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Final Report for Commercial Building Costing Cases Studies – Traditional Design versus Timber Project

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www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9927 3200 F +61 (0)3 9927 3288
E info@fwpa.com.au W www.fwpa.com.au

Final Report

For

Commercial Building Costing Cases Studies – Traditional Design versus Timber Project

Prepared for

Forest & Wood Products Australia

by

Timber Development Association (NSW) Ltd

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Researcher:
Andrew Dunn
Timber Development Association NSW Ltd
PO Box 154
St Leonards NSW 1590

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Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9927 3200 F +61 3 9927 3288
E info@fwpa.com.au
W www.fwpa.com.au

Executive Summary

This project developed Cost Plans for the structure of four building types; a 7 storey office building, an 8 storey apartment building, a 2 storey aged care facility and a single storey industrial shed. Each solution was designed and then independently costed for a timber option as well as a more conventional concrete framed or steel framed solution for a reference location in suburban Sydney. The site was assumed to have no significant cost implications concerning site access, ground conditions or neighbouring properties.

The investigations considered only the elements of the building for which there were significant difference and ignored the cost of elements that were the same. The table below details the cost savings for each building type considered:

Costed building type	Cost of structural solution		Cost savings of timber compared to traditional structure
	Timber	Traditional	
7 Storey office building	LVL $6,387,913	Concrete $7,289,508	-$901,595 (-12.4%)
8 Storey apartment building	CLT $5,015,705	Concrete $5,126,183	-$110,478 (-2.2%)
2 Storey aged care facility	Timber frame $697,020	Steel frame $809,620	-$112,600 (-13.9%)
Single storey industrial shed	Timber portal frame $216,342	Steel portal frame $238,861	-$22,519 (-9.4%)

The timber structural solutions were found in all cases to be significantly less than the competing non-timber solution. The cost of each of the main components were found to be significantly cheaper in timber for each building.

The gross savings were found to be even greater however the fire protection to some of these structural elements, the extra engineering cost (fire engineering) and the cost of termite protection reduced the cost savings. For the office and apartment building the major cost savings were generally found in the Preliminary Costs, an area not fully recognised when comparing costs.

This project found that the greatest potential benefits to the timber industry are in the industrial shed (girts and purlins), aged care and office building markets. The industrial shed (girts and purlins), and aged care markets are a ready to go opportunity for the timber industry but lacks awareness by the designers. The current timber industry supply chain could be easily adapted to supply the industrial shed’s girts and purlins, and aged care market with a little change to current supply arrangements.

The next best opportunity for the timber industry is the office and institutional building markets as both building forms are similar. This report shows that this market segment has great potential as this building design showed the significant cost savings particularly if a decorative ceiling is omitted.

To provide specifiers and code officials with the necessary information so the timber industry can take full advantage of these markets further specific research and evidence is required. This work is summarised below:

- Floor Vibration Assumptions (dynamics): Guidance is required on the assumptions and calculation methods for long span timber floors.

- Floor Diaphragm: Improved guidance on design of diaphragm action of large spaning timber floors.

- Timber shear wall design: Guidance on the design of timber based shear walls.

- Connectors Design and Standards: Updating the Australian Standard AS1720 to remove over conservatism and include proven innovative European connector systems.

- Better Acoustics Systems for Floors: Development of acoustic systems for timber floors that don’t rely on ceiling or building up layers on the top surface for increased acoustic performance.

- Fire Resistance of Timber Panels: Provide information on maintaining fire resistance in the joining of massive timber panels as well as provide certification for fire protection to systems that may penetrate timber elements such as doors, pipes, cables, service shafts, etc.

- Preliminary Costs: Provision of empirical evidence that timber buildings are quicker to erect.

The future for timber in commercial building application is promising as this project has shown that timber buildings can be as cost affective to that of traditional non-timber building design. As well non-timber building designs are relatively well known, have been applied many times throughout Australia and have a well-developed supply chain so there is little opportunity to reduce their costs further. Against timber design that is not well understood and has in its infancy a developing commercial supply chain, it is conceivable further savings are possible for timber buildings than what has been considered in the above reports.

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Introduction

The project's objectives were to provide a source of timber costing information to building professionals for the non-housing building sector by comparing the cost of timber commercial buildings to that constructed using traditional materials.

The project investigated four building types:

- Single storey portal frame industrial building,
- Medium rise (8 storey) residential building,
- Medium rise (7 storey) office building,
- Low rise (2 storey) aged care facility.

Accompanying the cost comparison is a commentary for each building type investigated. This commentary discusses the makeup of each building, issues encountered and how they were dealt with as well as the outcomes and areas of possible improvement.

Projects Objectives

Provide a source of timber costing information versus traditional designs for building professionals to the non-housing building sector and initiate communications between the timber industry and Quantity Surveying type of businesses aimed at providing realistic timber cost information.

