Academic Research

Perceived barriers to the widespread adoption of Mass Timber Construction: An Australian construction industry case study

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Mass Timber Construction (MTC) has significant potential to improve the way the world constructs. However, despite a number of significant projects in Australia, and reported success in Europe and North America, Australia's construction industry has been slow to adopt the system as a mainstream technology. The current study seeks to better understand the nature of the perceived hurdles to greater MTC use. A series of in-depth interviews explored perceived barriers to MTC adoption and strategies for overcoming them. Barriers can be categorised into two domains, 'material' and 'method'. Material based barriers include, the way timber structures are designed and delivered compared with more traditional forms of construction. Knowledge seems incomplete, or incorrect, concerning the technology's durability in terms of fire, rot and structural integrity. Method based barriers include a lack of open source financial and commercial information for risk management purposes. The study concludes with nine practical recommendations.

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Mass Timber Construction (MTC) is a technological innovation with the potential to disrupt the construction industry in Australia. It uses engineered wood products as the primary structural material of choice. Typically, MTC can be substituted for concrete – whether it is wet-poured, steel reinforced or solid section 'tilt-slab' – or steel, for low- to medium-rise buildings for utilitarian applications such as libraries and housing construction projects (Kremer & Symmons, 2015). MTC is an umbrella term that includes specific products such as Cross Laminated Timber (CLT), Glue Laminated Beams (GluLam) and Laminated Veneer Lumber (LVL). CLT is typically the product that comes to mind when talking about massive timber structures.

In terms of its use and benefits MTC is both a product and a process. As a product, MTC construction components – walls, floors, beams, and so on – are assembled in a factory and shipped to site for immediate installation as pre-fabricated units. The building components can be delivered as needed (i.e. just-in-time) or as an entire building or storey (to suit the client's needs). This means that the process of site works can be reduced in intensity and time, significantly lowering site costs and neighborhood disruption (noise, traffic, waste, etc.), minimising the impact of inclement weather and curfews, and reducing site labour costs (Yates, Linegar & Dujic, 2008).

MTC components are typically manufactured from certified plantation softwoods and come from sustainably managed forests, making it a renewable resource. These environmental advantages are in addition to the advantages of carbon sequestration (Depro, Murray, Alig & Shanks, 2008) and lower embodied energy (Lehmann & Fitzgerald, 2012) in using timber compared with steel and concrete; and all without sacrifice in strength, durability and longevity (Wood Solutions, 2013).

The advantages of MTC are being explored and realised in a number of markets, including European countries, the United States and Canada. In some markets governments have recognised the advantages of MTC and altered the regulatory environment to encourage or even advantage MTC use. For example, Canada's British Columbia enacted the Wood First Act as part of their Building Code to increase the allowable height of timber-framed residential buildings from four to six storeys (McGown, 2011). However, there is still hesitation to adopt the technology as mainstream in Australia, despite some significant and well-received demonstration projects. Anecdotally, interest seems high in Australia, but hurdles and barriers have delayed the promising start made by Lend Lease Forte apartment building and the Library at The Dock building – both MTC projects located in Docklands, Melbourne.

The present paper employed a qualitative approach with construction industry insiders to explore some of the factors holding back increased MTC use in Australia. While Australia serves as a case study in early market penetration, the findings should also be useful for efforts to further expand MTC use in other more established or still somewhat niche markets elsewhere.

One potential hurdle to greater MTC use is a perceived caution within the construction industry around public perceptions of an expanded use of timber more generally. Parry-Husbands and Parker (2014) found that for Australian consumers a paradox exists between the negative perceptions of harvesting trees, part-

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icularly from international non-plantation forests without chain of custody certification, and attitudes toward timber as a natural, aesthetically pleasing and environmentally friendly product. Consumers also raised concerns about risk factors associated with the use of wood, such as fire, rot, and termite attack (Forestry Innovation Investment and Binational Softwood Lumber Council, 2014; Parry-Husbands & Parker, 2014). These concerns do not arise in the public mind when thinking about steel and concrete as building materials. Such negative perceptions are bound to result in reluctance on the part of builders who must market projects to buyers.

