the Northern Pulp timber mill in Kaitaia in 1991 and went on to double production through a second line, and established mills in Gisborne and Masterton. Historically, the Kaitaia mill has supplied 80% of its output to the Japanese market, and has only recently looked to local and Pacific markets as Japan's demand has reduced. The parent organisation has supported an extensive research and development programme enabling over 200 different product code types to be created. Compressed timber sheet products include strand-board, oriented strand-board (OSB) and Triboard.

Triboard is a structural panel system consisting of a three layer composite board of strand core and fibre outer surfaces. It is made by soaking wood chips in resin and compressing them into four metre long moulds resulting in finished panel thicknesses 10–100mm. It is re-manufactured by associated companies such as Durapanel Systems whose role is to prime, cut and router using custom computer-aided-design and computer-aided-manufacture (CAD/CAM). Triboard can be used for floors, walls and ceilings with dual functions of structure and surface, in place of traditional timber framing and plasterboard. For this reason, it saves time at the site and increases equivalent standard floor areas by 6% due to its reduced wall thickness.

The construction process is significantly different to traditional methods. The house is built from the inside out. The 36mm thick wall panels are lifted into place by crane, Hiab or manually and then butted against each other for stability prior to installation of 18mm thick ceiling panels completing a structural bracing diaphragm. Traditional roof trusses, insulation and external cladding are then installed to complete the house. With the insertion of a ridge beam, Triboard ceilings can also be raking to achieve a variety of volumes. The uptake of JNL's Triboard has been challenged by competition from other panel manufacturers and traditional construction industry resistance. Despite these stumbling blocks, up to 400 homes are built each year by both Triboard and Metrapanel installers.

Triboard House assembly: stressed-skin floor panels, Triboard exterior and interior wall panels, stressed-skin ceiling and roof panels.

Durapanel

After previous experience as a Triboard re-manufacturer Ian Stewart established Durapanel Systems in Awanui in 1994. It has been steadily growing ever since, with acquisitions of surrounding factory buildings, a new spray booth and CNC machinery. The re-manufacturing process involves application of primer in a spray booth,

High Performance House series.

a vacuum lifter to transfer it to the CNC laser-cutter which produces the final shapes according to a CAD plan. These panels are then numbered, stacked, strapped and assembled into flat-packs for transport to site. Triboard walls are considerably more durable than traditional plasterboard walls, but they lack acoustic insulation and space for ducting. This means the design must allow for plumbing fixtures to be backed onto external walls or cabinetry and pipes to be run through subfloor cavities. The re-manufacturing process uses a router to make recesses to hide electrical conduits. There is very little wastage, with door leafs reused when cut from their wall panels, and offcuts from window openings reused as cabinetry shelving.

Durapanel worked alongside JNL, Opus International and Worldwide Building Systems on the design and assembly of a three-bedroom Triboard House aimed at the starter home market. The house was designed using as many JNL materials as possible in order to control costs and supply. Strand-board stressed-skin panels were used for floor and ceiling, and laminated veneer lumber (LVL) studs, battens and Triboard panels with insulation were used for exterior walls. The planning was based on a four metre module to coincide with the Triboard panel sizing and to reduce plastering costs. A show home was completed at the Durapanel site in mid–2009, and took only seven days to close in and make weathertight.

High Performance House

Wanaka's Salmond Architecture designed the High Performance House range. The first house was built using timber SIPs in 2010 near Albertown, Central Otago. The High Performance House series is an adaptable building design system that uses combinations of prefabricated pavilions and links to create customised and affordable site specific homes. The homes use predefined detailing to ensure a measured level of sustainable performance and energy efficiency. The Albertown house was the first house to be built in the series. Imported Kingspan Tek-panels from Germany were used for walls, ceiling/roof, and were installed in a matter of hours by hand and Hiab. The SIPs panels consist of chlorofluorocarbon (CFC)–free oriented strand-board (OSB) injected with closed-cell urethane, eliminating the need for adhesives. The superinsulation (R5) and airtightness of the wall construction have a 30 minute fire rating. Ventilation is with a two-way heat transfer system that changes 3 air-cycles each hour.

Tilt Panel House Tasman Bay.

The 236m² house (incl. garage) was built by Kiakaha Developments.

Tilt-Panel House

Nelson-based Jeremy Smith of Irving Smith Jack Architects designed the Tilt-Panel House in 2007. This family home sits within a new suburban subdivision, bordered by a forest reserve and overlooking Nelson's Tasman Bay.

The Tilt-Panel House was developed using a commercial approach to fabricating buildings with its structure made of precast insulated concrete panels. The two storey house used repetitive rectangular panels interspersed with full height glazing, in order to minimise complexity and cost of the panel manufacture. The concrete aesthetic is softened and warmed with the application of an exterior hung western cedar screen and internal plywood ceilings and joinery. The Tilt-Panel house's unconventional domestic construction earned it a commendation at the 2009 New Zealand Concrete Awards given in recognition of a residential building of outstanding achievement in the advancement of concrete practice in design, construction, rehabilitation or research. It also won a 2010 New Zealand Institute of Architects (NZIA) Local Architecture Award and has been published widely through NZ and internationally.

Modular Prefab

New Zealand does not have an established modular housing industry like that in the United States. Most businesses using the modular term actually use panel prefab, repetitive planning or standard material sizing rather than three-dimensional (3D) modular construction methods. McRaeway Homes is a business inspired by the US modular industry. Like IBS in the 1970s they visited US modular housing companies with an intention to bring to market a series of architect-designed modular houses and a display show home. These ideas never materialised because the economics didn't stack up, however several multiunit accommodation developments that do use modular methods have been realised, for example the Ahuriri Quadrant in Napier and the Chateau Tongariro extension in National Park. These were both built by Stanley Modular, at their Matamata factory.

Container House

A modular home of repurposed shipping containers was designed and built by industrial designer Ross Stevens of Victoria University of Wellington. The Owhiro Bay house has been extensively published internationally and has become a local Wellington icon. Three modular containers are stacked vertically above a garage, with their back turned away from the road towards the steep cliff site. Almost all materials used in the project were recycled or reused elements, redesigned in a careful way to create a highly refined house as industrial (bi)product.

Modular bathroom pods can also be found in hotels around New Zealand. The Rydges and the Quality Hotel in Wellington have bathrooms from De Geest Construction in Oamaru, and Auckland's Ibis All Seasons Hotel is fitted with bathrooms by PLB Construction Group in Huntly.

De Geest Construction

De Geest was established by Dutch émigré Albert de Geest in the South Island town of Oamaru in 1955. He built an innovative concrete-framed factory in 1969, in which it was large enough to build complete houses. This enabled the business to move from prefabricated bridge-beam components to the supply of 900 houses for 1970s hydropower schemes in the central South Island. A trip back to Europe provided the inspiration to supply houses with bathroom and cabinetry volumes together with flat-pack wall components to Cromwell for the Upper Clutha Power Scheme. This is an early example of hybrid prefabrication in New Zealand.

In 1983, De Geest built their first bathroom modules for a motor inn at Te Anau. Since that time they have supplied over 7,500 utility

Chateau Tongariro modular extension and final construction.

Interior of Container House
with reflective ceiling.

nonstructural pods to office and accommodation projects around the country and offshore to Australia and Vanuatu. The mid–1980s boom years saw De Geest factories set up in Otaki and Huntly. During this time they experimented with exporting houses to Japan and Venezuela as panelised components stacked flat into a shipping container, as well as a panelised indoor ensuite for use in renovations. The 1987 sharemarket crash forced a retreat back to Oamaru. Today, under son Brian De Geest's leadership, the business is primarily a commercial construction company with bathroom module production making up to half the workload dependent on demand.

The bathroom module construction process begins with prototypes that are tested and inspected by clients before production commences. The units are built from the floor up inside a factory using traditional construction methods. Modules are moved by forklift from station to station where up to twelve different trades work on them simultaneously. Panels are cut by hand controlled machinery, components are painted in the factory spray booth, and the completed unit is security-sealed, plastic-wrapped and plywood-braced prior to travel. Once at site, the first module is supervised by De Geest staff as it is lifted into place, secured, and connected to each of the major services, before hand-over to the project management team. Minimal remedial work is required due to the high-quality and minimal tolerances achieved in being built in controlled conditions off site.

Ross Stevens Container House
Owhiro Bay Wellington

Bathroom modules during construction at De Geest Oamaru.

Stanley Group delivered over 400 bedsit modules to create University of Auckland's Student Accommodation Project, 2011.

Modules manufactured in Stanley's Matamata factory.

Modules stacked three high at site in Auckland.

Stanley Modular

Matamata is the location of Stanley Group's Modular division established in 2004 from plant and factory that was originally Carters Modular. They completed a major multiunit refurbishment project at the Chateau Tongariro in mid–2005 using a similar method to that used in the US modular industry, where factory-produced units are wrapped and trucked to site, then craned and fixed into place on permanent foundations. The modular approach was chosen to adhere to strict Department of Conservation constraints and to avoid extreme alpine weather conditions.

In 2011, Stanley Modular produced 468 bedsit modules for the University of Auckland's Student Accommodation Project. The base building was designed by Warren and Mahoney architects with Holmes Consulting engineers. The modules were stacked three-up on a traditional concrete interstorey floor, to make up the 13 floors. The module design was by Dunning Thornton engineering consultants with Assembly and Motm Architects. The sophisticated and detailed exploded axonometric diagrams the consultants produced acted as both architectural and shop drawings for manufacture. It is estimated that the modular build saved several millions of dollars and nine months compared with a traditional construction system.

Other Stanley projects include architect-designed multiunit accommodation projects in Napier and Whitianga, as well as schools in Ruatoria and Albany. Stanley Group's international focus has seen them join the Modular Building Institute (MBI) and collaborate with Australia based Lend Lease Life on a retirement complex in Tauranga.

Hybrid Prefab

There are currently no built examples of hybrid module+panel standalone housing produced in New Zealand, although several concepts have been proposed. It is interesting that the hybrid typology has not been fully explored in New Zealand to date, as there are numerous benefits in this design approach. The combined use of modular and panelised existing technologies increases potential economic feasibility as well as collapsing the division between module and panel manufacturers in international prefabrication industries.

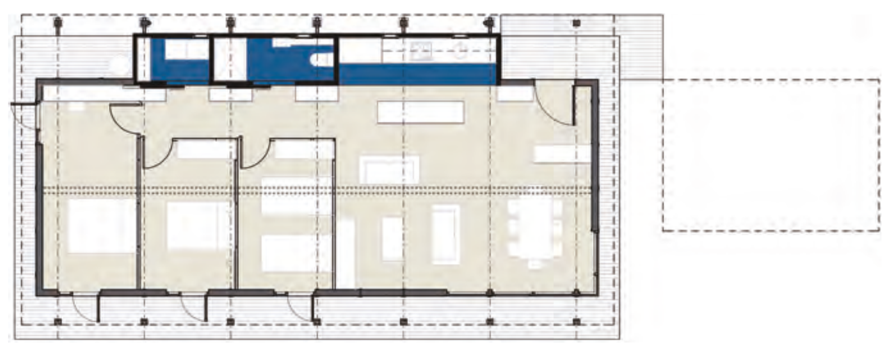
International hybrid module+panel design exemplars include the well-documented Loblolly House and Cellophane House by US architects KieranTimberlake and System 3 by Austrian architects Oskar Leo Kaufmann and Albert Ruf. Cellophane and System 3 were both shown at full-scale in the New York Museum of Modern Art *Home Delivery; Fabricating the Modern Dwelling* exhibition in 2008. The Loblolly House contains three utility modules, a precut aluminium framing system, and floor, ceiling and wall panels. The utility modules contain bathrooms, mechanical rooms and wardrobes in various configurations. The kitchen was installed on site. Cellophane House was similarly made of aluminium structural components, custom floor and roof panels, and prebuilt bathroom modules.

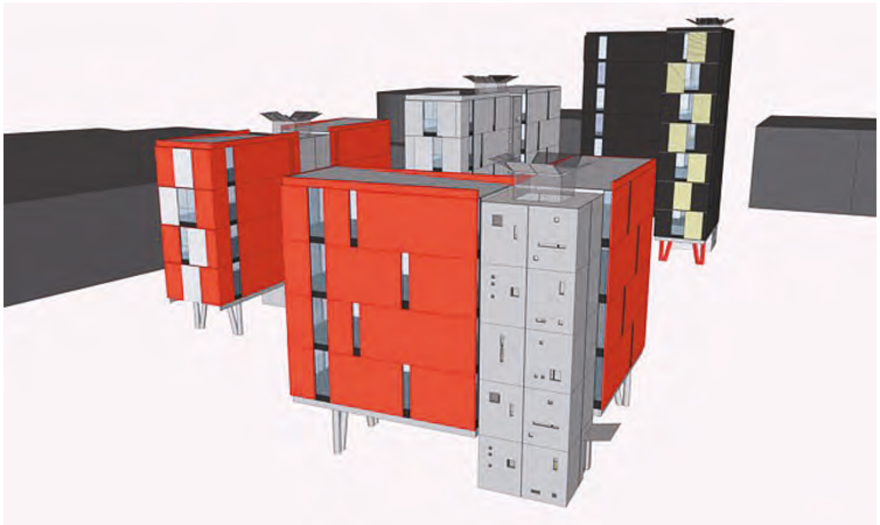
System 3 is a design based on a central shipping container-sized utility core with kitchen and bathroom placed at opposite ends, separated by a utility area with staircase and mechanical area. This core works together with panelised floor, wall and roof sections to make up the overall dwelling area.

Closer to home, Wellington architects Herriot

Quick Living Home, in Kuratau.

Module 1.2 by HMA.Floor plan showing module core+panel system and exterior view, below.





Multiunit hybrid module+panel construction.

and Melhuish Architecture (HMA) designed their Module 1.2 entry into the Department of Building and Housing 2008 Starter Home Design competition as a hybrid module+panel system. The utility module of kitchen, bathroom and laundry, was proposed to be set within bio-SIPs panel walls. The design made the final short-list of 20 entrants but only the winner was built.

The Wellington Company property developer, Ian Cassels, has experimented with prefabrication design in some of his projects. In 2008, he proposed a multiunit hybrid housing solution dubbed Model T as a reference to Henry Ford's motor car assembly line at the turn of the 20th Century. Cassels was motivated to provide a housing solution for under $200,000 by utilising leasehold land, prefab construction and a shared management structure. The design by architect Geoff Fletcher with Massey University has a hybrid two storey service module with panelised construction; tilt-slab concrete for the party walls, Triboard interior walls, and Kingspan aluminium SIPs roof and end-wall. These houses were planned to be grouped up to 10 at a time to offset potential negative effects from repetition.

A type of hybrid prefab system already on the market is Quick Living Modular Housing, designed by Christchurch based Module Creative. Contractor Nick Hall and retail designer Jeremy Pankhurst launched a range of sleek neo-Modern box-like designs in late 2008. Their approach was to package prefabricated components from a range of manufacturers and assemble them on site within a month. Modular kitchen and bathroom cabinetry come to site in a volumetric form but not as utility rooms with plumbing and electrical conduits in place. Steel frames, walls and windows were flat-packed for transport. Customers are limited to their selection of modular plans but can choose from a palette of colour schemes, materials and surface options. While not strictly hybrid module+panel, this concept begins to marry advantages of different component-based systems.

New Zealand's housing market is small and there is customer demand for differentiation. This indicates that an adaptable panel and service core design product using off-the-shelf parts is a logical choice. The hybrid module+panel typology offers significant unexplored potential for New Zealand prefabrication.

Complete Building Prefab

The widespread appeal of a complete building delivered to site is the magic of its instant delivery, an empty site one minute, then voila, a new home. House buyers benefit from being able to view a tangible show home so they can accurately visualise and understand what they are purchasing. Neighbours benefit from a lack of construction noise, dust, debris and traffic at the building site. Commonly referred to as portable, transportable, mobile or relocated, these kiwi prefabs along with kitset homes, have been the major types of prefabrication in New Zealand to date.

Portable buildings

Portacom or Portabuild and similar buildings are used for construction site offices and other short-term needs such as toilets and showers for events. They are usually made of metal SIPs, with steel or aluminium on either side of polystyrene insulation. Housing built using traditional construction methods in an outdoor yard prior to transportation is supplied by a number of businesses and referred to as transportable or relocatable. Contemporary exemplars of transportable housing include Laing Homes in Christchurch, Keith Hay Homes and Initial Homes nationwide, and until recently McRaeway Homes based in Timaru.

