A study on the feasibility of conducting laminated veneer lumber production in the Whitefeather Forest in Northwestern Ontario within the lands of the People of Pikangikum

by

Feiran Xu

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Daniels Faculty of Architecture, Landscape and Design

University of Toronto

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Abstract

Mass timber is an umbrella concept that refers to the large engineered wooden panels, columns, and beams that have been widely recognized as viable alternative to steel and concrete in the construction industry. In addition to the advantages of carbon sequestration, energy savings, fire resistance, and pre-assembly, mass timber offers Indigenous communities, especially those in rural areas like the Pikangikum First Nation in Northern Ontario, an opportunity to provide Indigenous youth training, to find a pathway for businesses in the community, to gain tax revenue, and to compete with the ordinary Canadian communities and their low-value commodity products such as pulp and softwood lumber. A BBC (Banker, Charnes, and Cooper) model in data envelopment analysis (DEA) is used to measure the technical efficiency of five small-scale Chinese mass timber manufacturers during 2012-2018, and a cost-benefit analysis (CBA) is used to analyze the feasibility of investing in a laminated veneer lumber (LVL) production line in the Pikangikum community. The technical efficiency results show that mass timber production technology is effective, mature, and can be imported. It is estimated to cost US$ 8.8 million and 33 people to set up the LVL production line with an annual output of 30,000 m^3. The estimated net sales margin is 18.87%, payback in 5 years, and the 12-year internal rate of return (IRR) is 23%. In conclusion, conducting laminated veneer lumber production in the Whitefeather Forest in Northwestern Ontario within the lands of the People of Pikangikum is expected to be feasible and profitable.

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1. Introduction

Mass timber is an engineered, wood-based building material suitable for use in structural applications such as columns, beams, and wall assemblies in buildings (Anderson et al. 2020; Smith et al 2018). In recent years, mass timber has gained wide attention around the world as a widely recognized viable alternative to the traditional reinforced concrete structures and demand for mass timber products is sharply on the rise (Harte, 2017; MFC Capstone, U of T., 2020; Anderson et al. 2020). Compared to the concrete and steel-based construction, which are carbon-intensive systems with large environmental consequences (Müller et al. 2013, Churkina et al. 2020), wood buildings are more energy efficient (Sadineni et al., 2011) and emit less carbon during construction (Nässén et al., 2012, Churkina et al. 2020). Canada, which ranks third globally in forest area and first globally in certified forest area (FPAC 2011, Natural Resources Canada, 2020) is well-positioned to benefit from this emerging trend. Yet, low-value commodity products such as pulp and softwood lumber remain Canada’s largest exports (Natural Resources Canada 2020); this presents a major challenge for the remote communities, especially Indigenous communities seeking enterprise opportunities on their ancestral lands, that are more reliant on the cyclical forest sector (Stedman et al., 2005).

For Indigenous communities in rural Ontario such as the Pikangikum First Nation, forest management at an operational scale represents an opportunity to help Indigenous youth receive training (B.C. First Nation Forestry Workforce Initiative Project Final Report, 2017), support Indigenous business and communities with more potential loans (Leach, 2019), and bring tax revenue into the communities (Brockington, 2007). This is particularly meaningful in the case of Whitefeather Forest, a Crown management unit in Northern Ontario which is managed by the Whitefeather Forest Community Resource Management Authority (WFCRMA) in Pikangikum (Palmer, 2012; MNRF, 2013). The Elders of Pikangikum see forestry as a route to enterprise opportunities for the community and are seeking to break the enterprise forestry barrier in the Whitefeather Forest while protecting the environment as they decide within their cultural beliefs and experience (Whitefeather forest Woodlands Business Plan, 2010; Keeping the Land, 2006). The WFCRMA believes that mass timber is a way to accomplish this (A. Chapeskie, Personal Communication 2020). The aim of this study is therefore to find a pathway of sustainable management that can bring benefits to Indigenous local communities and their youth, specifically by using economic tools to analyze the feasibility of an integrated mass timber production line in the Whitefeather Forest.

1.1 Mass timber

1.1.1 Mass timber

Mass timber is a general term for a large selection of engineered timber materials (Harte, 2017; Smith et al. 2018; Anderson et al., 2020). To be precise, mass timber is a series of wooden structures made of dimensional lumber, veneer, or strands that are combined (glued, nailed, or fastened with hardwood dowels) together to make large structural elements such as columns, beams and wall assemblies (Smith et al., 2018; Anderson et al. 2020).

Common materials under the mass timber category include two types (Figure 1): Glued Laminated Timber (‘glulam’, GLT; Figure 1a), Cross-Laminated Timber (CLT; Figure 1b), Nail-Laminated Timber (NLT; Figure 1c), and Dowel Laminated Timber (DLT; Figure 1d), which are generally made of sawn lumber while mass plywood panels (MPPs; Figure 1e) Laminated Strand Lumber (LSL; Figure 1f), Laminated Veneer Lumber (LVL, Figure 1g), Parallel Strand Lumber (PSL; h), and other similar products generally made of veneers or strands (Mass Timber Institute, 2020; Anderson et al. 2020)

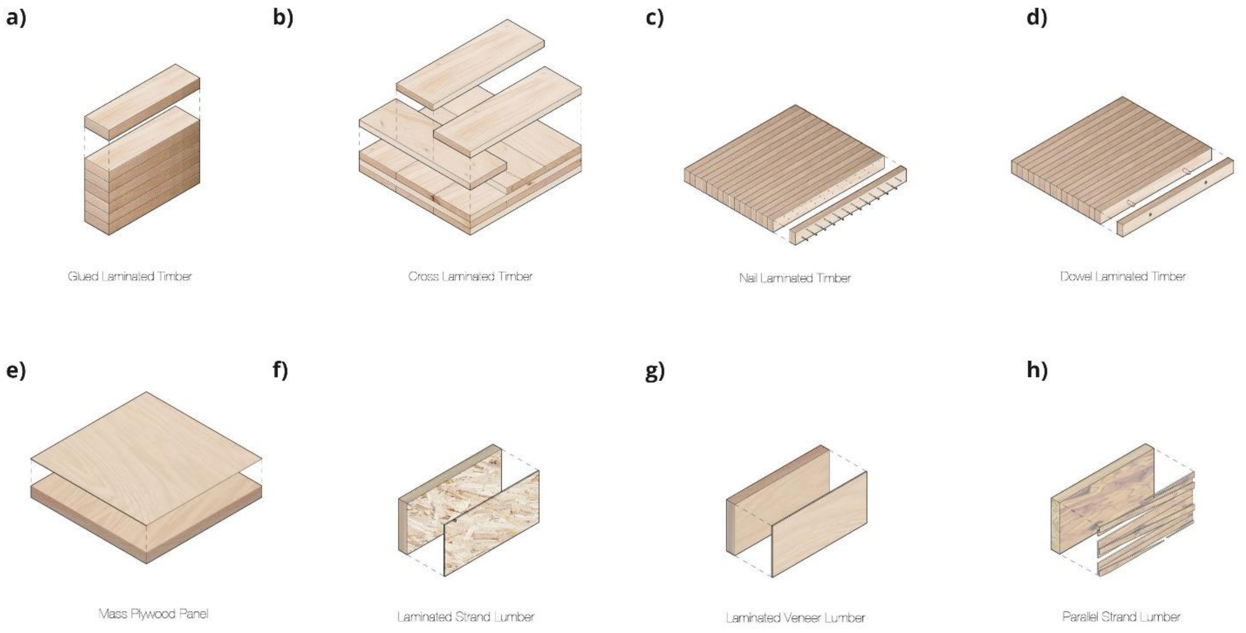

Figure 1: Major Mass Timber Products.

