ENGINEERED TIMBER IN MULTI-STOREY CONSTRUCTION: AN INDUSTRY PERSPECTIVE[1]

Kimberly Winson-Geideman and Giorgio Marfella

University of Melbourne

Abstract

This research investigates the perspectives of building and design professionals regarding the use of Engineered Wood Products (EWS) in multi-storey construction. The primary objective is to provide a baseline assessment, from an industry perspective, of the environmental, social and economic factors that affect the widescale adoption of EWS in Australia. Results are drawn from selected questions of a survey conducted in early 2019 that was designed to provide an understanding of the perceptions of a broad group of industry professionals, regardless of their level of knowledge of, or experience working with, EWS.

Keywords: Mass timber, engineered wood, sustainable construction, sustainable development

[1] This research was partially funded by Forest & Wood Products of Australia and the University of Melbourne.

Introduction

This research provides a baseline assessment of the perceptions of design and technical professionals related to the adoption of Engineered Wood Systems (EWS) in mid-rise and high-rise construction projects in Australia. EWS is a family of mass-produced, wood-based construction materials that includes products such as Cross Laminated Timber (CLT), Glue Laminated Timber (GLT) and Laminated Veneer Lumber (LVL). Lesser known engineered timber systems are also included such as prefabricated systems based on traditional timber construction systems, cassette floor systems and timber-framed wall panels, and emerging hybrid technologies that use mass-timber in structural applications such as composite with steel (e.g. pre-stressed timber columns and beams) or concrete (e.g. timber-concrete slab systems).

While the market for EWS in Australia is growing, it is still relatively new when compared to North America and Europe and substantially smaller than that of traditional materials such as concrete and steel. In this context, this research engages experts in the building design and construction industries to assess 1) the level of understanding and knowledge of EWS among design and technical professionals, and 2) the barriers to more widespread market adoption of EWS with a specific focus on environmental, social, and economic factors that affect the broader use of the materials. The information gathered will be used to explore differences between the groups in regard to their knowledge of EWS for the purpose of developing targeted, industry-specific education programs.

Literature

The literature related to the use of EWS in multi-storey construction is a relatively small, which is partially a function of the products' newness to market and corresponding information asymmetries. Much of it is drawn from the North American and European contexts where the use of EWS has a longer history than in Australia. Research from North America, for example, shows that lack of general knowledge and awareness of EWS is a substantial barrier to the widespread adoption of the material (Laguarda Mallo, & Espinoza, 2015). In Europe, incompatible regulation and lack of technical information are primary barriers (Espinoza, Rodriguez Trujillo, Laguarda Mallo, & Buehlmann, 2015). Research by Xia et al. (2014) considers a similar topic in Australia, suggesting that survey and interview participants view lack of industry awareness, fire risk and perception of high maintenance costs as significant barriers to more widespread use. Further, Kremer and Symmons (2015) apply a PESTEL analysis to the use of EWS by analysing the broader political, economic, social, environmental and legal hurdles facing domestic (Australian) production of mass-timber materials.

Studies related to engineering standards, safety, and environmental properties predominate much of the remaining literature. Fire resistance in LVL and CLT has been examined (Allen, & Iano, 2017) as has seismic performance (Iqbal, Smith, Pampanin, Fragiacomo, Palermo, & Buchanan, 2016; Evans, 2013) and structural performance (Sutton, Black & Walker, 2017). The sound insulation properties of CLT has been tested (Öqvist, Ljunggren & Ågren, 2012) and construction efficiency assessed (Jones, Stegemann, Sykes & Winslow, 2016). Research by Lehmann (2012) even suggests a link between the use of timber products and improved liveability measures.

This research extends the body of knowledge in the use of mass timber products by surveying 412 industry professionals about the environmental, social and economic factors that impact the adoption of EWS in mid- and high-rise developments in Australia. The relationship between design and technical experts is specifically explored to provide a baseline assessment of industry awareness regarding EWS and to identify knowledge and perception gaps between the groups. As mentioned earlier, this information will be used to develop targeted education programs related to Engineered Wood Systems.

Data and Methods

The data used in this study were collected via a survey administered to professionals in the construction and design industries. Researchers from the University of Melbourne collaborated with WoodSolutions, a non-profit organisation dedicated to the promotion of timber products in Australia, to collect the data.

