CLT Concepts®

White Paper

ADDRESSING MAJOR BOTTLENECKS FOR THE ADOPTION OF TIMBER IN THE EMERGING MID-RISE MARKET

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EXECUTIVE SUMMARY

There are positive trends emerging that will encourage the increased use of mid-rise timber buildings. As interest grows, new bottlenecks to market growth have emerged within specific design professions, including Structural Engineers, Quantity Surveyors and Fire Engineers. This white paper's main objective is to find solutions to bottlenecks apparent in Structural Design. Findings include;

- There are currently approximately 25 timber specialists serving the market of 42,000 m3. In recent years, the ratio of volume specified per structural engineer is approximately 1500 m3/timber specialist.
- The number of Timber Specialists will need to increase significantly to enable the timber building market's potential exponential growth. This cohort enables and proactively suggests timber buildings to architects, potentially the most powerful and influential catalyst for increasing demand.
- There could be an ethical cohort of 1000 Structural Engineers to become Timber Specialists, influencing architects at the beginning of projects and consequently could result in 750,000m3 – 1,500,000m3 of timber specified per year. Only a fraction of this number would need to be unlocked to fulfill the capacity of the timber industry in the near term.
- All Structural Engineers begin as "Engineer Traditionalist" as timber is not adequately taught at university. To become a Timber Specialist, Engineers must learn on the job.
- While an engineer is in practice, this investment required can be significant. In total, this equates to approximately 800 unpaid hours made up of:
    - Learning Structural Design of Timber =~325 Hours
    - Design Tool Development (spreadsheets) =~351 Hours
    - Learning Structural Analysis =~124 hours
- When the specific design elements required are grouped at the building level, and in financial terms, this equates to:
    - 506 Unpaid Hours for Post and Beam Buildings (Geelong Civic Precinct)
    - 466 Unpaid Hours for Light-frame / CLT Hybrid Buildings (Phoenix Apartments)
    - 505 Unpaid Hours for a CLT Wall/Floor Building (240 Vic Street)
- The learning investment required results in engineering firms needing to take a significant net financial loss (in the tens of thousands of dollars) to learn and build the internal design capacity to take on future buildings.
- Currently, there is significant focus on aiding engineers in the much needed area of Learning Structural Design of Timber within industry. However, there is currently no industry focused on assisting with Design Tool Development (even though it is a problem of similar magnitude).

- There is a significant opportunity for the industry to improve the status quo for all Engineer Traditionalists on their journey to become Timber Specialists. A set of features has been recommended that would work best in software developed to meet the particular requirements of the timber ecosystem in the emerging mid-rise market.
- This paper suggests over 400 new Timber Specialists may be unlocked. This would yield a return significantly greater than the cost of software development.
- Software could be one of the fastest solutions to reduce the barriers to becoming a Timber Specialist. This can enable engineers to move from being a blocker, to a powerful engine of growth for timber buildings.

Part A:
This paper demonstrates the bottlenecks in adopting timber buildings in mid-rise construction.

Part B:
Presents a survey of existing timber specialist engineers. Quantifies the entry costs for an Engineer Traditionalist to become a Timber Specialist.

Part C:
Provides evidence and opportunity in creating a tailored software solution that solves unique problems of timber in mid-rise.

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PART A: BOTTLENECKS TO THE ADOPTION OF TIMBER IN MID-RISE CONSTRUCTION.

The Mid-rise Opportunity

In recent years, there has been an overall push toward a more sustainable building industry. As our buildings are becoming operationally efficient, the proportion of impacts that come from materials is increasing. In addition, the targets of major clients, developers and architects are shifting from energy to embodied energy as it is being solved. The impacts that fall under the banner of embodied energy and structural materials are the greatest proportion. In addition, research shows remarkable improvements in a building's occupants' health due to the benefits of biophilic design. And finally, digital design trends and offsite fabrication favour a timber solution.

How big is the opportunity in mid-rise?

- Mid-rise construction is on the rise around Australia, with a rapidly growing urban population and support for increased densification at all levels of government.
- While reports of dwelling approvals by building height were paused due to the rise of COVID-19, statistics reporting organizations found it more difficult to do their jobs. Data for the period of 2018-19 showed a mid-long-term trend of growth in approvals of mid-rise dwellings (Australian Bureau of Statistics, 2019).
- According to reports and analysis from the Australian Bureau of Statistics (2019), the number of dwellings in new 4-8 storey projects rose from 9,660 in 2008-09 to almost 24,000 in 2018-19, an increase of over 148%, or 14.8% per year.
- Assuming no increase in the number of mid-rise dwellings starts through 2019–22 and that a typical mid-rise project features approximately 60 dwellings, this suggests that about 400 mid-rise projects will start during the year 2022–23.
- Detailed analysis undertaken during the Wood Solutions Mid-rise Advisory Program of all mid-rise timber buildings in Australia (at the time) suggests that the average mid-rise mass timber project utilises between 1,500m3 and 2,500m3 of mass timber.
- With a 30% share of the current mid-rise multi-residential market, mass timber construction would feature in 120 projects, resulting in consumption of between 180,000m3 and 300,000m3 this year..
- Applying the long-term growth rate of 14.8% per year, a steady 30% market share of mid-rise multi-residential construction may result in annual demand for between 470,000m3 and 788,000m3 by 2030.

- As sustainability targets and building rating incentives increasingly focus on the embodied energy of our structures, it is plausible that the market share of timber construction may rise above 30% (depending on a number of factors, including supply availability.)
- In a best case scenario, 90% market share of mass timber in mid-rise multi-residential construction correlates with a current demand of between 540,000m3 and 900,000m3, or between 1,419,000m3 and 2,365,000m3 by 2030 (assuming future growth is in line with the decade to 2018-19).
- This estimation of market size doesn't include the commercial office, or emerging high-rise market for mass timber.

How well the bottlenecks are resolved will determine whether the opportunity stays at 42,000 m3/year, increases to 300,000 m3/year, or even reaches its theoretical maximum of 788,000 m3/year.

The demand generation at the early stage of a project is building. According to interviews conducted, the "top of funnel" is less of an issue to the adoption of mid-rise timber buildings due to trends towards sustainability and reductions in embodied carbon. The major issues arise in the "mid-funnel", where different consultants significantly influence something new to them, in the direction of their comfort zone. According to interviews, the two most common responses for bottlenecks in adopting mid-rise buildings were Structural Engineers, Quantity Surveyors and Compliance.

Structural Engineer:
If an architect is looking for a specific low-embodied carbon structural material, they first speak to the building's structural engineer. This is a critical bottleneck moment based on the experience and willingness of the engineer.

Timber Specialist:
If a timber specialist is engaged, the timber option, assuming it is the best solution based on the client's goals, is likely to be included in a concept design.