Methodology

The research was carried out in four steps:

1. Develop model design for four building types.
2. Design each building in timber and a traditional material.
3. Develop an independent cost plan for each building type.
4. Develop a commentary on each building type so that design professionals know why decisions were taken and what was considered in the Cost Plan.

Model Building Design

The first step of the project was to develop design for each of the model buildings being considered. It was decided very early on that new designs would be developed in lieu of using existing building designs as privacy and intellectual property issues prevented publishing specific buildings information. To develop the model building a series of expert/stakeholders were involved and they were divided into three distinct groups, core collaborators, design team and timber industry.

> *Core collaborators*: Was led by TDA with the University of Technology Sydney (UTS) and Building Cost Information System (BCIS). UTS co-developed the research method and mediated the strategic direction of timber solutions pertaining to detailed design, construction, cost and site productivity issues. BCIS, a subsidiary of the Royal Institute of Chartered Surveyors who operate globally and specialise in gathering building cost data which is used for reporting on cost trends for a variety of building forms provided the quantity surveying, cost estimating and cost planning input for both the timber solution and the corresponding non-timber traditional solutions.

Design team: The design teams varied for each building type. The designs for the office and apartment buildings where developed by two separate design teams. These teams provided feedback into their particular building and working in a collaborative environment in directing the development process which included meetings, interviews, concept development sessions, design charrettes, cost planning studies and detailed design studies which were aimed at developing the model buildings under consideration and then finding a cost effective timber solution for it. These teams were comprised of staff from the following design organisations:

Office Building

- Fitzpatrick and Partners – An architectural firm specialising in office design with significant experience in all the major cities in Australia. They provided feedback on client needs, helped design the model office building and the related timber solution.
- Arup Ltd. – One of the largest and oldest multi-disciplinary engineering firms in the world with expertise spanning structural, acoustic, fire and services engineering. They provided design and engineering input into the timber solution and the corresponding concrete solution as well as assisted in HVAC and acoustic decisions.
- RBE Contracting – A construction project management company with a depth of expertise in many forms of building construction and specific expertise in large scale timber construction. They provided input into the timber solution and the competing concrete solution especially in terms of design management and site process driven variables.

Apartment Building

- Studio 505 – An architectural firm with a strong understanding of design and the effects of material and system selection. They led the design of the model apartment building and provided input into the related timber solution.
- Taylor Thompson Whitting (TTW) Consulting Engineers – An engineering firm with specialised services in Structural, Civil and Facade Engineering. They provided the structural concrete design for the concrete solution.
- AECOM – One of the world's largest multi-disciplinary engineering firms with expertise spanning structural, acoustic, fire and service engineering. They provided specialist advice on the design of the timber solution.

Aged Care Facility

The Aged Care building was much smaller in size and the chosen structural system is well established in timber and alternative materials within the marketplace so it was not necessary to establish a multi discipline design team. Here a building designer was used named Plan Source who developed the model design. They are a building design company experienced in residential and small commercial buildings.

Industrial Building

This building utilised an existing design developed for the Structural Timber Innovation Company. As the design already existed there was no need for a design team and the exercise was to reprice the existing design. To supplement the work an alternative timber design was considered to further explore attributes of a timber portal frame. This alternative design used the basic parameters developed for the Structural Timber Innovation Company.

How Much Design Work Was Done

Each building was designed enough so that it was possible to ascertain the key differences in costs for each. For office and apartment buildings the design had to incorporate much more than just structural considerations, it included HVAC, façade, acoustics and so on. As discussed later these aspects drove structural design decisions.

As is the case for these complex buildings, specific design for each building varied for each building type.

Office building
The concrete structural design was carried out by Arup. Arup also designed the HVAC and assisted in the design of the acoustic considerations. The timber structural design was carried out in a collaborative approach by TDA and input from various timber suppliers. This approach was driven by the need to test various timber systems to best understand the qualities and limitations of the products and system offered by the timber industry.

Apartment building
The concrete structural design for this building was carried out by TTW Consulting Engineers. Issues surrounding MEP, façade and acoustics where resolved by the design architects at Studio505. TDA in collaboration with the CLT supplier SmartStrut designed the cross-laminated timber (CLT) components. Specialist CLT assistance was provided by AECOM Consulting Engineers.

Aged care facility
Architectural design was carried out by western Sydney building design PlanSource. Structural design for both options was provided by TDA with assistance from Tilling Timber and Meyer Timber. The design was then supplemented with input from frame and truss suppliers.