Survey Design & Administration

The survey consists of 31 multi-option, matrix, yes/no and open-ended questions that was distributed to approximately 17,000 potential respondents recruited from the proprietary WoodSolutions database. It begins with three demographic questions related to industry affiliation, years of experience, and location. Subsequent questions delve into the respondents' opinions on a variety of EWS-related topics. As participants proceed through the survey, two elimination questions are used to progressively narrow the respondent group based on their knowledge of, and experience using, EWS. The elimination questions effectively divide the respondents into three groups, 1) those with at least a general knowledge of EWS, 2) those with a more sophisticated knowledge as well as experience using EWS, and finally, 3) only those who have hands-on experience using EWS. The results of this study are related to the responses of the first group.

In March 2019, an email from WoodSolutions invited respondents to participate in an electronic survey hosted on the SurveyMonkey platform. Approximately two weeks after the first email, a reminder was sent. The survey link was active for approximately one month. WoodSolutions distributed the survey email with the understanding that the primary investigators would be granted access to the full results. At no time did the primary investigators have access to the database of emails or any identifying information of the respondents.

Sample

Over 600 respondents began the survey, but that number quickly declined after the initial demographic questions. A core of 518 respondents remained in the survey after the fourth question, with most proceeding through to the end of the first section (the first elimination question). In this research, the focus is on two distinct groups (412 total respondents), comparing responses from design professionals (154 respondents) with those of engineering and construction professional background (258 respondents). The responses from the other professional groups are reserved for future studies.

Table 1 shows the professional composition of the industry groups targeted by this research. The technical group includes 96 structural engineers (37%), 26 non-structural engineers

(10%), 49 head contractors (19%), 29 sub-contractors (11%), 37 building surveyors (14%) and 21 project managers (8%). The design group is composed of 154 architects/building designers noted as a single category in the survey.

Table 1: Composition of respondent groups by profession

Construction/Engineering		
Structural engineer	96	37%
Non-structural engineer	26	10%
Head contractor	49	19%
Sub-contractor	29	11%
Building surveyor	37	14%
Project Manager	21	8%
Total Construction/Engineering	*258*	*100%*
Construction/Engineering	**258**	**63%**
Architect/Building Designer	**154**	**37%**
Total respondents	***412***	***100%***

Table 2 notes the years of experience and location of the respondents. Regarding experience, the groups are generally proportional to each other with 75% of the design professional indicating ten plus years in industry and 70% of the construction and engineer professionals indicating the same. There are, however, some notable differences in the location where the respondents are based. Tasmania is disproportionately represented in the construction and engineering category (16%) when compared to the design group (2%). Victoria, conversely, is disproportionately represented among designers, accounting for nearly one-third of the responses compared with less than 10% of the other group. Western Australia is unrepresented and only one participant responded from the Northern Territory (.39%).

Table 2: Professional experience and location of respondents

	Building Designer/Architect		**Construction/Engineering**	
Experience				
Less than 2 years	10	6.62%	7	2.27%
2 to 6 years	15	9.93%	38	14.79%
Between 6 and 10 years	14	9.27%	31	12.06%
10 to 20 years	41	27.15%	52	20.23%
More than 20 years	71	47.02%	129	50.19%
Location				
New South Wales	26	17.11%	59	22.87%
Australian Capital Territory	2	1.32%	8	3.10%
Northern Territory	0	0.00%	1	0.39%
South Australia	9	5.92%	7	2.71%
Tasmania	3	1.97%	42	16.28%
Queensland	28	18.42%	67	25.97%
Victoria	45	29.61%	25	9.69%
Western Australia	0	0.00%	0	0.00%
Country other than Australia	27	17.76%	39	15.12%

Given the depth of the experience of most of the respondents regardless of professional grouping, it is fair to say they are generally classified as industry professionals who are likely knowledgeable, experienced, informed or familiar with the topic of timber in multi-storey applications and/or possess an established understanding of the culture, trends and structure of the Australian architecture, engineering and construction industries. This is further confirmed by their answer to Question 4 wherein 83% of architects/building designers and 81% of construction and engineering professionals state that timber as a material is 'appropriate' outside its traditional low-rise domestic applications and suitable for 'multi-storey buildings higher than three floors'.