Mobile homes

These are similar to the US manufactured home industry where they are also known as trailer-homes. These caravan-like structures do not need building permits; instead they are approved by the Land Transport Authority to be considered as trailers with registrations and warrants of fitness. Towable caravans, campground cabins and motel units are made by a number of firms, several of which are based in the Greater Auckland and Waikato regions, such as Go Homes.

Recently there have been increased examples of architect-designed prefab homes. Many of these are aimed at the second home or bach market due to their smaller floor areas, but are also of interest to retirees or first home owners. Both iPad and K-bach can be made as a preassembled complete building in factories and are available for delivery in the North Island. The port-a-bach, Ecotech, Habode and i-houz are all made in Chinese factories so can be delivered anywhere in the world.

Wellington developers, Globe Holdings, launched a range of architect-designed

Strawberry homes Elsanta show home by Foster Architects.

Laing Homes' Smart House with Wilson & Hill Architects.

Habode being unfolded
at the final site.

transportable Strawberry Homes in 2008. The houses are constructed in their Hawke's Bay factory using the Metrapanel wall and ceiling system, then transported around the lower North Island. Architect Roger Walker designed the initial range and Angela Foster of Foster Architects designed a more recent series of houses. Other recent interesting prototypes include Cantilever Design's Bachbox, a fully towable Aquabach houseboat from Christchurch, and Axis Designer Homes by PLB Construction Group with Mark Frazerhurst Architects in Huntly.

Laing Homes

Grant Laing began relocating houses in 1992 and by 2000 had created an additional design-and-build brand, Laing Homes. Houses are supplied within a 500km radius from Christchurch to schools, lifestyle areas and the dairy industry. Standard dairy worker accommodation consisted 75% of total production during the dairy boom in 2007, with one farmer ordering a staggering 14 houses. Laing's construction yard has from 6–12 custom-designed houses in progress at any one time for 8–10 weeks before being delivered to site. The houses are constructed on a floor-plate using timber engineered I-beams as floor joists to eliminate squeaky floors. On this, Metrapanel interior and exterior walls are fixed before being clad in conventional lightweight waterproof materials. Internal finishes, fittings and fixtures are applied in the yard, so that single water and electrical connections can be made at site.

Laing credits a strong relationship with supplier PlaceMakers as being integral to the success of the house manufacturing business. He has enlisted the skills of several architects and designers over the last few years. Hill and Miles Architecture created the five-home Ultimate Range that was launched at the Christchurch Star Home Show in mid–2008, to a crowd of 14,000 people over just a few days. Architect Paul Wilkins collaborated on the monopitch Escape range of baches for alpine, coastal and rural environments. More recently, Laing Homes have worked with Wilson & Hill Architects on the minimal neo-Modern Smart House range as discussed in the next chapter.

Laing Homes' prefab housing is typical in the challenges it faces, including regulations that require building consents at place of manufacture and final building site, and consumer misperceptions that transportable dwellings are temporary. They would like to see more deregulation from councils, government subsidies for affordable housing, more debate about starter-house size, more consistent material supply and wider education on prefabrication.

Habode and i-houz

Fifteen years ago, Wellington designer Rod Gibson searched for a solution to the lack of timeliness of tradespeople and the resulting disruption to traditional construction. His design process began with international freight size restrictions and resulted in an ingenious unfolding design – the side panels fold down to complete an 80m^2 floor, while other hinged panels underneath fold up to form the butterfly roof. All the external wall panels, cabinetry, and appliances are stacked inside this single container form before being fitted into place once at site. An extensive multimillion-dollar research and development period resulted in a partial prototype in New Zealand which proved to be prohibitively expensive. Manufacture was moved offshore to China where 60–70% cost-savings could be made. An industrial design approach was taken to develop over 2,000 individual parts and a unique

TOP: Habode floor plan.

BELOW: Habode Governors Bay, near Christchurch.

Port-a-bach prototype during installation and opened with canvas covered bunk bed extension.

Port-a-bach interior storage wall containing all services and with open bunk bed extension.

patented wall-system of a singular floor-to-ceiling window frame with special transoms into which glazed or steel sandwich panels can be fitted. Both Habode and i-houz are overengineered compared with conventional buildings because of the 21 day voyage by ship from China. As a result of their robust engineering they are able to withstand typhoons and tropical storms making them suitable for seismic areas, extreme weather events and coastal locations. The Habode sells for approximately $175,000 to site.

In Australia, the distributor Habode Australia (HAPL) distributes Habode and targets i-houz to the mining industry through Western Australian-based developers Pindan. I-houz was developed for temporary housing of workers in inhospitable climates. The steel weatherboard-profiled container form arrives at site and expands widthways to create additional space. It can also potentially be stacked into multistorey iterations and costs approximately $100,000. With the addition of new models, more flexible kitchen designs, off-the-grid features and prefab foundation systems, demand was estimated to grow up to 600 Habode units per year in Australia and 200 units in New Zealand in 2009. However, the Habode team has faced numerous challenges that result from custom-designing thousands of parts, manufacturing offshore, and lengthy legal battles to protect intellectual property. Members of the original Habode team have gone on to develop their own China-based manufactured housing, such as Modular Housing Solutions' Ecotech Homes.

Port-a-bach

Wellington architects William Giesen and Cecile Bonnifait of Atelier Workshop designed the port-a-bach when a transportable holiday house was required for leasehold land. They were motivated by a lack of accessible and affordable architecture and the need to reclaim the concept of the original affordable bach. Their aim was to keep port-a-bach under $100,000 resulting in a clever and efficient design that evokes the raw and pioneering spirit of our early settlers.

Port-a-bach off the grid

The port-a-bach is made from a recycled shipping container which qualifies it as container architecture, also referred to as cargo-tecture. With the help of a China-based business partner and investor funding, the first prototype was produced in China in late 2007. Once at site, one long side of the container is hinged open to form a deck and reveal a glazed facade of hinged doors and adjustable louvres. Doors at a far end open and two single bunk-bed platforms insert to extend the space. Canvas covers can enclose this bunk-bed end and the deck to form a maximum of 36m^2 of extended living space. The interior comes complete with a long wall of cabinetry containing a toilet, shower, fold-out double-bed, and kitchen with

K-bach show home at Oakura Beach New Plymouth.

gas cooking, sink and under-bench fridge. The canvas-covered structures enhance the camping experience to be something between a tent, a caravan and a house.

The port-a-bach prototype received a lot of media interest, increasing their website hits from 20 per day to several hundred. One reason for the bach's wide ranging media appeal is its link with camping holidays and New Zealander's love affair with remote locations – potentially it could be airlifted into remote regions or transported between summer and winter sites. Giesen took a proactive approach to media generation, utilising friends and contacts, his Facebook web page and directly emailing architecture magazines. As a result media interest grew from local newspaper to national magazine, television, international websites and featuring in an international monograph. Atelier Workshop are content with the publicity that the port-a-bach has brought to the business as a flagship to attract new clients for their traditional custom work. Their design approach was extended to a proposed solution for displaced Cantabrians based on a larger 12m container. To date this concept is yet to make it off the drawing board.

Koastline Beachouses

Cheryl and Rocky Hawke of Kodesign Builders New Plymouth began their foray into prefabrication through the design process for their own small bach on a leasehold site at Urenui Beach, New Plymouth. Auckland architect Grant Boniface gave them a pocket-sized model to explain their project to friends which inspired them to think it would be a good construction technique to prebuild a house and then place it on a site. The resulting ultra compact bach won a NZIA design award for its design in 2005. In mid–2006 they joined GJ Gardner Homes with the idea that they would develop and distribute modular Koastline Beachouses within the wider network of 23 other franchisees. This proved not to be possible when the architect did not want to relinquish design copyright and the GJ Gardner network material supply proved to be too limited. This led on to the design of the K-bach by Wellington-based Studio Pacific Architecture. The resulting refined architecturally-designed beach house was built as a prototype in their New Plymouth factory and transported to a stunning site nearby at Oakura Beach.

Kodesign plan to offer a selection of models, including the Kabin containing a bedroom with ensuite and small living area. The K-bach has durable low maintenance materials such as plywood interior wall linings, stained cedar rain-screen, and stainless-steel screw fixings and pile legs. The 78m^2 space is cleverly designed with laminated veneer lumber (LVL) structure load-bearing outer walls that enable the nonstructural interior walls to be moved and adapted. There are several ingeniously designed features such as offset bunk-beds that make room for a wardrobe between them. It was originally priced at $280,000 dollars, which was about twice the price of lower-quality prefab houses on the market. This presents a challenge to communicate the architectural and construction quality when the New Zealand housing market is cost focused, simplifying cost references to price per square metre without taking spatial volume and build quality into account.

By mid–2009, due to tight macroeconomic conditions, the Hawkes' focus turned away from K-bach towards their GJ Gardner franchise – the launch of Koastline Beachouses was put on hold, and the show home put on the holiday home rental market. The K-bach remains a good example of high-architect-design, indoor factory construction and careful material selection to achieve a high-quality product. The outstanding issues are enduring ones – how to educate consumers about the value of architectural quality, and perhaps the need to consider spreading the development and initial setup costs of a prefab system over time and more than one built prototype.

iPad

Architect Andre Hodgskin of Architex Auckland followed the bachkit design with the iPad studio or bach. The prototype house was launched in 2007 at the Auckland Home Show where thousands of people visited. Further iterations have been built in the Marlborough Sounds, Taranaki, Auckland and Fiji. The iPad is available as kitset or complete building, and has been cleverly designed to extend past the transport restricted dimensions of its box-form. Once it arrives at site, it breaks out of its transport restricting virtual box, with winglike walls that extend to brace the house and conceal the opened sliding doors. The kitset component-based assembly process takes three people three weeks. Clip-on decking doubles the 50m^2 living area, and closely links the interior to the exterior landscaping reflecting traditional bach connections to site and mid–20th Century Californian space extending aesthetics. Like the bachkit, there are numerous possibilities for design iterations based on multiple module combinations to fit various site dimensions.

Taranaki iPad with doors open to landscape.

There are several interesting and well thought-out architect-designed details with electrical services and lighting attachments hidden away in a central conduit beam or within cabinetry. All services are contained on one side of the plan with an externally accessed utility cupboard containing gas heating, plumbing and electrical ready for singular site-based connections. Other well-considered details include the insertion of recessed

iPad prototype
promotional image.

roller blinds into purposely designed gaps in the edges of the ceiling plane, and the front-door-swing exactly matching the depth of the roof soffit.

Architex worked closely with building contractor Vistalite, who also supplied the steel structural sections and aluminium joinery. Traditional construction methods were used with steel post-and-beam structure and infill timber framing. Interior walls have been minimised to the wall of cabinetry and a central fireplace/bedhead, eliminating the need for plasterboard and wet trades. This paring back is in line with Hodgskin's goal to produce a more affordable alternative to his original bachkit design, and he has clearly achieved that with an estimated price of $125,000 to site. The iPad's design success is in its innovative approach to the restrictive limits of the necessary transport envelope; cost savings achieved through standardisation and reduced trades to site; and the design led iterative prototyping process starting from the bachkit, and being refined for future incarnations. A Taranaki-based iPad won the NZIA National award for Small Architecture in 2011.

On Kiwi Prefab Today

Prefabrication is an important way to improve housing quality and increase accessibility to architectural design, yet there are many challenges. Barriers to a strong New Zealand prefabricated housing industry include prohibitive start up costs, resistance from the traditional construction industry, widespread misperceptions about prefab design flexibility and misunderstandings of architectural quality.

Taranaki iPad entrance deck.

In response, contemporary approaches have been to target offshore markets and manufacture, take a flexible design approach to transport envelope limitations, maximise potential customisation through using smaller prefab parts, cross-disciplinary and industry collaboration, and use of marketing tools such as show homes, plan-books and housing events.

The building industry may still be based mainly on 200 year-old craft-based techniques, but the widespread uptake of prenail and small incremental advances occurring is evidence that New Zealand's house building process is capable of change over time, providing inspiration for the future uptake of innovative technologies and prefab building techniques. The next chapter will take a look at emerging prefab products, systems, and technologies influencing the kiwi prefab home today and tomorrow.

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[1] Rybczynski, W. Houses Made in Factories, *Slate* 20 August 2008 http://www.slate.com/id/2197176/slideshow/2197362/fs/0//entry/2197352/

[2] This chapter is based on first hand interviews and correspondence with New Zealand prefab industry participants.

[3] NZIA Awards Jury Citation 2005.

An Emerging Prefabricated Generation

PAMELA BELL

KIWI PREFABRICATION today has been buoyed by the recent prefab revival that has made everything old seem new again. At a time of critical housing demand, the wider industry is looking for ways to build high-quality homes as quickly and safely as possible. Prefabrication is a method that can deliver these results. Enthusiasm for increasing the use of prefab products and systems is moderated by the constrained economic conditions, limited investment and uptake by industry, and the wider international context for New Zealand manufacturing. This chapter looks at inspirational housing and radical built exemplars that are likely to inform prefab uptake by the next generation.

Recent industry-led precedents in prefab housing range from stand-alone to multiunit, custom-designed to replicable, and experiments that reframe the use of materials more commonly used in commercial applications. They all offer nontraditional alternatives to the crafts-based linear design and construction process that continues to dominate house building today. Importantly, they also offer glimpses of the next generation of kiwi prefabs. Several projects are introduced below, as grouped by attitudes to housing size, cross-disciplinary collaboration, nontraditional material use, greater levels of sustainability, and recently introduced materials and production systems.

Nano Whare by Unitec design studio led by Rau Hoskins.

Rethinking house sizes

Homes have been growing in size since World War II when material shortages limited house sizes. In the 1950s, $120m^2$ was the norm for a single storey three-bedroom house in NZ. This has grown to over $200m^2$ in 2012.[1] Micro house movements are gaining momentum offshore and are reflected in the Nano Whare by Unitec architecture students, James McNicholas and Azmon Chetty, under the supervision of Rau Hoskins. This seriously compact dwelling weighs in at less than $24m^2$ internal floor area, yet it contains all the ingredients needed for living.

Smarter Small Home

An Australian Smarter Small Home concept was adopted by James Hardie in New Zealand as a design competition in 2011. The brief was for a three bedroom home up to $140m^2$ costing no more than $1,500m^2. The home design features low embodied energy materials and a range of power saving appliances, along with energy efficient lighting. Reduced materials and minimised waste practices are part of the initial prototypes, with the intention to move into a panel-based prefabrication for future iterations.[2]

Cross-disciplinary Collaboration

The Canterbury earthquakes caused a shift in thinking about how housing can be delivered in short time frames to meet a wide range of urgent needs. A number of businesses began collaborating that would not have done so under business ‘as-usual. The result is the creation of several new housing models that can be dubbed ‘affordable architecture’ for their ability to mix high-end architect-led design with established housing manufacturers. Several of these houses became part of the HIVE Home Innovation Village at Canterbury Agricultural Park in Christchurch.

The HIVE was established by the prefabrication industry association PrefabNZ and opened in early 2012 to showcase high-quality, permanent, architect-designed, sustainable and affordable prebuilt homes. Development of the HIVE concept was inspired by European precedents of large-scale purpose-built villages that showcase 50 to 100 homes. By contrast, the HIVE was allowed to show ten houses for two years, according to its arrangement with the Christchurch City Council. Some stage one HIVE houses are outlined below.

Smart House

This is the first in a range of houses resulting from collaboration between David Hill of Wilson & Hill Architects and Grant Laing of Laing Homes. Laing Homes and Building Relocators have an extensive history in moving houses from their Christchurch base, having shifted over 2,000 buildings over the last 20 years, but this is their first time working with a high-profile architect. By comparison, Wilson & Hill have a wealth of experience in creating high-end custom-designed homes for prestigious locations, such as Christchurch's Port Hills. David Hill notes the benefit of the collaboration is showing the benefits of architecture applied to an economic prefab house to a wider range of people than their usual client base.

The result is an example of affordable prefab architecture starting at $220,000. The design is a neo-modernist styled pavilion with floor-to-ceiling glazed windows and an above average ceiling height that creates a sense of volume not normally found in a 98 m² house. The floor planning has been carefully thought out, with two bedrooms adjoining a generous dual-entry bathroom, and a large open-plan living-dining-kitchen area. Future iterations incorporate an additional bedroom,

Exterior and interior of the Smart House.

living or garage pod. The commonality between designing a home for transportation and for seismic activity was notable, as consideration for movement and flexibility for both is paramount. The roof has been designed specifically for transportation, with a low six degree pitch roof that allows for overhanging tree branches to slide off it easily. The floor uses joists made of engineered timber and the internal walls are Metrapanel reconstituted timber panels, in order to be durable and strong for movement. The Smart House is engineered to have extra strength to withstand high snow and wind loadings in order to make it suitable for popular South Island holiday locations in South Canterbury and Central Otago.

