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Enabling Prefabricated Timber Building Systems for Class 2 to 9 Buildings

Project number: PNA324-1314

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Forest & Wood Products Australia

Enabling Prefabricated Timber Building Systems

For Class 2 to 9 Buildings

Prepared for

Forest & Wood Products Australia

by

Centre for Sustainable Architecture in Wood (CSAW)

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Executive Summary

This project identifies ***drivers for*** and ***barriers to*** the increased use of **prefabricated timber building systems** in Class 2 to 9 buildings.

Currently, the use of prefabricated timber building (PTB) systems in Australia is predominantly limited to truss and frame construction in Class 1 buildings, but an increasing number of high profile large scale commercial projects utilising PTB systems suggest that there is growth potential into the commercial building sector. To leverage the momentum currently being generated by these projects and the recent changes to the National Construction Code allowing Fire Protected Timber for Deemed-to-Satisfy solutions in mid-rise construction, an increasing number of new PTB solutions are being developed and commercialised to compete with both traditional construction methods and increasingly sophisticated steel and concrete prefabricated solutions.

There is a growing awareness of both national and international developments utilising PTB systems, especially in the mid-rise sector, which is emerging as being the most suited to PTB systems. Several top-tier builders/developers have forged their own path in this field with significant investment in prefabricated timber design departments within their organisation and in actively testing their ideas on commercial projects. Some of these developments have received broad public attention through media coverage and have also been recipients of national timber design awards (Australian Timber Design Awards, 2013), (ArchitectureAU, 2014). Industry feedback suggests that PTB systems also have the potential to increase in prominence in commercial construction across Australia as its cities and regional centres continue to grow and population density increases. Both perceived and real barriers also exist which are having an inhibiting effect on the uptake of both new and existing PTB systems. Issues such as established conventions defaulting to steel and concrete, ensuring an accessible and affordable supply chain, ensuring tertiary, professional and industry training is effective and proactively communicating the viability and benefits of timber alternatives continue to temper opportunities for PTB systems.

The development of market ready PTB systems in Australia is in a formative stage as prefabricated timber construction is yet to achieve broad acceptance as a conventional method of building. Some sectors of the commercial building market will require regionally applied solutions, especially in places where the use of timber for low rise residential construction is less prevalent. This will be one of the challenges facing the expansion of PTB systems although, with an increase in large scale mid-rise prefabricated buildings, and with the increasing nationalisation and internationalisation of the top tier building companies, there are indicators suggesting that market acceptance will grow as an increasing volume of PTB solutions become normalised in commercial construction.

Opportunities for PTB systems can be leveraged off timber's well-established benefits such as high strength-to-weight ratio, design and construction flexibility, general environmental credentials including carbon sequestration, and prefabrication's suitability for use on brown field, restricted access and difficult sites and developments. Technical solutions are now being established for the many of the issues pertaining to PTB systems and regulative constraints have now been largely removed. The application of these solutions, the lessons learnt from applying the regulation across a broad range of building types along with continued education, will be the key areas influencing the enabling of PTB systems.

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1. Introduction

Prefabrication is defined as:

'The design and off-site manufacture of a project specific component, assembly or system that is utilised, in part or as a whole, to build a structure.'

Prefabricated components include structural or envelope timber components delivered to sites as:

- linear components prepared specifically offsite for the project, such as prepared glulam and nail-plate truss assemblies;
- pre-assembled panel elements, such as CLT panels, cassette floors and external envelope units; or
- fully finished volumetric modules.

Whilst in a number of overseas countries quite sophisticated prefabrication processes are used in a range of building sectors, in Australia the use of prefabricated timber building (PTB) systems is predominantly limited to truss and frame construction in residential (Class 1) buildings.

In other building sectors (or Classes) outside of single residential homes there is a growing awareness of international developments utilising PTB systems, especially in mid-rise multi-residential apartments which is emerging as being the most suited to PTB systems. Several top-tier builders/developers in Australia have forged their own path in this sector and demonstrated the significant cost benefits of these types of systems compared to traditional alternative material construction and are looking to expand their activities with PTB systems.

Also importantly are the recent changes to the 2016 National Construction Code (NCC) which now allows under the deemed to satisfy provisions the use of lightweight and massive timber in Class 2 (apartments), Class 3 (e.g. hotels) and Class 5 (office) buildings up to an effective height of 25m. This now makes design and construction of these types of buildings far more affordable, as an expensive 'alternative' fire design solution is now not required, and opens up the opportunities to a broader range of builders and developers.

To assist in progressing these new market opportunities, this project report aims to:

- identify drivers for and barriers to the increased use of prefabricated timber components in class 2 to 9 building;
- recommend strategies and identify success factors for industry and its members to benefit from the drivers and minimise the impacts of the barriers;
- provide case studies of prefabricated timber components being included in class 2 to 9 building and relate case studies to opportunities with different building types throughout Australia.

2. Report Structure

2.1 Methodology

This report draws upon the experience, expertise and insights of the project's industry consortium examining issues affecting the enabling of prefabricated timber building systems into the Australian building industry with a specific focus on drivers for and barriers to increasing PTB systems in Class 2 to 9 commercial buildings.

Prefabrication as a building methodology is initially discussed separately from PTB systems, proposing both a written definition and a graphic matrix to identify the various nuances and degrees of complexity that exist within the spectrum of prefabrication. Four broad typologies of prefabrication are identified to recognise and graphically represent their differences and commonalities. These have been used to inform and provide clarity to the the various types of both on and off site manufactured buildings and building elements that PTB systems can potentially be used in. Opportunities for more broadly increasing timber in construction and specifically with PTB systems in the context of prefabrication are then explored by discussing current and emerging opportunities.

Constraints effecting the establishment of both a broad-based prefabrication industry and PTB systems are discussed in the context of Australian specific and international experiences.

A desktop literature review has been undertaken to ensure relevance and to canvas state-of-the-art developments. Several case study buildings are presented to demonstrate recent examples of Australian projects which have incorporated significant PTB systems.

A series of questionnaires were circulated to design professionals (architects and engineers), builders, truss and frame prefabricators and nail plate suppliers to gauge industry's thoughts and opinions on a range of topical issues pertaining to the state of timber and prefabrication currently and where opportunities might lie into the future for PTB systems.

Conclusions and a series of recommendations complete the report with the appendix containing supporting information.

This report is intended to be disseminated through:

- The key stakeholders
- Distribution of the report to industry through the FWPA and the Wood Solutions website
- A series of face-to-face seminars presenting the research findings

3. Prefabrication in Construction

Discussing prefabricated timber building systems requires an understanding of prefabrication in general, therefore it is important to define prefabrication in such a way that acknowledges the broad range of typologies that comprise prefabrication as a methodology and have relevance to PTB systems.

As part of this process, a range of participants in the Australian prefabrication construction industry were asked to provide their own definition of 'prefabrication'. Their responses often expressed a nuanced understanding that reflected their position in the sector, highlighting the importance of canvassing a broad cross section.

Some of the typical responses were as follows:

- *'Delivery to site of pre-assembled structural components, ready to be fixed in place.'*
- *'Construction work completed prior to arrival on site.'*
- *'Built off site and manufactured under a roof in a controlled environment.'*
- *'Off site manufacture of roof, wall and floor panels both open and closed'*
- *'Factory fabricated building components (i.e. floor & roof trusses, wall frames, floor cassettes) delivered to site and lifted into position manually or mechanically, providing significant time savings and water protection.'*

In addition to feedback from industry, the following points have been identified from prior research as key elements which should be incorporated into a broad based definition of prefabrication:

Design	*Prefabrication is not just about the making, both the architectural and engineering design intent and processes are paramount and must be considered.*
Location	*Manufacturing or the act of making pre-determined elements must be away from the final destination/position in a building or structure. This could be on the same site or at another location off site.*
Purpose	*Prefabrication is not the manufacture of 'blanks' but rather specific pieces intended for a specific task or series of tasks in a particular building or structure.*
Singular Item or Entire Assembly	*The item being prefabricated can be a single component or an entire assembly of components.*
Simple to Complex	*Components or assemblies of components can vary in their complexity relative to the entire structure. They can form part of a structure or the entire structure.*

Taking the above factors into account, this report defines prefabrication as:

The design and off-site manufacture of a project specific component, assembly or system that is utilised, in part or as a whole, to build a structure.

4. Prefabrication Matrix

To complement and expand the definition of prefabrication developed by this report, a Matrix of Prefabrication has been developed to graphically represent the varying degrees of complexity that exist within prefabricated construction and the dimensional/spatial nature of the elements produced.

Four typologies for the matrix were identified to recognise and graphically represent the complexity spectrum and highlight their differences and commonalities. These are:

- **(ØD) -** Zero Dimensional (Nodes)
- **(1D) -** One Dimensional (Sawn or Engineered Timber Lengths)
- **(2D) -** Two Dimensional (Frames and Trusses, Floor Cassettes, Assembled Post and Beams and Massive Timber Panels)
- **(3D) -** Three Dimensional (Volumetric Modules)

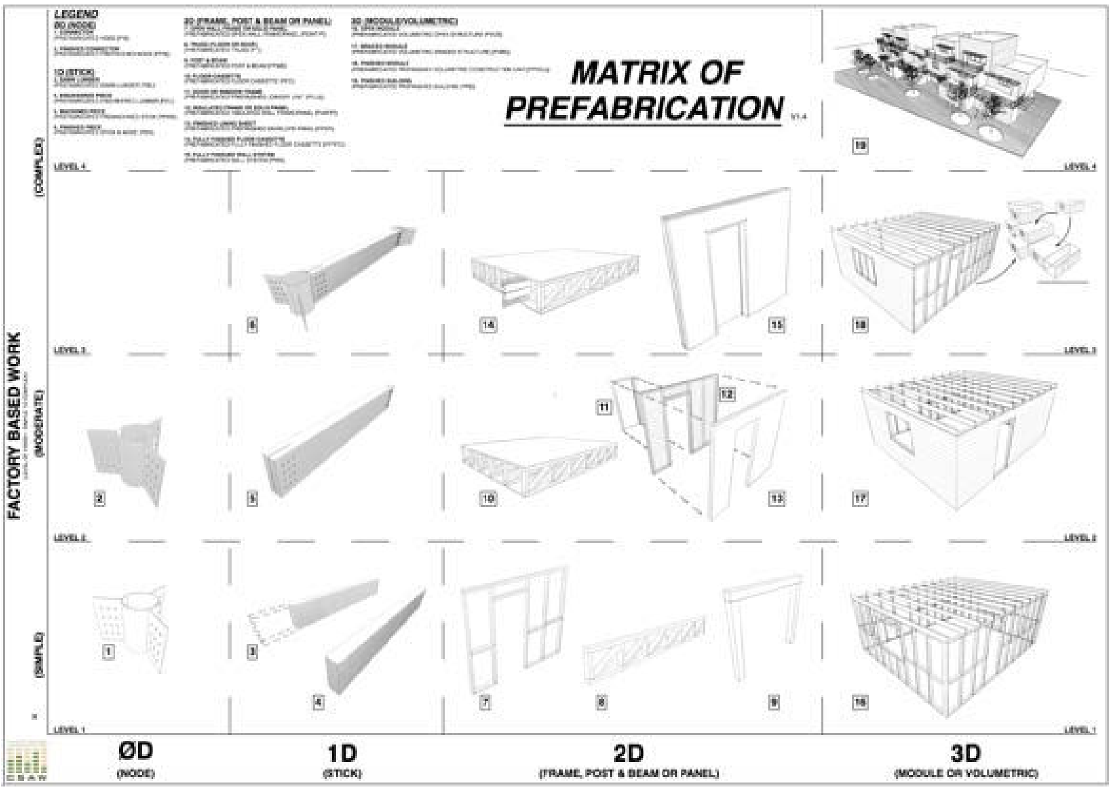


Table 1. Prefabrication Matrix (refer to Appendix 2 for larger image).

The Y Axis:

Elements along this axis represents the level of finish. Elements with a ‘simple’ level of finish relative to their typology (ØD, 1D, 2D & 3D) are positioned on the lower levels on the matrix. As their relative complexity increases, they are positioned higher up the table with Level 4 representing the most complex.

The X Axis:

Elements along this axis increase in relative complexity from left to right. Simpler ‘Zero Dimension’ nodes are on the left with a progression to ‘Three Dimensional’ modules and volumetric elements on the right.

Zero dimensional prefabricated elements or nodes act as connectors joining other elements together.

They can be unfinished, meaning they require a final surface treatment for corrosion protection or aesthetic reasons after installation, or are prefinished with the specified treatment as part of the manufacturing process. Basic components are widely available in all of Australian states and territories and are generally made with steel, more complex connectors such as those seen in Europe and North America are less widely available. They are represented in Levels 1 and 2 of the prefabrication matrix.

Figure 1. Unfinished connector (No.1) and finished connector (No.2)

4.1 One Dimensional (1D) Prefabrication

One dimensional prefabricated timber elements can be simple (Level 1) sawn lumber or an engineered timber member. To increase their complexity (Level 2), they can also have undergone additional processing or milling to allow an on-site fitting of a node element with minimal adjustment. The most complex type (Level 3) involves pre-cutting to length, milling to suit a specific node and the fitting of the node off site. While not strictly prefabricated as they are mass produced and therefore are a commodity product, sawn lumber could be included into level one of this category. Examples of level two and three are machined and finished elements made specifically for a project. They are also available in all Australian cities and most regional centres, are not mass produced and as such, are a made-to-order speciality item.

Figure 2. Sawn timber cut to length (No. 3) or engineered timber piece (No. 3 & 4). Machined piece (No. 5). Finished piece with connectors attached (No. 6).

4.4 Two Dimensional (2D) Prefabrication

The simplest form (Level 1), of the two dimensional (2D) prefabricated timber elements, typically comprises four sub-types which are:

- 'open' wall frames,
- floor and roof trusses, usually nail plated,
- pre-constructed post and beam assemblies, or
- Massive timber panels.

These types of prefabricated solutions are the most common type of prefabricated timber assemblies available in Australia and the wall frames and floor & roof trusses are widely used in the low-rise residential construction sector (Class 1).

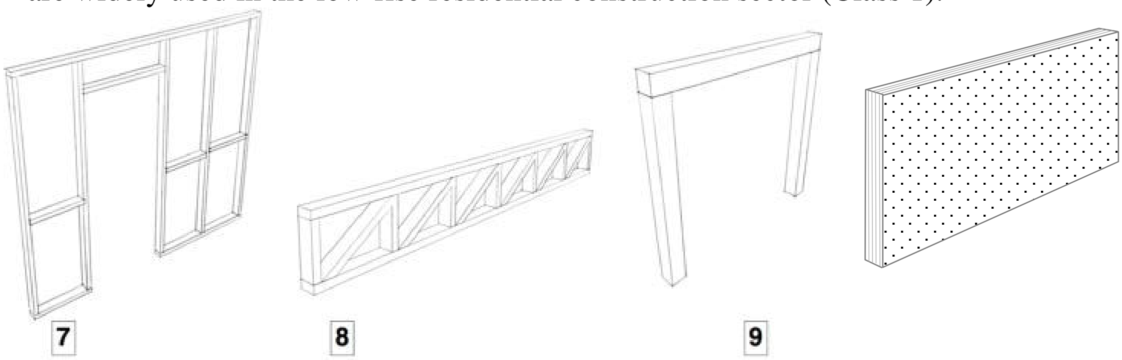


Figure 3. Wall frame (No. 7). Floor and/or roof trusses (No. 8). Post and beam assemblies (No. 9) and massive timber panel (far right).

Prefabricated assembled elements (Level 2) reflect the first step in value-adding to standard two dimensional open trusses and wall frames. These assemblies comprise the structural framing and/or truss components, flooring or claddings, and the bracing required for transport, lifting and building stability.

Floor cassettes comprise a series of individual floor trusses or joists positioned in a lineal fashion and inter-connected using the floor substrate which also braces the cassette panel.

Wall assemblies can include factory fitted door and window frames and are usually only lined on one side (partially closed) to allow for insulation and services to be fitted on site after installation.

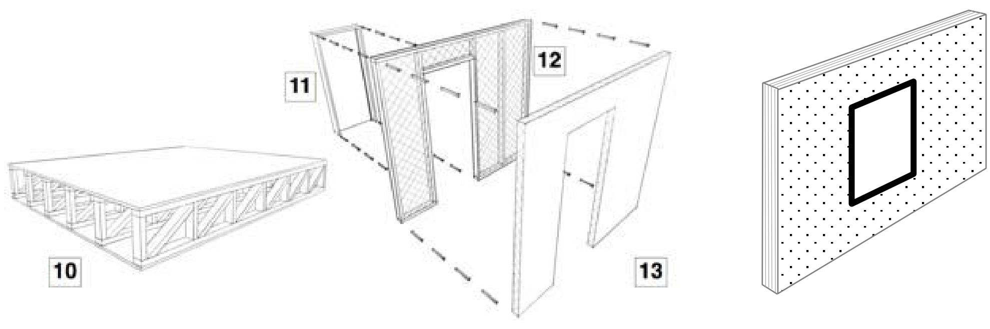


Figure 4. Floor cassettes (No. 10). Door or window frame (No. 11). Insulated frame or solid timber panel (No. 12). Finished lining sheet or panel (No. 13) and CLT panels (far right).

Finished assemblies (Level 3), such as types 14 and 15, represent the level of complexity that is typically seen in Scandinavia and central Europe's planar timber prefabrication sectors. In addition to the core structural timber frame or truss, these elements can typically include pre-fitted doors and windows, insulation as well as internal and external linings and services such as electrical and hydraulics (fully closed). This level of prefabrication is available in Australia although it is yet to be common place.

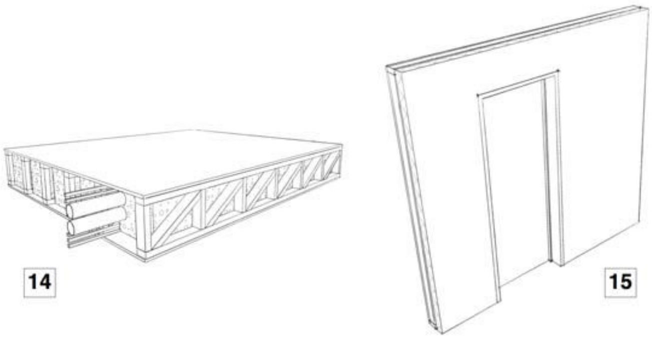


Figure 5. Fully finished floor cassettes (No. 14). Fully finished wall panel (No. 15)

4.5 Three Dimensional (3D) Prefabrication

Three dimensional prefabrication, involves a range of different assembly options of different complexity and finish including:

- Open Modules (Level 1),
- Braced Modules (Level 2),
- Finished Modules (Level 3), and finally
- Finished Buildings (Level 4).

These typologies are represented in the Prefabrication Matrix as follows:

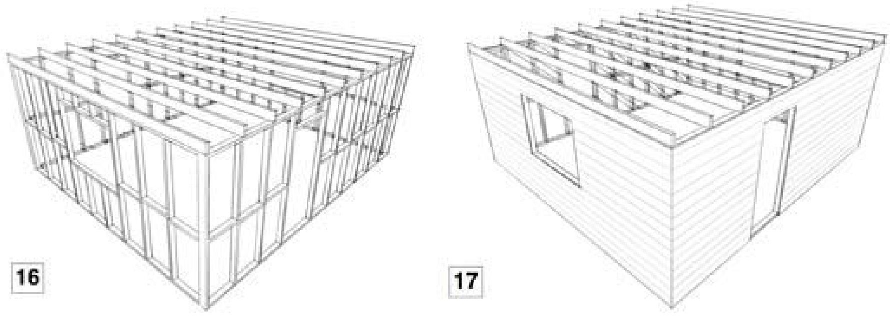


Figure 6. Open module (No. 16) and open module braced module (No. 17).

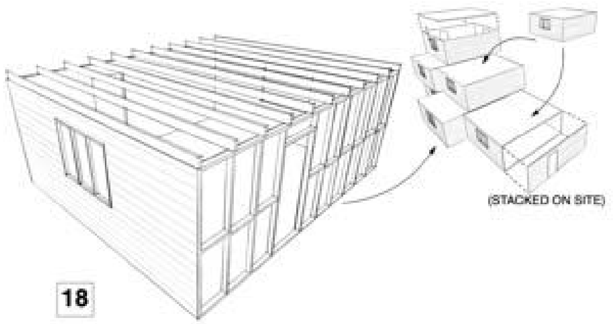


Figure 7. Finished module (No. 18).

Figure 8. Finished building (No. 19).

This level of prefabrication is yet to be readily available in Australia for larger scale projects although a number of companies are emerging that are developing these capabilities. Refer to Appendix 6.

5. NCC Building Classes and Timber Prefabrication in Australia

The National Construction Code (NCC) identifies different buildings by their use and assigns a number to easily identify a particular type for the purposes of establishing compliance to the code and Australian Standards.

- Class 1- (Residential - defined as "*a single dwelling being a detached house, or one or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit*".
- Class 2 - Typically these are apartments - a building containing 2 or more sole-occupancy units each being a separate dwelling.
- Class 3 - Hotels and other residential buildings other than Class 2.
- Class 5 - Office buildings.
- Class 6 – Shops.
- Class 9a – Healthcare.
- Class 9b - Schools and public buildings.

The primary building classes being investigated in this project are Classes 2-9. Whilst the Class 1 sector is not the main focus, its status will be briefly reviewed as it is currently the major market for timber products and there is a high degree of increased opportunity for prefabricated solution take up in this building Class.

6. Prefabrication in Class 1 Buildings in Australia

In Australia, the vast majority of prefabricated timber building is 'two dimensional (2D)' prefabrication, involving open wall frames, nail plated floor trusses and roof truss systems, which are used predominately in Class 1 buildings, Class 2 & 3 buildings up to four storeys and in many low rise commercial projects.

Figure 9 – A typical wall frame and nail plated roof truss house under construction in Australia. Image credit: CSAW

These factory-made frames and trusses are technically advanced, use resources economically and are for the most part, cost efficient to make and install. These products are supplied nationally by Frame and Truss (F&T) manufacturers who are supported by the three major nail plate manufacturing companies: MiTek, Pryda and

Multinail and their industry association the Frame & Truss Manufacturers Association (FTMA).

F&T manufacturers are predominately family owned companies with scales ranging from small locally focussed businesses to large-scale operations that can supply both locally and nationally.

F&T manufacturers utilise a range of sawn and engineered wood products both locally produced and imported. With some exceptions, major wood production companies are not involved in prefabrication (as can be observed internationally) and they remain primarily commodity producers, albeit operating at a very high technical level.

Whilst, most F&T manufacturers continue to focus on the supply of open wall frames and nail plated floor trusses and roof trusses, a number are now offering 2D (Level 2) prefabricated assembled elements, particularly floor cassette systems; and increasingly partially closed wall assemblies, which include external cladding and windows installed.

The wider interest in floor cassette systems follows a three year R&D project investigating why builders continue to use concrete slabs for ground floors on 'constrained sites', including: sloping blocks, flood prone areas and highly reactive clays, where it's known that raised floor systems simply offer a better construction option. Advice from builders was that the residential building industry today saw concrete slab-on-ground as the 'norm', as they provided a simple option and involved only one contract; if the timber sector wanted to offer a realistic alternative they advised that then it needed to offer what the concrete sector offered and that was *'a finished surface, on a specific site, for a specific cost - one contract'*. This market segment offers potential new market share for the F&T sector, where the competitor product is concrete, not another timber product; however for F&T manufacturers to participate they needed to be prepared to provide design, fabrication and 'installation' services under one contract. The nail plate manufactures have embraced this new opportunity and have modified their design software and provided design tools and even non-concrete footing system alliances (Pryda and Surefoot) to assist their members in offering these services. A number of F&T manufacturers around Australia now provide these ground floor cassette systems (see Fig 9a), however there is still large scope for further take-up in this market segment.

Whilst some F&T manufacturers have been reluctant to tackle the ground floor market segment with floor cassettes there has certainly been interest in providing this option for upper floor systems (see Fig 9b). This approach is particularly quick in terms of on-site installation and as such is appealing to builders; it also offers dramatic reductions in fall-from-height risks for workers compared to traditional open joist type construction. Experience has shown that generally once a builder has trialled this approach it then becomes the preferred option. The challenge for F&T manufacturers in the price sensitive and competitive residential sector, is extracting the appropriate financial return that these more efficient and improved construction processes provide. While many small-mid building companies in this sector are not particularly time sensitive, others do value and are prepared to pay for reduced build periods and for sub-contractors providing supply and install services.

