A Draft Report on

Analysis of location, feedstock availability, and economic contributions of a mass timber manufacturing plant in Michigan.

Prepared for

Michigan Department of Natural Resources

Lansing, Michigan

Prepared by

Dr. Raju Pokharel, Assistant Professor

Naresh Khanal, Graduate Research Assistant

Department of Forestry

MICHIGAN STATE UNIVERSITY

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Abbreviations

ABP	Analysis by Parts
ASAW	Annual Sustainable Availability of Softwood
BAU	Business as Usual
CLT	Cross Laminated Timber
CNC	Computer Numerical Control
FIA	Forest Inventory and Analysis
GHG	Green House Gas
GIS	Geographic Information System
GLT	Glue Laminated Timber
GWP	Global Warming Potential
IBC	International Building Code
IMPLAN	Impact Analysis for Planning
LP	Lower Peninsula of Michigan
LVL	Laminated Veneer Lumber
MBF	Thousand Board Feet
MDNR	Michigan Department of Natural Resources
MSU	Michigan State University
NLT	Nail Laminated Timber
UP	Upper Peninsula of Michigan
USDA	United States Department of Agriculture

1. Background

Construction industry contributes nearly half of annual global CO_2, one of the major Green House Gas (GHG) emissions (Architecture 2030, 2022, UNEP, 2009). Concrete and steel are the most important components of construction industry responsible for GHG emissions. Therefore, various efforts have been introduced to reduce the environmental impacts associated with building construction. Mass timber has been promoted and accepted as a viable alternative to concrete and steel for the construction industry as mass timber has demonstrated potential GHG emissions reduction when used instead of concrete and steel. Life cycle assessments by Oliver et al. (2014) have noted that about 14%-31% of the global CO2 emissions can be avoided if mass timber is used instead of concrete and steel structures. Another case study by Durlinger et al. (2013) of "Forte" in Austria also concluded that a mass timber building could reduce the global warming potential by 13%-22% compared to concrete and steel structures.

Mass timber is an umbrella term used for engineered wood products manufactured using woodblocks that are laminated together to form linear structures and includes Cross Laminated Timber (CLT), Glue Laminated Timber (GLT/glulam), Laminated Veneer Lumber (LVL), and Nail Laminated Timber (NLT), CLT being the most popular in the recent years (Brandner et al., 2016). CLT is produced by gluing the surfaces of at least three layers of wooden boards with an adhesive under pressure, where alternate layers are placed cross to each other to get a high level of stability (Harte, 2017). Mass timber is known for its aesthetics, long-term carbon storage, and engineering properties such as strength, durability, and consistency (Ahmed and Arocho, 2020). Also, mass timber is lighter in weight than steel and concrete and can be assembled on construction sites with less labor, materials, and environmental impact (Comnick et al., 2022). Both hardwoods and softwoods have been used in making mass timber, however, only mass timber made of softwood has been approved for construction by International Building Code (IBC) in most states, including Michigan. The use of CLT was incorporated into the International Building Code (IBC) in 2015 and amended in 2021. The 2021 amendment permitted the construction of mass timber buildings for residential and business purposes.

Mass timber was developed in Europe in the 1990s as an alternative to traditional building materials for commercial and high-rise buildings. Since then, it has been a topic of robust research enabling the formulation of products standard and design guidelines (Gagnon et al., 2013). As of 2020, about 2.8 million m^3 of mass timber was produced globally, of which Europe produced 48%, North America produced 43%, Oceania produced 6%, and Asia produced 3% (Forest2Market, 2020). The environmental and engineering benefits have expedited the adaptation of mass timber in the construction sector in the United States. More than 1,241 construction projects using mass timber have been completed by September 2021 across the United States, where most of them are commercial buildings or high-rise residential apartments (Comnick et al., 2022). Michigan State University (MSU) hosts the first mass timber building in the state. Following the suite, many more mass timber construction projects are underway. MassTimber@MSU program has recorded a total of 27 mass timber building projects in Michigan, where four are already completed. Table 1 shows the list of mass timber construction projects in Michigan.

Table 1: Mass timber projects in Michigan

		Number of buildings			
SN	Location	Education/training	Commercial	Family/mixed	Total
1	Ann Arbor	1	1	1	3
2	Cedarville	1			1
3	Detroit	1	1	1	3
4	East Lansing	4			4
5	Flint	1			1
6	Kalamazoo	1	1		2
7	Marquette		1		1
8	Muskegon	1	1	3	5
9	Negaunee	1			1
10	Newberry	1			1
11	St. Ignace	1		2	3
12	Traverse City			1	1
13	Wayland	1			1
	Total	14	5	8	27

As of 2022, 15 mass timber manufacturing companies are operating in North America with an annual capacity of about 1.6 million m^3 (Atkins et al., 2022). Of the 15 mass timber facilities, nine are in the United States, and six are in Canada. Most of these production facilities are owned or housed alongside a sawmill. The thickness (width) of produced mass timber also varies from industry to industry which typically ranges from 3 inches to 24 inches (Atkins et al., 2022).

2. Rationale

Mass timber has demonstrated positive economic and climate impacts over the concrete structure, and economic impacts are maximized when mass timber is produced locally (Scouse et al., 2020). Net economic impact assessment for a 12-story building using a mass timber design demonstrated larger economic impacts than traditional concrete buildings and generated added revenues for all income level households in Oregon (Scouse et al., 2020). Constructing a mass timber building can be cost-effective for building a school, library, or other utilitarian buildings with up to 10 stories (van de Kuilen et al., 2011). An assessment of a nine-story building in the United Kingdom built using CLT resulted in 30% higher material costs compared to concrete and steel (Bruno, 2008). Similarly, a more recent study also concluded that the mass timber building has a 6.43% higher cost than a similar concrete structure (Ahmed and Arocho, 2020). The cost rises mainly due to engineered wood costs, installation costs, and project staffing. However, the increased cost was offset by a reduction in labor costs resulting in lower total costs. The nine-story building project was completed 17 weeks earlier than it would have taken to complete had it been built using concrete and steel structures. Ahmed and Arocho (2021) also concluded mass timber building is built 5% faster than concrete and steel buildings. Additionally, There are other benefits including climate change mitigation, environmental benefits, and time savings.

According to the United Nations Department of Economics and Social Affairs (2018), approximately 68% of the global population is expected to live in urban areas by 2050. This will result in a substantial rise in the demand for multifamily residential and non-residential buildings. Although global mass timber production has increased in recent years, the proportion of softwood lumber for mass timber production is only about 1% (FAO, 2022). The number of mass timber projects increased by over 50% in 15 months and is expected to increase in the future (WoodWorks, 2018). This will ultimately increase the lumber demand. A study has forecasted that the global demand for softwood for mass timber production may reach up to 8, 25, and 58 million m^3 under conservative, optimistic, and extreme demand scenarios by 2060 (Nepal et al., 2021). The United States alone will need 3,064 thousand m^3under conservative, 6,535 thousand m^3 under optimistic, and 9,253 thousand m^3 of mass timber under extreme demand scenarios by 2060. The US imported mass timber in volumes of 15,000 m^3 in 2019, 24,700 m^3 in 2020, and 19,300 m^3 in 2021 (Atkins et al., 2022). It demonstrates the upward trending demand for mass timber. However, there are very few studies done to assess the potential to produce mass timber locally to meet this demand. Therefore, this pilot study was designed to evaluate the feasibility of mass timber production and the economic impacts assessment of mass timber facilities in the local and regional economy.