a) Glued laminated timber (glulam), b) Cross-laminated timber (CLT), c) Nail-Laminated Timber (NLT), d) Dowel-Laminated Timber (DLT), e) Mass Plywood Panel (MPP), f) Laminated Strand Lumber (LSL), g) Laminated Veneer Lumber (LVL), h) Parallel Strand Lumber (PSL). Diagrams by Sanjana Patel/Mass Timber Institute.

Glulam is made of dimensional lumber and is commonly used for columns and beams (Issa and Kmeid, 2005; Anderson et al. 2020). Cross-laminated timber (CLT) is a panel material made of pre-dried, laminated timber (Harte, 2017; Anderson et al. 2020). In CLT, lumber is arranged in an orthogonal manner, and then stacked by the machine into 3, 5, 7 or 9 layers and (fig 1b) and is commonly used in roof, floor, and wall assemblies and can even be used as a ground mat at construction and mining sites, allowing heavy equipment to operate on unstable soils (Anderson et al. 2020). Nail-Laminated Timber (NLT) is made by mechanically fastening boards of a certain size (usually 4 to 12 inches wide and 2 to 4 layers thick) together with nails or screws (NLT Design Manual, 2017; Anderson et al 2020). It is commonly used in floors, walls, roof structures and elevator shafts (NLT Design Manual, 2017). Usually in practice, designers will add plywood or oriented strand board (OSB) to one side of the NLT panel to provide shear resistance within the plane (NLT Design Manual, 2017). The NLT's advantages lie in its strength and durability, and it has a long history of being used in wood-frame buildings (Thinkwood, 2020). Similar to NLT, DLT uses a machine to hold small boards together in series and fastens them together with hardwood pins which enhances the structural strength of the DLT through strong friction between hardwood and softwood (Li, 2019; Anderson et al. 2020). Therefore, DLT does not use any glue or metal connections, which allows for CNC milling of the material, which is challenging with NLT (Li Yue kei, 2019). NLT and DLT are both suitable for use as panels in mass timber construction (NLT Design Manual, 2017; Anderson 2020).

Mass plywood panels (MPPs) are made by laminated sheets of veneer into large panels and are suitable for use in similar applications to CLT (Anderson et al. 2020). Laminated Veneer Lumber (LVL) is made by sawing and laminating the whole thick veneer slab along the direction of bedding, hot-pressing, and finally bonding together (Bakalarz et al., 2020). The appearance of LVL is similar to plywood, but in plywood the veneer will switch directions when stacked, while LVL stacks the veneer in the same direction and requires that the direction of wood grain is always parallel to the long axis of the plywood (Allen and Iano, 2019). Due to its parallel arrangement, LVL is straight and uniform, and is not easy to warp, twist or shrink, so it is commonly used in truss, beam, rafter frame and other structures (Palermo et al., 2005). Laminated Strand Lumber (LSL) is made in a similar way to LVL, but with two major differences. One is that LSL is made of long wood chips rather than whole veneer. The standard specification for LSL is 0.8 mm thick, 25 mm wide and 300 mm long (European Wood Industry Association, 2011). LSL has two ways to arrange the raw material wood chips: one is the veneer that all the wood chips are arranged in the same direction as the long axis to increase structural resistance, and after stacking four, six or eight layers (Hoesly and SE, 2020), it is suitable for beam, rafter, purlin, column; another difference is that some wood chips are arranged in the same direction on the short axis and are suitable for walls, floors and roofs, (European Wood Industry Association, 2011). Similar to LVL, PSL is made of veneers about 3 mm thick and 15 mm wide. (European Wood

Association, 2011). It is commonly used as long-span structural material (European Wood Association, 2011). LVL and its derivatives are very popular in North America—80% of the global produced LVL is used in North America every year (Australian Timber Industry Seminar, 2014). Because of its low technical threshold (Kilic et al., 2006), and because SPF veneer abounds in North America, good raw material that can be found everywhere, LVL is very suitable for small-to-moderate scale production.

1.1.2 Advantages of Mass Timber

Compared with conventional steel and concrete materials, mass timber has many advantages: it has stronger structural resistance (high-rise), can be assembled rapidly, has high fire resistance, can generate energy-savings, it is a thermal insulator, and it is more environmentally-friendly (Okada and Takai, 2000; Barber, 2018; Zelinka et al., 2018; Lineham et al., Waugh et al., 2010; 2016; Hasburgh et al., 2016; Su et al., 2018; Churkina et al. 2020). Mass timber also has low mass but high strength. A wood structure of the same scale is only 20% of the weight of steel or concrete structure, which can greatly reduce the depth of foundation and the speed of foundation pit construction (Okada and Takai, 2000). In addition, it also creates the possibility of modular design in tall (higher than six floors) buildings. For example, the Adina Hotel under construction in Melbourne, Australia, added 10 floors of wood structure to the existing 6 floors of concrete structure (Johanson, 2017). Due to the light weight of mass timber structures, the internal force of the structure generated in earthquakes is small, and the natural flexibility of the wood can make the wood structure effectively absorb and consume external forces, so it is not only suitable for the earthquake frequent areas, but also can be widely used in the construction of high-rise, even super high-rise buildings. For example, the tallest mass timber building in Canada is the 18-storey Brock Commons Residence at the University of British Columbia, which was completed in 2017 (Lou, 2017).

One of the largest advantages of mass timber materials is that they can be prefabricated (Katerra , 2020; Wong, 2012; Anderson et al 2020). For example, glulam beams and columns and CLT or DLT floors and wall assemblies can be fabricated in large-scale factories in indoor environments and assembled later. Importantly, prefabricated products enable mass timber to be engineered quickly, built and connected accurately, and with substantial waste reduction (Thinkwood, 2017; Waugh et al., 2010). This also enables the construction period of mass timber buildings to be shortened by up to 40% compared with other traditional structural systems (Waugh et al., 2010). For example, the main structure of Brock Commons Residence was constructed in less than 10 weeks, achieving an average construction rate of nearly 2 stories per week (Lou, 2017; Harte, 2017).

