Cross Laminated Timber (CLT) Future Potential in Ontario Compared With BC and Quebec

by

Zhikang Qin

FACULTY OF NATURAL RESOURCES MANAGEMENT, LAKEHEAD UNIVERSITY THUNDER BAY, ONTARIO

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A CAUTION TO THE READER

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ABSTRACT

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Cross Laminated Timber is a relatively new timber product in Canada with a bright future The product is an advancement that is allowing the industry to create products for larger structures and more specifically taller structures as building codes allow for taller wood structures in the three provinces being studied. This paper mainly focuses on whether CLT will progress in Ontario compared with how it has in British Columbia and Quebec. The analyze will look at the market, technological process, species used in CLT, and case studies of CLT in BC and Quebec to predict if Ontario has the opportunity to develop its own CLT production facilities. With global increases in engineered wood products there is opportunities for Ontario's wood industry to become a producer of CLT products. The benefit of innovations such as CLT are many, such as using a renewable resource to replace non-renewable resources in construction, sequestering large amounts of carbon in wood products and wood products are considered a carbon neutral product.

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1.0 Introduction

This paper aims at predicting the potential of CLT in Ontario compared to the industries existing in British Columbia and Quebec. CLT is cross laminated timber, which originated in Austria and Germany in the 1990's (Karacabeyli, Erol & Douglas, year). It is gaining popularity as a constructional material due to its production costs, convenience of installation, light and other building and environmental characteristics. CLT is still at an infancy phase in North America compared to European use. It has been used in North America for a decade, thus it has not been used widely nor is manufacturing at a high level yet in Canada. There is a potential opportunity in Ontario for a production facility, which means it is necessary to know this product's potential in Ontario. British Columbia and Quebec have already developed their technology of CLT for a period of time and they have been successful in their CLT technology to construct some brilliant buildings with CLT and CLT combined with other building materials such as Glulam and with concrete and steel. So, Ontario can draw on their experience to predict if CLT has a potential production opportunity in Ontario for internal as well as export markets.

Before beginning a comparison between provinces, it is necessary to know general information about CLT, then investigate how British Columbia & Quebec handle CLT, which can help Ontario to predict CLT potential in a reasonable way. This paper will discuss the general information relating to the above aspect relating to CLT. This will include a general introduction of CLT that is broken down into the technological processes of CLT manufacturing, tree species lumber used as the raw material, relevant properties of CLT market of the product, comparison to other construction materials, advantages and disadvantages of CLT use., and standards/codes for CLT.

2.0 Literature review

2.1 General introduction about CLT

2.1.1 Technological process of CLT manufacturing

In regard to technological process of CLT in most countries, the first stage is tree harvesting. Logs are delivered to a mill where they are converted to lumber. Generally, the lumber for surfacing should dried to the Moisture Content of 19% or less, the MC of lumber for CLT should be more less than this standard prior to planning (Karacabeyli & Douglas, 2013). Lumber for CLT requires that the edges are not rounded as is the case with traditional construction lumber, they are required to be squared during the planning stage of production (Karacabeyli & Douglas, 2013). This lumber is brought to the CLT production facility where adhesive is applied to the surfaces of the combined lumbers. There are three types of adhesive would be used in facility, Phenolic types such as phenol-resorcinol formaldehyde (PRF); Emulsion polymer isocyanate (EPI); and One-component polyurethane (PUR) (Karacabeyli & Douglas, 2013). The lumber is laid out in layers where each layer is opposing the layer above or below it at 90 degrees (Karacabeyli & Douglas, 2013). The number of layer depends on the requirement, generally it would be 3, 5, or 7 layers (Karacabeyli & Douglas, 2013). Vacuum press or hydraulic press would use to press both top and sides of combined layers to form the CLT panel, the recommended ambient temperature should be higher than 60°F for the adhesive cure and the time of press is generally from ten minutes to several hours, which is depend on the type of adhesive (Karacabeyli & Douglas, 2013). The manufactured CLT is completed following sanding of the surfaces and any trimming required (Karacabeyli & Douglas, 2013). Current CLT technology is comprised of softwood species, typically using strength graded material (Kramer 2014) as will be discussed further in this paper.