Another hurdle may rest with the uncertainty or lack of specificity in potential savings, or a question as to whether the savings are sufficient to warrant the use of a new system of construction. The cost savings of using MTC over concrete and steel for medium height buildings has been put at 11-12% (McGowan, 2011; Wood & Design, 2011; Walker, 2010), however it may be less. Dunn (2015) reported that for an eight-storey apartment building the saving was 2.2%, for a single-storey industrial shed 9.4%, 12.4% for a seven-storey office building, and 13.4% for a two-storey aged care facility. The savings varied with the unique elements of the projects. For example, timber columns within the office building cost more than concrete (+41%), yet the requirement for columns within the apartment building was negligible (due to a different approach to design), resulting in considerable savings (-92%). The financial savings for the office and apartment building were generally in the costs associated construction program savings (generally 6 weeks) over the concrete solution. Dunn (2015) also reports that cost savings would have been greater had it not been for the fire protection to some structural components and the costs of termite protection.

An assessment of the Murray Grove MTC project in the United Kingdom reveals that whilst there was a 30% increase in material costs for the cross laminated timber components compared to ferroconcrete, there was a considerable 17-week saving in the expected overall construction program (Yates, Linegar & Dujic, 2008). This time saving resulted in reductions in on-site costs, hire costs of crane, rigging and other plant and equipment, and reduced risk from external factors including inclement weather. Byle (2012) found MTC to be more economical by approximately 6% of the overall cost if materials were sourced internationally, and approximately 12% if materials were locally produced.

In an Australian example, the Lend Lease construction company built the 10 storey Forté building – the largest MTC apartment complex in the world at the time - and found it “was 30% faster to build, safer and with higher precision than traditional construction materials (Patterson in Walsh, 2013, para. 6). It also resulted in reduced construction traffic to and from site, caused less disruption to the community and produced less waste” (Patterson in Walsh, 2013, para. 6). The present study is qualitative employing interviews. it examines perceived barriers and suggested strategies for overcoming them from a number of stakeholders within Australia’s building and construction industry.

Method

Participants

Participants were 9 men with an average of 21 years’ experience (SD = 5.6 years) in the Australian construction, building, or forestry industry sector. Participants had diverse professional backgrounds including the architecture, design, building, forestry, and insurance industries. Participants were recruited either via a snowballing process – referral through networks – or through direct targeted contact initiated by the authors. The response rate for the interviews was approximately 9% of all individuals invited to participate. No invitees from the finance sector agreed to participate in the study. Several participants occupied multiple domains of expertise, thus the number of opinions offered exceeds the number of actual participants. For example, several participants are trained architects but were also working in a project management capacity as the builder. The many roles within which participants exist reflects the multi-disciplinary nature of their activities within their sector.

Measures

Semi-structured interviews included questions concerning awareness of MTC as a material/method, perceptions about MTC’s utility compared to traditional forms of construction, and how potential barriers such as perceptions about durability might be overcome in order to increase the large-scale use of MTC in Australia. Examples of the questions include: “What impact do you think this alternative construction method might have on your particular product or service?”, “What might industry do to increase the level of awareness?”, and “What do you perceive are some of the more general challenges facing the more widespread use MTC in the construction industry?”

Procedure

Following ethics approval (Monash University Human Ethics Research Committee - CF 15/458 – 2015000227), participants were sourced and sent an email in advance of the interview, with an explanatory statement, consent form and the semi-structured questions. Participants also received a written vignette describing MTC - this was identical to that used in an associated quantitative study. Participants accepted the invitation to participate via return email and attaching their signed consent form. Participants contributed data through a recorded interview or responded to the series of semi-structured questions in writing. The authors conducted phone interviews using an MP3 recording device to capture the data. All data handling was in accordance with Monash University data handling and management policies.

