A Review of Engineered Wood Products in Canada

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Source: NRCan 2016a.

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Thunder Bay, Ontario

April, 2018

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An undergraduate thesis submitted in partial fulfillment of the requirements for the degree of Honours Bachelor of Science in Forestry

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April, 2018

Major Advisor

Second Reader

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ABSTRACT

Corrigan, W.M. 2018. A Review of Engineered Wood Products in Canada. Lakehead University Faculty of Natural Resources Management.

Keywords: Engineered wood products, cost, exports, imports, manufacturing, supply chain, veneer, plywood, lumber, mass timber, construction

Engineered wood products, such as Glulam, Laminated Veneer Lumber, Oriented Strand lumber and Cross Laminated Timber, are increasingly being utilized for construction purposes both domestically and abroad. Mass timber building projects have been increasing in Canada through a variety of government – funded building initiatives and private sector research. The National Building Code of Canada has historically been a limitation for mass timber building structures which primarily use engineered wood products, however recent updates to the code allow for taller wooden structures. Ontario, British Columbia and Quebec now allow 6 storey wood framed buildings. Showcase projects, using exemptions in the code, such as Brock Commons Tallwood House (18 storeys) in Vancouver, B.C. have demonstrated the benefits of mass timber construction. Overall the engineered wood products industry in Canada has been improving since the recent recession, and is expected to improve with new research and developments in engineered wood products.

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ACKNOWLEDGEMENTS

I would like to thank Dr. Mat Leitch (Chair, HBScF) for his assistance in completion of this Undergraduate Thesis. I would also like to thank Dr. Leitch for running Portable Milling and Advanced Wood Science this year. Without them I would not have developed such an interest in primary and secondary wood products manufacturing.

INTRODUCTION

There has been an increase in production and utilization of wood products within Canada in the last 10 years. Between 2012-2013, total sales in the wood product manufacturing industry increased 19.7%. This can be compared to the total manufacturing sales over the same time period (excluding wood manufacturing) decreasing 1.1% (Statistics Canada 2013). Engineered wood products are a large part of the wood product industry in Canada, and these will play an ever-increasing role in the value-added forest products industry within Canada.

The physical and mechanical properties of wood can be improved through controlled changes, and this is the foundation of engineered wood products (Gaff et al. 2016). This increases the overall performance of structural wood products, leading to a more effective building material, thus expanding potential end uses. Engineered wood products have allowed wood to be used in situations where solid timber beams are ineffective, leading to specialized products to support a more diverse array of uses. This has expanded market opportunities leading to the positive economic growth of this industry.

Throughout the 20th century, the preferred construction materials have included steel and concrete. Wood is now re-emerging as a material of choice for mid-rise construction in residential and commercial buildings (Canadian Wood Council n.d.) For example, glue-laminated timber is increasingly used as a replacement for steel, and pre-fabricated CLT panels allow for more efficient building construction time (Gov. Ontario 2017). Wood is a renewable resource, has varying density levels, is processed easily, superior shock resistance, and high strength to weight ratio. All of these traits apply to engineered wood products, which has contributed to increased popularity over traditional engineering materials such as concrete, plastics, iron, and steel (Cihad Bal 2014).

In addition to being used as a substitute for more "traditional" engineering materials, engineered wood products have proven to outperform traditional sawn lumber in the structural applications for which they are designed for (Schmulsky and Jones 2011). This has enabled taller wood buildings to be possible now due to a new generation of engineered wood products, and a variety of case examples (Brock Commons Project, Vancouver, British Columbia) demonstrate this. Additional benefits of building with engineered wood products include: lower building costs with cheaper materials/quicker construction time, lower greenhouse gas emissions by not using energy intensive materials, superior flexibility under seismic loads, quieter to build on site, and better energy performance/efficiency (Gov. Ontario 2018). There has been a marked increase in a variety of economic indicators with regards to this industry, as per the data made available through Canadian Industry Statistics (Gov. Can. 2018). Tables and graphs are shown throughout to demonstrate improvement in this industry sector over the last 10 years.

OBJECTIVES

A recent study conducted on the knowledge of architects use of EWP's concluded that a lack of knowledge and information about these building materials can be a hindrance to their use in building construction (Markstrom et al. 2018). This paper will aim to compile knowledge of performance of engineered wood products (fire, seismic performance). The objective is to serve as an educational tool to address the knowledge and information gap which can exist when compared to more "traditional" engineering materials (concrete, steel). To examine economic improvement, the following economic indicators will be analyzed: exports, imports, trade balance, GDP per province, and total revenues. The data is available from Canadian Industry Statistics and the objective is that the data compiled from this will create a presentable case for the positive economic growth of the EWP industry. The continued growth of the industry since the recent recession will be shown using tables, and graphs. Manufacturing processes, strength properties, species utilized, and industrial uses will all be examined as they apply to specific products in this industry within Canada. The identified products for an in-depth analysis are glulam, LVL, OSL, CLT, and OSB, in addition other EWP's used within Canada will also be identified and explained.

LITERATURE REVIEW

Engineered wood products are making it possible to construct taller and larger wood buildings, and there is significant research and development on this topic. Single-family house ownership has long been the "North American dream", but in the post-recession housing market, many first time homebuyers are opting to rent, which has created a demand for more rental properties. In addition to a large number of senior citizens moving out of their homes, this has led to a new "boom" in multi-family unit construction (APA 2015). In January 2018, single home construction investment had a 0.2% increase which was the smallest year-over-year increase since January 2016. Apartment buildings saw the largest growth in year-over-year growth as construction investment was up 16.9% from January 2017 (Stat. Can. 2018). New multi-family structures are commonly three to six story structures which incorporate structural frames designed with engineered wood products. Glulam beams, floor systems with high fire-resistance ratings, and OSB sheathing are all noted as affordable and durable options (APA 2015).

