Academic/Industry Research

Understanding the risk and reward in the adoption of Mass Timber Construction in Australia

Paul D. Kremer[1], Philip Fahy[2] & Atiq Zaman[2]

Mass Timber Construction (MTC) is a relatively new construction technology consisting of both a material (timber) and a construction methodology (prefabrication). Whilst the uptake of MTC in Australia is currently outpacing many other parts of the world, industry stakeholders continue to hold tentative opinions about the risks and rewards of adoption. The present paper employed a mixed-methods approach to explore the opinions of 59 Australian industry stakeholders via an online survey and an additional nine professionals were interviewed. Results indicate that the Australian market has moved from a position of 'what if' to 'acceptance of' MTC and is now looking to improve the supply chain for the security of competitive rates for materials/services. Accompanying this step-change, a niche of industry stakeholders hold a level of cautiousness apart from those considered to be the next wave of adopters. Tentative views about the dynamics between 'risk' and 'reward' seem inhibitive to further adoption. In order to resolve this complex, stakeholders are advised to undertake an introspective review assessing their tolerance for ambiguity/uncertainty in adopting MTC.

Keywords: *Mass Timber Construction; MTC; Risk, Reward, Modern Methods of Construction (MMC), Prefabrication, Australia, AEC Consultant, Contractor, Stakeholder*

Cross Laminated Timber (CLT) is typically the product that comes to mind when talking about Mass Timber Construction (MTC). Other products include Glue Laminated Beams (GluLam) and Laminated Veneer Lumber (LVL). Massive timber structures may use a hybrid of materials as the 'best use' of technologies for the overall design intent and resultant building structure. MTC involves the prefabrication of materials off-site ensuring the on-site workforce is kept to a minimum (Yates, Linegar & Dujic, 2008), thus resulting in significantly less labour - estimated to be up to 25% more efficient than traditional construction. In addition to speed and labour cost reductions, MTC's use has a number of environmental benefits compared with traditional construction materials (typically concrete and steel), including timber's ability to sequester carbon (Kremer & Symmons, 2015; Depro, Murray, Alig & Shanks, 2008). Timber production also uses less energy than concrete or steel, equating to less carbon produced, also known as embodied energy consumption, and is a renewable and recyclable resource when compared with more traditional materials (Lehmann & Fitzgerald, 2012).

According to Kremer & Symmons (2015), MTC in Australia is relatively new with the first mass timber constructed residential building Forte constructed in 2012 and the first public building Library at the Dock completed in 2013 whilst the first office building was completed in 2017, International House Sydney (LendleaseDesignMake). The uptake of mass timber has seen a slow increase in the number of mass timber buildings being constructed or planned in Australia, approximating doubling the number of projects since 2014, however MTC has not taken over a large market share and has not been a significant disruptor (Evison, Kremer & Guiver, 2018). Yet, despite the impressive early adoption of the technology by a few larger contractors (a mix of varying tiered builders) there is yet to be an overall 'mass adoption' and acceptance of the product/methodology to truly challenge concrete and steel. MTC technology inhibition is due to a number of reasons including limited understanding by architects, quantity surveyors and structural engineers (Bylund 2017). Fire design consultants are very conservative and with the exception of some builders; the industry has been reticent to try a 'new' material (Bylund 2017).

A key determinant to MTC becoming a mass-market accepted product is the overcoming of the conservative, risk-averse and traditional Australian consulting and construction industry culture. An understanding of the risks can support the elimination of barriers for the increased uptake of mass timber technology into the mainstream. Therefore, the present study employed a mixed methods approach (survey questionnaire and interviews) seeking to investigate the attitudes of Australian consultants and contractors' attitudes toward the risks and rewards in adopting MTC. However, first the authors shall briefly examine what is known about MTC in the consulting world (Architects and Engineers etc) then move toward an exploration of what is known by contractors (Builders and Constructors) in order to frame the research.

There is a substantial education process required in order to provide the industry with the essential tools and knowledge in MTC (Kremer & Symmons 2016). The lack of knowledge has been acknowledged and is being addressed by organisations, such as the industry association Forest and Wood Products Australia, manufacturers such as XLam Australia and New Zealand and CLTP Tasmania, as well through social media and research by the Mass Timber Construction Journal through direct marketing to industry and the provision of consultation services to enhance knowledge.

