Economic Review

Understanding Costs and Identifying Value in Mass Timber Construction: Calculating the ‘Total Cost of Project’ (TCP)

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With any new technology introduced to market there is often an education process for industry stakeholders to understand the benefits. The present paper sought to explain the difference between ‘costs’ and ‘value’ in Mass Timber Construction (MTC). Specifically, the paper focuses on what has been termed the Total Cost of Project (TCP), in which the value (benefits) of using MTC technologies — such as Cross Laminated Timber (CLT) and Glue Laminated (GluLam) beams and columns — is quantified and offset against material costs in a pure cost-versus-cost calculation commonly used in traditional construction estimation/quotation. The quantification of ‘value’, as defined by various stakeholders along the supply chain, is seen as an opportunity to demonstrate the holistic advantage of MTC. The present paper provides a worked example looking at the cost and value of using MTC for the builder, as stakeholder, TCP of a mid-rise apartment complex in Australia. The analysis identifies a productivity gain, resulting in a 30% reduction in duration on site, ultimately resulting in reduced risk exposure and time related costs compared with traditional concrete construction.

Keywords: *Cost versus value, Mass timber construction, Cross laminated timber, Quantity surveying, Productivity*

Mass Timber Construction (MTC) is a new construction material and methodology that involves the production of timber elements within a manufacturing centre, which are then shipped to a construction site and assembled (Kremer & Symmons, 2015). One such technology within the suite of MTC ‘disruptive technologies’ is Cross Laminated Timber (CLT). CLT is a timber based technology in which timber boards are glue-bonded in layers in alternating directions and pressed to form a solid rectangular billet. From these billets, panels are cut and penetrations are made with millimeter accuracy using a Computer Numerical Cutting (CNC) machine. Once completed, the panels are sequenced for installation and shipped to the construction site for assembly. CLT falls under an umbrella of technologies within the ‘prebuilt’ or ‘preconstruction’ market, whereby construction industry stakeholders attempt to use controlled off-site manufacturing environments to achieve improved on-site productivity gains (Forsythe and Carrick, 2013).

Like any new technology introduced to market, there is often an education process required to be undertaken by various stakeholders within the industry to understand the benefits and the potential impacts of the technology on industry. The introduction of MTC into the global construction market is no different. Indeed, one of the advantages of MTC over more traditional forms of construction is the unique way in which the ‘value’ is quantified in order to derive a benefit for those adopting the technology. The value of MTC can be defined even further to relate to the exact position a stakeholder occupies along the supply chain. Unfortunately, some forms of ‘value’ are difficult to quantify and require additional calculation to realise completely. The aim of this paper is to educate industry stakeholders through a ‘costs versus value’ analysis of MTC. However, before we deep-dive into the topic, let’s settle and agree on some terminology, which shall be used throughout the paper.

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What do we mean by cost?

The Oxford dictionary defines cost as both a noun and verb. As a verb, it states a cost “(of an object or action) requiring payment of (a specified sum of money) before it can be acquired or done.” (Oxford Dictionary, 2018a) and to “estimate the price of” (Oxford Dictionary, 2018a). These should be very familiar terms to those in the quantity surveying profession. As a noun, the dictionary states “an amount that has to be paid or spent to buy or obtain something” (Oxford Dictionary, 2018a). These definitions seem pretty straightforward, thus let’s just focus our attention on cost to mean ‘the price that has to be paid for something’, and in the context of MTC let’s also state that what we are going to compare is the material “cost” of CLT with say wet-pour reinforced concrete.

By way of example, using a rule of thumb or heuristics, we know that for the same dimensional thickness of concrete, say 200mm thick concrete floor slab, and CLT floor panel we achieve about the same spanning properties in both technologies. We also know that the supply cost, currently, for CLT attracts a premium over in-situ steel reinforced concrete — depending on which brand of CLT you purchase, the location in world from which it is manufactured/shipped and the species of the timber. As with any new technology, this cost premium can be attributed to the limited supply volumes in a climate of increasing demand. However, ongoing expansion in global production capacity, and standardisation and commoditisation of the product is expected to result in reduced supply costs throughout the industry.