10a Ground floor cassette system on a Surefoot non-concrete footing system

10b Upper floor cassette system

Figure 10 – Prefabricated floor cassette systems. Image credit: Wood Products Victoria

A few F&T manufacturers are also now offering partially closed wall assemblies [2D (Level 2) prefabricated assembled elements], and some even fully closed including electrical and plumbing services [2D (Level 3)] – see Fig 10, however supply of these advancements from within the F&T sector is still extremely limited.

11a Partially Closed prefabricated wall assemblies

11b Fully Closed prefabricated wall assemblies

Figure 11 – Prefabricated wall assembly systems. Image credit: Drouin West Timber & Truss

Drouin West Timber & Truss are one example of an established Frame and Truss fabricator who can manufacture both 2 & 3D prefabrication solutions. They have completed a number of projects including the Corinella project where a single storey free standing home was completed from site works to lock-up in under six days utilising prefabricated ground floor cassettes on a *Surefoot* footing system, closed wall panels and timber roof trusses, see Fig 12 below.

Figure 12 – Corinella Project. Image credit: Drouin West Timber & Truss.

In the absence of the broader F&T sector moving into these more highly prefabricated assemblies one major building industry manufacturer in Australia, CSR, has recently developed their 'Velocity system' to produce entire wall and floors engineered off-site and then delivered and installed at the building site to reduce construction times and the reliance on multiple tradespeople. CSR recently partnered with Mirvac at its Brighton Lakes development in western Sydney to trial the Velocity system on two identical homes opposite each other: one using traditional methods, and the other prefabricated walls.

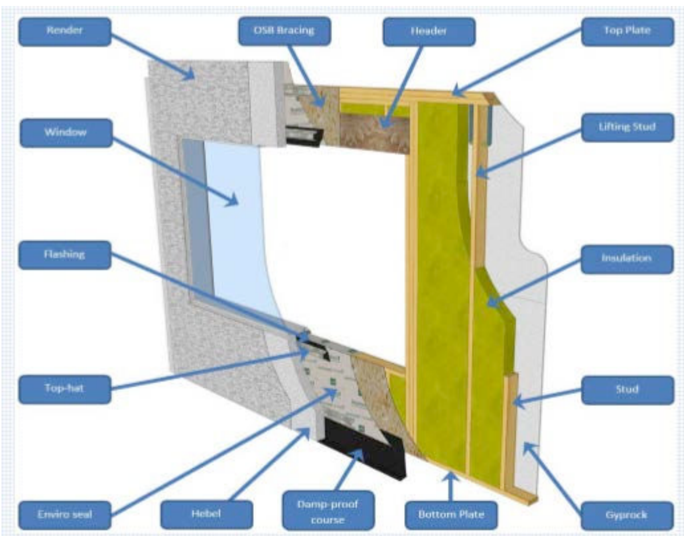


Figure 13 – CSR Velocity wall panel. Image credit: CSR, Frame Australia Conference 2016

The conventional build was completed in 24 weeks under 'best case' conditions, with all trades available when required and minimal inclement weather delays, by comparison, the CSR Velocity home was completed in just 14 weeks.

In the residential (Class 1) segment, light-weight 3D volumetric prefabrication has been available in Australia for many years in the form of kit homes and holiday homes, low rise accommodation (as well as service buildings for remote mining camps and as transportable or temporary school classrooms). In the past, the standard of construction and level of finish for these types of buildings has generally not been comparable with site-built structures. This has contributed to the perception that prefabrication is of a lower quality.

Figure 14 – Volumetric transportable construction

This volumetric prefabrication offering has dramatically improved in recent times as discerning consumers have started to demand faster build times with less site disturbance and a higher degree of quality control, and more environmentally sustainable building options. This has led to a broader range of high quality building types now produced through prefabrication as 3D modular, volumetric, unitized systems and pods constructed offsite - including installation of all cabinetry, fittings, fixtures, floor and wall finishes, that then seamlessly join together with minimal onsite time to complete to complete the project

Figure 15- Image source: The Esplanade by ArchiBlox

The emergence of architect led design and construct services that are capable of producing a quality product also has the potential to grow the sector. Design and construct residential solutions are now being offered that are effectively totally off-site manufactured with simply on-site installation rather than conventional construction. Examples of this are *ArchiBlox* or *ARKit* in Victoria and *Island Workshop* in Tasmania. New Zealand is also experiencing a similar trend with young architectural graduates such as *Concision*, *Makers of Architecture* and *First Light Studio* offering design and construct services thanks to innovative new timber based building systems being empowered by relatively small CAD/CNC driven production.

Whilst 3D Volumetric residential home delivery is increasing in popularity it is not anticipated in Australia that it will become the dominant form of delivery.

7. Prefabrication in Class 2-9 Buildings in Australia

Construction in Class 2-9 buildings in Australia is still predominately traditional reinforced concrete, precast concrete panels or steel framing. There are also several innovative companies utilising new prefabricated construction methods to assist in addressing on-site construction related cost and productivity issues. Recently three dimensional extruded concrete systems construction systems (Perrine 2016) and lightweight steel (One9 2016), have been promoted as well resolved prefabricated alternatives to on-site construction although these systems have yet to be successfully implemented. New prefabricated lightweight, and massive timber construction systems have also emerged in recent years which have been spearheaded by developers attempting to leverage the potential cost efficiencies of the different prefabricated timber construction systems now available. Figures 16a, b and c below are three of Australia's recently completed lager scale prefabricated timber projects.

Lend Lease's '*Forte Living*' building (2012), a ten storey multi-residential (Class 2) project in Docklands, Melbourne, was constructed totally out of Cross Laminated Timber above the first floor retail level which was reinforced concrete. The building was particularly quick, to construct around a third of the time of a reinforced concrete system and its lightweight nature suited the poor geological conditions of the area.

Figure 16a & b: Forte` (left), Library at the Dock (right)

Lend Lease's *Library at the Dock* (2014) a three storey (Class 9) project in Docklands, Melbourne, was constructed partially on an existing wharf using a post and beam system utilising glued laminated timber for the main beams and columns combined with CLT floor plates. The project provides a beautiful aesthetic example of timber construction.

Australand's (now Frasers Property) '*The Green'* Project (2014), a five storey multi-residential (Class 2) building in Parkville, Melbourne utilised lightweight open timber framed walls and prefabricated floor cassette systems, which were particularly quick to install. The builder has publically stated that this approach was approximately 25% more cost effective than a traditional reinforced concrete system. More detail has been provided on this project in the case study section.

Figure 16c: The Green. Image credit D.Bylund (left), Frasers Property Group (centre and left)

8. Australia's Timber Supply Chain for Class 2-9 Buildings

The following diagram (Fig 17) illustrates the timber industry supply chain for 'Class 2-9 type buildings', which by their nature require 'systems-based' approaches (different to the mature Class 1 sector which can easily function using commodity products either as packs of timber or Level 1 2D trusses and frames).

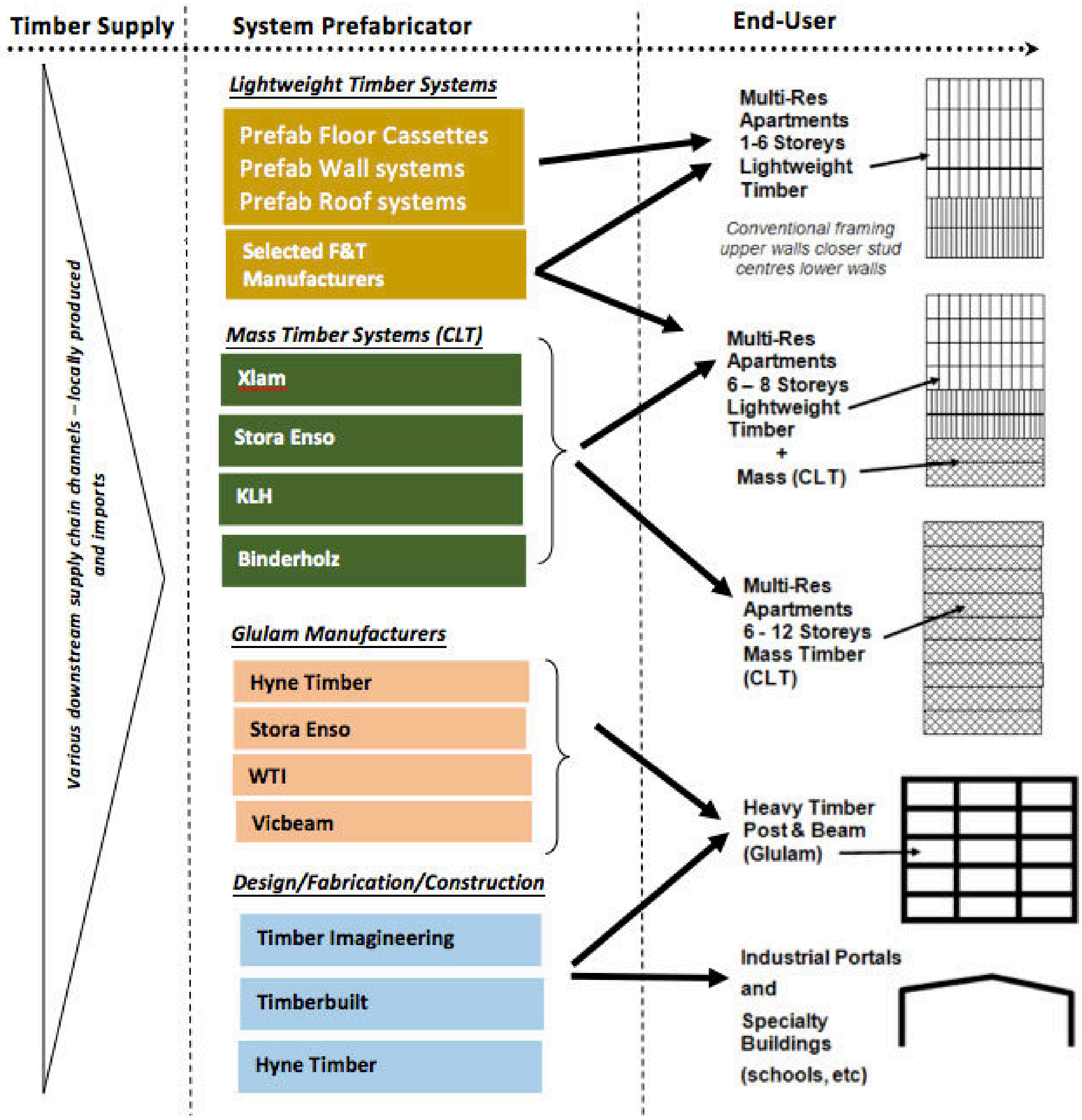


Figure 17 - Illustration of Timber Industry Prefabricated System Supply Chain for Class 2-9 Buildings as at 2016

9. Prefabricated Lightweight Timber Systems Supply in Australia

Prefabricated lightweight timber framed walls and floor cassette panels, such as those used in The Green are currently supplied by selected Australian frame and truss manufacturers; for The Green this was Bowens's Timbertruss. The broader take-up of higher levels of prefabrication by F&T manufacturers has to date been somewhat limited, the main reason being that these companies still tend to predominately operate in the Class 1 residential sector which appears to be quite satisfied with the Level 1 2D solutions of 'open' wall frames, floor trusses and roof trusses.

The move by interested F&T manufacturers into the Class 2-9 sectors will however require a more sophisticated prefabricated systems approach to maximise the on-site speed benefits. If Australian truss and frame manufacturers are to successfully service and compete in this sector, issues such as innovation and its associated risk management, staffing skills and existing business models will need to be addressed. The major nailplate companies will need to provide a leadership role in this area particularly in modification of member design software and also supply of connector systems to suit this construction. These constraints are discussed further in the Barriers chapter.

Figure 18 - Bowens Timbertruss floor cassette manufacture

9.1 Massive Timber Systems Supply in Australia

Australia is currently importing all of its CLT. The primary companies supplying CLT are NZ (New Zealand), KLH (Austria), Stora Enso (Austria), and Binderholz (Austria) and also provide design, fabrication, supply and logistical support.

Figure 19 - KLH's CLT Facility Austria

From the middle of 2017, XLam will be producing CLT in Australia. Having now completed over 200 building projects in NZ and Australia, its Australian plant, to be located in the Albury/Wodonga area, will 60,000m^3 of CLT per year which equates to approximately one Forte building a week.

Despite ready access to CLT in Australia, there have been limited projects featuring CLT. This is due to a number of reasons including limited understanding by architects, quantity surveyors and structural engineers. Fire design consultants have also adopted a very conservative approach resulting in uneconomical solutions and with the exception of builders such as Strongbrothers (Sydney) Lendlease (Melbourne and Sydney) and Morgan and Hanson (Adeleaide), builders have been reticent to try a 'new' material. The established 'supply only' culture that exist in the timber sector has also contributed to its limited uptake. CLT is more in keeping with building materials in terms of its capacity to be supplied and installed by one organisation. In recognition of this, companies such as Hyne Timber and Meyer Timber now offer full supply and install options with their respective engineered timber and massive timber products.

9.2 Glued Laminated Timber Supply in Australia

The glued laminated timber industry in Australia consists of a relatively small number of local manufacturers (moderate and small enterprises), importers, wholesalers and adhesive providers distributed throughout the country.

The two largest local manufacturers of glued laminated timber in Australia are

- Hyne Timber[1], with a manufacturing facility at Maryborough in Queensland (annual production approx 7,000 – 10,000m^3); and
- Warnambool Timber Industries[2], at Warnambool in south western Victoria (annual production approx 5,000m^3).

A number of other medium to small manufacturers exist including:

- Lambeam from Trussmaster[3] at Meadowbrook Queensland
- Vicbeam[4] at Montrose Victoria
- Merriwa[5] at Wangaratta, Victoria
- Australian Sustainable Hardwoods[6], at Heyfield, Victoria

Major Glulam importers include:

- Stora Enso
- Tilling Timber[7], SmartLam products

Local manufacturers and importers also distribute through a number of major wholesalers including:

- Dindas[8]
- Laminated Timber Supplies[9]
- Dale Glass Industries[10]
- Austim[11]

[1] See http://www.hyne.com.au/solutions-centre/architects-and-designers/glulamour.html
[2] See http://www.warrnambooltimberindustries.com.au/index1.htm
[3] See https://www.trussmaster.com.au/
[4] See http://www.vicbeam.com.au/
[5] See http://www.merriwa.org.au/commercial-enterprises/timber-division/
[6] See http://vicash.com.au/goodwood-supalam-range/
[7] See http://www.tilling.com.au/smartframe
[8] See http://www.dindas.com.au/building-products/glue-laminated-beams.aspx
[9] See http://www.lamtim.com.au/index.html
[10] See http://www.dgi.com.au/beams.html
[11] See http://www.austim.com.au/Product-Range/Structural-Posts-Beams/Specialty-glulams

A range of member sizes in different GL Grades are produced or imported depending on the different species of timbers used in manufacture. AS 1720 defines the characteristic design values for Australian GL grades and the Glue Laminated Timber Association of Australia (GLTAA) maintains a product certification scheme on the product of accredited producers. However, some confusion exists in the market due to different numbering systems used for Australian and some imported product. Australian GL grades use a GL number aligned to the material Modulus of Elasticity (MoE) while the GL number for some imported product aligns to the materials bending strength. So, Australian GL18 sound weaker than European GL 45 but actually provides the same performance. Major Glulam companies offer in-house design assistance services and on the ground sales and marketing personnel to independently promote their products. These companies are already active in seeking potential Class 2-9 projects.

10.Design/Fabrication/Construction Supply in Australia

To date in Australia, supply of timber systems into many Class 2-9 building projects has been through speciality design/fabrication and construction providers sometimes acting together with the larger engineered product producers. These companies have usually involved structural engineers experienced in wood design expanding their businesses to take on fabrication and installation in the absence of any other supply chain providers. Companies operating for many years in Victoria are Timber Imagineering[12] and Timberbuilt[13] and more recently, Hyne Timber provides a supply and install service. These companies offer full design, fabrication and installation services for Class 5-9 buildings (offices, schools, universities, hospitals, etc) and are not focussed on the supply of the potential higher volume Class 2-3 (multi-res apartments and hotels) type markets. Notwithstanding this there is still a need for more companies throughout Australia offering similar design/fabrication and construction services.

An international example of this approach is Eurban in the United Kingdom. Eurban is an engineering firm specialising in timber design and a non-manufacturing supplier of timber products. They provide an interface between cross-laminated timber producers in Europe and designers in the UK, and have extended their operations to provide design and construct services despite not being a producer of CLT themselves (Eurban, 2016). Regardless of the PTB system adopted, the question to be asked is, can this type of business act as a conduit between producers and developers in Australia by acting as a one-stop-shop to bring products to the market?

[12] See http://www.timberimagineering.com/

[13] Se http://www.timberbuilt.com.au/

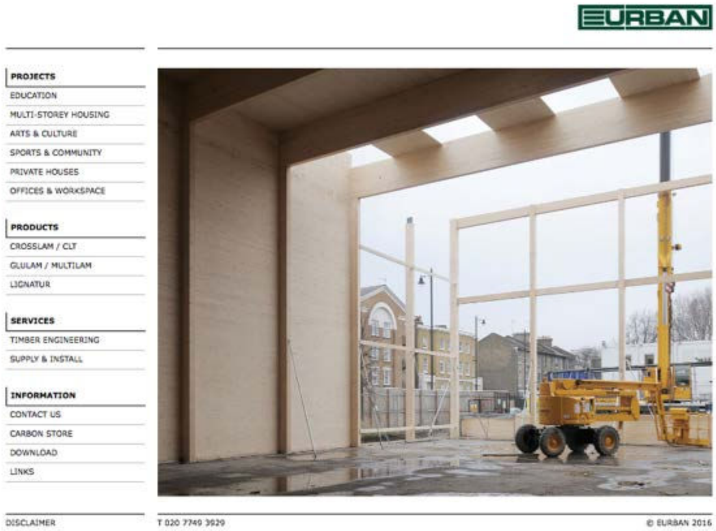


Figure 20 – Eurban's website showing a range of PTB systems and their engineering and supply and install capacity. Image credit: eurban.com.uk

11. A New Trend - Builder Owned Prefabricated Facility Development

In particularly Class 2-3 buildings, in the current absence of an expansion of services 'up the supply chain' by the existing timber industry (ie F&T manufacturers hesitant to take the risk around more sophisticated prefabrication into new market sectors), what is being observed is a move 'back down the supply chain' where building companies already active in Class 2-9 sectors are setting up their own prefabrication facilities allowing them to take more control over resource supply and off-site manufacture, effectively 'reducing some of their overall project risks'.

Lend Lease announced in Dec 2015 that it would launch its $15M Design Make facility in Sydney in late 2016 to manufacture $1 billion worth of pre-fabricated building material over the next five years. The 15,000 m^2 factory facility will employ 40 to 50 workers at peak production with another 15 to 20 more staff devoted to the high-tech design work required for pre-fabricated products. The facility's multiple production lines will manufacture a range of items, including walls, floor components and also full modular solutions and the custom building components and will predominantly use engineered timber products including cross-laminated timber but also include the handling and installation of glazing and plasterboard.

Lend Lease believes that this initiative will provide them with increased safety, lower costs and better productivity as they look to expand their involvement in mid-rise apartments, retirement homes, and offices.

A second Sydney based builder StrongBuild has also announced the opening in 2016 of a new 15,000 m^2 offsite prefabrication facility at Baulkham Hills. This state of the art facility will include: a wall & floor panel line (closed panel wall and floor cassette solutions), CLT wall and floor panel & Glulam processing and supply, volumetric pod construction, as well as the manufacturing of solid timber & carcass joinery. StrongBuild have a number of major timber projects commencing shortly, including Macarthur Gardens, Campbelltown, NSW which involves three CLT towers (6, 7 & 8 storeys) and Aveo Norwest in Baulkham Hills, NSW, two 10 level towers, 9 levels of which will be constructed from CLT. StrongBuild believe this initiative will assist in reducing their project risk whilst providing more control over quality, safety, skilled labour shortages, waste, time and cost.

Figure 21: Macarthur Gardens by StrongBuild. Image: Frame Australia 2016 presentation by Adam Strong, StrongBuild

It is certainly expected that more builder/developers currently in the Class 2-9 markets will look at establishing similar prefabrication facilities to further control their supply of building systems and thereby reduce their project risk; it should be noted that this trend has also been seen overseas as new non-residential markets have been developed.

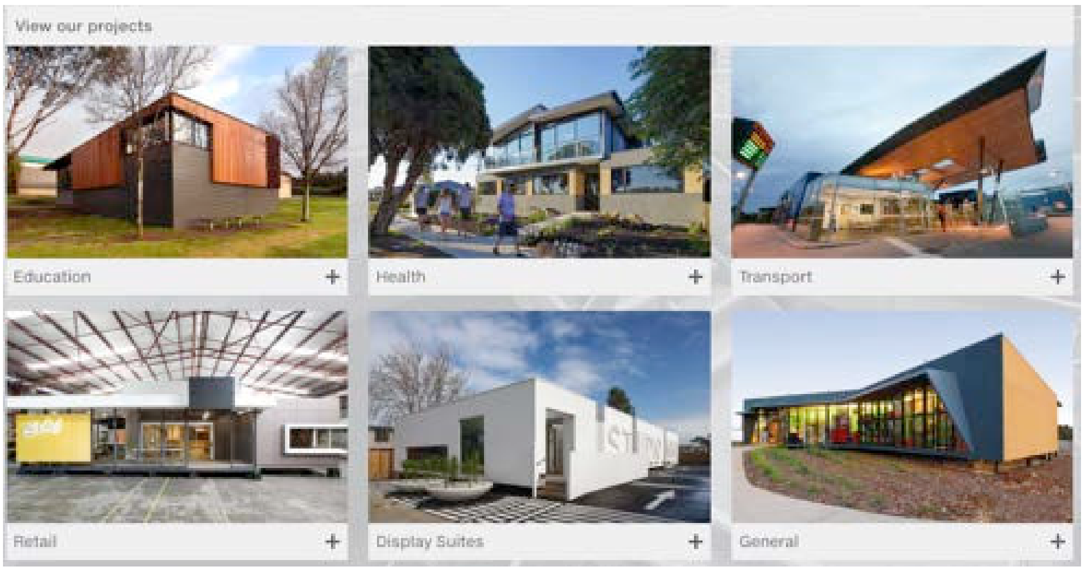


Figure 22 – Website of one of the emerging Australian prefabrication companies offering design and construction services for commercial projects. Image credit: prebuilt.com.au

A small number of design led prefabrication companies are also emerging, primarily on the eastern seaboard states of Victoria and New South Wales that are investing in prefabrication commercial construction or have a commercial wing off their residential operations (refer to Appendix 1).

12.International Entrants

Prefabrication has matured sufficiently in overseas markets, such as those seen in Scandinavia, German speaking Europe, North America and Japan, that established companies from these countries are also now investing into Australia (refer to Appendix 1). These companies are adapting their product offerings and business models to suit the various Australian markets, environments, available materials, skills base and cultural expectations.

13.Summary of Prefabrication in Australia

Whilst the current level of more sophisticated prefabricated timber system offerings beyond basic level 1 2D (open frames, floor & roof trusses) is still quite low in Australia, the potential in a range of different market segments and building Classes is high. The following table seeks to summarise this.

In Class 1 residential there are significant ('High') opportunities in 2D Level 2 assemblies such as 'partially closed wall' assemblies, and floor cassette systems for both ground floor (new market share – concrete being the competitor here) and upper storey floors (though the timber sector already owns this market share it is simply providing its products in a more efficient way to the builder). 'Medium' opportunities exist for 2D level 3 'closed panel' wall systems and 3D finished modules and fully finished buildings.

In Class 2 & 3 commercial buildings, apartments and hotels, where the industry is not currently very active, a 'High' level of opportunity exists for 2D Level 1 'open' wall frames and 2D Level 2 'partially closed wall' assemblies, and floor cassette systems.