Mass timber also has excellent fire resistance. Although wood is combustible, the burning of mass timber material with large cross sections leaves a layer of charred wood on the surface, protecting the internal material from direct contact with the flame and oxygen (Barber, 2018). In addition, the carbonization rate of wood is constant, so the required thickness of the material can be deduced according to the requirements of fire prevention design to ensure the safety of the structure (Bartlett et al., 2016). Many fire tests (Zelinka et al., 2018; Lineham et al., 2016; Hasburgh et al., 2016; Su et al., 2018) have shown that mass timber can meet the same fire standards as steel or concrete buildings. Moreover, if 3h or higher fire resistance are needed for special wall or floor, mass timber can also be equipped with fireproof plasterboard (Su et al., 2018). It is worth mentioning that despite the mass timber materials, other factors, such as water sprinklers, are required to provide further fire protection in a mass timber building (Ontario's Tall Wood Building Reference, 2019). Unfortunately, although experts have proved time and again that mass timber has high fire resistance, many municipalities are still reluctant to approve mass timber buildings (Östman, and Källsner, 2011).

Mass timber materials can also effectively reduce the energy consumption of buildings (Li, 2019;

Thinkwood, 2017). Wood is a good thermal insulator, so mass timber buildings generally have an advantage with regards to insulation (Lou and Ren, 2015). For example, at the same thickness level, the insulation value of wood was 3 times that of solid brick wall, and 16 times that of standard concrete (Li, 2019). Furthermore, Dong et al. (2019) assessed the CLT operation of building heating and cooling ability. Their results showed that in the winter, CLT can significantly reduce heating energy consumption; in Harbin, Beijing, Shanghai and Kunming, the CLT building heating energy consumption in winter decreased by 11.97%, 22.11, 30.94% and 23.30% respectively. Wang et al. (2017) also compared mass timber with steel buildings and concrete buildings, and found that mass timber materials can reduce buildings' energy consumption by 17% and 16% respectively.

1.1.3 Challenges

In addition to its many advantages, mass timber construction does have a few important challenges. Dust, gas emission and water pollution produced at the mill during mass timber production are the potential negative impacts on the environment, Secondly, although construction site noise is virtually eliminated in mass timber builds because of prefabrication (Mass timber report, 2020), noise is also an adverse impact which can potentially harm workers in mass timber workplaces (Ahmed and Arocho, 2019). Furthermore, adhesives are used in many processes and disposal remains a challenge, causing potential chemical pollution to water and soil if untreated (Andersen, 1975; Guo et al., 2000), and even indoor pollution to human health (Bernstein et al., 2008). Greenhouse gasses and sawdust, resulting from fuel burning and sawing respectively, can also pollute the air and pose a threat to worker health (Penninks and Zonneveld, 1995). In addition, at every step of the process, there will be waste that needs to be disposed of properly.

1.2 Economic analysis

1.2.1 Methods to test technical efficiency

In this study, technical efficiency is used as the evaluation index of input and output efficiency. Technical efficiency is the stable correspondence between various factor input and final output over a certain period of time (Färe and Lovell, 1978). Technical efficiency is used to measure the ability of a producer to obtain the maximum output in the process of stable use of technology (without technological progress or innovation); and indicates the extent to which the producer’s production activities are close to the frontier production level (maximum output). The measurement of technical efficiency was first proposed by Farrel (1957) and Afriat (1972). They believed that under different factor inputs, enterprises would get different maximum output. The curve formed by all maximum output points is the production function. However, not all enterprises can reach the maximum output, so technical efficiency is used to measure the difference between the actual output of an enterprise and the maximum output under ideal conditions: the smaller the distance, the capacity of the enterprise is closer to the maximum production. Subsequently, Leibenstein (1966) made a new definition of the concept of technical efficiency from the perspective of output, that is, technical efficiency is the ratio of actual output to maximum output, when the market price level, input scale, and ratio between production factors remain unchanged. So far, the output-based technical efficiency proposed by Leibenstein has been widely adopted.

In general, there are usually two methods for measuring technical efficiency, one is a non-parametric method, and the other is a parametric method. To avoid deviations in the establishment of the production function, in this study a non-parametric method that does not require component production functions is used. The non-parametric method is based on the work of Farrel and Afriat, developed and perfected by Varian (1984) in theory and Fare (1985) in application. This method first constructs a minimum production possibility set that can contain all the production methods of the sample enterprises based on the output and inputs of all sample enterprises, that is, an effective combination of all factors and outputs. It can be seen from this concept that an enterprise achieves effective production, that is, to produce a maximum output with a certain input, or to produce a certain output with a minimum input. The technical efficiency of an enterprise measures how much room for saving its input is compared with the amount of input that produces the same amount of output in the production possibility set, given that the output of the enterprise can be realized. The greater the room, the lower the technical efficiency of the enterprise. The advantage of the parametric method is that there is no need to estimate the production function of the enterprise, thus avoiding the problems caused by the wrong function form. But also, the disadvantage of the parametric method is that it requires enterprise data, needs a higher calculation method, and has no description of the production process.

1.2.2 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is an important parameter method commonly used in enterprise or industry input-output analysis. This method is mostly used to evaluate a group of decision- making units with multiple inputs and multiple outputs (Decision Making Units, DMUs) relative efficiency. In 1978, Charnes, Cooper and Rhodes proposed the first DEA model and named it the CCR model. This model is very effective in evaluating the scale effectiveness and technical effectiveness of multiple inputs and multiple outputs. Since then, with the joint efforts of scholars, and with the further in-depth theoretical research, and the continuous development of complete theories, methods and models on the concepts of decision-making units, production possibilities, efficiency, etc. The DEA model is now widely used in many fields such as society, economy and management, including the performance evaluation of profit-making and other non-profit organizations such as banks and industrial enterprises, and the social economy and management efficiency of national industrial departments, urban economy, and technological progress of enterprises, as well as forecasting the economic situation and other fields.

In the DEA model, a production process can be described as a single unit that allocates several factors of production and then produces a certain number of products through a series of decisions. Such a unit is called a decision-making unit (DMU). Each DMU has mainstream DEA models including the CCR model, the C^2GS^2 model, the C^2W model, the C^2WH model, and the BCC model (Xing and Sun, 2013). This study mainly introduces CCR model and BCC model, which are the most commonly used in DEA.