Park Terrace House

The Park Terrace House is the outcome of collaboration between long-established housing provider Keith Hay Homes and Auckland architecture practice Architex. Matthew Hay

Park Terrace House at HIVE Home Innovation Village Christchurch.

the grandson of founder Keith Hay, and Andre Hodgskin architect of bachkit and iPad prefabs, worked closely together to find the right balance between high-design features and affordability. Hodgskin intended to create a design solution that could meet the wide range of needs of an informed house-hunter on a limited budget.

The result is a cleverly detailed and generously proportioned two-bedroom house that can be constructed offsite in 8–10 weeks and transported in two sections. Once at site, the sections can be joined with decks in just a couple of weeks. The planning enables another two-bedroom module to be brought to site to complete a four-bedroom home. A key feature of the house is the low-pitch roofed living pavilion linking the two gable forms that contain utilities in one and sleeping areas in the other. This living area opens on both sides to partially enclosed decks that effectively double the usable living space.

Design details that are new to Keith Hay Homes include full-height glazed pocket sliding doors, negative details between junctions of different planes and materials, and the use of a single material for roof and wall cladding. A recessed lighting track in the open-plan living area runs the entire length of the space, cleverly concealing the joint between the two transportable sections. The house retails for around $300,000, proving that an affordable architecture can be achieved. According to Hay, this responds to a growing market where discerning customers are seeking greater living spaces and more design elements.[3]

Non-Traditional Material Applications

Materials commonly used in commercial applications are more recently being used to create comfortable homes. Precast concrete panels as used in the Tilt Panel House by ISJ Architects were discussed in a previous chapter, as was the repurposing of shipping containers to assemble a home by Ross Stevens. Stevens has gone on to produce a house from recycled cool-store panels for a rural Wairarapa site. The house is developing into an interesting hybrid between prefabricated panelised form and Steven's handcrafted approach to detailing and cladding. A completed 'fridge-panel' house is explained below, along with a Lego-like concrete building system.

Fridge House

This house is constructed from metal structural insulated panels (SIPs) usually used on large-scale warehouse or cool-store applications to produce an extremely economical house in the Nelson area. Dubbed 'Fridge House', this clever response to a clients' constrained budget was designed by Andrew Irving of Irving Smith Jack Architects.

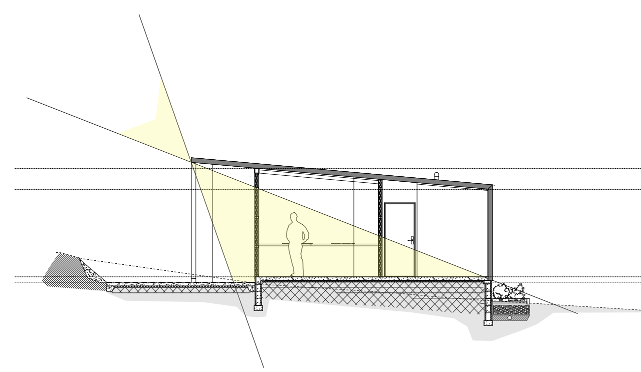
Irving comments that, "fittings and fixtures are recycled, invented or flat-pack-adapted throughout and located to allow ease of installation to the impenetrable shell walls."

The site was a challenging very cold, south facing location on a valley floor. Highly insulated SIP panels were used for roof and wall structure and cladding. Internal linings of plywood were applied and the exposed concrete foundation used as floor surface. The combination of materials used in dual-purpose ways, together with full-height glazing and efficient architectural floor planning, has resulted in an efficient and functional eight by eight metre home for the client couple that provides a generously proportioned, warm and light filled place to live.

Careful research and planning has resulted in a small but effective home that was delivered below the $100,000 budget and can now be efficiently heated in winter by a single electrical heater.

Rakaia House

New houses commonly use concrete as a floor structure and less often as the finished floor surface. Precast panels are used commonly in



Fridge House exterior and cross section drawing of Fridge House, Nelson.

Precast concrete Falcon Rakaia House.

Zuschlag House Arrowtown.

Custom panel assembly at site.

commercial structures and less often for residential buildings. Three-dimensional, or modular concrete forms are a recently developed niche led by companies such as Perrine Pod in Australia. Modular concrete is available in New Zealand through Falcon Construction, led by David Reid who formerly established the David Reid Homes design and build network.

The Falcon Cube system is a precast modular concrete system that has been earthquake engineered. A basic Cube module consists of an eight by four metre floor panel, a panel at one end and an open box-form at the other – the two long sides remain open. This creates a Lego-like building block that can be stacked in a number of ways to create a wide variety of structural forms. Once set in place, internal Metrapanel walls complete the desired floor plan. The speed of the system is impressive; a six module building was recently completed in 29 days.

Falcon worked with Allied Concrete on the Cube system Rakaia House at the HIVE Home Innovation Village in Christchurch. The house used a cast-in-place floor slab and precast end walls and box-forms and was fully complete within a four week programme. The four modules will enable the home to be moved to a permanent site when HIVE finishes in 2014.[4]

Towards Greener Prefabrication

Prefab has the potential to be a greener way to build, but not every project makes the most of this opportunity. There are several housing precedents emanating from New Zealand's colder climates in Central Otago, including timber SIPs houses and a Passive House influenced home. Several NZ companies are following the Passive House building-science based design approach originating from the German Passivhaus Institute.

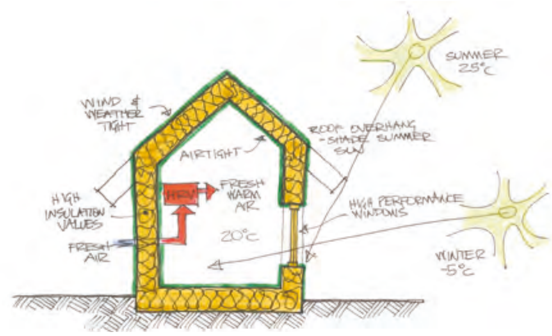
These prototypical homes demonstrate how prefabrication can be custom-designed by high-end architects, yet at the same time be based on simple principles and be able to be manufactured by small businesses in local factories. Sustainable design and engineering consultancy, GreenBeing, has been involved with a number of homes in the Southern Lakes District. At time of writing, a certified Passive House was also under development by Vicus Design to create another housing option for displaced Cantabrians.

Arrowtown House

The Zuschlag House at Bracken Street, Arrowtown, was the result of a meeting of similar minds within a close network of friends. Client and Creation Green landscape designer, Sandra Zuschlag, brought a German focus on energy-saving solutions to the project. Bronwen Kerr of Kerr Ritchie Architects brought a finely tuned aesthetic and knowledge of Central Otago conditions. Paula Hugens of GreenBeing added in the Passive House system into the conversation. The collaborative outcome was a 153m^2 single-storey, timber-clad, energy efficient home based on Passive House design standards.

The Zuschlag House tongue-and-groove timber clad walls were prefabricated in a carpentry workshop in Cromwell. The panels were erected

Panels on truck.



ABOVE: Concept design for Wanaka SIPs house by bc+a.

RIGHT: Passive House design principles.

at site on a concrete floor pad. On site, cellulose insulation was pumped through temporary access holes in the airtight wall-lining and into the 90mm cavity below the raised timber floor. Interior wall frames were also prefabricated, complete with their plywood lining. The roof was constructed at site using precut LVL rafters, with a 50mm batten to allow space for services, followed by the internal linings. The resulting house build took only about six weeks. Money saved on labour enabled high-quality environmentally friendly materials to be used. The home has a very high level of internal comfort due to airtightness, wind tightness and heat retention from triple-glazed manufactured windows and 200mm of insulation in the walls. Heat demand within the dwelling is very low; the home can be heated by using a single standard 2,000 watt electric heater.

Wanaka SIPs House

Bergendy Cooke of bc+a was commissioned to design a timber SIPs panel house in Wanaka in 2011 by a client familiar with the high thermal retention and indoor comfort of insulated panel construction. The 260m^2 house on Aubrey Road, Bremner Bay, uses imported Kingspan Tek-panels as the main structure for walls, roof and intermediary floor. Cedar cladding conceals the structure, broken only by double-glazed thermally-broken windows and large sliding glazed doors.

This house and the Salmond Architecture High Performance House in Albertown, are two of a handful of timber-based SIPs homes constructed in New Zealand to date. Advantages of the panel-based system are increased airtightness and insulation qualities, as well as faster construction from the short time taken to erect the panels on site. The architect noted that it was a challenge switching from a traditional construction system to a panel-based system late in the design stages. Future SIPs-based projects will take advantage of the maximum span and minimum waste achievable by specifying panels earlier in the house concept design stage.

Passive Houses

Vicus Design Group is focused on designing Passive Houses for Christchurch. These are built by using lightweight timber frame construction with plywood I-beams as wall studs. Factory-built panels for floor, wall and roof are craned into place at site in just five days.

Passive Houses effectively capture the inherent heat inside houses that comes from the sun, cooking, showering and the inhabitants. In order to retain the heat, increased levels of insulation and airtightness are used, along with a heat recovery ventilation unit. High insulation means typical measurements or R-values are R3 for floors, R5 for walls and R6 for ceilings and roofs, which are over double most traditional housing insulation levels. Careful detailing and construction eliminates thermal bridging. European high-performance windows with triple glazing are also used. Effective airtightness means no draughts, so the insulation can work as designed, cold air can be stopped from entering and moisture can be prevented from condensing within the built envelope.

The addition of a heat recovery ventilation unit is the most obvious feature to the inhabitants of a Passive House. This is a simple fan-based system that extracts damp air from the bathroom, kitchen, toilets and laundry and passes it through a heat exchanger. Incoming cold, fresh air is warmed by the outgoing warm air, so a constant supply of warm fresh air is provided. The building uses no more than 15 kilowatt hours per m^2 of floor area per year. To put this in context, a 200 m^2 Passive House, using a heat pump to provide heating, will cost about $250 per year to maintain a constant temperature of between 20 and 25 degrees Celsius. On the coldest night in winter, the same house can be kept at 20 degrees with only 2 kilowatts of heat, that's the amount of heat put out by a toaster or a hairdryer.

Emerging Materials and Systems

Recently introduced materials and construction systems offer options to the traditional stick-based building process. It is a long and involved process for an innovative material to make it to market. All materials must conform to Building Code regulations for 50 years of durability as well as strict weather tightness criteria. Persistence has paid off for cross-laminated timber (CLT), the jumbo plywood panels that recently began NZ production. Other recently developed prefab systems challenge the notion of traditional construction even further. One such system is the Click-Raft discussed in the following chapter.

Cross-Laminated Timber

There is a large latent interest from the design community eager to access Cross-Laminated Timber, a material that has been well publicised through European exemplars. XLam commissioned

XLam panels being flown to site.

CLT floor panels create an immediate working platform.

Cantilevered CLT floor panels.

Treehouse by day and night.

an Austrian press and started manufacturing CLT in their Nelson facility in May 2012. The next few months were spent mastering the manufacturing techniques and working with third-party testing labs to ensure the product matched up to theoretical performance calculations. The first set of XLam panels manufactured in the Southern Hemisphere was delivered by helicopter to a steep Waiheke Island site. Each floor panel took about five minutes to fly in, and the full set was stacked on a flat, clean working platform within a couple of hours. Other projects are in the pipeline at XLam to use CLT as floor, roof and wall panels, to achieve a fully factory prefabricated construction system.

Port Hills House

At time of writing, XLam had several other residential and commercial jobs lined up. One of which is designed by Ian Jack from ISJ Architects for a Christchurch-based client requesting a house that is safe from earthquakes. CLT was chosen for its strength and ability to absorb seismic shock and ease of repair if damage occurs from extreme events. Another benefit is the speed of assembly at site, which appealed to the builder who was emerging from four months of mud and concrete on an adjacent house. CLT panels of around six and a half metres by three metres can be craned into position within a single day to make an immediate working platform.

The material's ability to attain long spans mean a wider spacing of foundation supports can be utilised, and greater cantilevers than with a traditional joist system, thereby reducing work in the ground. The underside of the CLT floor is a clean surface for simpler and more effective application of sheet insulation. The CLT roof offers similar speed on site and enables rapid erection of a weatherproof building envelope. In this case, long raking XLam panels cantilever beyond an intermediate line of support to a simple paired connection at the ridge. The house will be a hybrid of prefab and traditional construction, with walls conventionally framed. Advantages of CLT were explored in the Jigsaw House VUW research project of 2010 and discussed in the next chapter.

Commercial projects leading the way

Innovative construction practices are already being used through industry-led experimentation in commercial projects around the country. The techniques, systems and materials employed in these projects hint at what is possible for the residential sector's future generations.

Treehouse

It started in 2008 as a daring high-risk advertising campaign for Yellow Pages and resulted in a piece of award-winning architecture, now known as the Redwoods Treehouse. The pod-shaped structure is sited 50 kilometres north of Auckland near Warkworth in the Rodney District, but more specifically it is 10m up a 40m tall Redwood tree accessed by a 60m ramp, amongst a forest on private land that can be reached only by coach. It functioned as a restaurant seating 30 people at one time, and was fully booked for lunch, high tea and dinner throughout the month-long advertising campaign period in early 2009.

Pacific Environment Architects (PEL) was commissioned to design the Treehouse and drew on inspiration from childhood dreams and playtime, fairy stories of enchantment and imagination. At night the treehouse lights up like a lantern, an elegant glowing beacon, in contrast to a tree-fort character by day.

The 10m wide treehouse platform is encircled by 12m high vertical timber fins that bow outwards to create the curve of the pod form. These glue-laminated pine fins were prefabricated by McIntosh Timber Laminates in Auckland. The fins and plantation poplar slats are intended to echo the linearity of the surrounding redwoods. A steel wrapping element that fixes to the base of the tree and again above the treehouse ties the timber structure together and to its foundation, the tree trunk. NZ Strong was the construction company that put all the precut, pre-nailed and glue-laminated puzzle pieces together at site.

The site, complete with Treehouse, returned to its owner in April 2009 for use as a private venue for weddings and functions. It has been successful both architecturally and as an advertising campaign. It generated more than 10,000 online articles and was featured on an Asian television channel with an audience of 50 million. Awards include a Gold BEST Design Award, a New Zealand Institute of Architects National Award, an Excellence Award from the New Zealand Institute of Building and a finalist in the World Architecture Awards 2009, as well as many international marketing and advertising awards.

The Showcase

In Auckland temporary retail buildings designed by Cheshire Architects with Assembly Architects for Cooper & Co at Britomart, were delivered by prefabricated means. Exterior bespoke steel panels were fabricated in Wellington and other parts came from Stanley Modular's facility in Matamata. The short design and construction time-frame necessitated an overlapping design-consent-fabricate process with five separate building consents being lodged in quick succession.

Waitomo Glow-worm Caves Visitor Centre

In the Waikato region, the Waitomo Caves Visitor Centre designed by Architecture Workshop

The Showcase Britomart Auckland.

has won several accolades including the NZIA Architecture Medal (2011) and several Timber Design Awards. The elegant lattice-like structure is made of prefabricated engineered pine LVL arched to reflect the curve of the Waitomo stream and contours of the land. The structure is interwoven to create a timber net reflecting to local hapu (Maori tribal) a Hinaki or eel trap.

The structure was calculated by Alistair Cattanach of Dunning Thornton Consultants. The arches are prefabricated by Hunter Laminates in Nelson from two layers of LVL ribs interconnected with blocks. These timber I-beams were laminated, twisted, joined, overlapped in layers, and then screwed together as they were assembled on site. Innovative soft pad connections are used between inflated ethylene tetrafluoroethylene (ETFE) pillow cladding and the gridshell structure described by the architect as being like a tent fly. Three-dimensional modelling tools were used to design the exceptionally light and strong NZ pine LVL structure with members that are only 316mm deep at 4.25m centres, and span almost 30m.