FPInnovations Advanced Building Systems department is conducting research on the structural performance, fire performance, mitigation of vibrations, acoustics (sound insulation), and energy efficiency of wood-based construction (FPInnovations

2018). This research will assist in increasing the engineered wood product market size in Canada and affirm Canada's position as a global leader in wood building construction. From 2013-2017 their research team provided research support to the design/construction teams for the Natural Resources Canada Tall Wood Building Demonstration Initiative (TWBDI), which was critical in the successful completion of the world's largest mass timber building (NRCan 2017). Brock Commons is a student residence at the University of British Colombia and is the largest mass timber structure in the world. It is 18 stories tall and contains 404 rooms. It was built using prefabricated glulam columns and CLT floor slabs.

The Canadian Wood Council (CWC) is another organization, which represents manufacturers of Canadian wood products used in construction. CWC participates in the process of developing building codes in Canada (NBCC), and sits on the same committees as other building material representatives (steel and concrete) (Canadian Wood Council 2014). CWC projects include "WoodWorks!" (aims to increase wood use in construction) and "WoodFacts" (provides information/facts on wood use in mid-rise construction). A variety of publications are available with a variety of information of wood building construction using EWP's. The Canadian Wood Council in conjunction with FPInnovations and the government of Canada programs/initiatives will ensure the increased use of EWP's in building construction within Canada.

<u>Mass Timber Building Initiatives, Funding, and Research</u>

The TWBDI has since been discontinued, but there is considerable effort through federal and provincial governments fund wood building initiatives. The Expanding Market Opportunities Program (EMO) provides funding to forest product associations, provinces, and wood research organizations (FPinnovations). This is actively increasing Canada's presence in national/international wood markets, enhance knowledge of wood products among both suppliers and customers, and to promote the use of Canadian wood in mid-rise and non-residential construction (NRCan 2017).

The Government of Ontario also has a Mass Timber Program (MTP), which is outlined as being for "developers, researchers, educators, trades people, fire safety officials, and municipal building officials" (Gov. Ontario 2018). This program aims to increase mass timber construction as part of a climate change action plan to reduce GHG emissions in building construction. Another objective of this program is to establish a tall wood building research institute in Ontario, partnering with researchers, universities, and colleges. This Institute has been established recently and is called the Mass Timber Institute (MTI), based out of University of Toronto and George Brown College in collaboration with Lakehead University, Univerity of Ottawa, Laurentian University and FPInnovations (Leitch, Pers Comm). The MTP is currently providing funding to tall wood buildings in Ontario 7 storey's and higher. Funding is available to costs associated with design, approval, and construction activities. Application to provincial funding through this program does not negate the eligibility for federal funding through the GCWood program.

The Brock Commons project proved that CLT is an affordable and efficient method to large-scale building construction. A site-specific regulation was issued for this projected which exempted it from the British Colombia Building Code. The building was stood up in 2017 at a rate of two floors per week, as the prefabricated engineered wood products allowed it to be constructed efficiently, with the entire project completed in less than 70 days (Haden 2017). The success of this project will ensure that it becomes increasingly commonplace once height restrictions under the National Building Code of Canada are lifted.

Research on increased use of wood in construction projects in Canada is now being headed by Natural Resources Canada's Green Construction through Wood program (GCWood). This program provides non-repayable contributions of up to 100% of a project's costs for the demonstration of mass timber products/systems (NRCan 2017b). Goals of this government initiative include: greater use of wood-based products in innovative wood/timber construction projects, and conducting research to create revisions to the National Building Code of Canada (NBCC) to allow for tall wood buildings beyond 6 stories (NRCan 2017b). Starting in 2018, $39.8 million will be available through this program over four years. Historically, the use of wood in tall wood buildings has been limited due to potential for increased fire risk. The base height and area limits have remained similar for close to 160 years, and over this time firefighting techniques and construction methods/materials have advanced (Calder 2015). Four to six stories have been the historical height limitation of wood buildings largely due to the reach of firefighting equipment (Calder 2015).

National Building Code of Canada

Up until the 2015 edition of the National Building Code the height limitation for wood buildings (classified as “combustible construction”) most Canadian provinces was 4 stories. The 2015 edition extended the allowable height to 6 stories (NRCC 2017). Studies on fire performance of mass timber structures are increasing to address the knowledge gap which exist in the fire performance of tall wood buildings (Zelinka et al. 2018). Research and development in the engineered wood products industry in Canada/North America will continue to allow for taller mass timber buildings to be possible, which will drive the demand for engineered wood products.

Industry Research

There is also an industry goal to make engineered wood products more environmentally friendly. Research at the University of Georgia investigated the environmental risks of making mulch from engineered wood products (APA 2017). This research was initiated to address the large amount of wood building construction which ends up in landfills in North America. Engineered wood products contain resins and glues which could potentially be harmful to the environment (formaldehyde). The mulches were tested to determine if they contain toxins, no toxic chemicals were found in any of the leachates. This was tested over the course of one year, and no difference was measured between the bare soil runoff and the mulch runoff. Conclusions from this study are that engineered wood product waste generated on construction sites can be ground up on-site and used as a safe and effective mulch (APA 2017). This will reduce tipping fees, transportation costs, and reduce the presence of EWP's in landfills. Ultimately lowering the environmental footprint as the construction industry in Canada moves toward more sustainable building materials/structures. This literature supports the idea that the uses and scope of engineered wood products is increasing and diversifying.

BENEFITS OF WOOD BUILDING CONSTRUCTION

Wood building construction has many social, environmental, and economic benefits. Energy efficiency is increased as wood is a natural thermal insulator, which contains millions of tiny air pockets (Canadian Wood Council 2017). This causes wood to lose less heat through conduction than other traditional building materials (concrete). Wood is one of the world's most readily available and flexible building materials, and recent advances in engineered wood products technology have allowed these to be used in a primarily load-bearing component (Maxim et al. 2013).