2.1.2 Species lumber used as the raw material in CLT

CLT is made from lumber, so the primary stage of choosing the right lumber is important for the properties of the product. The lumber used is mainly softwoods due to many properties such as strength per weight (SEC, n.d.), ease of use (SEC, n.d.), acceptance of properties in structural applications (SEC, n.d.), and available resources within the industry (SEC, n.d.). In the UK, they prefer to use softwoods (spruce and pine mostly) due to the above mentioned properties. The primary species used anticipated in the UK is Sitka spruce (*Picea sitchensis*) due to 50% occupancy volume of UK softwood resource (Crawford et al. 2015). In Austria, CLT is produced mostly from Norway spruce (*Picea abies*), White fir (*Abies alba*), Scots pine (*Pinus sylvestris*), rarely European larch (*Larix decidua*), Douglas fir (*Pseudotsuga menziesii*) and Swiss stone pine (*Pinus cembra*) (Stauder 2013). In Canada we use our SPF species group in CLT production (Mukhopadhyaya et al. 2014). In BC, the main lumber species utilized in CLT are SPF group species and Douglas fir-Larch species , hence, Douglas fir is the prominent choice for BC (Bill & John 2017). More specifically, the species are Engelmann Spruce (*Picea engelmannii*), White Spruce (*Picea glauca*), hybrid white spruce (mixture of White Spruce and Engelmann Spruce), Lodgepole Pine (*Pinus contorta*), Subalpine Fir (*Abies lasiocarpa*), Douglas Fir (Pseudotsuga menziesii) (West Fraser n.d.) and Hemlock (*Conium maculatum*) which is used for aesthetics on exposed surfaces in CLT manufacture (Bill & John 2017). In Quebec the main SPF species utilized in CLT are Black Spruce (*Picea mariana*), White Spruce (*Picea glauca*), Jack Pine (*Pinus banksiana*) and Balsam Fir (*Abies balsamea*) (QWEB n.d.). In Ontario the main SPF species that would be utilized in CLT are White and Black Spruce (*Picea glauca* and *Picea mariana*, respectively), Jack Pine (*Pinus banksiana*) and Balsam Fir (*Picea balsamea*).

Austrian manufacturers and American academics have begun to look into the use of hardwood/softwood hybrids and hardwood only species for CLT product development (Young 2016). The main reason for this is the use of lower quality wood layers in the neutral axis layers to save on costs and to utilize species in the neutral axis layer that do not require the same strength properties as the outer layers

(Young 2016). In the case of all hardwood CLT this can be a cost saving strategy by using undervalued hardwoods that are not utilized by industry but have properties sufficient for some applications for CLT (Young 2016). There are also studies looking at the use of Bamboo (Li et al. 2019) and Eucalyptus (Lu et al. 2018).

2.1.3 Relevant properties of CLT

The reason for CLT production's near exponential growths mainly because of its great manufacturing, installation and property characteristics. According to the research of Schickhofer (2016), CLT has developed over a few decades and its basic structure is comparable to common construction products with the major advantage of high dimensional stability in-plane due to cross-wise layering. The thickness of CLT allows using it as a stand-alone structural element with outstanding strength and stiffness properties (Schickhofer 2016). Additionally, it is easy to handle and its versatile applicability opens new markets for timber engineering and allows architecture and engineering to realize (super)structures and monolithic buildings in timber (Brandner et al. 2016). CLT is also a high-value alternative for reinforced concrete or other mineral-based solid construction materials where CLT is now a serious competitor on the market (Brandner 2016). The solid structure of CLT allows also using timber species with lower mechanical properties than Norway spruce (*Picea abies*), the species typically used in Europe. CLT has established itself as a superior building material through materials such as the Solid Timber Construction Technique in Cross Laminated Timber (Brandner et al. 2016), which describes CLT as a building construction system which demonstrates the potential use as well as economic and competitive advantages of CLT. This material presents product properties in conjunction with strength class systems, providing essential input parameters for the design process, as well as corresponding test configurations. There is a focus on Europe and the state-of-the-art production there and on the use of Norway spruce with homogeneous layup (all boards correspond to the same strength class) as a quasi-rigid composite structure with side face bonded layers (Schickhofer 2016). This is a good base to move forward the wide spread use of CLT in Canada and the USA, creating a growing market for this product and additional opportunities for an Ontario manufacturing facility.

2.1.4 The market of CLT

The CLT market has seen production with almost exponential growth globally in the last 20 years as figure 1 shows (Espinoza, et al. 2015) and the predicted production in 2021 is 1300,000 m^3 (PREIFER, n.d.). Although the last twenty years data comes from 2015, it still indicates that CLT is capturing a larger proportion in the wood products market year over year. Production is heavily concentrated in central Europe currently, specifically the German-speaking countries, which hold just under 80% of the global installed production capacity as of 2015 (60% in Austria, 17% in Germany, and 3% in Switzerland (Espinoza, et al. 2015)).

