Cross Laminated Timber: Perspectives on the Market, Environmental and Economic Considerations for the Puget Region and Washington State

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1.0 Introduction

Cross laminated timber (CLT), sometimes also called mass timber, is a composite construction system consisting of perpendicularly – oriented, glued layers of lumber, fabricated under pressure into large structural panels that can replace steel and concrete structural systems in taller buildings. This system is described in considerable detail in the CLT Handbook (FP Innovations, 2013). Its prospective Seattle deployment is addressed in a recent report by Seattle architect, Mahlum (Mahlum, et al, 2014).

Among the promising features of CLT for Pacific Northwest building applications are: the potential to utilize an abundant, renewable local resource; possible cost savings; its low embodied energy content; the ability to sequester carbon and the opportunity to contribute jobs and economic value to the local forest products industry.

A recent study completed by noted international architect, Skidmore Owings and Merrill (SOM, 2014), estimated the embodied carbon footprint of a prototypical timber high rise building structure to be 60% to 70% less than a similar conventional concrete or steel structure. SOM has asserted that even lower embodied energy levels may be achieved in CLT, depending on the methods by which its constituent lumber is processed.

This paper touches only briefly the technical aspects and code issues associated with CLT. It assumes that others are working on these issues and that progress will occur. Instead, it sketches an overview of the prospective size of the Puget Sound and statewide market for CLT, makes an estimate of some of the environmental benefits associated with the technology, suggests some economic opportunities arising from CLT adoption and also identifies prospective challenges and areas of further study and research necessary for its broader use in the construction industry.

2.0 Codes, Standards and CLT in Context

Most building codes do not now allow, as – of - right, wood or timber structures more than seven stories total, including a two – story, non - combustible base or podium structure, generally constructed of concrete. However, the forthcoming International Building Code (IBC) for 2015 will recognize CLT explicitly, paving the way for wider use and presumably taller, wood structures (Mass Timber, 2014). Recent construction in Europe, Canada and Australasia has demonstrated that taller CLT institutional, commercial and residential buildings can be successfully constructed as high as 14 stories.

Though not technically CLT, the most notable recent Seattle example of a similar technology is the Bullitt Center for the Environment, which employs a timber column and deck system. This structure consists of four timber stories constructed atop a 2 story concrete podium

The Seattle architect, Mahlum and others, recently completed a study of CLT, placing the technology in the context of local zoning and construction practices (Mahlum et al, 2014) The Mahlum report suggests that CLT's likely point of entry in the local construction market will be buildings taller than the typical "five over two," (stories); what they term "low, high - rise" construction ranging from 8 to 12 stories in height. Their preliminary findings indicate CLT could be technically feasible and cost competitive with concrete and light steel frame buildings of this size. We concur that this seems a reasonable first market.

3.0 CLT Market in the Puget Region

What is the potential for CLT as a system of construction in the Puget Region and statewide? Estimating the market for any new product is difficult. CLT is no different. It is new to North America and not a thoroughly proven technology. There are many uncertainties associated with the technology including: codes and standards, material and labor costs, building trades and construction policies and likely tradeoffs among various stakeholders.

It is possible to obtain a general sense of the potential for CLT by examining the local and state markets for construction and making some assumptions. McGraw Hill publishes a variety of reports on historical construction activity and projections of future construction throughout the country, broken down by metropolitan markets. We purchased data for the Seattle area since it is responsible for the majority of high - rise construction in the State, (McGraw Hill, 2013). This area includes King, Pierce and Snohomish Counties and the cities of Seattle, Tacoma, Everett and Bellevue as well as suburbs. McGraw Hill's data summarizes construction square footage by building type and covers a ten - year period; a five - year construction history and five - year forecast (2009-2018) (Table 1).

The McGraw Hill data does not tabulate construction by building height. We therefore made assumptions about the percentage of a particular building type that might be expected to fall in the high - rise category, e.g. greater than about seven stories and thus a prospective candidate for CLT. For example, we assumed a greater percentage of office construction would fall in the high - rise category than would retail, which tends to be low rise. We then summed the prospective high - rise construction categories to obtain a general idea of the high rise market. This sum is about 36 million square feet that could be a candidate for CLT.