Contact
[1]Paul Kremer
University of Melbourne
Email: drpaulkremer1@gmail.com

[2]Curtin University
School of Design and the Built Environment

Mass Timber Construction Journal
Received 1st of Feb 2019, Accepted 19th Nov 2019
DOI: Not Assigned

An early decision in the project lifecycle is required to implement MTC effectively on a project. Currently, there is a heavy reliance on suppliers to provide support to the project team to get a project off-the-ground as lack of knowledge and experience is evident within the Australian construction industry. MTC requires a different approach at all stages of the project lifecycle including design and procurement. In the feasibility stage, a certifier and a quantity surveyor (who is familiar with this technology) can have meaningful conversations with the client to ease advise the risks of using MTC. Generally, many architects in Australia are in favour of exploring MTC as they like the idea of something which is more sustainable (Kremer & Symmons, 2016). When the project requirements are established drawings, specifications, and construction detailing in timber is relatively straightforward to produce for the project team.

The Australian construction industry generally holds very strong and traditional construction views, specifically in relation to contracting regulations (Kremer & Symmons 2016). Contractor's resistance to shifting toward a construction methodology to suit pre-built or off-site manufacturing processes, including MTC, is seen as a key concern and worthy of investigation in the present study. Some Australian contractors recognise the benefits of MTC, such as labour reductions and the control over project programs MTC allows for, reducing the reliance on subcontractors. Australian tier one developer/builder/fabricator Lendlease explored new materials and methodologies in their current business model and kept coming back to timber as the best option for its lightweight and other utility, i.e. safety, renewability etc. (Lendlease 2016). Lendlease saw the benefits of MTC early and forged its own path as an industry leader in Australia and the United Kingdom building Australia's first CLT apartment tower and launching a fabrication facility to process blank CLT and panelised lightweight timber-framed systems. Following Lendlease's lead other builders such as StrongBuild also launched a facility to process CLT and panelised timber frames. Therefore, the overarching aim of the present study is to understand the nature of risk and reward for MTC in the Australian construction market.

In terms of the qualitative research component, the specific aim was to understand the common themes from the opinions of stakeholders positioned at different locations along the supply chain. Whilst the quantitative research component sought to understand the dynamics between the advantages of MTC (rewards) and the perceived risks commonly associated with knowledge about new MTC technology. It was predicted that the greater participants' perceptions regarding the benefits of MTC the lower the perceived risks in adopting the technology. Further, those participants' with lower levels of understanding MTC are associated with higher perceived risks in adopting MTC technology.

Method

A mixed-methods approach combining both qualitative and quantitative analysis was applied. The first study was on the perceptions of industry professionals with experience with MTC using semi-structured interviews. A qualitative method was used to allow flexibility in the interviews and allow open-ended questions.

Participants

Participants in the research participated in one or both components, the first of which was a survey and the second an "in-depth interview, both are detailed next.

Survey

Participants included 59 respondents, gender information was not collected. Over 80% of the sample had 20 years or less experience within the construction industry. Table 1 provides the breakdowns of the frequencies.

Table 1. *Frequency of Years in Construction by Participant*

Years Experience	Total (%)	Frequency
0-2 years	32.20%	19
3-5 years	11.86%	7
5-10 years	18.64%	11
10-20 years	18.64%	11
20-30 years	10.17%	6
30+ years	8.47%	5
Total	**100%**	**59**

Participants also indicated the type of organisation in which they were employed at the time of taking the survey. The majority of participants of the survey were either consultants or builders. Table 2 provides details of the frequency of employment within the category of organisation.

Table 2. *Frequency of Type of Organisation by Participant*

Years Experience	Total (%)	Frequency
Builder/Contractor	36.51%	23
Manufacture/Supply	9.52%	6
Consultant (AEC)	25.40%	16
Client/Developer	3.17%	2
Policy/Regulatory Body	3.17%	2
Academic	12.70%	8
Other	9.52%	6
Total	**100%**	**63**

Participants indicated if they did (30% of the sample) or did not (70%) have experience with MTC. Of the 30% that stated they had worked on MTC projects, 14% indicated they had worked on four or more projects, 6% had gained experience on two-to-three projects, whilst 10% of those indicating yes had only ever worked on one project.