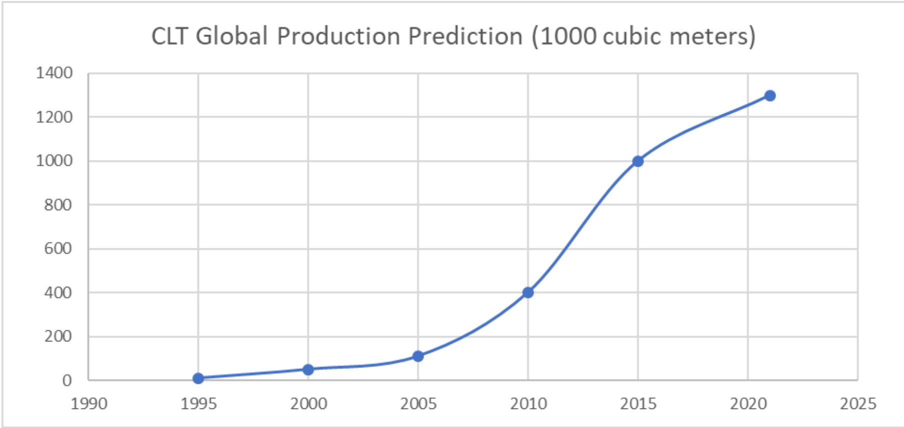

Figure 1: The global production of CLT (source: Espinoza, et al. 2015 & PREIFER, n.d.).

The figure 2 shows the large manufacturing range of CLT production facilities globally, which is a result of the near exponential growth of CLT in the construction industry. From central Europe to North America and Eastern Asia, the market of CLT is growing year by year (Espinoza, et al. 2015). Future growth is not expected to slow and with increasing environmental concerns globally it can be predicted that growth will remain strong or even increase.

Figure 2: Global distribution of CLT manufacturing plants in 2015/2016 (source: Muszynski et al. 2017)

2.1.5 Comparison with other construction materials

There is a wide range of construction materials, however the main materials to be compared with CLT are the most common construction materials like concrete, steel, and some engineered wood products such as plywood, glulam (glue-laminated-timber), dimensional lumber and OSB (oriented strand board). The properties to compare in building applications include fire resistance, corrosion resistance, acoustic absorption, strength, and cost. For fire resistance, CLT is not easy to ignite because it is thicker than most of the traditional wood panels (Xu, 2013). Compared with concrete and steel, CLT still shows better fire resistance properties because of this thicker solid wood structure and how wood chars and burns slowly (Xu 2013). This feature of solid timber is that once it has been burned, the exterior layer would form a charcoal layer to prevent the fire burning into an internal part rapidly (Xu 2013). Though the weight of CLT is five times lighter than the equivalent size of concrete, the strength of CLT is not inferior to concrete due to the specific structure (SMTC, n.d.).

The cost of CLT panels would be higher than other materials due to processing and particularly in tall buildings the restrictions from Codes and therefore extra engineering and architect costs for one off structures beyond what the Codes typically allow. However, if the salaries and installation costs are taken into consideration, the result would be different as the prefabricated nature of CLT brings benefits when it comes to the actual building construction phase. The time and difficulty of installation are less than concrete and steel. Therefore, cost would be less than concrete and steel (SMTC, n.d.).

Compared to glulam (glue-laminated-timber), glulam is more flexible to manufacture to any shape and length, but the properties are almost the same as CLT, the utilization of glulam in the construction phase has a different application than CLT (ASH 2018). For example glulam could be the supporting posts and beams for the CLT floor, wall and ceiling/roof panels. Glulam does have properties that make it a competitor for CLT in some instances such as main structural posts and beams where CLT can be utilized.

For OSB, it is used typically for sheathing and not structural or in exterior or moist environments, while CLT is much better in this respect and is structural (APA 2018). Similar to OSB, plywood is not moisture resistant (unless treated) and is not structural so possess no real threat in the market for CLT. This is particularly true for tall buildings where CLT is utilized while OSB and plywood have a large market in residential and low-rise buildings (less than 4 floors).

2.1.6 Advantages and disadvantages of CLT

As was mentioned previously, characteristics of CLT that are advantageous are its strength, use of various grades of lumber to manufacture it (lower grades up to No 2nd better grades), fire resistance, acoustic properties, utilization of underutilized species potentially, carbon sequestration, renewable and therefore environmentally friendly, a carbon neutral product and therefore reduced carbon footprint compared to steel and concrete, ease of installation at job site, accuracy of prefabricated panel dimensions, stability of the product, and cost. These are but some of the advantages as a material which do not include the benefits to communities who have manufacturing plants, forest workers, the environment and the tax revenue from facilities to governments as well as manufacturing products in Canada and in this case Ontario for projects in Ontario or other provinces of Canada.