3. Objectives

The objectives of this study are as follows:

1. To identify a location to establish a mass timber production facility in Michigan

2. To estimate the potential softwood availability for a proposed mass timber processing facility location.
3. To evaluate the economic impacts associated with establishing a mass timber processing facility in Michigan

4. Materials and Methods

4.1 Data

The data on milling facilities, such as location, capacity, and major species used, were obtained from the Michigan Department of Natural Resources (MDNR). MDNR compiled the most recent list of milling facilities from the 2018 mill survey. These mills were then differentiated into hardwood logs, softwood logs, pulpwood, and biomass consumers. Since IBC approves only softwood for mass timber production, only the mills that consume or use one or more softwood species were considered in this study. The stumpage price information was also obtained from the MDNR Stumpage Price Reports. The data on the transportation network was obtained from the Esri database (Esri Data and Maps, 2017). The forest inventory data for Michigan and Wisconsin was downloaded from the United States Department of Agriculture (USDA) Forest Services Forest Inventory and Analysis (FIA) DataMart (FIA, 2021). The US has more than 150 thousand FIA plots across the nation that are measured periodically. Michigan has 6,667 of these plots, out of which 4,367 are currently forested (Forests of Michigan, 2020). Figures 1 and 2 show forest types (Ruefenacht et al., 2008) and forest ownership types (Sass et al., 2017) in Michigan.

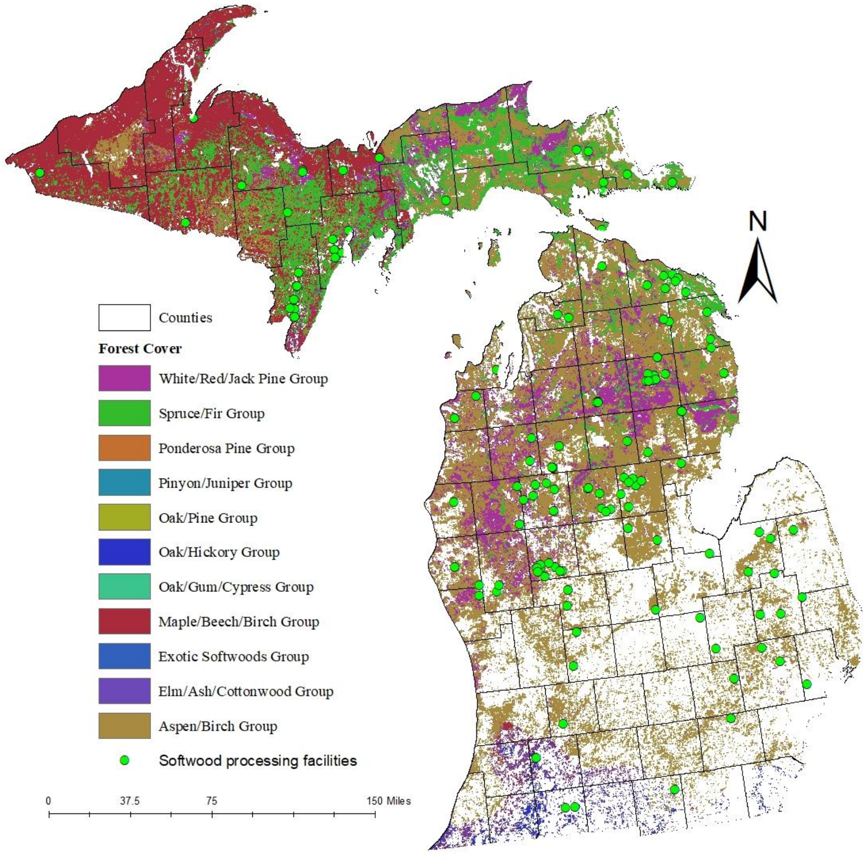

Figure 1: Forest cover and softwood milling facilities in Michigan

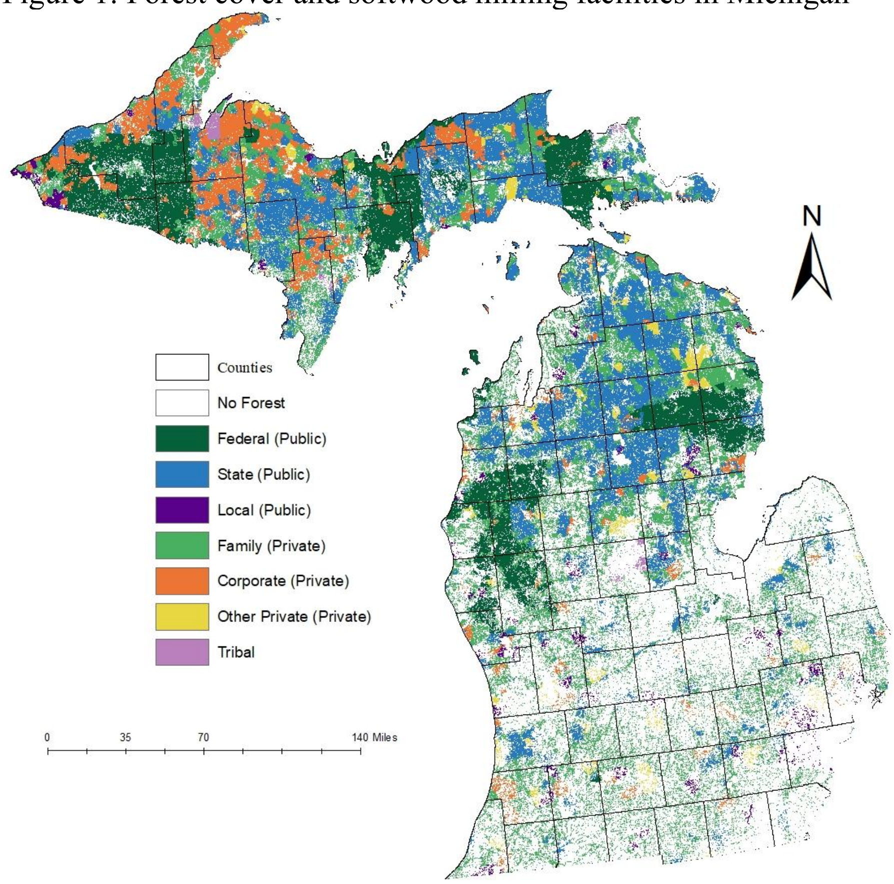

Figure 2: Forest ownership map of Michigan

4.2 Procurement zones and hotspots

'Create Service Area Layer' solver tool (Esri, 2017b) of Network Analysis in ArcGIS (Geographic Information System) was used to map out procurement zones around softwood milling facilities using the national transportation network (roads) to optimize cost-based procurement zones for softwood lumber producers. We didn't use the rail network due to data unavailability. We used haul-time derived from mill-delivered wood prices as a surrogate for the current cost of transporting softwood logs. The delivered wood price at a mill gate includes three major expenditures- stumpage, harvesting and logging, and hauling. Based on the literature, we assumed each cost category contributes one-third of the delivered wood price in the Lake States region (Steigerwaldt Land Services and Forest2Markets, 2015). A standard log truck hauls 4.5 MBF (thousand board feet) of logs at the average trucking rate of $85 per hour. We are using national average for standard log truck. However, Michigan trucks can haul more and in Michigan trucks can haul more and, in some cases, twice as much as other states. The average trucking rate was estimated using various costs associated with log hauling using information from Conrad (2018). With this information, we estimated the travel or haul time to represent the current available cost for transportation (Table 2). Since this is a cost optimization problem, all the wood is expected to be procured to the nearest mill. Thus, the identified procurement zone represents the economically feasible region to procure logs.

Table 2: Conversion of transportation costs to haul time to map out the procurement zones.