Mass timber structures require lower labour requirements on-site during installation when compared to concrete frame/steel frame construction (Green 2012). This is due to prefabricating parts off-site, which allow for quicker on-site installation (CLT floor, wall and roof panels, stock glulam beams and posts). Mass timber structures also have lower material costs, combined with savings from lower number of "trades" required on site (APA 2015). A recent study was conducted bv Mahlum, Walsh Construction, and Coughlin Porter Lundeen Engineering (2014) to evaluate CLT building construction costs. CLT construction costs were compared to traditional concrete and steel construction with the costs being directly attributed to a 10 – storey building. Results from this study indicated that CLT offered an estimated 4% cost savings over steel and concrete. Although this 4% margin is not large, it demonstrates that mass timber construction currently is cost – competitive, and may become more competitive in the future.

Engineered wood products used in mass timber structures are also able to utilize wood, which may otherwise not be economically viable. In addition to incorporating smaller lumber with a higher number of defects, Wang et al. (2009) found that manufacturing veneer-based EWP's (LVL) was possible in wood affected by the mountain pine beetle. This was part of the Government of Canada's Mountain Pine Beetle Program 2007 – 2010. Investing in research and development methods to use salvaged timber in traditional manufacturing mills and product markets was one of the main objectives. A special phenol formaldehyde resin was developed to mask the blue MPB stain in the affected veneers of lodgepole pine (*Pinus contorta* Dougl.). The blue stain and lower recovery are two reasons why MPB-affected wood is not used, and this study would address this in an effort to increase industry utilization of MPB-affected wood. MPB veneers have high permeability, thus easing resin application to veneer pieces (a simple dipping/soaking method). The resulting LVL members had high bending/shear strength, greater hardness, and good dimensional stability when treated with the resin. This made them suitable for structural and industrial uses. The resin developed has the potential to increase the value recovered from MPB affected wood by eliminating the blue stain (Wang et al. 2009). The incorporation of MPB affected wood will have a positive economic impact in areas where MPB infestations have occurred, as historically this was not preferred by industry due to blue stain and lower recovery rates. Not only does this increase the resource availability for engineered wood products, but it also enables sustainable harvest of wood, which traditionally has not been considered for use as a wood building construction material.

ENGINEERED WOOD PRODUCTS CURRENTLY USED IN CANADA

The engineered wood products analyzed in depth for this include glulam, laminated veneer lumber, oriented strand lumber, cross-laminated timber, and oriented strand board. Glulam, LVL, and CLT are all being incorporated in large mass timber structures, as well as residential housing. The projected outlook for the market of these products is that there will be growth in demand among these products, both within Canada and worldwide (UNECE 2017).

Glulam

Glulam (Glue-laminated timber) is an engineered wood product, which has assisted in expanding the structural applications of timber and traditional sawn timber construction. Solid-sawn heavy timber is in limited availably for very large sizes, and is not structurally efficient due to defects such as knots and checking. Glulam has eliminated the limitations of use of large sawn timber with regards to size of the stem cross-section, the length of the stem, and the structural defects present (Dietsch and Tannert 2015). Pound for pound, glulam beams are stronger than steel and can span 30 metres or longer (Gov. Alberta 2017). The use of glulam dates to the middle of the 19th century, however the first patented manufacturing of modern glulam was 1906 by Otto Hertzer (Dietsch and Tannert 2015).

Glulam is comprised of several pieces of dimensional lumber/machine stress rated lumber, glued together into a required form. Glulam is most often used in non-residential construction, and it can be manufactured for structural or aesthetic purposes (NRCan, 2016a). The desired species for glulam are softwood species with high strength properties (Douglas-fir, lodgepole pine, western hemlock, black spruce, and southern yellow pine). Glulam is constructed from wood laminations or lamstock lumber (1.5" thick) glued together. The lamstock is manufactured per guidelines dictated by moisture content and surfacing tolerances, and are available in a wide range of structural grades (Canfor 2017). The pieces are oriented so that the grain runs parallel with the length-wise direction of the glulam beam (NRCan, 2016a).

The laminations are finger jointed to increase length and edge glued to increase width. Edge glued panels are constructed from smaller pieces of wood to increase width. This makes the panels less likely to warp, twist, and cup. There can be many laminations connected by finger joints to increase length, and these are joined with glue at the finger joints. A finger joint is constructed so that there is several interlocking "fingers" or wedges between pieces (length-wise). Finger joints produce a wood product with greater structural capability, when compared to gluing the end grain of 2 pieces together to form a butt joint (NRCan 2016b). The success/performance of glulam products depends on the quality of the lamstock, the quality of the finger joints, quality of the edge-gluing, and the integrity of the cross-section (Dietsch and Tannert 2015). These areas of the glulam structure are vulnerable to damage such as cracks, fracture, moisture accumulation, decay, insects, failure of joints and open gluelines. The two most common types of damage to glulam structures are insects (12%) and failure of joints (8%) as identified in a study assessing the integrity of glulam timber (Dietsch and Tannert 2015).

There are various types of glues used to manufacture glulam. The type of glue used is often dependent on the moisture conditions to which the glulam is to be exposed to. Type 1 glues are usable in all climates (Service Classes 1-3), while there are restrictions to the use of Type 2 glues (Service Classes 1 and 2), and Urea-formaldehyde glues are only usable in Service class 1 (Dietsch and Tannert, 2015). Glulam manufacturing is regulated by standards in Canada, specifically CSA-O122-06 (CCOHS 2016).