As a building material, CLT has its limitations. The versatility of CLT as a building system is due to the change in capabilities as the thickness of the panels vary (Stauder 2013). Current manufacturing requirements limit CLT to dry service conditions which will prevent durability issues (Kramer 2014). Fire safety, seismic performance, acoustics, and other building materials' requirements all remain to be discussed. However, fire safety has been proven to be equal or better than other materials (David, 2018). Seismic tests have shown this product to perform better than other materials such as steel and concrete (Popovski & Karacabeyli, 2012). So although there are concerns there are also solutions that have been put into place so these concerns are being removed and are beginning to be seen as advantages, for example fire performance of CLT is being shown to be superior to concrete and steel. Time will put to bed many of these concerns as more and more research is conducted and as more structures are built. All will lead to more confidence in this as a building material of the future. Besides these, different countries have different standards for properties of building materials as well as different building Codes leading to variations in "what" can being built and "how" high can we go. For example in Canada the Building Codes in BC, Quebec and Ontario changed in recent years to allow wood construction to go from 4 stories to 6 stories now. Within these Codes there are exceptions that allow taller one-off mass timber wood structures such as the Brock Commons at the University of British Columbia, which is an 18 story mass timber structure. Different Codes and standards to testing wood products in different parts of a country or between countries relating to CLT panel properties can limit CLT's development and in particular its export from a particular region.

2.1.7 Standards/codes for CLT

The Standards/Codes of a country or region within a country are what CLT needs to adhere to in order to help CLT development and manufacturing. Different regions Standards/Codes may set barriers for CLT's global development. For example, compare product Standards of CLT between the USA and Europe. One of the major reasons for the difference between the two Standards for CLT in these countries is experience with the product (Young 2016). There are 29 pages in the USA Standard, which contains the tables for the modulus of elasticity and bending, and there is also reference to other topics about dimensional deviations to some other panel products (Young 2016). However, the Standard in Europe is 95 pages, which are more specific than the US standard (Young 2016). Much of this difference is based on the experience already in Europe compared to the USA and as such the USA Standards are being developed as the product becomes more popular. Therefore studies need to be conducted on species used in the product and all tests for properties including fire resistance etc. in order to adjust Codes to allow its use. This is a timely process to change Codes and to conduct all the testing, while Europe has conducted these tests already for their species and therefore have adjusted their Codes as well. It has only been a few years to nearly a decade for the development of CLT in the USA and Canada, while in Europe it has been since the 1990s. So here in North America Standards and Codes are updating continuously to accommodate the growth and knowledge of this product while a relatively complete EN Standard was finished in 2013 (Young 2016). In short, the Standard could determine how far and quickly CLT can develop in North America.

2.2. British Columbia and Quebec CLT

2.2.1 Species used as raw material of CLT in BC & Quebec

According to David Milton and Mark Kohlberg's (2015) report that softwood mainly supplies industries in BC are spruce, pine, and fir species while softwoods that supply the industry of Ontario and Quebec are also spruce, pine and fir species. Hardwood species are mainly present in central and eastern Canada and the main species supply to Ontario, Quebec, and the Maritimes are birch, maple, oak, ash, poplar and other deciduous trees (Milton & Kuhlberg, 2015).

As described earlier in this report, CLT is composed by glued pieces of dimensional lumber together to make a panel, so the raw material of panel should be the focus point, which means the species used in the panel of CLT is what will be discussed in this section. For British Columbia, the lumber they use primarily is SPF dimensional lumber and this kind of lumber produced by majority of saw mills could meet the requirement for CLT manufacture (Bill & John 2017). However, Bill & John (2017) has mentioned that Douglas-fir as the most prominent choice for CLT manufacture in BC. The reason for selecting Douglas-fir is that it is considered the most popular structural timber, which has broad applications in structural components and heavy timber, where the strength and stiffness give it excellent performance in load-bearing combined with good durability properties (CFPA 2003). Though Douglas-fir has great property, it is not the only choice for CLT manufacture in BC. The company Structurlam in BC mainly uses Douglas-fir and SPF group species as the primary raw material in their wooden construction (Structurlam 2016).

Nordic Structures in Quebec produce CLT and the main species they choose as their raw material for CLT is the SPF group species including black spruce, jack pine, and balsam fir. Generally, the SPF group contains white spruce, red spruce, black spruce, jack pine, and balsam fir in Quebec. The trees listed above all have a similar characteristic, so it is available to combine them to make lumber or engineered wood products from that lumber. Therefore, the panel with this SPF group species has an excellent gluing and wood property characteristics (CWC 2018).

Douglas-fir is found on the west coast only in Canada so it is a main species of BC while the SPF species listed above are found in Quebec so are the main species utilized there. As mentioned before in 2.1.2 of this report, BC has other spruce, pine and fir species as well. The main species used as raw material for CLT in both Quebec and BC is softwood, however they are different species of softwood. Table 1 shows the comparison of different softwood species in three mechanical properties. During the comparison, it is easy to find that Douglas Fir is outstanding among these species as most durable, highest crushing strength and highest elastic modulus property. For the other species, their properties are much the same.

Table 1: Comparison of different species in different mechanical properties.

