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A Review of Existing Commercial Mass Timber Buildings in the United States

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The proliferation of mass timber structures across the United States has begun. So much so, a comprehensive evaluation of key building attributes and identification of trends in built structures can be measured. This study utilizes a comprehensive market analysis of existing commercial mass timber structures to quantify important attributes to gain au fait and establish a baseline dataset. Specific interest lies in key areas, sustainability certification frequency and type, location, size, cost, and construction type. This study deploys descriptive statistics to evaluate 229 completed mass timber commercial projects across the United States. The study draws linkages and observes relationships between sustainability rating systems and mass timber structures, geographic concentrations, project cost, project size and height, building type, and building location. The expansion of mass timber is highlighted by the fact that nearly 80% of states across the country are home to a commercial MT building, with an average price per square foot of $344.89, and sustainability rating presence in over 30% of projects.

Key Words: Mass timber, sustainability, construction, United States, LEED

Introduction

Traditionally solely a European endeavor, mass timber has now proliferated across every region of the United States. Emanating from Austria in the early 1990's commercial applications started slowly, picking up when standards and "green" building practices started to gain traction (Gagnon, Bilek, Podesto, & Crespell, 2013). While Europe began mass adoption in the 1990's, the United States first mass timber projects did not start popping up until much later, around the early 2010s. The very first "mass" timber project in the US can be debated as nuances of building types gained the title of first; for example, the first high-rise (as defined by Emporis Building Standards) received approved permitting in 2016 (Lynch, 2017). Other sources point to early 2010's. Around 2013, the US had around twenty-six (26) mass timer structures. This number rose to around five-hundred and seventy-six (576) by 2017 and included all project types (residential, bridgework, small renovations, etc. (Thompson, 2021). By June 2022, 1,502 mass timber projects had been constructed or were in design in all 50 states, in the multi-family, commercial, or institutional (WoodWorks, 2022a).

As these projects grow in not only size (height and square feet), but breadth of geographic locations, we must take stock of their presence. The reasoning for such widespread growth is multi-faceted and complex; there are obvious reasons, and some that are not as clear. For example, mass timber's clear connection with sustainability has been a driver in the expansion of such projects (Abed, Rayburg, Rodwell, & Neave, 2022). Manpower efficiency gains in certain MT building types has been identified (Mirando & Onsarigo, 2022) along with pre-fabrication capabilities that dwarf the other construction methodologies. Other possible reasons include the aesthetics of exposed wood, the improved occupant health and well-being, the reduced jobsite noise, and advanced fire protection and seismic resistance (Think Wood, 2020).

Few seemed to predict the rapid adoption across the US, leaving large gaps and opportunities for researchers to catch up. Empirical studies have not attempted to evaluate the comprehensive grouping of US based projects. In addition to the rapid expansion, the sheer relative infancy of the technology commands further prodding. This study takes stock of a wide sample of mass timber structures across the county, providing important market indicators and trends across timber projects. A critical look at the trends and the current state of mass timber construction in the US can help inform decisions on when it may be advisable to utilize mass timber construction, and the impact of mass timber on the building construction industry.

Mass timber in the United States

Due to the technology's relative infancy in the United States, the preponderance of existing scientific literature is from regions outside of the US (Duan, Huang, & Zhang, 2022). The earliest relevant peer reviewed literature in the US discusses the applications of innovative wood for bridge systems in the U.S. (Moody, Ritter, & GangaRao, 1990). While most of the current literature in the United States lies in the form of professional publications and gray literature, there are various case studies in non-academic literature focusing on singular or small groupings of project performance (WoodWorks, 2022b). Mass timber adoption in the U.S. got to a slow start relative to other regions of the world. Some researchers have credited the initial slow adoption of mass timber in the U.S to practitioners' inexperience with the material and a lack of mass timber building construction projects (Ahmed & Arocho, 2022). However, as discussed in the previous section, the number of mass timber projects has seen exponential growth over the past few years. The increase and growth of mass timber knowledge and experience in the US over the past decade, and the availability of numerous case studies in these recent years, has made it possible for researchers to start filling the knowledge gap that had heretofore been difficult to bridge.