CLT should be considered as a technology with a prospective statewide application and impact. Having outlined the general market magnitude of the Puget region above what might be the larger market throughout Washington? The greater Seattle Combined Statistical Area has about 3.5 million inhabitants and the State about 7 million total population (Wikipedia, 2014, Wikipedia, 2014a). However, it would be misleading to extrapolate statewide high - rise construction as directly proportional to population. High - rise construction correlates with high population density and land values. Urban areas throughout the state are generally much less dense than greater Seattle. Even though non - greater Seattle population comprises about 50% of the statewide total we assume that a lesser percentage of that is dense enough to justify high - rise.

Therefore, we have assumed that non - Seattle high - rise could constitute perhaps an additional 20% to the total for Seattle, or about 7 million square feet as candidate for CLT construction. Taking Seattle and the balance of the State into account we suggest for the period 2009-2018 that about 43 million square feet of high - rise construction could have been a candidate for CLT construction, had the technology been available, technically feasible and cost competitive (See also Table 1).

We do not claim that CLT technology would have captured all of this construction. Instead this is a sketch of the general size of the prospective market. As the Mahlum report notes, low, high - rise is the likely first market. As with most new technologies, as challenges are overcome, there will be a few early adopter or pilot projects and then a gradual market uptake, likely following an "S" shaped curve.

What would this have meant in terms of statewide environmental benefits and economic development. To evaluate the benefits of CLT we need both prospective building square footage and an equivalent quantity of CLT material. The SOM study previously cited used a figure of .8 cubic feet of CLT timber required for each corresponding square foot of high - rise construction. This equates to about 34 million cubic feet of material or using the common measure of lumber, the board foot (a square foot of wood 1 " thick) a total need for 411 million board feet of CLT material statewide. This would mean an average of about 3.5 million board feet annually, over the 10 - year estimate period (See also Table 1).

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Table 1

Metro Seattle (King, Pierce and Snohomish Co) 10 Yr Construction History and Forecast and Potential for High Rise

Building Type (square feet)	2009	1020	2011	2012	2013	2014	2015	2016	2017	2018	10 yr total Construction Projected	% High Rise Assumed*	High Rise SF projected 2009 - 2018
Retail	1068000	927000	1150000	1054000	697000	1150000	1836000	2008000	1987000	2032000	13,909,000	10%	1,390,900
Office	2445000	764000	862000	557000	2973000	1880000	2052000	2159000	2459000	2286000	18,437,000	65%	11,984,050
Hotel	552000	275000	189000	200000	754000	606000	757000	699000	611000	523000	3,950,000	65%	2,567,500
Education	1953000	1562000	1826000	1143000	1304000	1105000	1371000	1792000	2202000	2269000	10,043,000	10%	1,004,300
Healthcare	637000	1200000	1107000	254000	184000	560000	585000	636000	684000	693000	3,342,000	20%	668,400
Other Non Residential (incl. institutional)	3756000	2802000	5341000	4720000	7152000	6391000	7427000	8146000	7953000	7752000	61,440,000	20%	12,288,000
Multifamily (units)	3303	2461	6906	9200	8690	9431	11207	12052	11107	10174	84,531		-
Multifamily SF**	1899225	1415075	3970950	5290000	4996750	5422825	6444025	6929900	6386525	5850050	36,030,075	20%	7,206,015
Ten Year Cumulative Total										**Total sf:**	**133,326,606**		**35,718,265**

Statewide Highrise Potential

Assumed balance of statewide highrise as % of Greater Seattle Total	**20%**	**7,143,653**
Total Seattle and statewide highrise as candidate for CLT		**42,861,918**

CLT Potential

Volume of CLT to construct statewide high - rise CLT @ .8 cubic ft CLT/square ft of building***	**34,289,534**
Board feet of CLT	**411,474,413**
Annual Average CLT over 10 years	**41,147,441**

Source for Base Construction Projections: McGraw Hill Construction Research & Analytics; Metropolitan Construction Market, Seattle 2013 4th Quarter

* Assumed % building greater than 7 stories

** Assume 600 sf avg unit plus 15% = 775 sf, based on sampling of recently built 1 BR apts currently advertised in Seattle market

*** SOM, 2013

4.0 Environmental Benefits

Quantification of the carbon footprints of various construction materials and methods is an emerging field. Several researchers have begun to quantify the carbon footprint of CLT. SOM's recent report (SOM, 2014) modeled the carbon footprint of a hypothetical timber high - rise residential tower and compared it to a previously constructed concrete tower of their own design. Other authors (Clark, 2013 and John et al, 2013) have modeled timber, steel and concrete building designs to determine their comparative carbon footprints. Table 2 following compares these findings, measured in pounds of carbon, emitted per square foot of building.