Glulam products are often custom produced for architectural projects and the sizes can vary (up to 130 feet long). Unique structures such as curved wooden arches can be created, this cannot be done with traditional timber beams. Due to the lack of standard sizes transportation is costly, glulam production facilities are often small and distribute to local markets (NRCan, 2016a). Glulam ranges between two and three times the cost of sawn wood, this is because an additional glulam manufacturing plant is needed after the sawmill, and transportation costs to these facilities can vary (Shmulsky and Jones 2011). Structural integrity of glulam when exposed to fire is very good. The glulam timber chars on the outside and does not allow for complete combustion, often steel is weakened to the point of failure (Shmulsky and Jones 2011). Glulam incorporated into mass timber structures has positively influenced fire-safety ratings and this will be discussed further under “fire performance of engineered wood products”.

Laminated Veneer Lumber

Laminated Veneer Lumber (LVL) is manufactured through gluing parallel layers of thin wood veneer. The wood veneer is produced from peeler logs, and these logs have size, form, and quality requirements to ensure consistent LVL properties (Shmulsky and Jones 2011). The most common adhesive/glue used for LVL is Phenol-formaldehyde (PF), which is optimal for exterior wood products (CWC 2017). It has good mechanical properties, high dimensional stability and thus commonly used in the building/construction industry (Gaff et al. 2016).

Unlike glulam, LVL is commonly used in the residential construction industry, but also has non-structural uses, such as door/window parts. Individual veneer pieces are graded for strength and defects, to ensure consistency in the finished product and allow for structural/strength classification for the product. Unlike glulam, a selection of both softwood and hardwood species can be used for production of LVL. In North America, the most common species used are Douglas-fir and southern yellow pine (NRCan 2016d). LVL can be manufactured at a variety of lengths up to 80 feet, thicknesses of 0.75-2.5 inches and widths of 24 inches to 48 inches. The thickness of each veneer piece ranges from 0.06-0.25 inches (Shmulsky and Jones 2011). The LVL members can be easily cut at the job site to meet the structural/construction requirements. The properties required for fastening/connection are like solid timber (NRCan 2016d). LVL beams and headers are marketed based on the MOE value, along with the size this helps determine the stiffness, which determines the level of deflection in a beam under a certain load (West Fraser nd.). The performance of LVL when exposed to fire is similar to that of glulam, with an outer char layer forming (UBC nd.).

Oriented Strand Lumber

Oriented Strand Lumber (OSL) is a structure grade engineered lumber capable of handling large loads. OSL is manufactured by aligning long strands of wood in parallel with each other and binding them together using adhesive glues, pressure, and heat (NRCan 2016f). OSL is commonly used in both residential and non-residential construction. Two of the most common OSL products available in North America are Parallam® (PSL) and TimberStrand®; these products are both manufactured by Weyerhauser®. PSL uses the same wood veneer which is used in LVL. The veneer which meets the specifications is cut into long strands, coated in glue, then pressed together under a patented microwave heat process (NRCan 2016f). Similar to LVL, the most common species used in North America for PSL are Douglas-fir and southern yellow pine. Weyerhauser constructs Parallam® in beams up to 7x18 inches and columns up to 7x7 inches (NRCan 2016f). Parallam® is coated in a sealant leading to a reduced rate of moisture absorption, this makes it ideal for exterior construction and ease of yarding (Weyerhauser 2016). TimberStrand® is produced from strands of wood up to 12 inches long cut from small logs of low density hardwoods (aspen). The strands are coated in a glue, layered parallel, then pressed together under pressure and steam (NRCan, 2016f). Because TimberStrand® uses low density hardwoods, it is not as strong under loads as Parallam® (PSL) and is used predominantly in residential construction (framing). Utilization of low density aspen in structural grade engineered wood products expands the traditional uses of those species, as aspen is largely unsuitable for structural dimensional lumber.

Cross Laminated Timber

Cross-laminated timber (CLT) is one of the more recent engineered wood products to come to market. As a new product in North America there are only a few existing production facilities, in Canada they are in British Columbia and Quebec. CLT consists of several opposing layers of dimensional lumber held together with adhesive glues (NRCan 2016g). It is commonly used in large panel format for walls, floors, and roofs. What makes CLT unique from glulam is that some layers are oriented perpendicular to others (glulam grain orientation is parallel). The perpendicular layers improve dimensional stability and allow for two-way bending when used in floor and roof settings (Gov. Ontario 2017). CLT most often consists of an uneven number of layers to ensure the top and bottom have the same grain orientation. As building codes change to permit taller wooden structures, CLT will be increasingly in demand. For manufacturing, the grain of each layer is placed at a right angle to bordering layers, and an odd number of layers is used to decrease warping (NRCan 2016g). Because it is an engineered wood product, CLT can be produced in large sizes (4 metres wide, 24 metres long, and 0.5 metres thick). Lower quality wood can be used for the interior layers of CLT, this provides a use for trees affected by insects, disease and lower quality lumber (NRCan 2016g). CLT is a good choice for midrise construction up to 24 storey's, as it was integral in the recent construction of the Brock Commons (18 storey's) building in Vancouver. CLT suppliers in Canada compete with a higher number of European suppliers for market share. As of 2012, there was only three CLT manufacturing plants in Canada (Green 2012). As of 2015, Europe accounted for 80% of global CLT production, which is estimated at 680,000m^3. By 2020, this number is expected to increase to 1.25 million m^3 (UNECE 2017). The manufacturing/supply chain in Canada will continue to evolve and grow as more tall wood buildings are built (Gov. Ontario 2017).