In Class 5-9 buildings again there is a 'High' potential level of opportunity for 2D Level 2 'partially closed wall' assemblies, and floor cassette systems and Medium' opportunities exist for 2D level 3 'closed panel' wall systems in schools and potentially 3D finished modules and fully finished building opportunities for some offices and schools.

Table 2: Existing Levels of Timber Prefabrication and Opportunities for Increased Timber Prefabrication.
Refer to the Matrix of Prefabrication for definition of Levels of Timber Prefabrication.

	Class 1 Residential	**Class 2 Apartments**		**Class 3 Hotels**	**Class 5 Offices**	**Class 9 Schools**
		Up to 3 Storey (Old DTS provisions)	Above 3 Storey (new DTS provisions)			
						
Current Level of Timber Prefabrication	Common use of 2D open frame (walls, floor and roof trusses), limited cassette floor and closed panel wall use	Use of 2D open frame (walls, floor trusses and roof trusses), some limited cassette floor use.	Limited CLT use. Some open frame use (walls, floor trusses and roof trusses).Limited cassette floor use.	Currently, very limited use of timber	Some heavy timber engineered products (Glulam, LVL, etc)	Some heavy timber engineered products (Glulam, LVL, etc)
Opportunity for increased timber prefabrication: Low, Medium & High						
2D Level 1 Open Frames	LOW (already widely used)	HIGH	HIGH	HIGH	LOW	HIGH
2D Level 2 Assemblies	HIGH (particularly floor cassettes)	HIGH (particularly floor cassettes)	HIGH (particularly floor cassettes)	HIGH (particularly floor cassettes)	HIGH (particularly floor cassettes)	HIGH (particularly floor cassettes)
2D Level 3 Closed Panels	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
3D Level 1 Open Modules	LOW	LOW	LOW	LOW	LOW	LOW
3D Level 2 Braced Modules	LOW	LOW	LOW	LOW	LOW	LOW
3D Level 3 Finished Modules	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
3D Level 4 Finished Buildings	MEDIUM (high quality, architecturally led)	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM

14. Issues Affecting Prefabricated Timber Building Systems

Prefabrication in general and prefabricated timber building systems have many benefits, which, if managed carefully, have the potential to suit a range of commercial building projects resulting in an improved outcome compared to traditional construction approaches. A range of opportunities for PTB systems have been identified through literature searches, international experiences and discussions with industry. The topics discussed herein cover a broad range of relevant issues. Different PTB systems, projects, clients, builders, legislative requirements, budgets and site constraints and timelines will all affect each project differently. Being aware of opportunities, drivers, and barriers, and discussing the experiences of others will promote an increased understanding of the benefits and opportunities of prefabricated timber-building systems and should be done on a case-by-case basis.

15. Drivers Enabling Prefabricated Timber Building Systems

There are a wide range of drivers that will assist in encouraging and enabling the take up of prefabricated timber systems into the Class 2-3 buildings sectors; they include in order of suggested priority the following.

- D1. The demonstrated cost & efficiency advantages of prefabricated timber construction systems over traditional alternative construction methods.
- D2. The inherent quality manufacturing and site impact reduction advantages of prefabricated timber construction systems.
- D3. The desire of Governments nationally for more medium density dwelling construction in urban infill areas.
- D4. The recent changes to the 2016 National Construction Code which now allows the use of lightweight and massive timber construction under the Deemed-to-Satisfy provisions for Class 2, 3 & 5 buildings up to an effective height of 25m.
- D5. Timber's inherent structural, fire, thermal and acoustic properties.
- D6. The increasing interest by architects, designers, building owners and governments in using more environmentally friendly materials and the introduction of government wood encouragement policies.
- D7. Increased interest and opportunities in using low-grade wood resource in higher strength engineered wood products.
- D8. The increasing interest by governments in encouraging more innovation and uptake in off-site manufacturing and site prefabrication use.
- D9. The increased acceptance and take up by governments and the design community of Building Information Modelling (BIM) and digital manufacturing.
- D10. The increase in training and education opportunities in the areas of prefabricated systems design, manufacture and supply.
- D11. The existence in Australia of established heavy lifting and transport logistics industry.

These drivers will now be individually examined in further detail.

D1.The demonstrated cost & efficiency advantages of prefabricated timber construction systems over traditional alternative construction methods

One of the major reasons for the growing interest by developers and building companies in timber construction for apartments, hotels and office buildings is the proven demonstration of cost efficiencies of timber systems compared to alternative materials particularly reinforced concrete structures. It has been reported widely that *The Green*, a 57 unit, 5100m^2, five storey apartment building, completed in 2014 by Australand (now Frasers Property) utilising timber floor cassettes and prefabricated wall frames, resulted in 25% savings over traditional construction (Jewell, 2014). Similar figures to this have been reported overseas.

It needs to be noted though that the opportunities for timber prefabricated construction are demonstrated not by looking at a straight comparison of materials, i.e. at a square metre rate (which is often what builders and designers like to look at), but by comparing the 'total cost of construction from beginning to end'. The shorter construction time using prefabricated timber construction can mean significant cost savings in overall project build.

There are many efficiencies, with related cost benefits, in the 'overall construction phase' of a building when using timber products, particularly prefabricated timber systems, compared to traditional steel and concrete construction.

- Direct savings can be made from faster on-site construction processes, particularly when offsite prefabrication is maximised.
- Reduced construction times means reduced on-site construction infrastructure and therefore 'preliminary costs'; items such as: fixed cranes, site accommodation, storage areas, scaffolding, edge protection, hoists and so on; it also means reduced 'holding costs' and the ability for developers to reduce finance costs and turn over more construction work per annum (these time related savings can be very significant in large commercial jobs and the more engaged builders are now recognising this).
- There is also the ability for follow-on trades, to commence much earlier in the construction process. They can effectively start fitting out the level below, as soon as the floor system above is in place. No lost time due to back-propping or slab curing. This can dramatically reduce the overall construction time.
- Prefabricated timber panels are also much lighter than concrete (around one-fifth of the weight) this reduced weight of the overall timber structure directly translates to reduced foundation requirements (on poor sites requiring piling - cost savings here can be significant), lightweight timber panels can also be more easily manipulated and installed. The reduced weight of timber construction is also an advantage when adding additional stories to an existing building – the lighter-weight meaning a greater number of additional stories.
- Using timber construction also means that there is the ability to use a 'residential' workforce (very familiar with timber) which is generally available at more competitive rates than the 'commercial' workforce.
- Timber buildings also tend to have a lot less occupational and health and safety issues - this is particularly the case with a shift to more offsite prefabricated solutions (OH&S is a significant issue for large building companies and therefore this benefit is particularly important).
- Sites using a high level of timber prefabrication also have far lower impact from 'noise and onsite activity' on the surrounding local neighbourhoods, due

to the dramatically reduced amount of truck movements required and the need for only low impact tools. This provides a major benefit in the case of suburban multi residential development in-fill sites and the education and health sectors.

The aforementioned items can result in significant savings and have the potential to offset the higher initial costs that may result from the use of the off-site construction process. Establishing the most appropriate construction method at the outset and working closely with suppliers is a fundamental of prefabrication. Designing a project assuming traditional construction and attempting to prefabricate late in the process will result in less economical outcomes (Bylund and Nolan 2016).

The investigation phase of this project reviewed a number of findings from other research (reThink Wood 2014) that also has of relevance to this report in some key areas in the design and construction process for maximising potential success, these include the following:

- Discussions with owners/developers' highlighted some key points, such as:
    - the importance of making a commitment to a wood solution from the outset,
    - ensuring the project's business case and budgets were adequately recognized and included costs of innovation,
    - ensuring that the owners'/developers' vision is aligned with the design team, and that
    - local authorities and construction teams be engaged early on to assist with the realities of meeting legislative requirements.
- Discussions with design teams also noted the following.
    - Owners'/developers' early commitment to a wood solution was important as was utilising test results from relevant research to help them create acceptable design solutions.
    - Additional design development time needed to be allowed for at the beginning of the project to resolve design details and design solutions were, in some cases, developed with direct input from the local authority, fire officials, construction teams and material suppliers.
    - Ensuring a cooperative atmosphere amongst the various participants during construction was critical to resolve unexpected or non-code compliant design details.
- The construction teams stated that
    - project/site/construction managers should be invited to provide input early on in the design development process of the project and integrating design teams, construction teams, material suppliers and building trades who embraced prefabrication and system integration shortened timelines.
    - Tolerances and complexities of details at interfaces between wood structural elements and other structural materials were seen as one of the greatest challenges.
    - Sub-trades and suppliers of materials and systems may be required to adapt their product to the specification and scope of work to the timber based structural solutions.

- Weather-related issues could affect both the wood's appearance and performance and therefore avoidance strategies should be incorporated and budgeted for.

D2. The inherent quality manufacturing and material and site impact reduction advantages of prefabricated timber construction systems

Prefabricated timber systems manufactured 'off-site' in factory controlled conditions also allow for a very high level of quality and fabrication tolerance control. Prefabricated elements can be manufactured and installed with 'mm-tolerances', a major benefit over 'constructed on-site' reinforced concrete buildings. An often quoted example of this is the construction of timber lift shafts compared to traditional reinforced concrete shafts where the plumbness and straightness of the timber walls significantly reduces the requirements for the adjustment and spacing packers traditionally required with concrete shafts.

Prefabrication off-site also dramatically reduces material waste in manufacture as input products can be optimised to maximise usage. It also substantially reduces on-construction site waste, and off-site landfill requirements, typically seen with traditional building methods as the only materials sent to site are there for installation. There are significant waste reduction benefits with off-site prefabrication.

Buildings constructed using prefabricated timber systems have the potential to be successfully positioned and marketed as environmentally friendly (more on this later), 'high-quality' advanced product offerings; this 'quality' approach thereby potentially opening up greater financial return opportunities to manufacturers (this is already a reality of the commercial market compared to the residential market – however the requirements and expectations of supply are also different; discussed in the next section on barriers).

D3. The desire of Government's nationally for more medium density dwelling construction in urban infill areas

Many of the world's cities have grown, and continue to grow, rapidly in both population and land size, and Australia, though even with its comparatively small population, is no exception. Governments in most states are now particularly focused on densification of their major cities and encouraging more urban infill and multi-unit residential accommodation particularly around existing transport hubs and infrastructure.

The growth in cities around the world and in Australia's urban and regional centres, particularly urban in-fill growth, represents a significant opportunity for prefabricated timber building systems.

Understanding the nature of these built environments will assist in promoting PTB systems in a targeted manner. The broadest scale of the built environment relevant to this report is the city or a regional centre as a whole which in turn it is suggested can be divided up into four zones.

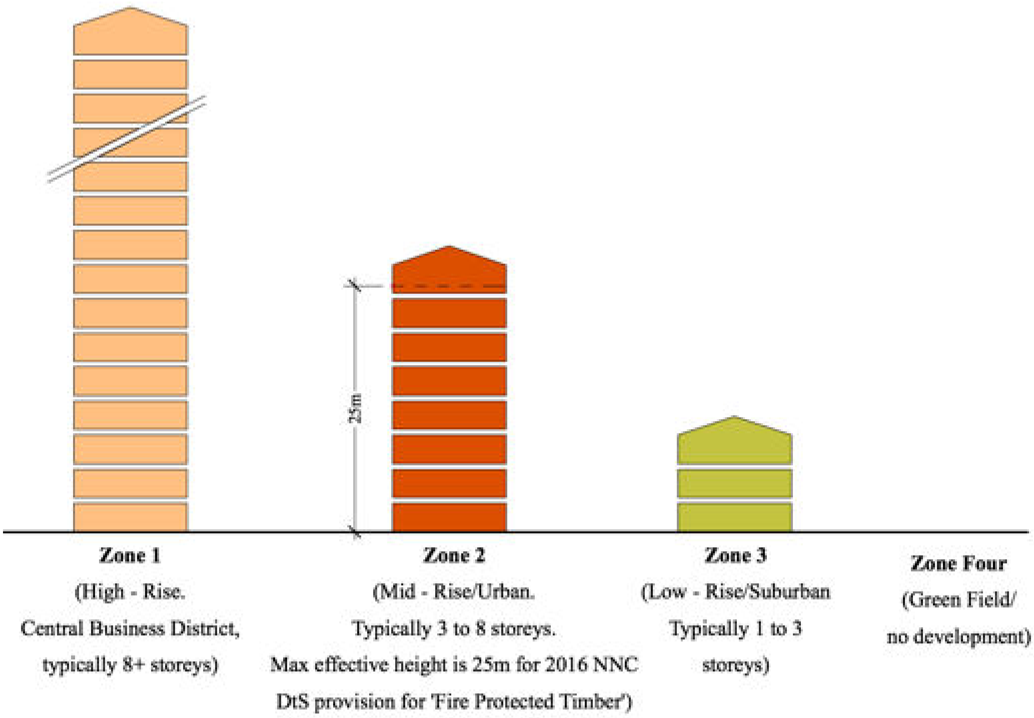


Table 3. Developmental zones and relative building heights.

Zone One - Central Business District (CBD)

Opportunities for prefabricated timber construction are comparatively limited in the Zone One CBD districts of major cities due to the typical scale and height of the buildings occupying this zone. It is reasonable to expect that new construction in this area will remain predominantly steel and concrete based. Some limited opportunity will exist for timber construction in buildings up to approximately fourteen storeys utilising CLT or for the use of some timber storeys above traditionally constructed buildings capitalising on timber’s light-weight advantage. Some theoretical building design and research has been undertaken for high rise timber buildings (Green 2012) and interest seems to be growing as several 30 plus storey high buildings are being planned in Stockholm, Vancouver and Vienna (Heaton 2016).

Zone Two – Urban

These areas are the established medium density residential areas either surrounding the CBD (typically radiating out from the CBD over three to four kilometres) or the designated urban in-fill zones around existing public infrastructure or transport hubs. These zones are often mixed use with mid-rise medium density housing and commercial, sometimes industrial, uses intermingled. Little undeveloped land exists in this zone and a number of Australian cities are experiencing a regenerative phase in these areas. Prefabricated timber construction is well suited to the sites that exists in this zone. High existing urban densities, involving limited access, requirements around noise and dust generation, and the benefits of minimising on-site time and disruption so as to not effect amenity, play a significant role in the construction process. This zone provides the major opportunity for new timber construction market opportunities in Class 2-9 buildings; further research on a city-by-city and regional centre-by-regional centre basis would assist in identifying specific areas with this zone that would benefit from targeted marketing of prefabricated timber construction. Construction over railways, vertical schools and extending the height of existing mid-rise buildings all represent opportunities for prefabricated timber construction.

Zone Three – Suburban

Zone Three is the established suburban areas (sometimes sprawl) typically seen in most Australian cities. The majority of construction is low-rise Class 1 residential buildings and timber construction is already very well established in this zone. Though outside the particular focus of this research these zones have clear opportunities to demonstrate greater timber prefabrication, either in new market opportunities such as ground floor construction on constrained sites (sloping blocks, flood prone areas, reactive clays), or in providing existing products in more innovative prefabricated ways: upper storey cassette floors, partially or fully panelised wall systems, prefabricated roof systems.

Zone Four – Green Field

Zone Four is developments in Greenfield sites. As with Zone Three, this is typically Class One buildings although with the increased occurrence of new satellite city centres featuring medium density mid-rise and mixed use buildings presents an opportunity for prefabricated timber construction. As with Zone Two, further study identifying these areas across the country could identify areas to target an increase in prefabricated timber construction.

The use of prefabrication across the board will become increasingly significant as Australia's towns start to go down the path of densification and urban infill. Prefabrication's benefits such as the relative speed of installation, and the minimal impact on a building site and surrounds, should be leveraged to assist in growing the sector. If a project requires sensitivity in these areas, builders versed in prefabrication can and do utilise it to fulfil their building contracts.

Figure 23. CLT installation at the Forte Living project, Docklands Melbourne. Note the proximity to occupied apartments to top of image, also limited impact: small on-site staff, small remote control crane, one truck movement per day with CLT panels.

D4. The recent changes to the 2016 National Construction Code which now allow the use of lightweight and massive timber construction under the deemed-to-satisfy provisions for Class 2, 3 & 5 buildings up to an effective height of 25m

The Australian National Construction Code (NCC) is a performance based building code that allows for the construction of buildings with either a ‘Performance Solution’ and/or a ‘Deemed-to-Satisfy’ (DtS) Solution. In 2016, as a result of a successful submission of a Proposal for Change by Forest & Wood Products Australia, the NCC was amended to include new DtS previsions permitting timber to be used structurally in Class 2 (apartments), Class 3 (e.g. hotels) and Class 5 (office) buildings with an effective height of up to 25 metres (approx. 8 storeys) with the inclusion of ‘Fire Protected Timber’ requirements for both lightweight and massive timber construction. The implications of this development for PTB systems in these new mid-rise timber building are significant and, in due course, may represent one of the single most influential actions contributing to an increase in the use of PTB systems in mid-rise construction in Australia.

It should be noted that Performance Solutions will still play a role in good timber design as they provide an avenue to a less conservative approach to fire protection. Care must be taken to ensure that fire brigades and certifiers do not relay on the DTS provisions as a default when assessing Performance Based solutions.

Prior to the inclusion of the above DtS solutions for commercial buildings, Anderson et al. identified the cost of meeting legislative requirements as being one of the key items inhibiting an increase in timber’s use in commercial buildings (Anderson & Fuller, 2016). The provision of a DtS timber based solution for commercial construction in the mid rise sector removes the need for costly and time consuming testing required for a Performance Solution and thus has largely removed this barrier. This has eliminated a significant obstacle to both PTB Systems and the architects, engineers, builders and developers who are considering the use of timber for mid-rise commercial buildings in Class 2, 3 or 5 buildings.

This amendment now brings Australia into line with similar international building codes in other international countries (see Table 4). A new Technical Design Guide 37 – *Mid-rise Timber Buildings*, has been produced detailing the new NCC changes and the requirements for fire protected timber construction (refer to the Wood Solutions website for more information). There is also potential further opportunity to expand the DtS provisions to other Building Classes beyond 2, 3 & 5 in future versions of the NCC, for instance, hospitals, schools, universities, etc.

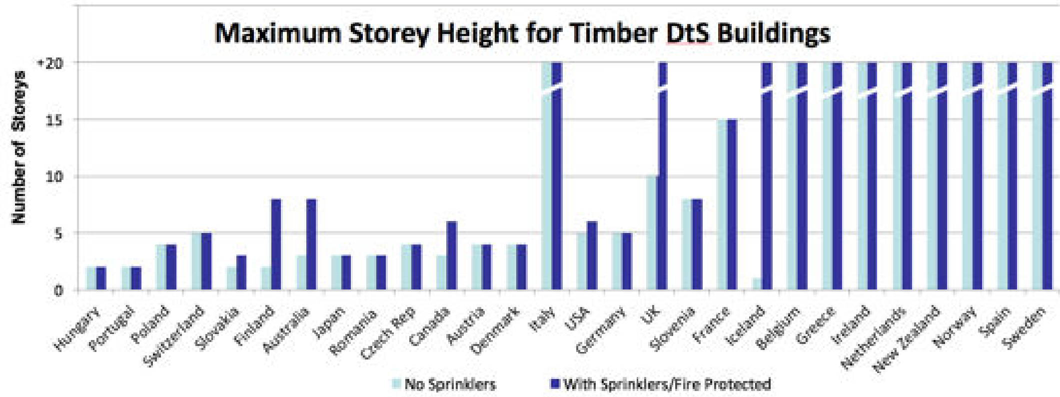


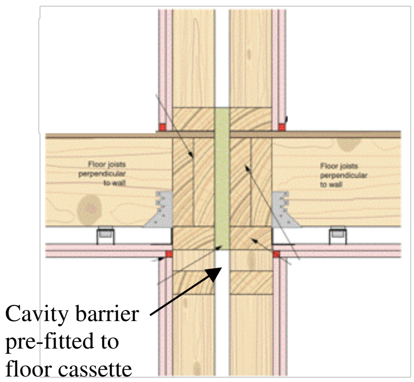
Table 4. International building height controls for timber construction.
(Adapted from information supplied by Timber Development Association NSW)

It should be noted that the new 2016 NCC DTS timber opportunities are based on a number of specific conditions as set down in Clause C1.13 Fire-protected Timber: Concession of the NCC and which stipulates that:

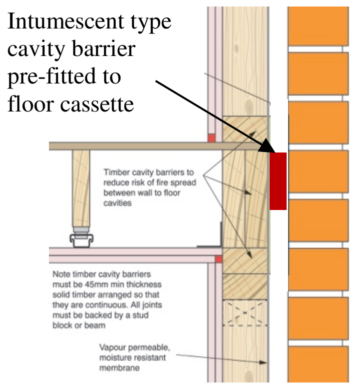
- the building is not more than 25m in effective height and of Class 2, 3 or 5,
- the building also includes automatic sprinkler suppression systems,
- the timber used is encapsulated with fire-grade linings, effectively 'fire-protected' to meet a specific Fire Resistance Level (FRL),
- any insulation used for acoustic or thermal reasons is 'non-combustible',
- that 'cavity barriers' are installed at all locations as required by the NCC.

The above clearly indicates the need for a 'systems' based approach to demonstrating performance. The timber 'fire- protected' timber structure is only compliant if all these system elements are in place and bare structural timber in these DtS compliant buildings as not permitted. This then means that the timber industry has a number of other major building product sectors that it can work closely with and leverage off to develop and promote these systems including: the fire-grade linings manufacturers (plasterboard, fibre, cement, etc.), the non-combustible insulation and cavity barrier product manufacturers, even the fire sprinkler sectors. Co-ordinating, innovative solutions, and market development promotion will benefit all involved. All the system sector groups need to work together to brainstorm, design and deliver smart and simple prefabricated solutions that will both save the builder time on site and ensure that the buildings are constructed correctly.

Figure 24. Typical cavity barrier installation in mid-rise timber buildings. Images adapted from WoodSolutions.



Internal Floor/Wall Junction



External Floor/Brick Veneer Wall Junction

One example of this is addressing the 'cavity barrier' requirement. Cavity barriers are a critical system element to stop the passage of fire and smoke within a wall or floor cavity in the very low probability event that the sprinkler system has failed and the fire has breached the fire-grade linings.

A major concern in construction is that the cavity barriers are correctly installed by the builder or their contractor (particularly when this might be for an instance an Through the prefabricator's involvement a simple solution is to have the cavity barrier directly installed in the factory to the edge of floor cassettes in those locations where cavity barriers were required. At internal wall junctions (as shown opposite above) an appropriate width compressible cavity barrier could be installed to one (or both systems) so that once the floor is fitted in place the cavity barrier is already located and active. Similarly, with an external wall (as shown opposite below) an Intumescent fire-expanding type barrier could be fitted to the floor cassette in factory so that it is already in place and does not require the bricklayers involvement thus contributing to overall building performance and quality.

D5.Timber's inherent structural, fire, thermal, and acoustic properties

Apart from just being very aesthetically pleasing when used in appearance or visually exposed applications, timber products and systems do also have a number of intrinsic and known benefits particularly from a structural, fire and acoustic perspective. Timber has a very high strength-to-weight ratio which means compared to alternative products particularly long-span large steel beams, timber beams can perform comparatively well.

Mass timber elements such as CLT wall and floor panels, or large section beams and columns also have a natural fire resistance due to outer layer charring during a fire event insulating and protecting the inside layers; steel by comparison loses its stiffness and tends to twist and buckle at comparatively low elevated temperatures.

Mass timber also has a very good thermal performance. CLT is often used in residential construction in countries with regular sub-zero climates; in Australia with its less harsh climates this is less of a benefit. With lightweight construction appropriate insulation is require for the respective climate zones, be they cool or hot.

Acoustic performance is definitely the biggest consideration for lighter weight timber construction methods particularly compared to reinforced concrete systems. This is particularly important in Class 2 (apartment) and Class 3 (eg hotel) type buildings – unless these timber structures offer equivalent or better performance to conventional concrete construction then they will not be acceptable to the broader market. Fortunately, whether for massive timber or lightweight systems appropriate acoustic measures can be delivered, this generally requires approaches such as acoustic insulation and isolated resilient lining mounts and/or acoustic mats, but can also include for improved performance the additional application of mass (ie for floors, the use of more floor sheeting, a sand-bed, or concrete overlay – preferably installed off-site to prefabricated cassettes), or the use of false ceilings or wall plenums.

