EPiC Series in Built Environment
Volume 5, 2024, Pages 405–413
Proceedings of 60th Annual Associated Schools of Construction International Conference

Determining the Sustainability of Mass Timber Structures Through Third-Party Sustainability Assessment Systems

Anthony Mirando, PhD, Lameck Onsarigo, PhD, Ivana Krsteska
Kent State
University Kent,
Ohio

Sustainability in the built environment is often judged by the presence and type of third-party sustainability assessment programs. Third-party rating systems offer independent and verifiable point- based metric systems to assess a building's adherence to a set of sustainable building principles. This study assesses mass timber structures' relationship to third-party rating systems in order to determine how sustainable mass timber structures are. A regression analysis of 370 completed commercial mass timber structures across the U.S. provides strong evidence that mass timber structures correlate with the presence of third-party rating systems, especially LEED. The data shows the presence of third- party certifications in over 36% of projects, a vast majority (64%) being LEED certified. Results highlight the overwhelming percentage of mass timber structures deciding to pursue sustainability certifications. Importantly, researchers gain additional building attribute knowledge relative to this new structural technology.

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

Introduction

Commercial scale mass timber structures have proliferated across every corner of the United States. As of June 2023, figures peg commercial mass timber projects under design and or constructed at 1,860 (WoodWorks, 2023). Importance lies in researching and identifying trends associated with this new methodology. Touted for its multifaceted benefits, mass timber structures offer rich testing grounds for a multitude of built environment inquiries. A proclaimed benefit (Onsarigo & Mirando, 2023), and the focus of this study, lies in the exploration of how sustainable mass timber structures are and what important attributes these structures carry. Quantifying sustainability in the built environment can present itself in several ways. Third-party sustainability certifications exist to evaluate and subsequently certify structures adherence to predetermined sustainability metrics.

This surge in mass timber adoption can be attributed to a convergence of factors, including enhanced efficiency, reduced construction costs, and the inherent sustainability of mass timber as a building material. As the momentum continues to build, it becomes increasingly essential for researchers to gain a comprehensive understanding of the key building attributes associated with mass timber structures; including size, location, height, and year constructed (Mirando & Onsarigo, 2023). In the United States, the dominant system, both in market share and prevalence, for commercial structures is the Leadership in Energy and Environmental Design (LEED). By quantifying the sustainability of mass timber buildings through the presence of these certifications, we aim to shed light on the crucial intersection of innovative construction practices and established sustainability standards. This research endeavors to explore the synergies between mass timber construction and LEED certification, providing valuable insights into how this burgeoning construction method aligns with established sustainability benchmarks.

Literature Review

Sustainability Paradigm

Sustainability in the context of construction and architecture has been defined and refined by various scholars and organizations over time. Kuhlman and Farrington (2010), drawing inspiration from the Brundtland Report (1987), articulate sustainability as the act of meeting the present needs of society while safeguarding the ability of future generations to fulfill their own requirements. The construction industry has embraced green construction, also referred to as sustainable or green buildings, as a key method. The US Green Building Council defines green construction as a holistic approach encompassing the planning, design, construction, and operation of buildings (Kriss, 2014). This approach emphasizes several core considerations, including energy and water efficiency, indoor environmental quality, material selection, and the building's overall impact on its surroundings. These efforts aim to optimize positive outcomes while minimizing adverse effects throughout a building's entire lifecycle, from inception and design to construction, operation, maintenance, renovation, and eventual demolition.

To achieve sustainability in construction, several strategies must be employed including waste minimization through thoughtful design, the careful selection of materials in terms of quantity and quality, and the use of sustainable or green materials that neither deplete nonrenewable resources nor harm the environment (Srinivas, 2015). Moreover, to reduce environmental impact and energy consumption, construction projects should prioritize the use of materials that are reusable, recyclable, recycled, possess low embodied energy, and are readily available within proximity to the construction site, thus minimizing fuel consumption, emissions, and road congestion (Wahlstrom et al., 2014). Yung and Chan (2012) aptly note that nearly half of the total waste generated by the construction industry results from building demolitions. Consequently, an environmentally friendly building can be one that is not demolished but repurposed, as advocated by Murray (2012). Building adaptive reuse is an effective alternative to conventional demolition (Conejos et al., 2012). Bullen and Love (2010) describe it as a process that converts disused or ineffective structures into new entities suitable for different uses, thereby aligning with the principles of sustainable construction, green materials for waste reduction, and recycling. This method, particularly when applied to the adaptive reuse of heritage or vernacular buildings, represents a synergy of approaches. It not only avoids the wasteful demolition process but also contributes to sustainability by conserving energy, resources, and materials, while reducing carbon emissions. In doing so, adaptive reuse supports environmental, economic, and social sustainability improvements (Bullen & Love, 2011).