We note here a distinction between the term "cradle to gate" and "cradle to grave" or "cradle to cradle" in green building technology. For consistency across sources, the footprint figures in this report are all "cradle to gate," meaning an estimate of the carbon footprint of a building material from its source through its manufacturing process up to the point it leaves the factory or mill gate. "Cradle to cradle" and "cradle to grave" are accounting methods addressing the full life cycle of a product and are beyond the scope of this short paper.

As Table 2 shows, while various authors do not concur on the absolute carbon emission numbers associated with concrete and steel construction, they tend to agree that these emissions are relatively, very similar.

In the case of timber construction these authors have mooted several different material and process scenarios; all of them being considerably less in emissions than concrete/steel construction. For the purpose of this study we have used a mean value for concrete/steel of about 50 pounds of carbon emitted per square foot. For timber construction we use "high" and "low" cases following SOM's high figure of 15 lbs/sf and a low figure of 0 lbs/sf emissions.

SOM arrives at the lower number assuming that the lumber in CLT is air dried, rather than kiln dried, saving considerable energy – and emissions. The "0" emission number is achieved due to the carbon captured and "sunk" in the wood, itself.

Table 2

Comparison of Structural System Cradle to Gate Carbon Carbon Footprints; Various Studies

Structural System	Authors						
	SOM*	Arup**	Bennett**	Easton**	Target 0**	Cundall**	John, et al***
Concrete structure incl. fndn.	60	31	36	57	54	31	90
Steel structure incl. fndn.	x	33	35	51	54	28	92
Timber structure incl. fndn	15	x	x	x	x	x	8
Sustainable Timber per SOM incl. fndn	0	x	x	x	x	x	x
Sustainable Concrete per SOM incl. fndn	40	x	x	x	x	x	x
Timber Plus per John, Perez et al	x	x	x	x	x	x	-3

All cases adjusted for "cradle to gate" and including foundations but not including construction process

All adjusted to CO2 in lbs/sf of building area

Sources: SOM 2013*, Clark and Bradley, 2013**, John, Buchanan and Perez, 2013***

What emissions savings could have resulted had CLT been used for the 10 year construction scenario outlined in this paper? Table 3 shows between 750,000 and over 1 millions tons of carbon emissions could have been avoided had CLT replaced concrete or steel high - rise construction.

As mentioned, we do attempt to compare timber against steel and concrete structures in terms of construction energy and carbon footprint. This is an area for future research and analysis. Anecdotal reports suggest timber may have an advantage due to its comparatively faster construction sequence.

Table 3

Estimated Carbon Savings: If CLT High Rise Replaced Current Technology

Estimated 2009 - 2018 High Rise Construction (sf)				42,861,918
Estimated Cradle to Gate Carbon Footprint if Concrete or Steel at 50lb/sf				2,143,095,900
			tons	1,071,548
Estimated Cradle to Gate Carbon Footprint if Timber (High Scenario at 15lbs/sf)				642,928,770
			tons	321,464.39
Estimated Cradle to Gate Carbon Footprint if Sustainable Timber (Low Scenario at 0lbs/sf				0
			tons	0
10 Yr Savings if using Timber Hi Scenario compared to Concrete or Steel			**tons**	**750,084**
10 Yr Savings if using Timber Low Scenario if compared to Concrete or Ste			**tons**	**1,071,548**

Source for Timber Scenarios: SOM, 2013

5.0 Economic Considerations

What economic benefits might accrue from the adoption of CLT? Two principal areas come to mind. The first is jobs and an associated stimulus to the forest products industry. The second is prospective cost savings in the construction process.

Forest Products Industry Benefits
It is hardly news that the forest products industry in Washington State has been in decline. Can CLT take up some of the slack? Lippke and Mason (2005) cited several authors regarding the ratio of board feet of timber harvest to job creation in the Pacific Northwest. The ratios of direct jobs/million board feet ranged from 9 to 13. For the purpose of this paper we use a figure of 10 jobs/mmbf. Another figure of 4 indirect jobs in related processing and services was also cited and we use it for a total of 14 jobs/mmbf feet. Therefore, if annual production of CLT was 41 million board feet as sketched in the preceding market scenario this would result in more than 500 new jobs (Table 4).