Oriented Strand Board

Oriented strand board (OSB) is an engineered structural panel made from strands of wood that are oriented lengthwise, arranged in layers at right angles, and then laid into mats (APA 2010). The strands are bonded using heat/pressure and waterproof glues, a process similar to earlier mentioned engineered wood products. The result is a structural engineered wood panel similar in strength and performance to plywood (APA

2010). A major strength advantage to OSB over other engineered structural panels is with the parallel orientation of the strands (Schmulsky and Jones 2011). Tests have proven OSB to be much stronger and more resistant to rupture (higher MOR value) than randomly oriented waferboard (Schmulsky and Jones 2011). Relative to weight, OSB panels are very strong and thus make ideal structural support panels for residential construction. OSB are also used to construct prefabricated wood I-joists by gluing LVL to OSB panels (UBC nd.). The “I” shape is possible by using the thin structural panel (OSB) in the middle, and combination of different engineered wood products give the “I” joists a high strength to weight ratio (UBC nd.). OSB is mainly used as a load bearing part of the frame for residential housing, can also be used for walls, flooring, and roofing (NRCan 2016h). OSB panels range from 0.25 inches to 2.5 inches, and the common size for retail is 4 feet x 8 feet panels. From 1990-2005 production of OSB in North America increased significantly, previously under-utilized species such as trembling aspen could be used (NRCan 2016h). In 2012 Canada produced 5.2 million cubic metres of OSB, accounting for one third of North American production (NRCan 2016h). This can be compared to only 1.7 million cubic metres of plywood produced in Canada during the same time. OSB has experienced increasing market share, slowly replacing plywood as an effective engineered wood panel used in construction (NRCan 2016h)

Additional Engineered Wood Products Used in Canada

The engineered wood products described in detail above only comprise a small percentage of the availability of products on the market. Structural composite lumber (SCL) includes a broad family of EWP's. It is manufactured by bonding layers of dried wood veneer into blocks called "billets". The manufacturing process enables these products to be made from small trees of many species, which allows for effective use of wood resources (APA 2010). Included within this category is LVL, PSL (parallel strand lumber), LSL (laminated strand lumber), and OSL. I-joists is an EWP designed for structural use (floor and roof construction), which combines two engineered wood products together. Structural composite lumber flanges are connected to an OSB web with adhesives. The flanges resist bending stress and the web provides shear performance (APA 2010). Similar to SCL, plywood is a EWP which consists of multiple layers of wood veneers. However, plywood is a structural panel which makes it unique from structural lumber. Primarily made from veneers of softwood species, plywood is used as a load-bearing component of platform-frame buildings (NRCan 2016i). OSB is noted to be a competing product occupying the same market niche, which has caused plywood to lose significant market share in recent years. This is largely due to the lower cost of OSB (NRCan 2016i). Although glulam has significantly increased building opportunities through expanding beam/header/post sizes past the limiting length of the individual tree, there is a way of creating a similar product through engineering dimensional lumber. Finger-joined lumber is used to join shorter pieces of wood together to form units of greater length. The joint consists of several “meshing” wedges which are glued together (NRCan 2016b). Finger jointed lumber is used in structural (vertical studs) and non-structural (moulding and trim) purposes for residential construction. Dowel Laminated Timber (DLT) is noted to be the first 100% wood mass timber panel (no glue, nails, or metal fasteners), using wood dowels to join laminations. DLT is used for floor/roof structures, and can be produced in panels spanning 12ft×60ft. DLT is made with a variety of Western tree species; including SPF, Douglas fir, hemlock, Sitka spruce, Western red/yellow cedar, and hardwood species are used to form the dowels (StructureCraft 2017). For floor structures, a DLT panel can be topped with concreted to create a timber-concrete composite (TCC), which results in a stronger/stiffer material than each on their own (StructureCraft 2017). Currently manufacturing is restricted to a StructureCraft facility in Abbotsford, B.C, however this product will see market demand increase as mass-timber building projects become more commonplace.

FIRE PERFORMANCE OF ENGINEERED WOOD PRODUCTS IN STRUCTURES

Under the National Building Code of Canada, wood building construction is classified under “combustible construction” (NRCC 2017). This emphasizes the importance of mass timber construction using EWP’s performance when exposed to fire. Engineered wood products manufactured outside North America are not subject to the same stringent fire safety tests which can pose safety issues with regards to structural failure and delamination of glues. In Canada, fire performance testing is regulated by CAN/ULC S101 “Standard Methods of Fire Endurance Tests of Building Construction and Materials” (APA 2016). Standardizing fire endurance testing methods to certify structural EWP’s (glulam and CLT) is not a common practice outside North America (APA 2016).

Mass timber construction is able to provide increased levels of fire resistance when compared to light timber construction (residential). In the National Building Code of Canada, the fire-resistance rating is defined as “the time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria” (Canadian Wood Council 2015). Large wood members have good fire resistance due to the slow burning rate of large timber and the insulating effects of the char layer which protects underlying unburned portions of wood. Mass timber construction using engineered wood products has cross-sections of significant size, which allows for charring to occur at a slow and predictable rate (Gov. Ontario 2017). Due to these characteristics, fire performance of mass timber construction is much higher than that of light timber construction (Gerard et al. 2013). Beams, columns, and arches with 4-sided fire exposure are to have a minimum cross-sectional size of 336mmx336mm (Gov. Ontario 2017). When fire exposure is reduced to less than 4 sides, the minimum satisfactory dimensions will be reduced.

In the Brock Commons project (TWBDI project) Fire protection is provided by encapsulation of mass timber (glulam) using several layers of gypsum wall board (Gov. Ontario 2017). This is a relatively new principle known as “encapsulated mass timber”, which protects the mass timber should it be exposed to fire. Encapsulation of mass timber within a double layer of gypsum board (16mm) has been found to increase fire resistance time by 60 minutes (Gerard et al. 2018). In addition to gypsum board, mineral wool and concrete can also be used. This reduces the minimum cross-sectional requirements for the mass timber beam/column (224mmx224mm for member with 4 sided fire exposure) (Gov. Ontario 2017). Fire testing using this method was conducted at various laboratories (Gov. Ontario 2017). In 2014, a new annex was added to the Canadian national wood design standard (CSA 086). This was titled “Fire resistance of large cross-section wood elements” and it provides a calculation method to determine the standard fire-resistance rating for use when designing mass timber construction.

