Timber: Trends in Availability, Sustainability and Durability for Bridges

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ABSTRACT

The Australian forestry industry produces around 30 million cubic metres of wood per year which is a readily available building material for infrastructure projects. However, there is a perception of a lack of availability of large dimension timber products. This paper outlines ongoing innovation with timber products and a number of emerging trends that may favour their longer-term use in bridge projects into the future. These trends include resource availability, the growing use of engineered timber products and the rising importance of sustainability policies.

An important sustainability factor that supports the use of timber products is the low carbon emission impact compared to substitute products such as steel and concrete. This has contributed to an increasing interest and adoption by many public authorities of Wood Encouragement Policies in the built environment.

Processing and manufacturing innovations are increasing the availability of new engineered wood products that enable a timber substitute or alternative to many traditional timber products including bridge components. These products are able to be made in a wide range of dimensions and offer many key benefits including being lightweight, stable and minimal variation in mechanical performances.

Timber preservation treatments that boost durability performance to suit intended product exposure are well established and detailed within the Australian Standards framework. In addition, the versatility of timber systems, in terms of their ease of replacement, can also extend service life outcomes to meet both short and long-term design needs. This can be a cost-effective solution with low capital and replacement costs over the typical life cycle of a bridge.

It is argued that these trends support timber solutions for bridge component replacement or renewal, as an increasingly more viable economic and environmental option which should be considered in the market.

1 INTRODUCTION

This paper looks at various factors influencing future wood availability and use for timber components in bridge construction in Australia. These factors include wood resource availability, emerging trends in timber processing innovation and manufacture, environmental sustainability, durability design and ease of replacement, and the growing awareness of biophilic design and use of natural materials such as timber in the built environment.

2 RESOURCE AVAILABILITY

Within Australia there is around 1.95 million hectares of wood plantation forest and 28.1 million hectares of native forest that is legally available for harvest with low to high wood commerciality (Commonwealth of Australia 2018). The Australian harvest of roundwood was 32.9 million cubic metres in 2017-18, representing a significant domestic resource for the production of timber products to supply building and construction projects such as timber bridges.

Hardwood plantations are predominately managed on a short-rotation basis for pulpwood and export woodchip markets and represent around 50% of the plantation forest estate. The remaining softwood plantation resource is managed on longer rotation (e.g. 25-50 years depending on species) and is used to produce sawn timber and a range of engineered wood products.

Over time, as some areas of public native forests have been transferred from state forests to other land tenures, the harvest from public native forests has declined. The annual harvest of hardwood sawlogs from public forests has averaged around 1.14 million cubic metres in recent years (Commonwealth of Australia 2018). However, there is growing interest in improving the management of private native forests (PNF), where there is around 13.6 million hectares of commercial PNF across Australia. Within areas such as South-East Queensland and northern New South Wales, for example, there is considerable potential to increase hardwood supplies from improved silvicultural management of these forests (Queensland Department of Agriculture and Fisheries 2018). This can provide an additional resource for solid timber products such as poles and bridge girders, as well as increase the availability of smaller diameter logs that could be manufactured into engineered wood products for bridge components.

In terms of future wood harvest levels in Australia, there is forecast to be an increase from around 30 million m^3 in 2015 to around 33 million m^3 over the period 2020 to 2050 (Figure 1). Most of this increase is due to maturing hardwood (HW) pulplog plantations, which are typically exported for pulp fibre markets. The harvest of plantation softwoods (SW) is expected to remain relatively constant in the absence of any additional drivers for new plantation investment.