Environmental Impact of Mass Timber

The Global construction industry has a significant impact on the environment. The industry consumes as high as 40% of global energy and contributes to as high as 39% of global greenhouse gas (GHG) emissions through the heavy construction equipment used, transportation, and the manufacturing of building materials (Liang, Gu, & Bergman, 2021; Zaman, Chan, Jonescu, & Stewart, 2022). The industry is continually exploring ways to reduce its impact on the environment and contribute to more sustainable societies by promoting and implementing sustainable design and construction practices. These include embracing new sustainable materials, methods and technologies, and increasing efficiency on the jobsite. Mass timber has emerged as a viable alternative to the traditional, carbon-intensive construction materials, primarily concrete and steel (Zaman, Chan, Jonescu, & Stewart, 2022). According to an article published in the Forest Products Journal that studied the global warming impact of softwood dimension lumber produced from logs in the Pacific Northwest (PNW) and Southeast (SE) regions of the United States, less than 180 (129 in PNW and 179 in SE) pounds of carbon dioxide equivalent is released for each cubic meter of lumber produced, while the same cubic meter of lumber stores about 2,000 (1887 in PNW and 2061 in SE) pounds of carbon dioxide equivalent (Milota & Puettmann, 2017). This represents a net carbon benefit of nearly one ton of carbon dioxide equivalent per cubic meter of lumber produced. A marked contrast to the other building materials (concrete and steel) which result in significant carbon emissions and do not store any carbon dioxide equivalent (Atkins, Anderson, Dawson, & Muszynski, 2022).

Economic Viability of Mass Timber

Studies comparing the construction cost using mass timber to that of concrete or steel have yielded different results with a majority concluding that mass timber is marginally more expensive while several others have found that mass timber is a cheaper alternative (Ahmed & Arocho, 2020; Onsarigo & Mirando, 2021; Van der Westhuyzen & Wium, 2021). Suffice to say that there are many variables that differ from one project to the next, and with the technology still in developing (when compared to concrete and steel), and the lack of an established, efficient supply chain, mass timber projects are projected to be more competitive going forward.

The number of buildings that have been completed using mass timber as the primary structural material has seen exponential growth in the United States over the past decade. However, there is no published work observing the general attributes of the existing mass timber structures. This work attempts to bridge that gap by presenting the general attributes which may be useful in guiding and predicting progress in building with wood.

Methodology

The goal of this study was to evaluate the existing mass timber commercial buildings and define what the data trends show, in a manageable form. This aim aligns with utilizing descriptive statistics to summarize the vast data accumulated primarily from the Woodworks Innovation Network database. The Woodworks Innovation Network (WIN) is an online community created by WoodWorks to facilitate collaboration among professionals using innovative wood building systems and technologies. A solid understanding of the characteristics of existing mass timber buildings is foundational to drawing generalizations and mapping trends that can aid decision making. Descriptive statistics allows us to condense data in a more manageable form and is the first and crucial step in assessment (Kaur, Stoltzfus, & Yellapu, 2018). A review of such condensed data forms can reveal significant facts crucial for guidance in decision making.

Data Collection and Analysis

The dominant resource for mass timber structures in the United States is the WoodWorks Wood Products Council, the council provides resources for commercial mass timber projects in the form of project assistance, continuing education, design tools, and on-demand training. This study takes advantage of WoodWorks online project tool, WoodWorks Innovation Network (WIN). The WIN was created by WoodWorks to help facilitate collaboration among professionals using innovative wood building systems and technologies (WIN, 2022). The database is public and provides important information relative to mass-timber projects across the globe. The network is a voluntary system for compiling real data from mass timber project participants, but the submissions are screened and verified.

Data collection started on August 7th, 2022 and finished on August 15th, 2022 by accessing the WoodWorks Innovation Network database. System defined filter options were selected in the following order; Building System-“Mass Timber”, include “unclaimed projects”, Building type-Assembly (Worship, Restaurant, Theater), Business (Office), Civic (Recreational), Educational, Government, Hotel/Motel, Institutional, Mixed-Use, Multi-Family (Apartments, Condos). The remaining filters were not included in the database search; Custom Innovative Residential (6) Mercantile (7). Exclusion criteria were based on non-commercial and unique building categories. Examples of excluded projects include pedestrian bridges, small civic pergolas, renovations and new projects under 10,000 sq ft are examples of projects included in the database but excluded from this study.

Individual project data was extruded from the WIN as captured in an excel spreadsheet for further analysis. Predetermined attribute columns were created in the excel document and were infilled after assessing each of the 229 completed projects. The data was stored on a google drive and was evaluated for error and outliers. Findings and discussions are presented in the following section based off of the extrusion of data from this extensive database.

Findings and Discussions

After applying the filters listed above, the WIN yielded two hundred and twenty-nine (n=229) mass timber projects fitting this study's established criteria. Each section below outlines findings for each independent variable extracted from the network.