What do we mean by value?

The Oxford dictionary also defines value as both a noun and verb. As a verb, it states, value is "the regard that something is held to deserve; the importance, worth, or usefulness of something" (Oxford Dictionary, 2018b), as a noun, value is an "estimate of the monetary worth of [something]" (Oxford Dictionary, 2018a). Again these two definitions seem simple to understand, so in the context of MTC lets define "value" as the benefit (monetary or other) to the customer derived from the positive difference in material or methodology between MTC compared with more traditional forms of construction. For example, a considerable value in terms of cost of MTC is a reduction in on-site labour, particularly where utilised as part of a prefabrication methodology, compared with traditional concrete formwork construction (Gasparri et al., 2015). This comparison is well illustrated in the case of Australia's first CLT apartment building, Forte, which was built by LendLease in Melbourne's Docklands precinct in 2012.

At ten storeys high, the multi-residential project features a steel reinforced concrete substructure, ground floor, and first floor podium slab, from which point the building's CLT superstructure begins. While the concrete footings and podium slab required an on-site workforce typical of any in-situ concrete project (i.e. formworkers, steel fixers, concrete pumpers, and concrete placers) the remaining nine storeys of CLT structure were installed by a crew of just six workers, comprising three to four apprentice carpenters, and two crane and support staff. Such efficiencies not only represent a significant reduction in individuals on site, but also the number of subcontractors involved in the project, simplifying contractual arrangements and on-site administration. It has since been noted anecdotally that the usage of mass timber resulted in a reduction in the vicinity of approximately 20 on-site personnel.

A simple approach to comparing the costs of this structure with those of a similar project in concrete would be to take the total cost of the labour on-site for the equivalent concrete structure and subtract the CLT on-site labour and the variance is the cost saving. While straightforward and somewhat logical, this comparison fails to consider the 'value' in each circumstance. 'Value' associated with the MTC option may include reduced disruption, minimized waste, low noise levels, and fewer live edges (resulting increased safety on site), however for this example we will examine the 'value' of a more ordered, and therefore safer worksite (Shroff, 2016). The prefabricated nature of MTC projects means that panel delivery can occur in a pre-determined sequence, at a predetermined rate. This, in addition to the minimal number of materials required for on-site assembly (typically the panels, props, fixings, tape, and eventually grout), means that MTC sites are often tidier, and present fewer trip hazards than a comparable project in either steel or concrete. So what 'value' does a business place on a safer work environment for its employees? Another example of 'value' can be seen in risk exposure, and ultimately reduced insurance premiums — a quantifiable value. However, it is more difficult to quantify the value of staff going home to her or his family each night. What price do we place on that?

What is the difference between cost and value?

The difference between cost and value is the "customer's" perspective on the use of one technology over another. For example, a developer or builder may find value in the lightweight of timber - CLT panels weigh 20% that of concrete panels for the same dimensional volume of material – which may allow them to build more sellable area than possible with heavier materials. The costs in this circumstance are easy to quantify; one can take the difference in the volumes, calculate the weight of the structure, and reconfigure the project's piling and footings to suit. The cost difference between the choice of the two technologies equates to the cost saving. However, how do you quantify the value to the customer who now has the opportunity to use 'reclaimed land', 'land with poor soil conditions' and 'the real estate air-space above concrete carparks'? Where these 'real estate' development locations couldn't viably accommodate heavy concrete structures or their large footings, the light weight of timber provides a solution. As increasingly seen around the world, mass timber buildings can be built higher, with smaller footings, rendering previously difficult projects feasible, and opening up entirely new markets for the use of MTC. In a traditional 'cost calculation' it is easy to miss or overlook the value to various stakeholders. In the instance of MTC a straight material-for-material cost calculation to determine 'value' is erroneous.