	Elastic Modulus	Crushing Strength	Natural durability
Jack pine	1,350,000 lb_f/in^2 (9.31 GPa)	5,660 lbf/in2 (39.0 MPa)	3-4
Black spruce	1,523,000 lbf/in2 (10.50 GPa)	5,410 lbf/in2 (37.3 MPa)	4
White spruce	1,315,000 lbf/in2 (9.07 GPa)	4,730 lbf/in2 (32.6 MPa)	4
Douglas fir	1,765,000 lbf/in2 (12.17 GPa)	6,950 lbf/in2 (47.9 MPa)	1-2
Balsam fir	1,387,000 lbf/in2 (9.57 GPa)	5,000 lbf/in2 (34.5 MPa)	4
Reference	The Wood Database	The Wood Database	BSI 1994

Note: 1 is very durable, 2 is durable, 3 is moderate durable, 4 is slight durable, 5 is not durable.

2.2.2 Case study of CLT in BC & Quebec

For BC, the newest building made by CLT is the 18 story UBC Brock Commons Residence shown in figures 3 and 4. Figure 3 shows the internal structure during the construction, which displays the general structure of this building, and it is clear that CLT and glulam make up most of the building. Note that the elevator shafts and foundation are concrete. Figure 4 is the appearance when the project was completed.

Figure 3: 2016 construction of UBC Brock Commons' tall wood residence(UBC Public Affairs) by KK Law. (Source from: https://dailyhive.com/vancouver/bc-building-code-tall-wood-buildings-2019.)

Figure 4: The Brock Commons — Tallwood House (UBC) by KK Law 2016. (Source from: https://vancouver.housing.ubc.ca/residences/brock-commons/)

Generally, Brock Common's tall wood residence is a 54m, 18 stories building, the floor area is 2315 m^2, and the gross area is 15120 m^2 (Poirier et al. 2016). It has

500 tones reduction in CO_2 emission as it costs 1973 m^3 CLT panels and saved 2650 m^3 concrete material (Poirier et al. 2016). The most innovative part is its structure, which used lots of wooden construction material like CLT, GLT (glue-laminated-timber), PSL (parallel strand lumber), combined with concrete and steel to complete the hybrid structure construction (Poirier et al. 2016). Additionally, there is some advanced method to ensure the safety of wooden material against fire, such as using three to four layers of fire-rated gypsum boards to wrap the mass timber up to resist fire better in the envelope section (Poirier et al. 2016). Apart from the fire issue, there are some specific requirements for the wood to make the building more stable. For example, the CLT ground floor used in this case is required to have better properties even beyond the standards requirements, and the solution is specifying higher grades of the lumber for CLT panels (Poirier et al. 2016). Other concerns like moisture resistant, earthquake resistance, and durability are the major issues for the wooden building. For moisture resistance, it is proved that it is infeasible to let wooden material handle this issue by itself in this case, so, the solution was using concrete acoustic topping to help prevent the water from going into wooden material (Poirier et al. 2016). The earthquake issue has been handled through strength of other materials like steel connection and durability test, in this case, is less than 10% delamination between individual pieces of laminated timber, which indicates it is relatively acceptable (Poirier et al. 2016).

The most remarkable feature of CLT, GLT, and other wooden construction material is prefab. Therefore, the wooden building using prefabricated timber could cost less time and money than an equivalent building. In this case, the time of floor installation is nine weeks quicker than an equivalent concrete structure, the duration of this building is 593 days (Pioere et al. 2016). Though the money used in CLT is 16% to 29% higher than that of the cast-in-place reinforced concrete option, the money saved by workers working shorter periods for installation cannot be ignored, in this way, it could say it cost less than the equivalent concrete structure (CRSI 2018). However, prefabricated means timber installation is after the overall structure is finished in the case of the Brock Commons. The problem with the prefabricated timber (CLT) in this scenario, is the timber is prone to flattening due to the great building's pressure in upper stories (Poirer et al. 2016). There exist as gap when using the prefabricated timber inserted in the upper floor structure, the solution was using a steel gasket mat under the prefabricated timber to fit the gap (Poirer et al. 2016). In a word, Brock Commons Tallwood House combines the CLT technique with other construction materials to make the tall wooden building feasible and stable.

For Quebec, the most well-known company manufacturing CLT is Nordic. Nordic has designed and constructed several buildings in Quebec and one in particular from CLT the Origine Pointe-Aux-Lièvres Ecocondos Quebec City will be discussed (Figure 5).