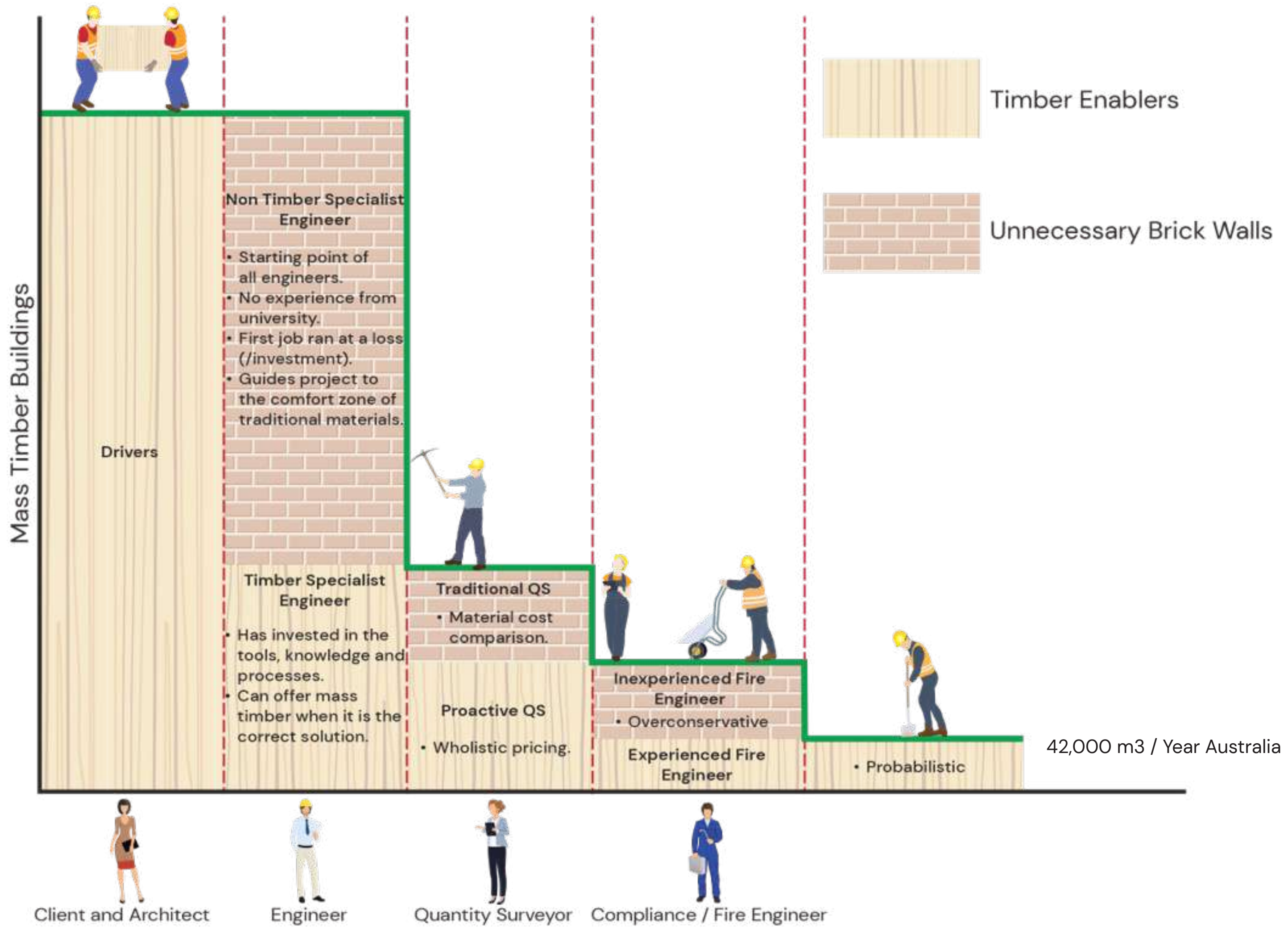
Engineer Traditionalist:
If the engineer is without experience, then a timber solution is unlikely to be proposed (for reasons explained later in the report).

Quantity Surveyor (QS)
Once the structural solution has been sized up, a quantity surveyor may be engaged.

If the QS has no experience in offsite construction, then they are likely to deliver holistic pricing. This considers the preliminary savings and opportunity cost for earlier occupancy alongside the material price for a fair comparison of concrete and timber.
A simple material price comparison will be made if the QS lacks experience or intent. The traditional solution is likely to be much more appealing when looking at the material alone.

Fire Engineer,
The subjectivity in the fire engineering community leads to varied fire-engineered solutions between buildings. One building may have a predominately exposed timber (demonstrating biophilia and sustainability benefits), and another may have the expense of 3 layers of 16mm plasterboard. This subjectivity may lead to significant costs on some buildings, whereas they are avoided altogether for others.

As depicted below:
The demand side of clients and architects is building. If they can get the engagement of a timber specialist, a proactive QS, and finally, an experienced and confident fire engineer and certifier, then a building is likely to proceed. This flow from the top of funnel to the bottom results in the market demand we see today (42,000 m3). Working on these bottlenecks (depicted as brick walls) will likely yield positive growth in the mid-rise market.



Mass Timber Buildings
Timber Enablers
Unnecessary Brick Walls
Drivers
Non Timber Specialist Engineer
• Starting point of all engineers.
• No experience from university.
• First job ran at a loss (/investment).
• Guides project to the comfort zone of traditional materials.
Timber Specialist Engineer
• Has invested in the tools, knowledge and processes.
• Can offer mass timber when it is the correct solution.
Traditional QS
• Material cost comparison.
Proactive QS
• Wholistic pricing.
Inexperienced Fire Engineer
• Overconservative
Experienced Fire Engineer
• Probabilistic
42,000 m3 / Year Australia
Client and Architect
Engineer
Quantity Surveyor
Compliance / Fire Engineer

Focusing On the Timber Specialist Bottleneck – Relieving Supply Bottlenecks by Increasing Timber Specialists
Out of the three brick walls raised, establishing more timber specialists is likely to yield the most significant change to the adoption of timber buildings. A Timber Specialist who is confident in designing with timber has more influence for the jobs at the early stages on architects, designs more cost efficiently and has secondary impacts on QS and Fire Legislation.

The purpose of this white paper and the proposed solution is specifically on Structural engineers.

As timber is not currently taught at universities and there are limited design tools available, engineers must invest their own time (often unpaid) in embarking on a learning journey to design a timber building. An Engineer Traditionalist provided their painful experience of attempting a detailed design of a mass timber building. He described how he spent over 100 hours learning and creating spreadsheets on his own. After investing significantly into the project's timber solution, he was kicked off the job in favour of a timber specialist. He also mentioned that it is too difficult and wouldn't suggest a timber option if he had his time again.

When architects are looking for a low embodied carbon solution, they often contact the engineers with whom they have already built a relationship and trust. If the engineer they seek is:

1. A Timber Specialist: The timber solution is likely to be proposed with confidence, assuming it is the most appropriate option.
2. The Engineer Traditionalist may seek a specialist engineer to aid with the timber design. This would need the traditionalist to acknowledge the lack of knowledge they might have in an area. If a collaborative scope is developed, then the timber option may still survive.
3. Engineer Traditionalists want to steer the project in the direction of their comfort zone, using traditional materials. This is a lost opportunity for a mass timber project.
4. Certification: A Timber Specialist skillset is required to assess the drawings and computations of the lead designer.

In addition, some timber experts may proactively suggest a timber solution to architects because it is crucial to the design and certification process. In this sense, the Structural Engineering community can transform from the major blocker, to a major engine of growth to the mid-rise market. As the supply chain is not engaged in the early stages of a project, these early timber suggestions can result in a significant increase of inbound leads and sales for timber suppliers.

In any scenario where a timber solution is successful, it is highly dependent on finding at least two timber specialists: one for the initial design and the other for the certification.

The m3 value that a timber specialist is responsible for is listed in the following section. We can then estimate how many Timber Specialists the timber industry will require to meet projected 2025 supplier capacities, as well as the theoretical demand that can come from the mid-rise sector. The reader is free to modify the assumptions as they see fit in order to reach their own conclusions.

How many timber specialists support the current volume of mid-rise timber construction?

- In 2020, approximately 37,050m3 of timber was specified in mid-rise timber buildings.
- Survey results suggest approximately 25 Timber Specialists in the Australian region.
- A single engineer is currently responsible for the certification of approximately 1500 m3/year in the status quo situation. Interviews suggest that the engineering standard for mid-rise timber buildings can improve significantly. In addition, there is a general gap in certifying engineers available for mid-rise projects. Therefore a “goal” of doubling the engineers for the current volume would have each timber specialist specifying 750m3 / year.
- With these figures, we can ascertain that a Timber Specialist can be responsible for between 750m3 (ideal) – 1500m3 (status quo).

How many timber specialists do we need to meet future projections?

- We can now plot the required Timber Specialists against the future market projections of mid-rise timber buildings.
- The timber industry may need to increase the number of Timber Specialists in the community by 10-20 times to meet the exceptional potential of the emerging mid-rise market.
- To meet theoretical best case scenarios for timber specification, the number would be much higher.

Future	m3	# Timber Specialists (Status Quo,1500m3/ Specialist)	# Timber Specialists (Ideal,750m3/ Specialist)
Status Quo	37,050	25	50
30% by 2030	400,000	267	533
80% by 2030	1,880,000	1253	2,507

Table 1

How many Engineer Traditionalists be willing to become Timber Specialists?