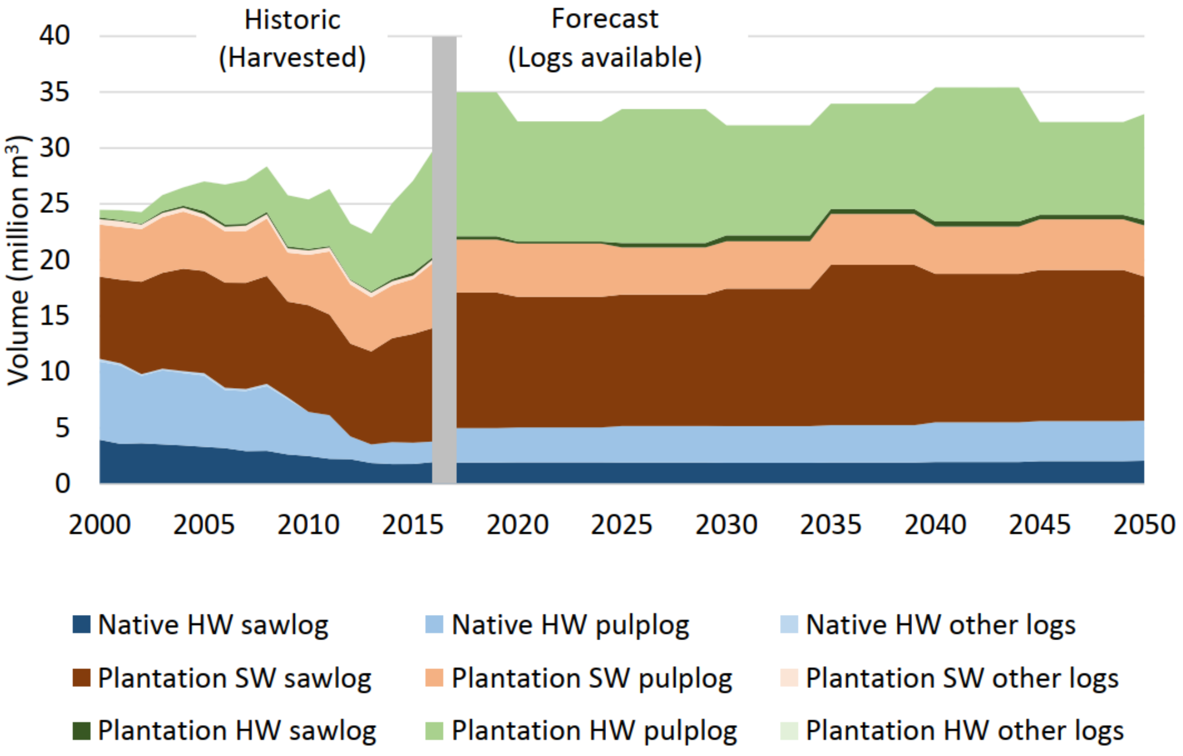

Figure 1 - Historic and forecast wood harvest levels Australia 2000 – 2050 (Whittle et al 2019)

Factors that may drive future plantation investment include carbon market incentives such as the Emissions Reduction Fund and any new carbon reduction policies by Government. Forestry can play an important role in emission reduction strategies due to the sequestration of carbon dioxide from the atmosphere in growing forests and storage in timber and forest products. The Australian Government has recently announced a new National Forest Industries Plan with a goal to plant an additional 1 billion timber production trees to boost timber supply for further processing (Prime Minister of Australia 2019).

In addition, there are emerging technologies that can convert the volume of smaller diameter or lower quality logs to high performance Engineered Wood Products (EWPs) such as plywood and glue laminated timber which can be used for bridge construction (refer processing innovation below).

Overall, domestic resource availability will be enhanced by these trends and any shortfall in future demand from local supply can be met by imported timber products, where Australia has remained a net importer of wood products. The Australian timber supply chain is well-established and capable of adapting to future market needs.

3 TRENDS IN TIMBER BRIDGE CONSTRUCTION

3.1 Timber processing innovation

As forest resources have changed over time (e.g. species mix, log grade) and processing and manufacturing systems advance, EWPs have begun to provide a complimentary material to traditional solid wood products. EWPs are a group of products which are manufactured by bonding and/or mechanically fastening together wood strands, veneers, sawn timber or other forms of wood fibre to produce a larger composite unit (Leggate *et al.* 2017). EWPs may also include the blending of forest resource feedstocks with other materials including steel, concrete, glass fibres etc. to provide advanced composite systems.

There can be many advantages in using EWPs. The design and manufacturing of EWPs allows greater flexibility in the type, dimension and quality of feedstock used meaning that there is less waste and greater utilisation of the available forest resources. EWPs provides opportunities to utilise variable feedstock qualities through their strategic positioning within the product cross section such that the final product is more consistent and often with superior performance properties.