Design

The present study adopted Braun and Clarke’s (2006) qualitative methodology; specifically, coding and extracting common elements, identifying, analysing and reporting patterns (themes) within the data. The authors aimed to produce both a descriptive and explanatory analysis of the findings. Descriptive outputs relate to similarities and differences between themes, whilst explanatory elements sought to provide new insights into how participants would resolve barriers to widespread adoption of MTC.

Results

Knowledge of MTC

The majority of participants (90%) had some prior knowledge of MTC as a method or group of material technologies (Cross Laminated Timber, Laminated Veneer Lumber, Glue Laminated Beams). Many participants (70%) indicated that their knowledge

came as a result of the first and second commercial MTC projects in Australia – the Lend Lease Forte apartment building and the Library at The Dock (both projects are located in the Docklands, Melbourne).

"[My understanding came] through the various demonstration projects that have been constructed around Melbourne. So, from a development point of view, I see it as an interesting and unusual addition to the range of products available and it has some specific and definitive uses in its place." Property Developer

"I am aware of the 'Library at the Dock' project in Melbourne, which is an exciting step forward" Designer

Another indicated that while knowledge of MTC may be widespread, the impact the technology is having on industry at present appears small,

"Well there is not enough of it around at the moment to be concerned with it at this stage." Property Underwriter

Perceptions of MTC

The two representatives from the insurance industry considered the technology to attract higher premiums due to the nature of the material it is constructed from – timber,

"From an insurance perspective, a building with more timber construction generally attracts a higher premium than a building constructed with brick or concrete. So, I guess, initially my thoughts are, it would most likely incur a higher premium." Insurance Broker

"Historically the insurance industry is very conservative. There was a category of products called massive timber construction. It covered very old buildings with large timber beams. We [insurance assessors] would treat this category as non-combustible, but that is only a beam, it's not a whole floor or a wall" Property Underwriter

However, for some, MTC is not a standalone solution. Rather it forms part of an integrated series of components along with other materials and technologies,

"I think that the timber industry has kind of put forward cross laminated timber as a solution in its own right for building and construction… But, buildings are using other materials to ensure stability for instance" Property Developer

"I see light timber as a much more traditional technique, and mass timber as the new kid on the block. My bottom-line on cross laminated timber is that it has innate benefits structurally that don't necessarily apply across a whole building. It is great as a shear wall, if you want load bearing walls, that may have a timber finish." Product Manufacturer

From a supply point of view, the interest in MTC is increasing however the technology faces some competition,

"There is a ground swell of interest in MTC, particularly looking at the low and mid-rise to high-rise, anything from four to 10-15 storey buildings and that is obviously the sweet spot for the massive wood. I think that people recognise that for single-storey, one-to-two storey family homes that a timber frame building is ultra-competitive and works extremely well" Supplier

"It is a different type of building process that we really need to rethink the entire process to see the full benefits from off-site pre-fabrication and how that impacts the total building process." Supplier

Another views the technology as,

"[MTC is] inevitable for medium to large scale projects" Architect/ Builder

Whilst the opposing view that MTC may have a place outside of the large-scale commercial and multi-residential market is offered by this participant,

"I believe that [volume] builders will be interested in massive timber as an alternative construction method due to its many benefits, environmental benefits included. This, with many construction items, relies upon availability, cost, and ease of construction." Designer

The mixture of participant responses concerning knowledge about MTC is not surprising given the technology is yet to take hold and find its niche in Australia.

Perceived benefits of MTC

The consensus amongst participants was that there are many benefits of MTC over traditional forms of construction.