Heavy construction elements require substantive footings which contribute substantially to construction time and cost; they can also impact a project's viability on unstable sites (Bylund and Nolan 2016). Prefabrication utilising lighter weight timber building systems can sometimes provide a more viable solution for a project that would not otherwise be possible using traditional construction methods and materials.

D6.The increasing interest by architects, designers, building owners and governments in using more environmentally friendly materials and the introduction of government wood encouragement policies

The impact on the environment from the use of construction materials is today a major focus for governments, building professionals and green building rating tools around the world, particularly with the international interest in global warming from increased carbon dioxide emissions (this is especially an issue for concrete as around 8% of the global CO2 emissions come from the production of cement). This aim to find and utilise more environmentally friendly materials is one of the major drivers in Canada, the US, and many major European countries for the renewed interest in timber systems.

Sustainably managed timber should be actively promoted as part of a holistic solution to our built environment. Ensuring timber resources are sustainably managed has been a major focus for the Australian timber industry and must be considered when sourcing timber for use in PTB systems. Sustainably managed timber's environmental credentials are now well documented and are having an impact on consumer choice (Forestry Tasmania 2016) (PEFC 2014). Prefabricated timber construction using timber sourced from sustainable forestry practises can be leveraged as a response to consumer concerns associated with issues related to unsustainable building practises and materials.

Governments around the world are also getting behind this recognition of timber as an environmentally friendly option. Internationally, wood encouragement policies are having a significant effect on the number of timber projects being built including Sweden, New Zealand, Canada, Finland and the Netherlands. Several local councils across Australia have also initiated or are considering adopting a wood encouragement policy. According to Planet Ark, a wood encouragement policy

'… generally requires responsibly sourced wood to be considered, where feasible, as the primary construction material in all new-build and refurbishment projects. This is usually limited to public sector buildings but could be applied across residential and commercial.' (Planet Ark, 2016).

This initiative was first adopted in Australia by Latrobe City Council (Victoria) in 2014 (Latrobe City Council, 2014) and has subsequently also been adopted by Kyogle Shire (NSW), Wattle Range Shire (South Australia) and Wallington Shire Council (Victoria), and a number of other local authorities are also considering similar policies (Planet Ark, 2016). The Australian Local Government Association (ALGA) passed a resolution at the 2015 National Assembly of Local Governments in late June that supported the use and promotion of timber products by local governments across Australia (Wood Solutions, 2016). Tasmania has also recently announced that it intends to enact a state-wide wood first policy for all public buildings, based on feasibility, for all new builds and refurbishment projects. Work needs to be continued in this area to achieve broader federal, state and local government support for wood encouragement policies.

D7. Increased interest in using low-grade wood resource into higher strength engineered wood products.

The development of more Class2-9 building opportunities, particularly in mid-rise timber buildings which will involve higher structural loads or greater spans, is going to also increase the opportunity for a greater variety of higher strength engineered wood products, both existing softwood, and new hardwood engineered wood products. There is also the opportunity when manufacturing engineered wood products such as Cross Laminated Timber (CLT) and Laminated Veneer Lumber (LVL) to potentially use lower grade sawlogs or even residual grade logs depending on the product.

Softwood

Australian mills producing softwood source their logs from plantations. Significant volumes of milled timber, potentially up to 40%, are produced that do not meet the minimum MGP10 structural grading requirements suitable for use in traditional framed construction (Schaffner 2011) (Stringer 2011). This resource is potentially available for use in engineered timber products and could supply the timber prefabrication sector with an economical resource (Bylund, 2014). Utilising this resource as a value-added product, Massive Timber systems like CLT or other engineered products represents an opportunity to provide a reliable, relatively low cost fibre to assist the development of PTB systems. Establishing markets, ensuring industry knowledge is adequate, and competing with imported PTB systems on price will be key to progressing this issue.

Hardwood

Currently, the Australian hardwood sector sources logs for milling from managed native forests to primarily supply the domestic market for appearance grade timbers. A large volume of hardwood is also grown in plantations specifically for paper and pulp. The paper and pulp market is in recession, bringing into question the industry’s commercial viability (Department of Agriculture and Water Resources, 2015), creating a large supply of logs potentially available for other uses. Timber from this resource is unlikely to meet market requirements for appearance or existing sawn structural grade products, therefore represents a potential fibre source for engineered timber products and PTB systems.

While neither the out-of-grade pine nor the eucalypt grown for paper and pulp is suitable for their original use or no longer providing an adequate return, they do have structural properties that can be measured and utilised to potentially create new engineered wood products. Most engineered timber products work collectively to create a co-action resulting in a significantly higher performing product that is not reliant on any one piece of wood or fibre and as such, both the out-of-grade pine and the residual and pulp hardwood resource have the potential to be used in engineered timber products and in turn, into prefabricated construction. The structural properties of pine are well documented, native hardwoods grown for paper and pulp may have the potential to be directed toward value added products and research is currently underway to determine suitable applications (ARC Center For Forest Value 2016) (University of Queensland 2016) (Qld DPI 2016). Increasing knowledge around their structural performance will be critical to their successful application as material in PTB systems.

D8. The increasing interest governments in encouraging more innovation and take up in off-site manufacturing and site prefabrication use.

There is a growing interest by Government’s around Australia in reducing urban sprawl and infrastructure requirements and encouraging densification, particularly around urban hubs and public transport nodes. There is also an interest in encouraging off-site prefabrication and innovation to reduce construction related issues and impacts on local communities and neighbouring residences.

The Victorian Government released in March 2016 its *Construction Technologies Sector Strategy*[14], the Minister for Industry in her forward states that the strategies aim is to “*strengthen collaboration, deepen alliances, build on innovation and grow opportunities to improve industry competitiveness through the adoption of digital and off-site technologies, and new products and materials*”.

[14] See http://www.business.vic.gov.au/__data/assets/pdf_file/0006/1275495/Construction-Technologies-Strategy-web-version-20160310.pdf

Under the off-site construction section the strategy states:

> *"As the national leader in off-site construction, Victoria is well placed to become a globally relevant centre for these technologies. We are already host to a number of leading organisations in the sector including:*
>
> - *The headquarters for Australia's most dynamic off-site construction firms and the national industry association, PrefabAus*
> - *The Australian Research Centre's Training Centre for Advanced Manufacturing of Prefabricated Housing at the University of Melbourne*
> - *The headquarters of the Innovative Manufacturing Cooperative Research Centre*
> - *Strong engineering and materials science capabilities at the universities of Melbourne, Monash, Deakin, RMIT, Swinburne, and the CSIRO; together with process engineering capabilities in the AutoCRC*
> - *The legacy of manufacturing productivity network programs for frame and truss development.*
>
> *The feasibility of off-site construction is driven by capturing economies of scale in production facilities that are large enough to offset transport and on-site placement costs. Building confidence for firms to invest in off-site production facilities will be key to this process.*
>
> *There is also opportunity to facilitate the transfer of surplus process engineering skills from the automotive sector for redeployment in the off-site construction sector."*

Tertiary institutions involved in the built environment around Australia are also currently engaging in a number of research projects targeted at prefabrication using a range of building materials funded by a range of initiatives from both government and industry (ARC Center For Forest Value 2016) (Australian Research Council 2016). As these projects mature, the resultant outcomes will inform policy, develop new products and impact building methodologies. Prefabricated timber is at the forefront of these developments.

D9. The increased acceptance and take up by governments and the design community of Building Information Modelling (BIM) and digital manufacturing

The increasing interest in the opportunities and benefits of Building Information Modelling (BIM) and digital manufacturing are also encouraging and empowering the broader interest in prefabricated solutions. It is now well recognised, particularly for big projects (or those with significant ongoing maintenance requirements), that the use of BIM, whilst requiring more time and attention to detail in the initial design phase, has significant payback benefits due to overall productivity improvements, and during construction, with far more efficient processes and reduced needs for on-site work variations, as potential 'clashes' or construction issues have already been identified and dealt with within the BIM design model.

BIM suits both massive timber and prefabricated systems as the design files can be sent directly to prefabricating companies for conversion to shop-drawing files. Manufacturing equipment is readily available that interfaces with design files to produce highly accurate building elements via Computer Numerically Controlled (CNC) machinery. Wall, floor and roof elements can be manufactured to a very high degree of tolerance quickly and efficiently.

Again in the Victorian Government's *Construction Technologies Sector Strategy* they highlight BIM as a significant productivity and economic improvement tool and have committed in 2015/16, as a major client of construction projects, to pilot the use of BIM to help inform Government construction projects across Victoria.

Whilst the construction sector today may still involve many middle aged to older design professionals or contractors who are less open to computer based approaches the current young and future generations of workers are highly conversant with computer technologies, computer gaming, virtual reality and digital printing and as such the use of BIM and of-site, 'out-of-the-weather' digital manufacturing will be a preferred option, and a simply accepted practice. On-site activities in the future will not be slow and tedious physical construction, but fast and efficient installation. Sector's that quickly recognise this and move to take advantage will benefit in the long run. This fact will provide great advantage to highly off-site manufactured and prefabricated timber solutions particularly in current reinforced concrete market share opportunities which by their nature require significant on-site construction.

The second aspect is the role that technology will play. Technological developments are ongoing and as such, can be considered an emerging factor that has the potential to assist more projects capable of being procured via prefabrication. This factor leverages from the emergence of technology as a driver of new materials, building systems and process management techniques.

Prefabrication is reliant on technology and will be at the leading edge of construction as it transitions into the digital age. Builders will need to adapt and prepare to facilitate a change in the established building culture and associated processes if they are to successfully produce buildings with this method. Retraining staff and contractors to build smaller elements in parallel rather than larger sections sequentially require significant preparation and a willingness to accept new risks as unfamiliar methods of construction are introduced.

Technology is rapidly developing new possibilities that will complement and expand prefabrication's traditional strengths. Building Information Management or BIM, now well established in the building design sector, has supplanted traditional 2D design and documentation methods.

D10. The increase in training and education opportunities in the areas of prefabricated systems design, manufacture and supply

In 2015, the Australian Research Council (ARC) funded two significant research projects that will directly impact prefabricated timber construction: the ARC Centre for Forest Value at the University of Tasmania and the ARC Training Centre for Advanced Manufacturing of Prefabricated Housing (Australian Research Council, 2016) which will focus on different aspects of 'timber value adding' (ARC CFV) and 'prefabrication' (ARC TCAMPH). These centres will be facilitated across four universities (Sydney University, University of Melbourne, Monash University and Curtin University) and these developments represent significant opportunities for proponents of prefabricated timber building systems across the country to benefit from targeted research with industry partners.

WoodSolutions also currently provides through its woodsolutions.com.au website an extensive selection of established industry funded printed and online resources for a wide range of general and specialised timber topics (Wood Solutions, 2013). New resources are alo being developed specifically for these new Class 2-9 market opportunities including *Technical Guide 37 Mid-rise Timber Buildings* detailing the

2016 NCC changes (note: a new online vido based eductaional resource is also being developed based on this technical guide), Further technical guides are also envisaged in the future, presenting information on prefabricated timber system solutions.

D11. The existence in Australia of established heavy lifting and transport logistics industry.

By its nature, prefabricated construction requires heavy transport and lifting logistics. Almost all types of prefabrication will require transport from the factory to the building site and from the truck into its final position.

The precast concrete panel industry has paved the way for other types of prefabricated construction by establishing an industry specifically catering for construction based heavy transport and lifting. The Australian commercial building sector is very familiar with efficiently transporting and lifting large scale elements and these skills and capacity are well established.

Without this sector being ready and able to provide the necessary logistical assistance, it would be difficult to establish this important element required to install PTB systems.

Creating relationships with established transport, logistics and lifting companies should be a priority for all types of prefabricated timber construction.

16.Barriers to Enabling Prefabricated Timber Building Systems

A range of issues facing the adoption of prefabricated timber building systems in Australia have been identified previously in a number of industry news articles and research reports (Truskett 1997), (Heaton 2016) et. al. A recent article focusing on overcoming obstacles facing multi-storey timber construction in *Construct* identified some reoccurring themes that can impede or constrain the adoption of PTB systems such as perceived cost-competitiveness, the role of clients, their preferences for particular building materials and the prevalence of concrete in the construction industry. (Anderson & Fuller, 2016). Establishing consensus on the issues negatively impacting the PTB systems will assist in establishing solutions. A number of speakers at a recent conference in Melbourne on prefabrication discussed a range of issues facing the adoption of prefabrication in Australia (PrefabAus Conference, 2015 & 2016). These items are broad based and will require consideration by advocates of prefabricated timber building systems. These were:

- *'Experts' advise clients that costs are not lower to prefabricate. This can be based on assumptions or misinformation as industry lacks sufficient case studies to accurately advise.*
- *Building conventionally remains industry's default position.*
- *Prefabrication companies can easily get distracted with the details.*
- *Prefabricators should be disciplined by restricting their services to modular compliant units and should not get trapped in trying to 'be all things to all men'.*
- *Adding value through modular construction should be paramount to help establish it in the market.*
- *The cost-on-cost nature of construction can make prefabrication uncompetitive. There needs to be a change in the way projects are built with sub-contractors adding costs. Main contractors adding costs onto the prefabricated contractor can also make projects financially unviable. There is a need to streamline the process to remove cost-on-cost situations where possible. One solution proposed was for prefabricators to consider taking on the role of main contractor to streamline the process.*
- *Banks are yet to provide financial products that suit prefabrication. Traditional payment triggers (slab, walls, roof, lock up etc.) don't fit prefabrication.*
- *Prefabrication can suffer from 'vanilla aesthetics' (uninspiring architecture). High quality design is required to recast this perception.*
- *Work flow issues for prefabricated construction need to be clear at the outset: Who is the client - the developer, the builder, the architect or the owner?*
- *What role does contract documentation play in prefabrication?*
- *What is the purpose of shop drawings? Document only as needed for the available skill base.*
- *What is the role of prototypes? To build prototypes and test ideas costs money – who pays?*
- *What about defects? Who is responsible - is it the builder, subcontractors or the prefabricator?*

This report is not intended to address all of these concerns although, as stated, they should be considering in the broader context of enabling PTB systems in Australia.

The issues raised at events such as the aforementioned and from discussions with participants involved in prefabricated timber construction, are intended to expand some of the specific barriers facing the PTB industry as it develops strategies to move forward, these include the following in order of priority.

- B1. Risk – and what it means to existing businesses wanting to expand their operations to participate in these new market opportunities
- B2. Dealing with existing financial models
- B3. Timber industry interest in Class 2-9 buildings and capacity to supply
- B4. Industry fragmentation and lack of coordination
- B5. Establishing a culture of prefabrication in an existing environment that is built on many layers of sub-contractors and cost-on-cost inefficiencies
- B6. Competition from other prefabricated materials
- B7. Public and industry's current understanding and perceptions of timber and prefabricated systems
- B8. Costs and effort involved in establishing prefabrication facilities
- B9. The impact of Australia's geography and isolated populations
- B10. The need for greater prefabricated timber buildings systems research and sharing that knowledge

These barriers will now be individually examined in further detail.

B1. Risk – and what it means to existing businesses wanting to expand their operations to participate in these new markets

New prefabricated timber building systems can be considered innovative depending on the project type, scale, location, degree of prefabrication and type of timber system used. With innovation comes 'perceived' and 'real' risk which must be managed. Put another way, risk management influences the effective adoption of innovation. In the context of this investigation on prefabricated timber systems, the issue of 'risk' needs to be discussed for both the users and the suppliers of the systems.

User Risk Issues

Design practitioners, builders and developers can be innovative but only inside the bounds of acceptable risk and within the reasonable constraints of experience across the whole design and construction team. The likelihood of adverse events in innovative building and the use of building systems, such as unanticipated costs and unexpected construction delays, is high and can occur regularly when dealing with new types of construction. The consequence of failure can also be high. In the worst cases, they can lead to death and significant injury. Invariably, building remediation is expensive and time-consuming. Gauging the likelihood and consequence of adverse events, when advocating a new building system, will involve deliberate and structured risk management processes (Bylund and Nolan 2016).

New methods of construction inevitably face resistance to adoption as the potential impact of adverse events that they may cause is often given more weight than the potential benefits of favourable events. This is based on an explicit sensitivity to risk by clients, architectural practitioners and partner professionals and an implicit lack of understanding and confidence in the delivery of innovation. This resistance is the norm and results from the real and imagined risks perceived at each stage of the procurement process. The level of this resistance at the key decision points in the procurement process is critical. If the perceived risk of innovation is felt to be higher than its identifiable benefit at any point in the process, innovation will generally be abandoned. As novelty undermines confidence in the delivery of innovation, participant caution is generated. The standard consultant response to caution is over-specification while the standard builder or sub-contractor response is to load the tender price (ibid).

The preferred means of introducing substantially new approaches to building is by collaborative engagement between the innovation proponent (supplier) and the design and construction team. This is an educative phase where the proponent introduces, trains and builds confidence in the design team, cost consultants and the risk managers in the delivery of innovation and its benefits. This allows them to adjust their perceived risk/reward ratio, or identify means of risks mitigation. In this role, proponents of new PTB systems can become intelligent brokers of innovation, ensuring questions are answered and solutions are found throughout the process. Disentangling this educative phase from the rest of the procurement process can also reduce perceived risks. With better knowledge gained during this separate stage, practitioners can make informed decisions and confidence increases (European Commission, 2010).

Prototyping solutions enhance this educative phase. Acceptance of innovation and confidence in its use is often incremental. The first application of innovation regularly involves excess discretionary tolerances until experience with the system generates confidence and increases efficiency (Edgerton, 2006). As most architect-designed buildings are unique, each presents additional challenges or the opportunity to refine innovative approaches such as PTB systems (ibid).

A major benefit at present is the increased broad awareness and desire for more prefabricated solutions from all materials, and associations such as PrefabAus have been established to assist in promoting generically the benefits of prefabricated solutions; the wider the understanding off the benefits and the acceptance of the overall prefabrication process the less perceived and real level of risk.

Supplier Risk Issues

On the other side of the equation is the ‘perceived’ and/or ‘real’ risk to the suppliers. When commencing new and different approaches companies rarely want to be the ‘first’ particularly if it is into a new market segment with which they are not familiar and which has different requirements, restraints, expectations and opportunities.

For broader market take up by suppliers from within the current timber industry there are certain generic ‘risk’ related issues which need to be investigated that are particular to supply of Class 2-9 buildings, compared with Class (residential buildings, these include:

- Licensing requirements (varies between Australian states)
- OH&S and crane requirements (may vary between Australian states)
- Insurance for commercial jobs
- Supply requirements (and possible liquidated damages if supply times are not met)

B2. Dealing with existing financial models

Existing building and construction finance approaches and models also do not always suit prefabricated construction, whether it be of timber, steel or concrete. Due to the significant off-site processes inherent in prefabricated construction, staged financing and payments according to traditional processes such as footings/slab, walls, roof cover, lockup and completion can make securing finance difficult (Gyrn, 2015). Tier one banks need to develop new products to suit prefabrication as they are the finance leaders. Some second tier funding organisations already recognise prefabrication as a significant development and are developing products to suit (ibid). Difficulties in securing finance for projects using prefabrication is a significant issue that will require significant industry cooperation to overcome and a clear understanding of how to equitably share risk relative to cost.

B3. Timber industry interest in Class 2-9 buildings and capacity to supply

Large scale industries capable of supplying prefabricated timber construction are yet to be established in Australia. Feedback from architects, engineers and developers wishing to utilise prefabricated timber construction systems, is that one of the most difficult problems is identifying within the current supply chain suitable companies capable of producing the required elements. Unless supply chain companies expand their activities in this area this is likely to become more of an issue with the recent release of the new 2016 NCC deemed-to-satisfy provisions and the current industry promotion activities around this change. The new NCC changes are generating significant interest by designers, builders and developers particularly for mid-rise apartment type structures – once this translates into projects the question will be who can supply? Nothing will dampen the enthusiasm of a potential developer or designer more than experiencing supply issues. A balance needs to be found to ensure the generating and promotion of timber solutions is tempered with and capacity of industry to supply.

In terms of prefabricated timber systems these will either have to come from within the current timber industry supply chain expanding their offerings up the chain into Class 2-9 solutions or it will come from building companies expanding their activities down the supply chain and setting up prefabrication facilities (Lend Lease and Strongbuild, discussed in the previous section, are two recent examples of this).

In regards to the current timber industry supply chain:

- for massive type construction such as CLT there already exists a number of large to medium sized overseas companies with an established design and import supply capacity and with the establishment of the Australian XLam factory, this services will also be available domestically;
- however, for lightweight timber prefabricated systems, the likely supply source will be the frame and truss sector, and this sector is currently strongly focused on the Class 1 residential market and accordingly has very limited current capacity to supply Class 2-9 type building systems nationally.

The frame and truss (F&T) sector nationally is predominately made up of small to medium family owned businesses, along with some larger enterprises, who are very skilled and experienced in supplying open wall frames, floor trusses and roof trusses to the domestic residential market. Currently, demand in the residential sector is very high with many F&T manufacturers being at full individual capacity (this is certainly a contrast to a few years ago when demand in many states was low and there was a significant oversupply of frame and truss manufacture resulting in a highly competitive commercial environment). Many F&T manufacturers spoken to on the opportunities of a move into new Class 2-9 prefabricated building systems were not at this stage particularly interested, rather being happy to remain in the residential market and with products they were familiar with. Many relatively small enterprises also cited their lack of machinery to manufacture, or space to store, prefabricated elements. Also often heard was the current lack of design software or connection and construction solutions for these taller timber buildings; this is an area the major nailplate manufacturers are currently reviewing.

As much of the opportunity generated by the new NCC DtS provisions will be in multi-residential apartment buildings up to six storeys, which more economically suits lightweight fire-protected timber based systems, the frame and truss sector seriously needs to assess and plan for its future capacity to supply – or either an alternative means of supply needs to be established and promoted.

As awareness of mid-rise timber building increases, on the design side there is also currently a lack of design professionals: architects, engineers, quantity surveyors, building surveyors, in Australia with the knowledge about and the capacity to design, specify, and cost prefabricated timber system solutions and supply and construction processes. It is well appreciated that design team members particularly engineers and quantity surveyors can sway a project away from timber because design team members either lack appropriate knowledge or carry misperceptions about timber.

FWPA's WoodSolutions program is planned to be expanded in 2016 with a Victorian pilot program engaging a dedicated technical field force (4 field force reps in Victoria, 1 in Qld) to identify new Class 2-9 building opportunities and to actively promote and inspire the use of timber buildings, and then to work with developers and the design team professionals to assist in finding the optimum solutions. Prefabricated off-site manufactured timber systems solutions are going to be absolutely fundamental to success in this venture. If the pilot program proves successful in Victoria over the next 3 years then the plan will then be to roll it out in other states).

It should be noted that access to commodity timber framing products, fixing & connection products and logistics are already well established; it is the access to market-ready prefabricated timber building systems that remains an issue.

B4. Industry fragmentation and lack of coordination

The overall timber industry operating in Australia is still highly fragmented in nature particularly in the area of innovation and new market development. As most of the industry's traditional markets are residential sector based there is also a long history of competition in both timber commodity product supply, and F&T manufacture, due to cyclic residential market demand, and 'overseas versus local' timber supply price variations.

This culture of competition sometimes makes it difficult for sectors to move forward collectively into new market development opportunities where the competition isn't another timber product, rather an alternative product such as concrete and steel. This is the case as new prefabricated timber system market opportunities for Class 2-9 buildings are pursued. The timber sector currently has virtually none of this market share, and thus will achieve far more by working collectively on solutions and approaches rather than working in isolation or competition.

At present there is no active coordination for structured market implementation and take up, nor a clear organisation who might facilitate this. It could possibly be the Frame and Truss Manufacturers Association (FTMA), however the FTMA doesn't represent all potential beneficiaries and as previously mentioned this sector is currently very focussed on a high residential demand; it could be the Engineered Wood Products Association of Australasia (EWPAA), however again EWPAA doesn't represent all potential beneficiaries, though the products it represents will be key to success.