Building Attributes, Building Type and Building Materials

Starting with square foot size, our sample represents a total of 21,948,189 square feet; the average MT structure yields 95,884 sq ft of space. The largest mass timber project was Wal-Mart's Corporate Headquarters listed at 3,000,000 square feet. Height of the structures averages just over three (3) floors, with the tallest building being twenty-five (25) stories, but the majority (59) are single-story buildings (see Figure 1).

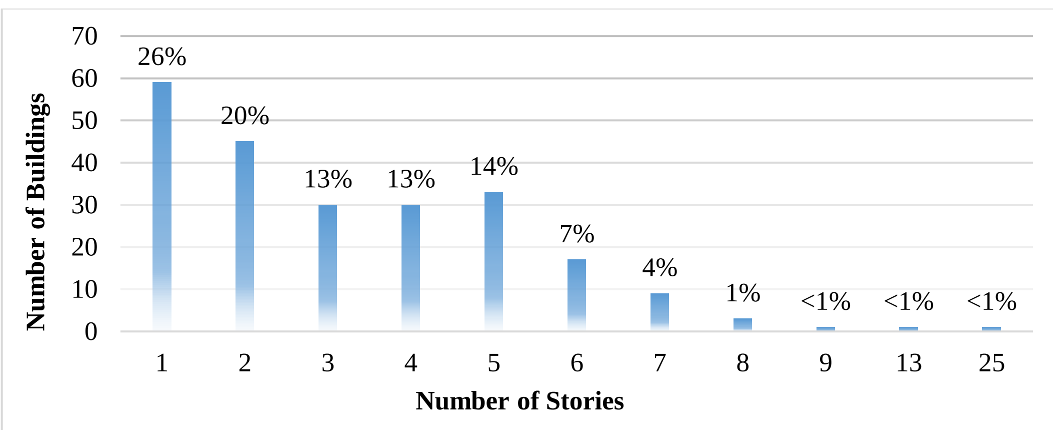

Figure 1. Frequency of Buildings by the Number of Stories

The WIN network produced thirteen categories of building types across our sample. The Business/Office category represents the leading building type at 30.56% (70 projects) of the sample.

Followed by the Educational building category at just under 22% (50 projects). In a tight grouping for third and subsequent places, Assembly at 10.04% (23 projects), Multi-family 9.6% (22 projects), and Mixed-Use 9.17% (21) projects make up a substantial portion of projects. The remaining projects are spread relatively thinly across the building types (see Figure 2).

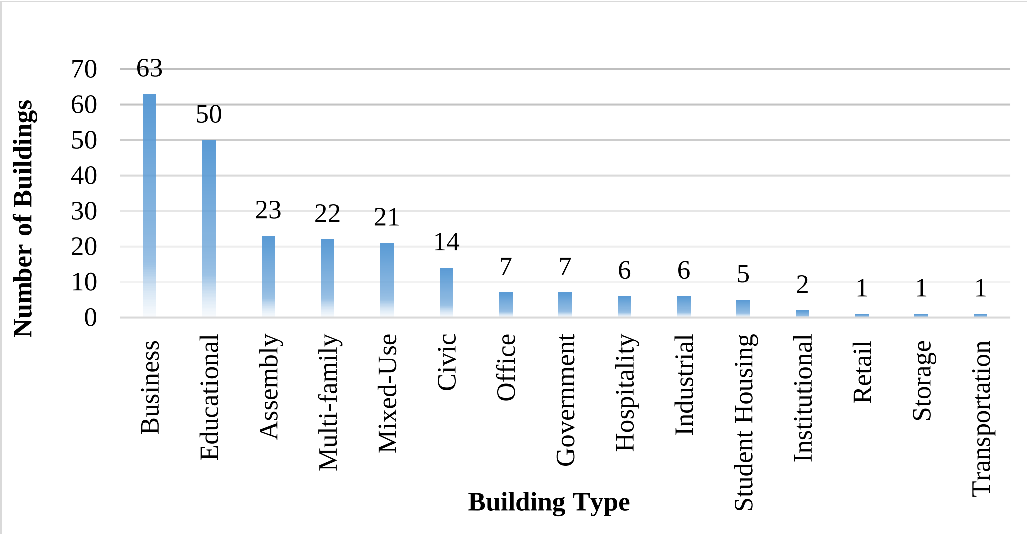

Figure 2 Building Type (Frequency)

Construction type is also an important attribute that offers insight to the project standards these structures adhere to. Surprisingly, V-B type construction leads the categories with 23% of projects (53) falling under the standards of a wood-framed building having no fire-resistance rating. This is deemed as the most commonly seen ISO 1 construction. This is a surprising finding especially since fire protection is a major concern of building with wood (Barber, 2018). Type III-B followed with just under 19% (43) defined as 'the roof/floors of combustible materials have no fire resistance rating". This is the most common of ISO 2 construction where the underside of the roof is exposed wood construction while the walls are other material such as masonry or concrete."