"[MTC] has far greater sustainability benefits to our service and allow for faster project delivery resulting in higher revenue and margins with a reduced number of site personnel" Architect/Builder

"I strongly believe that the environmental features are a key selling point for this product. Costs are of course an issue, but like most new technology, as demand increases productivity reduces costs in both manufacture and streamlining the process. I also believe that reducing time in installation and construction is a key component in making the product a viable option, as time in construction relates directly to cost." Designer

In relation to the industry as a collective, some suggest,

"Architects can definitely claim a benefit [from MTC] and claim that they are at the leading edge of design and thinking by using cross laminated timber. It ticks all those boxes." Architect

"The advantages come from the lighter weight and speed of building" Supplier

"[MTC] is great as a panel that can be delivered as an exterior facade, with a window already fitted, not that we can do that yet." Product Manufacturer

Barriers to widespread acceptance

Professional indemnity and public liability insurance are an important components of risk management for MTC, specifically for developers and design teams (Forestry Innovation Investment and Binational Softwood Lumber Council, 2014). Participants from the insurance industry had this to say about MTC and the impact this new technology has on premiums.

"The insurance industry rates things based on historical data. Traditionally timber constructed buildings have a higher propensity to have larger losses than a building constructed out of brick or concrete. I understand that this product is different to a standard piece of timber. However, insurers will probably charge higher premiums purely on the basis that a lot of these systems are new." Insurance Broker

"The insurance industry is very conservative. We tend to sit back and wait and see what things do. You wouldn't find insurers going out promoting new products or things like that." Property Underwriter

It seems important to ensure that the entire supply chain is onboard with the technology,

"I think the biggest hindrance is the unknown. People do not have enough understanding or knowledge about it [MTC], and even though you get the Developer, Architect and Engineer to support it [MTC]. Then there is the Quantity Surveyor, who says that "I am not so sure about this" and places some contingency funding into the project - extra costs - and then that blows the costs of the project right out…Sometimes the Developers say, 'I hear what you say, I see the logic. Nevertheless, I am not sure. Is it actually going to happen that fast? Can it happen as you claim it is going to happen?' So another hindrance" Supplier

On the subject of durability, specifically relating to fire, participants had this to say,

"Historically, there was a category of products called massive timber construction. Basically, it covered very old buildings with large timber beams…we were very comfortable with how that category was managed. Premiums depended upon fire loads in the building. If it has a low fire load and a large timber beam then we were comfortable enough that beam would withstand the fire and no structural collapse would occur in a fire. Our concern comes more when the building starts being clad with timber, or the walls are clad with timber, and you start loading it up with a lot of furniture and other things that burn. We have concerns over what the wood is going to do once it is exposed to a longer term fire." Insurance Broker

"When you combine different types of materials [Timber included] you have different behaviours and this can become quite a challenge, especially from a design point of view – including fire engineering, for example." Supplier

"I think there is a big perception problem. It is true that if you wet timber it isn't constructed or engineered to cope with wet, and it will cause a problem, and it will likewise burn if flame is applied." Forestry Academic

"I think that is going to take some years before they attract enough analysis and enough data to be able to make that judgement as to whether the premiums should be loaded. At the outset I just get the feeling that they will probably charge higher premium because it will fall into the timber construction rather than the brick or concrete." Insurance Broker

"[We] are doing one demonstration project after another… showing structurally it's capable and it meets all the requirements" Property Developer

Other impediments include the savings using an alternate technology,

"At this point the cost is higher, and even on a 'total cost of construction' the margin of saving is small. I mean what is being quoted in the media at the moment is about 4%. Nobody will make a buying decision on 4% overall. Because builders simply don't quantify their time, um, unless they are a larger organisation with the procedures and the people in place and they have the technology." Property Developer

Whilst the risk of attempting to use an alternative method might be too great because it's a 'new technology',

"You have got to have that upfront willingness to try it. To go through a design process, which is cost; before you can figure out whether or not it is suitable and so you have to motivate people across that first hump. Australia is behind the eight ball compared to an EU country." Property Developer