Results

The results are presented according to selected questions that address environmental, social and economic considerations related to the use of EWS in Australian multi-storey construction. Question five relates to environmental issues whereas question seven addresses social issues including public perceptions and larger social movements. Economic issues are covered in questions eleven and twelve, with particular attention paid to cost and financing, respectively.

In the matrix questions related to environmental and social issues, differences 10% or greater between the two groups are considered substantial enough to warrant further consideration. The 10% threshold is a conservative estimate that serves as a starting point for additional inquiry. Obviously, the greater the difference in responses between the two groups, the more likely the issue will trigger action in targeted education programs.

The matrix questions offer multiple options that include differing degrees of agreement/disagreement and the results are presented as a percentage of the total number of responses. The results for the economic questions related to project finance and cost are similarly presented, however, responses are limited to either yes or no/agree or disagree answers.

Environmental

Environmental issues are addressed in a matrix question where a number of environmental advantages associated with the use of timber in multi-storey buildings are described. These advantages include reduced carbon footprint, sustainable production, energy use in construction and service, the use of underutilised forest, and less waste and noise on construction sites. Respondents are asked to indicate if they are in agreement, disagree or are neutral on the advantage. Table 3 shows the complete results.

Table 3: Environmental advantages related to timber

Q5. The following is a list of possible environmental advantages associated with timber multi-storey buildings. Indicate your level of agreement or disagreement with each of the following possibilities as they relate to the environmental advantages of timber multi-storey buildings.

Factor	**Disagree**	**Neutral**	**Agree**
Reduced carbon footprint			
Construction/Engineering	3%	12%	86%
Architects/Building Designers	1%	7%	92%
Sustainable production methods			
Construction/Engineering	6%	10%	85%
Architects/Building Designers	0%	5%	95%
Less energy used in construction			
Construction/Engineering	6%	15%	80%
Architects/Building Designers	4%	17%	79%
Less energy used in service			
Construction/Engineering	7%	37%	57%
Architects/Building Designers	10%	38%	52%
Potential to use underutilised forest			
Construction/Engineering	13%	38%	50%
Architects/Building Designers	20%	44%	36%
Less waste on construction sites			
Construction/Engineering	13%	24%	64%
Architects/Building Designers	11%	27%	62%
Less noise on construction sites			
Construction/Engineering	12%	31%	57%
Architects/Building Designers	12%	35%	54%

The responses from both groups are generally aligned when responding to advantages related to on-site factors (energy used in construction and service, waste and noise on construction sites) with differences ranging from 1-5% in the agree category. That spread increases, however, when advantages are related to ecological factors. Construction and engineering professionals appear more sceptical than architects/building designers indicating 6% less support for reduced carbon footprint and 10% less for sustainable production methods, although architects/building designers are 14% less supportive of the potential to use underutilised forest.

Social

Social factors are studied in two ways, firstly by looking at public perception and then by investigating the impact of larger-scale movements on the adoption of timber. In regard to the perception of the public, respondents were asked their opinion of a series of factors that the general public may associate with timber including green building design, deforestation, reduced energy consumption, depletion of wildlife habitats, recycling and good aesthetics. In the survey, statements were shown in no particular order, however, some are associated with negative factors such as deforestation and the depletion of wildlife habitats. Others may be perceived more positively, such as the association of timber with recycling or good aesthetics. Table 4 provides the responses to the statements.

Table 4: Public perceptions

Q7 In your opinion, how often are the following statements about public perceptions true?

Factor	Never	Sometimes	Always
People associate timber with green building design			
Construction/Engineering	6%	43%	53%
Architects/Building Designers	8%	45%	47%
People associate timber with reduced energy consumption			
Construction/Engineering	27%	48%	26%
Architects/Building Designers	22%	53%	25%
People associate timber with recycling			
Construction/Engineering	27%	45%	28%
Architects/Building Designers	18%	60%	25%
People associate timber with good aesthetics			
Construction/Engineering	6%	29%	66%
Architects/Building Designers	6%	35%	59%
People associate timber with depletion of wildlife habitats			
Construction/Engineering	13%	42%	46%
Architects/Building Designers	6%	48%	47%
People associate timber with deforestation			
Construction/Engineering	9%	48%	43%
Architects/Building Designers	4%	60%	37%

In this case the responses of the two groups do not differ by substantial amounts in the "always" and "never" categories. Construction and engineering professionals and architects/building designers rank recycling and reduced energy consumption as the highest factors that the public *never* considers. Good aesthetics and green building design are the highest rank factors both groups tend to believe the public *always* considers. Differences greater than the 10% threshold are noted in the "sometimes" category, with 15% and 12% more designers indicating the public sometimes associate timber with recycling and deforestation, respectively.