Mass Timber as a Sustainable Alternative

The construction industry, responsible for nearly 40% of global energy consumption and approximately 39% of greenhouse gas emissions, is actively seeking sustainability solutions (Liang, Gu, & Bergman, 2021; Zaman, Chan, Jonescu, & Stewart, 2022). Among these, mass timber construction has emerged as an eco-friendly alternative. It utilizes large solid wood panels, such as cross-laminated timber (CLT) and glued-laminated timber (GLT), to create structurally robust buildings (Atkins et al., 2022).

Mass timber stands out for its capacity to distribute strength-limiting defects, like knots and splits, evenly throughout the wood (UNECE, 2023). Additionally, it has a minimal environmental footprint compared to traditional materials (Duan, Huang, & Zhang, 2022). For instance, softwood lumber production in regions like the Pacific Northwest (PNW) and Southeast (SE) United States results in less than 180 pounds of carbon dioxide equivalent emissions per cubic meter, while storing about 2,000 pounds of carbon dioxide equivalent. This translates to a net carbon benefit of almost one ton per cubic meter, a stark contrast to concrete and steel, which contribute to carbon emissions (Milota & Puettmann, 2017). The adoption of mass timber construction represents a significant departure from traditional building methods and holds the promise of addressing the environmental challenges posed by the construction industry. Its versatility in design and construction offers architects and builders innovative solutions to meet diverse project requirements, while its sustainability benefits align with the global push towards eco-friendly construction practices. In an era where environmental responsibility is paramount, mass timber construction stands as a beacon of hope for a more sustainable future in the construction industry.

Third-Party Sustainability Certification

Ensuring a building is sustainable is not an easy, or purely empirical task. Buildings and the construction process are riddled with unpredictable variables that affect the sustainability of the project (Opoku, Ayarkwa, & Agyekum, 2019). While third-party certification systems oftentimes draw criticism, they are the primary tool used 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 environment. 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. Table 1 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 its inception by the USGBC, the LEED certification system has maintained dominance in terms of market share, and visibility when compared to other rating systems.

Table 1.

Third party certification 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).

Methodology

The primary objective of this study was to determine the sustainability of mass timber structures through the presence of third-party certification and to understand the relationship between third-party sustainability certification and some major project characteristics (like size, cost, location, and building type). To this end, the study sought to answer these three questions:

1. What are the data trends relative to environmental certification of commercial mass timber projects? Descriptive statistics were utilized to summarize the vast amount of data accumulated primarily from the Woodworks Innovation Network database.
2. Is there a relationship between some key project characteristics (like size, cost, location, and building type) and third-party sustainability certification?
3. Binomial logistic regression was identified as the best statistical tool to answer this question.
4. Is there a difference in building size between environmentally certified and non-certified buildings? The independent samples t-test (two-sample t-test) was identified as the best test for this question.

Data Collection

The dominant resource for information on mass timber structures in the United States is the WoodWorks Wood Products Council. 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 was collected by accessing the WoodWorks Innovation Network (WIN) database. Projects included in this study were those in the WIN database on June 10, 2023. First, the overall data was extracted from every project in the WIN 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/Civic (Worship, Restaurant, Theater, Recreational), Business (Office), Educational/Institutional, Government, Hospitality, Industrial, Mixed-Use, Multi-Family (Apartments, Condos), Transportation. The remaining filters were not included in the database search; Custom Innovative Residential and Mercantile. Exclusion criteria were based on non-commercial and unique building categories. Examples in the database that were excluded from this study include pedestrian bridges, small civic pergolas, renovations, and new projects under 10,000 square feet. Not all needed information was available in the WIN database. Therefore, the research team scoured through other data sources to get complete information needed for the analyses. This included the project participants' websites and other grey literature. The collected data included the status and level of sustainability certification, the geographic location of the building, the building type, project size, and project value. The collected data was coded in an excel spreadsheet then imported into SPSS (Statistical Package for the Social Sciences) software program for further analysis.