"There is a perceived complexity associated with MTC." Architect/ Builder

"The only way to get a new product's measure from an insurance perspective, to be honest, is to have some fires in these buildings. We understand that the building code is designed to allow everyone to get out of the building in a controlled manner, and recently in the Docklands [Melbourne, Australia] there was a fire. It went up the façade of the building. The insurance industry has been warning about such failures for years. The product meets regulatory compliance at the moment but yet the fire happened. If you simply say 'oh its fully Building Code of Australia compliant' well the insurance industry would simply turn around and say ' well, we have had enough examples of things that are BCA compliant and we have had issues'" Property Underwriter

Ultimately, larger projects attract considerable cost and associated risks. For developers and builders assurances are needed that they won't make losses using the new technology – requiring a proof of concept. Such barriers are overcome by the release of case studies with actual financial forecasting models, however such 'commercial in confidence' material is not readily available,

"I agree that is always going to be the challenge. Everyone will be private about the projects and financial aspects." Supplier

In terms of establishing an MTC manufacturing presence in Australia there are some hurdles that must be overcome,

"Australia was for a while increasing its plantation resource and now it's sort of going backwards. Plantations are now being ripped out and turned into grasslands, croplands, and part of that is basic insecurity of industry and not foreseeing a future market. If we had some way of being able to reclaim those plantations, instead of replant them that would be great." Forestry Academic

Consumer perceptions are a constant reminder of the work ahead for industry marketing teams in dispelling or addressing concerns and advance MTC and more generally timber,

"I think there is an obvious concern amongst consumers in Australia about termites and other infestations for timber products. This would need to be addressed along with cost effective and easy solutions for not only the builders and clients but also for insurance purposes. I also think that external durability may be an obvious concern." Designer

"Timber is not durable when exposed to weather and any failure of waterproofing may lead to significant repair costs and poor reputation of the product" Architect/Builder

Suggested strategies for overcoming barriers

Participants were unanimously united that education campaigns about MTC technology are important in addressing many of the obstacles,

"There is evidence of the performance of this product in Europe for 10 years. Therefore, we are talking about the same material but just in a different country. That data could come from overseas and would certainly help the insurance industry here. Most of the larger firms have overseas offices anyway so they should be able to get such data. It is all based on these actuaries and the data. Therefore, if we can demonstrate the integrity of this product then insurers will certainly take that onboard. If it's new and they have no data, 'oh it's a new product' and it falls into the timber category then bang you get lumped in the timber classification, rather than the brick and the concrete hence higher premiums." Insurance Broker

"Australians can actually go and visit a huge range of projects - from small to very large - so there is not an unknown anymore. Therefore, the hurdles to progressing mass timber are not as high anymore. Plus, how they overcome several challenges and they are readily available through searching online." Supplier

"I guess as brokers, we might find that some of the US or EU companies that we deal MTC and their premiums are substantially cheaper. Once we find this out, we will go to those organisations and recommend insurance premiums that match the clients' expectations." Insurance Broker

"I think we need to create a series of product specific applications promoted through specific marketing material. For example, a cross laminated timber lift shaft. Develop a product for that application. That is an excellent example of how cross laminated timber can be used in a hybrid model with steel framed construction. Case scenarios are great." Architect

"We could develop a walk-through model that you could mount on the back of a van or trailer and meet at a University or other institutions and allow people to walk in and see how MTC works." Supplier

Yet some concede that such campaigns will not be easy or will come at a significant cost,

"There could be a very major training or educational campaign exercise that competing industries are going to hate, and unfortunately the mining industries have much more money than the timber." Architect

"Until there is a fire and we can see the effects [of MTC] I don't think the opinions will shift from 'combustible' to 'non-combustible'. What we do recognise is 'large-scale factory testing', the loss-prevention certification board approvals, so they tend to get more weight however come at a considerable cost. I think you would get your best buy-in from the insurance industry by someone like an FM Global doing large-scale testing and say 'yes we provide an approval if it's used in this way and in this manner'. Get an insurer recognised certification board to do their own testing is one way to overcome the barrier." Property Underwriter