EWPs are typically more efficient to install as they are often lighter in weight, more consistent in dimensioning and straighter than the equivalent traditional product. They also tend to be more stable when exposed to fluctuating climatic conditions. EWPs also tend to lend themselves to more efficient utilisation in prefabricated systems.

There are many opportunities to use EWPs in the maintenance of existing bridge systems or in the construction of new bridge systems. The common EWPs potentially best suited for bridge components are rotary veneer-based products such as plywood and laminated veneer lumber (LVL), and glue laminated timber (often referred to as glulam).

Veneer-based EWPs have been successfully used for bride components in Australia and some other countries for decades. The most common application has been bridge decks which have been manufactured using plywood panels which are jointed and then laminated together using adhesive and often mechanical fastenings to form mass plywood panels. If necessary, the durability of the timber is enhanced with regular preservative approaches to ensure the end-product is reliable for the defined service life and intended exposure class. Using this method, almost any size bridge deck panel can be manufactured. Other bridge components are also able to be manufactured from rotary veneer such as girders. These can be designed so that they are similar size to traditional ‘log style’ girders making them easily substitutable during bridge maintenance. Girders and other similar products are more suited to a LVL manufacturing method which ensures the timber grain alignment provides the best mechanical advantage for way in which load is applied to these product types. Several companies are manufacturing veneer-based bridge components and supplying to the Australian market.

Glue laminated timber (GLT) also has a long history in bridge construction. This product type is manufactured through gluing small-dimension sawn timber together to generate a beam of almost any dimension. Similar to the veneer-based products, glulam products can be manufactured using preservative treated feedstock if required to ensure the end-product has sufficient durability for the intended exposure. Bridge designs that include the use of glulam are relatively common in many parts of world, however are not as common in Australia. A number of suppliers are beginning to provide glulam products specifically for bridges in Australia.

The rise of EWPs has also been driving a world-wide trend for tall timber buildings, with many examples of tall buildings constructed of timber such as the Tallwood House student accommodation (53 metres) in British Columbia and Lendlease's 25 King Street (45 metres) office building in Brisbane. In Norway, an 85 metre residential tower has just been announced as the world's tallest timber building, including elevator shafts made entirely from cross laminated timber (CLT), and columns made from GLT. In addition, Australia's National Construction Code (NCC) has recently been revised to allow for deemed-to-satisfy timber buildings up to 25 metres (typically 8 storeys).

These trends that include timber innovation in tall buildings are likely to have similar implications for bridges in Australia, which could equally benefit from the use of strong, lightweight and cost-effective materials such as EWP systems. It is argued that some of the limitations to date include lack of awareness of these systems, a conservative culture and a lack of trained engineers that are more accustomed to using traditional concrete and steel.

3.2 Environmental sustainability

Trends in environmental sustainability and greenhouse gas policies are beginning to have an impact on the choice of building materials such as timber in the wider construction market (Arup 2019). Timber products by their very nature contain a broad range of positive environmental attributes including their:

- renewability as a re-growable natural resource;
- recyclability;
- ability to capture and store large amounts of atmospheric carbon dioxide; and
- low embodied energy relative to other materials.

The Australian construction sector is estimated to have a carbon footprint of around 90 million tonnes or 18 per cent of Australia's total annual emissions, with roads and bridges accounting for 9 Mt per annum (Yu et al., 2017). Building materials represented 21 per cent of sector emissions, with energy intensive materials such as cement, concrete and brick representing 39 per cent of the materials impact. Construction services such as demolition and concreting also accounted for 8 per cent of the construction sector carbon footprint (Yu et al., 2017).

Strategies for reducing the impact of the building sector include greater use of low carbon emission materials such as timber. Teh et al. (2017) looked at a number of mitigation scenarios for the residential and commercial building sector for Australia and identified increasing the use of timber delivered the most significant reductions of all material choices modelled.

At an individual bridge level, carbon impacts will obviously vary depending on scale and pre-existing conditions. A recent case study in Norway has shown that the use of stress laminated timber (SLT) bridge decks over concrete generate considerable carbon benefits using life-cycle analysis whether as a greenfield project or replacement (O'Born and Vertes 2017). In the first case, a new timber network arched bridge resulted in 31 per cent less emissions (1410 versus 2032 tonnes) compared to a steel arch and concrete deck bridge, and in the second case the replacement of a degraded concrete deck with timber resulted in 35 per cent less emissions (13 tonnes).