(1) The CCR (Charnes, Cooper and Rhodes) Model:

Charnes, Cooper, and Rhodes proposed this CCR model in 1978 which firstly extend the model variables of efficiency measurement to multiple inputs and multiple outputs under the assumption of constant returns to scale. The model equation set is as follows:

$$\max h_{j0} = \frac{\sum_{r=1}^{s} u_r\, y_{rj0}}{\sum_{i=1}^{m} v_i\, x_{ij0}}$$

$$s.t.\begin{cases} h_j = \dfrac{\sum_{r=1}^{s} u_r\, y_{rj}}{\sum_{i=1}^{m} v_i\, x_{ij}} \leq 1 \\ v = (v_1, v_2, \dots, v_m)^T \geq 0 \\ u = (u_1, u_2, \dots, u_s)^T \geq 0 \end{cases} \qquad j = 1,2,\dots,n$$

In the equations, *j* represents *j*-th decision-making units (j=1, 2, ..., n), and each decision-making unit has the same *m* input, and the same *s* output. x_{ij} represents the *i*-th type input of the *j*-th decision-making unit, y_{ij} represents the *i*-th type output of the *j*-th decision-making unit.

v_i is the weight of the *i*-th type input, and u_r is the weight of the *r*-th type output. So the comprehensive input value of the *j*-th decision-making unit is $\sum_{t=1}^{m} v_i\, x_{ij}$, and the comprehensive output value is $\sum_{r=1}^{s} u_r\, y_{rj}$, which together defines the efficiency evaluation index of each decision-making unit DMU$_j$:

$$h_j = \frac{\sum_{r=1}^{s} u_r\, y_{rj}}{\sum_{i=1}^{m} v_i\, x_{ij}}$$

In the model, x_{ij} and y_{ij} are known numbers to determine a set of optimal weight vectors *v* and *u* to maximize the efficiency value h_j of the *j*-th decision-making unit. We also limit all h_j values (j=1, 2, ..., n) not to exceed 1, that is, $\text{Max}\, h_j \leq 1$. This means that if h_j=1, the decision-making unit has the highest productivity relative to other decision-making units and the production system is relatively effective; if h_j<1, the decision-making unit, compared to other decision-making units, needs to be improved, and the production system is not effective.

The above equation set is a fractional programming model, and we must convert it into a linear programming model to solve it. For this order:

$$\mathrm{t} = \frac{1}{\sum_{i=1}^{m} v_i x_{ij0}}, \quad \mu_r = t u_r, \quad w_i = t v_i,$$

The final model is transformed into:

$$\max h_{j0} = \sum_{r=1}^{s} \mu_r\, y_{rj0}$$

$$s.t. \begin{cases} \sum_{r=1}^{s} \mu_r\, y_{rj} - \sum_{i=1}^{m} w_i\, x_{ij} \leq 0 \qquad j = 1,2,\dots,n \\ \sum_{i=1}^{m} w_i\, x_{ij0} = 1 \\ \mu_r, w_i \geq 0 \qquad i = 1,2,\dots,m; \quad r = 1,2,\dots,s \end{cases}$$

The above formula is based on the input orientation of the decision-making unit, that is, on the premise that the sum of the weights of the inputs is 1, find the combination of the maximum value of the weights of the output items.

(2) The BCC (Banker, Charnes, and Cooper) Model: an expansion of the CCR Model

The CCR model is realized under the assumption of constant return to scale of the decision-making unit. But in real life, the decision-making unit is more in the production state of scale returns. Therefore, in 1984, Banker, Charnes and Cooper proposed a DEA model with variable returns for estimating scale efficiency, which is called the BCC model. Because the change of production scale always affects the important premise of return to scale, the three scholars have continuously optimized the premises and assumptions of the CCR model. Based on the variability of return to scale, the function Shepherd introduced for the first time to divide technical efficiency for pure technical efficiency and scale efficiency has successfully avoided the evaluation result of return to scale on technical efficiency. In this model, by dividing the efficiency value obtained in the CCR mode by the efficiency value in the BCC model, the scale efficiency value can be obtained to explore whether the return to scale of each production unit is increasing, decreasing or fixed. The common BCC model is as follows:

$$\begin{cases} \sum_{j=1}^{n} \lambda_j Y_j \geq Y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \qquad\qquad j = 1,2,\dots,n \\ \sum_{j=1}^{n} \lambda_j X_j \leq \theta X_0 \end{cases}$$

Where X_0 represents the input items of the decision-making unit, and Y_0 represents the output items of the decision-making unit. λ represents the ratio of the newly constructed effective decision-making unit to the original decision-making unit. In this linear programming model, θ represents the efficiency value of the decision-making unit, that is, the effectiveness (or utilization) of X input items relative to Y output items in the production unit.

In this model, DEA comprehensive efficiency = pure technical efficiency * scale efficiency. When DEA comprehensive efficiency = pure technical efficiency, the scale efficiency of the decision-making unit = 1, and production is in the best state; otherwise, the scale efficiency is less than or greater than 1. That is, there is a loss in the scale efficiency of the decision-making unit, which can be divided into over-scale and under-scale.

1.2.3 Cost-benefit analysis

The cost-benefit analysis method is a common method for estimating and measuring costs and benefits based on currency units. The premise of the cost-benefit analysis method is the pursuit of maximum utility. The subjects of economic activities, starting from the pursuit of profit maximization, always strive to obtain the maximum benefit with the minimum cost. In economic activities, the reason why people want to conduct cost-benefit analysis is to get the most benefits with the least input.

The cost-benefit analysis has three basic assumptions: the subjects are self-interested, the production process is beneficial, and the process is computable. Net present value method (NPV), Present value index method, and the internal rate of return method (IRR) are the tree main methods of cost-benefit analysis. These three methods have their own characteristics and different applicability. Generally speaking, if the investment project is indivisible, the net present value method should be used; if the investment project is divisible, the present value index method should be used, and projects with a high present value index should be preferred; if the investment project's return When it can be used for reinvestment, the implicit rate of return method can be used.

1.3 Indigenous Context

1.3.1 Barriers to enterprise

The number of mass timber buildings erected in North America is expected to double annually for at least the next decade (Anderson et al. 2020). This represents a major opportunity for the forest sector, especially in remote Indigenous communities with rich forest resources such as Pikangikum. However, there are many challenges associated with the Indigenous context that need to be overcome in order for this opportunity to be realized. Firstly, federal law prohibits reserve land from being used as collateral on commercial loans to non-Indigenous groups or people (Indian Act, 1985), which can make securing these loans in the first place challenging. For example, by one estimate at least an additional CA$ 83.3 bil in capital was needed to fulfill the financial gap of Indigenous people, and this amount has been increasing over the years (National Aboriginal Development Board, 2017). Secondly, there is the history of poverty and isolation. Many Indigenous communities are remote and do not always have the full attention of government and business (Dodson and Smith, 2004). Moreover, access to training has been an important issue but unobtainable among Indigenous communities. For example, on average, only 50% of Aboriginal people in Canada have a high school degree or above (Statistics Canada, 2020). Although young Indigenous people now have higher educational levels than the elderly, this proportion is still far lower than that of non-Indigenous people. Finally, the Indigenous peoples' emphasis on the cultural and traditional values of forests determines the amount of wood and what is harvested on the lands. Such traditional values include fire renewal, religious belief, protection of wildlife (for example caribou protection in Pikangikum), and traditional medicines and uses (Keeping the land, 2006).