A crucial element in the discussion concerning value is 'who is the customer'? In the aforementioned example the customer has been identified as the property developer or builder. However, it is understood that those stakeholders do not constitute the entire supply chain. So the 'value equation' will likely be different for each stakeholder along the supply chain. For example, the architect might want to use the technology to achieve airtightness ratings required for a Passivehaus or six star GreenStar rating, or alternatively to prove the sustainability focus of the firm. So, the 'value' to the architect might be in the minute cutting tolerances of the CNC, or alternatively the firm's contribution to supporting the environment. How do you quantify these desired value derivatives? Equally, a home or apartment owner, the end user stakeholder, wants to purchase a CLT home because of the health benefits (reduced stress, lower anxiety etc.) of living in a timber structure (Cameron et al., 2015). How do you quantify this value? Of course we could apply some fancy statistical technique, such as modifying a Bayesian inferencing model (Bernardo & Smith, 1994), where 'value assumptions' are assigned to outcomes and using a modified 'likelihood function' we might create a statistical model for interpretation — yet not everyone is a statistician nor has the capacity to do so.

What is the value for stakeholders in the MTC supply chain?

An important question for determining the actual value for a stakeholder is what benefit they will likely require/want from using MTC. Table 1. depicts the various stakeholders and their likely 'value' from using MTC technology. In terms of the costs, each stakeholder will want to understand what the cost is to use MTC. This can easily be derived from a budget estimate and, with more complete and full information, a quotation. However, the 'value' element of MTC stems from the stakeholder with whom we are interacting with. Indeed, the cost versus value calculation is likely to be highly complex given the complex nature of stakeholder requirements with respect to the uniqueness of each project.

It is typically at the tender stage of a project—first round to find a builder for the project and then second round to determine the subcontractors—that the costs of the project are revealed. Project costs often do not consider the 'value' that accompanies the use of MTC as this can vary from project to project, and is often difficult to quantify. To attempt to accurately estimate the impact of the 'value' in MTC one must define the value in the context of the stakeholder to whom that value belongs. With the stakeholder's context clarified it may be possible to quantify this

Table 1. *Perceived Value of Stakeholders Using Mass Timber Construction*

Stakeholder	Perceived Value
Property Developer	Accessible and reimagined real estate opportunities — city above the city, land that was not fit for development is now, differentiation in market, shorter build duration resulting in reduced interest costs and risk exposure.
Architect	New and novel construction method/material, sustainability, making a statement, being ahead of the design curve for industry, reduced variations, opportunity to optimise designs for cost and operation.
Engineers	Understanding of the new technology, ability to push the limits and boundaries, new frontiers in engineering.
Builder	Program savings, competitive advantage, risk management, fewer first aid incidents, cost reduction, labour savings, reduced lifting requirements.
Constructor/Trade	Reduction in manpower, ease of assembly, faster build times, project completion with lower skilled labour, increased on-site safety.
Public/Local Council	Reduced duration and extent of disruption to neighbours, traffic, and authorities.
End User	Comfort, reduced energy costs, socially conscious investment, homely feel, reduced maintenance, etc.

value, and identify any potential ‘cost-offset’ that improves MTC’s position (for any material cost impost) against more traditional forms and materials in construction. A worked example of this has been provided next.

A worked example of cost and value in MTC

So far we have established that cost is different to value. We have also established that while MTC attracts a higher material cost (mainly due to the relatively limited production capacity and increased global demand), installation typically involves a fraction of the workforce required for in-situ concrete, and as such attracts a smaller cost. Whilst cost is the price paid for an item or service and remains fairly constant no matter the stakeholder, value, on the other hand, is actually different depending on the stakeholder’s position in the supply chain. One of the difficulties of assessing value is how we quantify it and how this might then be reintroduced back into the project (potentially as an offset) for a more thorough and complete evaluation of the usefulness of MTC technologies. Outlined next is a potential ‘cost versus value’ scenario for the builder, as stakeholder, on a mid-rise apartment complex in traditional construction versus MTC.