Promoting the core economic benefits of MTC and appealing to industry stakeholder's sense of 'commercialism' was another popular strategy,

"[If builders] have got a lift shaft and they could build it out of timber, because my span is say seven metres and I could use a timber solution for a 4 storey building, do I really want to bring in the concrete trucks if I can do it with my carpenters? Plus, it will go up in days, not in weeks, and the labour component is reduced compared to concrete, not wet trades etc." Architect

"They could go to a broker and the insurers would be played-off against each other. The broker would then go to the other insurers and say 'I can get it for this amount, are you prepared to do it as well?' That would drive the discussion further. Each underwriter would have to say 'are we prepared to take that risk'." Property Underwriter

"You could work in MTC manufacturers and distributors to formulate the ideal and optimal design to make the most of the complex problems found on site. The specifics for the designer and the shop drawings for the detailers… there could be some specific information that makes it very easy to use the product." Architect

"[Builders] could invest resources in order to up-skill to be able to get the answers in the first place." Property Developer

"The use of timber/steel composite materials could actually expand their grid, and with timber and steel composite it could have been a match made in heaven." Product Manufacturer

Using a brokerage and a 'leverage strategy' to secure lower premiums,

"We have a pool of clients and we are able to leverage premiums and demand better fees and better policy conditions. The more you have got of something the more discount and competitiveness you are going to get from the under-writer and the insurer." Insurance Broker

Another suggested that the up-take of MTC is itself a barrier breaker,

"The steady progress of MTC year on year, despite the lack of openness about [confidential] project costings etc., provides strong evidence the technology is a viable…there has to be a driver behind it." Supplier

From a forestry industry perspective, this participant provides a solution addressing barriers in advancing MTC production and suitable resource acquisition,

"If we can bring the [MTC plant and equipment] scale down and make things portable or transportable, we can take the plant to where the current resource is… If you can move around a bit that is a brilliant move." Forestry Academic

A final word

Participants from varying sectors of the building and construction industry offer a few final words for contemplation of the advancement of MTC in Australia,

"Selling MTC as a solution is a very long-term prospect, and I don't think it's going to be successful…components are the best way forward" Property Developer

"When the product hits critical mass then the change will occur." Property Underwriter

"You need to convince the insurance industry, a very conservative industry, that this product can perform. The minute you talk timber, bang it goes into the timber classification. Providing the data that demonstrates the integrity of the product is the most important thing. I am not sure if they have that data. It's also very early stages for the product, we haven't seen any clients constructing out of MTC so it will be interesting to see their reaction when we try a couple in the near future." Insurance Broker

"My bottom-line on cross laminated timber is that it has innate benefits structurally that don't necessarily apply across a whole building. It is great as a shear wall, where you want load-bearing walls, that may have a timber finish. It's great as a panel that can be delivered as an exterior facade, with a window already fitted, - not that we can do that yet - but if that was the case, then we can compare apples with apples with some of the other systems in the market, and that would be a good use of it." Product Manufacturer

"The development economics for MTC in an institutional building or a commercial building are quite different. For a start, in Australia, you have Green Star applicable to commercial buildings that has a cost benefit to the developer if they have that [Green Star rating]." Architect

"The only way to really understand the product is to do a full-scale test and literally load one of these building up and see what happens." Property Underwriter

Discussion

Despite MTC's reported benefits in terms of on-site costs and sustainability, the potential remains unrealised – more so in some markets – due at least in part to a lack of understanding about a number of aspects of the MTC product and its use across a range of stakeholders in the building process. The present paper sought to identify some of the barriers affecting a wider uptake of MTC in Australia. Many participants in this study expressed they had some idea of the concept of MTC as either a material or method prior to being interviewed for the study. Participants attributed their knowledge to the pair of MTC projects in Melbourne, Australia – the Forte apartment building and the Library at The Dock. Similarly, many participants expressed that there are considerable advantages to MTC over alternative construction methods in the form of environmental advantages and construction efficiency, particularly construction program time reductions.