Item	Conversion equation	Value
Current average stumpage price for softwood sawlogs ($/MBF)	a	81.83
Average representative harvest costs ($/MBF) [$b=a^*$]	$b=a$[1]	81.83
Average net revenue at the stand that can go towards transportation ($/MBF)	$c=a$[1]	81.83
Delivered softwood log price ($/MBF)	$p=a+b+c$	245.49
Max transportation cost for a truckload at the stand ($/trailer)	$d=c*4.5$	368.24
Round-trip possible with d in hours (trucking rate=$r=\$85/hour$)	$e=d/r$	4.09
One way-trip in Minutes	$f=0.5*e*60$	122.79
One-way trip on the road in Minutes (40 mins load-unload time)	$f-40$	82.75

[1] stumpage cost =logging cost=hauling costs = one-third of delivered wood price

Once the procurement zones were identified for the delivered wood price, they were overlapped to create hotspots where many facilities would compete for softwood logs. The hotspots represent the level of competition for sawmills.

We also estimated the price of delivering mass timber from the facility to major cities. 'Create Closest Facility Layer' solver tool (Esri, 2017a) in the Network Analysis in ArcGIS was used to create routes and estimate travel time and distance to major cities from the candidate mass timber production site. Then the travel time was converted to transportation cost reversing the method outlined in Table 2.

4.3 Softwood Sawtimber Availability Analysis for a new facility

Using rFIA package in R (Stanke et al., 2020), we summarized the forest growth, removals, and standing volume of growing stock from FIA data inside the procurement zone of the proposed mass timber facility. The annual sustainable availability of softwood (ASAW) was then estimated using Equation 1, following the method developed by Goerndt et al. (2013). ASAW assesses the net availability of softwood sawtimber in a year after considering growth, mortality, and removals.

$$ASAW = \frac{V_g - V_r}{V_t} * V_{sw} \qquad 1$$

where V_g is the estimated average annual growth volume within a procurement zone, V_r represent the estimated average annual removal volume on timberland before new demand for woody biomass within a procurement zone. V_t represents an estimated volume of live trees on timberland within a procurement zone, and V_{sw} represents the total volume of the softwood sawtimber in MBF within the procurement zone.

4.4 Economic Impacts Analysis

Impact analysis for planning (IMPLAN) based on the I-O model (Minnesota IMPLAN Group Inc., 2004) represents the flow of money in an economy among industries, government, and households within a region and imports into and exports out of the region. IMPLAN enables us to assess the regional economic impact on income, household spending, or employment due to new industry establishments or the contribution of existing industry (IMPLAN, 2019). IMPLAN expresses how income or expenses in one part of the economy ultimately affects other parts based on purchasing and selling relationships. Economic contributions are generally reported as three components, depending on how they occur: direct, indirect, and induced. Direct effects result from the business or organization's initial spending in the study region. Indirect effects result from business-to-business transactions indirectly caused by the direct effects as businesses increase spending on goods and services from other local businesses. Induced effects result from increased personal income generated by the direct and indirect effects as businesses increase payroll or hire more employees and households, increasing spending at local businesses. Induced effects measure the increase in household-to-business activity. This study uses 2017 IMPLAN data for the analysis. The economic measures based on IMPLAN that are used for the study include employment, labor income, value added, and industry output. Employment includes full-time and part-time employees as well as self-employed individuals associated with an industry. Labor income is the dollar total of employee compensation and proprietor income. Output refers to the total value of production or service by industry within an area for a specified period. Value added is the sum of labor income, other property income (e.g., rents and profits), and indirect business taxes. The economic value for impact analysis is presented in 2017 nominal dollars.

4.4.1 Economic Impacts Analysis of a mass timber production facility.

To analyze the economic impact associated with a mass timber production facility, we assumed that the new mass timber facility would be a part of an already existing sawmill and incur no new construction expenditures. We only include the equipment costs for Computer Numerical Control (CNC) machines and trucks to deliver mass timber. The CNC are complex machines and are widely used due to their capacity to provide a high level of accuracy, efficiency, and consistency in producing fabricated mass timber.

Since there is no separate sector for the mass timber industry in IMPLAN, we used Analysis by Parts (ABP) technique to estimate the economic impacts of this industry. ABP technique allows the user to create a customized industry sector by using the information about that sector's budgetary spending pattern and labor income. In other words, it allows the user to split the ripple impacts of an industry change into its individual impact components- budgetary spending pattern and income (Lucas, 2022). When using the ABP technique, primary data serve as direct effects. Ideally, the user is required to have information about direct employment, direct labor income, and either the total budgetary (goods and services) value or direct output (Lucas, 2022). Section 4.5.1.1 to 4.5.1.3 shows the estimation of direct impacts, including total outputs, spending patterns, and labor income. For indirect impacts, we imported the industry spending pattern of 'Engineered Wood Member and Truss Manufacturing Sector (Sector 137)' of the 2017 IMPLAN model and modified it based on the production function information for the mass timber industry presented in section 4.5.1.2. For induced impact, we obtained the number of employees needed for the operation of the mass timber facility from Masstimber@MSU, and the labor income value for the mass timber industry was obtained following the distribution pattern of labor income for sector 137.

Finally, IMPLAN activities were created for modified industry spending and labor income and analyzed to estimate the indirect and induced impacts of the mass timber facility in Michigan. The total impacts were then reported by adding direct, indirect, and induced impacts.

4.4.1.1 Estimating the total output of the mass timber facility in Michigan

A total of 27 mass timber projects were identified in Michigan by MassTimber@MSU program. On average, the floor area of a commercial building is about 16,441 square feet in the United States (Center for Sustainable System, 2018) In general, a 1,000 square foot floor plan requires 28 cubic feet of mass timber (Berghorn, 2022). Hence, the total mass timber used by these projects in Michigan was estimated at 12,429 cubic feet (27 * 16,441* 0.028) or 5,267 MBF. This is the rough estimate of mass timber usage with conservative estimates to present the lower end of the economic impacts if mass timber was manufactured in Michigan. Further analysis is recommended to estimate the true demand for mass timber in the region to better estimate economic impacts. The selling price of mass timber was calculated using Beck's mass timber report (The Beck Group, 2017), and transportation cost was estimated using ArcGIS. The average price of delivered softwood lumber in the Lake States region was $550/MBF for 2019 (Random Lengths, 2019). The Beck's report estimated that about 52% of mass timber production costs go toward purchasing lumber (The Beck Group, 2017). Our analysis in ArcGIS estimated the average cost of delivering mass timber from the LP facility is $39.02 per MBF. Figure 3 shows the transportation routes used to calculate the average costs of delivering mass timber. Therefore, the average selling price of mass timber (CLT in particular) is $1,057.69 per MBF at the manufacturing facility and $1,096.71 per MBF at the construction site. Selling price at manufacturing site means the total manufacturing cost, but at construction site includes delivery cost up to the site. The total industry output is then calculated by multiplying the unit price of mass timber with the mass timber demand for 27 ongoing and completed projects in the state. The total industry output would be $5.78 million if all projects used mass timber produced in Michigan.