Geographical landscape

An impressive thirty-nine states (78%) across the United States have a minimum of one commercial mass timber project, with additional projects planned in some of the remaining states. Leaders at the state level are concentrated in the Pacific Northwest, topping out the top three with Oregon (48), followed by California (32), and Washington (29). The southeast of the country (NC, SC, and GA) also shows a high density of projects, accounting for almost 10% of the sample. Evaluating these structures through a geographic lens is integral in understanding the application of mass timber. While the Pacific region hosts most MT structures, the other regions are steadily picking up. We are seeing a trend typical of technology and development, where the coasts initiate new trends that eventually spread inward. Today, some manufacturers that were founded in the Pacific Northwest and Canada are seen to be expanding production and materials sources to the southeast to include southern yellow pine (Mesia, Mawema, & Farren, 2022). It is evident mass timber can be used in various climates and applications as evidenced by the sheer geographic distribution of projects and the growth trend is projected to continue going forward.

Cost

Due to privacy concerns, not every project provided cost information. Of the total sample n229, n92 provided cost information. One outlier was discovered and was omitted in terms of cost; the Nashville MLS Project included the total stadium cost of $300,000,000 in the project submission. However, just the canopies were mass timber structures, therefore it was omitted from the cost data. After outlier adjustment, the average completed price per square foot landed at $344.89. The most expensive project in the sample topped out at $130,000,000. Bigger projects exist in terms of dollar value but were not submitted. The smallest reported project landed at an even $1,000,000. See Figure 3 for the distribution across mass timber projects in the U.S.

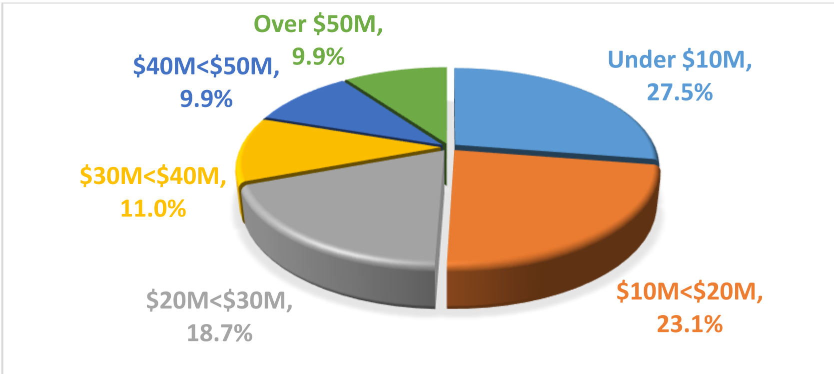

Figure 3. Construction Cost Distribution of Mass Timber Projects in the U.S.

More than half of the projects 50.6 percent were valued at below $20 million. The smallest categories were for projects values between $40 $50 million (9.9%) and those over $50 million (9.9%).

Sustainability

Table 1 represents the linkage between sustainability certification and mass timber construction.

Table 1.

Sustainability Certifications for Mass Timber Projects

Third-Party Sustainability Certification	Total Projects	Percent of MT Projects
LEED	89	38.86%
▪ Platinum Certification	19	08.30%
▪ Gold Certification	37	16.16%
▪ Silver Certification	17	07.42%
▪ LEED Certified	11	04.80%
▪ Certification Undetermined	5	02.18
Net-Zero Energy	9	03.93%
WELL	3	01.31%
Not certified	135	58.95%

Of the two-hundred and twenty-nine (229) buildings, 41% (95) reported achieving some level of third-party rated sustainability certification. Of that 41%, Leadership in Energy and Environmental Design is clearly the most prevalent system chosen, accounting for roughly 38.86% of that sample. Due to that fact, the breakout of level of certification within the LEED system seemed appropriate. When compared to the overall sample, the gold level of certification represents the majority at 16.16%, followed by Platinum at 8.3%, Silver at 7.42% and Certified at 4.8% of the sample. NZE certification follows far behind LEED at 3.93% and WELL certification, even farther behind, at 1.31%.