Figure 5: Project of Origine under construction. (Source from: Nordic Structures http://nordic.ca/)

Origine is a 43m, 13 stories wooden building, where the most significant difference between the Brock Commons Tallwood House and Origine is the utilization of CLT in elevator sections and the extensive use of CLT. The elevator shaft in the Brock Commons mainly relies on reinforced concrete as the load-bearing walls, while Origine is depended upon CLT as their shear walls (Mohammad et al. 2015). Like the Brock Commons Tallwood House, the safety issue has also been brought to the forefront, and it can be seen in the total investment, for wood part the assumption cost is \$1,100/m^3 while it is \$900/m^3 for concert (Poirier et al. 2016). For the fire safety test part, the construction team designed a test method that burned a CLT elevator shaft for two hours and found there was almost no damage, and the same test has also been applied to later mass timber buildings (Mohammad et al. 2015). CLT was also used as a floor in Origine, actually, except the basement and ground floor, all the floors from the second story to top were all made of CLT, which effectively reduced the construction time, where it was estimated it took only one week per floor (CWC 2018). What is more, the erect time was only four months. It is estimated that the equivalent concrete building would take six months longer (CWC 2018). In addition to that, Origine used CLT as their exterior wall, covered by gypsum and other fireproofing materials, which prevent heat conduction effectively compared with using the traditional concrete material (CWC 2018).

For earthquake resistant, the outstanding design is installation of large nailed on metal plates replaced by shear keys system, and it would not affect the earthquake resistant effect, simultaneously, it could save lots of installation costs (CWC 2018). Another design highlight is the extensive use of CLT and other wooden materials to construct this building. In addition to the utilization of renewable forest resources and a reduced carbon footprint, the Origine is located adjacent to the banks of the Saint Charles River which has a low bearing capacity. Therefore, they determined a wooden structure, which is much lighter than concrete structure could be built in this location.

All in all, the case study of Brock Commons Tallwood House and Origine Pointe-Aux-Lièvres Ecocondos Quebec City have important guiding significance for later mass timber construction and CLT applications across Canada.

2.2.3 Market of CLT in BC & Quebec

The most important thing for the market is supply and demand. For the supply, there are only 3 factories that produce CLT in BC and Quebec, (table 2).

Table 2: The company could produce CLT in BC & Quebec.

Company name	Location	Website	Raw Material
Structurlam	Peticton, BC	http://www.Structurlam.com/	SPF & Douglas-fir
Structurecraft	Delta, BC	http://www.structurecraft.com/	SPF & Douglas-fir
Nordic Structures	Montreal, Quebec	http://www.nordic.com/	SPF

There are only a few companies that produce CLT mainly due to it is still a relatively new product for the North America market, where the time that CLT has been produced in Canada is from 2010 (Bill & John, 2017). Not only BC and Quebec, in the whole of North America there is little demand for single-family housing in CLT as it is a mass timber product meant mostly for taller structures and not single family residence. Instead, there is considerable demand for a tall wood house like the case study of BC and Quebec, i.e. the multi-story residential market. In addition to that, some mixed use, as well as commercial and public type projects are also favorable in the market (Schwarzmann 2017). Thus in short, there is no significant difference in the market between BC and Quebec, because the trend is a tall wood house or commercial building at present (Bowyer et al. 2016).

Though there are only a few markets for civilian, the market for fundamental public infrastructure still exists. Structurecfaft in BC has already completed 5 CLT wooden construction projects (Structurecraft n.d.). Structurlam in BC has completed 421 CLT projects, and it has left its footprint in six provinces, eight states and four countries (SMTC, n.d.). The influence is relatively intense if only considering the Canadian market, and for the company Nordic in Quebec, it has also constructed 4 CLT buildings. More and more CLT buildings are still being constructed in Canada and the USA increasing the market demand for the product, it was less than 50 mass timber projects but it was 439 projects until 2018 (CWSF 2018). The meaning of these buildings is significant, one is improving the public awareness, one is accumulating experience for the future, and the last one is pushing the development of CLT in North America.

