Mass Timber's Love for LEED: Quantifying Sustainability in Mass Timber Structures Through the Presence of Third-Party Sustainability Certification

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Abstract (Mirando)

The proliferation of mass timber structures across the United States has coincided with continued environmental concerns relative to the building industry. The main measure of environmental impact for commercial construction projects are "sustainable", third-party certification rating systems. In order to gain an understanding of mass-timbers relationship with sustainability, through presence and type of rating systems, we quantify and analyze building attributes in projects across the United States. This study examines ### completed, commercial (<10,000 GSF) mass-timber structures across the US, from date to *date*. Statistical analysis was performed using descriptive statistics and hedonic regression from our robust building attribute database. Impressively, __% of projects are certified by a recognized third-party rating system, of which __% are LEED certified. The data points towards a clear correlation between mass timber structures and sustainability rating systems, at a much higher level when compared to traditional structures (%). This study provides evidence that mass timber structures are more sustainable, using current measures. The linkage of sustainable building practices to mass timber structures can provide valuable insight to the further development of green infrastructure.

Keywords: mass timber, LEED, sustainability, United States

1 Introduction (Mirando)

Commercial mass timber structures are proliferating in every corner of the United States. Currently there are 1,860 multi-family, commercial, or institutional mass timber projects that are in progress and/or completed across the US; with exponential growth expected over the coming years (WoodWorks, 2023). A rather recent phenomenon domestically, the spread of this new methodology is attributed to several factors. Some are obvious and proven; like manpower efficiency potential (Mirando and Onsarigo, 2022); embodied carbon sequestration through mass timber material selection (Abed, et al. 2022). 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).

This study lies at the intersection of mass timber's relationship to sustainability, through the lens of third-party certification. Previous studies have identified the benefits of choosing mass timber as a structural system in the sustainability sense, but have failed to identify any third-party certifications that coincide with these projects (Abed, et al. 2022). It is important to understand why project teams select these systems, where market presence stands in relation to third-party systems, and

e, mass timber's clear connection with sustainability has been a driver in the expansion of such projects (Abed, et al. 2022)

Current measures of sustainable construction typically include third-party certification processes. In the United States, the predominate system in both market share and presence for commercial structures is Leadership in Energy and Environmental Design (LEED)

As project number grows, it is imperative for researchers to understand important building attributes associated with mass timber structures.

Few seemed to predict the rapid adoption across the US, leaving large gaps and opportunities for researchers to catch up. 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.

2 Sustainability and construction

Massive or “mass” timber is a category of framing styles typically characterized using large solid wood panels for wall, floor, and roof construction. It consists of multiple solid wood panels nailed or glued together, providing exceptional strength and stability. The ability of these engineered lumber to carry large loads has made it possible to use mass timber for construction of larger and more complex structures, including high-rise buildings. A solid piece of lumber typically has critical strength-limiting defects such as knots, grain deviations, splits, checks, or decay, which tend to concentrate in a single area of the lumber, making that part of the lumber the weak spot and where the wood is most likely to fail. However, if these weak spots are distributed across the entire wood, the result would be a stronger product with predictable strength characteristics. Engineered Wood Products include structural building materials such as plywood, oriented strand board (OSB), laminated veneer lumber (LVL), wooden I-joists and mass timber. Mass timber consists of multiple solid wood panels nailed or glued together, providing exceptional strength and stability. There are various types of mass timber including cross-laminated timber (CLT), nail-laminated timber (NLT), glued-laminated timber (GLT), dowel-laminated timber (DLT) and structural composite lumber (SCL). Figure 1 is a picture from a project that utilized glued-laminated timber for its beams and columns and cross-laminated timber for its floor panels.

2.1 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).

3 Sustainability Certifications - Mirando

Ensuring a building is sustainable is not an easy, nor purely objective task. Buildings alone, not to mention the construction phase, are riddled with unpredictable variables that affect the sustainability of the project. While third-party certification systems oftentimes draw criticism, they are the main conduit in which to judge a building's sustainability attributes. Since the early 1990’s with the creation of the USGBC (amongst other organizations), third party sustainability certification programs have grown

substantially. The growth can be measured by sheer market presence and widespread acceptance from the building community. The goal of the third-party certification system is multi-faceted, but is based in the foundation theory of sustainability. This includes the equal representation of three stakeholders; oftentimes described as economy, social, and environmental. The purpose and value of third-party sustainability certifications is well documented and often debated as to effectiveness in relation to the sustainability paradigm (Mirando, 2021).