We note that in comparison to the California market, and perhaps more importantly the Asian market, Washington State is quite small. Future research should explore whether a profitable local CLT industry can be created to serve these vastly larger markets.

We have suggested a likely scenario where a few pilot CLT projects would lead the way and thus initial employment impact would be very small. We also assume that CLT related job creation may follow general industry trends, e.g. greater productivity, leading to few jobs per unit production.

Table 4
Employment Implications

Average Annual Board Foot CLT Production if replacing concrete and steel				41,147,441
Direct Employment at 10 jobs/mmbf				411
Indirect Employment at 4 jobs/mmbf				165
Total Direct and Indirect Jobs				576

Source: Lippke and Mason, 2005

There is presently no CLT mill or production capacity in Washington State although several mills produce glue laminated (glulam) beams and could be prospective candidates to upgrade to CLT production given adequate demand (Table 5).

Table 5
Engineered Wood Mills in WA State

Name	Type
Calvert Company, Vancouver, WA	glue laminated beams, columns trusses
Calvert Company Washougal, WA	glue laminated beams, columns, trusses
G.R. Plume Company, Ferndale, WA	custom laminated beams, columns, trusses
Pacific Woodtech, Burlington, WA	engineered joists and beams
Shelton Lam and Deck, Chehalis, WA	tongue and groove glulam decking

Only one CLT Mill lies within this geographic (Northwest) region; Structurlam, in Penticton, British Columbia; another is in Quebec. The APA (APA; Engineered Wood Association, 2013) compiles statistics on various engineered wood products and mills and mentions in the yearbook for 2012 that only approximately 2 million board feet of CLT was produced in 2011 throughout North America While Structulam's production capacity is unknown and is likely proprietary information, we speculate that CLT demand in Washington State would have to grow considerably before an in - State CLT facility could be justified.

<u>Construction Cost Savings</u>
Mahlum (Mahlum et al, 2014) has suggested there may be modest cost savings associated with CLT, due to more rapid construction, less field fitting and less labor necessary from more expensive labor categories, such as iron workers. Other anecdotal reports (Fountain, 2012) on completed CLT buildings, also note modest cost savings.

From a broad economic perspective there may be tradeoffs resulting from widespread adoption of CLT. For example, more prospective forest product jobs and cheaper high rise construction may need to be weighed against fewer, shorter duration, high paying construction jobs. More study is clearly needed on this topic as with other issues raised in this paper.

6.0 Summary and Future Research

This report has outlined at a conceptual level some considerations associated with introduction of CLT as a widely used technology for high - rise construction in Washington State. Given its growing acceptance and Washington State's position as a leading producer of forest products, as well as the State's reputation for innovation and environmental leadership, CLT is a compelling technology.

In addition to a host of architectural/engineering, code and construction issues, many questions remain concerning environmental and economic benefits and tradeoffs associated with CLT. Following is a partial list of future research needs:

Material Quantities
As more CLT buildings are constructed, measures of material quantities of CLT should be validated for comparison with other construction systems.

Labor Inputs
As in the foregoing, with more constructed buildings there should also be a much better assessment of the actual construction labor involved. How does this compare with other construction systems.? Who wins and who loses among the building trades.

Construction Costs
What are actual construction costs with CLT compared to competing systems? What are the potential labor, material and time savings?

CLT Production Technology
This paper did not examine the manufacturing of CLT in any detail. How much capital and labor are required to build and operate a CLT mill and what production scale is economic? Can existing engineered wood mills Washington convert to CLT or are all new production facilities necessary? Assuming greater automation, how many jobs will actually be created?

More Consensus on Environmental Impact
More real world experience and analysis on the above topics, should lead to better estimates of environmental impacts and benefits.

Market
What is a realistic first market and subsequent market penetration for CLT? Could Washington State realistically target much larger, more distant markets in the United States and elsewhere?

Industry Stakeholders
As with any prospectively disruptive technology there will likely be winners and losers. Which industries and stakeholder groups may benefit and which may not?

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