- Engineers do not currently get their education at university. Therefore, we need to pull from the existing cohort of Structural Engineers practicing today.
- ABS Labour Force Survey suggests there were 118K employed engineers (heavy and civil engineering construction – appears to include services, Geotech, etc.) in August 2022, but Aus government Labour Market Insights suggest there were 6,300 operating structural engineers. If we index this total number of Structural engineers to 2022 based on the growth in the total number of engineers, we get 9,945 structural engineers.
- Assuming the number of structural engineers continues to increase in a linear fashion, following the growth rates since 2016, we can calculate that in 2030 there will be ~24,000 structural engineers.
- Consumer archetypes suggest that 10% of the population act with the future in mind for the benefit of others. This can be applied as ethically conscious engineers willing to proactively suggest a timber solution instead of concrete and steel.
- Within the 10,000 structural engineers in 2022, there may be an active and willing segment of 1000 willing to become Timber Specialists available today.
- This ethical cohort of 1000 Timber Specialists, influencing architects at the beginning of projects, could result in hypothetically 750,000m3 – 1,500,000m3 of timber specified. Only a fraction of this number would need to be unlocked to fulfill the capacity of the timber industry in the near term.

Theoretically, analysis has shown that there could be 1000 engineers who might be ethically conscious of designing timber. However, we are only left with approximately 25 specialists. Why are we left with such a small number?

Part B of this White Paper provides further context on the significant unpaid learning investment required to make the transition.

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Australian Bureau of Statistics (August 2022) 'Table 06: Employed personas by Industry sub-division of main job (ANZSIC) and Sex' [data set], 6291.0.55.001 Labour Force, Australia, Detailed, accessed 19 November 2022.

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PART B: DEMONSTRATING THE BARRIERS THAT AN ENGINEER TRADITIONALIST FACES IN BECOMING A TIMBER SPECIALIST.

How hard is it to become a timber specialist?
Because there is a reasonable degree of learning timber design in mid-rise construction at university, all engineers must become Timber Specialists on the job. This requires a level of investment from the engineering firm and/or the individual themselves to make the journey.

The best cohort to understand the nature of this investment required best comes from the Timber Specialists. Given the planning fallacy, they are best positioned to understand all of the unknown unknowns that an Engineer Traditionalist is likely to encounter while designing a timber building.

This[1] detailed survey was conducted by prominent engineers who have spent time working in engineering consultancies. The nature of the question requires a high understanding of all of timber design; therefore, the survey was kept limited in its number of applicants. The goal was to quantify the exact learning investment required for a timber building. The learning and development journey was broken down into:

Design Learning Curve:

- Structural design is the design of a specific element. For example, the engineer may need to read a Guide, such as FP Innovations CLT Handbook, to learn how to design a CLT floor panel.
- Learning could be defined as the time spent reading, experimenting, or checking calculations. This is a period that is required when you first design the element, which is no longer needed once you become a “timber specialist”

Design Processes and Tools:

- Typically, there is a big difference in the time it takes between the first time you create the computation, and when you are more experienced. This is due to the “set up” time it takes to make the calculation routine automated and reliable for future efficiencies. For example, an engineer may create an excel spreadsheet based on the design routines mentioned in CLT handbook for a CLT floor panel.

This detailed survey was of 3 Leading Timber Specialists in Australia. Each were very experienced in design of mass timber which typically requires spreadsheets for all design. We can expect more off-the-shelf software such as Cadecomp or Clear Calcs to replace the spreadsheets for some light-weight applications. A smaller cohort of Timber Specialists with the full context of timber design allowed for higher quality data for the purposes intended. The survey and interview methodologies can be found in Appendix 1.

Analysis Tools and Learning Curve:

- Although “analysis” is based on engineering fundamentals learnt at university, there are new things to learn when it comes to mass timber. For example, an engineer may use familiar software that is material agnostic such as Etabs, in their first attempt at structural analysis. This is used to determine the forces on the structure. However, there is “additional learning” for the timber-specific components of analysis and new software tools like Dlubal RFEM.

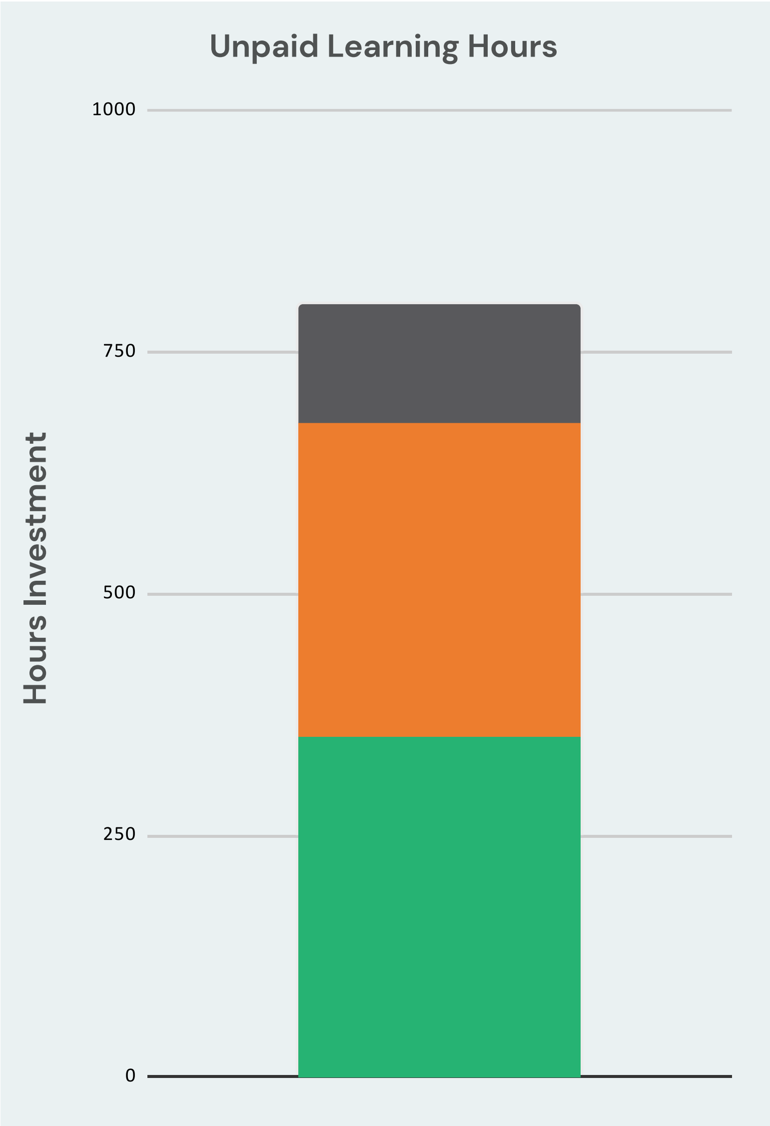
Unpaid Learning – The Full Journey to Timber Specialist

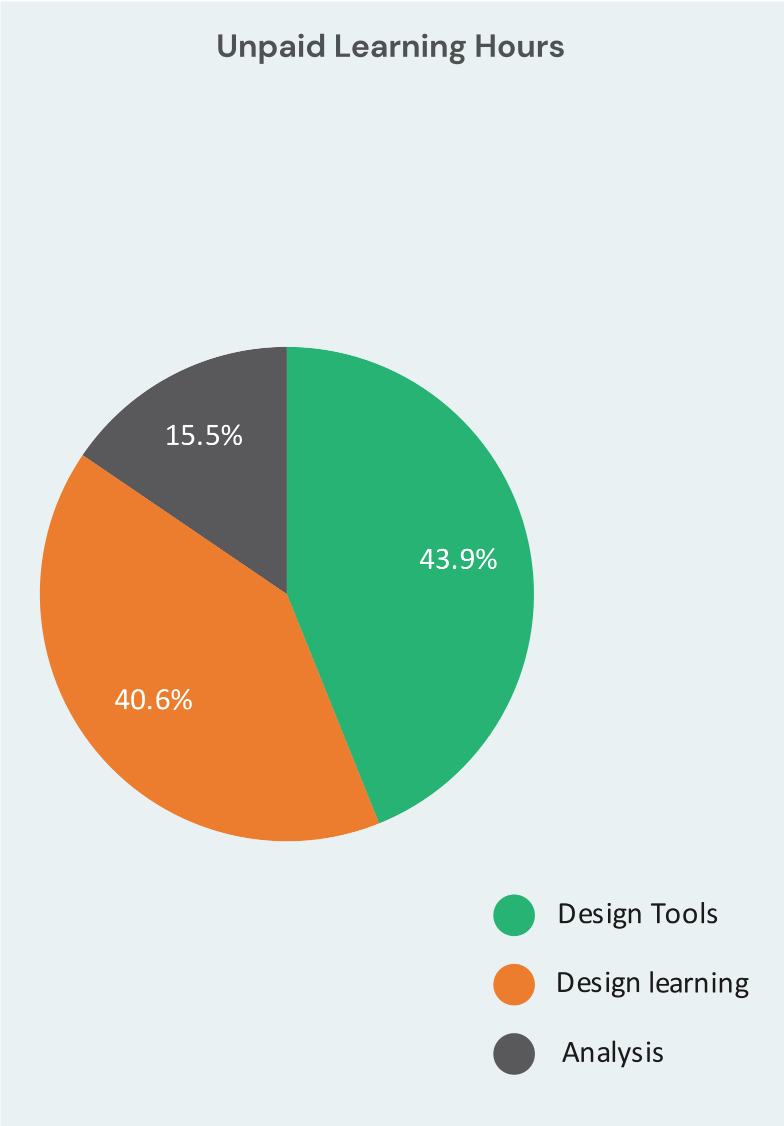
The findings of the overall learning investment journey are below.