Over the past 30 plus years, multiple rating systems have been developed (figure below). Table # below outlines the various third party certifications that currently exist in the United States commercial construction market. Each organization brings a slightly different evaluation process, goals, and certification criteria for projects. Since it's inception by the USGBC, the LEED certification system has maintained dominance in terms of market share, and visibility when compared to other rating systems,

Certification	Description
Leadership in Energy and Environmental Design (LEED)	LEED is issued by the U.S. Green Building Council (USGBC) and was created in 2000 by the USGBC. LEED is now being used in North America and in over 150 countries globally.
WELL Building Standard	This certification focuses on the overall impact of buildings on human health and wellbeing. It achieves this by focusing on the ten concepts: Air, Water, Nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind, Community, and Innovation (WELL, 2022).
Green Globes Building Certification	This certification is issued by the Green Building Initiative (GBI). It was developed in Canada by the Building Owners and Managers Association (BOMA) and introduced in the U.S in 2004 by GBI
The Living Building Challenge (LBC) certification	This certification, issued by the International Living Future Institute (ILFI), is based on your building's sustainability performance over a 12-month period. The certification was introduced in 2011.
Enterprise Green Communities	Enterprise Green Communities is the only national green building program created with and for the affordable housing sector. Launched in 2004, the comprehensive program has evolved to address the growing threats of our changing climate.
The Sustainable Sites Initiative (SITES)	This certification is for development projects located on sites with or without buildings, ranging from national parks to corporate campuses, streetscapes to homes, and more.
Net Zero Energy (NZE) Certification	The International Living Future Institute's (ILFI) Zero Energy (ZE) Certification was created to allow projects to demonstrate zero energy performance. Certified building must demonstrate that all of the building's energy needs on a net annual basis are supplied by on-site renewable energy, and no combustion is involved (ILFI, 2022).

034_green-building-standards-and-certification-system.pdf (internationalgbc.org)

The dominance of LEED certification in the data beckons further understanding and unraveling of the building rating system levels, in addition to presenting the data (figure) aligned by level. The LEED rating system offers tiers of certification project teams can pursue. The highest level is platinum (80+ points), followed by gold (60-79), silver (50-59), and certified (40-49). The importance of providing distinction between the levels is the relationship to performance and cost within the structure. It can be assumed that

a platinum structure will perform both environmentally and economically better than tiers beneath. Points are awarded based on project team selections, point totals then correspond to their respective levels.

4 Methodology (iVana)

The goal of this study was to evaluate the existing mass timber commercial buildings and define what the data trends relative to sustainability certification presence 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.

4.1 Data Collection and Analysis (Mirando)

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 (show image of map). 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 _____, and finished on _____, by accessing the WoodWorks Innovation Network (WIN) database. First, the overall data was extracted from every project in the WIN network (link to website), totaling 631 projects across the United States.

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. Justification for the 10,000 square foot size requirement comes from several sources including;

Individual project data was extruded from the WIN database, coded in an excel spreadsheet for further analysis using SPSS.

Limitations: (Mirando)

Every database has its weaknesses, and the WIN network is no exception. Firstly, the database is voluntary. Project teams can choose to supply project information, which is enticed by offering various MT resources. This limits the database in terms of size and it means the database reflects a portion of the total completed projects across the country. However, WIN is smart, they also track "unclaimed projects". These are projects that the network knows are being built (through various connections), but are not submitting data. This allows us to get an understanding of the total number of projects vs. voluntary data submitted. Unclaimed projects total 198 as of June 27th, 2023 vs. our sample size of ____. Thus our sample represents the clear majority of projects across the county, even though a good amount are not represented here.