Nga Purapura Kakano

The Institute for Maori Lifestyle Advancement (IMLA) at Te Wananga-o-Raukawa is in Otaki in the Kapiti District. It houses the Kakano, a beautifully crafted standalone meeting room space within the larger structure of Nga Purapura, along with indoor sports courts, classrooms and offices. The design by Tennent+Brown Architects with engineering by Dunning Thornton Consultants was manufactured by Stanley Modular at Matamata. In the factory, the 268 triangular plywood pieces were carefully fabricated and assembled according to CAD layouts. The Kakano travelled 460km to Otaki in two halves on two trucks and was carefully placed into the

The Waitomo Caves Visitor centre with LVL interwoven I beams detail below.

new building before the last glazed panels were fitted. Kakano means seed pod and represents a new beginning – a fitting tribute to a peaceful contemplative space and haven amongst the busy communal area.

Alan MacDiarmid Building

A new Victoria University of Wellington (VUW) building that utilises Precast Seismic Structural Systems (PRESSS) developed in the United States in the late 1990s. PRESSS is a simple construction technique and design method to develop damage-resisting multistorey precast concrete buildings with large spans and open space. Precast concrete structural elements are jointed together through unbonded post-tensioned steel strands or bars. The structural system responds to seismic events much like childhood animal toys made of plastic tubes with elastic running through them in that the structure returns to its original condition after a disabling event. There are two multistorey PRESSS buildings in New Zealand, the other being the Southern Cross Hospital Endoscopy Building in Christchurch.

College of Creative Arts

The Te Ara Hihiko building (CoCA) at Massey University in Wellington is designed by Athfield Architects with Dunning Thornton Consultants. The LVL structure is a hybrid Pres-Lam system,

using laminated timber to deliver a similar result to concrete-based PRESSS. During an earthquake the building is able to rock back and forth then return to an upright position without significant structural damage. It is a world first in seismic engineering.

The post-tensioned timber Pres-Lam system was developed in 2005 by researchers at the University of Canterbury. As a result, the CoCA building will be able to continue to be used safely after a major earthquake. As well as the structure, other prefabricated elements include precast concrete walls, the façade cladding system and the roof. The roof was prebuilt at ground level before being craned into position. This innovative roof assembly resulted in 50% cost savings and 30% time savings compared with traditional roof construction.[5]

NMIT Arts and Media Building

The Nelson Marlborough Institute of Technology (NMIT) Arts and Media building was designed by ISJ Architects to be a timber showcase, in response to a competition involving the Ministry for Primary Resources (formerly Ministry of Agriculture and Forestry). This building is a world first for innovative use of wood in the structure of a multistoreyed building. All structural beams, columns and floors are of engineered timber construction in LVL.

Kakano seed pod meeting space.

Massey College of Creative Arts building, Wellington.

This locally manufactured product has excellent strength properties, is durable and fire resistant. This allows the design of beams, columns and floor systems that are the equivalent of steel and concrete. The rocking timber walls designed by Aurecon Engineers are joined with energy dissipaters, so the structure is able to absorb seismic energy and reduce building damage during an earthquake. This is a new generation of seismic engineering known as damage avoidance design.[6]

Structural Timber Innovation Company

In Christchurch (STIC) is a research-based technology company owned by timber industry shareholders and the universities of Auckland and Canterbury. STIC is developing a portfolio of LVL and glue laminated timber (gluelam) structural building systems for multistorey commercial and long-span industrial portal framed buildings. They envisage that commercialisation of these new technologies will enable timber to effectively compete with structural concrete and steel, the two present materials of choice in these market segments.

Marae Utility Pods

In the central North Island King Country the beginnings of a prefabrication project to provide high-quality affordable marae facilities has relevance for iwi (Maori tribal groupings) all around the country. In 2012, a number of ablution facility blocks were produced for Tuwharetoa sites around Lake Taupo by Stanley Modular with Assembly Architects and Dunning Thornton. Iwi common land ownership, funding and decision-making models provide an opportunity for preplanned, prefabricated solutions to be presented to communities. Limited design options, factory-based manufacture, reduced time for the project, and fast delivery all aid community decision making processes and minimise the shut down time of the marae. Furthermore, the prefab delivery of marae buildings enables personalisation at site, via the application of carvings unique to each particular hapu (subtribe). Future marae buildings plan to draw on flat-pack methods refined by Stanley Modular during development of their Fast Class series of educational buildings.

This brings us full circle from where we began in pre-European times when Maori whare were constructed by pre-bundling raupo beside wetlands for ease of transport, and assembling the bundles into wall panels at the building site. Today, utility blocks may arrive on the back of a truck. Tomorrow, an entire marae could come as a flat-pack, ready for integration into a community and personalisation with traditional weaving and master carving practices or digitally designed and manufactured Maori artwork.

Towards an emerging prefab generation

These recent prefab precedent projects have shown us a glimpse into the emerging future, into the next generation where design and construction team members cross disciplines, where materials and processes are constantly evolving. These projects throw the spotlight on collaboration. The complex process of design and construction has always involved a team of people, and prefabrication has always necessitated an equal focus on design, communication, and business fundamentals.

This concise overview of recent prefabrication projects shows the benefits of collaboration,

Assembly Architects present their prefab Marae model in Kakahi.

new construction methods and technology that produce inspiring precedents. Digital technologies and fabrication are having major roles in research, design and manufacture and are considered in more detail in the following chapter, with examples of research based projects initiated within New Zealand universities. There is increasing crossover between university and industry led research and its application. Projects such as the Unitec Studio 19 Onemana Bach, the Click-Raft and the First Light House all make links between the academic world and industry in applied research projects that would not be possible without significant added value through collaboration. The inspiring VUW First Light House project included inputs from forty different industry organisations and resulted in a US Solar Decathlon competition podium place on a world stage.

1 Page, I. Changing Housing Need, *Study Report 183:*. Wellington, BRANZ, 2007.

2 This chapter is based on first hand interviews and correspondence with New Zealand prefab industry participants.

3 PrefabNZ, Affordable Architecture, *Build 130*, June/July 2012 pg 15.

4 PrefabNZ, Lego Like House Stands its Ground, *Build 131*, Aug/Sept 2012, pg 12.

5 Chisholm, P. PrefabNZ, New Zealand Wood Wellington Event presentation,12 June 2012.

6 Irving, A. PrefabNZ, Nelson Event presentation,12 November 2010.

Digitally Fabricated Futures

MARK SOUTHCOMBE

THE POWER of the computer to accommodate the expression of the architect and the individual needs of a client promises to offer an unpredictable panorama of choices to the consumer rather than the limited palette of types that characterise the prefabricated systems of the Modern movement.[1]

We are witnessing an architectural revolution facilitated by digital craft and fabrication. In this section of the book we look at projects that showcase the next generation of architects who have a confident familiarity learning new computer software as an ever changing immensely powerful tool for the creation and realisation of architecture. Research and experimental work of some of my university peers and some of my own design-led research over the last few years will be drawn together in a range of case study experiments. The work demonstrates cutting edge applied architectural research, examples of research led design, prototypes, experiments, exhibits, student projects, unbuilt work, and emerging examples of digital fabrication occurring in New Zealand universities.

OPPOSITE: Skyrise City Event Studio University of Auckland SoAP 2010.

Barcode Event Studio SoAP 2006.

Event Studios

In 2006, the University of Auckland School of Architecture and Planning (SoAP) initiated Event Studios, in which students design and fabricate installations at 1:1 scale. The installations were created to make an atmosphere where a free public event could be staged. This has often been a party in association with Auckland Architecture week attracting a couple of thousand visitors in a single night. Event Studios framed architecture as the product of labour, craft, technique and design for and through production, material selection and economy. Students led by Uwe Rieger, Mike Davis, Kathy Waghorn and team developed an ability to work collaboratively and within constraints to generate a project. They worked to fast time frames; a maximum of ten weeks from brief to realisation. Students shaped the project through various focal points, such as material properties, availability and costs and logistics. The installation may need to be installed and dismantled within 24 hours, so the actual limitations of working in a public space and the health and safety issues that arise are all important project considerations. The event design and its staging were part of the project. The architecture was not merely proposed but was also made and tested in the public realm. Design progressed through prototypes and large scale tests. The fast nature required that construction 'on the night' was pre-planned in every detail, from heavy lifting to every mechanical fixing. The studio has run most years since 2006 and has been a collaborative project run in association with Unitec and Auckland University of Technology (AUT).


Britomart

Cupcake Pavilion

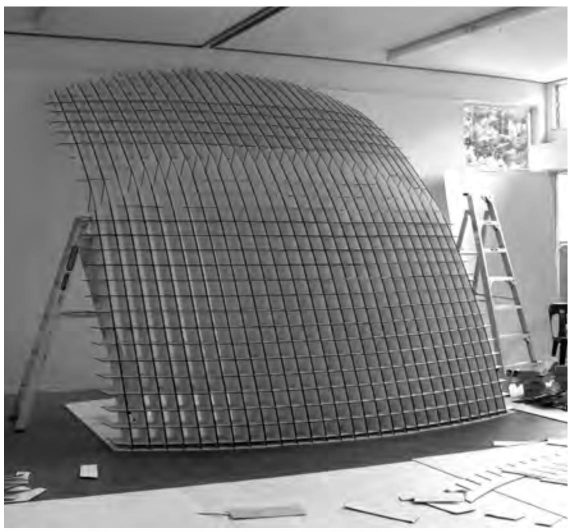
The Cupcake Pavilion was a one day temporary installation sited at Auckland's Britomart Transport Interchange as part of Auckland Architecture week, October 16, 2009 by design collective Oh.No.Sumo Sarosh Mulla, Patrick Loo, Katherine O'Shaughnessy and James Pearce. The young architectural graduates have experimented with design installations outside of their usual working hours developing their design and fabrication skills in the process.

The Cupcake Pavilion was a fund-raising bake sale stand designed to engage with the wider community to help sell cupcakes to raise funds for the Starship Children's Hospital. The pavilion was designed incorporating digital modelling and fabrication techniques. Parametric modelling

ABOVE: Cupcake purchase and storage in the pavilion grid structure.

LEFT: CUPCAKE PAVILION AS erected for a day in its Britomart setting.

Cupcake Pavilion precut elements.



Cupcake Pavilion off-site fabrication.

Cupcake pavilion on-site assembly.

took into account material limitations, cupcake packaging sizes and the overall design intent to create an installation to foreground innovative architecture and engage with the public in Architecture Week. A digital model was able to accommodate varying cardboard thicknesses according to the needs of the manufacturer who would sponsor the project allowing simple and quick updates to be made without a complete redesign of the project. The myriad of minor dimensional adjustments required could be changed via a simple change of a parameter and the republishing of drawings.

The resulting design used only donated materials and services with generous volunteer help from members of the community. The pavilion was constructed, the donated cupcakes sold raising money for the Starship Children's Hospital, and the pavilion deconstructed ready for recycling, all within the one day event period. The uniqueness of the event, activity and the pavilion design within a busy city environment intrigued people. It triggered them to give generously to a worthy cause through the purchase of a cupcake, and also attracted them to interact with the architecture in a new and exciting way. The 1000 cupcakes baked for sale sold within 90 minutes. The pavilion design and a second installation titled Paper Sky by Oh.No.Sumo received Gold and Silver awards at the Designers Institute New Zealand (DINZ) Best awards 2010.

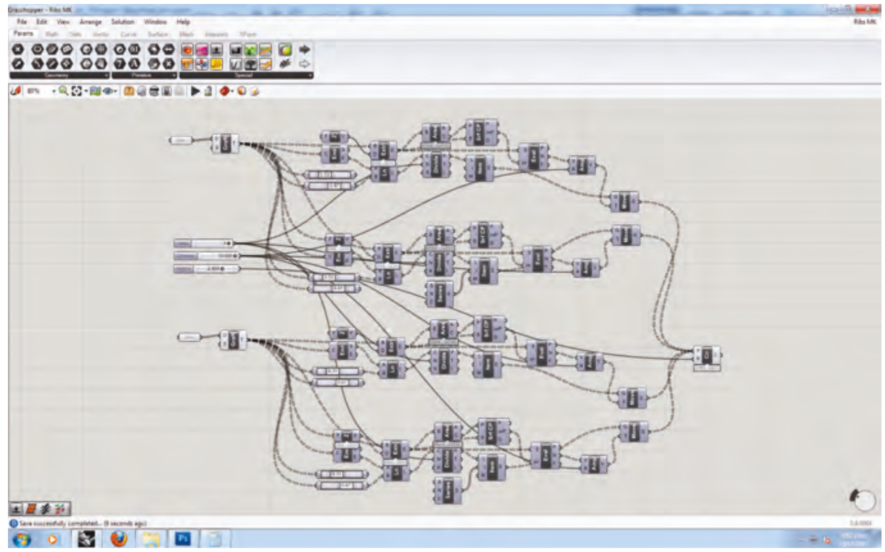
Creature

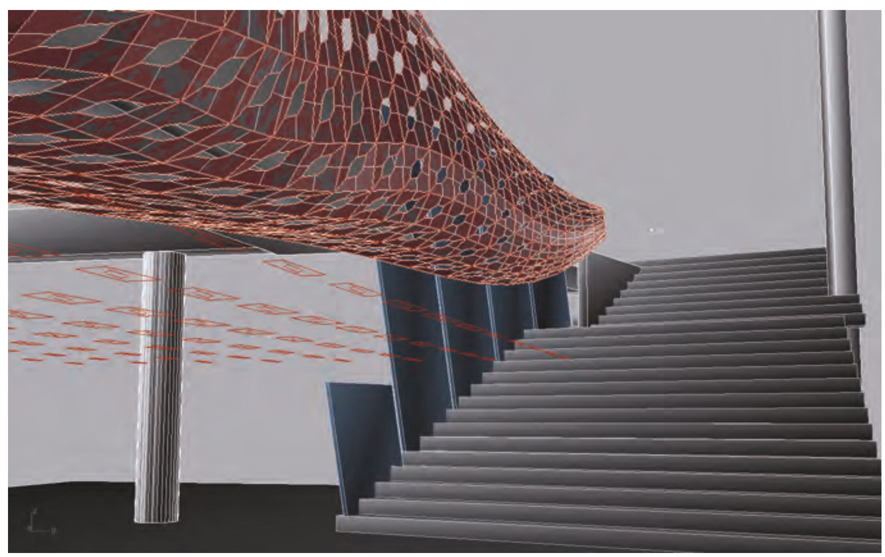
The installation affectionately known as Creature is a digitally designed prefabricated 3mm corflute suspended screen that curves in two directions. It was designed specifically to fit within the double height main exhibition gallery at Puke Ariki Museum and came to be referred to as Creature because of its large scale and its muscular aesthetic qualities. The installation was commissioned for the Kiwi Prefab exhibition by Puke Ariki Museum in partnership with Victoria University of Wellington to show the potentials of digital fabrication to simplify and describe complex design, to translate this to physical form by precisely precutting material off site and to assemble the same complex form in place on site.

The concept design and initial design led research occurred in the winter of 2011 and was undertaken by VUW Senior Lecturer in architecture, Mark Southcombe, with collaborative research assistance from Xuanyi Nie and Jeremy Robinson. The design was developed and precut using digital files directly to a CNC router in the VUW School of Architecture in the summer of 2011. It was assembled on site in New Plymouth November 2012.

The muscular design concept was developed using Grasshopper generative modelling software. The specialist software facilitates parameter-based design without specialist script coding computer programming knowledge. Adjustments to parameters such as the ratios of the facets and holes to the main Creature surface geometry, are made via a graphical algorithm editor. This allows an ease of designing complex surfaces and forms, and the ready change and development of the design of these.

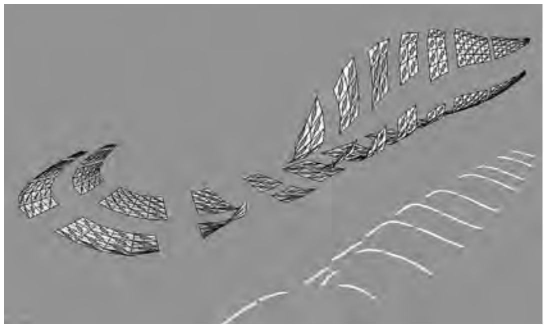
The Creature design process utlised a design-led research format. Initial freehand sketch concept designs were developed and tested through a series of generations using different software including Sketchup, Rhino, Illustrator, and through parallel freehand sketching, and built experiments using physical materials. Form, material, connections, fabrication and assembly were all considered and tested as a part of this process.