Finding – Survey results estimate a total of 800 unpaid hours is required to make the journey from “Engineer Traditionalist’ to a “Timber Specialist”.

This includes:

- 352 hours in building internal design tools, 325 hours in learning design and 124 hours in learning structural analysis (as it relates to timber).


Unpaid Learning Hours
1000
750
500
250
0
Hours Investment


Unpaid Learning Hours
15.5%
43.9%
40.6%
Design Tools
Design learning
Analysis

Unpaid Learning – By Project
In the survey, the design elements were broken up into their individual components. This enables the regrouping of design elements and quantifying learning hours required for each building.

Three buildings have been considered to represent the majority of timber building products relevant to mid-rise timber buildings in the supply chain.

Title: Geelong Civic Precinct (Watpac)

Sturcture: CLT Floors, GLT Post and Beam.

Building: Office

Title: Phoenix Apartments (Strongbuild)

Sturcture: CLT Floors, LVL studs, ply bracing, concrete core.

Building: Apartments

Title: 240 Vic St (Multiplex)

Sturcture: CLT Floors, CLT walls

Building: Hotel

Figure 5

	Approach	Design Tools Development (Hours)	Design Learning (Hours)	Geelong - Post and Beam	240 Vic St - CLT Wall / CLT Floor	Pheonix Apartments
CLT Floor (Ambient)	Excel	26.7	21.3	✓	✓	✓
CLT Floor (Fire)	Excel	17.3	21.3	✓	✓	✗
CLT Wall (Ambient)	Excel	26.7	21.3	✗	✓	✗
CLT Wall (Fire)	Excel	16.0	21.3	✗	✓	✗
Mass Timber Beam (Ambient)	Excel	23.3	4.7	✓	✗	✗
Mass Timber Beam (Fire)	Excel	2.7	4.7	✓	✗	✗
Mass Timber Beam Penetration and Reinforcement	Excel	10.0	4.0	✓	✗	✗
Mass Timber Column (Ambient)	Excel	9.0	8.7	✓	✗	✗
Mass Timber Column (Fire)	Excel	6.7	6.0	✓	✗	✗
Mass Timber K-brace (Stability)	Excel	1.3	5.3	✓	✗	✗
CLT Floor Point Load (Ambient)	Excel	4.0	7.3	✓	✓	✗
CLT Floor Point Load (Fire)	Excel	2.0	6.7	✓	✗	✗
CLT Lintel Design	Excel	9.3	8.0	✗	✓	✗
CLT In-plane Strength (Shear Wall / Diaphragm)	Excel	11.3	13.3	✓	✓	✗

CLT In-plane Stiffness (Shear Wall / Diaphragm)	Excel	5.3	10.7	✓	✓	✗
CLT / GLT Ribbed Deck Design	Excel	16.7	8.7	✗	✗	✗
CLT / Concrete Composite	Excel	16.7	8.0	✗	✗	✗
Screw Design	Excel	17.3	16.7	✓	✓	✓
Bracket Design	Excel	16.7	14.0	✓	✓	✓
Beam Column Connection (Custom Bracketry)	Excel	9.0	11.3	✓	✗	✗
Beam Column Connection (Proprietary)	Excel	6.8	9.0	✓	✗	✗
Robustness Design Calcula-tions (Full Suite of Checks)	Excel	13.3	30.7	✓	✓	✓
Stud Design (Light frame)	Excel	8.7	11.3	✗	✗	✓
Light-frame Shear Wall Design (Strength)	Excel	16.7	4.7	✗	✗	✓
Light-frame Shear Wall Design (Stiffness)	Excel	19.3	2.0	✗	✗	✓
Crushing (CLT Floor / CLT Wall)	Excel	5.0	4.0	✗	✓	✗
Crushing (Light-frame Building)	Excel	4.3	4.0	✗	✗	✓
Crushing (Post and Beam Building)	Excel	6.7	1.3	✓	✗	✗
Tolerance Calculations (CLT Floor / CLT Wall)	Excel	10.7	12.0	✗	✓	✗
Tolerance Calculations (Post and Beam)	Excel	6.0	11.3	✓	✗	✗

Tolerance Calculations (Light-frame)	Excel	6.0	11.3	✗	✗	✓

Table 3

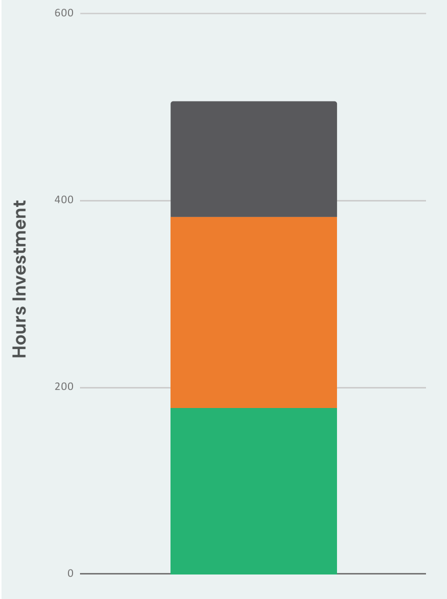
Analysis					
	Common Approach (Mode)	Learning (Hours)	Geelong – Post and Beam (Hours)	240 Vic St – CLT Wall / CLT Floor (Hours)	Phoenix Apartments (Hours)
Analysis	Dlubal RFEM	120	120	120	120

Table 4

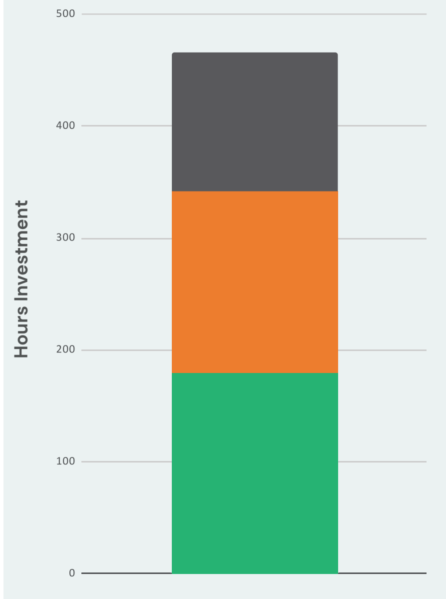
An Engineers Perspective

There is a significant learning curve for new engineers looking to design their first mid-rise timber building.