For these reasons, many building policies are emerging to proactively promote the benefits of carbon friendly materials. This has included, for example, recent revisions to the green credit rating system used by the Green Building Council of Australia to better capture the low embodied energy of using timber in buildings.

The other related trend by governments globally and locally has been the adoption of a wood encouragement policy (WEP), which requires timber to be considered as a preferred construction material in projects when it is equally fit-for-purpose. Within Australia, 16 local councils have already adopted a WEP, as well as one State Government (Tasmania) and two local government associations (figure 2).

These types of policies are relevant to bridge projects in either the public (e.g. local government) or private sector, given increasing interest in ‘carbon neutral’ projects and corporate social responsibilities.

Another relevant environmental factor is the sustainability of forest management from where the timber is sourced. The timber industry was one of the first internationally to develop and then adopt independent third-party certification schemes for sustainable forest management. Globally, the area of certified forest has increased thirty-fold since 2000 covering a total area of over 450 million hectares or around 30% of the world’s industrial roundwood (figure 3).

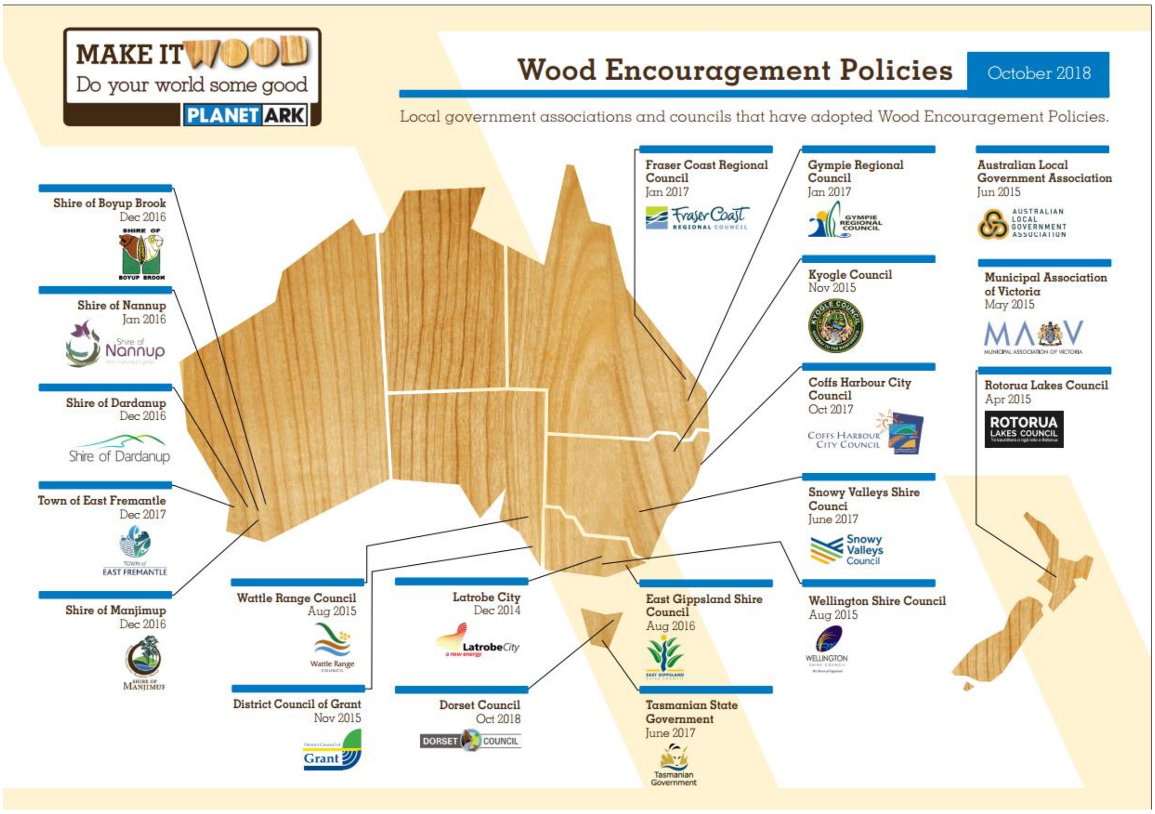

Figure 2 - Wood Encouragement Policies adopted in Australia and New Zealand by local and state governments (Planet Ark 2019)

Within Australia, 8.8 million hectares is certified under either or both of the major international schemes being the Forest Stewardship Council (FSC) or the Programme for Endorsement of Forest Certification Schemes (PEFC). There are also over 440 Chain of Custody Certificates with either scheme held by suppliers within Australia (Commonwealth of Australia 2018), making it relatively easy to source certified product.