The establishment of a facilitated Market Implementation Group would be highly beneficial; this approach was adopted previously with the introduction of new prefabricated timber cassette floor systems to the market place facilitated by FTMA and Wood Products Victoria and included technical representatives of the three major nailplate manufacturers, as well as innovative F&T manufacturers are other industry system suppliers. The Market Implementation Group approach provided a formal forum for strategic and technical discussion and for resolution of generic issues such as: insurance, licensing and OH&S requirements. The participants approached the group activities with a strong spirit of collaboration and accordingly much was achieved in a short period for all involved. In particular to their credit the nailplate manufacturers quickly started to develop up their own member tools particularly design, fabrication and costing modules for their software, and also in-house technical support, which allowed the Market Implementation Group to disband.

It is recommended that a similar generic Market Implementation Group approach be adopted for these new Class 2-9 market opportunities to allow collective discussion around new prefabricated systems and approaches and to address generic technical and market development related issues.

B5. Competition from other prefabricated materials

Prefabricated timber construction is not developing in a vacuum. Interest and advances in prefabrication is a particular focus for lightweight steel and heavier steel and concrete materials in Class 2-9 buildings.

Panelised construction using precast concrete walls and floors has been commonplace in Australian commercial construction for several decades and is today widely used.

Companies using lightweight steel are also today creating sophisticated volumetric modules designed to work in conjunction with precast concrete walls and floors. This combination will potentially compete directly with volumetric timber framed modules and massive timber developments. As both are potentially well suited to in-fill and mid-rise construction, PTB systems will need to develop specific strategies to address this competition; promoting timber's environmental benefits, potential cost savings, fire performance and acoustics will be key to its success.

Figure 25. CSR Velocity System presentation. Source: Frame Australia

As the timber industry moves further into more prefabricated lightweight timber systems it also needs to be careful that it is simply not opening up opportunity for lightweight steel framing. This will be particularly the case in the Class 1 residential sector where lightweight timber framing has long been dominant. One of the reasons the timber industry has been quiet in the past promoting higher levels of prefabrication is the steel framing sector has never really had more then 8-10% of market share, builders preferring the combination of timber frames and trusses but also easy adjustment if needs be on site. A greater acceptance of prefabricated systems is likely to make it less of a decision for builders to potentially switch between materials. At the 2016 Frame Australia conference the CSR representative talking about their new Velocity prefabricated wall and floor systems made just this point, advising that they were plasterboard manufacturers, not timber suppliers, and if timber elements were not up to quality they could easily switch over to steel.

B6. Establishing a culture of prefabrication in an existing environment that is built on many layers of sub-contractors and cost-on-cost inefficiencies

Over the last 15 to 20 years, northern and central European countries such as Sweden, Norway, Germany and Austria have been establishing their timber prefabrication industry's capacity to reliably produce large buildings to successfully compete with conventional building techniques and materials. In doing so, these sectors have successfully established substantive market shares (Nord, 2008). Each country has adapted ideas and methods, often feeding off each other by developing products and methods targeted to their own individual market expectations, materials and technology availability, climate types and building cultures.

As Australia is progresses toward establishing its own prefabrication capacity for PTB systems sectors, there is benefit in considering the issues faced by other advanced countries who have already established capacity to prefabricated timber commercial buildings. In discussing how Sweden has dealt with the growth of prefabricated timber construction, Professor Lars Stehn of Sweden's Luleå Technical University states that careful consideration of a range of different factors, such as the types of building materials that best suit prefabrication, the cost of establishing and maintaining a facility with equipment and suitably trained staff will directly influence success or failure (Höök and Stehn 2008) and that maintaining a balanced view is essential to growing a mature prefabrication industry. Stehn goes onto point out that it can be easy to become too focused on pragmatic technical considerations as '…there is the risk that you can get so involved in making critical and good engineering solutions, that you can lose market perspective'.

This means that solutions which focus on the technical aspects of prefabrication without an appreciation of design, quality, cost and construction time expectations, should be avoided. Simply moving on-site construction methodologies off site will fail to optimize the potential of prefabrication. An example of one attempt at modifying an existing building culture can be seen in the adoption of massive timber in conjunction with Lean principles by a major builder/developer in Australia in the form of 'The 7 Wastes' model (Lendlease, 2011).

Figure 26. Eight storey CLT building in Sweden under construction. Image credit: D.Bylund

A key component of Lendlease's approach is to ensure of the company's staff structured projects according to Lean principles.

According to *The 7 Wastes of Lean* as defined by Michale Cyger of iSixSigma (Cyger, 2015), these are:

1. Defects (reduce defects)
2. Overproduction (reduce overproduction)
3. Transport (minimise transportation)
4. Waiting (reduce waiting times)
5. Inventory (minimize materials held unnecessarily in inventory)
6. Motion (reduce inefficient staff movement)
7. Processing (reduce processing time)

The Toyota Production System (refer to Appendix 3) was instigated as a response to overproduction. Construction does not suffer from overproduction in the same sense as the manufacturing industry, but it does produce large volumes of waste as a by-product. By default, an optimised prefabrication approach will significantly reduce building waste and become more efficient. Lendlease's stated waste reduction target is to reduce all waste by 20% of the 2014 levels by 2020 (Lendlease, 2011).

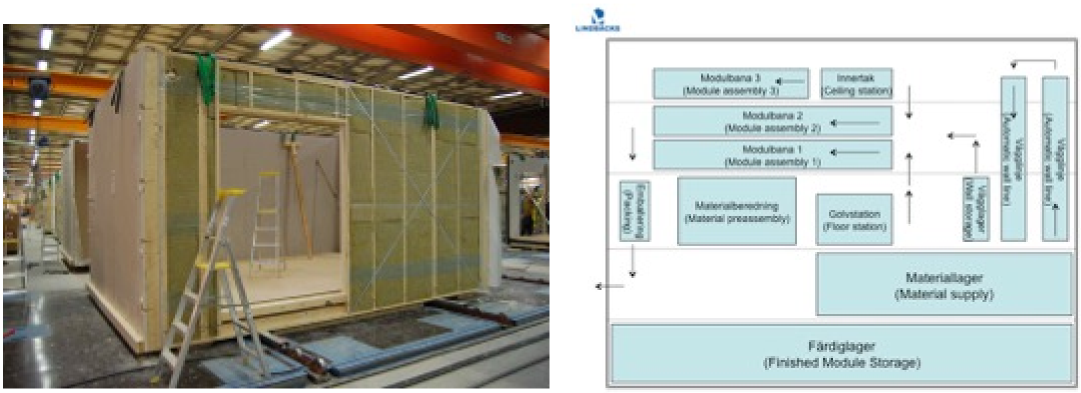


Figure 27. Swedish builder Lindbäcks factory floor (left) and Lean inspired workstation layout plan (right). Image Credit: D.Bylund and Lindbäcks

Nord states that in the establishment of both industrialised construction processes and strategies, total solution requirements are necessary when developing an engineered timber building solution (Nord 2008). This 'total solution' equates to architects and engineers being trained to take the particular constraints of off-site building into account when designing a new structure in conjunction with the prefabricator and the builder. Simply applying traditional design methods associated with steel or concrete construction to a prefabricated timber building will often cause conflict. As relatively new timber building systems, such as CLT and prefabricated volumetric construction, become more common in Australia, education in how to design structures featuring them is paramount. Simply designing a building assuming span, loads and tolerance of a steel structure but attempting to then construct the building as a CLT or a volume module structure will not work. This may seem self-evident, but interviews with Scandinavian building companies such as Martinsons and Lindbäcks have demonstrated the need to explain this to organisations and individuals new to prefabricated timber construction. According to Nord, in response to difficulties experienced in educating industry, Swedish timber companies have now begun to '… cut across the specialised value chain by incorporating design, procurement and production from in-house or established relations, to a pool of competencies needed to meet client requirements and market conditions' (ibid). Nord's 'specialised value chain' are the mainstream architects and engineers who have much experience in traditional construction, but who are yet to appreciate or understand prefabrication's unique set of constraints and opportunities. This need to communicate with the 'specialised value chain' in a timber prefabrication industry is also discussed by Höök and Stehn. Referring to the process of refining a system or structural design solution, they state that:

> 'If you look at the individual companies that have developed timber, all of them are prefabricating and are developing integrated building solutions where the technical and engineering solutions are integral. Once they have a solution from an engineering point of view, they stick to it. If they have a jointing detail that works for them, they don't need five different jointing techniques. They only use one joint solution and then they develop their value-adding by building as much as possible indoors, right down to installing the kitchen and hanging the wallpaper. The answer is not to have a multitude of timber engineering solutions, but to have one *and a selling organisation that communicates with architects and clients explaining how to use their prefabricated solution*' (Höök & Stehn, 2008) (Italics supplied).

Thus the ability to communicate and promote a particular PTB system *with all* involved in construction is critical to gaining traction in an established industry.

B7. Public and industry's current understanding and perceptions of timber and prefabricated systems

Timber is well regarded as a structural material for housing construction and as a high quality cladding or lining material. More research needs to be undertaken to determine attitudes towards its use in Class 2-9 buildings as part of a prefabricated building system. Anecdotal evidence for its use in significant timber buildings such as the Sydney Showground Exhibition Building (Gulam), Forté Apartments (CLT), Docklands Library (Glulam & CLT) and The Green (lightweight fire protected timber) indicate that it has been well received. Traditional fears pertaining to susceptibility to fire, rot and termites do not appear to have had a significant impact on the use or uptake of these projects, but ongoing efforts are required to counter such concerns. Good design practices such as utilising reinforced concrete structures in the ground for basements or car parks, or the use of first floor concert podium structures should also be encouraged as part of moisture and termite management approaches.

B8. Costs and effort involved in establishing prefabrication facilities

It is often thought that the cost of establishing prefabricated timber facilities capable of producing volume modules, closed wall frames or massive timber is prohibitive without an established market. The instances cited are often based on costs from plants in Europe. For example, Martinsons, a large Swedish sawmill, recently announced the expansion of its existing CLT manufacturing plant that will triple their existing production (Martinsons, 2015) at a cost of SEK 80 million (AUD $13 million). While new plants can represent large investments, these were often made on the back of much smaller facilities that were used to test markets and establish skills and that did not require such large commitments. Conservative models of production in conjunction with industry and government backed research and seed funding are the primary methods that prefabricated timber building systems have developed in Europe. There will always be a degree of failure experienced by early adopters of a new (ASIC, 2013). Examples of this in prefabrication are Unitised Building System and PanelBuild. One o fthe key constraints associated with developing a new approach to construction is in finding the right balance between establishing and managing operating costs, securing projects and the capacity to successfully market a new product into an established market.

The cost to frame and truss manufacturers of moving into basic Level 2 2D prefabricated elements such as cassette floors and partially closed wall panel systems can be quite low where simple static jigs are used to provide set out and squareness for panel construction, the main issue for many F&T manufacturers is usually available floor space for the jig and for completed panel storage. Obviously for higher levels of machinery based manufacture and panel movement logistics such as butterfly tables and automatic nailers a greater cost is involved. For companies wanting to focus on higher levels of prefabrication obviously the ability to invest in and develop new facilities from scratch provides the greatest opportunity to optimise workflows and maximise machinery based manufacture and potential output.

B9. The impact of Australia's geography and isolated populations

Australia is a very large country, with large distances between its capital cities and regional centres. Despite its growing population, Australia has a comparatively low population base from which to service its needs. Advocates of prefabricated timber building systems will need to consider the optimal location to access raw materials, suitably skilled and qualified staff and ongoing and sustainable markets. Australia's two largest population centres, Sydney and Melbourne, potentially afford the best opportunity to supply into well established markets. While they are approximately 900km apart, both are well serviced by road and rail. A large prefabrication facility is currently being established in Sydney to service both cities by one of Australia's largest builder/developers (Lendlease, 2016). While output from this facility is targeted to service the organisation's own projects, service and allied industries stand to benefit which may provide a critical mass capable of supplying and supporting other prefabricated timber building systems optimised to service New South Wales, Victoria and surrounds by creating prefabrication hubs. It has also recently been announced that XLam and Hyne will construct a new CLT manufacturing facility in the Albury-Wodonga region on the border of NSW and Vic.

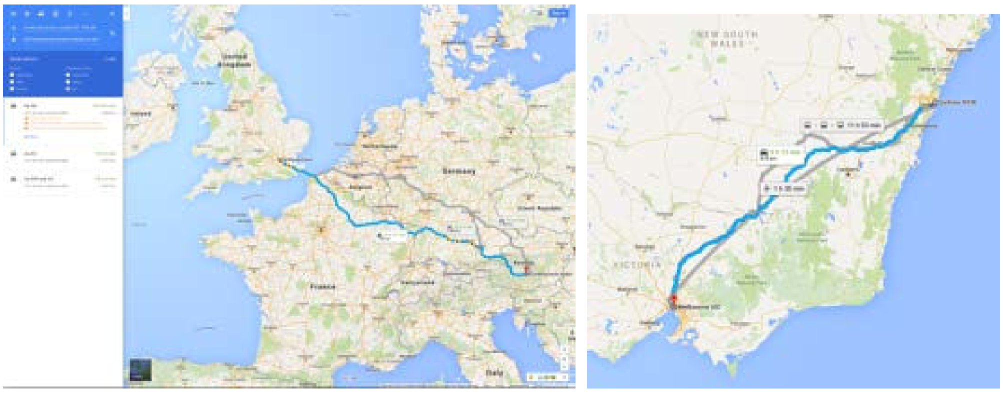


Figure 28. Left – Austria to Murray Grove, UK. Right – Sydney to Melbourne, Australia. Image credit: Google Maps

Overcoming large distances to transport prefabricated elements is also a factor for timber construction industries in other countries. The StadHaus in Murray Grove, England is often cited as a seminal project for CLT. This building imported its PTB system from Austria. It required 926m^3 of timber which was transported over 1,450 km. Both CLT panels and completed volume modules in Sweden are often transported from the factories in the far north down to Stockholm and further in the south. These distances can exceed 800 km.

Australia's isolated capital cities such as Perth, Adelaide and Hobart may not directly benefit from the development of prefabrication hubs in the population dense east coast, but as knowledge and skills increase in prefabricated timber building, these centres may develop smaller enterprises that can benefit from experiences and projects forged by the larger operations.

B10. The need for greater prefabricated timber buildings systems research and sharing that knowledge

As new building systems are developed and applied to Australian conditions, building regulations, materials and the prevailing building culture, a degree of intellectual property is accumulated that has value. Early adopters and innovators who invest heavily and commit to new building systems or methods usually rightfully protect that investment. As projects are completed that have benefitted from that investment, and in turn influence the following project or venture, a degree of market understanding, knowledge and acceptance develops that then serves to dilute any early mover advantage.

As mentioned previously (Section B4) when developing new opportunities in an established market, there are benefits associated with participants acting collectively rather than in isolation. Whilst market share is low (or in effect non-competitive with other timber products) knowledge sharing should be encouraged and practiced. The same goes for investment in generic R&D around systems and solutions. There will be a wide range of generic questions that need to be answered, or common specification details that need to be developed, this is best approached initially in a collective way. If individual companies, as part of this process identify particularly proprietary opportunities, then these should be encouraged to ensure a wide range of solutions are available to the market for different needs.

Technical innovation and practical prefabrication solutions suitable for Australian conditions need to be identified, developed, tested and then clearly specified. – *examples here include: should off-site prefabricated wall frames to Class 2&3 buildings be 'open' or 'partially or fully' closed; also is it possible for some fire-rated ceiling linings be preinstalled to floor/ceiling cassettes off-site to save time on-site?*.

At present there is no formal framework to allow for discussion and pursuit of generic prefabricated timber system focussed R&D and sharing of knowledge; this needs to be addressed.

17.Gauging Perceptions of Prefabricated Timber Building Systems

To gauge the perceptions of designers (architects and engineers etc.), timber prefabricators and builders across all Australian states and the A.C.T. to prefabricated timber systems, three questionnaires were developed and circulated.

The questionnaires comprised two sections.

- Section one, focused on the interviewees business in a quantitative sense for the purposes of determining the general nature and structure of the business, types of services provided, the nature of the materials used and the size and budget ranges typically serviced.
- Section two, was more qualitative in nature and focused on the respondent's thoughts on the current state of timber prefabrication in Australia, where opportunities might lie and what constraints exist that were preventing them, and the sector generally, from moving forward.

The capacity to design, prefabricate and build with timber varies across Australia. Timber prefabrication capacity is not evenly represented across the country and as such, there is a degree of fragmentation. This is evidenced in the geographical distribution of designers, prefabricators and builders who would be suitable to be included in a study of this nature.

State/Territory	Prefabricators		Designers		Builders	
	Aim	Actual	Aim	Actual	Aim	Actual
Victoria	4	1	5	4	3	2
NSW	2	0	3	3	2	0
WA	2	2	4	4	2	1
QLD	3	1	1	0	1	0
TAS	1	1	3	2	2	1
SA	1	0	0	0	1	0
ACT	1	0	0	0	0	0
SUB TOTAL	14	4	16	13	11	4
TOTAL	AIM	ACHIEVED				
	41	26	32	26	22	8

Table 5. Geographic distribution of potential research participants.

Forty-two companies consisting of fourteen prefabricators, seventeen designers and eleven builders were sent the questionnaire. The companies were selected on their past or present involvement in the design, manufacture and/or construction of prefabricated timber buildings or components. Twenty-three responded to the invitation to participate with twenty-one agreeing to participate, two declining to be involved and seventeen did not respond. This effectively resulted in a participation rate of 50% of those targeted.

It is beyond the scope of this report to comment in depth as to the reasons why this is the case beyond the impact that this might have on both the opportunities and constraints that this represents. All three major nail plate suppliers, Multinail, Pryda and MiTek, were also invited to respond to the questionnaire, as was the Engineered Wood Association of Australia (EWPAA).

Name	Name
Drouin West Timber & Truss	Multinail (as supplier)
EMCEE Truss & Frame	Multinail (as engineer)
Studio 505	ARUP
AECOM	Timber Insight
MiTek	WA Span Truss
Pryda	ALDA
Fraser Property Group	ANDdesign
Arkit	Prompt Engineering
Robert Morrison-Nunn	Wesbeam
Fairbrother	Nordic Homes/Nordic North
	Ecotruss

Table 6. List of participating organisations.

17.1 Designers' Responses

Seventeen design professionals across all states and the A.C.T. were approached to participate in the questionnaires and thirteen agreed to contribute. Difficulties were experienced in identifying architects and engineers from each state and territory who were willing to contribute to the research *and* who had experience in prefabricated timber construction for Class 2 to 9 buildings. The difficulty in identifying suitably qualified and experienced design practitioners experienced by this report has the potential to also be an obstacle to progressing timber and prefabrication experience in Class 2 to 9 buildings in Australia. Refer to *Access to Prefabricated Timber Building Systems* in the *Barriers to Enabling Prefabricated Timber Building Systems* chapter.

Professional organisations that represent both architects and engineers, such as the *Australian Institute of Architects*, the *Building Designers Association of Australia* and *Engineers Australia*, provide publically searchable membership databases on their websites, however these services do not have the capacity to find practitioners with specific expertise beyond the broadest category ranges and are limited to architects, building designers or engineers who opt in to being publically searchable in this manner.

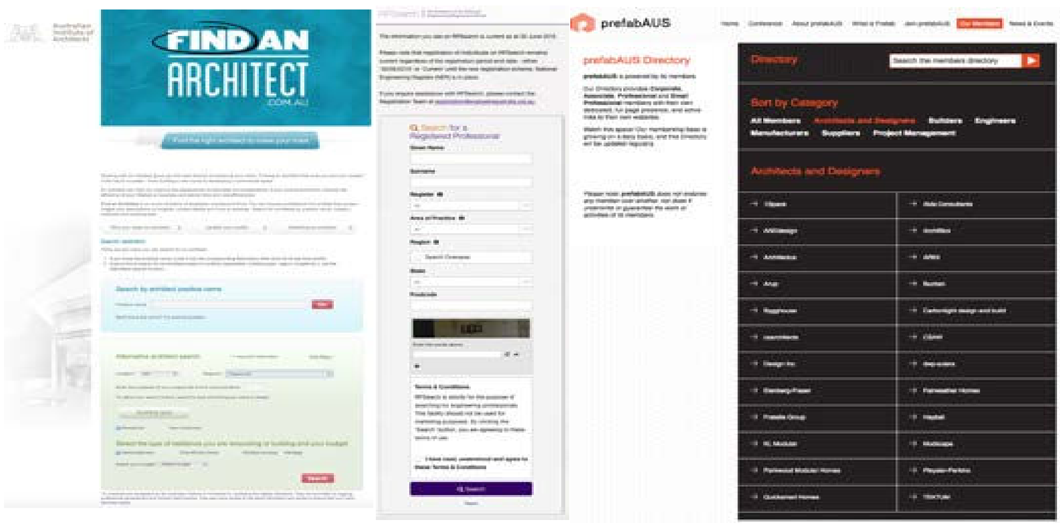


Figure 29. Australian Institute of Architects online search engine (left), Engineers Australia online search engine (centre) and prefabAUS online search engine (left).

Unless a design professional specifically promotes their capacity to design larger projects using timber, developers will encounter difficulties in sourcing the necessary skills using traditional methods of procurement. An alternative to searching for design professionals with the relevant experience via their respective representative organisation is to utilise resources and events promoted by prefabrication industry specific peak bodies such as *prefabAUS* or *Modular Construction & Prefabrication Australia*. For example, *prefabAUS* was established in 2013 to 'represent, showcase and advance the industry through collaboration, innovation and education' and it provides a publically searchable database of their members by categories including Architects and Designers, Builders, Engineers, Manufacturers, Suppliers and Project Managers. As a relatively new organisation, it is currently establishing its membership base and as such, its publically available membership database is relatively small with limited functionality and does not allow searches by both type and region. Both *prefabAUS* and *Modular Construction & Prefabrication Australia* hold annual prefabrication conferences and online resource libraries.

Developing and promoting an impartial searchable database of design professionals who have experience in prefabricated timber construction with cross links to and from peak bodies and professional organisations will assist in removing a significant barrier and assist with enabling PTB systems.

Refer to the Disclaimer at the end of this report to see the author's affiliations with respect to the content of this section.

17.2 Prefabricators' Responses

Fourteen prefabricators across all states and the A.C.T. were approached to participate in the questionnaire. Nine companies agreed to be involved, one declined and four did not respond. Attempts were made to canvas companies producing both volumetric and planar solutions. Of the nine companies who agreed to participate, seven were frame and truss, one was volumetric and one was massive timber.

The Australian timber prefabrication sector is relatively well represented by residential frame and truss factories and to a lesser extent, by volumetric companies. The Frame and Truss (F&T) sector operates primarily as made-to-order engineered timber fabricators. With a few exceptions, they do not normally provide on-site installation services.

The volumetric module sector is structured to provide turnkey solutions, often as both fabricator, manufacturer and builder. Frame and truss companies service both city and country locations whereas the volumetric prefabricators supply predominantly into the remote and rural markets. While frame and truss manufacturers are primarily only supplying Class 1 buildings, volumetric manufacturers also supply other classes of buildings such as those required by the remote mining industry and through the provision of new facilities for hospitals and schools, especially in established locations where space, time and the need to minimise site disruption are factors inhibiting conventional construction.

The planar solid timber prefabrication sector is yet to be firmly established in Australia. Several international Cross Laminated Timber (CLT) manufacturers have recently formed partnerships with either Australian sawmills or large-scale developers. Several key projects featuring massive timber have received significant press exposure, which has raised the profile of the product and its potential application in Australia. As an emerging market, panelised massive timber prefabrication appears to suit some types of Australian mid-rise residential construction. This is evidenced by the success of the Forté building in Melbourne and subsequent indications by the developer suggest massive timber will feature more prominently in their future projects (Lendlease, 2016).