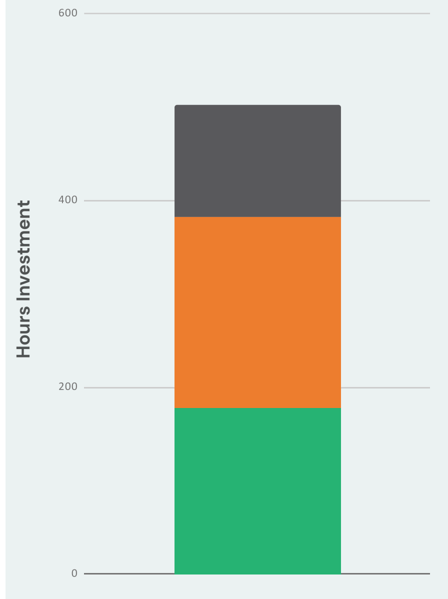
506 Unpaid Learning Hours



466 Unpaid Learning Hours



505 Unpaid Learning Hours



This learning investment can be put into dollar terms using the estimated market rate of a design engineer ($200 / hour). Best guess estimates and assumptions of structural design fees have been made.

	Cost	Design Fee	Net Profit
Full Journey	$160,100	-	
Geelong - Post and Beam	$101,300	$80,000	-$21,300
240 Vic Street	$101,000	$40,000	-$61,000
Phoenix Apartments	$93,200	$60,000	-$33,200

Table 5

Finding – The learning transition could cost an engineering firm approximately $100,000 in development. This could result in a significant loss when bidding for projects.

Here underlies the potential friction for a structural engineer traditionalist looking to move into timber buildings. Quite simply, the investment required might be too steep for a company/individual to make.

There will rarely be adequate time in a design program to take 800 hours to learn (100 days of unpaid work). Engineers can start learning before the opportunity to arises, but this is a big ask for an individual to do outside of work hours. The company would need to grant the engineer training time. However, this is unlikely as:

- The individual learning is less likely to get assistance from industry experts or suppliers if there is no project opportunity involved.
- The investment is harder to justify if no project income is available to offset the time spent.
- The investment is risky as the individual may leave the company, and with it take that large learning investment.

Therefore, reducing this upfront investment of time and money to learn is key to unlocking more Timber Specialists.


Status Quo
Become A Timber Specialist
Learn Structural Analysis
124 Unpaid Hours
Develop Design Tools
178 Unpaid Hours
Learning Timber Design
204 Unpaid Hours

Options to Reduce the Unpaid Learning of Engineers
Ideally, there would be zero friction for engineers choosing the path to become a timber specialist. Unfortunately, there is currently a significant bridge to overcome. We can assume that there is a correlation between reducing the unpaid hours required to invest in a timber building and the number of timber specialists available. This, by nature, is extremely uncertain but directionally accurate.

Plotting the removal of friction against # of timber specialists.

Status Quo = $100,000 Cost for Only 25 Timber Specialists

The current status quo yields $100,000 transition costs and only 25 timber specialists.

Ideal Scenario = Zero Relative Cost For 1000 Timber Specialists

In the previous reasoning, we found that 10% of structural engineers might be at least interested in becoming a Timber Specialist based on ethical grounds. This could be a cohort of 1000 willing engineers (assuming no relative investment is required). This could be plotted as “an ideal” scenario for developing timber buildings.

By removing entry costs, we can enable a greater cohort of timber specialists in the community. The frictions are plotted against the potential number of engineers in Figure 7.

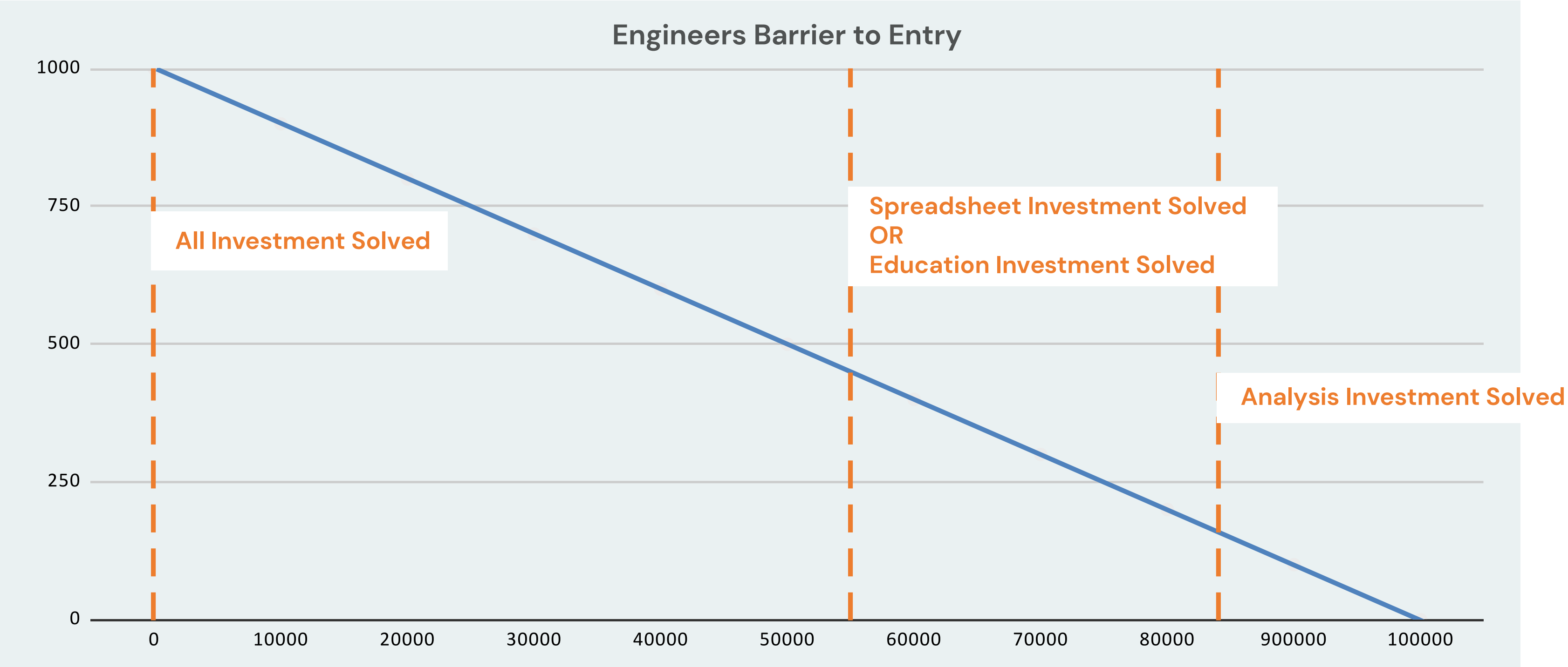


Figure7

This chart has a large amount of uncertainty and variability but can be considered directionally accurate. If there was a reduction in the overall investment required to overcome the journey, we are more likely to have Timber Specialists proactively designing timber buildings.

Currently, some parties are focusing on improving the education of Structural Engineers, particularly at university level. This is likely to pay significant dividends in the future.

However, an equal and typically overlooked opportunity is the time an engineer invests in creating internal design spreadsheets. There is an opportunity for the industry to collaborate on eliminating this investment for incoming Engineer Traditionalists. This is covered in the final section of this white paper.

By removing "Spreadsheet Investment", 352 hourse of unpaid learning can be saved. This could unlock the bottlerneck of Timber Specialist Engineers to enable significant growth of EWPs in the emerging mind-rise sector.

PART C: THE CASE FOR AN OFF-THE-SHELF SOFTWARE SOLUTION TO ENABLE GROWTH IN THE ADOPTION OF TIMBER BUILDINGS.

Addressing the Friction Of Engineer Traditionalists

As the market of structural material matures, software solutions are developed, and key frictions are solved. The mid-rise timber industry is yet to develop to the point of automating the most common design calculations for Australian engineers. A key step in developing and closing the gap between concrete and steel is providing the tools required to design efficiently and effectively.

Currently, structural engineers are building spreadsheets in order to complete their designs. This is a flawed solution for several reasons:

- In order to build the 31 Design Spreadsheets to quickly and accurately specify timber buildings, it would take up to 352 total hours ($70,400). This is likely a barrier that will make an engineer perform in the direction of their comfort zone.
- These costs, in one way or the other, are likely to be accounted for in design fees. This will make the timber option more expensive than the concrete option.
- Each design firm creates a different spreadsheet. This is unnecessary waste across projects as the wheel is constantly being reinvented.
- A single design spreadsheet undergoes a significant number of evolutions as an engineer becomes more confident in timber design. It is unlikely that the Engineer Traditionalist is efficiently or accurately designing products in the timber ecosystem on their first attempt.
- Being an immature industry, new design methods are constantly evolving (and spreadsheets are required to change). For example, in 2023, a new vibration method will be proposed in the next iteration of CLT design in Eurocode. If this were considered the superior vibration method, all spreadsheets would have to change.