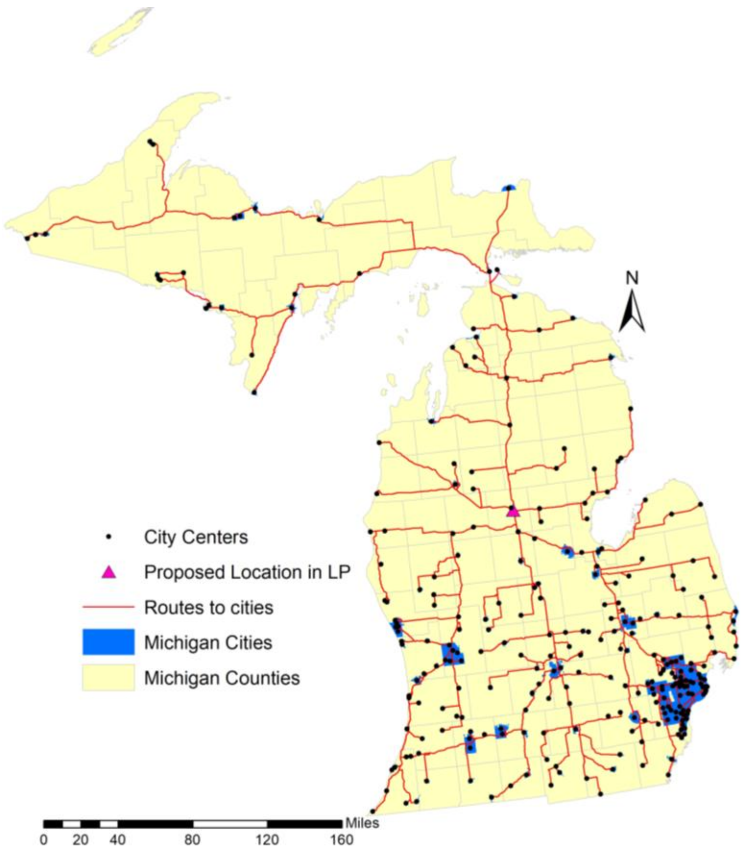

Figure 3: Map displaying routes from the proposed mass timber processing facility in the LP to demand sites (major cities) in Michigan

4.4.1.2 Spending pattern for mass timber facility

Based on the Beck Group report on mass timber (The Beck Group, 2017), we split the unit price of mass timber into different commodities inputs that go into the mass timber production, as shown in Table 3.

Table 3: Distribution of costs associated with mass timber production using Beck's report (The Becks Group, 2017).

Commodities	Proportions of total cost per unit of mass timber production price	Total costs ($)
Dimension lumber	0.52	550.00
Management of companies and enterprises	0.16	169.23
Fabricated structural metal products	0.04	42.31
Architectural, engineering, and related services	0.10	105.71
Electricity transmission and distribution	0.02	25.38
Other fabricated metals	0.03	31.73
Hardware	0.02	16.92
Compounded resins	0.11	116.35
Total	1.00	1057.69

In addition to the commodities listed in Table 3, the new mass timber production facility will also need investments in CNC machines and hauling trucks to deliver mass timber. The CNC machine price based on the quotes from Machinery Marketing International in Chicago is $595,000. The loan payment would then be 126,936/year (paid monthly) at a discount rate of 9% (Machinery Marketing International, 2022). A log truck costs $138,956 on average (Conrad, 2018). The loan payment would then be $27,609/year (paid monthly) with an annual interest rate of 9%. Table 4 presents the modified spending pattern after adding CNC machines and delivery truck costs.

Table 4: Industry spending pattern input for IMPLAN analysis

Commodities	IMPLAN sector	Proportion of total cost
Dimension lumber	3134	0.49
Management of companies and enterprises	3461	0.15
Fabricated structural metal products	3238	0.04
Architectural, engineering, and related services	3449	0.09
Electricity transmission and distribution	3049	0.02
Other fabricated metals	3261	0.03
Hardware	3247	0.01
Compounded resins	3185	0.10
Truck transportation services	3411	0.03
Machined products	3249	0.03
Industrial trucks, trailers, and stackers	3293	0.01
Total		1.00

4.4.1.3 Labor Income Information

A study report on mass timber from California has reported that at least 20 people are needed to operate a mass timber production facility (Redmore et al., 2021). The existing facilities that produce mass timber in the US, such as Vaagen Timber in Washington, currently employ 32, and Mercer International employs 50 people (Nellis, 2020). The number of workers in any mass timber production site varies with the capacity, type of mass timber, and other factors. MassTimber@MSU program has estimated that at least 35 direct employments will be created due to a new mass timber facility in the state. We used the coefficients of the Industry Balance Sheet for Engineered Wood Member and Truss Manufacturing sector (137) from IMPLAN and the total output assessed in this study to estimate total value added, employ compensation, proprietor income, other property tax income, and taxes on production as presented in Table 5. It is estimated that the total value added is equal to 29.40 % of the total industry output for mass timber facilities. Employee compensation, proprietor income, other property tax, and production taxes are 24.00%, 3.77%, 032%, and 1.31 % of total industry output, respectively.

Table 5: Labor income inputs to inform the IMPLAN Analysis

Outputs	Coefficients	Total Outputs ($000)
Total value added	29.40	1698.44
Employ compensation	24.00	1386.65
Proprietor income	3.77	217.52
Other property tax income	0.32	18.71
Taxes on production	1.31	75.55

Table 6 presents the direct impacts of a mass timber production facility, assuming that it would have supplied the mass timber required by ongoing and completed projects in Michigan.

Table 6: Direct impacts of new mass timber facility

Impact Summary	Employment (#)	Labor Income ($)	Total value Added ($)	Output ($)
Direct	35	1,604,170	1,698,000	5,776,033

4.4.2 Economic Contribution of Capacity Upgrade in Sawmill Sector.

The lumber industry is already optimized and is producing lumber based on market demand. This study estimated an additional requirement of 5,266.69 MBF of mass timber in the state for mass timber projects. If 90% conversion of softwood lumber into mass timber is assumed, the total lumber requirement is 5793.36 MBF. Therefore, the total output for the sawmill sector (sector 134) due to this added capacity would be $3,186,348 at the lumber price of $550/MBF. We modified the total output for the sawmill sector (sector 134) and created industry change activity to run the analysis in IMPLAN.

5. Results

5.1. Procurement zone and Competition hotspots of softwood milling facilities

There are 305 active primary wood processing facilities in the state, of which 137 mills use one or more softwood species to produce lumber or related products (MDNR, 2022). The average softwood stumpage price was $81.83 per MBF (MDNR, 2018). Figure 4 shows all wood processing facilities in Michigan.

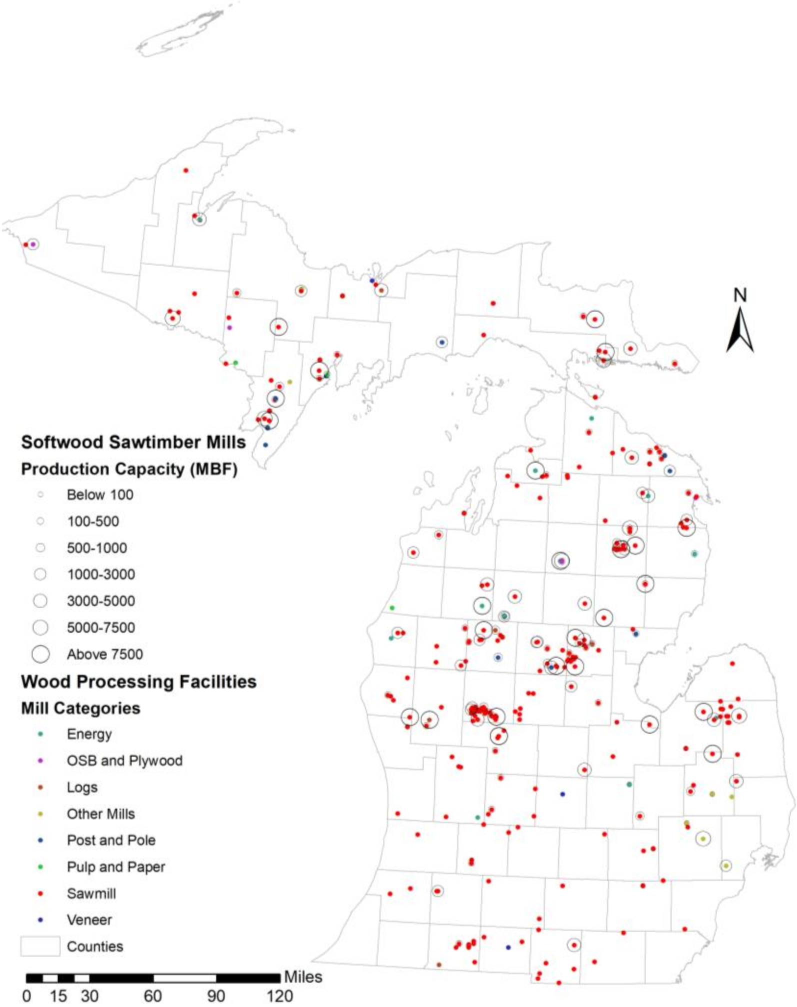

Figure 4: Primary softwood wood processing facilities in Michigan.