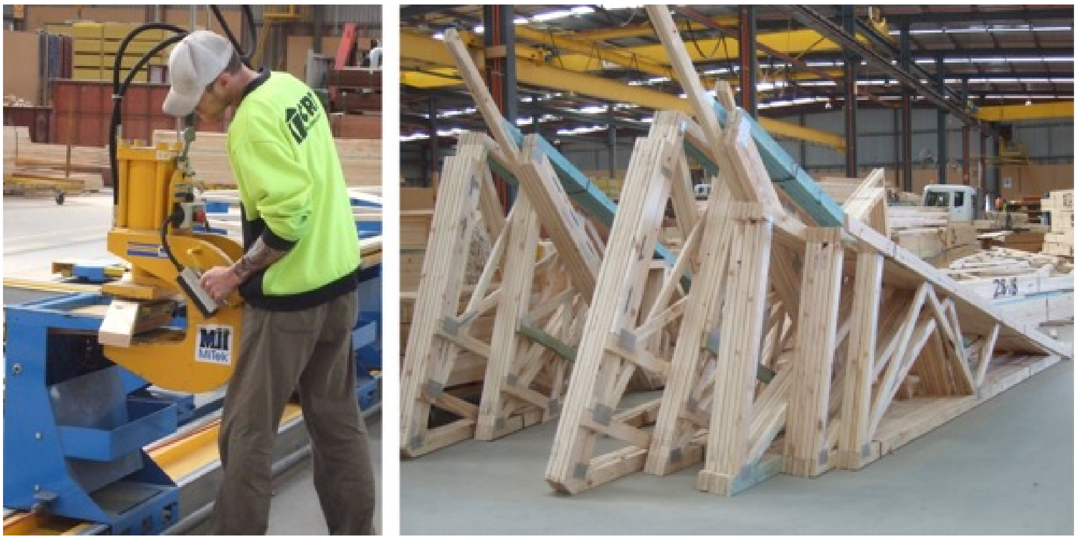


Figure 30. Typical Frame and Truss manufacturing in Australia. Image credit: CSAW

A number of constraints inhibiting the F&T sector from expanding into larger scale commercial projects emerged directly from the interviews. These are listed in point form below:

- Frame & truss manufacturers tend to be inherently conservative and most are unwilling to take 'risks' due to the lack of resources to develop panelisation without a clear market. Economies of scale is an ongoing factor.
- Many of the truss manufacturer's business models suit fast turn over residential scale projects rather than fewer but larger commercial scale projects.
- Storing large volumes of timber required to undertake bigger projects is an issue for both cost and physical space.
- Factory floor space for cassette manufacture is greater than that required for truss & frames. Few producers have the capacity to dedicate space for both.
- Unlike the UK, Australia does not automatically require a crane on site. This allows Australian F&T companies to deliver with just a Hiab. If a crane were mandatory, it might be more conducive to also supply cassettes etc. as crane cost would become less of an inhibitive factor.
- Shortage of F&T Detailers who have the capacity or willingness to design outside standard parameters. This is in part because producers tend to train in-house, selecting from a small pool of labourers who may not have the initiative to extend themselves. Many detailers start work in factories with only minimal standards of education.
- F&T industry generally lack the innovation to look beyond detached and semidetached housing towards the 3 to 5+ storey market.
- All nailplate suppliers operating in Australia provide additional design and certification support to the F&T residential sector. These companies could do more to encourage them to expand into the commercial market.

17.3 Builders' Responses

Of the eleven building companies approached, four agreed to participate, two in Victoria, one in Tasmania and one in Western Australia. All of the builders' responses focused around several key points such as:

- Conventional on-site sequential building using steel and concrete will remain the dominant commercial building method in Australia for the foreseeable future.
- The Australian building culture is relatively conservative and as such, is unlikely to adopt a rapid increase in prefabrication although all participants would be prepared to consider small, calculated steps into new prefabricated timber construction as opportunity and support increases.
- Conventional building is optimised for green field sites. If Australia's towns and cities continue to expand outward, conventionally built green field type developments will remain competitive.
- As builders are increasingly faced with constructing within established areas, conventional building methods become less practical and can add significant cost and inconvenience creating opportunity for prefabrication.

Figure 31. Hybrid timber steel cassette floor being lowered into position Image credit: Unknown

18. Case Studies

18.1 NRAS Inveresk Student Housing

- Project Details: University student accommodation, Invermay, Launceston, Tasmania
- Client: University of Tasmania
- Architect(s): Morrison & Breytenbach Architects in association with Circa Morris Nunn Architects
- Head contractor: Hutchinson Builders
- Prefabricators: Hutchinson Builders, EcoTruss (frame and truss supplier), XLAM (CLT supplier)
- Production/Installation: Approximately 9 months
- Unique features:
    - Fully finished timber framed prefabricated modules
    - CLT corridors and flooring in all upper level public areas
    - Nail-plate roof trusses assembled with roof cover on ground
- Build Cost: $15 million
- Completion: February 2016
- Web: accommodation.utas.edu.au/university-accommodation/studio-apartments/inveresk-apartments

Figure 32. Completed NRAS Inveresk student accommodation. Image credit: CSAW

The University of Tasmania commissioned a four storey, 120 unit student accommodation building to be designed by Morrison & Breytenbach Architects in association with Circa Morris Nunn Architects. The project's head contractor was Hutchinson Builders following a competitive tender. It was funded by the Australian Federal Government's National Rental Affordability Scheme (NRAS) and is located on its Inveresk campus in Launceston. The choice of material and off-site construction methodologies represent the first of its kind in Australia and in doing so, it has provided a number of valuable insights into the opportunities and constraints facing Australian prefabrication and timber construction for commercial and multi-residential buildings.

One full scale prototype module was built to test construction methodologies, structural capacity to withstand lifting and transporting as an example for the contractors to assess prior to submission of tenders.

Figure 33. Views of construction elements and modules in the factory. Image credit: CSAW

The building comprises 120 prefabricated volume modules for the apartments and CLT for all upper level connecting walkways. These two elements, working in combination, were deemed to be the most suitable for the prevailing 18m deep silt riverbank site conditions and, in conjunction with the speed of prefabricated construction, were instrumental in making the project feasible. They were also considered a manageable balance between the builder's existing knowledge and experience in prefabrication with timber and the introduction of a 'new' material to Tasmania in the form of CLT.

A key tenet of the design team was to use locally available products and materials where possible, with the exception of the CLT components, and as such, a local chain hardware and two local frame and truss manufacturers were contracted to supply the majority of the materials.

An empty warehouse close to the building site was used to house a temporary production facility for the construction of the modules. Two rolling lines were established to produce the modules in parallel, with the net result being one full module produced per day. Each module was finished with all services, insulation, cabinetry, internal and external linings and floor coverings. Labour was sub-contracted from local trades and inducted into an off-site, Lean inspired construction philosophy specifically for this project. The work force's transitioning from traditional on-site sequential construction was initially slow, but improved as workflow management techniques developed and the workers' familiarity with the project and tasks increased. This resulted in a marked increase in productivity over the term of the build.

Figure 34. Nearing completion. All modules in place, CLT stairs, walkways and common areas installed, roof truss assembly completed and framing for external cladding completed. Image credit: CSAW

Providing temporary waterproofing for the volume modules during installation sufficient for the Tasmanian winter proved to be problematic. Several top floor apartments suffered from water ingress resulting in some post installation rectification. Connection detailing between the CLT panels and the steel frame also resulted in on-site installation difficulties due to standard steel work tolerances being less exacting than the CLT. Tradesmen unfamiliar with large-scale heavyweight timber panels struggled to install the interlocking detail as designed.

The prevalence of sub-contractor labour impacted the knowledge flow resulting from the building experience. When introducing a new construction method or material, it became evident that benefits can be gained by adopting bottom-up feedback from trades' experiences throughout the build. The disjointed nature of the Australian sub-contractor model did negatively impact on some of the potential for bi-directional feedback.

18.2 Caulfield Grammar – The Learning Project

- Project Details: 217 Glen Eira Rd, St Kilda, Victoria.
- Client: Caulfield Grammar School
- Architect: Hayball Architects
- Head contractor: Prebuilt Commercial
- Prefabricator: Prebuilt Commercial
- Production/Installation: 5 months
- Completion: October 2014
- Unique features: Timber and steel framed volume modules
- Build size/cost: 800m^2 @ \$3,100/m^2
- Web:
  - commercial.prebuilt.com.au/our-projects/education/caulfield-grammar-caulfield/
  - hayball.com.au/projects/caulfield-grammar/

This project was the result of a school master plan by Hayball developed in 2013. According to Hayball a '… key outcome of the planning process is the Learning Project, heralding another phase in the school's shift towards bespoke facilities for a new pedagogy. It involves the introduction of a prefabricated prototype building to each of the three metropolitan campuses' (Hayball, 2015).

Hayball describe the project as:

- A prototype.
- A vehicle for change.
- Enabling the school and designers to test settings and spaces which are designed for purposeful and differentiated learning.
- Offering greater affordability.
- Having potential to be demounted and relocated after the testing phase.
- Bespoke prefabricated modular buildings with a focus on design quality.
- Each building is designed with dedicated and connected spaces for whole-group work, small group collaborations, production, presentation and performance activities, quiet reflection and individual study.
- Being the subject of broader research to evaluate the role of design in learning environments being undertaken by the University of Melbourne.

Figure 35. View of the main entry. Image credit: D.Bylund

Figure 36. Modular classrooms at Caulfield Grammar School. Image Credits. D.Bylund and prebuilt.com.au

18.3 The Green

- Project Details: Parkville, Melbourne, Victoria.
- Developer/head contractor: Fraser Property Group (Formerly Australand)
- Completion: 2nd Quarter 2014 (12 months' build time)
- Unique features:
  - Five storey building with 57, 1, 2 & 3 bedroom apartments.
  - 'Hybrid' construction utilising Tecbeam timber cassette floors, prefabricated wall frames and SIPS external cladding.
  - Overall project cost was 25% lower than traditional construction
  - Largest floor cassette – 2.7m x 8m
  - Most prefabricated wall frames were 3.6m long
  - Sub-contractors sourced from residential sector. Upskilling involved improving the competencies required for larger scale projects and ensuring workmen understood that behavioural and standards associated with a commercial builder and building site must be respected.
  - Appears as a traditional rendered multi-storey building
- Web: towardsnetzero.com.au/the-green-apartment-australands-hybrid-construction/

According to Fraser's Estimating Manager Kase Jong, the project '…used a timber frame design based on a 'structure first' approach, which considers the engineering capacities of timber to define design parameters, the building was constructed in layers, with the floor of each level 'dropped in' using largely prefabricated flooring cassettes' (Towards Net Zero, 2014). Furthermore, Jong states that the use of prefabrication allowed:

- The use of cassette floors spanning from load bearing wall to load bearing wall removed the need for propping.
- Roughing of services followed directly behind the installation of each floor allowing for faster construction times.
- Benefits and savings associated with prefabricated technologies and techniques:
  - Allowed greater design flexibility, ease and speed of installation
  - Excellent thermal and acoustic properties
  - Manpower requirements were greater than that of concrete based construction, but were offset by extracting savings through the use of domestic labour force and supply chain
  - Speed of construction and reduced material costs
  - Labour costs are expected to fall as greater levels of prefabrication are adopted
  - All cladding was installed on site with the next step being to look at pre-cladding systems.
  - Prefabrication allowed for enhanced worker safety. Hazards associated with floor joist construction were mostly averted through the use of drop in floor cassettes.
  - Hybrid building construction will apply to about 50% of Fraser's medium density houses/apartments
  - Savings (from hybrid prefabrication) '…will revolutionise the supply of medium rise apartments in the middle to outer ring suburbs as it creates a price point that people can afford to buy'

Figure 37. Top – Installing cassette flooring. Bottom – Completed building. Image credits: techbuild.com.au and D. Bylund

19. Conclusions

This research has identified a number of *drivers for* and *barriers to* the increased use of prefabricated timber building systems in Class 2 to 9 commercial buildings.

The evidence presented in this report would indicate there is significant industry interest in increasing prefabricated timber building systems in commercial construction. The majority of barriers are also acknowledged and it is apparent that they will require continued attention. Assessing the various prefabricated timber building systems on their merits, cost and availability in the light of the recent NCC2016 inclusion of DtS timber solutions for mid rise construction will contribute significantly to growth in the sector.

19.1 Drivers for Prefabricated Timber Building Systems:

D1. The demonstrated cost & efficiency advantages of prefabricated timber construction systems over traditional alternative construction methods.

Prefabrication's advantages, such as speed of construction, waste minimisation, potential reductions in footings and site works can result in cost savings which, when considered in the context of whole-of-cost modelling can significantly reduce overall project costs and should be considered when assessed and strongly promoted against traditional construction. Recent projects have clearly demonstrated the speed advantages and cost savings opportunities of prefabricated timber construction systems.

D2. The inherent quality manufacturing and site impact reduction advantages of prefabricated timber construction systems.

Prefabrication has inherent advantages over traditional construction such as high levels of quality control, waste reduction and minimisation on the site and surrounding areas during construction are powerful advantages which can be promoted.

D3. The desire of Governments nationally for more medium density dwelling construction in urban infill areas.

As Australian cities and regional centers grow and populations increase Governments nationally are encouraging higher density residential construction, accordingly opportunities for prefabricated timber building systems exist, especially in urban infill areas, unstable and restrictive sites and locations not suited to traditional construction. Various commercial building types in addition to mid-rise rsidential construction, such as schools and hospitals, public infrastructure, etc can all benefit from the use of prefabricated timber building systems.

D4. The recent changes to the 2016 National Construction Code which now allows the use of lightweight and massive timber construction under the Deemed-to-Satisfy provisions for Class 2, 3 & 5 buildings up to an effective height of 25m.

The new 2016 NCC changes will streamline the approvals process and remove a significant barrier to using timber in mid-rise buildings. The implications of this development for PTB systems in these new mid-rise timber building are extremely significant and, in due course, will potentially represent one of the single most influential actions contributing to an increase in the use of PTB systems in mid-rise construction in Australia. Increasing awareness of prefabrication as a viable alternative to traditional construction amongst industry and developers by industry funded organisations needs to be a major focus coupled with the development of innovative building products and systems to create new building opportunities.

D5. Timber's inherent structural, fire, thermal and acoustic properties.

Timber's inherent properties, such as its strength-to-weight ratio, natural fire resistance (mass timber), and thermal performance represent significant advantages over other building materials when designed and detailed correctly.

D6. The increasing interest by architects, designers, building owners and governments in using more environmentally friendly materials and the introduction of government wood encouragement policies.

The environmental impact of using prefabricated timber building systems over traditional construction and other building materials is increasing in importance and the adoption of wood encouragement policies by local authorities will boost projects that utilise prefabricated timber building systems.

D7. Increased interest and opportunities in using low grade wood resource in higher strength engineered wood products.

With taller buildings comes the need for stronger wood products, this now opens up opportunities for a new range of hardwood engineered wood products, potentially manufactured from residual native hardwood or low-grade plantation hardwood resource. Specifically, researching the potential of Australia's largely untapped excess out-of-grade softwood and native and plantation hardwoods has the capacity to provide industry with a significant and economical input resource.

D8. The increasing interest by governments in encouraging more innovation and take up in off-site manufacturing and site prefabrication use.

Govermnets around Australia are now encouraging and supporting the greater use of innovative off-site construction practices and digital manufacturing. This needs to be encouraged and supported.

D9. The increased acceptance and take up by governments and the design community of Building Information Modelling (BIM) and digital manufacturing.

The rise of building information management (BIM) and digital manufacturing is empowering the growth of prefabrication. Prefabricated timber building systems can leverage the opportunities this presents. Increased government and industry support for BIM is also increasing.

D10. The increase in training and education opportunities in the areas of prefabricated systems design, manufacture and supply.

Training and education opportunities are growing with more tertiary opportunties to gain expertise and qualifications in timber design and timber systems. Ensuring credible research proposals can be matched to funding resources will contribute to growth in the sector.

D11. The existence in Australia of established heavy lifting and transport logistics industry.

The established heavy lifting and transport logistics industries are well placed to provide the necessary support required to transport and install many prefabricated timber building systems.

19.2 Barriers to Prefabricated Timber Building Systems:

B1. Risk – and what it means to existing businesses wanting to expand their operations to participate in these new market opportunities

The introduction of new systems will involve 'risk'. Risk can, by its nature, work to inhibit innovation in a conservative industry, therefore risks associated with new construction systems, materials and methods must be managed both on the 'new user' side and the 'new supplier' side.

B2. Dealing with existing financial models

Existing financing models don't automatically suit the nature of prefabricated projects. Traditional payment triggers do not always occur in a prefabricated project. New financing products will need to be negotiated with the banks to allow prefabricated projects to be adequately funded.

B3. Timber industry interest in Class 2-9 buildings and capacity to supply

Large-scale industries capable of supplying prefabricated timber construction are yet to be widely established in Australia. Feedback from architects, engineers and developers wishing to utilise prefabricated timber construction systems, is that one of the most difficult problems is identifying within the current supply chain suitable companies capable of producing the required elements. In terms of prefabricated timber systems these will either have to come from within the current timber industry supply chain, frame & truss manufacturers expanding their offerings up the chain into Class 2-9 solutions - or it will come from building companies expanding their activities down the supply chain and setting up prefabrication facilities. Either way a balance needs to be found with generating demand for prefabricated timber solutions with Class 2-9 buildings and supply of the systems.

B4. Industry fragmentation and lack of coordination

Currently no formal framework exist to allow a collective and coordinated approach to market implementation and take up of prefabricated timber solutions in Class 2-9 buildings. Far quicker market development advancement will be achieved if all interested parties work together to address key generic technical and market development issues, rather than working in isolation.

B5. Competition from other prefabricated materials

Prefabricated timber construction is not developing in a vacuum. Interest and advances in prefabrication is a particular focus for lightweight steel and heavier steel and concrete materials in Class 2-9 buildings. The timber industry needs to find efficient and cost effective solutions and be vigilant regarding other possible competitive prefabricated products impacting on market share.

B6. Establishing a culture of prefabrication in an existing environment that is built on many layers of sub-contractors and cost-on-cost inefficiencies

Establishing a culture of efficient prefabrication in an existing environment that is built on many layers of sub-contractors and cost-on-cost inefficiencies can be difficult to change. By its nature, prefabrication does not rely on a sub-contractor model to the same degree as traditional construction methods and as such, changing the existing building culture to suit prefabrication and prefabricated timber building systems will take time.

B7. Public and industry's current understanding and perceptions of timber and prefabricated systems

Timber is generally well regarded as a structural material for housing construction and as a high quality cladding or lining material. More research needs to be undertaken to determine attitudes towards its use in Class 2-9 buildings as part of a prefabricated building system.

B8. Costs and effort involved in establishing prefabrication facilities

The cost of establishing prefabrication facilities is often cited as a barrier but in reality for assembly of prefabricated elements such as floor cassettes thus can actually be done at its most simplest with relatively little cost; obviously the greater the level of mechanisation and handling pursued the greater the cost. Determining appropriate levels of investment into plant, processes, systems and training is needed.

B9. The impact of Australia's geography and isolated populations

Australia's geography and isolated populations make the cost of transporting prefabricated timber building systems long distances a significant impediment with some projects, though not all. It is anticipated that some prefabrication companies will establish facilities either directly in key market areas or in selected geographic locations between market areas.

B10. The need for greater prefabricated timber buildings systems research and sharing that knowledge

Both the tertiary sector and the construction industry are undertaking an increase in prefabricated timber buildings systems research and as a result intellectual property is increasing. A certain degree of knowledge sharing is being undertaken, but in parallel, restrictions on sharing that knowledge are being imposed resulting in fragmented expertise levels across the sector. Technical innovation and practical prefabrication solutions will need to be identified, clearly thought through, tested and then clearly specified – this is best initially done collectively. At present there is no formal framework to allow for discussion and pursuit of generic prefabricated timber system focussed R&D and sharing of knowledge, this needs to be addressed.

On the following page a SWOT analysis is provided looking in an industry wide sense at the prefabricated timber opportunity in these new Class 2-9 building sectors and summarising some of the internal considerations (strengths and weaknesses) and the external factors (opportunities and threats).

20.SWOT Analysis: Prefabricated Timber in Class 2-9 Buildings

Strengths ***Internal Factors***	**Weaknesses**
• Plenty of scope and opportunity for greater timber prefabrication take-up and system development (plenty of overseas examples to illustrate this) • Prefabricated timber systems have lots of benefits: cost effective, lightweight, easily installed, low impact on neighbouring communities, etc. • Large existing infrastructure of frame and truss manufacturers which could potentially expand services into Class 2-9 building • Reasonable number of Australian Glulam suppliers available • Good selection currently of large and experienced overseas CLT suppliers • New Australian investment in local CLT manufacture has now been announced • Timber has strong intrinsic environmental, structural, fire and thermal attributes that can be positively promoted • With Class 2-9 buildings there is potential for new hardwood engineered wood products made from current native residual and low-grade plantation resource	• Current F&T manufacturers not experienced in commercial Class 2-9 building markets and quite 'risk' sensitive against expansion • Biggest issue may be the potential inability for the timber industry supply chain to have a critical mass to effectively supply these new Class 2-9 buildings, need to balance promotion with capacity to supply • Timber industry is highly fragmented and currently has no mechanism for coordination and cooperation in developing these new markets • Timber industry has a history to cost-cutting and competing on price to secure market share – care needs to be taken that these 'residential' practices are not taken into these new commercial market opportunities • Current level of in investment in prefabricated solutions R&D and innovation is currently low and strategically uncoordinated.
Opportunities ***External Factors***	Threats
• Major interest being driven by a number of major developers and builders who have tested and proven the cost efficiencies of timber systems compared to alternative materials, this needs to be highly leveraged • New 2016 NCC changes likely to generate significantly more interest by developers and builders particularly in Class 2 (apartment) and Class 3 (e.g. hotel) type buildings, this is currently being strongly promoted • Possible expansion of NCC DtS solution beyond Class 2,3 & 5 buildings, a Proposal for Change submission needs to be planned for next NCC update • Strong interest by governments and building practitioners in more environmentally friendly products, this needs to be strongly leveraged particularly with more government Wood Encouragement Policies • Existing commercial building companies interested in expanding back down the supply chain into prefabrication (reducing their own risks), this should be encouraged • Increasing interest in BIM and digital manufacture which suits prefabrication (particularly by many governments departments), timber industry needs to understand and get behind this as it strongly benefits timber prefabrication	• Finance and insurance requirements are currently not well suited for prefabricated solutions into Class 2-9 projects, this needs to be investigated and addressed • Current poor quality construction practices (in some states) pose a major risk to mid-rise timber buildings (worst case scenario would be a fire-destroyed building) • The Timber industry needs to vigilant regarding other possible competitive prefabricated products impacting on market share ie lightweight steel framing

21.Recommendations

Based on the findings in this study a series of recommendations are presented here to provide guidance to those interested in the further take up of prefabricated systems in the Class 2-9 markets.

R1. A national Class 2-9 Prefabricated Timber Systems Market Implementation Group should be established to provide a formal and active networking and discussion forum for those companies and sectors interested in pursuing these new market areas.

This group should focus on collectively and collaboratively investigating and addressing generic technical and market development issues including:

- Supplier 'risk' based considerations (ie supply: logistics & potential penalties; finance: set-up costs, staged payments, cost carrying, etc)
- Insurance requirements for supply of Class 2-9 buildings (supportive insurance companies and financial institutions should be identified and promoted)
- OH&S and crane requirements
- Technical issues
- Innovative prefabricated timber system approaches: agreed details need to be developed for common building applications and situations: ie optimum fire-protected and acoustically performing floor cassette systems, prefabricated wall panels (both internal and external with facades), external deck details, etc
- Collective promotion

A lead facilitating organisation needs to be identified for this Group perhaps FTMA or EWPA or a joint facilitation.

R2. Network and leverage technical support and promotion with other system component suppliers

Identify, establish network linkages, and directly work with other fire-protected timber system component manufacturers and suppliers to investigate system needs, and innovative prefabricated systems based approaches, and develop specific specifications, details and technical literature to further promote the overall prefabricated fire-protected and acoustically performing timber systems approaches.

R3. Identify and assist established Truss and Frame manufacturers who currently service the Class 1 residential market and who are considering expanding their production capacity/range to service larger-scale buildings.

Activities here will need to include: identification of innovative F&T manufacturers nationally in conjunction with FTMA, providing assistance with advice around new market requirements, providing assistance with developer/builder networking & linkages, and investigating training needs for detailers to acquire the necessary skills and confidence to engage with larger projects. This activity will also be contingent on support from the three primary nailplate producing companies and a willingness by owners to extend their traditional business model.

R4. Target developers operating in urban densification brownfield sites and actively support Government initiatives in this area

Identify districts in all Australian cities and larger regional centres and developers/builders involved with ongoing brownfield rejuvenation programs and specifically promote prefabricated timber construction as a viable solution. Also actively support government initiatives in all states looking to advance urban densification particularly promoting the low-neighbourhood impact and environmental benefits of prefabricated timber systems. If state or local governments buy into the benefits of these approaches then going promotion of government wood encouragement policy take up should also be pursued.