During the interview process, it was discussed how a tailored software solution could meet the unique design requirements of the timber industry.

Exploring Software Solution Requirements
Structural engineers and suppliers were all interviewed on what a tailored software solution would look like for the timber sector. The priorities, pitfalls and opportunities of a solution are described below:

Interview Finding: Software should be supplier agnostic
In the Zoom interviews, some software was mentioned, such as "Stora Enso Calculitis". Such software is useful in assisting engineers in designing their products. However, such software is known to be a "sales tool" built for the benefit of the supplier rather than the engineer. Engineers would prefer to "pay" for a tool that was built for them. This would allow them to swap suppliers and compare design solutions on an apples-to-apples basis.

Interview Finding: Software should not be a black box
There was overwhelming consensus that all software shouldn't operate in a black box. When designing concrete and steel, there is a greater understanding and context of the design approaches (given that it is taught at university). When it comes to timber, there is less understanding and multiple design approaches. This will allow the engineer to trust the calculations produced in the design.

Interview Finding: Software should overcome the difficulty of suppliers having different grades.
Suppliers have different product grades, which can be confusing for engineering traditionalists. This is a specific problem with CLT because it has various lamella thicknesses, grades, layups, and orientations.

Interview Finding: Software should have the stock that is available.
A critical component of timber design is to specify what is readily available in the supply chain. For engineers and the supply chain, going through the design development process with items that seem to be unavailable later is painful.

Interview Finding: Software should have the ability to plug-in to the evolving software ecosystem.
A timber specialist was especially interested in the need for the software to plug-in to the software ecosystem they are developing. This can be conducted through Application Program Interfaces and be able to attach itself to the design automation available with applications such as grasshopper and Revit.

Interview Finding: Software should be verified with a design committee.
Ideally, the software recommended design approaches would be based on the technical input from the most experienced engineers in the region. This would remove some of the uncertainty about whether or not a particular engineer is utilizing the best practice design method.

Interview Finding: Software should be educational.
As illustrated in Part B, engineers take 325 hours to learn the fundamentals of timber design. This could perhaps be improved if the software had a focus on education. For example, this could include resources, tutorials and videos on design.

Interview Finding: Analogues software in concrete and steel.
A common useful software that is quick, easy and intuitive is the "Structural Toolkit". This is a software used for quick element design of concrete and steel. Something similar would be highly valuable for an engineering traditionalist in designing products in the timber ecosystem.

Current Software Solutions

Existing software solutions have been rated against the requirements suggested in the interviews.
As described in Table 6 below, no software solutions are specifically tailored for solving the replication of design spreadsheets in the timber design ecosystem.

	TimberTech	Tekla Teds	Calculitis
1. Supplier Agnostic	✓	✓	✗
2. Not a Black Box	✗	✓	✗
3. Ease of Supplier Change	✓	✓	✗
4. Up-to-date Availability	✗	✗	✓
5. Evolving Ecosystem (APIs etc)	✗	✗	✗
6. Verified by Technical Experts	✓	✓	✓
7. Educational Opportunity	✗	✗	✗

Table 6

Market Approach To A Software Solution

Investment:
The timber industry has consistently produced software as a single supplier. It is commonly used as a free software sales tool. This is a model used by Stora Enso Calculitis for CLT (Europe), Spax Screw Design (Europe), Rothoblaas Connections (My Project), and Hyne Design Software. The industry consensus on software costs is that development costs at least $1 million, with annual maintenance costs in the hundreds of thousands of dollars. This would equate to an investment of approximately $2m over 5 years.

Return:
As discussed in Part B, Design Tool Development equated to approximately 44% of the overall investment an Engineer Makes in becoming a Timber Specialist.

- Each Timber Specialist can be considered responsible in todays figures for approximately 750m3 – 1500m3 (Part A of Report).
- Figure 7 shows the linear scale of the return on investment for removing the barriers for Structural Engineers. Removing the frictions in design tool development could unlock over 400 new Timber Specialists.
- This equates to approximately 450,000m3 – 900,000m3 of material specified each year. At $1500 / m3, this equates to $450m - $900m / year of revenue.

Such an ethical cohort of Structural Engineers, specifying the timber solution could result in a transformation of the emerging market of engineered wood products. This could result in inbound leads for the EWP industry far exceeding near term capacities.

Path 1 – Single Supplier Solution
One option is for a supplier to build the solution themselves. In doing so, they will likely obtain a competitive advantage in providing the simplest path for structural engineers to design their product.

According to game theory, if one supplier moves and develops this much-needed software to gain a competitive advantage, the competing suppliers are likely to follow. In the process, they reinvent the wheel and replicate development and maintenance costs. Competitively, both suppliers would start and finish at the same relative position.

Furthermore, it is likely that the suppliers will not combine forces with a technical committee that creates consensus on design methods. And in addition, it is not what the engineer would prefer. The engineer would ideally like software built with them as the primary user, allowing them to switch between suppliers and design efficiently and effectively, as well as successfully design in timber.

Path 2 – Multiple Supplier Solution
A grow the pie approach would allow for the splitting of the initial product development and software maintenance fees. In addition, costs can be dramatically driven down by subsidizing development costs by charging the primary customer (the engineer) a subscription fee.

It also serves the benefits of:
- Sharing initial software development costs.
- Sharing of ongoing software maintenance fees.
- Dedication to the needs of the timber industry.
- Centralized design committee to agree on preferred design methods.
- Dedication to the needs of structural engineers designing with timber in mid-rise.

Recommendation:
The timber supply chain can unlock significant demand by building a software tailored to the unique needs of designing with timber in mid-high rise.

Conclusion

In summary, the overall demand for mass timber products is rising in Australasia due to architects and developers. The mid-funnel designers have been flagged as the potential bottleneck for the next growth stage in mid-rise buildings. Structural engineers have been identified as a key deciding stakeholder who determines whether a building will successfully timber or not. In Australia, there could potentially be 1000 structural engineers saying "yes" when the time arises or proactively specifying a timber solution in lieu of concrete and steel.

In order to achieve the goals of a growing and thriving market of timber products in mid-rise construction, there should be adequate Timber Specialists to design and certify timber buildings. Given the lack of university education, this transition will need to be taken by practicing engineers who are designing with traditional materials today.

There is likely an ethical cohort of the structural engineering community who would proactively design with timber products. But from an Engineer traditionalist's perspective, one must have the arduous approach of the learning curve and building in-house design tools. Some may be willing to trudge through the mud with determination in order to become timber specialists. For most, however, the average time investment of 500 hours ($100,000) is simply too much. The comfort zone of the status quo is preferable. In the process, the adoption of timber mid-rise buildings is compromised.

The learning curve cannot be completely cheated. However, reducing the overall friction for the path of a traditional engineer going through the timber route will likely increase the overall market volume EWPs. Suppliers will directly benefit from helping structural engineers design their products.

In terms of action and tangibility, the major solution presented is an off-the-shelf solution that designs with the entire timber ecosystem. This would reduce and expedite a major cost (spreadsheet design development) of engineering designing with a timber solution for the first time. Being software, there is an opportunity to tailor it to the unique needs of the emerging market in mid-rise construction. This white paper estimates that 400 new Timber Specialists could be unlocked out of the identified 1000 Structural Engineers who may proactively suggest ethical solutions. Currently, no software solutions are adequately tailored to the unique needs specified in interviews.

A timber design software that can design with the whole ecosystem of timber products, specifically for the Australian and New Zealand region, can significantly give a helping hand to the structural design community. By reducing the friction of the learning journey, the supply chain can unlock a major bottleneck for the volume output of timber products.

APPENDIX A - METHODOLOGY

The study had the following engagement with structural engineers and the industry supply chain:

Zoom interviews with the Structural Engineering Community.