Figure 5 shows the competition hotspots of softwood processing mills for softwood species at a given delivered wood price. The hotspot or region with the highest number of softwood processing facilities was observed in central Michigan in the Lower Peninsula (LP). In the hotspot region, as many as 53 softwood processing facilities' service areas overlapped, indicating that at least 53 facilities competed for softwood sawlogs. We call this a base case scenario (BAU) in further discussion.

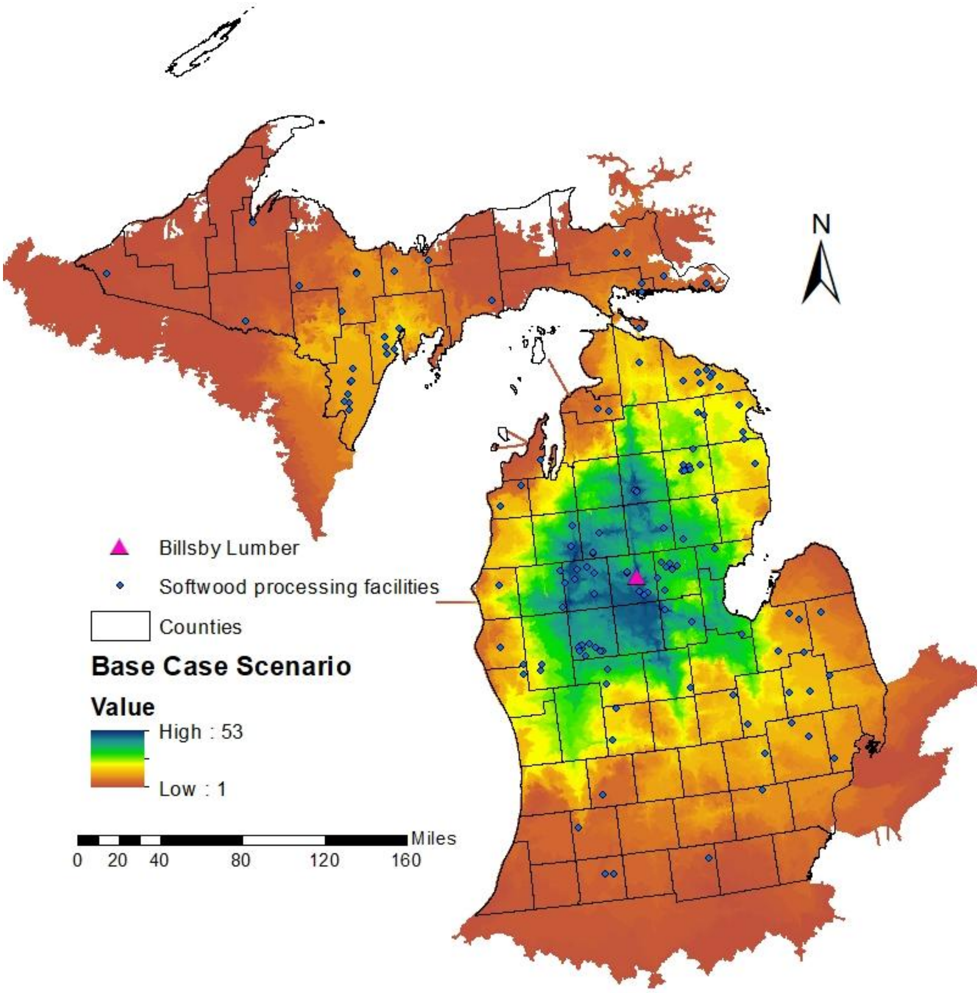

Figure 5: Hotspots of the service area representing market extent and competition of primary softwood processing facilities at the current market price for softwood sawtimber (BAU: Business as usual scenario).

The economic theories dictate that with an increase in the demand for lumber for mass timber production, lumber prices are bound to increase, positively impacting softwood milling facilities. Assuming production and stumpage costs remain constant, the increased profits could go toward procuring logs for longer distances and expanding the softwood sawmills' service areas or procurement zone. This would expand the market coverage for these softwood lumber producers. When observing for 10%, 20%, and 30% increase in the available transportation costs, the expansion of hotspots was not uniform. It can be observed that the expansion was not linear, and a larger impact was observed in 10-20% of price hikes. The hotspots expanded towards the southeast (Bay city area) and south. With the increasing availability of transportation costs to procure and supply softwood to sawmills and then to mass timber facilities, there is real potential to establish mass timber facilities in the south-central part of the state. Also, the competition index increased from 48 to 71 for a 10% increase in transportation, a 20% rise expands the hotspot much farther, and most of the counties would be able to host a mass timber facility with a potential supply of lumber from a good number of softwood lumber producers in the LP. With a 30% increase in transportation cost, having a mass timber producer in any county in LP would be able to procure softwood lumber from most of the sawmills in LP. This indicates more opportunities or competitive advantages for new mass timber facilities to procure lumber. This could increase the usage of softwood species fetching higher prices and increasing the demand, a much-needed market stimulus in Michigan. Also, the increased demand could increase the use of low value or low diameter softwood such as jack pines managed for Kirtland Warbler habitats.

a. 10% price increase b. 20% price increase c. 30% price increase

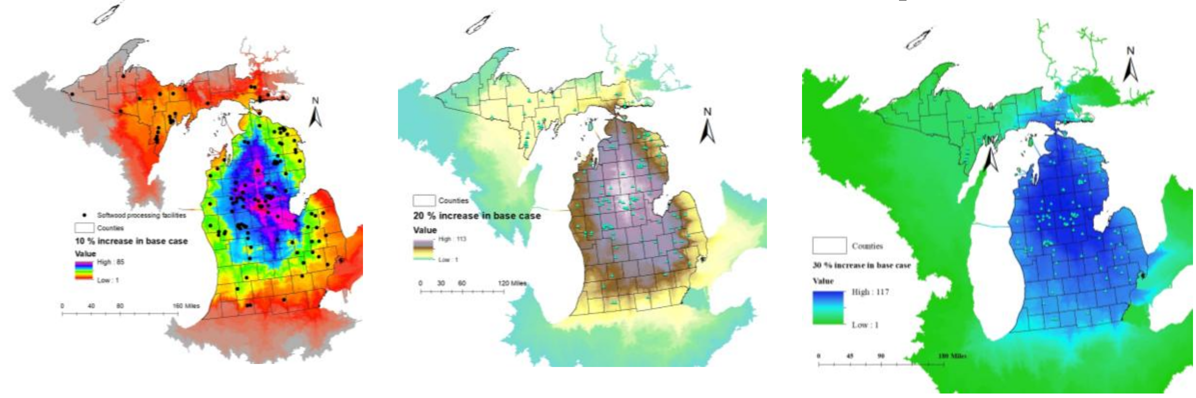

Figure 6: Hotspots of the service area representing market extent and competition of primary softwood processing facilities at the current market price for softwood sawtimber with a) 10%, b) 20%, c) 30% increase in transportation costs from BAU scenario.