Data Analysis

First, descriptive statistics were used to enable us to understand the trends of mass timber relative to sustainability certification. Descriptive statistics condense data in a more manageable form and is the first and crucial step in assessment (Kaur, Stoltzfus, & Yellapu, 2018). They are key to understanding the primary characteristics of the dataset and can reveal significant facts crucial for guidance in decision making. Binomial logistic regression was used to analyze the data to determine the relative influence of multiple independent variables on the level of sustainability. The data were applied to the model which is explained below.
MODEL-Sustainability Certified Project = Region + Building Type + Project Size + Project Value + μ

1. Sustainability Certified Project is a variable equal to one for projects that have a sustainability certification and zero otherwise.
2. Region distinguishes between various regions in the United States where the projects are located. The projects in this study are distributed across five regions in the U.S: Northeast (1), Southwest (2), West (3), Southeast (4), and Midwest (the reference category).
3. Building Type is a variable that distinguishes between Assembly/Civic (1), business (2) education/institutional (3), government (4), hospitality (5), industrial (6) mixed-use (7), and multi-family (the reference category).
4. Project Size refers to the size of the building in square feet
5. Project Value is the cost per square foot of the project. The cost per square foot enables us to

compare the projects more equitably, since this study includes projects of varying sizes.
6. The error term is μ.

A two-sample (independent) t-test was also used to determine whether there is a significant size difference between mass timber buildings that are certified and those that are not. Size was an important parameter to test because it has been observed that LEED-certified buildings tend to be larger than their non-LEED counterparts (CBRE, 2022). This inferential statistical test determines whether there is a statistically significant difference between the means of two unrelated groups. For the two-sample t-test, the null and alternative hypotheses below were used.

- H_0: μ1 = μ2 (mean size of non-certified mass timber projects is equal to mean size of certified mass timber projects).
- H_1: μ1 < μ2 (mean size of non-certified mass timber projects is less than the mean size of uncertified mass timber projects).

Findings and Discussion

The descriptive statistical analysis revealed that 36.1% of the projects in the database had obtained certification from reputable third-party sustainability rating systems, with an impressive 63.9% of those achieving LEED certification. The linkage between LEED certification and commercial mass timber structures is undeniable (M=36.1%) and has a substantially stronger relationship than more traditional building types. Though solely based on certification rates, this finding suggests that mass timber is a more environmentally sustainable alternative to the other conventional methods.

Several points can be made when considering such a high correlation of mass-timber structures to the presence of sustainability rating systems. First, the recent development of incentivization programs and in some cases, requirements for LEED certification by municipalities, federal, state, and institutional bodies, has led to growth in certified projects. For example; the City of Cleveland requires third-party sustainability certification for development teams to receive tax abatements (Mirando, 2021). In addition to the timing of policies outlined above; market acceptance and knowledge of LEED rating systems is at its highest level ever (USGBC, 2023). These coupled with the current trend that has seen consumers demand more sustainable products, has made pursuing some sustainability certification a necessary investment for developers.

In the logistic regression analysis, the focus was on examining the relationship between Sustainability Certification and several predictor variables (Region, Building Type, Size and Cost) in predicting LEED certification. The analysis revealed significant results (x2 = 32.834, df = 13, p = .002), indicating that the model had explanatory power. The model accounted for a noteworthy portion of the variance in LEED certification, with Cox & Snell R Square at 20.1% and Nagelkerke R Square at 29.1% (see Table 2). This suggests that these variables collectively can explain LEED certification within that range of variation.