The authors designed and developed a customised survey based on the work of previous research of Kremer & Symmons (2015, 2016). The survey consisted of 34 questions. Participants were asked to rate their agreement, or not, with several statements. Examples of the types of questions include; *"Do you think using mass timber construction on a project in Australia increases the risk (Time, Cost, Quality, Scope etc) of that project compared to if the project used conventional building materials?"* and *"How likely would you be to promote and encourage the use of timber over conventional building materials?"*

A series of questions aimed to explore/ understand participant knowledge, attitudes and willingness to adopt MTC as a construction system in Australia. As well as a series of demographic questions. The survey used a 5-point Likert scale ranging from *"not at all aware"* to *"extremely aware"*, dichotomous responses and open-ended text fields.

Interviews

The researchers recruited nine Australian industry professionals to conduct semi-structured interviews. Interviews were recorded with participants comprising the following areas; two suppliers, three contractors/builders, one architect, one structural engineer/academic, one academic/supplier and one timber building consultant. Participants had an average of 23.8 years' experience within the construction sector. The present study employed a semi-structured interview approach. The survey consisted of 10 questions including items such as "*Based on your experiences, what are the key limitations, challenges, and barriers to implementing MTC in the Australian construction industry?"* and *"What were the stakeholder's perception and attitude implementing MTC on their project? Did their perception or attitude change after the project was delivered?"*

Procedure

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number 13434). The study employed a mixed methods approach as a way to go beyond mere survey responses in attempting to investigate the underlying attitudes. The procedure section is split into two sections, quantitative and qualitative.

Quantitative Survey

A survey was created by reviewing literature. The survey was distributed via email & LinkedIn an anonymous link was generated via qualtrics (www.qualtrics.com). The anonymous link was sent to a predetermined group of industry professional's currently in the Australian building industry. The quantitative data were exported from Qualtrics to PDF and Excel. This Qualtrics software-generated graphs and tables. The data was then analysed using SPPS Version 23.

Qualitative Interviews

The method adopted by this study was also the method used in the study by Kremer and Symmons (2016). Interview participants were acquired through snowballing referrals and invited to partake in interviews. Interview data were transcribed and analysed using Braun and Clarke's (2006) qualitative methodology by identifying, coding and extracting common elements and analysing patterns and creating themes based on the patterns.

The themes identified will be discussed in findings from Survey questionnaire. Responses were reviewed to become familiar with the data. Then nodes were created based on the content of the data on themed codes were created. Then coding into groups based on common themes, based on the codes that occurred the most frequently occurring themes were noted and created into nodes in Nvivo. Then the most frequently occurring nodes (nine nodes), themes were created, and the references were deleted. Then the qualitative data was reread based on paying attention to the identified nine nodes and the relevant data was placed into the relevant node folder.

Results

Statistical modelling of participant data was performed to test the predictions that participants holding positive views about the benefits from using MTC will be associated with decreased risks in adopting the technology. Further, that participants who lack understanding about MTC will be associated with increased risks in adopting the technology. Data screening uncovered no missing values. A frequencies analysis was conducted to assess normality (Skewness, Kurtosis, Histograms/Normality plots).

A correlational analysis was conducted to assess the relationship between participants' responses toward the benefits (M = 36.37, SD = 11.16) and risks (M = 4.0, SD = .74) of using MTC. The results revealed that no relationship existed between risk and reward in using MTC r = .11, n = 59, p = .39. In other words, the benefits of using MTC, according to this sample, are not perceived to attract higher or lower risk when compared to more traditional forms of construction.

The authors assessed perceptions of risk in using the technology between two groups of participants, those "very familiar" (M = 3.8, SD = .83) with MTC and those "who knew about it" (M = 4.12, SD = .65). A two tail t-test was conducted revealing that there were no differences in risk perception between the two groups t(57) = 1.425, p = .160. An additional analysis was conducted looking at perceptions of the benefits of using the technology between two participant groups, those "very familiar" (M = 42.23, SD = 9.37) with MTC and those "who knew about it" (M = 31.76, SD = 10.36). A two tail t-test was conducted revealing that there was a significant difference between the two groups in terms of perceptions regarding the benefit of MTC, t(57) = -4.02, p = <.001. Results here indicate that messages concerning the benefits of MTC are penetrating the Australian construction industry portraying a positive outlook for MTC.