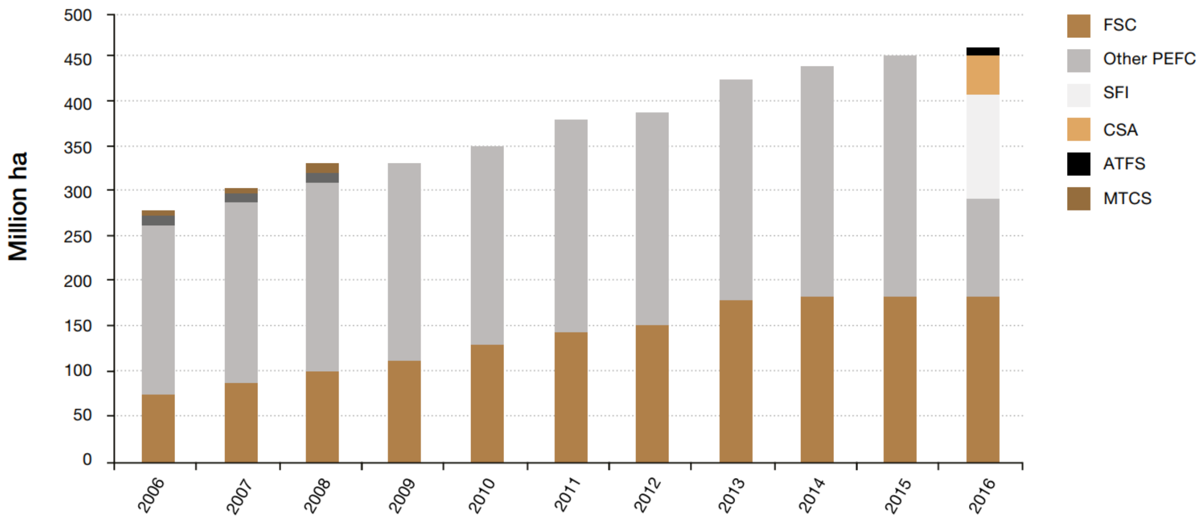

Figure 3 - Cumulative global forest area under sustainable forest management certification (UNECE / FAO in Arup 2019)

3.3 Durability and cost effectiveness

The other major factor influencing asset management decisions and material choices for bridges is the durability of timber relative to design life. Australian Standards for timber durability have led to extensive guidance on hazard classes and use of timber for varying hazard levels in terms of exposure to fungal and termite risks. Durability can typically vary from 25 years to up to 100 years or more depending on exposure (e.g. above/below ground, inside/outside), location (climatic conditions) and treatment type. The range of preservative treatments for timber has also expanded over the past few decades. Engineers need to become familiar with the range of treatments when using timber and their applicability to the longevity of timber bridges.

The other, and perhaps more compelling factor, influencing durability and long design life considerations is the rising ability for timber bridge components to be easily replaceable at the end of their relative service life (e.g. 25 or 50 years). Given their light weight and ability to be prefabricated and transportable at relatively low cost, the life cycle costs factoring in periodic replacement can be lower than the larger upfront capital costs of traditional alternatives such as concrete and steel.

Significant opportunities therefore exist to increase the use of EWPs as direct replacements for end-of-life components within existing bridges allowing the service life of the bridge systems to be extended. In addition, EWPs can be used to manufacture entire bridge systems which can also be faster to install than alternatives.

Some examples of recent bridge replacements in Australia using EWPs such as glulam and plywood, as well as solid timber girders in some instances, are provided below (figures 4 and 5).

Figure 4 – PNG Forest Products NiuBridge system with plywood deck on the New England Highway

These examples demonstrate the versatility of EWP systems for bridges and their modular and prefabricated advantages being reflected in the market.