- Organisations include WSP, TTW, ARUP, Robert Birds, SDA Structures, PTL, Structerre, Van Der Meer, Laker Group, Mott McDonalds, Born-horst and Ward, and Van Der Meer.
- Seniority within the company varied during the interviews. Some worked with the Director of Structures (in charge of leading a team), while others worked with Design Engineers (in charge of completing a design).
- The number of interview participants varied between 1 and 9 (based on the firm's curiosity to participate in the questions).
- The engineer interviews were recorded, suggesting it was only for "my use".

Zoom Interviews with the timber supply chain (and suppliers of other materials when exploring hybrid solutions).

The purpose was to discover:

- The perceived bottlenecks to timber adoption in mid-rise
- The issues regarding the lack of engineering knowledge in the design community
- The willingness to collaborate between suppliers on shared issues.

A survey of Top Timber Specialists in Australia

The purpose of the survey was to:

- Quantify the total friction in the transition from an engineer traditionalist to a timber specialist. It was considered that the quality of the data was best if it came from only the best timber specialists who had already overcome the learning curve for timber.

All of the major findings based on the interviews and surveys are clearly labelled as "Findings" for transparency. Any finding can be substantiated upon request but will require permission from the engineer who was interviewed.

The findings are based on the chronological order of the interviews conducted. All findings are related specifically to the frictions that result in bottlenecks for the adoption of timber

APPENDIX B

The Design Process And Corresponding Frictions For Structural Engineers Interviewed

The following section details the frictions as they relate to the different stages of the structural design of a timber building.

Concept Design

Finding 1: Conservatism in Early Design
According to the interviews, conservatism is layered on top of the design to deal with uncertainties. If an engineer can confidently design in timber, then they are likely to find more efficiency.

Finding 2: Inadequate Considerations for DfMA at Early Designs
Amongst suppliers, it was consistently mentioned that concept designs typically do not adequately consider the supply chain at these early stages. For example, one supplier stated that the beam sizes specified were greater than the overall truck length, and another stated that the screws specified were unavailable.

Detailed Design – Analysis

The detailed design process consists of both “Structural Design” and “Structural Analysis”. Once a structural design is completed, an engineer will also be more confident with future concept designs and find more efficiency.

Analysis uses engineering theory that is taught at university. Engineers are somewhat familiar with analysis principles that span across all materials. However, given that timber is orthotropic, some unfamiliar principles may require additional learning.

In terms of tools, Engineer Traditionalists use Etabs, Microstran or Spacegass. Timber Specialists are typically able to use these tools but use Timber Specialist analyst software such as Dlubal RFEM.

Most engineers didn’t label analysis as a major friction. However, many engineers are unaware that their analysis software isn’t fit for the purpose of timber buildings. It may fall into the category of “unknown unknowns

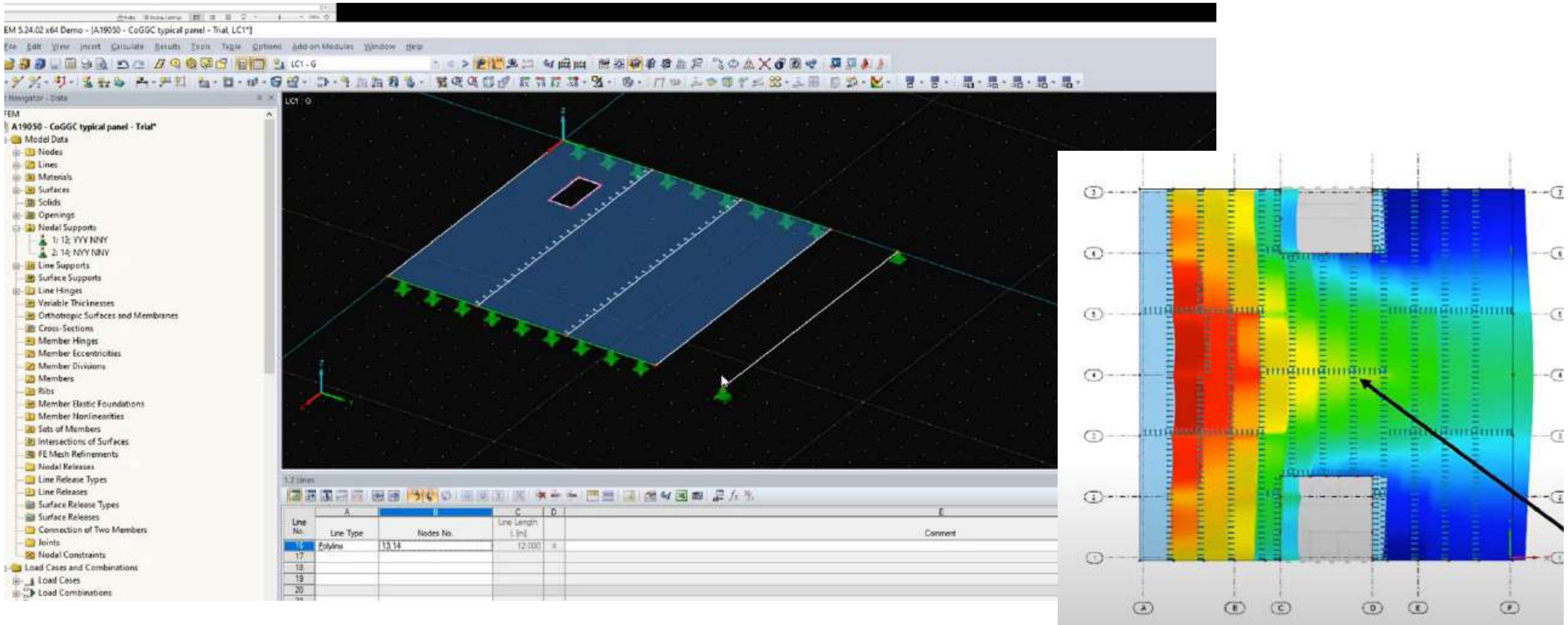


Figure 8: Structural Analysis via Dlubal RFEM

Detailed Design – Structural Design
Structural Design relies on codes and standards around the world. If there is a clear compliance pathway, as in concrete and steel, the engineer can use it to complete the design. If there isn't, the engineer is required to follow a performance-based design (as required with CLT). This was consistently considered a friction point for the structural engineers interviewed. A list of findings on the friction for design includes the following.

Finding 4: Lack of consensus on design methods for mass timber.
There are many ways to design in mass timber as it is performance-based. Given there is no clear consensus, engineers must learn how to combine different design methods from around the world with local codes. This is time-consuming and there is also some uncertainty about the path an engineer will take.

Finding 5: Supplier span tables don't provide support for detailed design.
Some engineers were surprised to learn that a supplier span table was insufficient to be used for a detailed design. Instead, they needed to go through the processes and build the internal tools to produce the computation report required for certification. This was an extra hurdle they initially didn't know they had to deal with.

Finding 6 - Certifiers finding it difficult to read timber specialist computations.
One common building delivery method is to have a base building engineer provide the design of the entire building and have a timber specialist focus on the timber component. However, the building certifier is typically not a timber specialist. Hence such certifiers find it difficult to understand and check the designs of the timber specialist.