The authors also assessed perceptions of risk and benefits using the technology between two groups of participants, those "very familiar" with MTC and those "who knew about it". For the group that was "very familiar" with MTC, a correlational analysis revealed a non-significant relationship between risk and benefits of MTC r =-.16, n =26, p =.44. However, for the group who that "knew about" MTC a correlational analysis revealed a significant moderate relationship between risk and benefits of using MTC r = .59, n = 33, p = <.001. Those who are less familiar with MTC indicating greater risk in using the technology.

Understanding the Risks

The term "risk" was mentioned on 14 occurrences by seven participants. Respondent's knowledge and experience with MTC varied as such 'unknowns' about MTC presented several challenges for interviewees who indicated an increased perceived increased risk of implementing MTC on projects.

> *"I think one of the biggest issues is around risk and the supply chain. Yeah it's still a relatively unknown building method and know a lot of cases that are relatively limited suppliers who can you know able to supply the products or fabricate things"* Designer

> *"So knowledge in the industry is obviously an obstacle and that the detection and protection of risk and those unknowns. But as I explained to a number of people this risk has to do with ignorance, not anything to do with the material. So it's not that the material is inherently risky it's not it's just we don't know and that's easy to resolve" Consultant*

MTC requires a holistic and whole-of-construction approach to achieve benefits. The challenge is transforming the industry that is very conservative and risk adverse. It is clear from this participant's accounts that both contractors and consultants are engaged with the concepts MTC offer, yet there are some hurdles to overcome,

> *"…design risk, supplier's installation risk, engineering risk the whole lot. We [industry] have to try and burden that risk. What the builder or customer whoever you contract with has to consider is the risk of not hitting their straps in terms of getting a program reduction because that's ultimately where the money saving is for them. They need to take a risk that I can install in the right amount of time…"Builder*

"There are not many experts in that field in Australia and I'd say not many structural engineers in Australia that have mass timber experience. You know it's a handful. So being able to get a design in what would be a normal sort of tender process and to be able to competitively tender is difficult. There were a lot of individual testing and proving the various fire brigades, fire engineering, for the acoustics and even weatherproofing and thermal, because the design consultants and just not familiar with the product to satisfy the criteria there is a lot more work involved getting it across the line on the first one or two projects." Builder

"…getting a contractor or builder to price it [MTC] early…I find that architects actually pretty keen on timber, engineers and civil engineers are quite inclined to come on-board. Quantity surveyors are probably a bit of a stumbling block. They are very good at pricing but don't have the information from the supplier and then they price risk into the project they inflate their price to deal with the unknowns." Design Manager

The industry is still learning how to use mass timber efficiently. Higher prices for the technology often include a risk component, which can have a significant impact on the true cost of construction when compared to using conventional building. Other additional costs from MTC include higher design fees and fire testing.

"Quantity surveyors can be a barrier; they are very good at pricing but then when it comes to it the builder at the end of the day who decides how much the project's going to cost. So knowledge in the industry is obviously an obstacle and adds risk and unknowns." Supplier

Likewise, this participant articulates that a considerable obstacle to MTC adoption is the perceived risk of not achieving a reduced construction programme. A determination regarding which technology a building will be constructed in is required at the feasibility stage. Any doubts at that stage, the benefits may not be realised, and the risk appears to increase.

"… risk to the program is significant, even though it [MTC] promises time-savings it was too innovative for the [client] and too many unknowns …the housing project got to feasibility and not in MTC" Consultant

Capturing the Rewards

Whilst the risks are important to understanding, there is a significant global movement for the adoption of MTC as a modern and more mainstream approach to constructing. MTC has captured the attention and is disrupting the industry, as this participant puts it,

"People (clients) are coming to us asking if they can walk through because they really like the building (International House) and want to show their tenants and architect" Building/Developer

"Yeah, I've got 20 tenants lining-up for the next timber building in Sydney right now. I've got 30 levels on concrete in Sydney, however, I haven't necessarily got tenants racing to get into there. I can build a timber building and know the tenants will come but I can't do that with concrete. That's our experience in NSW and QLD." Builder/Developer

With the more frequent uptake of MTC new innovations and uses have occurred and further innovations and new uses for the technology are likely to occur in the future, as well as time & cost saving to increase is extremely high. Significant cost saving can also be achieved through the reduction of preliminaries and dematerialisation. A participant reported a reduction in on-site supervision and edge protection because given the simplistic construction method eliminates other materials, plant, and equipment for example.