5.2. Location for a mass timber production facility

The idle and well-observed phenomenon in North America in placing a mass timber facility is to house it in or next to a large softwood processing facility to secure lumber supply as well as minimize or eliminate the cost of transporting lumber. We select one potential or candidate sawmill for this study in the Lower and Upper Peninsula of Michigan. To identify a location for candidate facilities and estimate softwood sawtimber availability and economic impacts, we observed the hotspots of mill distribution of softwood processing facilities, road infrastructures, and their processing capacities. We also looked at the potential markets for mass timber within Michigan. We identified locating a new facility in or near Billsby Lumber in Clare County in LP and PotlatchDeltic sawmill in Marquette County in UP.

5.3 Procurement Zone and Feedstock availability for a mass timber facility in LP

The rationale behind proposing the location of a new mass timber facility at or near Billsby Lumber in LP are:

- It is situated in the hotspot area where it can source lumber from as many as 48 softwood sawmills with a hauling cost of $81.83/MBF (base case scenario). It has an average production capacity of 7,500 MBF per year and is the highest capacity category for sawmills in the area reported by MDNR.
- It is situated right next to the highway. The produced mass timber can be transported to both north and south conveniently.

5.3.1 Procurement Zones

Figure 7 shows the procurement zone of the proposed mass timber facility in LP. Based on the average delivered wood price, the proposed mass timber facility can procure logs or lumber from the region indicated by the red color polygon in Figure 7. It was identified that at $631/MBF, the proposed facility has as many as 48 softwood lumber producers to supply lumbers. On the flip side, all 48 mills also will compete for the same softwood resource giving rise to competition for softwood in the region. In the next section, we estimate the availability of softwood after accounting for removals for mass timber production in the state to account for the competition. The procurement zones in Figure 7 show the extent of softwood access and distribution of softwood lumber producers to indicate the feasibility of mass timber production in LP.

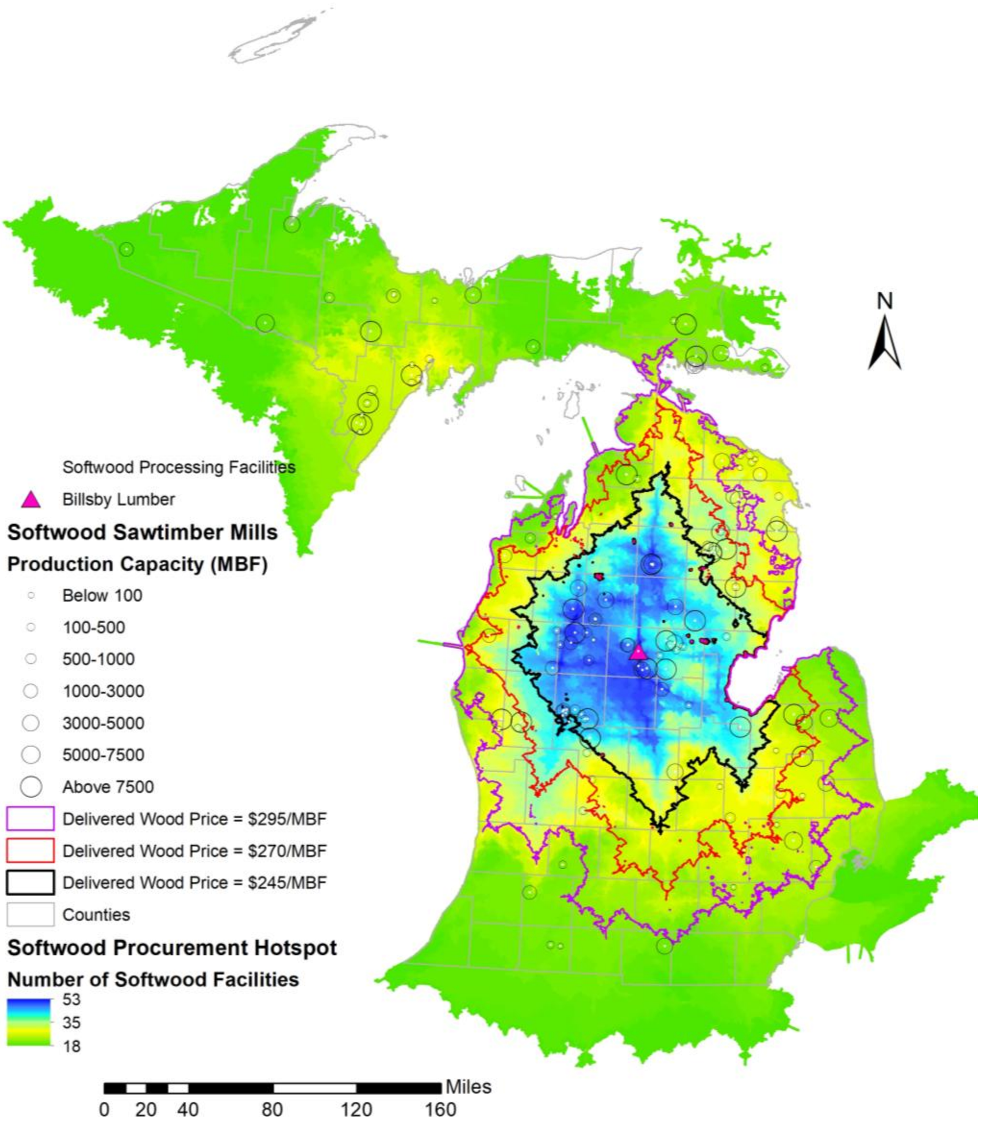

Figure 7: Procurement zone for the proposed mass timber processing facility for different delivered prices of the wood at mill gates.

5.3.2 Softwood sawtimber availability for mass timber production

This study estimates 81,508 MBF, 176,604 MBF, and 231,064 MBF of ASAW for the delivered wood price of $245/MBF, $270/MBF, and $295/MBF, respectively, in the LP after accounting for removals. Private forests have maximum ASAW volume available, followed by state and federal forests. Private forests have an additional 37,798 MBF, 84,917 MBF, and 118,177 MBF of potential softwood at delivered softwood prices of $$245/MBF, $270/MBF, and $295/MBF, respectively, that can be economically accessible by the new mass timber facility as logs or lumbers if processed by other sawmills in the region. State forest can provide 27,472 MBF ASAW at $245/MBF, 47,759 MBF at $270/MBF, and 53,371 MBF at $295/MBF to this mass timber facility. Table 7 presents the ASAW by ownerships at different delivered wood prices.

Table 7: Annual sustainable availability of softwood (ASAW) for mass timber production in for a mass timber facility in LP Michigan.

Delivered wood price at mill gates ($/MBF)	Volume of softwood for mass timber (1000 MBF)			Total (MBF)
	Federal	State	Private	
245 (current scenario)	16.23	27.47	37.80	81.50
270 (10% increase)	43.93	47.76	84.92	176.61
295 (20% increase)	59.52	53.37	118.17	231.06

5.4 Procurement Zone and Feedstock availability for a mass timber facility in UP

The rationale behind proposing the location of a new mass timber facility at or near PotlatchDeltic Land and Lumber LLC in Marquette in UP are:

- UP accounts for only 29% of the area of Michigan, but it has 45% of the forest area with the presence of softwood species like pine, spruce, and white cedar (Forests of Michigan, 2019).
- PotlatchDeltic Land and Lumber LLC is one of the state's largest softwood sawtimber milling facilities. This is also one of the facilities which can produce enough softwood lumber to support mass timber production in the UP.
- PotlatchDeltic Land and Lumber LLC has an average production capacity of 185,000 MBF (PotlatchDeltic, 2019) per annum and is one of the mills with the highest annual production capacity in the United States.