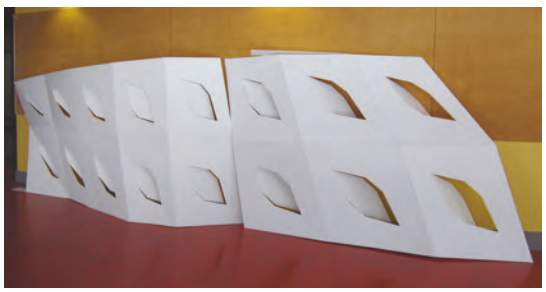


TOP: A screen shot showing the digital interface of the Grasshopper parametric software used to generate the parametric model for Creature.

BELOW: Parametric digital model of Creature by Xuanyi Nie.



Fabrication digital model of Creature.



Test fabrication of sectional elements of Creature.

Folding Whare

The ideas are not new, nor are the parts themselves, but the way they're combined displays an original assembly system. No one's built anything quite like this – it's a prototype for the future.[2]

The Folding Whare is an example of the value of research-led design. It was undertaken by Callum Dowie at Unitec Auckland 2009 with supervision from Jeremy Treadwell and technical assistance from Tom Whelan. The design of an asymmetrical unfolding hut was inspired by close study and analysis of structural systems employed in traditional Maori architecture, in particular the tension and compression system used to interconnect or 'spring' rafter, ridge, and wall elements together. A series of prototype tension details were constructed to test performance of materials and different ways they could be jointed. Eventually, the constructed details were scaled up to become a full size prototype.

From the full-scale model, evaluations were made of the firmness of the structural system and the utility of the building created. The use of an external tensioning structure not visible to the inside, gives the Whare (Maori house) its structural integrity and aids the simple erection of the shelter. Traditional Maori buildings were bound with twine but this hut uses wire, readily available NZ patented Hayes wire strainers and purpose made plywood and polystyrene structural insulated panels (SIPs).

The design is being developed as a hut or emergency shelter that allows for ease of transport and rapid deployment in situations where existing housing has been destroyed. Transportation and assembly are easy and efficient. The original prototype material cost $6,700 and utilised standard size plywood sheets. The Folding Whare takes four people two hours to assemble with only

Assembling the Folding Whare in the Unitec School of Architecture Courtyard.

One of a series of design experiments inspired by Maori building techniques.

Laser cut scale model and shadow tests.

a spanner. The particular significance of the system is the hinging and unfolding panel construction method. The prototype demonstrates the success of a demountable detailing system comprised of panels and parts.

Depth of Shadow

The VUW School of Architecture Depth of Shadow project was developed by Mark Southcombe with collaborative research assistance from Lisa Cumming from 2009 – 2011. The project created light filtering screens and documented the operation of an iterative design process as a formalised research methodology. It was motivated by observations regarding the relative lack of variation and depth of shade and shadow quality from typical architectural pergolas and projections compared with the richness of shade through a tree canopy. This prompted the research question 'how might a thin architectural element be designed to provide a variation and depth of shade and shadow that approximated the qualities of shade below a tree canopy?'

CNC Routing in progress.

Sun and shadow tests at full size.

A design-led research approach was applied to resolve a simple architectural problem; the relative lack of depth of shadow able to be projected through thin sheet architectural elements. Architecture is not easily recognised as a research output within a university setting in comparison to written work. Until recently it has been a related publication that quantifies the value of architectural design work, not the design itself.

Documenting the Depth of Shadow design-led research process was a means to record and demonstrate its rigour, and to tease out differences between design-led research and conventional design practices. A secondary aim of the project was to explore the potentials of digital file translation between the first generation three-dimensional visual files, and realisation through a CNC router complete with specialist interface software. A full size built prototype was constructed to calibrate the design performance.

The project provided insight into how design used as a research method happens. Results were published as a conference paper at the Australia New Zealand Architectural Science Association (ANZAScA) conference at Unitec in Auckland 2010[3]. The project revealed that design operating as a research method is slower than a conventional design process. This was documented as a related series of visual outputs, and required a recorded critical reflection at each stage of development.

Physically modelled artefacts including drawings, scale models and full-scale architectural elements were found to provide evidence of intention and effects independent to written commentary. The project demonstrated that design may operate as a research method to explore architectural questions or problems in the manner of an experiment. Outcomes of design-led research processes provide visual evidence that may be assessed independently to the research questions or problems that generate the research.

Click-Raft

The Click-Raft began as experiments by Chris Moller of CMA+U and colleagues towards an evolutionary architecture. Inspired by Henry David Thoreau's Hut at Walden Pond, Click-Raft is inexpensive fabrication, a minimum prototype that adjusts to its environment in the sense that a tree does. It is conceived as being autonomous in relation to energy use, internal information communication and systems. It will integrate structure, servicing and environmental systems with sensors that monitor temperature, wind, moisture and light.

This Frame so lightly clad, was a sort of crystallisation around me.[4] Click-Raft, like Lego or Meccano, is an open system. It doesn't have a fixed shape so it can be assembled in what ever way is appropriate for the kind of shelter needs people may have and this can be adapted as it is assembled. The idea underlying the system is of a new more intelligent way of building. The design should be able to make buildings that are more responsive and interactive with their environments. Architecture should also provide the mechanisms where by users can learn, and

Click-Raft Future Schools competition award winning entry.

thus adapt or tune to changing environmental conditions, in the sense that a sailing boat is tuned.

The architecture of the Click-Raft is constructed of CNC cut plywood Click-leafs and Click-beams to form a lattice-like structure. Standard panels can be assembled quickly, clicked together to form floor, wall, and roof elements in different configurations. Structure, cladding, power, data networks, plumbing, energy, water systems, storage and furniture are all integrated within the weave of the plywood lattice.

The system's flexibility offers many alternative open ended configurations to enable builders to respond to site specific conditions. Construction is generated by an assemblage of click together components which can be adjusted on site – engaging user input, imagination and exploration. To date the Click-Raft system has been developed for various scales and types of projects for work-live, retail, school and emergency shelter needs. The addition of laminated veneer lumber (LVL) structural elements allows potential for multilevel and larger structures. The Click-Raft is the basis of an award winning entry into the Australian Future Schools Competition in 2012 that is currently under development.

Architecture and prefab currently focuses on object as shelter, and is most often driven by the economics of the 'hardware' that keeps the rain out and allows occupants to live a healthy happy life. What if architecture was the software where materials and components are embedded with intelligence via new technologies and smart materials. Each element of Click-Raft can potentially have integrated intelligence, e.g. the Click-beams can have an integrated data-power track which enables you to plug in a switch, light, sensor or microprocessor wherever you like. Made of renewable materials the system responds to challenges of global warming. Eventually it will be powered by nano-solar generating cladding materials. In the future, dwellings will be intelligent, and they will operate as computation devices; a technological leap like moving from telephone to iPhone, where a house becomes a fully fledged computer which can enable you to do all sorts of things from anywhere. The Click-Raft vision is of an inexpensive enabling construction tool: a device that is in tune with our fragile planet.

Jigsaw house

The Jigsaw house project aimed to design and model a house using large jigsaw-like pieces to enable construction to occur more quickly and easily than is currently possible. Conventional multitrade, multilayered, multimaterial construction is complex, time consuming and often inefficient. Construction projects include inputs from increasing numbers of specialist trades who fix and interweave in place multiple independent parts, work independently and require a significant amount of coordination.

The Jigsaw house was designed to minimise the numbers of parts and trades involved. Main walls, floors and roof panel elements interlock and gain strength from each other as a composite structure. Services are separated rather than woven within walls to facilitate construction, future adaptation and maintenance. The house is also designed to be simple and quick to assemble on site. The interlocking panel system self supports as panels are connected to each other during assembly. Savings in materials used occur from the material efficiencies, and the integrated structure and internal finishes.

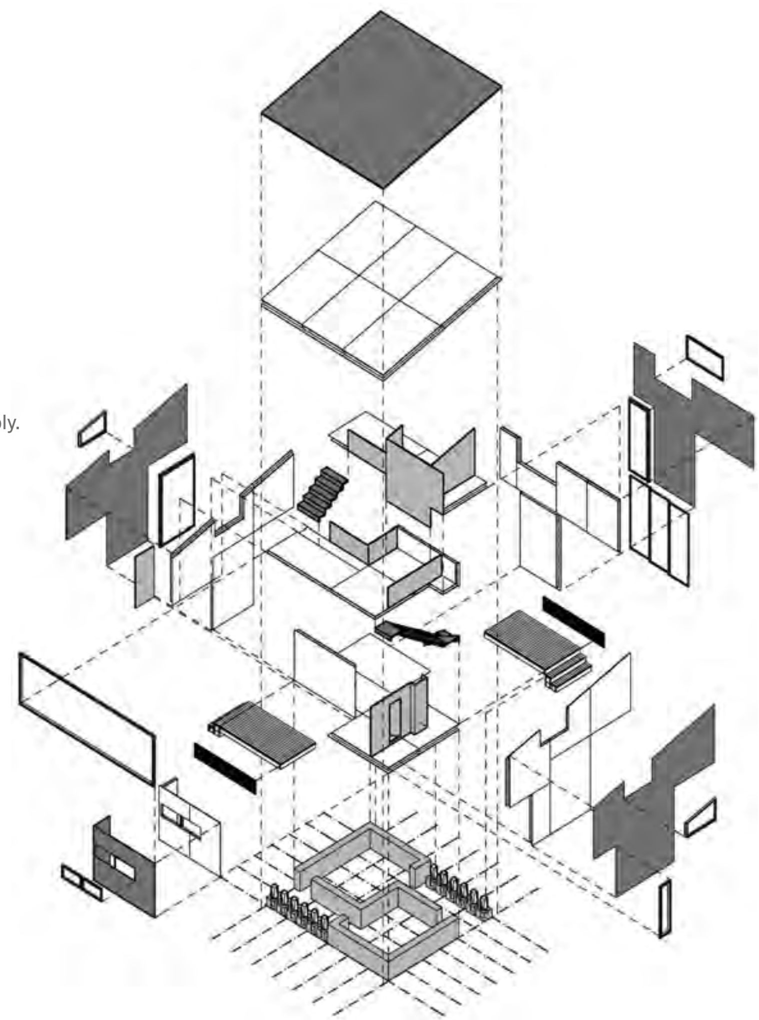
The Jigsaw house design was initially investigated using interconnecting composite

Jigsaw house model wall panels prior to assembly. Solid timber floors interlock into walls.

Interlocking interior panels of jigsaw house.

Jigsaw house assembly. Note interconnected floors and walls.

Jigsaw house model. The same material is used for floor walls and roof.



Early exploded construction diagram showing how parts fit together like a jigsaw.

Onemana Bach presentation and critique of student bach designs.

Onemana Bach, external deck area entry.

plywood panels that were laboratory tested to structural failure. The next series of design experiments used SIPs,[5] before cross laminated timber CLT[6] was finalised as the primary construction material. The house is designed as an interlocking three-dimensional volume with a minimal number of large panels assembled on site. This occurs using a light Hiab crane system. The solid timber floor, wall and roof panels of varying thicknesses are connected to each other with simple bolts on site. The panel joints run past each other in two directions and enable panels to hold each other up during assembly on site.

Assembly occurs in the manner of a jigsaw puzzle where predetermined parts fit precisely together. All panels are able to be erected on site in a single day. The speed of CLT construction, its accuracy, and its sustainable and structural properties combined with the ready customisation of the CLT solid timber base material via digital cutting and manufacture (computer aided manufacture CAM) have significant implications.

Today and in the future houses could be cut out and assembled literally like a doll's house or a deceptively simple jigsaw. The Jigsaw house project was designed as an interlocking 'Loft' type space and to allow repetition in groups like terrace houses. It was designed by VUW Senior Lecturer in architecture Mark Southcombe with collaboration from Associate Professor Andrew Charleson and research assistance from Lisa Cumming and Katherine Roberts at VUW School of Architecture from 2009–2011. It is an example of emerging technologies with likely significant effects on future construction in New Zealand.

External view towards lounge.

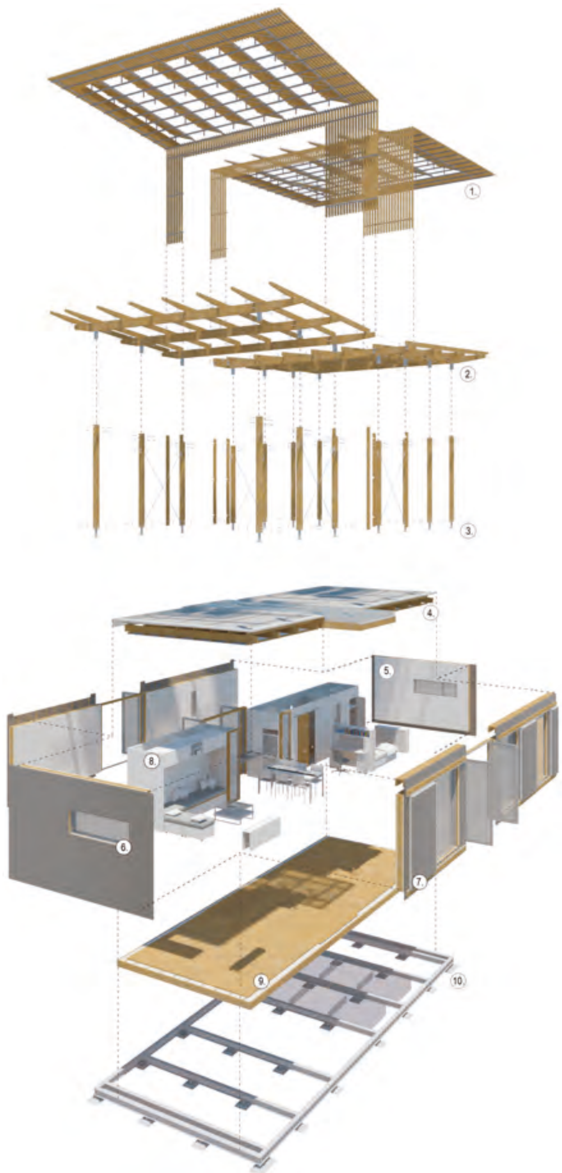
Onemana Bach

The idea is to introduce students to a real life client, real life site, real life budget and build a real life building. It's not just about getting them to design something for someone else to build, but about getting them to see how practical or impractical their design elements are when it comes time to build from their design. Everyone benefits from this project. The clients get an architecturally designed holiday home that's within their budget and the students gain valuable experience on what they can expect when they go into the industry.[7]

Studio 19 is a popular annual applied architecture student design and construction project offered at Unitec Auckland. The Onemana Bach project ran from March to December 2010 and was coordinated by architect David Strachan with architect Marshall Cook, celebrity builder John Cocks, and assistance from Unitec's Tom Whelan. The project enabled student involvement in all stages of a project from client liaison and design through construction to completion. From this extended project involvement they learnt consequences of their design decisions for the construction and detailed design of their project.

Sixteen third year students were split into four groups, and designed a two bedroom bach based on the clients' needs and budget. The clients and Unitec programme leaders selected the most suitable design which was refined and developed. The final design building consent documents were prepared by students working out of Strachan's practice office Strachan Group Architects (SGA). In the final quarter of the year with assistance from their mentors, the students built the holiday home off site in a yard adjacent to the workshop at Unitec's architecture campus. After exhibition it was lifted onto a truck and

Interior of kitchen, dining and living area.



Exploded elemental diagram from First Light House initial competition entry prior to prefab modular design development.

transported to its present location at Onemana on the Coromandel Peninsula.

The design uses predominantly component-based prefabrication systems and in addition to framing, window and door joinery, plywood and batten systems, it also includes specifically designed built-in pre-cut furniture and joinery cabinets, and a metal SIPs roofing system. It is a complete building constructed off site on temporary foundations and transported in one piece to location. The project was shortlisted for *Home* magazine's 2012 Home of the Year competition, and won a NZIA regional award.

First Light House

The First Light House was Victoria University of Wellington's entry into the biennial United States Department of Energy Solar Decathlon competition in 2010–2011. The project by four VUW students: Eli Nuttall, Ben Jagersma, Anna Farrow and Nick Officer, was supervised by Tobias Danielmeier and Guy Marriage. The competition entry needed to meet a prescribed series of ten strict criteria: architecture design, market appeal, engineering, communications, affordability, comfort, hot water, appliances, home entertainment and energy balance. The project also required a short assembly period of one week.