"Other cost savings were a reduction; cost of supervision goes down, edge protection because we have far fewer things to fall out of the building during the formwork stage meant that we didn't need to have screens on the outside of the building." Building/Developer

The weight of MTC (20% the weight of concrete) is a considerable advantage to this participant, his organisation seeks to increase building yields through vertical extensions.

"…we are designing a 10 storey hotel in Melbourne at the moment on top of an office building and they are interesting building in Melbourne and it's a project that simply can't happen in that area. There is no way to make it that tall the way concrete will be too heavy. I mean you know it's much easier to build as well in a building and the height can find confined sites in the city." Builder

Discussion

The overarching aim of the present study was to understand the nature of risk and reward for MTC in the Australian construction market. In terms of the qualitative research, the specific aim was to understand the common themes from the opinions of stakeholders positioned at different locations on along the supply chain. Prior to the present study, anecdotally, industry perceptions suggested that in order to secure the benefits of using MTC those in the construction industry viewed its adoption as too risky. The present study hypothesised that the greater participants' perceptions regarding the benefits of MTC the greater the perceived risks in adopting the technology. Further, that participants' lower levels of understanding MTC are associated with higher levels of perceived risks in adopting MTC technology.

For participants within the survey portion of the present study, the adoption of MTC as an alternative construction method/material did not indicate an increased propensity for higher or lower risk, compared with more traditional materials. It is to be noted that a potential bias in sampling may be responsible for this outcome because the respondent recruitment was via snowballing techniques possibly resulting in participants within the MTC industry. It is conceivable that the recruited cohort of survey participants being aware of the benefits and perceived risks are also aware of how to overcome them through education and practice.

Looking at perceptions of the benefits from using the technology between two groups of participants, those very familiar with MTC and those who merely knew about it, results indicated that messages concerning the benefits of MTC are penetrating the Australian construction industry portraying a positive outlook for MTC as an alternative construction material and methodology.

The results presented here may actually support the effectiveness of substantial education provided to industry an area of research recommended for the future. Organisations such as WoodSolutions provide essential tools and knowledge to design in MTC free to the market. In addition, private investment in MTC technology to delivery locally produced products like CLT (by manufacturers such as XLam Australia and New Zealand, the Hermal Group (CLTP) and Cross Laminated Timber) provides evidence of maturation in the market, a 'coming-of-age' for MTC in Australia. Further evidence from the present study supports this view with the results suggesting that those who are educated

about MTC understand the risks and also the benefits gained from using MTC. Thus, those individuals are more likely to make rational and deliberate decisions to engage with MTC.

Despite the relatively positive results from participants of the survey, it is clear that a more in-depth analysis of various stakeholders' perspectives regarding MTC (industry interviews in contained within this paper) reveals additional concerns about its adoption. A major concern for several participants was the supply chain. The supply chain is still establishing itself in Australia due to several factors, firstly the realisation of locally produced MTC products currently becoming available, and secondly is importing MTC products from overseas has become a more common practice (Byland 2017).

Local familiarity and experience with MTC (as a material and as a method) is primarily limited to only a handful of industry stakeholders experienced with MTC. However as one consultant put it "*the risk has nothing to do with "timber" per se, timber is a traditional method and material, the concern is primarily to do with lack of knowledge*". A barrier that can be overcome through education and constructing more MTC buildings. One of the authors of this present paper is currently involved in the development of a nationally accredited registered training program has just been completed and accredited to support the development of vocationally focused training to educate the masses. It is believed this is a world first course, thus adding to the knowledge of industry regarding MTC.

Participants within the present study recognised that cost savings from the MTC method of construction (shorter program) are critical in order to make MTC competitive compared to traditional construction. The failure to meet the programme timelines is a risk for the contractor, who must ensure the construction programme is adhered to capture the reduced cost reward. Consultants such as architects and structural engineers are generally on board with MTC however quantity surveyors add a 'risk component' into their costing models to cover the contractor against risk and unknowns which has the potential to inhibit MTC on a project as a feasible alternative.