5.4.1 Procurement Zones

Figure 8 shows the procurement zone at different delivered wood prices for UP's proposed mass timber facility. Based on an average price of delivered wood price ($245/MBF), the proposed mass timber production facility can procure wood logs or lumber from the region in pink color in Figure 9. Only ten softwood facilities compared to 53 facilities in LP compete for sawlogs with the procurement zone. At $270/MBF and 295/MBF for a delivered wood price, the number of competing facilities increased to 13 and 20, respectively. However, a lower number of mills in the competition hotspots also implies that there are only a few mills to supply additional lumber if needed. This may not be an issue for the proposed location since the mill housing mass timber production has about 185,000 MBF dimension lumber production capacity. The availability of the softwood itself could be a limiting factor for this location, with very intense softwood milling practices and larger land cover with hardwood species.

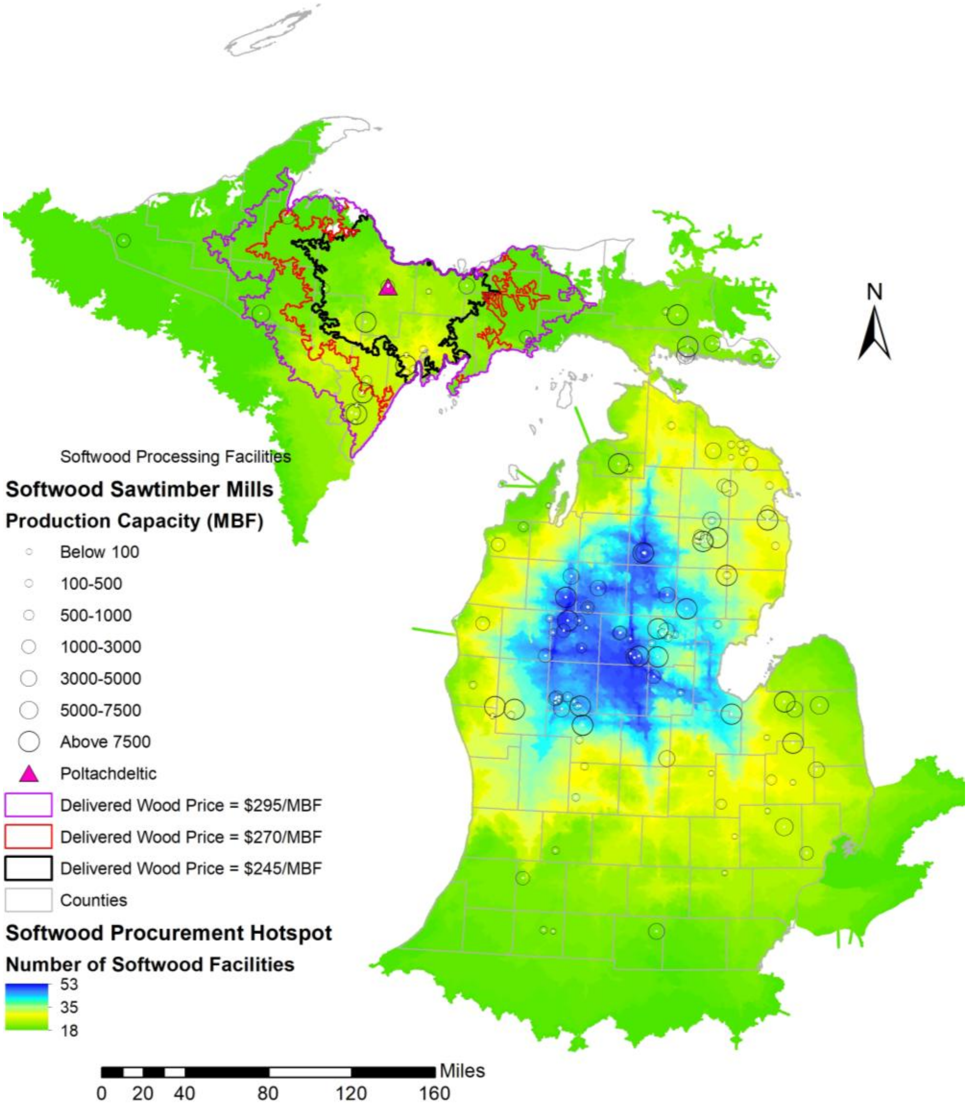

Figure 8: Procurement zone for the proposed mass timber processing facility in UP for a different delivered price of the wood at mill gates.

5.4.2 Softwood sawtimber availability for mass timber production

This study estimates a lower ASAW for a mass timber facility in UP compared to a facility in LP. However, there is already a large softwood facility that can absorb the demand for lumber without the need to procure a significant volume of additional softwood. However, there is less competition for softwood as well. Around the proposed location in UP, the ASAW is 32,719 MBF at $245/MBF, 63,603 MBF at $270/MBF, and 103,577 MBF at $295/MBF. However, the annual growth of softwood in private forests does not exceed the annual harvest in UP, indicating that additional softwood from private forests won't be available for mass timber at current delivered wood prices. The availability increases in private forests with the increase in delivered wood price such that 11,280 MBF and 21,950 MBF of softwood are available for mass timber at $270/MBF and $295/MBF of delivered wood prices. The procurement zones expand south into Wisconsin with increasing prices indicating out-of-state logs may be needed if softwood in the region is already used for other products. The state forest has a significant volume of softwood available for the proposed facility. About 21,686 MBF at $245/MBF, 32,950 MBF at $270/MBF, and 46,260 MBF at $295/MBF of ASAW is available from the state lands. Table 8 presents the ASAW by ownerships at different delivered wood prices.

Table 8: Annual sustainable availability of softwood (ASAW) for mass timber production in the proposed mass timber facility in UP.

Delivered wood price at mill gates ($/MBF)	Volume of softwood for mass timber (1000 MBF)			Total (MBF)
	Federal	State	Private	
245	11.03	21.69	0	32.72
270	19.37	32.95	11.28	63.60
295	36.27	46.26	21.95	103.57

5.5 Economic Impact Assessment

5.5.1 Economic Impact of the mass timber industry

This study estimates 35 direct, 31 indirect, and 24 induced employment opportunities in the state, with a mass timber industry supplying 27 mass timber projects in Michigan. About $1,604,177 is estimated as the direct contribution in labor income, which further produces $2,216,482 in indirect and $1,140,309 in induced labor income in the economy. The total value added from the mass timber industry in the economy is $6,460,536. The industry generates a direct output of $5,776,032 in the state which further generates $6,448,523 as indirect and $3,427,102 in induced output. The total output resulting from the operation of the proposed mass timber facility in Michigan is $15.7 million. Table 9 presents the potential economic contribution of a mass timber industry in Michigan.

Table 9: Economic Impacts of mass timber industry in Michigan using Michigan wood.

Impact Summary	Employment (#)	Labor Income ($MM)	Total value Added ($MM)	Output ($MM)
Direct	35	1.60	1.70	5.78
Indirect	31	2.22	2.78	6.45
Induced	24	1.14	1.98	3.43
Total	90	4.96	6.46	15.65

The top ten sectors impacted by the mass timber industry in Michigan include Sawmills, Commercial logging, Management of companies and enterprises, Architectural, engineering, and related services, Wholesale trade, Truck Transportation, Real estate, Full-service restaurants, Hospitals, and Limited-service restaurants. The mass timber industry in

Michigan supports seven additional job opportunities in sawmills, five additional jobs in commercial loggings, three additional jobs in management of companies and enterprises, and architectural, engineering, and related services, two additional jobs in truck transportation, real state, and full-service restaurants, and one additional job in hospitals and limited-service restaurants. Table 10 presents economic impacts by sector in Michigan with a mass timber industry.