Those without an awareness of MTC, particularly participants from the insurance industry, offered a risk-averse evaluation of the product. Such responses, they noted, reflect the ultra-conservative nature of their industry.

The Survey of International Tall Wood Buildings (Forestry Innovation Investment and Binational Softwood Lumber Council, 2014) also found considerable risks in terms of insurance and financing options. Of the ten projects reviewed for that research, four required an alteration to existing insurance policies. These changes related to the developers' requirement to carry "third party liability insurance and contractors' all risks insurance" and "professional indemnity, public liability, employee insurance and construction insurance" (p. 19). For design teams the main alteration related to public liability and professional indemnity. Advising insurance entities about intentions to use MTC allows for the segregation of the risks associated with a prototype design and gaining sufficient coverage. The cost to stakeholders for policy alterations averaged about 25% more than that for a conventional construction development. As the product and process continues to improve and the lack of adverse outcomes becomes evident, it is likely that competition will gradually erode this premium.

The increased difficulty of securing insurance for a significant MTC project and the cost premiums, coupled with hesitancy around perceived consumer opinions, make financing for an MTC project challenging. This may have contributed to Lend Lease's decision to self-fund the two Melbourne-based MTC projects they delivered. Participants within the Forestry Innovation Investment and Binational Softwood Lumber Council Survey (2014) did not indicate any unusual financing practices or discuss any challenges they faced when securing finance associated with MTC projects. However, 60% of projects listed within the survey were self-financed (by the developer) and a further 20% obtained finance through governmental programs. Traditional builder-owner financing situations accounted for an additional 10% of projects listed (Forestry Innovation Investment and Binational Softwood Lumber Council, 2014).

Within the present study several participants offered insights into how they think other industry stakeholders perceive MTC. One participant submits that people encountering MTC for the first time require more than a simple verbal explanation in order to understand the technology. Explanations relating to what MTC is and how it fits into the existing paradigm of construction and design are influenced by the frame of reference of the person communicating the ideas. Some participants in the present study viewed MTC as a series of discrete components with the sole benefit of integrating with traditional materials. Yet others see MTC as a total solution devoid of a hybridsation of materials – such as concrete and steel. The key message from these findings is that MTC as a material/method is difficult to define because of its versatile nature. This, it is argued, makes communication about the technology difficult, especially when attempting to explain what MTC is to people who have never been exposed to the technology.

Participants within the present study offered a myriad of barriers they believe are hindering the widespread adoption of MTC in Australia. Such barriers are categorised into two domains, 'material' and 'method'. Material-based barriers include the considerable difference in the way timber structures are designed and delivered compared with traditional forms of construction. The often lacking or prejudicial perceptions of MTC present considerable challenges because of uncertainty concerning

concerning the technology's durability in terms of fire, rot and structural integrity. Method-based barriers include a lack of open source financial and commercial information for risk management purposes. However, there is a common thread to the solutions recommended by industry to break down barriers. The primary approach recommended centers around credible, accurate and timely information gathering and dissemination. However, that dissemination may need to be active rather than passive, championing MTC use rather than simply suggesting or advocating for it. Such an approach was implicitly indicated by Yates, Lingar and Dujic's (2008) note that Telford Homes, the developer for the Murray Grove building in the United Kingdom "needed to be convinced of its [MTC] viability at all levels having never procured a building in this way before" (p. 1).

Limitations

Several limitations apply to the findings from the present paper. First, considerable difficulty was experienced recruiting participants prepared to provide their thoughts and perceptions about MTC. Second, the majority of respondents were already advocates for the technology, or at least were more than familiar with it, which may mean the findings are not reflective of the true position of MTC in the market. However, this limitation is somewhat mitigated as MTC technology has now become a truly global movement and whilst the present study is limited to findings from Australia, anecdotally messages from this industry correlate with those of Europe.