A further compounding factor is the lack of experienced MTC designers, suppliers and contractors operating in a traditional competitive tender model. MTC challenges the status quo by offering an early engagement model, however many organisations appear not to be cognizant of this modern method of construction, rather pushing for competition due to probity issues/concerns. Using a traditional approach of tendering and the lack of supply options for MTC (materials and services) increases the likelihood of builders returning to conventional materials and missing out on the rewards of MTC. However, it is likely this will change over time, and sometime it will take given the recent history of a stagnant global construction sector.

Several limitations of this research must be considered, the first limitation is the number of industry professionals interviewed who had MTC experience. As a niche sector, it is hard to secure numerous participants. Another was the literature reviewed in the creation of survey questionnaire and interviews. MTC in Australia has significantly matured with a rapid uptake in recent years initial literature reviewed (2014-2015) did not reflect the progress in the uptake and implementation of MTC in the industry on the present day, therefore research was not as advanced as it could have been to reflect the progress of implementation and acceptance of MTC generally evident in the Australian construction industry. A further limitation concerned the participant knowledge of MTC technology. Whilst some participants clearly had knowledge, others merely speculated and spoke about 'what might be', rather than what was a genuine experience. Despite the limitations, the findings are of significant interest to those looking to adopt a mass timber approach to construction.

Conclusion

The overarching aim of the present study was to understand the nature of risk and reward for MTC. The present paper explored the dynamics between risk and rewards in the adoption of MTC in Australia. It is clear from the results in this study that industry stakeholders familiar with MTC recognise the benefits (rewards) and also the pitfalls (risks) in its use. The wider adoption of MTC in the industry as a credible and viable alternative to more traditional forms of construction is slow in up-take. However, this study seems to support the notion that what industry associations and other organisations are doing (education and engagement) is having an impact on the adoption of MTC in Australia.

A deep dive into stakeholders' current views of MTC reveals that the market has moved from a position of 'what if' to somewhat accepting MTC and looking to improve the supply chain and secure competitive rates for materials/services. Accompanying this step-change is a level of cautiousness from those considered to be the next wave of adopters. It is clear from the research that the dynamic between 'risk' and 'reward' is a very complex one requiring a very introspective review of a stakeholders position in market, the type of projects they build, levels of skills and knowledge, and level of tolerance for ambiguity/uncertainty for a tackling any new technology, not only MTC.

Recommendations

1. The risk versus reward equation is predicated on apparent risk, evidence from the survey suggests that the risk of using MTC technology is neutral when compared to other technologies on the market. However, interview participants expressed several adverse views, due to the adversarial nature of contracting, therefore those wishing to invest in MTC should do so with the right approach and mindset to the technology.

2. Stakeholders must be aware of the total value proposition for using mass timber technology, not just making a cost versus cost comparison between requisite material inputs. Significant cost savings can be achieved through an add-back of reduced preliminaries due to a shorter construction program, thus reducing the overall cost of the project. Savings are realised at the end of the project, therefore making the value proposition for mass timber difficult to calculate prior to construction handover without legacy history and experience, no different to any other new technology.

3. Early adoption can provide first mover advantages to stakeholders braving a new frontier, however second or third movers have the advantage of reaping the benefits of lessons learnt by those forging ahead. Taking a conservative approach to mass timber can have its benefits, especially in risk-averse organisations.

4. In Australia, the role of industry associations is having an impact on the adoption of the mass timber movement. Stakeholders should take advantage of the considerable resources available in order to determine the right timing, correct pathway and application of MTC to project pipelines and make the numbers stack up. Be aware that there have been companies that have not succeeded in their MTC journey, therefore understanding others mistakes will improve outcomes.

References

Braun, V., & Clarke, V. (2006) Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2).77-101. http://eprints.uwe.ac.uk/11735/2/thematic_analysis_revised...