Inspired by the classic kiwi bach, the one bedroom house was intended to be functional, flexible and visually appealing. A striking design feature of the house is the timber canopy. It takes the form of a butterfly pergola over the roof. The canopy houses a large solar array and provides shade to windows below. The efficient 75m^2 interior creates flexible social spaces that can be transformed to suit the homeowner's needs. The living area contains a built-in lounge unit which pulls out to reveal a full double bed and bunk

The First Light House competition design.

for guests. In addition to the Solar Decathlon requirements, the team wanted to design and build a house that would be a beautiful and comfortable home long after the competition was over. Judges and the public commented on the attention to detail, quality and craftsmanship.

The one week on site assembly time constraint had a big impact on the design of the First Light House. It meant the house would need to be prefabricated for transportation from New Zealand to Washington DC. The initial construction of the First Light House took place over a few months in Wellington in a large shed. The walls, floor and roof panels were prefabricated in different locations before transport to Wellington and assembly into volumetric modules. Modules were then fully fitted out with glazing, electrical, plumbing and fixed furnishings to allow for quick and easy assembly in the US. Setting the modules in place on site took just a few hours by crane. Significant design time and energy had gone into the module connection detailing, highlighting and hiding the module 'seams' ('mod-line' joints) between the sectional modular volumes. The full assembly was completed in six and a half days during the competition. Visitors to the house expressed surprise at how solid and permanent it felt.

Affordability was one of the contest criteria with a goal to keep house costs below US$250,000. The VUW team carefully considered the cost, quality and performance of every part of the house including the solar array. The size of the solar system was designed to generate only what the house would need to reach a net zero energy rating. The First Light House is a fully solar powered Net Zero energy home.

Sustainability was not an officially judged category in the Solar Decathlon; however, the house was deliberately designed to be as sustainable as possible. The construction materials used in the house include a number of sustainable timbers such as pinus radiata and recycled rimu. It is insulated with a thick layer of recycled wool made from carpet offcuts. LED lighting, energy efficient appliances and low flow taps ensure the house energy use is less than the energy it produces.

The First Light House captured the NZ public imagination when it was assembled and opened

First Light House interiors: office/wall divider; couch/hideaway bed; dining/kitchen to living

to the public at Frank Kitts Park on the Wellington waterfront in May 2011. Twenty thousand people visited the house over the 18 days that it was open to the public as a full-scale exhibit. It was then disassembled, shipped to the US, transported overland to Washington and was reassembled and presented for the competition. When it was assessed against the Solar Decathlon criteria it won first prize for engineering, hot water and energy balance, second prize for architecture and third prize overall in the competition. It was returned to NZ after the competition, purchased for use as a private bach, and relocated to the Hawke's Bay where it was reassembled on a permanent site; its third fully functional location in a year!

The First Light House design, research and development demonstrate a high level of design and technical sophistication. This is documented in four VUW MArch theses that record the research process and outcomes with visual and technical clarity. Some innovations occurred during the journey as the design was customised and logistical and technical demands of prefab were attended to. The modularisation as a series of sectional volumetric units, the economy of the wall panel and plywood ceiling panels, and the specific design of the clip-on sectional cladding systems have potential for further research, development and application. The ability of the First Light House to be disassembled and reassembled is a precursor to a more sustainable future where architects and designers will consider future disassembly with potentials for maintenance, retrofitting, and material uses beyond the design life of a building.

First Light House in Washington DC, USA for the Solar Decathlon Competition.

Prefab in a digital age

The architect who proposes to run with technology knows they will run in fast company.[8] Prefabricated design in a digital age is changing at a rate so fast it goes beyond conventional understanding of change and its potentials. Today there are opportunities for complex forms to be simply and economically designed, manufactured and assembled. Design can be potentially as simple or as complex as we can imagine it, and software advances mean that we can readily map, scale, replicate, duplicate and develop a design via digital modelling.

The future will be likely to see natural systems, organic and geometric forms infiltrate design processes and combining with digital manufacture and prefabricated construction techniques to realise visionary architecture that was impossible to comprehend in the past. Digital manufacture and assembly processes, coupled with the elements and components that result from them also lend themselves to temporary and movable architecture. They also support future disassembly and more sustainable long term building practices as will be reflected on in the final chapter of this book.

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1 Bergdoll and Christensen *Home Delivery, Fabricating the Modern Dwelling*, MoMA NY 2008 exhibition text.

2 Dowie, Callum *Presentation to Graphisoft Design Awards*, Auckland Dec 27 2009

3 Southcombe, Mark *Depth of Shadow: Research and Design* 44th ANZAScA Annual conference proceedings, Auckland, 24-26 November 2010 p79

4 Thoreau, H. *Walden or Life in the Woods* P.62

5 See also page 71 and 98 for elaboration of SIPs panels

6 See also pg 72 and 99 for elaboration of CLT including initial NZ use of CLT.

7 David Strachan, *Project commentary* 2012 Unitec Lecturer in Architecture and co-ordinator of Studio 19 architecture design and construction project.

8 Reyner Bantham in the conclusion to *Theory and Design in the First Machine Age*.1960.

Kiwi Prefab: Cottage to Cutting Edge. The Exhibition

GERARD BECKINGSALE

IN 1833 a small Colonial Georgian style house found itself inhabiting a vast flat plot in coastal Waitangi. Designed originally in Sydney to be surrounded by others of its suburban caste, it must have looked curiously displaced sitting alone on a field surveying the harbour. At a time when makeshift shelter was the order of day this resolved yet compact home spoke of permanence and possibilities. Like many new arrivals to New Zealand in those early days, the house soon found its new provincial identity, when in 1840 it bore witness to a momentous event; the making of modern New Zealand. A pivotal gathering of Maori and Pakeha was staged in front of the house to address an accord to sign the Treaty of Waitangi, and consequently New Zealand's founding document was cemented on the front lawn of a prefabricated house. Designed by a Sydney architect John Verge as a residence for British Consul, James Busby, precut timber frames and fittings were transported across the Tasman Sea and assembled on site. Known now as The Treaty House, it sits today as a reminder of a fractious time in New Zealand's history, and that our founding document is still passionately contested.

Ironically perhaps, and symbolic of turbulent times that followed with significant and ongoing impact in Taranaki, one of the world's oldest surviving corrugated iron buildings sits high on the slopes of Mount Taranaki, sheltering a well kept secret – it too is a prefab. Shipped from Melbourne in 1855 as a section of military barracks, it was moved to Mt Taranaki in 1891 to provide accommodation for tourists. It seems fitting then, that Puke Ariki, sitting proudly between the Taranaki maunga and the sea, should stage an exhibition about the prefabrication of New Zealand's homes.

Military Barracks on the background hill in its original New Plymouth location.

Martin Coffee's house circa 1870. Camp Waihi, Normanby.

Kiwi Prefab: Cottage to Cutting Edge December 2012–April 2013, is an exhibition which captures a renewed vigour for prefabrication in New Zealand. Shifting landscapes have forever changed the face of Christchurch and fuelled interdisciplinary conversations about prefabrication and architectural practice. When invited to join forces with Mark Southcombe and Pamela Bell from Victoria University School of Architecture to develop the Kiwi Prefab exhibition, there was no hesitation. Puke Ariki is dedicated to nurturing and communicating critical thinking and innovation, and Victoria University School of Architecture's reputation as a prolific hothouse of ideas and productivity guaranteed a good fit. The story of prefab is a discursive mechanism enabling us to indulge our visitors in important conversations that have implications far beyond architecture.

Puke Ariki is deeply grateful for the opportunity to collaborate with them on the exhibition. We are grateful too for the support and encouragement received from Barry Bergdoll at MoMA New York, allowing Puke Ariki to engage with conversations started at MoMA's 2008 exhibition *Home Delivery: Fabricating the Modern Dwelling* and explore them within a New Zealand context. The Taranaki Savings Bank Community Trust was quick to grasp the significance of Kiwi Prefab and their generous support enabled us to develop the concept with vigour.

Pamela Bell's research and thesis on prefabrication in New Zealand provided the foundation for Kiwi Prefab, offering a comprehensive history and inspiring window into the future of prefabrication in New Zealand. Pamela's extraordinary capacity to respond to my team's requests and dissection of her research into exhibition format is something we are also grateful for. Combined with Mark Southcombe's guidance, astute design, research and critical analysis, we have an opportunity to engage and challenge New Zealanders in something our culture has long embraced – our homes. The story of kiwi prefab has never been exhibited in New Zealand on such a scale before, and captures stories and endeavours which, while in some ways reflect for better or for worse prefab endeavours worldwide, are anchored in an undeniably local dialogue.

New Zealand has a comparatively short history of European building construction, yet prefabrication is deeply embedded in our architectural psyche. Less than 200 years ago, colonisation of New Zealand was actively facilitated by the English government, and between 1841 and the mid 1850's, an influx of new arrivals to the country encountered an acute accommodation shortage. The indigenous Maori provided an ingenious prefabricated solution in the form of raupo huts, comprising of wall and roof panels made off site from bundled raupo (bulrush), which was assembled efficiently on site to realise an effective shelter. Raupo construction was still in use in the New Plymouth township up until the 1870's, scattered amongst predominantly board and batten houses, a cladding solution apparently unique to Taranaki at that time.

Kiwi Prefab: Cottage to Cutting Edge is far from simply retrospective, and modern museums are no longer merely purveyors of history. Like Puke Ariki, they position themselves as machines for harnessing creativity, collective genius and critical analysis. Barry Bergdoll reinforces this in his essay, noting that prefab research and provocations from the MoMA *Home Delivery* exhibition continue and are poised to reveal enormous possibilities. If creative pursuit is inevitably a form of social commentary, then architecture is particularly vocal. Current interdisciplinary conversations reveal a wealth of ideas and research into prefabrication.

Reviewing and recontextualising architecture is a powerful way to identify who we are as a community, a culture. Kiwi architecture has always been imbued with a DIY ethic, and is arguably still guided by a perceived right to construct our homes in any way we see fit. Our homes are expressions of individuality, and therefore, cultural identity. A perceived threat to kiwi identity lies in strict legislation around compliance, consents and practitioner obligations, so it is heartening to read Peggy Deamer, in her essay, argue that prefab is DIY at the most sophisticated level. In the past, prefabricated houses apparently offered very limited ability to negotiate final design, and have been dismissed as ubiquitous structures driven by social demands, of poor quality and limited individuality. Deamer talks of 'Critical Regionalism,' architecture and construction driven by use of local materials, craftsmanship, and engagement with the landscape, as being a primary driver behind misconceptions around prefabricated architecture.

Modern prefab systems are responding to demands of sustainability, affordability and consumption, alongside new technology offering unprecedented design innovation. The shift from mass-standardisation to mass-customisation poses exciting challenges for traditional architectural practice. Beyond the idea of mass-customisation are issues of integration and interoperability of secondary systems and smart materials. *Kiwi Prefab: Cottage to Cutting Edge* observes a new galvanisation of professionals, industry players and academics, facilitated by forums like PrefabNZ, tackling these issues head on and generating new thinking about future construction methodologies.

We see a new agility in design and construction, allowing scalable responses to particular demands. The ISJ Fridge House is a unique response to an insignificant site and extremely tight budget. The result is a small and eccentrically enchanting home which punches above its weight. On a larger scale, when New Plymouth District Council commissioned Boon Goldsmith Architects to design a new integrated museum library complex, the challenge was to respond to the ultimate significance of the site. Home to the great chieftain Te Rangi Apiti Rua in the 1700's, the pa named Puke Ariki was eroded by settlers until the last remnants were used to fill the Huatoki estuary in 1905. Creating a structure that reclaims the sense of place almost lost to tangata whenua and upholds mana that was never lost is a difficult brief. The response had to be appropriate and significant, and the result is an almost extreme reduction in materials to achieve an appropriate economy of scale. It is anchored on the landward side with tilt slab concrete panels supporting an industrial skeletal structure, thinly veiled in the same prefabricated insulated panels as the Fridge

Puke Ariki Museum with prefab metal SIPs panel roofing.

House. Puke Ariki rises again out of the ground, rediscovering the physical prominence of the original Pa site. It achieves this in a composed yet undeniably assertive manner, maintaining a humble, almost gracious stance within the landscape.

Visitors to Kiwi Prefab at Puke Ariki are drawn into the exhibition space by an expansive digitally fabricated structure, affectionately known as Creature, that soars down the balustrade and under the ceiling of the mezzanine level tailing off after it swoops around a structural column. Creature is a deliberately invasive cellular structure and a highly visual way of conveying complex information about how 3D modelling and parametric research is rethinking our living environments. Its complex form goes far beyond replicating organic structures as decorative element. It is a provocation that looks further than just possibilities of homes with artificial intelligence inserted into the structure, and into the realm of inherent structural intelligence. It suggests a synthesis with nanotechnology and projects the ability to manipulate architectural materials on an atomic scale. Engineering functional materials and systems at a molecular level could see for example, replication of micro organic structures such as the water repellent and dirt resistant leaves of a water lily, offering properties clearly desirable in architecture. Right now, these fast evolving digital design processes allow unlimited creativity and design input.

Architects are at the forefront of client-led projects that require the constant negotiation of ideas leading to the final product. True creativity and innovation is too often stifled by commercial, economic and environmental constraints. New digital technology enables clarity of real constraints, clear communication between architect and client, agreed outcomes with predictable costs and quality. Prefab is the bleeding edge of architecture research and its development. Its pursuit is exciting, challenging, risky, and rewarding, and offers ultimate engagement.

Port-a-bach by Atelier Workshop. *What If* exhibition, Puke Ariki 2010.

Interaction with new architecture is a proven way to reinvigorate discussions about the way we live, and full-scale prefabricated structures inhabit a high profile waterfront plot adjacent to Puke Ariki as part of the Kiwi Prefab exhibition, allowing visitors to experience the products of prefab thinking. Port-a-bach by Atelier Workshop is a concept that captured global imaginations, and confirms that up-cycling has an intrinsic role in prefabrication. In 2010 the Port-a-bach featured in Puke Ariki's 'What If' exhibition as a mechanism to provoke debate about the future of Taranaki, and how our community could respond to impending social and economic change.

Kiwi Prefab: Cottage to Cutting Edge ultimately speaks to the end users of all these prefabricated pursuits. Reignited by new possibilities and deeper understanding of social and environmental issues needing be addressed, there is a consumer desire to have our built environment respond appropriately.

KIWI PREFAB
COTTAGE TO CUTTING EDGE
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CONCLUSION

Back to the Future: Reflecting on Kiwi Prefab Potential

PAMELA BELL AND MARK SOUTHCOMBE

WILL PREFABRICATION 'take on'? was a question posed by an editorial in *NZ Home and Building* magazine in December 1942. It was concluded that it would and that it was possible that demand for the prefabricated house would result in a biannual new prefab model as occurs in the motor industry.

Prefabrication in 2012 has taken on and is increasingly important to the architecture profession and construction industry. This book began with four notable essays and continued to outline past, present and emerging kiwi prefabs for the first time. History highlights the need for business planning, contemporary case studies show the challenges of New Zealand's disparate and competitive industry, and emerging projects exhibit opportunities for collaboration and digital technologies. New Zealand's legacy of experimentation and innovation is important to draw on to construct a vision for potential kiwi prefab futures. This section reflects on findings teased out in this book and lessons learnt, summarises opportunities and challenges today, and considers future change. The final words flesh out the elusive dream, a tangible vision for kiwi prefabricated futures.

On lessons from the past

You succeed only when you stop failing.[1]

Barry Bergdoll's opening essay urged us to learn from the past, commenting that "it is too wasteful to discard the lessons of over a century of experimentation…" The major drivers for prefab remain the same as always, so we would be wise not to forget lessons from the past. In a culture that has a do-it-yourself (DIY) mentality and retains a pioneering confidence to give anything a go, it is important that the stories of our prefab innovators are not lost. Prefabrication is too often a poorly documented design development or production process, as much as it is a series of built architectural outcomes.

Historical highlights worth remembering include:

- Railway houses, State houses and villas are all notable for their use of a pattern-book formula. All of these house types remain sought after housing options today.
- The State house panelised programme showed an effective use of groups of less skilled labour led by a trained carpenter.
- Industrialised Building Systems (IBS) developed some of the first one-piece fibreglass bathrooms, provoking a change in the way all bathrooms were manufactured.
- IBS also developed a stressed-skin floor, wall and ceiling panel and panelised-modular approaches that are still relevant today.
- Lockwood's legacy of almost 70 years is a series of individually custom-designed built outcomes, demonstrating that prefab processes do not need to result in a standard product.