In the Far North region of Queensland, for example, the Cassowary Coast council has undertaken a timber bridge replacement program with newer EWP systems which has been driven largely by the considerable asset management cost savings (Roads and Civil Magazine 2017).

Figure 5 – Timber Restoration Systems glulam bridge pre-assembled for transport to a Queensland project

3.4 Health benefits

There is a growing body of evidence demonstrating that a connection to nature, biophilic design and natural materials such as wood are associated with improved physical and mental wellbeing (Planet Ark 2018).

Building designers and architects are increasingly incorporating timber as a natural material in interiors (e.g. flooring, cladding) and other visible structural elements (e.g. beams, columns) in the built environment based on the principle that connection to nature is essential to human well-being. Recent research has revealed that natural-looking wooden surfaces in the workplace are strongly associated with increased employee wellbeing and satisfaction, with less stress and higher productivity (Knox and Parry-Husbands 2018).

These principles equally apply to bridge design and construction in Australia, given the important role bridges play in urban and rural infrastructure (e.g. roads, rail, and pedestrian), and their aesthetic and related health impacts on individual well-being and community values.

4 CONCLUSION

This paper has outlined a number of technological and environmental trends that will influence the future use of timber in bridges across Australia. It is argued that these trends will have a positive effect in promoting timber bridge constructions, whether new or replacement projects. This will be driven by cost-effectiveness considerations for bridge asset managers and owners as well the ability of timber bridges to deliver multiple economic, environmental and social benefits.

5 REFERENCES

- Arup (2019). *Rethinking Timber Buildings. Seven perspectives on the use of timber in building design and construction*, London, February.
- Commonwealth of Australia (2018). Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018, *Australia's State of the Forests Report 2018*, ABARES, Canberra, December.
- Knox, A. and Parry-Husbands, H. (2018). *Workplaces: Wellness + Wood = Productivity*, Pollinate report prepared for Forest and Wood Products Australia, February.
- Leggate W., McGavin R., and Bailleres H. (2017). *A guide to manufacturing rotary veneer and products from small logs*. Australian Centre International Agricultural Research, Canberra, Australia.
- O'Born R., and Vertes K. (2017). *Comparative life cycle assessment of concrete and timber road bridge deck designs,* Conference Proceedings, ICTB 2017, 3rd International Conference on Timber Bridges, Sweden.
- Planet Ark (2018). *Wood: Nature Inspired Design*. An update of the Wood – Housing, Health, Humanity Report. Accessed at: https://makeitwood.org/documents/doc-1501-wood---nature-inspired-design-report-final.pdf
- Prime Minister of Australia (2019). *Securing the future of our forestry industry*, Media Release, 16 February.
- Queensland Department of Agriculture and Fisheries (2018). *Private native forest management: South eastern Queensland,* Fact Sheet.
- Roads and Civil Magazine (2017). *A Renewed Focus*, June/July 2017, pp.26-28.
- Teh S.H., Wiedmann, T., Schinabeck, J., and Moore, S. (2017), Replacement scenarios for construction materials based on economy-wide hybrid LCA, *Procedia Engineering* 180: 179-189.
- Whittle, L., Lock, P., and Hug, B. (2019). *Economic potential for new plantation establishment in Australia: Outlook to 2050*, Research report 19.4, ABARES, February.
- Yu M., Wiedmann, T., Crawford, R. and Tait, C. (2017). The carbon footprint of Australia's construction sector, *Procedia Engineering* 180: 211-220.

6 ACKNOWLEDGEMENTS

The authors wish to acknowledge the use of photos of timber bridge projects from Timber Restoration Systems and PNG Forest Products.

7 AUTHOR BIOGRAPHIES

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His experience has included plantation development and sustainable forest management, rangelands, agroforestry, renewable energy, timber standards, regional development, forest products manufacturing, paper recycling and climate change policy.

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He has over 23 years' experience in forest product research and development focusing mainly on solid wood and veneer processing, engineered wood product design and manufacture, and wood product utilisation.

He has completed PhD studies on the "Analysis of small-log processing to achieve structural veneer from juvenile hardwood plantations" and has managed over $12 million in research funding since 2000 which has included leading numerous large scale, multi-party, Australian and international research projects.