Industrial building
As discussed previously this building design was already available as it was prepared for a Cost Plan that the Structural Timber Innovation Company commissioned when they explored the cost of their innovative timber connector, Quick Connect. A supplementary design was prepared by Carter Holt Harvey Wood Products New Zealand utilising their software. This design explored another bay spacing arrangement and an alternative connector system. The steel design was later value engineered as the steel price was considered too high. This additional design work was carried out by TTW Consulting Engineers.

Timber industry
In all the building designs considered various companies within the timber industry itself assisted by providing specific input to the design solutions. This was done as it allowed timber companies to explore options that could not be done under real project conditions. The companies involved were engineered timber manufacturers, suppliers and associated connections including Tilling Timber, Meyer Timber, Nelson Pine, Carter Holt Harvey Wood Products, MiTek and Hyne. They provided input on timber supply costs, the viability of designs, design properties, manufacturing processes and the availability of appropriate timber componentry.

Cost Plans

BCIS, a subsidiary of the Royal Institute of Chartered Surveyors provided quantity surveying, cost estimating and cost planning input for both the timber solution and the corresponding alternative material solution.

In most circumstances they used the pre-existing knowledge within their information system to develop the comparison costs. As the timber design for the office and apartment building was unique, a price was obtained from the marketplace that included all costs up to delivery to the reference building site. BCIS sourced these prices directly from the market independent from the research team. SmartStruct provided the CLT price to BCIS for the apartment building and the cores in the office building whilst Meyer Timber provided the price for the office building's beams, columns and floor and roof cassettes.

For the aged care building the costing information was provided by BCIS's data base. As a parallel exercise independent prices were sourced from the market place. The market place prices confirm that BCIS's cost information was relatively accurate.

One key element in developing a cost plan was the consideration of the construction program time. Time savings impacted on preliminary cost and in the end was a key difference for the office and apartment building costs. To understand program times an independent contractor experienced in both timber and concrete construction was used to program the office building. The apartment building was estimated by BCIS as they have information on CLT design from their parent company in the UK where CLT design has been around for more than 11 years.

Results

The cost comparison was only undertaken for the parts of the building that were considered to have significant different costs, positive and negative, under the competing scenarios. Therefore items such as mechanical, electrical, plumbing, floor coverings, car parking levels and fit out were excluded. In order to create stable costing, it was assumed that the building would be constructed in suburban Sydney.

In all cases it was found that the timber solution was more cost effective than the alternative material considered, refer Table 1 for the summary of all building types considered. It is important to note that the price difference shown in the following tables are for elements of construction considered and do not represent the overall cost of the building.

Table 1: Summary of all cost comparisons

Costed building type	Cost of structural solution		Cost savings of timber compared to traditional structure
	Timber	Traditional	
7 storey office building	$6,387,913	$7,289,508	-$901,595
8 storey apartment building	$5,015,705	$5,126,183	-$110,478
2 storey aged care	$697,020	$809,620	-$112,600
Single storey industrial shed	$216,342	$238,861	-$22,519

Detailed Cost Comparisons

Office Building

Table 2 details the cost difference in key element of the seven storey office building.

Table 2: Cost comparison of major items between each building solution considered

	Timber	Concrete	Variance
Columns	392,505	234,424	+158,081
Floor			
Beams	1,481,982		
Floor Cassettes	2,772,518		
	4,254,500	4,422,810	-168,310
Roof			
Beam	207,387		
Roof Cassettes	352,569		
	559,956	689,720	-129,764
Lift, Stair and Air shafts	793,698	1,177,620	-383,922
Suspended Ceiling	764,934	764,934	0
Connectors	59,769	0	+59,769
Termite & Fire Engineering	50,000	0	+50,000
Preliminaries	-460,000	Nil	-460,000
Total	**$6,387,913**	**$7,289,508**	**-$901,595**

In analysing the differences between the two plans it can be seen that the timber building provides a saving of $901,595.00 being a 12.4% saving compared to the reinforced concrete solution. Specific savings under the timber solution were as follows:

- Floor: $168,310.00 (3.8% saving relative to concrete).
- Lift, stair and air shafts: $383,922.00 (32.6% saving relative to concrete).
- Roof: $129,764.00 (18.8% saving relative to concrete).
- Preliminaries: $460,000 saving relative to concrete.

Additional costs under the timber solution relative to the concrete solution included:

- Columns: $158,081.00 (a 67% increase relative to concrete).
- Connections: $59,769 (an additional cost relative to concrete).
- Termite & fire engineering: $50,000 (an additional cost relative to concrete).

Additional savings could be possible by deleting the suspended ceiling and exposing the timber beams and floor. This would result in a potential further savings of $764,934 but this would incur additional costs for neater fixing of the mechanical air supply and lights, estimated to cost $266,064. The overall saving for the timber solution in this case would be $1,400,490 (19.2% less than the concrete solution), a very substantial cost saving.

Apartment Building

Table 3 details the cost difference in key elements of the eight storey apartment building.