2.2.4 Standards of CLT in BC & Quebec

This report mainly focuses on the potential of CLT in Ontario. Therefore, this section would not go into the detail of CLT Standards like the specific data about it, and it will primarily talk about the effect of the Standards of CLT. BC and Quebec demonstrate how the standards of CLT use can be pushed leading to the further promotion of CLT applications. Both case studies of Brock Commons Tallwood House and Origine indicate that it is the project that pushes the development of adapting the Standards for tall wood building construction. Even though they are one-offs they showcase the potential of tall mass timber construction, which will lead to permanent changes in the Codes via displaying how Standards can ensure safety in these types of structures. The Standards of construction had not considered or allowed a high-rise wooden building before these project occurred. The main barrier for mass timber system is the combustible construction, however, the fire resistance testing has confirmed that CLT has the ability to meet Type IV construction requirement, which could help promote CLT and other mass timber materials fit the relevant building codes (AWC n.d.). Another thing is that there is alternative methods provisions for mass timber systems (AWC n.d.). For Brock Commons, the relevant legislation about the high-rise building comes into force through the alternative solution approval process (Moudgil 2017). The buildings once beyond the scope of BCBC then it has to choose an alternative solution to seek approval and Building Act (2015) in BC is the alternative solution (Moudgil 2017). This act aims at giving the chance for specific innovative project and it mainly has three parts. First is make guideline for the project, then set the technique reviews, once pass the test, there will have a SSR(site-specific regulation) for the project (Moudgil 2017). The Origine case in Quebec is almost the same as BC, they use intense fire-safety test to prove the ability of CLT material as well as concrete and steel (Mohammad et al. 2015). Fortunately, BC, and Quebec both are devoting themselves to the study of CLT, and they do have lots of successful examples now. Like what was mentioned in section 2.1.7, experience is the primary element to decide the degree of Standards testing and subsequent knowledge, which leads to Code changes. What is more, the way BC and Quebec handle the Code problem is to proceed with Standard formulations and construction requirements simultaneously (Mohammad et al. 2015; Poirier et al. 2016). The meaning for the success of CLT tall wood construction in BC and Quebec is that it has great effect to push the development of building codes for CLT and other mass timber materials, additionally, both the cases shows the feasibility of CLT in fire resistance which is also the major concern for beyond the 6 story building, it has the ability to compete with current materials like concrete and steel. All in all, the bold strategy about Standards formulating has pushed its CLT application and manufacturing development effectively.

2.3 Ontario background in CLT

2.3.1 Construction background in Ontario

For the Ontario background in CTL, as mentioned in the above section, CLT is widely used in the construction field, so the construction situation in Ontario should be investigated first. The construction market in Ontario has been on a steady rise since the early 2000s, and the market has gained around 50% from 2002 and 2017 (BuildForce 2018). The reason for the increase is mainly due to the population growth where immigration is the primary driver for population growth (BuildForce 2018). It is estimated that the construction market will maintain a steady rise, and the growth would primarily concentrate on fundamental public infrastructure in the next ten years (BuildForce 2018). However, the company BuildForce (2018) indicates that the pace of the residential market would moderate and the extent would depend on relevant government policies, but it does not mean a declining trend; instead, the residential construction market has achieved the peak, and the growing population of immigrants would still be the primary driver.

Another sector that should be considered is the construction workforce, it is healthy currently where the employment is approximately 413,600 jobs (BuildForce 2018). While a decade from now, around 87,300 workers would retire and the need would be around 107,500 workers in 2017 based on the demand for future construction service consideration (BuildForce 2018). In short, the construction field prospect is quite bright.

Currently there is no company could produce CLT in Ontario. But there is one company called Gurdian Structure which is planning for the CLT manufacture. Structures.

2.3.2 The wood supply in Ontario

Another parameter that should be taken into account is the timber type in Ontario to see whether wood supply could meet the requirement of CLT. For the timber supply overview mentioned in 2.2.1. However, according to the Ontario Available Wood Report shown in table 2, the available wood of SPF group species achieved 143200 m3/year and it is the second highest species group of available wood; additionally, the highest available wood is poplar and third is white birch which means Ontario has potential to become one of the significant hardwood supplying provinces if these species should be used in CLT. The SPF group in Ontario has a significant utilization and therefore there is not a lot of this group available for a new industry. This is a consideration in the development of new industries in this province. Currently we are not cutting the allowable cut, however the numbers would have to be run and the Ministry of Natural Resources and Forestry would have to determine this allocation.

Table 3: Merchantable available wood supply in Ontario by different species (m^3/year).

Merchantable	
Species	Avaiable wood (m3/year)
Bw	1014000
Ce	215000
Oc	344000
Po	1641000
Pwr	252000
SPF	1432000
Tol	387000
Total	5285000

Source from: Available wood report in Ontario (April 2019).

The panel made by SPF group species for CLT has been done and properties have been discussed in section 2.2.1.

3. Discussion

For the market, the most critical aspect is demand and supply (Heakal 2015). For the supply, the raw material species used in BC for CLT is Douglas-fir and SPF group species (Bill & John 2017), and Ontario has enough SPF group species wood supply like Quebec (QWEB n.d.). Therefore, in terms of raw material supply, Ontario could compete with BC and Quebec for regional, provincial, national and export markets. Hence, accompany could manufacture CLT panels in Ontario, if the wood supply can be secured which is the case for the new Plant "Gurdian

Structure" in Southern Ontario (Gurdian Structure n.d.). Though there is not much experience for high-rise wooden CLT construction in Canada compared to Europe, there has been a steady rise in mass timber tall wood buildings in the last decade with many examples across the country (CWC n.d.-c). Currently the Brock Commons Wood Building is one of, if not, the tallest modern mass timber building in the world (Poirier et al. 2016). This shows the technology is there and the will is also there in Canada to push the limits. The main area for growth that will sustain tall wood buildings in the near future is mid-rise CLT wooden construction for residential purposes (BuildForce Canada 2018). More large structures in Ontario are occurring as there is a 12 story mass timber structure in Toronto as part of University of Toronto as well as a few others in Toronto and Sudbury that are between 8 and 12 stories (Yasmin Aboelsaud 2018). A recent announcement on the water front in Toronto is a large project of mass timber buildings that will be the largest of its kind in Canada and will push and promote the use of mass timber greatly (Yasmin Aboelsaud 2018). As more buildings go up the experience will also go up and Standards will accommodate this product for testing and Codes will adjust the more information we provide.