In a 2013 research assessment several fire safety concerns were noted (Gerard et al. 2013). An occurrence known as “second flashover” is when the passive fire protection (charred layer/gypsum wallboard) falls off and the underlying layer is exposed to ignition. Delamination can also occur and is when the adhesives fail and an underlying layer of CLT laminate is exposed. Certain adhesives used have been known to fail at a temperature lower than the char temperature of wood (Zelinka et al. 2018). It was found that with two or more CLT walls exposed, delamination and “second flashover” occurred during fire safety testing. It was concluded when in fully encapsulated compartments (gypsum board) CLT did not contribute to the intensity of the fire on the structure (Zelinka et al. 2018).

As research continues into fire performance of engineered/mass timber products, fire safety will also increase. Adhesives connecting laminations and encapsulating materials will ensure that fire performance improves even when placed under load/stresses. Dr. Sam Salem is an associate professor with the Civil Engineering department at Lakehead University. Dr. Salem has published several referred publications in structural fire engineering. As the director of the LU Fire Testing and Research Laboratory, Dr Salem received a NSERC 5-year Discovery Grant to investigate the structural fire performance of new engineered wood building systems (Salem 2018). This will contribute to the increased use of engineered wood products and increase general height restrictions for mass timber (combustible) structures as indicated in the NBCC. The next edition is scheduled for 2020.

MATERIALS AND METHODS

To examine the market size of the engineered wood products industry, several economic indicators were analyzed. These indicators are exports, imports, trade balance, and GDP by province/territory. Data going back to 2007 was obtained to show how the industry has recovered from the recent recession and is continuing to grow. The data was obtained from Canadian Industry Statistics data on Veneer, Plywood, and Engineered Wood Product Manufacturing. This is as per the North American Industry Classification System (NAICS) code 3212. Data from NAICS code 32111 (sawmills and wood preservation) was also obtained from Canadian Industry Statistics. This is the industry engaged in manufacturing boards, dimensional lumber, timber, and poles (lumber may be rough or planed, but is limited in structural performance subject to the specific tree as it is not engineered further). NAICS code 32111 retains the same title as NAICS code 3211 however the wood preservation industry is exempt from this.

The EWP and sawmilling industries were then compared. For this comparison, exports going back 5 years were used. Exports was chosen as the method of comparison because exported products have been manufactured domestically. The EWP industry will also be compared to the overall wood product manufacturing industry (NAICS 321) which encompasses both EWP products and dimensional lumber products from sawmills. This is in order to assign a percentage value which the EWP industry occupies as a member of the more general wood products manufacturing. The assumption is that this percentage will show an upward trend over the five-year period for which the data is available, thus displaying that the expanded use of engineered wood products is leading to increased demand when compared to dimensional sawn lumber. Graphs and tables have been completed using Microsoft Excel. Manufacturing data provided by Canadian Industry Statistics was obtained from the Statistics Canada Annual Survey of Manufactures and Logging. This survey collects the value of products produced, purchased, and used by the logging industries in Canada.

RESULTS

The economic indicators used to analyze the engineered wood products industry in Canada were: imports, exports, trade balance, GDP by province/territory, and total revenues. Exports (Figure 1) and trade balance (Figure 3) showed similar trends during the 2007-2016 period. While imports remained relatively stable throughout the 2007-2016 time period (Figure 2) and did not reflect the same trends as exports and trade balance. All values in Figure 1 through Figure 3 are given in thousands of Canadian dollars, and the numbers have been adjusted by Statistics Canada as to not be subject to inflation. Referencing Figure 1, Canada had high export values in 2007 ($3370112.419) and this followed a similar trend as trade balance which reflected the recession, a low of $1772301 was exported in 2011. After 2013, these numbers began to steadily increase and in 2016 a 10-year high was observed at $3924685.957. (Trade balance is the sum of exports minus the sum of imports). A positive trade balance indicates that Canada has a strong manufacturing sector for engineered wood products. Referencing Figure 3, high values were observed in 2007 $2244.975, although due to the recession the values lower each year until 2012 when recovery from the recession is evident. The values observed in 2016 ($2515.508) are higher than in 2007. This shows the relatively quick growth of the industry since the recession.

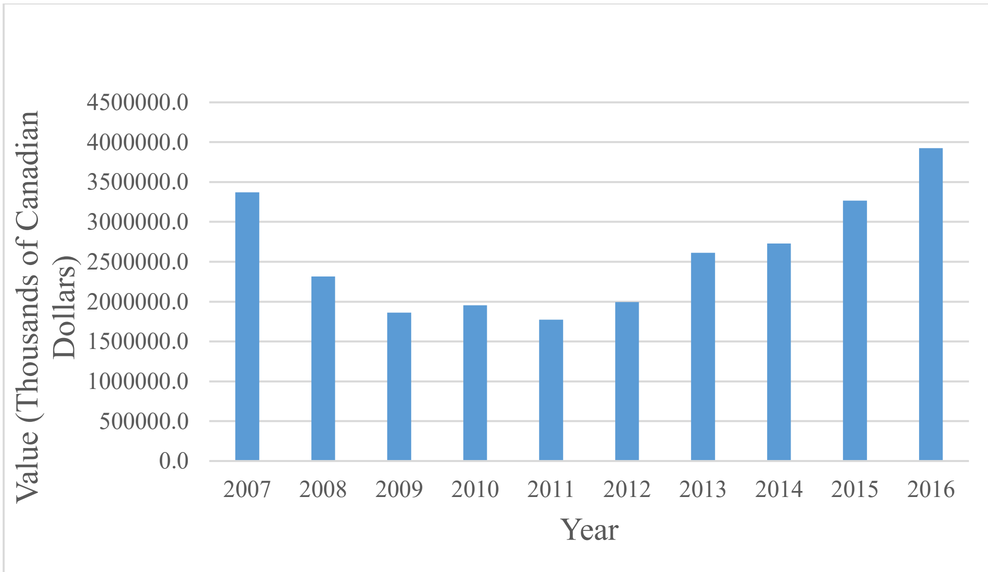

Figure 1. Exports of Engineered Wood Products from Canada 2007-2016 (Gov. Can. 2018)