Table 3: Cost comparison of major items between each building solution considered

	Timber	Reinforced Concrete	Variance
Columns	28,305	306,130	-277,825
Level 1 Transfer Slab	312,660	480,340	-167,680
Upper Floors	1,132,287	1,180,395	-48,108
Roof	147,135	205,530	-58,395
External Walls	1,087,910	1,098,327	-10,417
Internal Walls	939,037	954,955	-15,916
Wall Finishes	867,998	414,416	+453,582
Ceiling Finishes	792,373	486,090	+306,288
Termite & Fire Engineering	35,000	0	+35,000
Preliminaries	-312,000	Base	-312,000
Total	**$5,015,705**	**$5,126,705**	**-$110,478**

In analysing the differences between the two construction methods it can be seen that the timber solution provides a saving of $110,478 being 2.2% less when compared to the reinforced concrete solution.

Specific savings under the timber solution (relative to concrete) were found to exist as follows:

- Concrete transfer slab at Level1.
- The loadbearing structure including walls, floors, columns and roof.
- The preliminary costs for the project; (including reduced crane, site sheds, supervision, scaffolding, and traffic control costs).

Additional costs under the timber solution relative to concrete were found to exist in:

- Increased fire protection of the CLT elements.
- Termite protection of the timber elements.
- Fire engineering costs for the Alternative Solutions required for the load bearing and fire resisting walls.

Each is discussed in more detail below under dedicated headings.

Savings in the concrete transfer slab
As the timber solution is lighter in weight (20% of the mass of concrete) than the concrete solution a thinner and cheaper concrete transfer slab was possible.

Timber	$312,660	
Concrete	$430,340	
Difference	-$167,680	(39% cheaper)

Savings in the loadbearing structure
Savings were possible due to reduction of material required for the roof and core walls and also the removal of columns throughout the building by the use of loadbearing walls.

Timber	$2,055,252	
Concrete	$2,359,412	
Difference	-$304,160	(13% cheaper)

Preliminary savings
The timber solution included an estimated saving in preliminaries of $312,000 based on a construction program saving 6 weeks over the concrete solution. Each week was estimated to save $52,000 based on labour cost savings for site management, site sheds and plant such as crane, hoist and scaffolding hire when compared to concrete.

Additional fire protection costs
Extra cost for the timber solution related to the additional linings required for fire protection of timber load bearing walls and floors $734,940.00.

Additional fire engineering costs
The timber solution required additional consultancy fees (relative to the concrete solution) as a Deemed-to-Satisfy solution was not possible for the external and/or load bearing fire resistant walls. This results in the need for an Alternative Solution. Based on quotes from Sydney based fire engineers, the fire engineering fees for this, under normal project based scenarios, would cost $20,000.

Additional termite protection costs
The timber solution sits on top of a concrete basement (car park) and concrete retail level. As an additional precaution, the timber structure has termite protection by way of a stainless steel mesh to all hidden entry points from the ground to the concrete structure. This protection was estimated at an additional cost to the timber solution of $15,000.

Aged Care Facility

Table 4 below compares major items considered in the cost plan for the two storey aged care facility.

Table 4: Cost comparison of major items between each building solution considered

	Timber	Steel	Variance
Columns	$2,646	$3,330	-$684
Upper Floors	$63,138	$226,357	-$163,219

Roof	$259,611	$300,635	-$41,024
Walls	$371,625	$279,298	+$92,327
	$697,020	**$809,620**	**-$112,600**

It can be seen that the timber framed solution shows a saving of $112,600 being a 16% reduction when compared to the steel frame solution. These costings include wall and floor coverings.

Savings for the timber solution were found to be mainly in the:

- Upper floor framing $163,219 or 258% saving.
- Roof framing $41,024 or 15% saving.

Additional costs were found to be in the wall framing $92,327, a 33% additional cost.

Quotes from the marketplace

As mentioned above an exercise was carried out to independently verify the cost plan findings via real quotations from the market place. Quotes were obtained from leading timber and steel frame suppliers as a package delivered to site. The quotes are for framing materials only; note the cost plan included coverings:

Steel	- $231,000	
Timber	- $193,133	
Difference	-$37,867	(20% saving)

Like the cost planning exercise these figures again indicate that the timber solution is cheaper but at a lesser amount of $37, 867 (20%) when compared to steel. The savings were again identified to mainly exist in the upper floor framing which parallels the main findings from the cost planning exercise.

Industrial Shed

Table 5 below compares major items considered in the cost plan for the single storey industrial building.