1.3.2 The Pikangikum First Nation

Pikangikum is a First Nation community in Northwestern Ontario and lies just east of the Manitoba border (Figure 2). Pikangikum sits within the Whitefeather forest, a Crown forest management unit (MNRF 2006; Palmer 2012). The forest is the subject of a unique agreement signed between the government and the community (Keeping the land, 2006) so that Indigenous people can, in their words, continuously live on this sacred land given by their god. In 2015, the population of Pikangikum First Nation was over 3,000, 75% of whom were under 30 years old, and 90% were unemployed (WFI Forestry Enterprise pathway, 2015).

To address livelihood challenges, the elders of Pikangikum established a community economic renewal and resource stewardship Initiative in 1996, named Whitefeather Initiative (WFI) (O' Flaherty et al., 2008). The WFI is guided by the Elders though the Whitefeather Forest Initiative Steering Group. The objective of WFI is to help find pathways for the community to make better use of the Whitefeather Forest though harvesting and manufacturing, without damaging the forest (WFI Forestry Enterprise pathway, 2015).

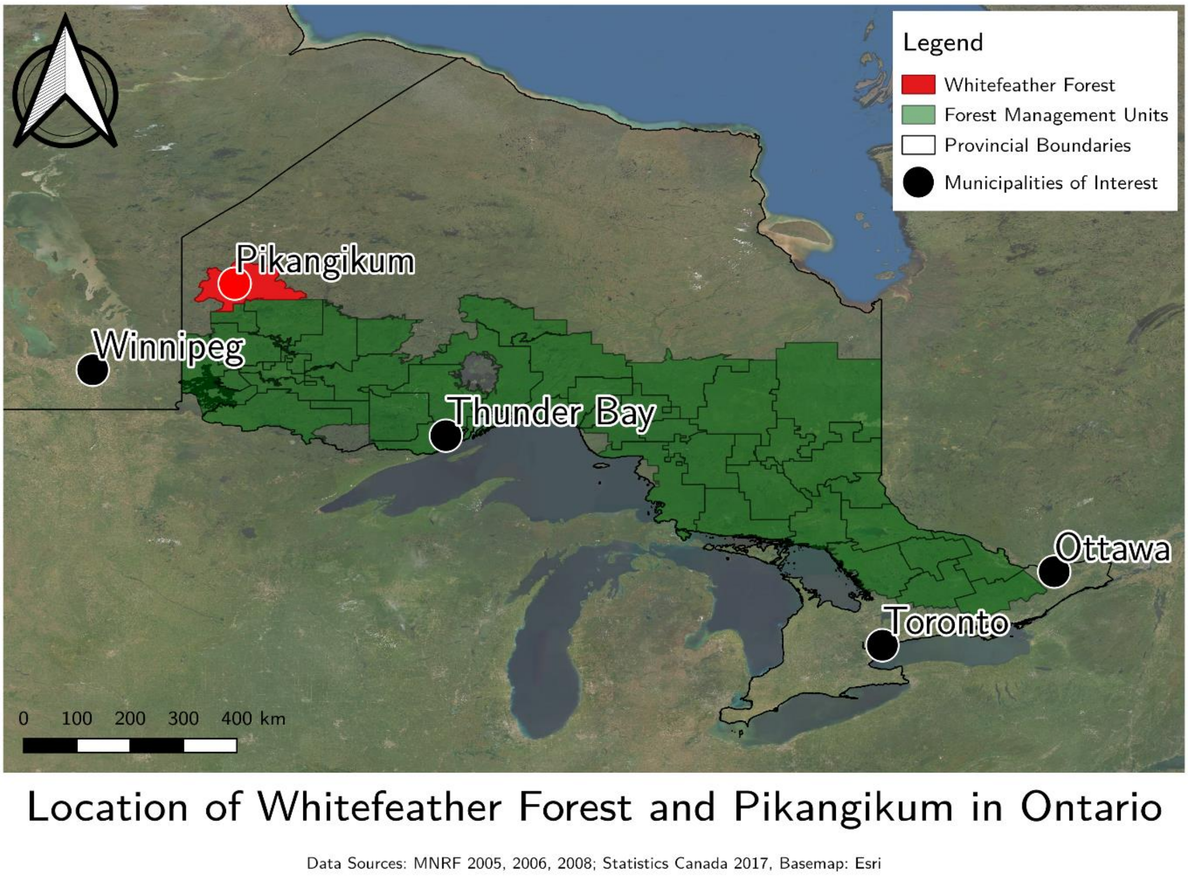

Figure 2: Location of Whitefeather forest and Pikangikum in Ontario.
Map by Emmett Snyder/Mass Timber Institute.

Pikangikum community and WFI have their own principles of the managing of Whitefeather Forest, called *Keeping the Land Approach* (WFI Forestry Enterprise pathway, 2015). It is a sustainable management tapproach based on the wisdom of the Elders, and a concept of achieving a light footprint Indigenous management while protecting both the environment and the Indigenous culture. According to the 2019-2022 Contingency Plan (Whitefeather Community Forest Resource Management Authority, 2018), the planned harvest area in the next 3 years is 13,872.9 hectares, mostly of black spruce and Jack pine, which are the dominant species in the Whitefeather Forest, typical of the boreal forest.

In order to practice the Keeping the Land Approach, WFI claims that all aspects of the forestry operations in the Whitefeather Forest should be viewed as part of a long-term value chain. This can be achieved, it is asserted, by adopting light footprint harvesting and renewal techniques, customary resource stewardship techniques such as Indigenous prescribed burning, and maintaining long-term partnerships with the market (Woodlands Business Plan, 2010). From this perspective, the diversity and abundance of the forest can be protected, and the benefits of the forest can be achieved in the long run. According to the business plan, the community has an objective of providing 100 plus jobs in forest management, harvesting and silviculture, and more than 150 jobs in manufacturing (WFI Business Plan, 2012). Currently, the WFI is investigating the feasibility of a community-owned mass timber plant so that more community members can benefit from the forest resources (A Chapeskie, Personal Communication). It is important that the benefits of any operations remain in the community given the challenges identified above. Therefore, the aim of this study is to investigate the feasibility of a mass timber value-chain in the Whitefeather forest. Specifically, this study uses economic modelling and historical data from five LVL manufacturing facilities in China to address the question:

“Does mass timber manufacturing represent a feasible strategy for breaking the enterprise barrier in the Whitefeather Forest?”

2. Methodology

In this study, a BCC model was used in a DEA analysis to evaluate technical efficiency of LVL production for a mass timber manufacturing facility in Pikangikum. A cost-benefit analysis assuming an annual production volume of 30,000 cubic meters of LVL annually is then used to test the profitability of LVL production in a hypothetical plant in Pikangikum. The data standardization was performed in Matlab (2016a) on an hp Pavilion x360 convertible pc with an Interl(R) Core(TM) i5-7200 CPU@2.50GHz and 8.00 GB of RAM. The BCC model was solved to optimality with DEAP version 2.1, and the Cost-Benefit Analysis was performed in Microsoft Excel (2013).

2.1 Selection of technical efficiency indicators

2.1.1 Selection of input variables

According to the business operations of the target mass timber manufacturers, three indicators are chosen based on capital and labor input: total cost of production factors, total cost of personnel wages, and net fixed assets.