Table 2

Model Summary

Step 1	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
	138.620[a]	0.201	0.291

Notably, when considering the Building Type variable, Mixed-use stood out as a significant predictor (p = .030). Its odds ratio of 6.671 suggests a substantial association with LEED certification (see Table 3). This means that, compared to our reference category, Mixed-use was 6.671 times more likely to have LEED certification. This underscores the importance of delving deeper into the specific attributes of Mixed-use buildings, as they evidently align well with LEED criteria. Understanding what makes these structures particularly suited for sustainability certification can inform future design and construction practices. The conducted independent samples t-test aimed to investigate the potential differences in building size, as measured in square footage, between LEED-certified and non-LEED-certified buildings (see results in Table 3).

Table 3.

Logistic regression of variables predicting sustainability certifications

	B	S.E.	Wald	df	Sig.	Lower	Upper
Region			4.151	4	0.386		
Region (1)	21.62	9819.23	0	1	0.998	0	
Region (2)	20.54	9819.23	0	1	0.998	0	
Region (3)	19.34	9819.23	0	1	0.998	0	
Region (4)	20.89	9819.23	0	1	0.998	0	
Building Type			6.405	7	0.493		
(1) Building Type	0.65	0.755	0.743	1	0.389	0.437	8.4
(2) Building Type	0.76	0.67	1.315	1	0.252	0.58	8
(3) Building Type	-19.9	14587.5	0	1	0.999	0	
(4) Building Type	-18.58	28420.7	0	1	0.999	0	
(5) Building Type	0.3	1.389	0.047	1	0.828	0.089	20.57
(6) Building Type	-0.185	1.038	0.032	1	0.859	0.109	6.361
(7) Building Type	1.898	0.877	4.686	1	0.03	1.197	37.19
Size	-0.439	0.307	2.05	1	0.152	0.353	1.176
Value	0.395	0.272	2.108	1	0.147	0.871	2.533
Constant	21.82	9819.23	0	1	0.998		

The t-test results, both assuming equal variances and not assuming equal variances, reveal statistically significant differences in building size between LEED-certified and non-LEED-certified buildings (t (355) = -2.116, p = .035). The calculated effect size, Cohen's d, provides additional insight into the practical significance of these differences. With a value of -0.260, the effect size falls within the small to moderate range, indicating that while there is a statistically significant disparity in building size, it may not be of substantial practical importance.

Table 4.

Mean Comparison between LEED certified and non-certified buildings

Variable	LEED not Certified		LEED Certified		t(355)	p	Cohen's d
	M	SD	M	SD			
Size SF	9.11	19.79	14.26	19.97	-2.16	.035	-.260

Conclusion and Recommendations

The data presented in this study highlights the relationship between mass timber commercial construction projects and LEED certification. Several reasons for this connection are presented here for dissemination and discussion. In addition, this study uncovered interesting factors influencing the presence of sustainability certifications in mass timber construction. The data shows a higher correlation between mixed-use occupancy mass timber structures through a 6.671-fold higher likelihood of LEED certification compared to other building types. Other variables such as region, size, and value did not exhibit significant relationships, yet remain close. The relationships observed from these results are dynamic and could potentially change as mass timber continues to grow and more datapoints are generated.

Reasons for the strong relationship between mass timber structures and LEED certification can be attributed to a multitude of factors. Firstly, mass timbers proliferation coincides with the height of the utilization of third-party rating systems. When compared to traditional structures, it makes sense that mass timber structures align closely with third-party certifications since it is a new structural system in the US. Secondly, municipalities across the country are incentivizing the use of third-party rating systems through tax abatements for urban developers. Thirdly, mass timber structural systems mesh well with sustainable systems, highlighting the strengths of the material. Third-party systems have endorsed the use and are rewarding teams for selecting its use as a structural system. Finally, it makes sense that progressive development teams, who are often more aligned with sustainable structures, are building these cutting-edge structures. By leveraging the strength and sustainability of mass timber, builders can reduce carbon emissions, promote eco-friendly practices, and create structures that not only stand tall but also stand as symbols of a more sustainable future. With ongoing innovations and increased adoption, mass timber has the potential to reshape the construction landscape in the United States and beyond, ushering in an era of greener and more efficient building practices. This is certainly evident by the overwhelming presence of LEED certified mass timber structures.