Table 5: Cost comparison of major items between each building solution is considered

	Timber portal solution 1 6.67 m Bay Spacing	Timber portal solution 2 10 m Bay Spacing	Steel portal solution 8.0 m Bay Spacing
Purlin	39,483	74,595	46,190
Girts and columns	20,761	28,247	60,496
Portal Frame	147,310	91,500	98,635
Footings	19,480	22,000	33,540
Totals	**227,034**	**216,342**	**238,861**

Cost Variations around Australia

Considering the variations of costs between locations around Australia is a very vexed issue as there are many and often conflicting views and opinions. Much depends on the information that is available to the cost planner, what they have or haven't been exposed to and on how they base their opinions. Other issues such as current demand for products and services vary from region to region as well as over time making the issue more complex.

BCIS supplied an estimate of relative variations of costs between the different capital cities and these are included in Table 6. Note that these are very broad and should be used as indicative only. This project assumed Sydney as the location of the buildings so the figures are based around Sydney.

Table 6: Cost variation in major Australian centres

Location	Costs weightings (%)
Sydney	100
Melbourne	100
Brisbane	95
Adelaide	100
Perth	105
Canberra	105

Discussion

Many lessons learnt from this project are already assisting in the design of actual commercial timber buildings by the project partners. Considering the four building types investigated, the design of the timber model buildings for the aged care and industrial buildings are were well understood, easy to details and have cost information readily available. This was not the case for the office and apartment buildings where the timber options were relatively unknown. The office building was particularly difficult to design as the solutions available from the timber industry were numerous but there was little experience in what system worked best or suited the building constraints.

Key findings were:

1. Maximise the use of stock timber products and sizes.
   Using timber items and sizes that are readily available in the supply chain provide cheaper building solutions. Where items are especially manufactured or fabricated costs quickly inflate. Non-standard sizes also may generate significant wastage which also adds to the cost. This finding is not surprising as this occurs for all products. For example a steel building using stock sizes is much cheaper than a fully fabricated building.

2. Increase fire resistance through timber's char capacity.
   Designing for the required fire resistance was found to be cheaper when the char capacity of timber itself was used and dependence of plasterboard was reduced.

   There are two general approaches in providing fire resistance, the first and considered the traditional approach is to install plasterboard fire protection. The second is to use the char capacity of timber and oversize elements so that there is capacity in the timber element to provide fire resistance and structural resistance under fire load conditions. The cost to install plasterboard makes systems designed around this relatively very expensive. By increasing the size of key timber elements, although there is more material cost, there are substantial material and labour cost savings as there is less plasterboard to be installed.

3. Reducing crane movements.
   It became very clear that it is very important to consider the number of elements that are need to be moved by crane as this directly affects the construction program and consequently costs. Having large elements or combining elements together on the ground and lifting in place, saves time and costs. However, this needs to be balanced with waste generation, best seen in CLT wall use. If a wall has a large opening in it, such as for doors or windows, this can potentially can creates a lot of offcuts. If the CLT offcuts can't be used elsewhere, then they are waste. Dividing the panel into a number of separate components to reduce the generation of offcuts will increase the number of crane lifts required for the same amount of installed wall. Consequently there is a balance between waste generation and construction program time increase. What scenario creates the less cost is dependent on a number of variables that can only be understood by experience.

Supply Chain

The timber industry is almost entirely geared to supply the domestic housing and renovation market. In dealing with the design of the timber office and apartment buildings this was problematic as timber solutions for these buildings revolved around a less developed supply chain. As a result it was difficult to obtain detailed and informed feedback on designs, fabrication issues and costs impacts from the timber industry. The timber industry's very small presence in the structural commercial building market (in comparison with the concrete and steel industry) is a barrier for take-up as the services needed are completely different to that required for the supply within the domestic buildings. For the timber industry to be successful in the commercial building market a change in approach to support the market and design professionals is required. Timber systems are new to most commercial builders and there is very little experience with using timber products within this sector.

Preliminaries Cost Savings

For the office and apartment buildings much of the savings in a timber solution were found using pre-fabricated methods of construction. Pre-fabrication reduced onsite construction time due to compression of the construction program and reduced need for expensive construction site labour. The compressed construction program saves site infrastructure costs such as scaffolding, site accommodation, hoists, craneage and construction site administration costs. These cost savings can potentially be very large but are hard to recognise under a cost plan scenario as these costs are included under a cost centre called Preliminaries. Cost Planners tend to use set percentage rates for Preliminaries which means that these costs are often the same for each material considered. Until more timber buildings are actually built and real data is incorporated into Cost Planers databases these fixed Preliminaries will hide some real advantages for timber solutions from the wider building industry.