From capital input perspective, capital investment includes short-term and long-term capital investment. Short-term investment is mainly to maintain the company's daily production and operation investment that year. Therefore, also considering the reality of mass timber production, "raw material cost + energy consumption cost + glue and other auxiliary materials cost" was selected to calculate the manufacturer's total cost of production factors. Long-term investment mainly includes fixed asset investment in the field of production, so it is measured by net fixed assets. Because different companies enjoy different land development policies, they may have gaps in land rent as part of the net fixed assets.

In terms of labor input, "total cost of personnel wages" was chosen to measure labor input. This indicator reflects both the quantity and quality of labor input.

2.1.2 Selection of output variables

Because the chosen manufacturers are generally small in scale (the average annual production is about 24,000 m^3, which can be applied in our Indigenous communities), it is impossible to collect data on corporate financing and equity. Therefore, in order to accurately measure the scale changes and profitability of companies, this article chooses the companies' net cash flow as an indicator to measure the current profitability of the manufacturer, and to calculate the return on equity (ROE) as a measure of the future profitability of the selected manufacturer. These two indicators constitute the output of the mass timber manufacturers.

2.2 Data collection

In order to make the economic analysis have reference value for the Aboriginal communities, this study selects 5 small mass timber manufacturers in China and uses their 8-year production data for analysis. The average annual output of the 5 manufacturers is about 24,000 cubic meters (table 1). The average fixed assets of the five manufacturers are US$ 10.87 million (RMB 72.49 million), and the average net cash flow for eight years is US$ 3.29 million (RMB 21.92 million).

Table 1. Basic information of the sample mass timber manufacturers

Facility Number	Facility Name	Location	Average Fixed assets 2012-2018 (in millions of USD)	Average net cash flow 2012-2018 (in millions of USD)	Average LVL production volume 2012-2018 (in m^3)
1	Shenzhen Planation	Shenzhen city, Guangdong province	9.49	5.20	18,452
2	Yunnan Pure	Pu'er city, Yunnan province	6.67	1.44	12300
3	Guangdong Jiahan	Heyuan city, Guangdong province	10.64	4.24	30,582
4	ESwood	Shenzhen city, Guangdong province	8.86	3.67	16,300
5	Suzhou lvyuan	Suzhou city, Jiangsu province	18.43	7.00	42,121
Mean value			10.82	4.31	23,951

2.3 Data standardization

Although the DEA model does not need to be dimensionless, the BCC model selected in this article requires non-negativity and comparability of data. Because the input and output index values vary greatly, it does not meet the model requirements. Therefore, before using the model evaluation, the data set for input must be standardized. This study chooses to use Matlab 2016a software to standardize the data, and to ensure that the relative relationship between the decision-making units will not be changed, and the evaluation results will not be affected.

Standardized processing has the following two goals: (1) In order to make data processing easier,thee data was standardized as decimals in the range of 0.1-1; (2) Change the dimensional expression into a non-dimensional expression, and then become a scalar.

Principle of standardized processing:

Let X be the original data group with the same basic measurement unit, and Y be the standardized data group.

Known $X = (x_1, x_2, \dots, x_n)$, $Y = (y_1, y_2, \dots, y_n)$,

$A = \max(x_1, x_2, \dots, x_n)$, $B = \min(x_1, x_2, \dots, x_n)$, and $n \geq 3$。

Thus $Y = 0.1 + \frac{X-B}{A-B} * 0.9 \quad Y \epsilon [0.1,1]$

See **Exhibit 1** the processed standardized data.

3. Results

3.1 DEA result

The BBC model has the following results as shown in the Table 2. It can be seen from the table that the mean value of technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) are 0.853, 0.976, and 0.874, respectively.

Table 2. The result of the technical efficiency of five mass timber manufacturers 2012-2018.
(TE = Technical efficiency, PTE = Pure technical efficiency, SE = Scale efficiency, RTS = Return to scale)

No.	name	TE	PTE	SE	RTS
1	Shenzhen Planation	1.000	1.000	1.000	-
2	Yunnan Pure	0.526	1.000	0.526	irs
3	Guangdong Jiahan	0.760	0.879	0.865	irs
4	ESwood	0.978	1.000	0.978	irs
5	Suzhou lvyuan	1.000	1.000	1.000	-
Mean value		0.853	0.976	0.874	

The values of TE vary greatly among different firms. The Shenzhen Planation and Suzhou Lvyuan have the highest values 1.0. Followed by ESwood and Guangdong Jiahan, which are 0.978 and 0.526 respectively. Yunnan Pure has the lowest technical efficiency, which is 0.526.

When it comes to PTE value of the sample manufacturers, the values range between 0.879 and 1, with a mean value of 0.976, and overall the relative difference is small. Guangdong Jiahan is the only firm that has not achieved pure technical efficiency.

SE is the ratio of TE to PTE, therefore when PTE values are very close to 1.0, SE values and PE values would be very similar. Here in this case, four of the five PTE values are 1.0, leading to the SE values of Shenzhen Planation, Yunnan Pure, ESwood, and Suzhou Lvyuan equal to their TE values respectively. The SE value of Guangdong Jiahan is 0.865. In addition, Yunnan Pure, Guangdong Jiahan, and ESwood have increasing returns to sale, while Shenzhen Planation and Suzhou Lvyuan have constant returns to sale.

3.2 Cost-benefit analysis result

Table 3 shows the summary of investment costs and benefits. The fixed asset investment that is estimated to build an integrated LVL production line is US$ 8.8 million, and the total labor demand for such a production line is 33 laborers (including 24 workers, 3 operators, and 6 production lead managers). The total production cost per cubic meter of LVL is US$ 266.45. If the product is sold based on the average market price, which is US$ 350/m^3 (2020-10-28 LVL market price, Alibaba), a net sales margin of 18.87% is achieved. In general, the estimated Internal Rate of Return (IRR) is 23%, and it will take 5 years to payback. Detailed information is shown in the following tables. See **Exhibit 2** the list, price, and unit energy consumption of machinery, **Exhibit 3** the list of all costs, and **Exhibit 4** the 12-year estimation of margin and payback period.

Table 3. Summary of investment costs and benefits

Total Fixed assets investment (thousands of USD)	Total labor demand (persons)	Total product cost (USD/m3)	Selling price (USD/m3)	Net sales margin	12-year Internal Rate of Return (IRR)	Payback period (Year)
8,800	33	266.45	350	18.87%	23%	5

Discussion and conclusion

According to the 2019-2022 Contingency Plan (Whitefeather Community Forest Resource Management Authority, 2018), the planned harvest volume of the Whitefeather Forest is 1,823,121 m^3, which equals to approximately 600,000 m^3 per year. This is a very impressive number, which ensures that Whitefeather Forest has an adequate supply of wood. However, considering the loan and other enterprise barriers mentioned in section1.3.1 above, it is very unrealistic to invest in the construction of a factory with an annual processing capacity of 600,000 cubic meters (which the estimation of capital cost will exceed US$150 million, not including land purchase and plant construction costs). The average annual output of the sample LVL manufacturers selected for this study is 23,951 cubic meters, and the average fixed asset investment is US$7.249 million, which is in line with the acceptable range of the first mass timber production investment in the Indigenous communities. In addition, the DEA result of the scale efficiency (SE) shows that 3 of the 5 factories have increasing return to scale, which means that it is reasonable for us to appropriately expand the scale of production on their existing basis and can theoretically obtain higher returns.