Byland D. (2017).Transition strategies: Accelerating social acceptance and removing the barriers to prefabricated multi-story timber urban infill developments in Australia using

CLT construction systems http://www.fwpa.com.au/images/marketaccess/PNE293-1213_FWPA- UniSA_CLT_Report 0.pdf

Cambridge University. (2017). Cambridge University Press https://dictionary.cambridge.org/dictionary/english/perception

Crosslamaustralia. (2017). Accessed June 2017, http://www.crosslamaustralia.com.au/

DesignMake. (n.d.) Accessed October 27, 2017. http://www.lendlease.com/au/expertise/areas-of-expertise/designmake/.

Depro, B. M., Murray, B. C., Alig, R. J. & Shanks, A. (2008). Public land, timber harvests, and climate mitigation: quantifying carbon sequestration potential on U.S. public timberlands. *Forest Ecology and Management. 255*(3): 1122–1134.

Dunn, A. (2015). Final report for a commercial building costing cases studies: Traditional design versus timber project. Melbourne, Australia: Forest and Wood Products Australia.

Evison, D. C., Kremer, P. D., & Guiver, J. (2018). Mass Timber Construction in Australia and New Zealand: Status, and economic, and environmental influences on adoption. Wood and Fiber Science Journal: *50 (special issue)*,128-138.

Fernanda, M., & Mallo, L. (2017). "Awareness, perceptions and willingness to adopt Cross- Laminated Timber by the architecture community in the United States" http://www.sciencedirect.com/science/article/pii/S0959652615001031?via%3Dihub#!

Forest & Wood Products Australia. (2017). Accessed June 2017, http://www.fwpa.com.au/

Green, M. C., & Karsch, J. E. (2012). Tall Wood: The case for tall wood buildings. Retrieved from http://wecbc.smallboxcms.com/database/rte/files/Tall%20Wood.pdf

Innovations & Developments. (n.d.) CrossLam Australia. Accessed September, 2017. http://www.crosslamaustralia.com.au/news/.

Kremer, P. D., & Symmons, M. A. (2016). Overcoming Psychological Barriers to Widespread Acceptance of Mass Timber Construction in Australia. *Forest Wood Products Australia Report.*

Kremer, P. D., & Symmons, M. A. (2015). Mass timber construction as an alternative to concrete and steel in the Australia building industry: a PESTEL evaluation of the potential. I*nternational Wood Products Journal 6*(3), 138-147.

LeadingEdgeGroup1. (2016). "Lean Construction in 3 minutes" https://www.youtube.com/watch?v=OTH0z6xSSJM

Lean Construction. (n.d.)YouTube." Accessed September, 2017. https://www.youtube.com/results?search_query=lean+construction.

Lehmann, S., & Fitzgerald, G. B. (2012). Sustainable urban infill development using low-carbon prefabricated timber construction systems: wood in the city. Sustainability. 4: 2707–2742.

Metsawood. (2017). Accessed June 2017, http://www.metsawood.com/global/Pages/default.aspx

Milne, G., & Reardon, C., (2013). Materials, Embodied Energy – Your Home Australia's Guide to Environmentally Sustainable Homes, Commonwealth of Australia (Department of Industry), Australia.

PlanetArk. (2017). Accessed June 2017, http://planetark.org/

ReThinkWood. (2016). An Integrated Perspective on Mass Timber and the Opportunities Beyond Building. Acceszsed June 2017 from https://www.youtube.com/watch?v=8KzeYvynRhs

Strongbuild. (2017). Accessed June 2017, http://www.strongbuild.com.au/

University of Auckland (n.d.) About thematic analysis. School of Psychology - Leading psychological science, scholarship and practice Accessed June 2017, https://www.psych.auckland.ac.nz/en/about/our-research/research-groups/thematic-analysis/about-thematic-analysis.html

United States Environmental Protection Agency. (2015). What is Sustainability? Access September 2017, http://www.epa.gov/sustainability/basicinfo.htm.

WoodSolutions. (2017). Innovative, Informative, Inspiring. Forest & Wood Products Australia. Accessed June 2017, http://www.woodsolutions.com.au/

Xia, B., O'nill, T., Zuo, J., Skitmore, M., & Chen, Q. (2014) Perceived Obstacles to Multi-storey Timber-frame Construction: An Australian Study http://eprints.qut.edu.au/70475/2/70475.pdf

XLam. (2017). Accessed June 2017, http://www.xlam.co.nz/