In regard to larger social movements (Table 5), both groups generally find that the environmental movement and climate change awareness have positively affected the adoption of timber in multi-storey buildings, though notably, architects/building designers are more bullish in that respect than construction and engineering professionals (70% to 60%). Both groups tend to think industry and public resistance is generally a negative factor whereas supportive government policy is most highly ranked in the neutral category.

Table 5: Social factors

Q8 What impact do the following social factors have on the adoption of timber in multi-storey projects in Australia? Select one option for each row.

Factor	Negative	Neutral	Positive
The environmental movement			
Construction/Engineering	17%	22%	60%
Architects/Building Designers	7%	19%	70%
Climate change awareness			
Construction/Engineering	13%	23%	63%
Architects/Building Designers	9%	23%	67%
Resistance to change by the industry			
Construction/Engineering	47%	29%	23%
Architects/Building Designers	58%	26%	14%
Supportive government policy			
Construction/Engineering	20%	40%	38%
Architects/Building Designers	24%	41%	33%
Resistance to change by the public/consumers			
Construction/Engineering	45%	33%	21%
Architects/Building Designers	51%	36%	10%

Economic

Economic factors were tested in two ways, firstly by investigating project cost and then project finance. In regard to cost, respondents were asked to choose from a list of factors considered cost advantages. Multiple options could be selected and include cost reductions related to design, tender, structure, preliminaries, contracts, time and maintenance. In this case the respondent groups are aligned across most categories with the largest spreads in reduced cost of design, noted as an advantage by 8% more for construction and engineering representatives than building designers. Conversely, 8% more architects identify reduced cost of contract variations as an advantage associated with timber. This is not entirely unexpected as architects may possess a better understanding of design costs whereas construction and engineering participants may be more likely to be affected by contract variations, giving the groups a specialised and perhaps more accurate knowledge of the two factors. Table 6 includes the full results related to cost.

Table 6: Cost advantages of timber

Q11 Which of the following do you consider a cost advantage associated with the use of timber in multi-storey buildings? You can select more than one option.

Factor	Construction/ Engineering	Architects/Building Designers
Reduced cost of design	21%	13%
Reduced cost of tendering/procurement	11%	13%
Reduced structural cost	50%	51%
Reduced cost of preliminaries (cranes, temporary works)	62%	62%
Reduced cost of contract variations	17%	25%
Reduced cost of construction time	74%	73%
Reduced cost of maintenance	12%	7%

Economic factors were further explored in questions related to project finance and insurance. A series of financial disadvantages were presented to the respondents who were asked to choose the options they believed related to the use of timber in multi-storey buildings. Results are shown in Table 7.

Table 7: Disadvantages related to project finance and insurance

Q12 Which of the following financial disadvantages are related to the use of timber in multi-storey buildings? You can select more than one option.

Factor	Construction/ Engineering	Architects/Building Designers
Increased insurance premiums	26%	28%
Lack of traditional financing options	14%	21%
Higher interest rates	5%	6%
Special disclosure requirements to insurers	20%	28%
Special disclosure requirements to lenders	13%	18%
Unaware of any financial disadvantage	64%	61%

Whilst the majority of respondents are unaware of any financial disadvantages, those who are cite insurance as a more important disadvantage than factors related to lending. The groups are closely aligned when responding to increased insurance premiums, with 26% of construction and engineers and 28% of architects/building designers indicating it is a problem. The same number (28%) of architects/buildings designers are aware of special disclosure requirements to insurers (20% for the rest analysed), and there also appears to be more awareness among the designer group than the rest about the availability of traditional financing options (21% and 14%, respectively).

Discussion

There is a strong consensus among the participants regarding the environmental design advantages of timber in multi-storey buildings, particularly in regard to reduced carbon footprint and sustainable production methods. The groups are also generally aligned in regard to advantageous environmental factors such as reduced noise and waste on site and less energy consumption in construction and service. Broader differences are apparent, however, in the area of ecological concerns where there is a relatively large spread between designers and construction and engineering professionals in regard to the potential to use underutilised forests. Fifty per cent of construction and engineering representatives agree it is an advantage, compared to only 36% of building designers.