The evaluation of the input-output efficiency of the mass timber industry requires model selection based on the characteristics of the mass timber industry itself as well as the situation of the target factories. The models are mainly selected from two aspects. The first step is to choose an input or output model. The input-based model minimizes input while maintaining the same output, while the output-based model maximizes output while maintaining the same input. In this study, it is assumed that in China the mass timber business is an output-oriented industry that is greatly affected by orders, and the production of the target companies are more restricted by the market. This is the case that deals with the minimum input under the condition of constant output, so the DEA model was chosen based on input. Secondly, the evaluation model also needs to be chosen. The CCR model assumes that the return to scale remains unchanged,and it achieves overall effectiveness (which are technical effectiveness and scale effectiveness); while the BCC model considers changeable returns to scale, which reflects the effectiveness of technology, scale and overall effectiveness. Therefore, this study selected the BCC model in the DEA model as the analysis model.

This DEA result shows that the technology of mass timber production is relatively mature, which allows small-scale producers with poor access to production materials and capital to master the technology and carry out effective production. Among the five mass timber manufacturers in China that were examined in this study, only two of them have a comprehensive technical efficiency (TE), pure technical efficiency (PTE) and scale technical efficiency (SE) all reaching 1, indicating that the production decisions of these two manufacturers are more effective (Table 2). However, examining pure technical efficiency (PTE), four of the five manufactures, except Guangdong Lvyuan, have reached 1.0, which means the mass timber technology itself is relatively mature, the problem of technical inefficient lies in the scale.

According to the DEA result, the scale technical efficiency (SE) of Yunnan Pure, Guangdong Jiahan, and ESwood is lower than 1.0, meaning their production scales have limited the effectiveness of the input and output efficiency of the manufacturers. Besides, the manufacturers whose scale technical efficiency need to be improved all show an increasing return to scale, which indicates that these manufacturers can promote the improvement of comprehensive technical efficiency (TE) by expanding the scale of production, while other manufacturers can also keep the return to scale constant. There are no diminishing returns to scale, which shows that the mass timber industry has good development prospects and is suitable for small-scale manufacturers to participate in market-oriented production.

Since the Pikangikum community has a history of selling logs and lumbers, and is going to produceLVL, it is reasonable to say that the Pikangikum community has the ability to provide veneer from their own land as the material of LVL (rather than buy veneer sheets from somewhere else). According to the BDC (Business Development Bank of Canada) business plan, the delivered log price of Whitefeather Forest was CA$ 55/m^3 (US$ 42.9/m^3), andthis local price has not changed much from 2017. Besides, in current veneer production, 85% of logs can finally be turned into veneer, with 5% lost in drying and 10% loss of leftovers (L. Yang, consultant of Shenzhen Plantation, Personal Communication 2020). Therefore, in this study, the veneer cost is assumed as US$ 50.47/m^3 (=42.9/0.85).

The total fixed asset investment (excluding land fees and the cost of the site area) is about US$ 8.8 million, which is a challenge but can be pursued by the Pikangikum community. The project requires a site area of 20,000 square meters, which includes the mill, a wood yard, a drying room, and warehouses. Secondly, a great deal of equipment needs to be purchased and transported in, which is a challenge for such communities without transportation road, except winter roads which are available for four months a year but with climate change, is shortening (Seymour, 2016). In addition, equipment maintenance and production development require more skilled workers and managers, which requires the community to carry out extensive employment training for employees, especially the younger generations. Although we now expect that only 33 people can produce 30,000 cubic meters per year, the community can fully expand the scale of production in the future. Moreover, skilled workers can also find jobs outside the community, which can also improve the local employment environment.

This study estimates that under the premise that the market sales price and cost remain unchanged, and the sales-production ratio is 100%, the annual gross sales are US$ 2.52 million, and the annual net profit after tax is US$ 1.695 million from the second year. The overall 12-year Internal Rate of Return

(IRR) is 23%, and the estimated payback period is 5 years. In conclusion, conducting LVL production in the Pikangikum Indigenous Community is both feasible and profitable, and LVL represents a feasible pathway to breaking the enterprise barrier on the Whitefeather forest.

Exhibit 1. 2012-2019 input-output indicator mean data standardization table

Factory	Year	Output indicator		Input indicator		
		Y1	Y2	X1	X2	X3
		Cash flow	ROE	Fix assets	Production cost	Labor cost
1	2012	0.5355	0.5105	0.3978	0.2685	0.1832
2	2012	0.1000	0.1000	0.2079	0.1000	0.1000
3	2012	0.3889	0.3680	0.3799	0.4400	0.1816
4	2012	0.3604	0.3422	0.3555	0.1844	0.2409
5	2012	0.5127	0.2132	1.0000	0.1865	0.2126
1	2013	0.6118	0.6300	0.3732	0.3453	0.2244
2	2013	0.1182	0.1442	0.1906	0.1618	0.1329
3	2013	0.4487	0.4657	0.3560	0.5653	0.2226
4	2013	0.4142	0.4325	0.3326	0.2545	0.2878
5	2013	0.8687	0.4297	0.9522	0.6927	0.4018
1	2014	0.6247	0.6785	0.3495	0.3643	0.2697
2	2014	0.1247	0.1694	0.1740	0.1692	0.1690
3	2014	0.4554	0.5003	0.3330	0.6523	0.2677
4	2014	0.4233	0.4692	0.3105	0.2859	0.3395
5	2014	0.8816	0.4628	0.9063	0.7347	0.4649
1	2015	0.6134	0.6981	0.3268	0.3769	0.3744
2	2015	0.1327	0.1990	0.1580	0.1537	0.2526
3	2015	0.4358	0.5006	0.3109	0.6269	0.3720
4	2015	0.4153	0.4840	0.2892	0.2582	0.3901
5	2015	0.8822	0.4890	0.8622	0.7719	0.6105
1	2016	0.6899	0.8369	0.3049	0.4589	0.4347
2	2016	0.1594	0.2685	0.1426	0.2021	0.3007
3	2016	0.5148	0.4364	0.4657	0.7611	0.5422
4	2016	0.4694	0.5890	0.2688	0.3459	0.4520
5	2016	0.9846	0.5913	0.8197	0.8339	0.6944
1	2017	0.6813	0.8655	0.2839	0.4658	0.5010
2	2017	0.1338	0.2323	0.1279	0.2518	0.3536
3	2017	0.6285	0.5877	0.4385	0.6740	0.6193
4	2017	0.4633	0.6106	0.2492	0.4023	0.5200
5	2017	0.9929	0.6285	0.7789	0.8844	0.7868
1	2018	0.6893	0.9190	0.2637	0.4867	0.5740
2	2018	0.1439	0.2709	0.1137	0.2501	0.4119
3	2018	0.6262	0.6157	0.4123	0.7925	0.7041
4	2018	0.4690	0.6510	0.2303	0.3516	0.5949
5	2018	1.0000	0.6664	0.7397	0.8267	0.8883
1	2019	0.7137	1.0000	0.2443	0.5216	0.6543
2	2019	0.1678	0.3437	0.1000	0.2402	0.4759
3	2019	0.6274	0.6490	0.3872	0.8138	0.7973
4	2019	0.4862	0.7123	0.2122	0.3551	0.6773
5	2019	0.9981	0.6987	0.7019	1.0000	1.0000