Finally, since the project submission is voluntary, even if a project team decides to submit information, they can limit the amount of information submitted. For example, in some cases the square footage, location, and LEED certification are provided, with cost being excluded. This could be attributed to a number of factors, including privately owned projects who do not want to disclose cost information. In other cases, cost, square footage, and location were provided with LEED information excluded. In order to mitigate missing information for individual projects gray literature was scoured. Reliable sources to backup project data submitted to WIN were architect, engineer, consultant, developer, USGBC databases, and even local municipality publications. Oftentimes the architect of record would boast of the LEED accomplishments of a project, while the construction team left out this information in the WIN submission. In this case, the missing WIN data was recorded from the gray literature source and was included in the database. Each source used outside of the WIN network is included in our excel database for reference (appendix # dataset). If no reliable data outside of the WIN network was found, it was simply left out of the database and was recorded as not being certified, or not having cost information.

1.1.1 Data analysis

As mentioned above, multiple regression is used to analyze the data in order to determine the relative influence of multiple independent variables on the level of sustainability. The data are applied to the model which is explained below.

MODEL

Sustainability Certified Project = Project Cost + Project Size + Construction Type + Building Location + Building Type + Year +μ

In this model,

1. Sustainability Certified Project is a variable equal to one for projects that have a sustainability certification and zero otherwise.

2. Project Cost is the cost per square foot of the project. The cost per square foot enables us to more equitably compare the projects in this study, since this study includes projects of varying sizes.

3. Project Size refers to the size of the building in square feet

4. Construction Type refers to the construction types including Type I-A, Type I-B, Type II-A, Type II-B, Type III-A, Type III-B, etc.

5. Building Location distinguishes between various States where the projects are located. The projects in this study are distributed across 38 States in the U.S.

6. Building Type is a variable that distinguishes between education. Multi-family, mixed-use, civic, government, hospitality, industrial, student housing, etc.

7. Year is a vector of dummy variables measuring distinctions between 1995 and 2022.

8. The error term is μ.

Findings and discussions are presented in the following section.

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5 Results

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%

*three of these buildings were also LEED certified and one was LEED and WELL certified
**one of these buildings was also LEED certified and another (1) was LEED and NZE certified

Of the two-hundred and thirty-six (229) buildings, 42% (101) reported achieving some level of third-party rated sustainability certification. Of that 42%, Leadership in Energy and Environmental Design is clearly the most prevalent system chosen, accounting for roughly 37% 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%.

Double counting 7 projects 3 projects LEED and NZE, one project LEED and WELL and One project is certified by LEED, WELL and NZE

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.

6 Conclusions, Discussion, and Recommendations-Mirando

The linkage between LEED certification and commercial mass timber structures is undeniable and has a substantially stronger relationship than more traditional building types. This section not only unpacks reasons why, but also outlines the importance and significance of our findings; whilst offering recommendations for future research.

Several points can be made when considering such a high correlation of mass-timber structures to the presence of sustainability rating systems. It is our opinion that the main factor in facilitating the marriage of these structures to high levels of LEED rating systems is timing. Firstly, recent developments in the

incentivization and in some cases, requirements of LEED rating systems throughout municipalities, federal, state and institutional bodies. For example; the City of Cleveland requires third-party sustainability certification in order for development teams to receive tax abatements (Mirando, 2021). Kent State University requires a minimum of LEED Silver for all new structures, or major renovations on campus (Kent Sus. Website). The United States General Services Administration (US GSA) requires LEED Gold for all new buildings and major renovations (BEATTY, GSA). Hundreds of additional examples exist, showing clear mandates of the utilization of this system throughout each level of major policymakers. The codification of sustainability mandates throughout impactful entities standard operation nomenclature is a recent development, and coincides with the growth of mass timber. Importantly, it can be inferred that these policies are having an impact on mass-timber (amongst others) structures.

In addition to the timing of policies outlined above; market acceptance and knowledge of LEED rating systems is at its highest level ever (LEED numbers). Frankly, architecture firms, development teams, construction managers, and owners are more experienced with

Secondly, end use of the struct

Additionally, the findings present here can aid rating systems in adopting new parameters for emerging technologies.

Further research is warranted as projects continue to develop across the country. As the database continues to be populated with more and more projects, certification systems among other building attribute data should be captured. This data is not only important for researchers, but can aid third-party rating systems (especially LEED) in developing rating systems relative to mass-timber structures. Furthermore, as the data set grows, further empirical analysis through statistical regression can

Conclusion

Arguably, the emergence of such an industry changing structural component can be traced back to the development of structural steel (1855). Researchers, industries, and regulatory industries have a chance to collect and disseminate building attribute data.

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