Often the shape of the building and what building material will be used is decided at a very early stage of a building's design. At this early stage a rough cost exercise is often carried out and Cost Planners point out that consideration of Preliminaries are often treated as a percentage as the Preliminaries for traditional materials like concrete and steel are very well known from experience. For timber there is little information available to do otherwise. There are no actual timber construction program examples publically available to justify a documented Preliminaries cost saving that the timber design is heavily dependent on to justify a reduced cost comparison. Cost Planners point out that acceptance of the shorter program time for timber buildings is presently hard to accept as there is little documented evidence in real buildings construction programs available.

Therefore consideration of which material to use, if it is considered at all, generally falls back to what building material is the cheapest. Rarely is timber cheaper in head to head material costs. For example, the delivered concrete costs is around $200/m^3 compared to CLT at $1,500/m^3.

For construction time savings to be better accepted within the critical early Cost Plans a greater understanding of the productivity gains and their effect on Preliminaries around timber product installation is required.

Recommendation: Evidence of the type or attributes of a timber buildings that are quicker to erect is required. This can be achieved through a productivity study of various building sites and/or examples of actual buildings.

For this project and for the reasons stated above construction programs were developed for the office and apartment building. This information was used to base the Preliminaries cost savings. Even with this information the Cost Planer for this project took a very conservative view to what Preliminaries savings could be used. Again this was because there is a lack of sufficient real evidence to do otherwise. The Cost Plans developed for this project's buildings only included hire cost savings for major items such as site accommodation and plant (crane and hoists) and the reduced site administration labour cost.

Further cost savings were identified but were excluded because, as stated above, there is little real evidence in the marketplace that there are actual time or material savings. The commentary that accompanies each Cost Plan discusses these other possible savings, some of which are discussed below:

- Removal of scaffolding as a timber structure can be constructed with hand rails.
- Reduced first fix time being the time to carry out rough-in for mechanical, electrical and plumbing within timber structures. Generally for timber structures less time is needed to fix brackets and supports structure to the superstructure of the building. This is because only lightweight cordless screw guns which are light, quick and easy to use are required. Fixing to concrete structures requires drilling into the concrete and then plugging which is slow, noisy and dirty work.
- Reduce footing/foundation costs as the timber structures are generally estimated to be 50 per cent lighter than the concrete structures as timber is 20% the weight of concrete. This would allow lighter footings for the timber model potentially providing even greater savings. The Cost Plans assume that the footings are the same for both timber and non-timber solutions.
- Reduced crane size or type. The cost comparison assumes that the same tower crane is used for both solutions. The crane savings included in the timber Cost Plan are just that there is less hire time required. The timber solution has generally lighter elements and it is conceivable that a light electrical and remote crane could be used in lieu of very expensive standard tower cranes offering further savings.

Cost Planners

A factor that can’t be resolved is that for the use of traditional materials there is an extensive knowledge base that it well understood by Cost Planers whilst timber structures are generally new and not well understood. When faced with new systems or materials all building professionals, including Cost Planners, err on the conservative side. The best resolution of this issue is to provide experience and consequently early adopters of timber building systems should be actively encouraged to share experiences with their peers (e.g. through WoodSolutions and other forums). If this is not possible empirical evidence needs to be developed through research and disseminated effectively.

Recommendation: Early adopters of massive timber buildings should be actively encouraged to share experiences so that greater knowledge is available to Cost Planners. In the interim, further examples of timber building designs could be carried out to add to the database of knowledge.

Balancing Drivers for the Design Solution

This is best described by articulating the experiences that were had in carrying out the design of the timber office building. The initial solution suggested by the timber industry was not considered viable by the design team and in a real project situation would have seen the timber option discarded at a very early stage. As expected the timber option first offered suited the supply and availability of timber elements but this did not match well with the key decision parameters that drove the project.

These drivers vary for the building type under consideration and some of these are discussed below.

For the office building the main parameter that drove the design of the building was maintaining the floor to floor height to that of the traditional design solution (i.e. concrete). This is because higher floor to floor heights affect the overall building height which in turn is limited by planning approval and additional cost constraints, such as overall height limits, overshadowing limits as well as increased facade costs from a higher building.

Two key reasons are offered to why timber design causes greater structural depths for the equivalent span. The first is timber's Modulus of Elasticity, a key structural parameter for determining building elements' depth, and is generally less than alternative non-timber material resulting in deeper structural depth. The other reason is due to the stock maximum length of engineered timber, which comes in around 12 metres. This limits the ability of engineered timber to be used in continuous spans. Continuous span (spanning over three supports) elements are shallower in depth than simple sported spans (spanning over two supports). The example office building has grid spacing of 9 metres requiring continuous span elements to be 18 metres in length, a length not readily available.

Investigations into what timber product or system worked best in the timber office building resulted in around thirty different timber floor systems being considered. Great effort was placed in designing the floor systems as the floors represented three-quarters of the material used in the building. Selecting the best timber system for the floors meant consideration of the large range of timber products i.e. LVL, glulam, lightweight trusses and CLT as well as combinations of these timber products.