R5. Provide technical support for design professionals, builders and prefabricators.

Actively provide technical support for design professionals, builders and prefabricators in their endeavours to develop the necessary knowledge and strategic partnerships to introduce new developments in engineered timber building systems in line with recent NCC changes supporting timber's use in mid-rise construction. In Victoria the new FWPA Technical Field Force will undertake these activities, in other states responsible representatives needs to be identified.

R6. Develop a database of current timber-wise design professionals

Develop a searchable database of currently available prefabricated timber designers, builders, suppliers and prefabricators that will reduce the current level of fragmentation that exists. A lack of access to knowledge has contributed to constraining the growth of the PTB sector.

R7. Organise ongoing and regular site visits to look at systems approaches in new Class 2-9 buildings

As new Class 2-9 timber projects undertake construction throughout Australia, formal site visits should be arranged (possibly through WoodSolutions) to allow other developers, builders, building design professionals, regulators and timber industry members to see and learn firsthand about the processes, design & construction methods, benefits and possible issues of prefabricated timber construction and timber commercial buildings.

R8. Develop detailed case studies of all significant new Class 2-9 projects constructed

As new Class 2-9 timber projects are constructed and completed, detailed case studies should be developed (again possibly through WoodSolutions) detailing the project, the design considerations, the prefabricated and on-site construction methods used, any unique construction details developed, the project timing and the cost breakdown. A detailed library of visual and informative case studies needs to be produced to assist in gaining broader acceptance or prefabricated timber systems.

R9. Actively promote and support the use of Building Information Modelling (BIM) and support the new wave of tech and timber design professionals.

Actively support and promote (particularly with governments) Building Information Management (BIM) and digital manufacturing including Computer Numerically Controlled (CNC) equipment. Also actively support the new breed of design professionals graduating from architecture and building design and engineering schools who are BIM and CNC trained and knowledgeable.

R10. Support value-adding research into Australia's out-of-grade softwood and plantation hardwood resource.

New stronger engineered wood products will be needed for taller timber buildings; these could potentially be manufactured from residual native hardwood or low-grade plantation hardwood or softwood resources. Specific technical R&D on possible product opportunities needs to be undertaken along with detailed business plans for establishing new engineered wood products facilities.

R11. Encourage R&D and University Centres of Excellence

Collectively and collaboratively discuss, determine and develop briefs for specific timber prefabricated system R&D needs and support University Centres of Excellence nationally to focus in this area.

R12. Actively support the off-site and prefabrication sector through conferences/summits and peak bodies such as PrefabAus and the Modular Construction and Prefabrication Australia.

The timber industry (possibly through the proposed Market Implementation Group) should actively support and participate in PrefabAus and the annual Modular Construction and Prefabrication summit. One approach would be to establish a specific prefabricated timber sub-program within PrefabAus such as *PrefabTimberAus* or similar within Modular Construction and Prefabrication Australia's program.

R13. Expansion of NCC DtS Provisions to other commercial building classes and taller builders

The NCC is now updated only every three years. Before the next update a formal Proposal for Change should be prepared to expand the current DtS provisions to other forms of commercial buildings outside of Class 2,3 & 5, this could include, health buildings, schools, universities, etc.

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Disclaimer

CSAW is a member of *prefabAUS* which is referred to several times throughout this report.

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Appendices

Appendix 1: Australian Prefabrication Building Companies

Appendix 2: Matrix of Prefabrication

Appendix 3: Lean Construction

Appendix 4: Designers' Industry Questionnaire

Appendix 5: Prefabricators' Industry Questionnaire

Appendix 6: Builders' Industry Questionnaire

Appendix 7: Timber and Timber Construction Education Services

Appendix 8: Forestry Innovation Investment (FII) and the Binational Softwood Lumber Council's (BSLC) experiences into international experiences from building with massive timber over five storeys. – An Overview of respondents' comments.

Appendix 1: Australian Prefabrication Building Companies

Note:

The following table is not intended to be a complete list of all building companies operating in Australia who utilise some degree of prefabrication. It is for reference only and provides a cross section of the types of companies that were considered in this report.

Legend:

Market penetration:

- 1=Low -' developing' (or 2-3 per year)
- 2=Low/Moderate
- 3=Moderate - 'significant no. of established businesses' (or 2-3 per month)
- 4=Moderate/High
- 5=High- 'dominant or prominent use' (or 2-3 a week, or whole suburbs)

Note: Refer to Prefabrication Matrix for definitions of the following (Appendix 2)

Ød (Node)

1. Connector (Prefabricated Node [Pn])
2. Finished Connector (Prefabricated Prefinished Node [Ppn])

1d (Stick)

3. Sawn Lumber (Prefabricated Sawn Lumber [Psl])
4. Engineered Piece (Prefabricated Engineered Lumber [Pel])
5. Machined Piece (Prefabricated Premachined Stick [Ppms])
6. Finished Piece (Prefabricated Stick & Node [Psn])

2d (Frame, Post & Beam or Panel)

7. Open Wall Frame or Solid Panel (Prefabricated Open Wall Frame/Panel [Powf/P])
8. Truss (Floor or Roof) (Prefabricated Truss [Pt])
9. Post & Beam (Prefabricated Post & Beam [Pp&B])
10. Floor Cassette (Prefabricated Floor Cassette [Pfc])
11. Door or Window Frame (Prefabricated Prefinished Joinery Unit [Ppju])
12. Insulated Frame or Solid Panel (Prefabricated Insulated Wall Frame/Panel [Piwf/P])
13. Finished Lining Sheet (Prefabricated Prefinished Envelope Panel [Ppep])
14. Fully Finished Floor Cassette (Prefabricated Fully Finished Floor Cassette [Pfffc])
15. Fully Finished Wall System (Prefabricated Wall System [Pws)

3d (Module/Volumetric)

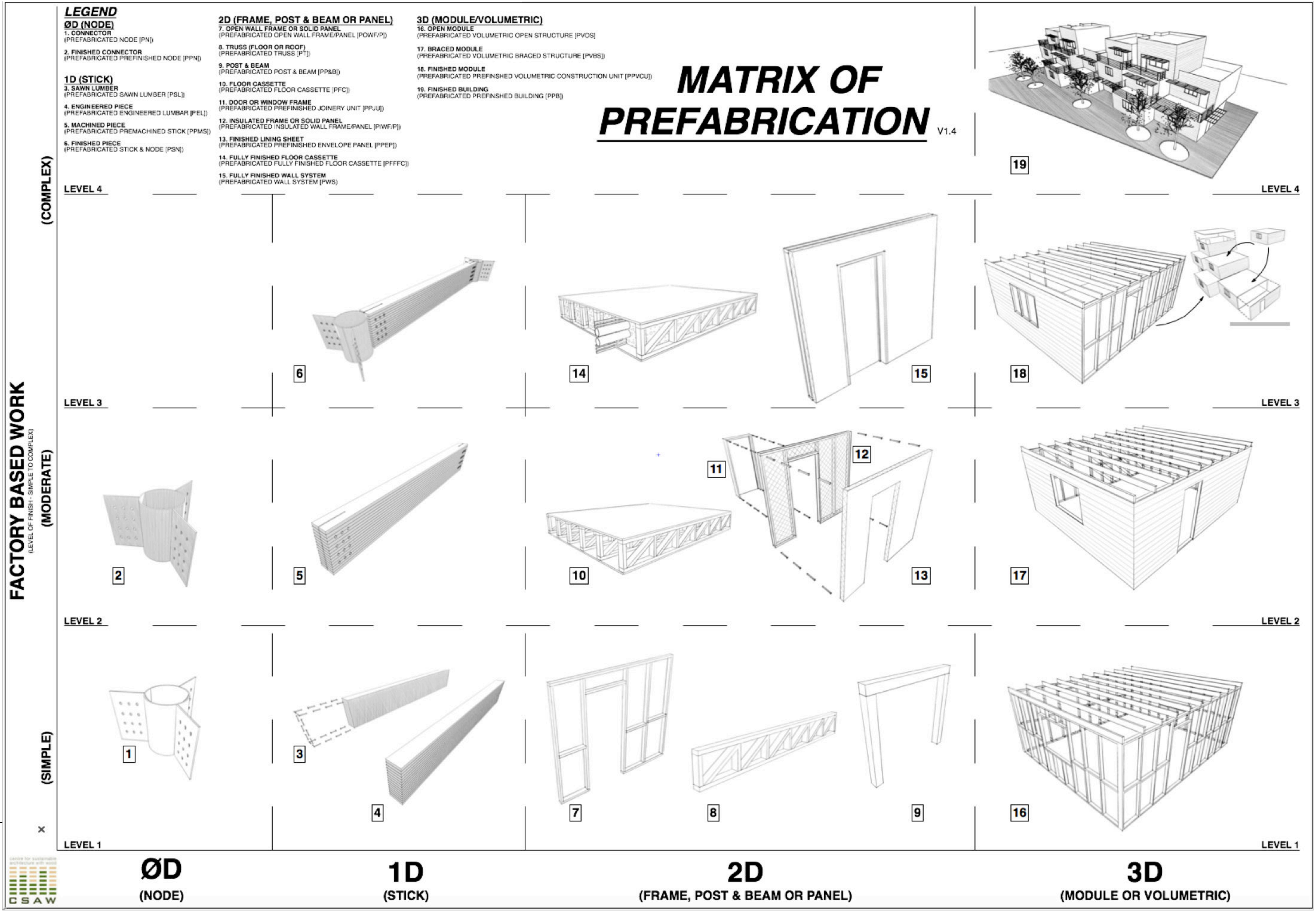
16. Open Module (Prefabricated Volumetric Open Structure [Pvos]
17. Braced Module (Prefabricated Volumetric Braced Structure [Pvbs])
18. Finished Module (Prefabricated Prefinshed Volumetric Construction Unit [Ppvcu])
19. Finished Building (Prefabricated Prefinshed Building [Ppb])

Company name	Market Penetration	Major Material	Building Typology:				Prefabrication Type:			
			Domestic	Multi-res	Commercial	Other	Node	Stick	Panel	Module
Lend Lease	5	timber		X	X				PEP	PPB
Ausco Modular (Algeco Scotsman)	4	steel frame	X	X		X				PPB
ASKIN	5	SIPs			X				PSSP, PPEP, PPPJU, PPPCU	
Bondor	5	SIPs	X		X	X			PSSP, PEP, PPEP	
BGC	4	steel frame	X		X	X			POSP	PVOS
MBSWA	1	timber, steel,	X							PPB
Summit North West	2	steel frame	X						POSP	
Norfolk Homes	2	steel, brick, SIPs							POSP, PPPCU	
Kingspan	4	SIPs	X		X	X			PSSP, PEP, PPEP	
SIPS Industries	2	SIPs	X		X					
TR Homes	2	steel frame	X							PPB
Mcgrath Homes	2	steel frame	x							PPB
BRB (Fleetwood)	2	steel frame	X		X	X				PPVCU, PPB

Hickory Group	4	steel	X	X		X			PSSP, PEP	PPVCU
Ecoliv			X							PPB
Modscape	3	timber, steel,	X							PPB
Arkit	2	timber							PPPCU , PEP?	
Unique Modular Buildings	2	steel frame								
Structural Panels Australia	2	SIPs							PSPB	
Prebuilt	3	timber, steel,	X							PPB
Tasbuilt Homes	2	timber, steel,	X							PPB
Tassie Homes	2	timber	X							PPB
Hutchinson Builders	4	timber, steel,	X	X						PPB, PVSS
Sekisui House Australia	4	timber	X						POSP	
Hoek Modular Homes	2	timber, steel,	X							PPB
Happy Haus	2		X		X					PPVCU,PPVS
Glendale Homes	4	timber, steel,	X							PPB, PVSS
Remote Building Systems			X			X				PPB
Pearls MiiHome	3	SIPs	X			X			POSP, PSSP	PPVCU, PPB
Paneco	1	SIPs	X			X			PSSP	

SBP Construction	2	SIPs	X			X			PSSP, PEP	
Project Modular	2	steel frame		X						PPVCU
Swanbuild	2	timber	X							PPB
APB Modular	2			X	X	X				PPB
Austwide Homes	2	timber								PPB
Austech Panel Systems	2	SIPs	X			X			PEP	
Versiclad	3	SIPs							PSSP	
Paneltech	1	SIPs	X			X			PSSP, PEP	
Gumpy Homes		steel frame	X						PSSP, PEP	
TimberImagineerin g	3	timber		x	x	x	x	x	x	
Timberbuilt	3	timber		x	x	x	x	x	x	
ArchiBLOX	2	timber, steel,	x	x	x					x
Impresa House	1	timber	x	x	x				PPPCU	
Timber Built Systems	1	timber		x	x				PPPCU	
Engenuity	1	timber	x	x	x	x			POSP	

Appendix 2: Matrix of Prefabrication



Appendix 3: Lean Construction

Methods developed by other manufacturing industries can also benefit prefabrication. One of the most widely studied and adapted approaches to 'prefabrication' by European and North American prefabricators is the production line system optimised through the *Lean* method as pioneered by the Toyota Motor Corporation. Toyota began producing cars in in large volumes throughout the 1950s, 60s and 70s. Throughout this period, it refined and developed its production line approach to manufacturing cars by developing the Toyota Production System (TPS). The TPS system was '… established based on two concepts.

The first is called "jidoka" (which can be loosely translated as "automation with a human touch") which means that when a problem occurs, the equipment stops immediately, preventing the production of defective products. The second is the concept of "Just-in-Time," in which each process produces only what is needed by the next process in a continuous flow' (Toyota 2015). A key component of the TPS is to acknowledge and optimise integrated socio-technical systems that result from the interaction of people and technology in the work place.

The underlying philosophy of the TPS system has been adapted to suit the production of many types of mass produced items and is now more widely known as 'Lean Manufacturing'. The term 'Lean Manufacturing' has been credited to John Krafcik following an article he wrote in 1988 entitled, "Triumph of the Lean Production System," which was based on his master's thesis undertaken at Massachusetts Institute of Technology's *Sloan School of Management* following work he undertook for Toyota in its Californian operation. This approach to construction is now being applied to prefabrication in Scandinavia and North America. According to Howell and Ballard of the American based *Lean Construction Institute (LCI)*, the Lean approach to construction can be summarised in the following four points:

1. The facility and its delivery process are designed together to better reveal and support customer purposes. Positive iteration within the process is supported and negative iteration reduced.
2. Work is structured throughout the process to maximize value and to reduce waste at the project delivery level.
3. Efforts to manage and improve performance are aimed at improving total project performance because that is more important than reducing the cost or increasing the speed of any one activity.
4. "Control" is redefined from "monitoring results" to "making things happen." The performance of the planning and control systems are measured and improved.

(Lean Construction Institute 2015)

When applying the Lean approach to the production of buildings, LCI's Howell and Ballard claim that '… Lean Construction is particularly useful on complex, uncertain and quick projects … (and) … it challenges the belief that there must always be a trade between time, cost, and quality' (ibid). As a manufacturing philosophy, its application to industrialised construction '… is a production management-based approach to project delivery …', that, when employed in construction, '… changes the way work is done throughout the delivery process' (ibid).

This change in 'the way work is done' involves a rationalisation of existing building methodologies and cultures. Traditionally, buildings are built in a sequential manner, literally from the ground up by sub-contractors and overseen by a primary contractor. Once a building has been designed, the process starts with various materials being delivered to a building site and a variety of contracted tradesmen undertake a series of tasks in a sequential manner to complete the building as directed by the builder's on-site supervisor. This typically involves preparation of the site for the services, compacting the ground and pouring footings and a slab or installing piles or stumps to create a stable level platform from which to build the structure. Walls, doors and windows are installed on the ground level, followed by any upper floors, walls, columns and beams and finally the roof. Internal fit outs include the services equipment, often in a multistage process, along with the cabinets and floor and wall finishes which are undertaken last.

Prefabrication in conjunction with a Lean approach to building, especially when applied to off-site construction, has reinvented this process by breaking down large structures into smaller components that can be built or manufactured in parallel and by rationalizing the actual work flow of each trade into a series of predetermined tasks. The various tasks are often undertaken by semi-skilled labourers working under close supervision of a tradesman who is often employed on a full time basis. The personnel employed by the building company are usually employed full time rather than as independent contractors and work in a clean, dry and controlled factory environment.

For a building that is to be constructed by an off-site factory operating under the Lean philosophy, it is crucial that the design team involve the building company at an early stage to ensure that they optimise the benefits of both Lean Manufacturing and off-site construction.

For example, a multi-storey residential building will often have similar floor layouts across each level. The construction requirements of the repetitive elements can be analysed to ensure the most efficient method of constructing and incorporating them into the bespoke elements of the design. A Lean based off-site prefabrication approach aims to optimise this process. The structure and fit-out of each floor is broken down into smaller elements and built simultaneously, often right down to the internal finishes and fittings. Typically, in large scale, off-site, Lean based construction, building materials are stored in an adjacent warehouse and teams of workers, directed by an exacting program, supply the required quantities to the main construction floor production line according to pre-determined take-off lists and programmed schedules. Throughout this process, the bulk of a structure itself does not come together as a whole until each individual element is transported to the site and finally 'montaged' to form the entire building.

According to Swedish researchers Höök and Stehn, simply employing Lean principles in the construction of buildings does not create a true Lean environment as pre-existing cultural imperatives within the construction industry can be in conflict with the aspirations of the Lean approach. They claim that the cultivation and establishment of a *Lean Culture* within the employees of a company attempting to implement Lean principles is critical to its success.

In defining the culture that exists in the Swedish construction industry, Höök and Stehn state that, 'Culture is a concept that generally refers to "… the way things are done around here"' (Höök and Stehn 2008). This can be translated to the Australian building culture as well. Simply repeating yesterdays choice and application of materials and methods will slow innovation in construction. Höök and Stehn also claim that in order to successfully instigate Lean methods into industrialised construction, the work environment or 'culture' that exists in both management and employees must first be understood. This key point is where resistance to change can occur, especially when 'outsiders' are engaged to introduce a Lean approach who do not first spend time getting to know and evaluate the specific work culture that exists within a company or locality.

They further argue that when approaching the introduction and ongoing management of Lean into a company, it is fundamental to manage the culture within the work environment. This claim is lent support by G.L Pepper's *Communications in Organisations: A Cultural Approach*. According to Pepper, 'A cultural approach is argued to increase the understanding of an organization both from a philosophic and practical view point' (Pepper 1994). In addition, Höök and Stehn claim that, 'The key message is that it is not enough to just apply a Lean principle or tool without a simultaneous strive for a Lean culture. What is also needed is a balanced whole system view emphasizing improved performance through a focus on the persons delivering value to customers' (Höök and Stehn 2008).

Appendix 4: Designers' Industry Questionnaire

Introduction

This questionnaire is intended to gauge Australian design professional's perceived aspirations, impediments and opportunities for increasing the use of timber in *Class 2 to 9 buildings.*

All identifying information will be kept ***strictly confidential***. Please feel free to expand your responses on a separate sheet if required.

Section One focuses on general information about your business, the type of services you provide, the types of materials you specify and types of buildings that you are involved in including typical project sizes & budgets.

Section Two focuses on an expanded future of prefabrication and panelised systems and seeks to gain your views of your company's current and potential future position in these areas, and your perceptions on possible impediments and opportunities particularly compared to international advances in these areas.

The **Prefabrication Matrix** is supplied to assist with quantifying the various degrees of prefabrication from nodal, stick, planar to volumetric.

The **Prefabrication Table** is intended to assist with quantifying the types and extent that a company designs, produces or incorporates prefabrication into a specific project. It is intended to be complementary to both this questionnaire and the Prefabrication Matrix.

Definition of terms used herein:

Prefabrication: The design and off-site manufacture of a project specific component, assembly or system that is utilised, in part or as a whole, to build a structure.

Prefabricated timber element: a product that is fabricated primarily of timber components, i.e. a roof truss, floor truss, or wall frame, etc.

***Panelised systems*:** a product that includes multiple elements to form a building type system, i.e. cassette floor systems or panelised wall systems.

Section One

1. Which of the following business type best describes your organisation?
   - ☐ Sole trader
   - ☐ Partnership
   - ☐ Company
   - ☐ Other (please define)____

2. Indicate your practitioner type:
   - ☐ Architect
   - ☐ Engineer
   - ☐ Building Designer
   - ☐ Architectural Draftsman
   - ☐ Other: ______________________________

3. Which capital cities, regional centers or region(s) do you provide your services to (e.g. Melbourne, Ballarat and Regional Vic etc. or nationally)?

   ____
   ____
   ____

4. Briefly describe the type of design services you provide.

   ____
   ____
   ____
   ____

5. To whom do you provide your design services (the total should equal to 100%)?

Type		%
Architects		________
Engineers		________
Builders		________
Prefabricators		________
Timber Mills		________
Other (please describe)	____________	________
Total =		100%

6. Indicate as a percentage, the NCC/BCA Building Class you typically design (the total should equal to 100%):

NCC/BCA Building Class	%
Class 1 (Residential – Single Dwelling)	_______
Class 2 (Multi-residential [Sole Occupancy])	_______
Class 3 (Multi-residential [Temporary Occupancy])	_______
Class 4 (Residential Class 5, 6, 7, 8 or 9 [Caretaker etc.])	_______
Class 5 (Commercial)	_______
Class 6 (Retail)	_______
Class 7 (Car park or storage)	_______
Class 8 (Industrial)	_______
Class 9 (Public)	_______
Total =	100%

7. If you design Class 2 Multi-residential apartments, indicate a percentage for each storey.

2 storey	3 storey	4 storey	5 storey	6 storey	7 storey	8 or above

8. If you design Class 3 Office Buildings, indicate a percentage for each storey.

1 storey	2 storey	3 storey	4 storey	5 storey	6 storey	7 storey	8 or above

9. Indicate as a percentage the typical project floor area ranges you design (e.g. projects totalling 150m^2 – 350m^2 = 20% of the time and projects totalling 750m^2 – 1,000m^2 = 80% of the time. The total should equal to 100%):

Project area	%
<150m^2 =	____________
150m^2 – 350m^2=	____________
350m^2 – 750m^2 =	____________
750m^2 – 1,000m^2 =	____________
1,000m^2 – 2,000m^2 =	____________

> 2000m^2 =	______
Total =	100%

10. Estimate as a percentage, the Total Project Construction Cost for the projects that you typically design.

    (For example, you might typically design projects that have a total construction cost of between $100,000 - $250,000 approximately 20% of the time and projects that have a total construction cost of between $250,000 - $500,000 = 80% of the time. The total should equal to 100%):

Total Project Construction Cost	%
$50k - $100k	______
$100k - $250k	______
$250k - $500k	______
$500k - $1m	______
$1m - $5m	______
$5m - $10 m	______
$10m - $20m	______
>$20m	______
Total =	100%

11. According to the attached ***Matrix of Prefabrication*** typology, indicate the percentage of each *type of prefabrication* that your projects incorporate (the total should equal to 100%):

Type	%
ØD (Connectors etc.)	______
1D (Stick)	______
2D (Frame, Post & Beam or Panel)	______
3D (Module or Volumetric)	______
Total =	100%

12. What type and percentage of prefabricated timber products or structural systems do you design with (the total should equal to 100%)?

Type	%
Wall Frame	______
Roof Truss	______
Floor Truss	______
Floor Panel (cassette)	______
Wall Panel	______
Glulam posts and beams	______
LVL	______
All of the above	______
Other (please describe) ____________	______
Total =	100%

13.Indicate the types of documentation/drawing detail for prefabricated or panelised timber systems you normally provide.

- ☐ Concept Drawing
- ☐ Preliminary building drawings
- ☐ Preliminary specification documentation
- ☐ Preliminary cost information
- ☐ Detailing building drawings
- ☐ Detailing specification documentation
- ☐ Detailing cost information
- ☐ Detailed shop drawings

14. How do you source prefabricated or panelized timber building systems?

- ☐ Specialised timber fabricators
- ☐ General frame and truss manufacturers
- ☐ General builder/carpenter contractors
- ☐ In house (i.e. your company has fabrication capacity
- ☐ Other (please describe) ____________________

____

Section Two

In the future it is anticipated that there will be a much broader acceptance and demand for prefabricated and panelised systems, due to:

- wider reaching NCC/BCA Deemed-to-Satisfy provisions covering a range of prefabrication typologies and building classes
- less restrictive building height allowances for timber (in May 2016 it is expected that the Deemed-to-Satisfy provisions of the NCC will allow timber construction up to an effective height of 25m, approx. 8 storeys)
- greater emphasis on environmental considerations that reward buildings procured through prefabrication
- established cost competitiveness and improved understanding and awareness of prefabrication amongst suppliers, trades, building design professionals, developers and regulatory and financing bodies

1. Briefly describe ***your*** understanding of 'prefabrication'?

 ____

 ____

 ____

 ____

2. Assuming the scenario presented above:

 What future products might you like to see used more widely in both Class 2 (Residential) and other building classes?