Challenges to creating a strong New Zealand prefabricated housing industry include prohibitive start up costs, resistance from the traditional construction industry, and widespread misperceptions about prefab. In an effort to reduce cost challenges, several firms have experimented with manufacturing in China, and others are looking to do so.

Offshore manufacture is perceived as threatening to some New Zealand construction industry participants. There is also a need to communicate that prefab housing products are complimentary to the traditional industry, and not intended to replace it. Cost-savings from offshore manufacture need to be weighed against intellectual property risks and quality control issues that need to be adequately resolved prior to manufacture and market entry.

Several businesses choose a strategy of prefab specialisation to secure additional niche market demand to an established construction or manufacturing company. In this way prefab products become part of an overall diversification strategy which enables businesses to also carry out traditional construction work and help smooth out fluctuations in demand for their prefab products. A global trend is towards specialisation by country, where New Zealand could become a major supplier of structural and value-added timber products.

Collaborations and joint ventures with industry members enable greater resources for research and development. There is however, a level of pessimism and exhaustion from past failed partnerships. Innovation has flourished where there is internal funding from private ownership and an open attitude to creating new knowledge. There is further scope for cross-disciplinary partnerships between industry associations, businesses and research institutions.

Battling misperceptions through marketing and communication tools is an ongoing challenge. Proven marketing tools such as a nationwide franchise network, high profile show homes, promotional plan-books, and well-known architect designs all help to open up new customer markets.

Taking stock: a challenging context for the next prefab generation

Internationally, the past few years have been a challenging period of economic tightening. Yet a fundamental switch has already been made from mass production of prefabs last century to the design-led mass-customisation of tomorrow. The industry is poised to offer one-off custom-designed prefabricated housing solutions.

In New Zealand at the time of writing, the tight economic times and a constricted building industry cause concern in the design and construction sectors, despite a growing housing shortage including,

– Around 42,000 Leaky Homes needing repairs or replacement were measured in 2009, some of which had been repaired at time of writing in late 2012. The legacy of the leaky buildings crisis is litigation and a fear of alternative materials, products and systems.[2]

– There are 15–17,000 homes needing to be replaced for the Canterbury Rebuild in the wake of the ongoing earthquakes since late 2010. A further 110,000 homes have been identified for repair, with 15,000 homes needing major repair in excess of $100,000. This work continues to be held up by insurance issues. There is an overall estimated cost to the NZ economy of $30 billion.[3]

– Over 27,000 houses are needed to fill Auckland’s shortfall. On an ongoing basis, the region needs 10,000 houses every year for the next two decades. Many of the city’s 400,000 existing homes are poor performers – cold, damp and adding to the population’s health problems. The wider region faces urban design issues about constrained land supply and educating the market about well-designed high-quality multidensity infill housing options.[4]

The need is clearly established. The argument for prefabricated housing as a solution is based on research. Prefab’s role as *a critical agent in invention in architecture, formal and material research, and sustainability*[5] means it can deliver urgent housing solutions. Prefabrication is internationally identified as an efficient and effective way to deliver high-quality buildings using integrated digital interfaces called Building Information

Modeling or Management (BIM) to create greener and more productive built outcomes.[6]

In New Zealand, the BRANZ Building Research Industry Agenda (BRIA) 2012 highlights concerns about quality in the construction sector along with generational mind-sets that are holding the sector back. Quality is closely related to perceived value by customers. New house owners' satisfaction levels are high but call-backs occur in 60% of new houses that are built using traditional methods. Overall, the level of satisfaction with house designs is high and similar amongst clients who chose a standard designs with no changes, or changed standard plans and one-off designs.[7]

The BRIA priority topics for the next five years include weather tightness, sustainability, productivity, automation, industrialisation and new technologies. Taskforces set up by government since 2008, led to the development of the Productivity Partnership (PP) joint venture with industry in 2011 and the launch of a productivity focused Research Action Plan (RAP) in 2012 to tackle questions such as; what is stopping us from using more efficient construction processes, what are the barriers to uptake of standardisation, and, how can it be made more attractive? The integration of BIM is widely considered to be the key to sharing information and communication technology throughout the building process to enable the integration of nontraditional construction methods and processes such as prefabrication.

Any commentary on the New Zealand design and construction industry context would not be complete without a reference to Canterbury. The devastating Christchurch-based earthquakes that began in 2010 have caused the building industry to focus on seismic resistant engineered solutions and resilience has become the word of the day. Various innovative systems have found new applications or been developed in response, by academic and industry collaborations. New takes on using Laminated Veneer Lumber (LVL) component-based structural systems have been developed for commercial applications rather than residential solutions so were not able to be covered in detail in this book. They include the Structural Timber Innovation Company (STIC) Expan glue-laminated system, LVL rocking panels used in the Nelson Marlborough Institute of Technology Arts and Media Building in 2010, PRESSS technology in concrete and timber applications, and hybrid solutions such as Pres-Lam used in the Massey University of Wellington College of Creative Arts building in 2012.

Prefab opportunities and challenges today

The benefits of prefab remain unchanged. There are economic benefits from building production via application of well designed prefab systems, the material supply chain, and labour productivity efficiencies. Increased productivity along with parallel off site and on site production creates significant time efficiencies. Higher quality building results from controlling and refining the conditions of production in a factory environment. Sustainability gains arise from waste minimisation, reduced construction tolerances and lower energy use during construction.

Catering to the individual

The economics of design repetition are increasingly problematic as there are few identical building sites and New Zealanders expect increasingly individualised housing designs. Design and build housing companies manage this process with pattern-books that act as conversation starters. Lockwood suggests that no two houses they produce are exactly the same,[8] and the company longevity suggests they are in touch with the needs of their customer base. It can be argued that many of the modernist failures in industrialised housing of the early 20th Century were because of excessive design repetition and the resulting institutional architectural character.

Mass-customisation

Contemporary digital-based design and resulting mass-customisation potential indicates a greater role for design in prefabrication systems. Smart prefabricators, such as Stanley Modular, recognise the need to marry an investment in high-quality design with regular technical revision in order to meet client and regulatory demands.

Regulatory context

Currently, there is great dissatisfaction about the time, costs and work associated with consent approvals. These have grown as regulatory processes have become more detailed, complex and bureaucratic in the wake of the Resource Management Act and the leaky buildings crisis. Statutory time limits for consent considerations are regularly extended through additional information requests by consent authorities who have had a monopoly on the provision of consent approvals and charge out the time they take.

NZ building legislation allows for performance-based alternative solutions, however the building consent process favours 'acceptable' approved solutions and tends to stifle innovation. The Cooper & Co Showcase in Auckland's Britomart precinct[9] is a case that demonstrates the problem. Despite staged consents and great cooperation from the territorial authority, the consent processes took longer than the design and building processes with parallel offsite construction and onsite assembly.

Encouraging moves addressing the extent of red tape include the introduction of Multiproof single consents for standard designs, some cross local authority boundary consenting, off-site and staged consents processes, and increased use of online consenting. Geobuild is a current joint strategy between the Ministry for Business Innovation and Employment (MBIE) and Land Information NZ (LINZ). The Geobuild work programme aims to include a nationwide online consenting system, building information modelling (BIM) and integrated geospatial information. This will potentially save processing time and costs from the consenting process.

Digital communication

Digital communication has changed architecture and building practices. Drawing boards have gone from most architects' offices, replaced with computer screens, large servers and a range of specialist software to facilitate design processes and simulate building virtually. The ability to create virtual digital architecture has changed design processes significantly. Arguably one of the most significant ways this occurs is in three-dimensional perspectival projections that allow simulation of architecture to occur in real time as design develops. This benefits clients who are also digitally literate and expect greater interaction with the design as it develops. Never before have we

The Showcase at Britomart where the building consent took longer than design and construction.

ABOVE: Massey CoCA by Athfield Architects interior with LVL beams and CNC router cut ceiling carving panels by Jacob Scott.

BELOW: The Click-Raft utilises CNC digital cutting.

known so much about a building before any work occurs at site.

File-to-factory manufacturing

The virtual model, and its ability to simulate and test construction before it occurs via file-to-factory manufacturing is pushing into the construction realm. Sophisticated machine cutting based on digital files allows complex component construction and prototypes of components and assemblies to be made easily and economically. These digitally-driven machines are now found in many specialist prefab plants, joinery factories and university workshops. This technology also allows sheet surface figuration and pattern to be readily manufactured and the potential emergence of new Baroque surface effects as is occurring in contemporary Maori art practices. Customised digital cutting and assembly is becoming a more widely understood and practiced construction process.

Willingness to embrace change

Architects and designers sometimes feel threatened by the idea of design or part-design repetition in different contexts. A great many architects have also been motivated to make good design more accessible to more people in the manner of Charles and Ray Eames who aimed *to create the best to the most for the least.*[10] There is a tradition of NZ architect-designed prefabs that engage with the economies and challenges of designing for high-quality, custom design, efficient and repeatable construction elements. That tradition continues today in the work of a great many architects as has been noted throughout this book.

Builders may also feel threatened by the idea of offsite prefabricated systems and manufacture. When parts of a traditional site built house are completed elsewhere the builder's role shifts to one of assemblage and project management. New construction systems require different building techniques and continued up-skilling.

Customisation poses a threat to manufacturers who are asked to provide differentiated products for clients and site conditions. Manufacturing processes are most efficient when they are repeated with minimal variation. Design requirements that stretch the capabilities of a particular prefabrication system may attract a premium cost to reflect the additional time involved at set up.

Interdisciplinary collaboration

There is growing interdisciplinary collaboration occurring across the NZ prefab industry, bringing together design, manufacturing, construction and marketing sectors. The establishment of PrefabNZ has been instrumental in addressing the diverse nature of the prefabrication sector and lack of prefab education. As a result, there has been a significant increase in information and education on prefab in NZ, an increased uptake of prefab technologies and a great many interdisciplinary collaborations facilitated. The prefab process draws architecture, construction and industry closer together.

Tomorrow's opportunities and challenges

The prefab industry has demonstrated options to respond to opportunities and challenges around leaky buildings, Canterbury's re-build and Auckland's housing shortages. As we move into an increasingly digital age, traditional bespoke building practices will integrate with more sophisticated design and fabrication processes. Prefabrication is being incrementally assimilated into contemporary building practices and this process will continue to happen as efficiencies give advantages to early adopters and others catch on. Clients will experience increased value based on receiving more quality, reduced time and known costs, as well as understanding a greater return on investment from a life cycle assessment perspective. A construction paradigm shift based on the pervasiveness of digital technologies is upon us. Some opportunities, challenges, a few observations and predictions follow.

Skills shortages

The focus on rebuilding in Canterbury has already identified shortages in construction skills and subtrades, some of which are being met by an influx of international building professionals. The mid-20th Century state housing panel programme showed the value of lower skilled workers in groups led by trained professionals. In the near future, this method may enable prefab businesses to utilise unemployed youth workers and lower-skilled workers suited to repetitive or factory-based building work under supervision. Smaller scaled and higher-skilled builders will be freed up for more challenging bespoke site-based work and addition and alterations. Retaining newly skilled participants through the next bust cycle will be another challenge. A safe, healthy, pleasant prefab working environment may be more acceptable to the young, talented, skilled workforce that the industry needs.

Cheshire Architects proposed Church in the West. Project Architect Andrew Barrie.

State housing panel programme utilising low skilled workers and panel based prefab construction.

Building Information Modeling (BIM)

Digital Building Information Models (BIM) are increasingly used to exchange virtual building and geographic site information between consultants and client groups facilitating collaboration and information management. Changes proposed to a building design are able to be simulated and tested through multiple specialist performance programs before being approved or implemented. BIM virtual knowledge extends to schedules and cost plans that accurately determine the extent of materials and funding needed for a project even as its design is developed. Several different software systems compete to offer interdisciplinary BIM functionality. There are inter-operability issues between the major software programs that need resolution to make the most of BIM potentials.

In the near future, BIM will be the required standard for information delivery on major building projects, allowing facilities management and updating of the virtual building. The copyright, ownership, liability for and value of the BIM model are being debated by parties on a contract by contract basis. The role of architect as the primary creator of the BIM model in the same realm as construction contract documents seems a likely default position.

Continuing education

The pace of digital technological change places key knowledge with the young who are familiar with the use of emerging software. This highlights today's requirement for lifelong continual learning. Prefab focused educational programmes that introduce new technologies, techniques, methods and materials are required on an ongoing basis. The interdisciplinary body PrefabNZ has taken on a major public and industry wide educational role in NZ to date and been instrumental in beginning to change public misperceptions regarding characteristics and potentials of contemporary prefab. PrefabNZ has also facilitated information exchange across disciplines, and to the wider public, acting as a front door portal to prefabrication expertise. The binding relational value of such a broad interdisciplinary body is clear to us as is its potential to add enormous value to the NZ economy by facilitating a strong collaborative culture.

Design-led-research and complexity

Tectonics of computing operations such as easy replication through copy and paste, design manipulation through rotation, mirror, stretch, reshape and crop, have an impact on design and research. These types of digital operations and their development in more sophisticated parametric forms have facilitated the emergence of extended recorded design processes. The ability to create multiple iterations quickly and virtually represents an important change to the way that architecture has been taught and understood in universities. Design changes and effects are able to be readily tracked and tested, reflected on and recorded. Multiple design options can be generated through a process of digital morphogenesis where effects of a force or impact on a design population can be tested through programming changes.[11] More recently programmes such as Grassshopper, as used on the VUW Creature installation project at Puke Ariki, have provided a diagrammatic interface for parametric scripting, easing access and widening availability of parametric technologies to designers without developed expertise in computer programming. The increasing ease of access and operation of such sophisticated tools will increase the potential complexity of architecture able to be readily created.

Export markets

New Zealand's small size means that prefab manufacturers need to diversify and find ways of expanding markets. Long distance transport costs are a problem that needs to be engaged with to bring unit costs down. Opportunities lie in reducing unit cost by targeting closer markets, reducing unit size to fit more products within a transport container, or increasing value through additional manufacturing of products. Major opportunities exist closer to New Zealand in Australia and Asia-Pacific. Precedents exist in high value timber panels from Germany and Austria serving wider European markets. NZ has the potential to become a prefab timber export hub for the Pacific and wider timber industry strategies are acknowledging this. Manufacture or part manufacture of diverse high value goods closer to export market sources, and free trade agreements with countries such as China open the door to further possibilities.

Transportation

Historically, the NZ strength in individual component (pre-nail trusses and frames) and complete building prefabrication is not well suited to value-added exports. Panel and hybrid module+panel systems minimise transport volumes and add value to raw material to a greater extent

Tennent+Brown Kakano seed pod meeting room at Nga Purapura Te Wananga o Raukawa.

NMIT Arts & Media Building innovative post-tensioned timber rocking panel installation.

than component-based prefab. There is no doubt that a greater amount of future prefab products will be panel and hybrid typologies. Opportunities exist for the design and fabrication of smart utility cores or modules integrating services. Compact modular prefab precedents that expand or combine at site to create larger homes include the First Light house, Habode, port-a-bach and iPad.

Resilience

The Canterbury earthquakes have brought into sharp focus the short-term minimum capital cost focus of the NZ building industry. Engineers have designed buildings for clients to comply with minimum code standards with no consideration of medium-term serviceability and resilience. As a consequence, although most buildings survived and many are structurally sound, they are no longer serviceable. Subsequently, a wide extent of demolition and waste to landfill has resulted. This is not economically or socially sustainable.

The ways that buildings are detailed to fit together, the ways they move, and the ways they are constructed needs to change. Flexible prefabricated products can be part of the solution. New resilient design technologies in concrete, timber or steel enable movement without excessive damage, are already available today, and are likely to become more familiar in the future. Insurers recognising reduced future risk may help to change the minimum cost focus of the engineering and construction industry. Alternative forms of more direct funded housing delivery for social housing that offer more than a short-term minimum-cost, maximum-profit focus will encourage a refocus on medium-term design and construction performance.

Design for disassembly

Current practice places an emphasis on building once. However, the reality of the way our building stock operates is that it is has regular cycles of maintenance, refurbishing, and reconfiguration. Changes in political, commercial, economic or cultural factors have as much effect on building life cycles as the material and spatial qualities of a building. Design in the future will address more than the initial life cycle and more readily accommodate future change of materials and components. Prefab design focuses on connection, assembly and fabrication for future disassembly, ready adaptation, and the sustainable reuse of parts. As Australian architect Tone Wheeler comments, the future will be more about ‘the spanner, than the hammer’ with a subtle shift away from glue, nails and waste, towards bolts, screws and ready reuse.[12]

Trading prefab parts

The tradable adaptable prefab house design that grows and changes according to demand is one that IBS imagined in the 1960s. This concept requires a trading market for the storage and resale of prefab parts. Currently, this occurs in NZ as a market for relocated houses removed from their original sites. The central North Island town of Bulls is home to two such house relocators, Brittons House-movers and Central House-movers. It is just a small step from here to establish an internet-based market for prefabs, prefab panels, modules or parts. It is already possible to search, locate and purchase small prefab sheds and buildings through the TradeMe website.