As well as depth of the structural timber elements there are other issues such as acoustics performance, fire resistance and floor vibrations that had to be considered. Overlaying all of this there is the consideration of the construction program time i.e. the time required to install a system. As discussed above the construction program time affected Preliminaries, the key areas for savings in a timber solution. Keeping the timber floor system within a set comparative floor to floor height meant all of these issues needed consideration as one package and this greatly complicated the design process.

All of these issues are not experienced in the concrete solution as concrete based systems set the benchmark in these building types. The floor to floor height in concrete has come about from well understood design and construction practices which have been developed over a very long time. They have a lot of real building examples and to keep prices down there are many concrete suppliers in the marketplace. Paradoxically this also why timber design is worthy of consideration. The cost of traditional concrete systems are so refined and efficient there very few opportunities for further savings to be made by building professionals whilst for timber design there are many opportunities for savings to investigate.

To resolve which floor system to use the thirty different floor designs were submitted for consideration by a construction program exercise. This assisted the design team as they began by discarding the designs that would have took longer to build than traditional materials. The floor system chosen was the one that met the floor-to-floor height constraint and had the least number of elements required to be craned into place. The selected floor system (detailed in the attached reports) was used in the cost comparison. It should be noted that additional savings are possible but due to constraints the already numerous options being considered were not possible to include them all in the final Cost Plans. The researchers have already identified a number of these.

In the end there are a number of factors that drove the floor system design and they are summarised as:

1. Use timber elements that are readily available from the supply chain and don’t require additional (and costly) fabrication.

2. Consider the number of crane movements required for the erection of the system. A system that has the least amount of individual components to lift is quicker to erect. For example, the office building had the beam supporting the façade fixed to the floor cassette removing one whole construction day per floor in the construction program. Also the twin primary beam and columns were prefabricated into one element on the ground before lifting onto the building. This reduced the number of crane movements for the installation of the beam and columns by a factor of four.

3. Use massive timber elements’ char capacity for fire resistance rather than site applied plasterboard. In addition the massive timber elements that have added timber for char capacity help to resolve structural issues such as deflection and vibration as well as provide a decorative covering, i.e. removing the need for ceiling or cladding to beam or columns. Also using char capacity in timber meant that installation requirements were also reduced, i.e. a team of plasterboard installers are not needed.

Further Research Needed

Further research work has been identified as necessary to address specific structural, fire and acoustic issues as these are limiting the uptake of timber in buildings of these types.

Structural Considerations

There were a number of structural design issues that limited design options. The main issue were:

- Floor vibration assumptions (dynamics). Methods to analysis the performance of timber floors as well as what are reasonable parameter inputs are not well understood and knowledge varies amongst consulting structural engineers. A guide based on acceptable assumptions and design methodologies would help tremendously in this area.

- Floor diaphragms. Relating to the above issue is knowledge about diaphragm design in timber floors which is relatively low or overly simplistic among consulting structural engineers so a more detailed design guide is required. The Structural Timber Innovation Company's EXPAN guide is a good start but only provides rudimentary information which is insufficient for complex buildings.

- Timber shear wall design. Knowledge on the design of timber based shear walls is relatively low or overly simplistic so more detailed design guidance is required.

- Connectors design. The Australian timber engineering Standard AS1720 is overly conservative for the design of connectors for timber. It is also out of step with the new European innovative and efficient connector systems and reduces their uptake in Australia. In addition, knowledge about these efficient modern timber connector methods is relatively poor amongst the structural design professionals.

Fire Resistance

As discussed above timber systems that utilise the char capacity of timber itself were found to be more cost effective than systems that required protection from non-wood linings such as plasterboard. The dominant issues for fire resistance of timber solutions is not the resistance of timber itself but the associated construction that is required such as the joining of massive timber panels as well as fire protection to systems that may penetrate them such as doors, pipes, cables, service shafts, etc. There is a requirement for generic information on methods to join timber and construct penetrations whilst ensuring fire resistance requirements are met.

Acoustics for Floors

Most timber floor systems require a suspended ceiling or considerable additional layers on the top surface of the timber to meet acoustic requirements. Both solutions are costly involving many non-timber products as well as substantial installation labour. A greater understanding on cost effective acoustically compliant timber floor solutions is required for multi-residential and commercial building applications.

Conclusions

This project developed Cost Plans for the structure of four building types, a 7 storey office building, an 8 storey apartment building, a 2 storey aged care facility and a single storey industrial shed. Each solution was designed and then independently costed for a timber option as well as a more conventional concrete framed or steel framed solution for a reference location in suburban Sydney. The site was assumed to have no significant cost implications concerning site access, ground conditions or neighbouring properties.