Additionally, the experience accumulated by BC and Quebec could help Ontario get into the high-end market earlier. As section 2.2.3 discussed, the meaning of Origine project is that it provides the fire resistant test design for later buildings, what is more, the way it handles the exterior wall by CLT also set an example for later manufacturers. A key advancement in the Codes in the Origine building is the use of CLT in the elevator shafts (Mohammad et al. 2015), which is a significant advancement for CLT and opens this for Code changes in mid-rise residential buildings and other mass timber structures. The case study of the Brock Commons in BC and the Origine project in Quebec all give Ontario the chance to fit into the market quickly. All of these make it feasible for the manufacture and application of CLT in Ontario.

In terms of demand, another question to consider is the possible extent of CLT construction in Ontario. Compared with the market in BC and Quebec, the general trend about CLT is still high-rise wooden construction and some public basic structures due to government support policy (Bowyer et al. 2016). However there is an increase in mid-rise residential buildings in areas just outside of city centers where high-rise buildings are not preferred (BuildForce Canada 2018). This is a very large market opportunity for CLT manufacturing in Ontario. The population growth due to immigrants would help make the construction market rise smoothly in Ontario, and it has been discussed in section 2.3.1 that there is a requirement for more fundamental infrastructure to accommodate this population growth, this will likely be in the form of mid-rise structures. Above is the overall market in construction where CLT could replace other construction materials, which has also been discussed in section 2.1.5. Benefits such as less pollution, less cost due to less time to finish the project, great properties of the product compared with other construction materials, excellent performance in aesthetics, high level of renewable resource utilization, accord with sustainable principle, low carbon foot print and high carbon sequestration in wood combined with other environmental, social and economic aspects make CLT a desirable product. Based on so many advantages and a large potential market across Canada and internationally, the demand part is also proved to be feasible. Therefore, there is reason to believe that Ontario has potential in the CLT market.

However, there still exists challenges from many angles. The first challenge is the prejudices, some people would not care about what the truth is, they hold the view that wooden construction means a forest is felled and it is not right, even though we have strict guidelines on sustainable harvesting of the forests in Ontario (Crown Forest Sustainability Act, 1994). Another aspect of engineered wood products is the volatile organic compound emissions, which has been mentioned in Schwarzmann's report (2017) that the wood adhesive in CLT would release VOC emissions, even though some CLT is made with PUR is (polyurethane adhesive) they still release VOC's. Many of the CLT panels are not exposed, rather there is a covering of some other product such as a gypsum board for fire protection or drywall etc. (Dagenais et al. 2012) so this issue may not be as severe as is thought. The most common limitation is the Codes, though BC and Quebec could provide information from of experience, eventually, the Standards and Codes in Ontario will be fully developed and allowing Code changes based on science and research.

The Ontario government should support research leading to complete Codes for building with CLT and Standards for testing CLT. Such group exists in Ontario, called the Mass Timber Institute that is government funded to look at and research the use of Mass Timber Products in mid-rise to tall buildings (MTS, n.d.). What is more, according to Schwarzmann's report (2017), the old fashioned Design-Bid-Build process may increase the competitivity with traditional construction material. In the design process, the price of CLT mainly depends on the raw material while the price of raw material is fluctuant. The suggestion Schwarzmann (2017) provides is that by combining the manufacturer, sawmill and forest management departments could control the price easily. Which could be feasible in the Ontario boreal forest region where there is 74% forest coverage and it is a coniferous mixed-wood forest as a high raw material source area with large sawmill operations.

4. Conclusion

Compared with the demand and supply part in the discussion, the result is that Ontario has significant potential in the CLT market. BC and Quebec as the pioneer province who produce CLT and build mid- to high-rise wooden structures could take a great leader role that Ontario could learn from to get into the market as soon as possible. Ontario should seek for more opportunities for their wood products sector. It is available for wood products to get into the construction area nationally and worldwide as Canada construction materials are world known for quality. In the past century, it was the Concrete Age, while for this century it is the Wood Age, seizing a piece of the market quickly in this era will be Ontario's forest future goal.

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