Exhibit 2 Total fixed asset and labor investment estimation

No.	Objectives	Unit	Quantity	Amount	labor	Power
				1000'USD	3shift	Kw
1	A mill, a wood yard, a drying room, and warehouses	㎡	20,000			
2	Equipment investment					
2.1	**Veneer preparation line**		**1**	**1500**	**3**	**140**
2.1.1	Veneer stacker		1			
2.1.2	Veneer feeder		1			
2.1.3	Veneer moisture content detector		1			
2.1.4	Veneer straight edge bevel milling machine		1			
2.1.5	Veneer strength graded stacker		1			
2.1.6	Single board preparation line center console	suit	1			
2.2	**Continuous pre-compression line**		**1**	**2500**	**6**	**300**
2.2.1	Veneer graded feeding system	suit	1			
2.2.2	Infeed conveyor belt		1			
2.2.3	Glue machine		1			
2.2.4	Reciprocating veneer blank assembly conveyor belt		1			
2.2.5	Veneer group billet positioning table		1			
2.2.6	Continuous assembly conveyor belt		1			
2.2.7	Layer slab pre-press machine		1			
2.2.8	Preloading and shaping slab cutting saw		1			
2.2.9	Pre-pressing line center console	suit	1			
2.3	**LVL hot press forming production line**		**1**	**3000**	**3**	**100**
2.3.1	Double-layer slab loading platform	suit	1			
2.3.2	Slab feeding roller device	suit	1			
2.3.3	2-layer LVL heat press 18000x1950		1			
2.3.4	Pressure plate temperature control and heating device	suit	1			
2.3.5	Roller device for forming blank board	suit	1			
2.3.6	Double-layer conveyor belt	suit	1			
2.3.7	Double-layer unloading and rolling table		1			
2.3.8	Hot press line operation center console	suit	1			
2.4	**LVL secondary processing production line**		**1**	**1800**	**12**	**230**
2.4.1	Horizontal conveyor lifting platform		1			
2.4.2	Cutting saw longitudinal feeding conveyor		1			
2.4.3	Cutting saw		1			
2.4.4	Cutting saw longitudinal discharge conveyor		1			
2.4.5	LVL straight edge splitting saw		1			

2.4.6	LVL specification material stacker		1			
2.4.7	LVL specification sheet stack transverse conveyor		1			
2.4.8	Plate stack packaging longitudinal feeding conveyor belt		1			
2.4.9	Moisture-proof film and winding packaging machine		1			
2.4.10	Packing machine plate stack feed rolling table		1			
2.4.11	Steel strapping machine		1			
2.4.12	Slab stack storage conveyor rolling table		1			
2.4.13	LVL secondary processing line center console	suit	1			
Total (3 shifts production)				**8800**	**24**	**770**
Operator (3 shifts X1 person)					3	
Production lead manager (3 classes X 2 people)					6	
Total labor					**33**	

Exhibit 3. LVL unit cost and benefit estimation

No.	Cost	Unit cost	unit	Unit price	Amount (USD)	remarks
1	**Raw materials**			USD	**143.56**	
1.1	Veneer	1.20	m³	50.47	60.56	
1.2	Glue	130.00	Kg	0.60	78.00	
1.3	Accessories	10.00	Kg	0.30	3.00	filler
1.4	Packaging fee	2.00	Kg	1.00	2.00	
2	**Energy consumption**				**4.89**	
2.1	Heat	250.00	MJ	0.01	2.50	Including Wood burning waste and superheated steam
2.2	Electricity	130.00	KWh	0.18	2.39	local electricity price
3	**Labor**	0.001	USD	48000.00	**48.00**	33people，US$ 4000/month*person
4	**Producing cost**				**50.00**	Including production manager wages, other indirect costs of the factory
4.1	Indirect labor costs				7.00	
4.2	Indirect material cost				2.00	
4.3	Low-value consumables				1.00	
4.4	Depreciation				26.00	USD 10 million, 10 years
4.5	Office expenses				2.00	Office expenses, business trip
4.6	Labor insurance and welfare				10.00	
4.7	other				2.00	
	Factory cost				**246.45**	
5	**Sales expense**				10.00	Including travel, short-distance freight, etc.
6	**Administration expenses**				5.00	
7	**Financial expenses**				5.00	
	Total cost				**266.45**	
	LVL market price				**350.00**	2020-10-28 LVL market price, (US$/m³), from alibaba.com (see reference)
	Gross sales				**83.55**	Gross profit margin of sales 23.87%
8	Tax				17.50	Assume 5% of selling price
	Net profit				**66.05**	Net sales margin 18.87%

Exhibit 4 Estimated payback period (unit: thousands of USD)

Year		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Overall
production	Producing from Sept year 1st	7,500.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	
Production to sales rate	%	50.00	80.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Investment	Land and factory	100.00	100.00											
	equipment	8,800.00	1,000.00											
	Start-up fee	500.00												
Working capital	Cycle 1 quarter	3,500.00	1,000.00											
Selling cost	0.266/M3	1,995.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	7,980.00	
Sales income	0.35/M3	2,625.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	10,500.00	
Gross sales		630.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	2,520.00	
Financial and administrative expenses	0.01/M3	75.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	
Tax	0.0175/M3	131.25	525.00	525.00	525.00	525.00	525.00	525.00	525.00	525.00	525.00	525.00	525.00	
Net profit after tax		423.75	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	1,695.00	

depreciation	0.026/M3	195.00	780.00	780.00	780.00	780.00	780.00	780.00	780.00	780.00	780.00	780.00	780.00	
Cash in		618.75	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	
Cash out		9,400.00	1,100.00											
Net cash flow		-8,781.25	1,375.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	2,475.00	
Cumulative net cash flow		-7,406.25	-4,931.25	-2,456.25	18.75	2,493.75	4,968.75	7,443.75	9,918.75	12,393.75	14,868.75	17,343.75	17,343.75	
Internal Rate of Return (IRR)			-84%	-39%	-14%	0%	8%	14%	17%	19%	21%	22%	23%	23%
Payback period (PT)														5

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