MTC employs a ‘flipped construction model’ to deliver program savings on the construction site. In essence, all of the decisions regarding the superstructure are made at an early stage of the design process, much sooner than a traditional construction project. Often, the basement, ground floor, and potentially the first floor are produced in steel reinforced concrete, as seen at LendLease’s Forte project, with the mass timber structure beginning on the first floor transfer deck. This reinforced concrete substructure and “podium” provides sufficient separation between different building classes (e.g. car parking, hospitality, or retail and the multi-residential superstructure), and minimizes the risk of exposing the timber structure to pooling ground water or floods.

While MTC typically requires more time within the ‘design’ phase, the ‘construction phase’ is generally shorter by approximately 30% — for those skilled at installing CLT and GluLam (Kremer & Symmons, 2015). This reduction in on-site time can be attributed to several factors, not limited to: increased levels of prefabrication, pre-coordination of services, high levels of design resolution resulting in fewer variations, simplification and reduction of deliveries, fewer trades on site, and increased safety for workers. Figure 1. illustrates the differences in the project program between the two technologies.

The cost saving achieved through the reduced on-site program can be estimated through the consideration of all time-related costs of the project. Tangible costs associated with this area include (but are not limited to): tower or mobile crane hire, other plant and equipment hire, permits and insurances, labour, finance costs, interest costs, etc. while intangible time-related cost sav-

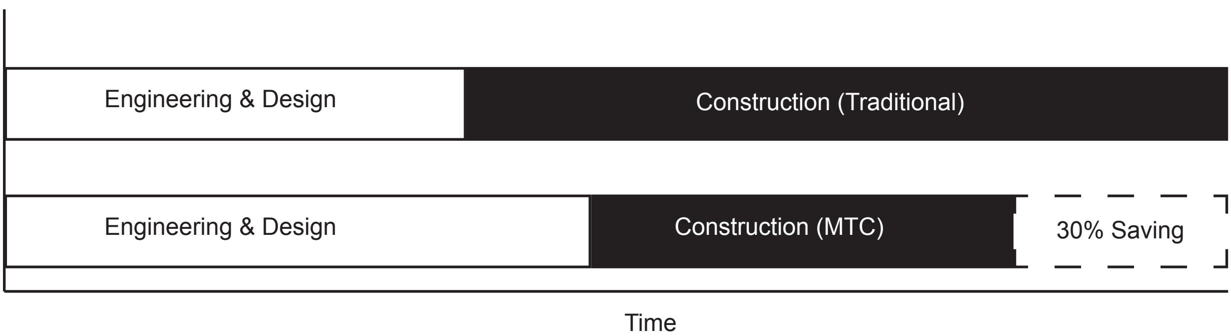

Figure 1. Differences in Programs for Traditional and MTC Construction Methods

ings may include reduced risk exposure and reduced disruption to the area. In terms of 'value' it is not often that these 'cost reductions' are off-set against the project costs.

Given the aforementioned, what looked like a simple assessment of the costs of MTC becomes a more complex equation when you take into consideration a number of different factors, which can have a significant impact on the Total Cost of Project (TCP) for the project. TCP is introduced here as being similar to the 'total cost of ownership' concept, however limits the costs associated with TCP to the completion of the project only, not the total lifecycle of the project as well as running and maintenance costs associated with the asset over time unlike total cost of ownership. TCP should be considered as part of the overall assessment when comparing costs associated with MTC and traditional construction (i.e. steel reinforced concrete).

TCP comparison of CLT and concrete construction for a mid-rise residential project

In this section we shall explore the cost comparison between steel-reinforced concrete and CLT construction for an eight storey multi-residential project. Prepared by MBMpl (MBM), a quantity surveying and cost management firm, this cost comparison provides a comprehensive cost assessment for the construction of a theoretical mid-rise building designed for both CLT, and reinforced concrete structural systems (Dunn & Perrie, 2017).

Table 2 provides a summary of the cost estimates for the CLT and steel-reinforced concrete constructed mid-rise residential apartment complex.