Changing demographics

The silver tsunami is almost upon us, as the baby boomer population reaches retirement age. Smaller households of more educated occupants are likely to demand high-quality housing. This demand together with new technologies and a shortage of construction skills will lead to a rise in factory-built houses utilising standardised components.[13] Increased demand for prefab housing will be likely to shift industry towards larger offsite firms working with traditional small site-based firms. Universal design and climate change adaptation features will need to be included in new housing.[14] In 2011, the Lifemark certification and the Homestar certification systems were both launched for lifetime design and residential sustainability rating respectively. Both tools have begun as voluntary schemes to increase awareness of design features for home owners and to provide a measuring stick to help prospective home purchasers evaluate different houses.

Life cycle energy use

There is growing recognition of the importance of energy cost and use as a determinant of housing affordability, comfort and health. As Brenda Vale notes in her introductory essay, the lifetime energy use of housing is a larger sustainability issue than the efficiency of its construction. Reducing the net energy demands of housing will accelerate as a future design focus. Technological innovations such as smarter building materials that integrate solar panels with roofing or wall cladding, and increased insulation and energy efficiency standards demonstrated through energy use simulation are already on the horizon.

Changing urban housing forms

The decreasing availability of land for housing, the increasing cost of infrastructure, the rising cost of housing, and the contemporary lack of time in our culture have combined to change the nature of housing demand. Less people own housing and more will rent than has historically been the case. People prefer to live closer to their work, central city services and infrastructure than they did in the past. In the future, the quarter acre dream will look more like a conveniently located efficiently designed, stacked, no maintenance terraced dwelling. Pent-up regional housing demand in Auckland and Christchurch as a result of population demographics and the earthquakes, combined with the changing demand is already resulting in a call for higher-density housing. This will increasingly mix public and private rental and social housing with private housing in higher-density housing close to city centres and transport arteries. Prefab terrace and apartment housing with shared management structures will result on the fringes of our city centres. Options will include studio and shell housing, live-work housing, dual-key adaptable-use housing, and housing designed to be more responsive to changes in topography, tenant and ownership needs. Green and cohousing initiatives are likely to emerge, with common facilities and shared ownership.

Housing showcase

The NZ tradition of demonstration show homes has been used to powerful effect by design-and-build companies. The historical parade of homes concept where a variety of housing products by different manufacturers are colocated has occurred at the HIVE Housing Innovation Village in Christchurch. Built housing innovation is readily understood by a wide cross section of potential purchasers, industry and governmental sectors. European prefab housing village precedents feature up to a hundred permanent show homes in one location. In the future, housing villages will be able to introduce modes of living such as multiuse (live-work) and medium-density options as a way to familiarise the public and industry with new urban patterns for living.

Prefabricated futures...

As this book draws to a close, NZ's design and construction industry is in a tight spot. Building consents are at a 25–year low with significant skills shortages predicted along with an impending building industry super-boom which will undoubtedly be followed by a super-bust as in the past. Prefab housing can help address the current need, and with diversified markets can help smooth out the peaks and troughs in economic cycles. The extent of prefab uptake will depend on industry leadership to demonstrate the advantages to the public and key government agencies and stakeholders.

It is likely that future successful kiwi prefabs will offer flexible design solutions at medium to upper house prices. Prefabs that deviate too far from traditional sociocultural aesthetic acceptance will not survive, particularly those with inhospitable interior surfaces or that are too small to be comfortable. Established housing firms that work alongside architects and designers to focus on design quality will have greater acceptance in an increasingly design savvy culture. Changes will be seen in specialised material technologies, the cost-benefit analysis of prefabricated typologies, multiunit prefab housing precedents and further promotion of change from within the construction industry's innovation-resistant culture.

Peggy Deamer's proposition that "industrial production and cultural authenticity can go hand in hand"is timely, noting the shift for 21st Century prefab from standard solutions to local site specific customised solutions. Prefab will continue to offer complimentary alternatives to traditional design and construction processes, which are also using increasing amounts of prefabricated components. Prefab is a natural leader, innovator and provocateur – an agent for change.

Dreaming a kiwi prefab future…

There is no doubt that prefabricated building innovation and the increased quality and productivity associated with it will continue to change in our rapidly evolving digital information based future. That future will be able to readily design, pre-make and assemble increasingly complicated products, efficiently. Through prefab means we will make the sophisticated, technological and complex seem simple, easy, affordable, of a high build quality and delivered quickly. Clients will be happier with an integrated design and building process and feel encouraged to repeat it. Ready collaborations between design, construction and industry will have the satisfaction of a job well done. Are we dreaming yet?

Imagine a future where you can visit a show-housing park on the weekend to experience different housing models. At the information centre you explore possible housing designs customised to your needs in an immersive walk through virtual environment, before you watch a short film about the manufacture and assembly process, or witness simulated seismic performance

of structural systems on display. You choose from a selection of material finishes, stair treads, bench-top heights and other customisation choices. You decide to test-dwell a home by spending a night in it with your family. After your visit, you continue the process online by making a selection and final individual design changes with transparent cost and timing implications communicated. From here on in, it is a simple customised product purchase transaction. You make a down-payment with finance options, login to watch the webcam at the manufacturing plant, then visit your site to see the parts arrive onto the pre-formed foundation system. Your house is beautifully designed, strong, resilient, smart and energy efficient, and is assembled at site in a third of the time houses were in the past.

When your needs change you may choose to alter the house by adding modules or components, exchanging or selling parts, or ordering a customised upgrade package. This will all readily disassemble and reassemble for ease of change.

Far-fetched? Idealistic? Or like IBS, just out of time? Most of these dreams will shape the near future with existing technologies and processes, and a little focused effort. The future is closer than we think, and it will be well designed and crafted from creative prefab assemblies.

iPad Taranaki.

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GLOSSARY

This glossary expands on key terminology explained in the Prefab Primer section.

BACH OR CRIB a colloquial term for a second home or holiday home in New Zealand. Bach is prevalent in the North Island, while Crib is more commonly used in the South Island.

BUILDING INFORMATION MODELLING (BIM) is integrated software tools of which three dimensional digital drawing is just one part. Elements embedded in a digital model are assigned values that can be independently accessed and cross-referenced to produce schedules and assist coordination during the documentation and construction process.

COMPLETE BUILDING PREFAB OR BOX-FORM prefab units enclose usable space and form all or part of the completed building or structure. Typically they are fully factory or yard finished internally and externally, so that a connection to utilities and foundations is all that is needed at site. In New Zealand these buildings are commonly referred to as transportable, portable or relocatable, although each of these terms have subtle distinctions.

COMPONENT-BASED OR COMPONENTISED PREFAB are relatively small scale items such as light fittings, windows, and door furniture usually assembled offsite. These include structural members (trussed and frames), fittings, fixtures, and joinery that is cut, sized or shaped away from the site for assembly on site. A complete set of components is a subassembly and commonly referred to as a kit, kit-of-parts, or kitset.

COMPUTER-AIDED DESIGN (CAD) is design using computer software that enables design, drawing, rendering, and modelling with electronic files. Commonly used programs include SketchUp, AutoCAD, ArchiCAD and Revit.

COMPUTER-AIDED MANUFACTURE (CAM) is the use of specialist computer software to control machine tools and related machinery in manufacturing.

COMPUTER NUMERICALLY CONTROLLED (CNC) is cutting or machining technology that is controlled by computer programming. It is the interface between computer software and manufacturing hardware which enables designs to be directly translated from digital to physical means without manual interference. The manufacturing sectors use this technology widely, whereas the construction industry generally uses the software to produce drawings, but not physical products. CNC machinery is programmed with specialist software.

GREEN MODERN PREFAB refers to prefab housing (particularly from the west coast of America) that is architect-designed, has neo-Modernist design aesthetics and exhibits sustainable technologies.

HYBRID-BASED OR HYBRIDISED PREFAB is also referred to as semivolumetric prefabrication. It consists of a mixture of volumetric or modular units and nonvolumetric or panelised units (module plus panel). There are currently few examples of hybrid-based prefabrication in New Zealand.

INDUSTRIALISED HOUSING was a term popular in New Zealand in the 1970s and 80s. It refers to a large-scale manufacturing approach to construction. Prerequisites for industrialisation include a large consumer market and high volume output.

KIWI is a large flightless bird but is also a colloquial term for the people of Aotearoa New Zealand. So a Kiwi is a New Zealander. The term arises from the unique Kiwi bird that is a national symbol of New Zealand.

MANUFACTURED HOME is a current United States construction industry term for mobile homes.

MASS-CUSTOMISATION This is the use of digital technology and CAD-CAM interfaces to produce individual custom designs from standard manufacturing technologies.

MOBILE HOME also known as trailers in the US are similar to caravans in NZ. They are manufactured away from site, and can be towed to the site in a largely completed state with minimal onsite labour. A mobile home does not conform to building codes and is not necessarily fixed to permanent foundations at the site.

MODERN METHODS OF CONSTRUCTION (MMC) is a British term that refers to both offsite or prefabricated construction technologies and innovative technologies applied at site.

MODULE OR MODULAR PREFAB or volumetric prefab units enclose usable space and are installed within or onto a building or structure. They are typically fully finished internally, such as toilet/bathroom pods or plant rooms. Structural units may be rooms or large parts of the building referred to as modules, blocks, chunks, volumes or sections. Nonstructural units are used inside conventional buildings usually to contain utilities, and are referred to as cores, units or pods.

OFFSITE OR OFFSITE MANUFACTURING (OSM) is a term increasingly used to describe the spectrum of applications where buildings, structures or parts are manufactured and assembled remote from the building site prior to installation in their final position. The term is interchangeable with Prefabrication.

PANEL-BASED OR PANELISED PREFABRICATION includes two-dimensional or planar units such as panel systems and cladding panels that do not enclose usable space. They may include windows, doors or integrated services, and are either open-framing (open panels) or closed-in with cladding and/or lining (closed panels). A closed panel may be referred to as a cartridge, and a structural floor panel may be a cassette. Panels are usually transported to site as flat-packs.

PORTABLE BUILDINGS (also commonly called Portacoms in NZ) are generally those intended for short-term temporary applications such as utilities at events or site offices.

PRE-CONFIGURED, PRE-DESIGNED OR PRE-PLANNED terms refer to existing house plans designed prior to site knowledge. They are often presented in plan-books or pattern-books for clients to choose from. They are commonly used as conversation starters to aid the early design process between client, designer, builder or manufacturer.

PREFAB OR PREFABRICATION refers to processes of construction from prefabricated parts or assemblies. Prefab is also the colloquial New Zealand term for a completed prefabricated building.

PRE-NAIL COMPONENT refers to an assemblage of timber based materials that are cut, shaped and joined together using nail-plate technology. Nail-plate technology uses engineering software, computer controlled cutting machinery, and steel plate fasteners, as supplied by Mitek and Pryda. It is a technique commonly used for roof trusses and wall framing in traditional housing construction.

RELOCATABLE HOUSING OR 'RELOC'S also known as transportable houses can be of any style, age, or material. The term does not necessarily infer a new prefabricated house. It is a dwelling that is built or assembled at one site and then transported in parts, or in whole, to a different site.

STANDARDISED housing utilises components, methods or processes in which there is regularity, repetition and a background of successful practice. Standardisation is useful to gain efficiencies in prefabrication and does not require identical outcomes.

TRANSPORTABLE HOUSING includes any house that is purposely built away from its intended final site. In New Zealand, this includes yard and factory built housing supplied by a number of businesses.

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Abbreviations: L=left, R=right, A=above, M=middle, B=below

Andre Hodgskin P66, P67, P68R, P90
Andrew Barrie P137
Archives ABVF 7484 W4925/1 (1-16) P4-5, P42-3, P51AB, P138
Archives AQT 6401 A32127 P53
BNZ Archives P47B
Bergendy Cooke P98L
Beth Kirkwood P73A
Bronwen Kerr P96M
Callum Dowie P115AB
Charlotte Bowie P87
Christopher Kelly P104A
CMA+U P117A B, P136B
Designscape Issue 50 1975 P26
De Geest Construction P54AB, P55
Denis McGowan P59MB
Dwell Magazine P64
Eli Nuttall P39, P40AMB
Estate of Roger Hay P27AB, P30AMMMB, P31AB, P32AB, P33
Foster Architects P83A
Geoff Fletcher Architects P82
Glenn Murdoch P98R
GreenBeing P96B
Group Architects P58
Hamish McAul P62
Herriot Melhuish Architects P81MB
Ian Stantial P72A
Irving Smith Jack Architects P95AB, P140
Ivan Juriss P28, P29, P57, P59A
James McNicholas & Azmon Chetty P92
Jeff Brass P136A
Jeremy Toth P102-103, P135
Joe Fletcher Photography P48
Juken NZ Triboard P74
Keith Hay Homes P60A, P94
KieranTimberlake P37A B
Keith Collie P46A
Laing Homes P93A B
Leap Australasia Limited P11, P124A
Lisa Cumming P116A, P119
Lockwood P68L, P69AB
Louise Ryan P107
Malcolm Walker Architects P73MB
Mark Southcombe P114M B, P116M
McRaeway Homes P61
MoMA New York P15
NZ Home Magazine P23
Oh.No.Sumo P110, P111, P112AMB
Pacific Environment Architects P100A B
Pamela Bell P38A, P80A
Patrick Reynolds P76, P104B
Paul Hillier P116B, P119AMMB
Paul McCredie P86ABLR, P105, P139
Peter Mitchell P46B
PlaceMakers P65AMB
Puke Ariki P126-127, P128, P130, P131AB
Quick Living P81A
Ralph Oswald P13
Rod Gibson P84AMB, P85AB
Roger Walker P60B
Roll-Forming Services P36A
Ron Blunt P124M B, P125
Salmond Architecture P72B, P75
Sandra Zuschlag P97
Scott Frances P19, P20
Simon Devitt P78, P79
Sophie Prebble P96A
South Australian Record P44
Stanley Group P77AB, P80MMMB
Strachan Group Architects P34
Studio 19 Unitec + SGA P120AB, P121AB,
Studio Pacific Architecture P88, P38B
Tomio Ohashi P47A
Touchwood P36M, P71AB
Trends Publishing, P106
Trevor Read, P89, P91, P143
Trower Panel P70
University of Auckland Architecture Library Archives P50B
University of Auckland SoAP P108, P109
VUW First Light house Solar Decathlon project team P36B, P122, P123
Wichita-Sedgwick County Historical Museum P45
William Mein Smith, Hocken Collections Uare Toaka o Hakena, University of Otago P49
William Toomath P50A
Wilson & Hill Architects P83B
XLam P99AMB
Xuanyi Nie P113A B, P114A

INDEX

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Kiwi culture has revered the caravan, the tent and the shed, but until now the prefab home has been left out in the cold. *Kiwi Prefab: Cottage to Cutting Edge* reflects on New Zealand prefabricated housing. It publishes for the first time a New Zealand prefab housing history, survey of contemporary and emerging prefab design, and some cutting edge research projects.

It includes essays on prefabrication by international authors from the Museum of Modern Art in New York (MoMA), Yale University, Victoria University of Wellington, and an historic essay on the 1970s Industrialised Building Systems (IBS) project. The ground-breaking exhibition *Kiwi Prefab: Cottage to Cutting Edge* held at Puke Ariki Museum New Plymouth from December 2012 – April 2013 is also discussed in an essay by the exhibition curator.

Kiwi Prefab explains prefabrication basics and terms, and illustrates past, present and possible futures for NZ prefab homes in an accessible written style. The book's end section provides a glossary and index that will make it a useful reference source. This book will appeal to a wide range of audiences from design, construction and manufacturing, to the homeowner, academic and student.

Prefabricated architecture has been a part of the New Zealand landscape almost as long as people have built here. Particularly suited to our lightweight buildings, prefabrication is as much about collective, efficient, improved building processes as it is about a quality built result. Its enduring legacy is the design innovation that continues to result from people from different fields talking to each other and working together.

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