As more building designers, users, and investors have become more aware of the need to invest in sustainable options, we have seen an increase in green buildings. The number of mass timber buildings that reported as achieving some sustainability certification was anticipated (by the researchers) to be higher and is expected to rise as more buildings are erected. The 2019 Global Commercial Real Estate Services (CBRE) study on the U.S green building adoption index for office buildings found that only 4,879 or 13% of all commercial office buildings across the 30 largest U.S office markets were green certified (ENERGY STAR and LEED) (CBRE, 2019). Sustainability third party certification does not necessarily mean sustainability.

Conclusions and Limitations

This study successfully evaluated two-hundred and twenty-nine (229) existing mass timber projects across the United States identifying key building attributes, geographic locations, sustainability certification presence, cost, building size (height and square footage), amongst other important attributes. Important data trends in each key area were evaluated and presented within this study. Further research is required specific mass timber building sectors, which may be hindered by the scarcity of relevant, reliable and representative data. The recent exponential growth in number of projects, development team input and more concerted research efforts are required to gather more data for analysis. As this building type expands its influence across the country, a deeper understanding of all its facets is paramount. This study is a significant first step in presenting data that can inform decisions on when it may be advisable to utilize mass timber construction, the impact of mass timber on the building construction industry, and it can provide an indication of future trends relative to mass timber buildings. Additionally, the study can help in guiding the investment need relative to mass timber manufacturing in the United States.

The WIN database is the most extensive mass timber building database available; however, the database runs on voluntary project team submissions. In some cases, the database identifies projects that are built (or close to completion) but have not had voluntary project submissions from development teams. As a result, accurate and relevant information on such projects may be lacking. As at the time of this study, there are 140 “unclaimed” projects that have yet to be voluntarily submitted, and that cannot be included in the data even if they offer an opportunity for growth in the dataset. Soliciting this information form project teams and their subsequent involvement is integral to data sharing and improvement of the quality of data available. Project cost is one of those items that is not always available, and the reported number cannot be verified for accuracy. There are many reasons for this. For example, private development firms may not make their investment public, public projects (military, schools, government etc.) may publish overall project costs, including land acquisition, development fees, and other soft cost of a broad variety. For this study ninety-two (92), or roughly 40.17% of projects reported their cost to the WIN network. Year of completion also shares similar issues with cost in that certain outlets publish conflicting data. Since the WIN network reports on projects near completion, the date could still be in flux. This highlights how current the data is, and how rapid projects are being constructed. This important finding makes it difficult for complete date accounting, and even cross-referencing of databases (USGBC, WIN, grey literature, etc.)

The dataset established here offers a plethora of future empirical analysis opportunities. Regression analysis of the sample can take place to determine the impact of various parameters on other parameters. For example, price per-square foot data analyzed through the lens of LEED certification, height, location, and construction type. This requires further project information to fill the existing data gaps. Since a good number of projects have been developed recently, or are currently under development, complete data can be difficult to come by, highlighting the importance of this study, and the need for continued data gathering and analysis from researchers and practitioners.

This study highlights the need for continuing research in the field of mass timber. Numerous angles of inquiry and testing exist; sustainability, code compliance, engineering, cost, safety, efficiency, durability, etcetera, and they should be explored. Exploration of each area through various testing methods should continue to be encouraged and expanded upon. The options for inquiry are quite broad as evidenced by the literature, mass timber focused conferences, and journals. Now that structures are beginning to be occupied, life cycle analysis can and should be conducted to determine longevity of the structures, health and safety of occupants, energy performance, and maintenance requirements. Case studies of this nature are beginning to populate the literature, however, many more are needed.

References

Abed, J., Rayburg, S., Rodwell, J., & Neave, M. (2022). A Review of the Performance and Benefits of Mass Timber as an Alternative to Concrete and Steel for Improving the Sustainability of Structures. *Sustainability, 14*(9), 5570.

Ahmed, S., & Arocho, I. (2020). Mass timber building material in the U.S. construction industry: Determining the existing awareness level, construction-related challenges, and recommendations to increase its current acceptance level. *Cleaner Engineering and Technology*.

Ahmed, S., & Arocho, I. (2022). Identifying the Level of Awareness and Challenges to Adopt Mass Timber by the Construction Practitioners in the United States. *Construction Research Congress* (pp. 502-512). Arlington, Virginia: ASCE.