Table 10: Top 10 Industry Impacted by the mass timber industry in Michigan.

Description	Total Employment (#)	Total Labor Income ($000)	Total Value Added ($000)	Total output ($000)
Sawmills	7	415.48	443.78	1918.41
Commercial logging	5	177.35	202.00	300.95
Management of companies and enterprises	3	436.09	483.66	766.19
Architectural, engineering, and related services	3	283.56	272.31	463.08
Wholesale trade	2	161.89	301.95	433.58
Truck transportation	2	95.99	118.42	265.10
Real estate	2	47.52	218.75	310.71
Full-service restaurants	2	32.99	35.86	72.32
Hospitals	1	111.82	121.30	233.22
Limited-service restaurants	1	27.63	65.88	120.25

The state and local tax contribution from the mass timber industry includes $201 from employee compensation, $280,587 from production and import, $80,932 from households, and $8,974 from corporations. The federal tax contribution is $350,237 from employee compensation, $17,178 from proprietor income, $30,991 from tax on production and imports, $255,856 from households, and $49,485 from corporations. Table 11 presents tax contributions from a mass timber industry in Michigan.

Table 11: Tax contribution of a purposed mass timber production facility in Michigan

	Employee Compensation	Proprietor income	Tax on production and imports	Households	Corporations
Federal tax ($000)	350.23	17.18	30.99	255.86	49.49
State & Local tax ($000)	0.20		280.59	80.93	8.97

5.5.2 Economic contribution due to added sawmill capacity for mass timber

The capacity expansion in the sawmill generates 40 additional jobs (11 direct, 19 indirect, and ten induced) in Michigan. The total labor income contribution with additional capacity is $2,163,973 ($698,529 direct, $976,063 indirect and $489,381 in induced impacts).

The additional value-added and total output from the mass timber industry is $2,939,700 and $7,046,332, respectively. Table 12 presents the economic impacts of capacity upgrades in sawmills for mass timber production in Michigan.

Table 12: Economic Contribution from sawmills sector with increased lumber production capacity for mass timber production.

Impact Type	Employment (#)	Labor Income ($MM)	Total Value-Added ($MM)	Output ($MM)
Direct Effect	11	0.70	0.75	3.23
Indirect Effect	19	0.98	1.34	2.36
Induced Effect	10	0.49	0.85	1.47
Total	40	2.16	2.94	7.05

Sawmill and commercial logging sectors benefit the most in terms of employment with capacity expansion, followed by Wholesale trade, Truck transportation, Limited-service restaurants, Full-service restaurants, Real state, Hospitals, Management of companies and enterprises, and Services to buildings sectors. There are 12 additional jobs in sawmills with a total value added of $793,880, followed by the commercial logging sector with eight additional employment opportunities with total value addition of $350,170. An additional total output of $3,431,885 in sawmills and $519,133 of total output in the commercial logging sector is observed from the mass timber industry. Table 13 presents the economic impacts of capacity upgrades in sawmills for mass timber production in Michigan.

Table 13: Top 10 Industry Impacted by the capacity upgrade in sawmills for mass timber production in Michigan.

Description	Total Employment	Total Labor Income ($000)	Total Value Added ($000)	Total output ($000)
Sawmills	12	743.25	793.88	3431.88
Commercial logging	8	305.92	350.17	519.13
Wholesale trade	2	177.62	331.27	475.68
Truck transportation	1	52.36	64.60	144.61
Limited-service restaurants	1	15.28	36.43	66.50
Full-service restaurants	1	16.96	18.44	37.18
Real state	1	21.82	100.45	142.66
Hospitals	1	47.80	51.85	99.70
Management of companies and enterprises	1	80.23	88.98	140.96
Services to buildings	1	12.60	14.45	23.12

The state and local tax contribution from capacity expansion is $178,813 from production and imports, $52,500 from households, and $4,740 from corporations. The federal tax contribution is $208,465 from employee compensation, $16,900 from proprietor income, $19,750 from production and imports, $165,990 from households, and $26,110 from corporations.

Table 14: Tax contribution from sawmills sector with increased lumber production capacity for mass timber production.

	Employee Compensation	Proprietor income	Tax on production and imports	Households	Corporations
Federal tax ($000)	208.47	16.90	19.75	165.99	26.11
State & Local tax ($000)	0.12		178.81	52.50	4.74

6. Discussion

When produced in Michigan, the average price for mass timber is about $1096.71/MBF (~$13.16/cubic ft). Our study estimated a lower price than the 2018 price published in the International Mass Timber Report 2022 ($20/cubic ft) for North America. A direct comparison is not advised. Our estimates are based on assumptions on production costs from 2017. The Becks reports and cost optimization of transporting mass timber. It is important to note that the price of mass timber is affected by the price of lumber, labor costs, and other essential items such as equipment, fabrication materials, and adhesives. So, the price varies by place, type and dimension of mass timber, and production capacity.

The LP region of MI has hotspots of softwood lumber producers, hence a higher probability of lumber supply and competitive advantage for a new mass timber producer. On the hind side, additional demand for lumber would increase competition for softwood in the region. This study concludes that softwood is available with the economically feasible procurement zone for mass timber in the LP region. To account for the regional variation, we also identified a facility in UP as a candidate facility to produce mass timber. There is less competition and a significantly large lumber producer in UP to support mass timber production, however, the available softwood sawtimber is limited from private forests. The study can conclude that mass timber production in UP is also economically feasible. A detailed supply-demand study is recommended to better pin down a location and capacity for mass timber production in the state. The findings of this study can be used to spur discussion among policymakers, investors, and other stakeholders. Our simplified estimation shows that the current market demand for mass timber from 27 projects in Michigan is approximately 5,267 MBF, and softwood sourced within Michigan could have provided it. Additionally, there are a significant number of softwood processing facilities around the proposed location to supply softwood lumbers if needed.

Although there is a concern about softwood availability for mass timber production in the state, our study found that there is softwood available for mass timber production within the economically feasible regions in both peninsulas. The real concern is the landowner's willingness to sell it. About 54% of the landowners in Michigan manage the forest for non-timber purposes (Sass et al., 2021), so further analysis of social sciences and landowners' willingness in the procurement regions would help estimate more accurate softwood availability. Thus, we need more robust research on this issue to determine the demand and supply of softwood lumber for mass timber.

The economic impact analysis showed that a mass timber industry in Michigan produces a two-fold impact on the economy. First, the new mass timber facility generates 90 additional jobs and $15.65 million in total output to the state's economy. Second, the capacity upgrade in the sawmills to produce additional lumber for mass timber supports 40 additional jobs producing a total output of $7,046,332. This also brings in significant tax contributions at the state and federal levels. Therefore, mass timber production in Michigan is an economically feasible opportunity with the potential to create 130 additional jobs in the local economy. This is a conservative estimate, and with the popularity of mass timber projects, the impacts are going be much larger in coming future.

7. Conclusions

The findings of this study suggest that there is sufficient softwood to procure for mass timber production in Michigan, and the facility can be housed in both regions (LP and UP) with pros and cons. The private forest has the highest amount of ASAW in LP with increased competition between the softwood consumers. On the other hand, there is less competition between the softwood consumers in UP, but there are a few mills with significantly high annual lumber production capacity. Economic impact analysis informed that establishing a mass timber facility in Michigan to provide for 27 projects generates and supports additional jobs and taxes and contributes more than $20 million in total output.

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