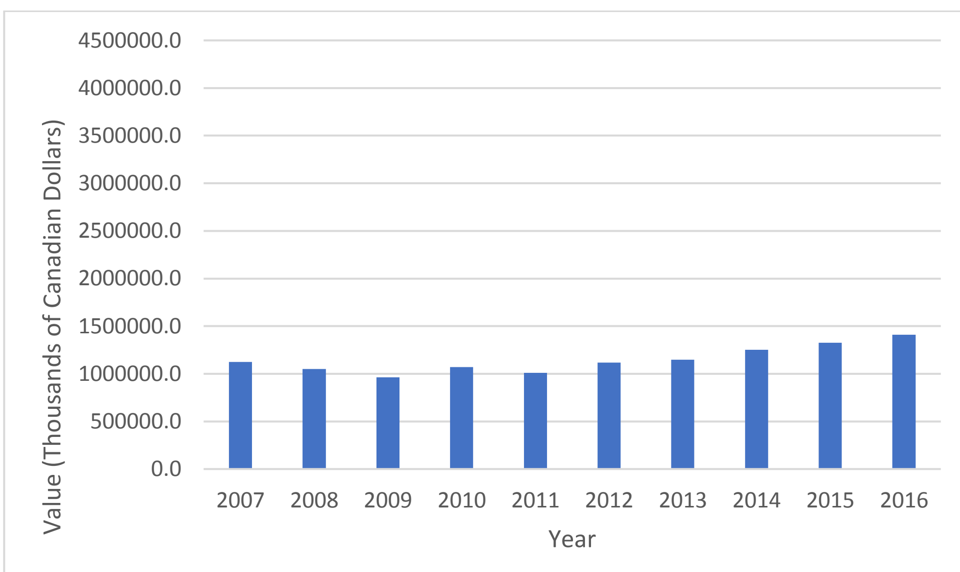

Figure 2. Imports of Engineered Wood Products in Canada 2007-2016 (Gov. Can. 2018)

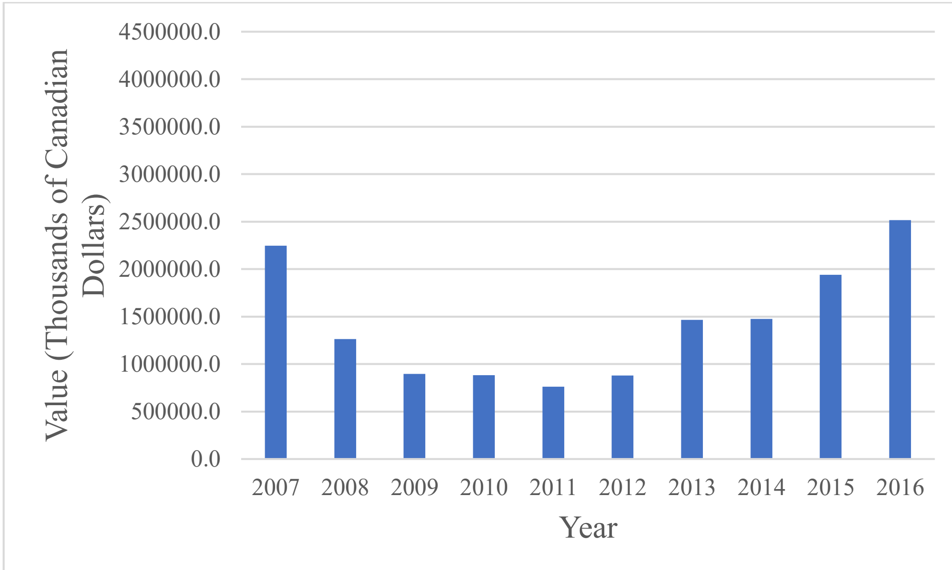

Figure 3. Canada Engineered Wood Products Trade Balance (Gov. Can. 2018)

Table 1 displays the gross domestic production by province/territory for veneer, plywood, and engineered wood products manufacturing (NAICS code 3211). It can be noted that 7 provinces recorded positive growth during the 2014-2016 time period. It is notable that between 2015-2016 Manitoba experienced a 96.5% growth. Table 2 shows export data for the sawmills and wood preservation industry. NAICS code 32111 provides data solely on sawmill output, with the wood preservation industry exempt. When comparing Table 2 and Table 3, it is evident that the sawmill products industry has a greater volume of exports, shipping $11336.1 in 2017 versus $4242.13 for NAICS code 3212 (values given in millions of Canadian dollars adjusted for inflation). The data in Table 2 and Table 3 provide export data for the same time period (2013-2017), and will be compared to obtain the percentage each industry occupies as a member of the entire wood products manufacturing industry exports (NAICS 321). Table 4 shows the overall wood products manufacturing exports (NAICS 321) which encompasses NAICS 32111 and 3212. Table 5 shows these two respective industries as a percentage of wood products manufacturing exports. It can be noted in Table 5 that during the 2013-2017 time period, the percentage of which sawmill products exports occupy decreases and veneer, plywood, and engineered wood products manufacturing increases as a result.