While the participants appear to be generally well informed of the environmental benefits of EWS, they lack the same confidence in the public. In most instances, the opinion among the respondents is that the public identifies timber as ‘aesthetically’ pleasing and indicative of ‘green building design’ at least some of the time. These advantages are potentially outweighed, however, by the perceived negative impacts on forests and natural habitats as noted by the vast majority of respondents. Less convincing are the roles energy consumption and life cycle matters play in public awareness of the benefits of timber products. These opinions are fairly consistent between construction professionals, engineers and building designers.

Despite the concern that the public may lack a comprehensive understanding of the environmental benefits of EWS, respondents recognise that larger social movements such as 'the environmental movement' and increasing 'climate change awareness" are potential contributors to the future adoption of timber in multi-storey buildings. This agreement is shared by all participants analysed here. Conversely, about half of both groups also share the opinion that 'resistance to change by the public' will have a negative effect as will 'resistance to change by the industry', although about 1/3 of respondents cite 'supportive government policy' as one way that these cultural issues may be mitigated.

In regard to economic factors, respondents across both groups seemed sufficiently aware of the most significant cost-related advantages of EWS in multi-storey projects in areas such as preliminaries, construction time and structural costs. Deviations between the groups exist in those factors where they are most likely to have first-hand knowledge such as contract variations and design. When responding to issues with financing and insurance, the groups indicated a general lack of awareness to any barriers, although those who did indicate insuring projects as a potential problem.

Conclusion

The purpose of this research is to assess the opinions of design and technical professionals regarding the environmental, social and economic factors that contribute to the use of Engineered Wood Systems in Australia. The data used was collected via a survey conducted by the authors in conjunction with WoodSolutions, an organisation dedicated to the promotion of timber products in Australia. The information was gathered to develop a baseline assessment of the industry for the purpose of developing targeted education programs about the use of materials such as Glue Laminated Timber, Cross Laminated Timber and Laminated Veneer Lumber in mid- and high-rise construction projects. Selected questions from the survey are used to produce the findings discussed in this paper.

As noted in the North American and European literature, the primary barrier to the adoption of EWS is lack of knowledge by industry participants and consumers. Whilst the responses of the design and technical groups in this research are similar in most cases, there are gaps in the areas of ecological and economic concerns. This suggests that programs targeting designers should emphasise aspects different from those targeting construction and engineering, although there are topics from which both can benefit.

References

Allen, E. and Iano, J. (2017). The architect's studio companion. 6th ed. New Jersey: John Wiley & Sons.

Espinoza, O., Rodriguez Trujillo, V., Laguarda Mallo, M.F., Buehlmann, U., 2015. Cross-Laminated Timber: Status and Research Needs in Europe. *BioResources* 11.

Iqbal, A., Smith, T., Pampanin, S., Fragiacomo, M., Palermo, A. and Buchanan, A., 2016. Experimental Performance and Structural Analysis of Plywood-Coupled LVL Walls. *Journal of Structural Engineering*, 142, 2, 04015123.

Jones, K., Stegemann, J., Sykes, J. and Winslow, P., 2016. Adoption of unconventional approaches in construction: The case of cross-laminated timber. *Construction and Building Materials*, 125, 690-702.

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. *International Wood Products Journal* 6, 138–147.

Laguarda Mallo, M.F., Espinoza, O., 2015. Awareness, perceptions and willingness to adopt Cross-Laminated Timber by the architecture community in the United States. *Journal of Cleaner Production* 94, 198–210.

Öqvist, R., Ljunggren, F. and Ågren, A., 2012. On the uncertainty of building acoustic measurements – Case study of a cross-laminated timber construction. *Applied Acoustics*, 73, 9, 904-912.

Sutton, A., Black, D. and Walker, P., 2017. *Cross Laminated Timber: An introduction to low-impact building materials*. [online] Available at: http://www.bre.co.uk/filelibrary/pdf/projects/low_impact_materials/IP17_11.pdf [Accessed 13 Sep. 2019.

Xia, B., O'Neill, T., Zuo, J., Skitmore, M., Chen, Q., 2014. Perceived obstacles to multi-storey timber-frame construction: an Australian study. *Architectural Science Review* 57, 169–176.