References

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

Bullen, P. A., & Love, P. E. (2010). Towards a Collaborative Theory of Sustainability Development: Adaptive Reuse of Industrial Buildings. In CIB World Congress Proceedings (pp. 1-15). Bullen, P. A., & Love, P. E. (2011). Sustainability and the adaptive reuse of commercial buildings.
Facilities, 29(3/4), 151-167.

CBRE. (2022, October 26). *Green ls Good: The Enduring Rent Premium of LEED-Certified U.S. Office Buildings*. Retrieved from CBRE: https://www.cbre.com/insights/viewpoints/green-is-good-the-endurance-of-the-rent-premium-in-leed-certified-us-office-buildings

Conejos, S., Vidaurre, D., & Ruiz, F. (2012). Adaptive reuse of heritage buildings: A literature review

and methodology proposal. Sustainability, 4(8), 1764-1786.
Duan, Z., Huang, Q., & Zhang, Q. (2022). Life cycle assessment of mass timber construction: A review. *Building and Environment*, *221*, 109320.
ILFI. (2022). Zero Energy Certification Overview. Retrieved from International Living Future Institute: https://living-future.org/zero-energy/certification/
Interactive Mass Timber Project Map I WoodWorks Innovation Network (WIN). (2022). Woodworks Innovation Network. Retrieved January 26, 2024, from https://www.woodworksinnovationnetwork.org/projects/
Kaur, P., Stoltzfus, J., & Yellapu, V. (2018). Descriptive Statistics. *lnternational Journal of Academic Medicine*, *4*(1), 60-63.
Kriss, J. (2014, August 6). *What is Green Building?* Retrieved from U.S. Green Building Council: https://www.usgbc.org/articles/what-green-building
Kuhlman, T., & Farrington, J. (2010). What is sustainability? Sustainability, 2(11), 3436-3448.
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
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. M. (2021). Social Equity Ignored: An Examination of LEED Rental Premiums in the Multi-Family Market [Doctoral dissertation, Kent State University]. OhioLINK Electronic Theses and Dissertations Center. http://rave.ohiolink.edu/etdc/view?acc_num=kent1627557232122465
Mirando, A., & Onsarigo, L. (2023). A Review of Existing Commercial Mass Timber Buildings in the United States. *59th Annual Associated Schools of Construction lnternational Conference* (pp. 560-568). Liverpool: EPiC Series in Built Environment, vol 4.
Murray, V. et al. (2012). Determinants of risk: Exposure and vulnerability. In Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change (pp. 65-108). Cambridge University Press.
Onsarigo, L., & Mirando, A. (2023). Quantifying MEPFP Mass-Timber Trade Efficiency Through Vertical Mechanical Fastener Analysis. *Mass Timber Construction Journal*, *6*, 17-23.
Opoku, D.-G. J., Ayarkwa, J., & Agyekum, K. (2019). Barriers to environmental sustainability of construction projects. *Smart and Sustainable Built Environment*, *8*(4), 292-306.
Srinivas, N. (2015). Handbook of Green Building Design and Construction: LEED, BREEAM, and Green Globes. Butterworth-Heinemann.
UNECE. (2023). *Circularity concepts in wood construction.* Geneva, Switzerland: United Nations and the Food and Agriculture Organization of the United Nations.
USGBC. (2023). *usgbc.org.* Retrieved from LEED rating system selection guidance: https://www.usgbc.org/leed-tools/rating-system-selection-guidance
Wahlstrom, K., Berger, A., & Widome, R. (2017). Relationships between school start time, sleep duration, and adolescent behaviors. Sleep Health, 3. https://doi.org/10.1016/j.sleh.2017.03.002
WELL. (2022). WELL Certification. Retrieved from International WELL Building Institute: https://www.wellcertified.com/certification/v2
WoodWorks. (2023, June). *Building Trends: Mapping Mass Timber*. Retrieved from WoodWorks: https://www.woodworks.org/resources/mapping-mass-timber/
Yung, P., & Chan, E. H. (2012). Post-demolition waste recycling management in Hong Kong. Resources, Conservation and Recycling, 65, 30-40.