Atkins, D., Anderson, R., Dawson, E., & Muszynski, L. (2022). *2022 International Mass Timber Report.* Missoula, MT: Forest Business Network.

Barber, D. (2018). Fire Safety of Mass timber Buildings with CLT in USA. *Wood and Fiber Science, 50*, 83-95.

CBRE. (2019, October 17). *US Green Building Adoption Index for Office Buildings 2019.* Retrieved from cbre.com: https://www.cbre.com/insights/reports/us-green-building-adoption-index-for-office-buildings--2019

Duan, Z., Huang, Q., & Zhang, Q. (2022). Life cycle assessment of mass timber construction: A review. *Building and Environment, 221*, 109320.

Gagnon, S., Bilek, E., Podesto, L., & Crespell, P. (2013). Introduction to cross-laminated timber. In FPInnovations, E. Karacabeyli, & B. Douglas (Eds.), *CLT handbook: cross-laminated timber.* Pointe-Claire, Quebec Canada: FPInnovations.

Kaur, P., Stoltzfus, J., & Yellapu, V. (2018). Descriotive Statistics. *Biostatistics, 4*(1), 60-63.

Liang, S., Gu, H., & Bergman, R. (2021). Environmental Life-Cycle Assessment and Life-Cycle Cost Analysis of a High-Rise Mass Timber Building: A Case Study in Pacific Northwestern United States. *Sustainability, 13*(14), 7831. doi:https://doi.org/10.3390/su13147831

Lynch, P. (2017, June 9). The United States' First Mass-Timber Highrise Receives Planning Permission. *Arch Daily*. Retrieved from https://www.archdaily.com/873350/the-united-states-first-mass-timber-highrise-receives-planning-permission

Mesia, K., Mawema, V., & Farren, C. (2022, July 29). *Is Mass Timber the American South's Best Kept Secret? Not for Long.* Retrieved from Gensler: https://www.gensler.com/blog/is-mass-timber-the-american-souths-best-kept-secret

Milota, M., & Puettmann, M. E. (2017). Life-Cycle Assessment for the Cradle-to-Gate Production of Softwood Lumber in the Pacific Northwest and Southeast Regions. *Forest Products Journal, 67*(5/6), 331-342.

Mirando, A., & Onsarigo, L. (2022). Construction Productivity Comparison Between Cast-in-Place Concrete and Mass-Timber Framing: A Case Study of the Nation's Largest Mass-Timber Building. *ASC2022. 58th Annual Associated Schools of Construction International Conference. 3*, pp. 443-451. Atlanta, GA: EPiC Series in Built Environment.

Moody, R. C., Ritter, M. A., & GangaRao, H. (1990). Applications of Wood Materials for Innovative Bridge Systems. *Serviceability and Durability of Construction Materials* (pp. 423-432). New York, NY: American Society of Civil Engineers.

Onsarigo, L., & Mirando, A. (2021). Construction Productivity on Mass-Timber Framing: A Case Study of the Nation's Largest Mass-Timber Building. *Associated Schools of Construction. Great Lakes Region (Region 3)* (pp. 5-15). Downers Grove, Illinois: Associated Schools of Construction (ASC).

Think Wood. (2020, August). *Think Wood.* Retrieved from Mass Timber in North America: Expanding the possibilities of wood building design: https://www.thinkwood.com/continuing-education/mass-timber-north-america

Thompson, M. (2021, November 7). *Is mass timber the building material of the future?* Retrieved from PBS: https://www.pbs.org/newshour/show/is-mass-timber-the-building-material-of-the-future

Van der Westhuyzen, S., & Wium, J. (2021). A development cost comparison between a multi-storey mass timber and reinforced concrete building in South Africa. *Journal of the South African Institution of Civil Engineering, 63*(4), 35-44.

WIN. (2022). *WoodWorks Innovation Network (WIN)*. Retrieved from WoodWorks: https://www.woodworks.org/woodworks-innovation-network/

WoodWorks. (2022a, June). *U.S. Mass Timber Projects*. Retrieved from WoodWorks: https://www.woodworks.org/resources/u-s-mass-timber-projects/

WoodWorks. (2022b, August 16). *Mass Timber Business Case Studies*. Retrieved from WoodWorks: https://www.woodworks.org/resources/mass-timber-business-case-studies/

Zaman, A., Chan, Y.-Q., Jonescu, E., & Stewart, I. (2022). Critical Challenges and Potential for Widespread Adoption of Mass Timber Construction in Australia—An Analysis of Industry