	Class 2 (Residential)	Other Classes (Non Res)
• Cross laminated timber floor & wall systems	☐	☐
• Post and beam systems (Glulam, LVL)	☐	☐
• Panelised Floor Cassette Systems	☐	☐
• Panelised Wall Systems (including cladding, insulation, windows & doors)	☐	☐
• Panelised & Pre-finished Wall System (incl. above + electrical, plumbing & lining)	☐	☐
• Fully finished bathroom or kitchen modules	☐	☐
• Complete buildings	☐	☐
• Other______________________________		

3. What other opportunities do you think might become available for prefabricated and panelised timber construction?

____

____

____

____

4. What assistance or training do you think you or your staff would need if you were to pursue building design utilising prefabricated and engineered timber products and systems, particularly for use in multi-residential and non-residential applications (Classes 2-9)?
   - ☐ Timber system design / specification - technical assistance
   - ☐ Fire & acoustic system specification assistance
   - ☐ Commercial sector costing and tendering advice/training
   - ☐ Other:____

5. What do you consider would need to change in areas of *Supply*, *Contractors* and *Demand*, to allow an increase in the use of prefabricated timber construction in Australia?

____

____

____

____

6. Have you encountered resistance amongst builders, clients, other design professionals, or regulators ***in the use of timber as a structural material?*** If yes, can you give examples of the issues raised or perhaps provide an explanation?
   - ☐ Yes
   - ☐ No

____

____

____

____

7. Have you encountered resistance amongst builders, clients, other design professionals, or regulators ***in the use of timber prefabrication***?
   If yes, can you give examples or perhaps provide an explanation?
   ☐ Yes
   ☐ No

   ____
   ____
   ____
   ____

8. Have you investigated recent advances in prefabrication using timber in Europe, North America or Asia and if so, briefly describe what interested you about these developments and why you undertook these investigations?
   If yes, can you give examples or expand on why you have were interested?
   ☐ Yes
   ☐ No

   ____
   ____
   ____
   ____

9. Do you have any other comments or issues you feel should be considered in the context of further enabling prefabrication using timber in Australia and increasing the use of timber in Class 2 – 9 buildings?
   (Feel free to expand your response on a separate sheet of paper)

   ____
   ____
   ____
   ____

End of Section Two

Thank you for your assistance with this survey.
The information provided will be aggregated to produce an industry wide overview of opportunities and constraints for *Prefabrication Timber Construction Systems for Class 2 to 9 Buildings* in Australia.

A copy of this report will be forwarded to you when completed.

Appendix 5: Prefabricators' Industry Questionnaire

Introduction

This questionnaire is intended to gauge Australian building & construction prefabricator's perceived aspirations, impediments and opportunities for increasing the use of timber in *Class 2 to 9 buildings.*

All identifying information will be kept ***strictly confidential***. Please feel free to expand your responses on a separate sheet if required.

Section One focuses on general information about your business, the products or systems you supply to the market and typical project size, budget and types of buildings that utilise your products.

Section Two focuses on an expanded future of prefabrication and panelised systems and seeks to gain your views of your company's current and potential future position in these areas, and your perceptions on possible impediments and opportunities particularly compared to international advances in these areas.

The **Prefabrication Matrix** is supplied to assist with quantifying the various degrees of prefabrication from nodal, stick, planar to volumetric.

The **Prefabrication Table** is intended to assist with quantifying the types and extent that a company designs, produces or incorporates prefabrication into a specific project. It is intended to be complementary to both this questionnaire and the Prefabrication Matrix.

Definition of terms used herein:

Prefabrication: The design and off-site manufacture of a project specific component, assembly or system that is utilised, in part or as a whole, to build a structure.

Prefabricated timber element: a product fabricated primarily of timber components, i.e. a roof truss, floor truss, or wall frame, etc.

Panelised systems: a product that includes multiple elements to form a building type system, i.e. cassette floor systems or panelised wall systems.

Section One

1. Which of the following business type best describes your organisation?

   ☐ Sole trader (an individual trading on their own)
   ☐ Partnership (an association of people or entities running a business together, but not as a company)
   ☐ Company (a legal entity separate from its shareholders)
   ☐ Other (please define)____

2. Indicate your business's annual gross business turnover range:

   ☐ <$250,000 - $500,000
   ☐ $500,000 - $1,000,000
   ☐ $1,000,000 - $5,000,000
   ☐ $5,000,000 - $10,000,000
   ☐ > $10,000,000

3. Please indicate staff numbers in each of the following areas:

Management & Admin	_______
Designers & Estimators	____________
Sales & Marketing	____________
In-factory Assemblers	____________
Transport	____________
Other: ____________________________________	____________
TOTAL STAFF	____________

4. Which capital cities, regional centres or region(s) do you supply (e.g. Sydney, Newcastle and Regional NSW etc. or nationally)?

   ____
   ____
   ____
   ____

5. Indicate as a percentage, the NCC/BCA Building Class your products or systems are typically used in (the total should equal to 100%):

NCC/BCA Building Class	%
Class 1 (Residential – Single Dwelling)	_______
Class 2 (Multi-residential [Sole Occupancy])	_______
Class 3 (Multi-residential [Temporary Occupancy])	_______
Class 4 (Residential Class 5, 6, 7, 8 or 9 [Caretaker etc.])	_______
Class 5 (Commercial)	_______
Class 6 (Retail)	_______
Class 7 (Car park or storage)	_______
Class 8 (Industrial)	_______
Class 9 (Public)	_______
Total =	100%

6. To whom do you supply your product(s) or systems (the total for each Class should equal to 100%)?

Type	Class 1	Other classes
	Residential	(Non–residential)
Small Builders/DIY	______________	______________
Volume Builders/Developers	______________	______________
Wholesalers	______________	______________
Building Material Supply Companies	______________	______________
Other ______________________	______________	______________
Total =	100%	100%

7. **Project Construction Cost**. If known, indicate the percentage that your product or system is used in the following total project construction cost ranges.

   (For example, you might typically supply your product for projects that have a total construction cost of between $100,000 - $250,000 approximately 20% of the time and projects that have a total construction cost of between $250,000 - $500,000 = 80% of the time. The total should equal to 100%):

Total Project Construction Cost	%
$50k - $100k	____________
$100k - $250k	____________
$250k - $500k	____________
$500k - $1m	____________
$1m - $5m	____________
$5m - $10 m	____________
$10m - $20m	____________
>$20m	____________
Total =	100%

8. **Project Floor Areas**. Indicate the percentage that your product or system is used in the following project floor area ranges (e.g. projects totalling 150m^2 – 350m^2 = 20% of the time and projects totalling 750m^2 – 1,000m^2 = 80% of the time. The total should equal to 100%):

Project area	%
<150m^2 =	____________
150m^2 – 350m^2=	____________
350m^2 – 750m^2 =	____________
750m^2 – 1,000m^2 =	____________
1,000m^2 – 2,000m^2 =	____________
> 2000m^2 =	____________
Total =	100%

9. What type of prefabricated timber products or systems do you make and what do these approximately equate to as a percentage of your business (the total should equal to 100%)?

Type	**%**
Wall Frame	______
Roof Truss	______
Floor Truss	______
Floor Panel (cassette)	______
Wall Panel	______
Glulam Posts & Beams	______
Cross Laminated Timber	______
LVL	______
Other (please describe) ______	______
Total =	100%

10. If you build timber wall frames etc., indicate which nail plate manufacture suppliers your hardware:
- ☐ MiTek
- ☐ Pryda
- ☐ Multinail
- ☐ Other: ______

11. Indicate the percentage of each type of timber your prefabricated product(s) or system(s) use (the total should equal to 100%):

Type	**%**
Structural Pine ______	______
Structural Hardwood	______
Laminated Veneer Lumber (LVL)	______
Orientated Strand Board (OSB)	______
Glulam (GL)	______
Cross Laminated Timber (CLT)	______
Other (please describe) ______	______
Total =	100%

12. Indicate the percentage of each type of timber your prefabricated products or systems use (the total for each component should equal to 100%):

For Roof Trusses:

Type	Top Chords	Bott. Chords	Webs
Struc. Pine (untreated)	______	______	______
Struc. Pine (treated)	______	______	______
Struc. Hardwood	______	______	______
LVL	______	______	______
OSB Beams	______	______	______
Other (please describe)	______	______	______
Total =	100%	100%	100%

For Floor Trusses:

Type	Top Chords	Bott. Chords	Webs
Struc. Pine (untreated)	______	______	______
Struc. Pine (treated)	______	______	______
Struc. Hardwood	______	______	______
LVL	______	______	______
OSB beams	______	______	______
Steel	______	______	______
Other (please describe)	______	______	______
Total =	100%	100%	100%

For Wall Frames:

Type	Plates	Studs	Lintels
Struc. Pine (untreated)	______	______	______
Struc. Pine (treated)	______	______	______
Struc. Hardwood	______	______	______
LVL	______	______	______
OSB beams	______	______	______
Steel	______	______	______
Other (please describe)	______	______	______
Total =	100%	100%	100%

For Wall Frames – bracing:

Type	Bracing
Hardwood Plywood	______
Softwood Plywood	______
OSB	______
Hardboard	______
Other:______	______
Total = 1	100%

13. If you produce panelised floor cassettes systems, what do you include?

Structure:

☐ Floor joists

☐ Floor trusses

☐ I-beams

Flooring:

☐ Particleboard

☐ Ply

☐ OSB

☐ Other

Acoustic Attenuation Material:

Type:______

Wet Area Flooring:

Type: ______

Insulation Material:

Type: ______

In-floor Plumbing Penetrations:

Type: ______

Wall Position Set-out Markings:

Type:______

Lifting Hooks:

Type:______

Other:

Type:______

14. If you produce **panelised wall systems**, what do you include?

- ☐ External wall cladding:
  - ☐ Foam - Type:____
  - ☐ Board - Type:____
  - ☐ Other - Type:____
- ☐ Insulation - Type:____
- ☐ Windows- Type:____

  _
- ☐ Doors - Type:____
- ☐ Electrical Elements/ Fittings - Type: _________________________
- ☐ Plumbing Elements/ Fittings - Type: - Type:___________________
- ☐ Internal Plasterboard Linings- Type:_________________________
- ☐ Fire/Acoustic Rated Linings- Type:__________________________
- ☐ Other:____

15. Do you provide **on-site installation services**?

- ☐ Yes
- ☐ No

If yes, for what products

- ☐ Roof trusses
- ☐ Ground floor cassettes
- ☐ Wall framing
- ☐ Upper story cassettes
- ☐ Upper story floor truss joists
- ☐ Panelised wall systems

16. Do you offer services in addition to prefabricated elements or panelised systems, i.e?:

Complete buildings

(e.g. an entirely prefabricated, turnkey project)

☐ Yes

☐ No

Complex building elements

(e.g. modules combined with other prefabricated and/or site-built elements to complete a structure)

☐ Yes

☐ No

☐ Other:____

If you ticked yes to any of the above, please provide additional information:

____

____

____

End of Section One

Section Two

In the future it is anticipated that there will be a much broader acceptance and demand for prefabricated and panelised systems in Australia due to:

- wider reaching NCC/BCA Deemed-to-Satisfy provisions covering a range of prefabrication typologies and building classes
- less restrictive building height allowances for timber (in May 2016 it is expected that the Deemed-to-Satisfy provisions of the NCC will allow timber construction up to an effective height of 25m, approximately 8 stories)
- greater emphasis on environmental considerations that reward buildings procured through prefabrication
- established cost competitiveness and improved understanding and awareness of prefabrication amongst suppliers, trades, building design professionals, developers and regulatory and financing bodies

1. Briefly describe ***your*** understanding of prefabrication?

____

____

____

____

2. Assuming the above scenario:
   a. What future products might you like to supply to the market?

NCC/BCA **Class**	**2** (Res)	**3-9** (Non–Res)
• Cross laminated timber floor & wall systems	☐	☐
• Post and beam systems (Glulam, LVL)	☐	☐
• Panelised Floor Cassette Systems	☐	☐
• Panelised Wall Systems (including cladding, insulation, windows & doors)	☐	☐
• Panelised & Pre-finished Wall System (incl. above +electrical, plumbing & lining)	☐	☐
• Fully finished bathroom or kitchen modules	☐	☐
• Complete buildings	☐	☐
• Other ______________________________		

   b. What other opportunities do you think might become available for prefabricated and panelised timber construction?

____

____

____

3. What assistance or training do you think you or your staff would need if you were to pursue these new product system opportunities, particularly in new non-residential opportunities (Classes 2-9)?

☐ Production / process advice

☐ Equipment and logistics advice

☐ Staff panelised system fabrication/assembly training

☐ Design / specification - technical assistance (from Nailplate manual)

☐ Design, specification and estimating software assistance
☐ Commercial sector costing and tendering advice/training
☐ Other: ____

4. What do you consider would need to change to allow an increase in the use of prefabricated timber construction in Australia?

____
____
____
____
____

5. Have you encountered enthusiasm *or* resistance amongst builders, clients, design professionals, or regulators in the use of timber as a *structural material*?
If yes, can you give examples of the issues raised or perhaps provide an explanation?
☐ Yes
☐ No

____
____
____
____
____

6. Have you encountered enthusiasm *or* resistance amongst builders, clients, design professionals, or regulators in the use of timber *prefabrication* construction?
If yes, can you give examples or perhaps provide an explanation?
☐ Yes
☐ No

____
____
____
____

7. Have you investigated recent advances in prefabrication using timber in

Europe, North America or Asia. If yes, briefly describe what interested you about these developments and why you undertook these investigations?

☐ Yes

☐ No

____

____

____

____

8. Any other comments or issues you feel should be considered in the context of further enabling prefabrication using timber in Australia and increasing the use of timber in Class 2 – 9 buildings?
(Feel free to expand your response on a separate sheet of paper)

____

____

____

____

End of Section Two

Thank you for your assistance with this survey.
The information provided will be aggregated to produce an industry wide overview of opportunities and constraints for *Prefabrication Timber Construction Systems for Class 2 to 9 Buildings* in Australia.

A copy of this report will be forwarded to you once completed.

Appendix 6: Builders' Industry Questionnaire

Introduction

This questionnaire is intended to gauge Australian builder's perceived aspirations, impediments and opportunities for increasing the use of prefabricated building techniques and timber in *Class 2 to 9 buildings.*

All identifying information will be kept ***strictly confidential***. Please feel free to expand your responses on a separate sheet if required.

Section One focuses on general information about your business, the type of services you provide, the types of materials you use and types of buildings that you build including typical project sizes & budgets.

Section Two focuses on an expanded future of prefabrication and panelised systems and seeks to gain your views of your company's current and potential future position in these areas, and your perceptions on possible impediments and opportunities particularly compared to international advances in these areas.

The **Prefabrication Matrix** is supplied to assist with quantifying the various degrees of prefabrication from nodal, stick, planar to volumetric.

The **Prefabrication Table** is intended to assist with quantifying the types and extent that a company designs, produces or incorporates prefabrication into a specific project. It is intended to be complementary to both this questionnaire and the Prefabrication Matrix.

Definition of terms used herein:

Prefabrication: The design and off-site manufacture of a project specific component, assembly or system that is utilised, in part or as a whole, to build a structure.

Prefabricated timber element: a product that is fabricated primarily of timber components, i.e. a roof truss, floor truss, or wall frame, etc.

Panelised systems: a product that includes multiple elements to form a building type system, i.e. cassette floor systems or panelised wall systems.

Section One

1. Which of the following business type best describes your organisation?
   - ☐ Sole trader
   - ☐ Partnership
   - ☐ Company
   - ☐ Other (please define)________________________________

2. Indicate your business type:
   - ☐ Registered Builder
   - ☐ Other: ________________________________

3. Indicate your business's annual gross business turnover range:
   - ☐ <$250,000 - $500,000
   - ☐ $500,000 - $1,000,000
   - ☐ $1,000,000 - $5,000,000
   - ☐ $5,000,000 - $10,000,000
   - ☐ > $10,000,000

4. Please indicate staff numbers in each of the following areas:

Management & Admin	_______
Designers & Estimators	__________
Sales & Marketing	__________
In-factory Assemblers	__________
Transport	__________
Other: ______________________	__________
TOTAL STAFF	__________

5. Which capital cities, regional centers or region(s) do you provide your services to (e.g. Melbourne, Ballarat and Regional Vic etc. or nationally)?

____

____

____

____

6. Briefly describe the type of building services you provide.

____

____

____

____

____

7. To whom do you contract to (the total should equal to 100%)?

Type		%
Private Clients/Developers		________
Public Clients/Entities		________
Architects		________
Engineers		________
Other Builders		________
Prefabricators		________
Self		________
Other (please describe)	____________	________
Total =		100%

8. Indicate as a percentage, the NCC/BCA Building Class you typically build (the total should equal to 100%):

NCC/BCA Building Class	%
Class 1 (Residential – Single Dwelling)	______
Class 2 (Multi-residential [Sole Occupancy])	______
Class 3 (Multi-residential [Temporary Occupancy])	______
Class 4 (Residential Class 5, 6, 7, 8 or 9 [Caretaker etc.])	______
Class 5 (Commercial)	______
Class 6 (Retail)	______
Class 7 (Car park or storage)	______
Class 8 (Industrial)	______
Class 9 (Public)	______
Total =	100%

9. If you build Class 2 Multi-residential apartments, indicate a percentage for each storey.

2 storey	3 storey	4 storey	5 storey	6 storey	7 storey	8 or above

10. If you build Class 3 Office Buildings, indicate a percentage for each storey.

1 storey	2 storey	3 storey	4 storey	5 storey	6 storey	7 storey	8 or above

11. Indicate as a percentage the typical project floor area ranges you build (e.g. projects totalling 150m^2 – 350m^2 = 20% of the time and projects totalling 750m^2 – 1,000m^2 = 80% of the time. The total should equal to 100%):

Project area	%
<150m^2 =	____________
150m^2 – 350m^2=	____________
350m^2 – 750m^2 =	____________
750m^2 – 1,000m^2 =	____________
1,000m^2 – 2,000m^2 =	____________
> 2000m^2 =	____________
Total =	100%

12. Estimate as a percentage, the Total Project Construction Cost for the projects that you typically build.

(For example, you might typically build projects that have a total construction cost of between $100,000 - $250,000 approximately 20% of the time and projects that have a total construction cost of between $250,000 - $500,000 = 80% of the time. The total should equal to 100%):

Total Project Construction Cost	%
$50k - $100k	____________
$100k - $250k	____________
$250k - $500k	____________
$500k - $1m	____________
$1m - $5m	____________
$5m - $10 m	____________
$10m - $20m	____________
>$20m	____________

Total =	100%

13.According to the attached ***Matrix of Prefabrication*** typology, indicate the percentage of each *type of prefabrication* that your projects incorporate (the total should equal to 100%):

Type	%
ØD (Connectors etc.)	______
1D (Stick)	______
2D (Frame, Post & Beam or Panel)	______
3D (Module or Volumetric)	______
Total =	100%

14. What type and percentage of prefabricated timber products or structural systems do you build with (the total should equal to 100%)?

Type	%
Wall Frame	______
Roof Truss	______
Floor Truss	______
Floor Panel (cassette)	______
Wall Panel	______
Glulam posts and beams	______
LVL	______
All of the above	______
Other (please describe) ______________	______
Total =	100%

15. How do you source prefabricated or panelised timber building systems?

- ☐ Specialised timber fabricators
- ☐ General frame and truss manufacturers
- ☐ General builder/carpenter contractors
- ☐ In house (i.e. your company has fabrication capacity)
- ☐ Other (please describe) ______________________________

____

End of Section One

Section Two

In the future it is anticipated that there will be a much broader acceptance and demand for prefabricated and panelised systems in Australia due to:

- wider reaching NCC/BCA Deemed-to-Satisfy provisions covering a range of prefabrication typologies and building classes
- less restrictive building height allowances for timber (in May 2016 it is expected that the Deemed-to-Satisfy provisions of the NCC will allow timber construction up to an effective height of 25m, approx. 8 storeys)
- greater emphasis on environmental considerations that reward buildings procured through prefabrication
- established cost competitiveness and improved understanding and awareness of prefabrication amongst suppliers, trades, building design professionals, developers and regulatory and financing bodies

1. Briefly describe ***your*** understanding of prefabrication?

   ____

   ____

   ____

   ____

2. Assuming the scenario presented above:

   What future products might you like to see used more widely in both Class 2 (Residential) and other building classes?

	Class 2 (Residential)	Other Classes (Non Res)
• Cross laminated timber floor & wall systems	☐	☐
• Post and beam systems (Glulam, LVL)	☐	☐
• Panelised Floor Cassette Systems	☐	☐
• Panelised Wall Systems (including cladding, insulation, windows & doors)	☐	☐
• Panelised & Pre-finished Wall System (incl. above + electrical, plumbing & lining)	☐	☐
• Fully finished bathroom or kitchen modules	☐	☐
• Complete buildings	☐	☐
• Other________________________________		

3. What other opportunities do you think might become available for prefabricated and panelised timber construction?

____

____

____

____

4. What assistance or training do you think you or your staff would need if you were to build utilising prefabricated and engineered timber products and systems, particularly for use in multi-residential and non-residential applications (Classes 2-9)?

   ☐ Timber system design / specification - technical assistance
   ☐ Fire & acoustic system specification assistance
   ☐ Commercial sector costing and tendering advice/training
   ☐ Other:____________________________________

5. What do you consider would need to change in areas of *Supply*, *Contractors* and *Demand*, to allow an increase in the use of prefabricated timber construction in Australia?

____

____

____

____

6. Have you encountered resistance amongst clients, design professionals, or regulators ***in the use of timber as a structural material?***

   If yes, can you give examples of the issues raised or perhaps provide an explanation?

   ☐ Yes
   ☐ No

____

____

____

____

7. Have you encountered enthusiasm or resistance amongst other builders, clients, other design professionals, or regulators ***in the use of timber prefabrication***?
   If yes, can you give examples or perhaps provide an explanation?
   ☐ Yes
   ☐ No

   ____
   ____
   ____
   ____

8. Have you investigated recent advances in prefabrication using timber in Europe, North America or Asia and if so, briefly describe what interested you about these developments and why you undertook these investigations?
   If yes, can you give examples or expand on why you have were interested?
   ☐ Yes
   ☐ No

   ____
   ____
   ____
   ____

9. Do you have any other comments or issues you feel should be considered in the context of further enabling prefabrication using timber in Australia and increasing the use of timber in Class 2 – 9 buildings?
   (Feel free to expand your response on a separate sheet of paper)

   ____
   ____
   ____
   ____

End of Section Two

Thank you for your assistance with this survey.
The information provided will be aggregated to produce an industry wide overview of opportunities and constraints for *Prefabrication Timber Construction Systems for Class 2 to 9 Buildings* in Australia.

A copy of this report will be forwarded to you when completed

Appendix 7: Timber, Prefabrication and Timber Construction Education Services:

Note:

The following is not intended to be a complete list of all entities operating in Australia who provide support, education and resources to the timber construction and prefabrication sectors. It is for reference only and provides a cross section of the types of companies that were considered in this report

- PrefabAUS (national)
- Modular Construction & Prefabrication Australia (national)
- Modular Building Institute (International)
- Modular Codes Construction Board (Victoria)
- WoodSolutions (national)
- Australian Timber Database (national)
- Center for Sustainable Architecture with Wood (Tasmania)
- Victorian Association of Forest Industries (Victoria)
- Wood Products Victoria (Victoria)
- Timber Development Association (NSW)
- Timber Queensland (Queensland)
- Timber Insight (Western Australia)
- Jazzcorp (Western Australia)
- Forest Industries Association of Tasmania (Tasmania)
- Tasmanian Timber Association Board (Tasmania)