The investigation considered only the elements of the building for which there were significant differences and ignored the cost of elements that were the same. The table below details the cost savings for each building type considered.

Building type costed	**Cost of structural material solution**		**Cost savings of timber solution**
	Timber	**Traditional**	
7 Storey office building	$6,387,913	$7,289,508	-$901,595 (-12.4%)
8 Storey apartment building	$5,015,705	$5,126,183	-$110,478 (-2.0%)
2 Storey aged care facility	$697,020	$809,620	-$112,600 (-13.9%)
Single storey industrial shed	$216,342	$238,861	-$22,519 (-9.4%)

The timber structural solutions were found in all cases to be significantly less than the competing non-timber solution. The cost of each of the main components were found to be significantly cheaper in timber for each building.

The gross savings were found to be even greater, however the fire protection to some of these structural elements, the extra engineering cost (fire engineering) and the cost of termite protection reduced the cost savings. For the office and apartment building the major cost savings were generally found in the Preliminary Costs, an area not fully recognised when comparing costs.

This project found that the greatest potential benefits to the timber industry are in the industrial shed's girts and purlins, aged care and office building markets. The industrial shed's girts and purlins and aged care markets are a ready to go opportunity for the timber industry but lack awareness by designers. The current timber industry supply chain could be easily adapted to supply the industrial shed's girts and purlins and aged care market with a little change to current supply arrangements.

The next best opportunity for the timber industry is the office and institutional building markets as both building forms are similar. This report shows that this market segment has great potential as this building design showed the significant cost savings particularly if a decorative ceiling is omitted.

The future for timber in commercial building application is promising as this project has shown that timber buildings can be as cost affective to that of traditional non-timber building design. As well non-timber building design is relatively well known, practiced many times throughout Australia and has a well-developed supply chain so there is little opportunity to further reduce their costs. Whereas timber design is not well understood and has in its infancy a developing commercial supply chain so there are further possible savings for timber buildings than what has been considered in the above reports.

Further investment into research and knowledge would result in even further savings. To the design professional a timber building design for commercial buildings application offer the greatest opportunity to reduce costs as they are less known, they are lightweight and can be utilised in off-site construction formats.

Recommendations

The three building types that have the most immediate opportunities for increased sales for the timber industry are industrials shed's girts and purlins, aged care facilities and timber office buildings.

The industrial shed's girts and purlins and aged care facility markets for timber is ready to go but there is distinct lack of awareness among designers of these building about using timber. The current timber industry supply chain could be easily adapted to supply the industrial shed market with a little change to current supply arrangements.

Recommendation: Conduct marketing activity to promote the benefits of timber construction for industrial sheds and aged care buildings among building professionals.

The next best opportunity for the timber industry is the office or institutional building markets as both building forms are similar. This market has the most potential as this building design has the greatest savings after aged care facilities. These buildings are inherently more complex so the following work is recommended to be undertaken to assist the timber industry in further access to this lucrative market.

- Recommendations: Floor vibration assumptions (dynamics): Method in the analysis of timber floors is not well understood and varies amongst structural engineers. Guidance is required on the assumption and calculation methods to assess floors.

- Floor diaphragm: Similar to the above issue guidance on diaphragm design in timber floors is relatively low or simplistic. A more detailed design guide is required. The Structural Timber Innovation Company EXPAN guide is a good start but is too rudimentary for complex buildings.

- Timber shear wall design: Again guidance on the design of timber based shear walls are relatively low or simplistic. A more detailed design guide is required.

- Connectors design: This was also identified as an issue as Australian Standard AS1720 is very conservative, out of step with European innovative systems and relatively unknown amongst the design community.

Acoustics for Floors

Most systems available for timber floors require a ceiling or building up of the top surface. Much of these solutions are costly involving many layers of non-timber products and labour. A greater understanding on cost effective acoustic solutions is required for residential and commercial building applications.

Fire resistance

As discussed above timber systems that utilise the char capacity of timber itself were found to be more cost effective than systems that required protection from non-wood coverings. The dominating issues for timber fire resistance is not the resistance of timber itself but the associated construction that is required such as the joining of massive timber panels as well as fire protection to systems that may penetrate them such as doors, pipes, cables, service shafts, etc.

Preliminaries

As discussed the main savings for the timber buildings, particularly for the office and apartment buildings, were related to the savings in Preliminaries. Therefore research and other activities that provide credible evidence that can be used by Cost Planners in future cost plans at a very early stage of building projects is required.

Recommendation: Evidence of the type or attributes of a timber buildings that are quicker to erect is required. This can be achieved through a productivity study of various building sites and/or examples of actual buildings.

Recommendation: Early adopters of massive timber buildings should be encouraged to share experiences so that greater knowledge is available to Cost Planners. In the interim actual massive timber building designs could be developed to add to the database of knowledge.

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