Recommendations

The following recommendations offer industry stakeholders an opportunity to resolve identified barriers.

1. *Develop data and information exchange programs/ collaborations with European organisations. Data relating to the considerable amount of work performed using MTC in Europe would certainly benefit Australian construction, particularly the influence of the insurance industry. The insurance industry participants suggest that if developers can demonstrate the integrity of this product then insurers will certainly take that on board, indicating that premiums would potentially remain on par with ferroconcrete. Industry education and training providers could be commissioned to assist in disseminating research findings etc.*
2. *Participate in overseas study tours. Australians can visit a huge range of projects in Europe and Canada. Projects from the very small to very large now provide a sense of what is achievable. Forest and Wood Products Australia, in conjunction with the Timber Development Association (New South Wales) has offered several such trips to industry over the last few years.*
3. *Leverage financial service premiums (insurance and investment) through global organisations. It is evident from the present study that local financial services organisations load premiums. Builders, developers and associated stakeholders could locate international finance and insurance organisations that provide services to customers working with MTC. This might result in a completely different view of the product and premiums might be cheaper. Many project case studies list the associated companies supporting the development. This may include insurance and financial services organisations. This is a suggested starting point for Australian developers to secure competitive services.*
4. *Use brokerage firms. Builders, developers and associated stakeholders could use brokers for insurance and finance. Brokers would communicate with organisations and recommend financial and insurance services that match the clients' expectations. Industry insiders suggest that brokers are able to reverse-auction premiums for services that benefit the client. Pooling projects and clients together provides brokerage firms with leverage. Buyer bargaining power is a useful strategy to secure lower premiums.*
5. *Manufacturers could produce a series of product specific applications using MTC. These applications could be promoted through specific marketing material. For example, a cross laminated timber lift shaft or stair system.*
6. *Case study scenarios specific to builders at various tiers/ levels. In collaboration with key stakeholders, Australian manufacturers and industry suppliers could develop a series of easy to understand non-commercial in confidence cost saving case studies. These can be developed and disseminated to tier one, two and three builders expressing interest in using MTC, avoiding the requirement of costly quantification comparisons to more traditional forms of construction. Cost savings might also be expressed in percentage terms to assuage concerns about releasing actual cost information.*
7. *MTC portable displays. Suppliers and manufacturers of MTC, and its various stakeholders and component manufacturers/ suppliers could develop walk-through showcases or displays that could be mounted on the back of a trailer. Such displays would represent a cross-section of an actual building with internal linings, external cladding, wiring and plumbing etc. Such displays could be parked at common meeting areas, such as a University or other institutions, trade shows and conferences allowing people to walk in and see how MTC actually works.*
8. *Full-scale testing. Research conducted by internationally credible sources, such as FM Global, could be commissioned to undertake large-scale testing. Approvals may be granted if product applications are tested and replicated on-site. Approved methods of construction may satisfy the insurance and financial services industries*.
9. *Pre-fabricated solutions for complex on-site problems. MTC manufacturers and distributors could formulate optimal designs using mass timber components, solving some of the more complex problems found on building sites. The specifics for the designer, the shop drawings and the detailers, provide very specific information that makes it very easy to use the product.*

Many of these recommendations might be more easily implemented as a suite through the formation of an international MTC industry body, perhaps funded by MTC manufacturers and others. Such a body could centralise a rigorous testing program (though not necessarily carry out the testing themselves) to assuage concerns and continue to refine the process and product for use in taller buildings. They could also collect and disseminate case studies that highlight mechanisms for maximising cost savings, offer advice for manufacturers establishing in new markets, and so on. By virtue of their size and reach they could also function as an insurance broker or aggregator, or at least apply pressure for premium reductions. To further ease the way such a body might provide advice and lobbying *to regulatory bodies so that local rules do not unduly stifle MTC use due to lack of knowledge or misperceptions.*

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