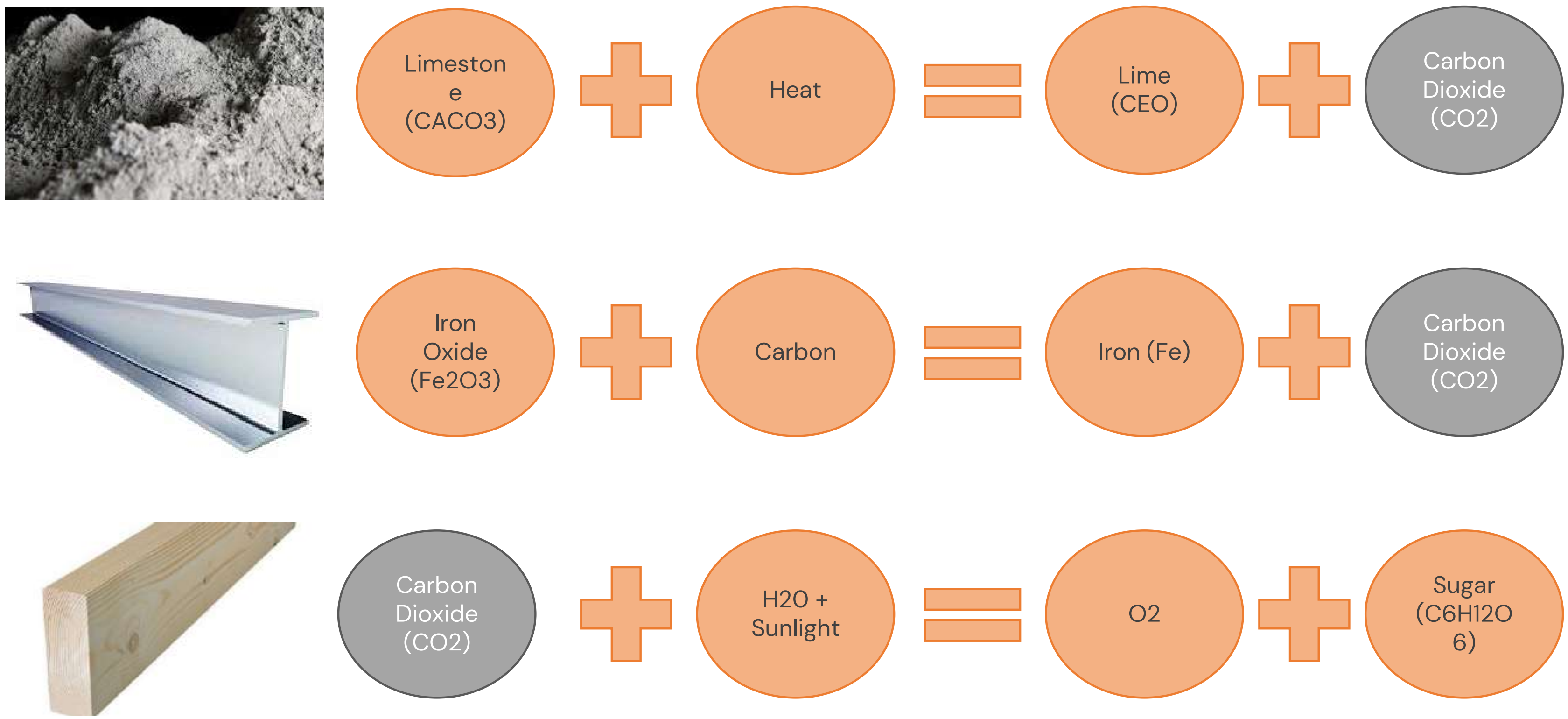
Finding 7: Engineer will design to the path of least resistance
As an analogy, an engineer mentioned the process of designing chemical anchors. One supplier, Ramset, offers large design guide booklets. Another supplier, Hilti, offers very intuitive and easy-to-use software. The engineer chooses to design with Hilti as it is the simplest and quickest path to design (all products being equal).

Finding 8: Engineers look for off-the-shelf software solutions, then fill the gaps with spreadsheets.
Engineers will typically use off-the-shelf solutions that are reliable in the design of an element. If the solution is unavailable in software format, the engineer will then develop in-house spreadsheets to perform the design.

Finding 9 - The significant learning investment required in pursuing a timber building.
As timber is not currently taught at university, and limited tools are available to aid design, engineers are required to invest their own time (often unpaid) in learning how to design a timber building. An Engineer Traditionalist provided their painful experience of attempting a detailed design of a mass timber building. In his account, he described how he dedicated more than 100 hours of his own time to learning and building spreadsheet. After investing significantly into the timber solution for the project, he was fired in favour of a timber specialist. He also mentioned that it is too difficult, and wouldn't suggest a timber option if he had his time again.

APPENDIX C

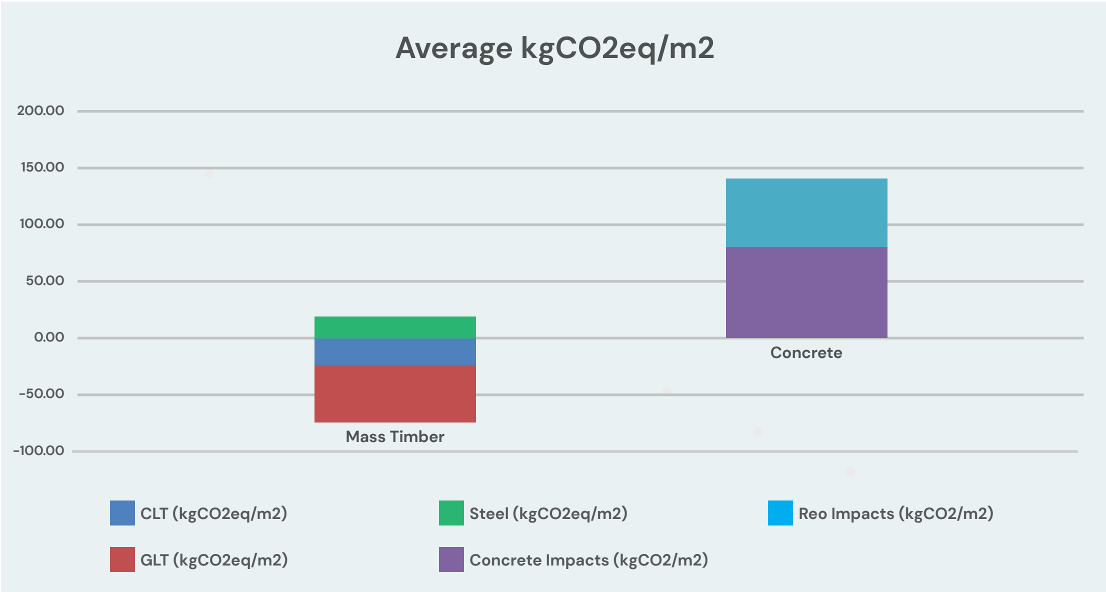
The Sustainability Impacts Of Increasing The Specification Of Timber In Lieu Of Concrete And Steel
Cement is currently considered to be above 8% of the world's greenhouse gas emissions, due to chemical processes and heat requirements.



What is the impact of 1,000,000m3 of timber, specified in lieu of concrete in this emerging market?

Using timber has the opportunity to sequester biogenic carbon, and offset the impacts of concrete. A quick back of the envelop comparison of the two per m2 is possible if we can make the following assumptions.

- For the mass timber building we can assumer:
    - A mass timber volume of 0.3 m3/m2
    - Steel quantities of 5 kg/m2
- For the traditional construction building we can assume:
    - Concrete volume of 0.25m3/m2
    - Reo rate of 200 kg/m3
- On average, there is an approximate diffrence of 200 kgCO2equiv/m2



- Assuming a mass timber density of 0.33m3/m2, this amounts of 600kgCO2equiv /m3 of mass timber specified.
- If 1,000,000m3/year of timber was used in lieu of traditional materials, this accounts of 600,00tCO2/equiv/m3.
- This is equivalent to:
    - The impacts of 33,000 Australians in a single year.
    - 131,000 cars off the road for a single year.

What about the land?
This white paper is illustrated an enormous opportunity for the emergence of timber in our buildings. It plays a vital role in reducing the embodied carbon emissions from cement and steel.

This white paper has shown that the emerging market could hypothetically be greater than 1,000,000m3/year by 2030. This would exceed the existing capacity of the timber supply chain and likely offset the residential market today. The longer term benefits of exceeding the demand of supply with timber has the benefit of:

- A portion of the tree which had a lower value, can now be used in Engineered Wood Products such as CLT. This improves the overall value in harvesting a single tree.
- By increasing the value of a tree, the return on investment for growers improves. This then shifts the cost-benefit analysis of other forms of land use, towards that of growing trees. Therefore, the land use can be shifted towards planting more trees and overall improvement in biogenic carbon by improving the value of a tree.
- A single of hectare can grow approximately 330m3 / 30 years. This is approximately 11m3/year.
- The emerging market of EWP requires approximately 91,000 hectares of new land to service an additional 1,000,000m3/year.
- Australia has 134 million hectares of forest covering 17% of Australia's land area. Commercial plantations are approximately 1.95 million hectares.
- Assuming no other timber products are displaced, the emerging market would require less than 5% increase in commercial plantations.
- The Australian government plan was for a billion trees, uses 400,000 new hectares of growth. This initiative alone have the capacity to enable the growth of this sector.