Table 1. Gross domestic product by province/territory – Veneer, Plywood, and Engineered Wood Product Manufacturing, Value in chained 2007 ($ millions)

Province/territory	2014	2015	2016	% change 2015 - 2016
Manitoba	37.1	28.5	56	96.5
Saskatchewan	115.5	119.6	145.6	21.7
Ontario	434.4	482.9	562.8	16.5
New Brunswick	67.8	76.5	85.6	11.9
Nova Scotia	37.8	37.4	39.9	6.7
Alberta	416.1	456.3	468.2	2.6
Quebec	649.3	690	702.5	1.8
Northwest Territories	0	0	0	0
Nunavut	0	0	0	0
Prince Edward Island	1.9	0.7	0.7	0
Yukon	0	0	0	0
British Columbia	712.4	770	762.9	-0.9
Newfoundland and Labrador	7.3	6.3	5.7	-9.5

Source: Statistics Canada, Gross Domestic Product at basics prices, by industry, provinces and territories.

Table 2. Canadian total exports – sawmills and wood preservation (NAICS 32111) – value in millions of Canadian Dollars

	2013	2014	2015	2016	2017
All Countries (Total)	8090.47	9123.16	9407.56	10911.7	11336.1

Source: Trade Data Online (accessed: March 26, 2018)

Table 3. Canadian total exports - veneer, plywood, and engineered wood product manufacturing (NAICS 3212) - value in millions of Canadian Dollars

	2013	2014	2015	2016	2017
All Countries (Total)	2611.22	2727.63	3266.88	3923.85	4242.13

Source: Trade Data Online (accessed: March 26, 2018)

Table 4. Canadian total exports - wood product manufacturing (NAICS 321) - value in millions of Canadian Dollars

	2013	2014	2015	2016	2017
All Countries (Total)	11868.6	13141.9	14202.2	16622.8	17451.4

Source: Trade Data Online (accessed: March 26, 2018)

Table 5. NAICS 3212 and NAICS 32111 as a percentage of all wood product manufacturing exports (NAICS 321) from Canada

		2013	2014	2015	2016	2017
All Countries (Total)	NAICS 3212	22%	21%	23%	24%	24%
	NAICS 32111	68%	69%	66%	66%	65%

Source: Trade Data Online (accessed: March 26, 2018)

DISCUSSION

As shown in Table 1, provinces with large forest industries (with the exception of British Columbia) experienced a large increase in GDP in EWP manufacturing during the 2014-2016 time period. New Brunswick, Ontario, Manitoba, and Saskatchewan all experienced growth greater than 11%. Manitoba experienced very significant growth, recording a 96% increase between 2015-2016. This can be partially attributed to a $95 million dollar investment by Louisiana Pacific® into the Swan River mill, which expanded the mill to produce SmartSide® trim and siding (Gov. Manitoba 2018). This is the first of its kind in Canada, and Swan River has benefitted from an increase in 40 permanent jobs.

Referencing Table 2 and Table 3, both manufacturing industries (NAICS 3212 and 32111) displayed growth in exports during the given time period although there was a more significant growth for veneer, plywood, and engineered wood products. This can be seen in Table 5, which displays the two industries as a percentage of the overall wood products manufacturing industry (NAICS 321). Engineered wood products increased from a low of 21% to 24% in 2017, and sawmill products decreased from a high of 69% to a low of 65% in 2017. This shows that engineered wood products are gaining market share within the wood products manufacturing industry in Canada, and the growth of this industry may lead to lower demand of dimensional lumber products. One of the major factors contributing to this may be the new “boom” in multi-family unit construction, which incorporates structural frames with engineered wood products (APA 2015). Construction investment in apartment buildings was up 16.9% in 2017 compared to single home construction experiencing a 0.2% increase (Stat. Can. 2018).

Engineered structural panels (such as OSB) do not use dimensional lumber as part of the product (uses rectangular wood stands). As previously stated, OSB is used in I-Joists with LVL and as a structural wood panel on its own. I-joists are lighter weight using 60% less wood fibre than solid-sawn joists. They can also be handled easily by 1-2 workers, making them an effective structural use of OSB (Russelberg 2005). Increasing demand for this product along with veneer-based products (LVL) would impact the sawmill products industry as dimensional lumber is not an input. This may likely be a reason for the declining percentage of the sawmill products and increasing percentage of the engineered wood products as a part of the overall wood products manufacturing industry.

CONCLUSION

Based on the literature reviewed and results presented, engineered wood products will see an increasing market share within the wood products manufacturing industry within and outside of Canada for the foreseeable future. There are numerous factors influencing this such as the benefits of wood building construction (reduced environmental footprint), improved fire performance over dimensional lumber products, changes to the National Building Code of Canada, and availability of provincial and federal grants for mass timber projects. Buildings such as the Brock Commons at UBC (as part of the Tall Wood Building Demonstration Initiative) have demonstrated the successful construction of mass timber buildings beyond the 6-storey limit outlined in the NBCC. For this review, only a few engineered wood products are analyzed in detail however there is current research and product development by a variety of engineered wood product companies (Louisian Pacific® recently introduced SmartSide® trim and siding) and those that support the wood products manufacturing industry (such as FPInnovations and APA). This is in order to produce specialized products to the increasing number of market niches to which engineered wood products will occupy within the construction industry in Canada. As the 4% cost saving margin published by Mahlum et al. (2018) is expected to increase, engineered wood products will become a more attractive building materials option. This paper has conducted a broad analysis of engineered wood products and serves to educate for their increased utilization, and address the knowledge gap which has been identified by Markstom et al. (2018). This industry is focused on drawing the maximum value and performance from wood, and will be a significant manufacturing industry as Canada moves toward a more sustainable future by substituting traditional building materials with increasingly varied engineered wood products.

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