The MBM analysis (Dunn & Perrie, 2017) indicates some substantial savings are achieved from using the CLT option. In particular the authors cite sources of significant savings are related to: the concrete transfer slab on level one, loadbearing structure including walls, floors and columns and roof, plus a line item indicating the variance in preliminary costs between the structural systems – or the "value" of the CLT system. This line item accounts for over 98% of the savings in this cost comparison, and as such warrants further investigation. The adjustment to preliminaries considers only the impact of the reduced on-site program on time-sensitive costs such as crane hire, site shed hire, supervision, scaffolding, and traffic control costs. This adjustment has been calculated based off the assumption that the CLT project will reach practical completion six weeks (or 17%) earlier than the reinforced concrete design. The preliminary costs have been estimated to equal $52,000 per week, resulting in a total adjustment of -$287,000 after an extra sum is deducted for termite protection. Without this value off-set being added, looking at the pure project 'cost only', we see that they are almost equivalent ($4,693,714.00 versus $4,698,581.00). Thus not capturing the TCP can potentially have a detrimental impact on the assessment of adoption for technologies like CLT.

When compared with traditional reinforced concrete construction, projects utilising MTC have been reported to achieve practical completion between 25% and 40% faster (Kremer & Symmons, 2015; Eurban, 2018). What's more, the weekly sum allocated to preliminary costs could be argued to be relatively minor in comparison to those experienced on a typical eight storey mid-rise project on a brown-field site. These factors suggest that the comparison provides a correct, yet conservative view.

Table 2. *Total Cost of Project Comparison Between CLT and Concrete Low-Rise Apartments*

Description	Cross Laminated Timber	Concrete Construction	Difference CLT to Concrete
Columns	$34,935	$365,644	-90%
Upper Floors	$2,539,961	$1,810,398	+40%
Staircases	$81,200	$66,150	+23%
Roof	$233,100	$356,617	-35%
External Walls	$518,082	$416,165	+24%
Internal Walls	$1,286,436	$1,224,522	+5%
Wall Finishes	Included	Included	-
Ceiling Finishes	Included	$459,085	-
Preliminaries Adjustment	(- $287,000)	-	-
Total Cost of Project (TCP)	**$4,406,714**	**$4,698,581**	**- 6%**

Note. Adopted and adapted from Dunn and Perrie (2017).

While the preliminary cost calculations have captured savings associated with time-related costs, there are several other potential sources of value that must be considered to provide a holistic estimate. These factors refer to the intrinsic properties of CLT identified earlier in this paper, including its light weight, high degree of prefabrication, and ease of install. These properties can provide significant value for a project, with lighter wall and floor panels allowing for the use of a smaller crane, the smaller installation crews directly impacting the scale of amenities and extent of supervision required, and the opportunity to prefabricate façade elements prior to their delivery to site potentially reducing scaffolding requirements. This added value results in tangible savings, and can be calculated through an in-depth review of a project, its design, and any site constraints.

It is also important to note the intangible value that MTC brings to this case study project. The intangible value afforded to this project by MTC is different for each stakeholder and can be particularly difficult to calculate until it is realized through the occurrence of an event, if at all. For example, the reduced on-site program and on-site workforce associated with a MTC project reduces the risk exposure for all parties involved, however the monetary value for this reduced risk is difficult to calculate. While contingencies can be estimated through the use of advanced risk calculation tools, these are not widely understood or utilized within the Australian construction industry. It is not until an incident occurs, and the emergency response, review, and investigation has taken place that we can know the true cost of a risk event (and subsequently, the value of it not occurring).

In conclusion, understanding the 'cost versus value' relationship is an important concept in determining the TCP for a massive timber project. An analysis that merely explores the costs only for materials on a project, for example the comparison between CLT and steel-reinforced concrete, is erroneous given the very different benefits MTC provides in terms of a construction material and methodology (i.e. lightweight material and program savings etc.). The TCP concept presented here provides some guidance on how cost and value can be captured together providing a holistic indication of MTC's use in project development, relative to the position of the stakeholder within the supply chain, and with due consideration for the value, or benefit, stakeholders might seek/derive from using MTC.

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