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Research Needs Assessment for the Mass Timber Industry

Proceedings of the 3rd North American Mass Timber Research Needs Workshop

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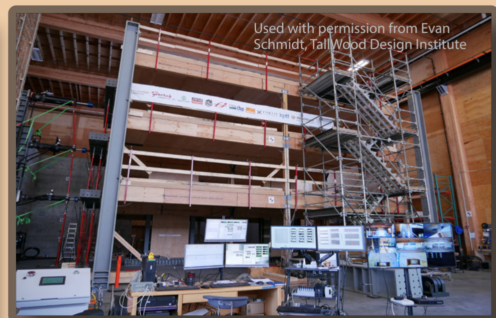

Abstract

The 3rd Mass Timber Research Needs Assessment was held on September 20–22, 2022, at a location nearby the USDA Forest Service, Forest Products Laboratory. The workshop was co-sponsored by the Forest Products Lab and WoodWorks. The purpose of the workshop was to gather a diverse group of people with expertise in mass timber, in particular cross-laminated timber, to discuss and prioritize the research needed to move the mass timber industry forward in North America. The workshop was attended by more than 130 design professionals, researchers, manufacturers, industry leaders, and government employees. The meeting resulted in a list of well over 100 research needs. Following the meeting, the list of research needs was condensed into common themes. This report presents the prioritized research needs of the mass timber industry in North America. Also included in the appendixes are the meeting agenda and a list of the participants along with their professional titles and affiliations.

Keywords: Mass timber, fire, structures, durability, buildings, economics, sustainability, research needs

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Proceedings of the 3rd North American Mass Timber Research Needs Workshop

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Introduction

Mass timber, a relatively new type of construction in North America (Ahmed and Arocho 2020, Dawson and others 2022, Fernholz and others 2022), refers to “massive” engineered wood composites such as glue-laminated timber (glulam), structural composite lumber (SCL), mass plywood, nail-laminated timber (NLT), dowel-laminated timber (DLT), laminated veneer lumber (LVL), and cross-laminated timber (CLT) (Fernholz and others 2022, Jakes and others 2016, Stark and Cai 2021). CLT consists of layers of dimensional lumber that are typically rotated 90 degrees from each other; it can be used as wall, roof, or floor assemblies and is delivered to the job site as massive panels with precut penetrations for connectors and fasteners and fenestrations for mechanical, electrical, and plumbing (MEP) services (Brandner and others 2016, Ding and others 2022, Gagnon and others 2013). Although many mass timber products have been incorporated into buildings for nearly 100 years, the rise of CLT in North America and associated research and development is advancing wood construction, allowing buildings as tall as 18 stories to now be constructed out of wood as per the 2021 International Building Code (ICC 2020, Stegner and Fotheringham 2022). Europe led the development of CLT. They continue to produce CLT competitively for global export. Other countries (Australia, Canada, China, Japan, New Zealand, and the United States) have made recent strides in mass timber construction (MTC) prevalence, awareness, and adoption in commercial markets (Dawson and others 2022, Du and others 2021, Evison and others 2018, Nakano and others 2020, Zaman and others 2022). Mass timber holds great promise as a new market for wood materials and for new, sustainable archetypes of urban housing that will help meet emission reduction goals for fighting climate change (Ahmed and Arocho 2020, Brashaw and Bergman 2021, United Nations Environment Programme 2022). Despite major advances of standardization and realization of MTC in recent years, research is still needed to support the burgeoning industry and open new markets for this type of construction.

Government, academic, and private sector (NGO) research programs are focusing on delivering results to help the North American mass timber industry. A finite amount of research funding is invested in mass timber across many different federal, state, and private agencies. Therefore, a needs assessment is crucial for identifying, prioritizing, and conducting the research needs of the mass timber industry. Such a research needs assessment should benchmark the current state of knowledge, focus calls for research proposals, and evaluate those proposals (Bergman and others 2022). Built on the first mass timber research needs workshop in 2015 (Williamson and Ross 2016), the second research needs assessment workshop for mass timber was conducted by the USDA Forest Service, Forest Products

Laboratory in 2018 (Zelinka and others 2019). Since 2018, the industry has evolved and has seen an increase in MTC domestically and globally (Comnick and others 2022, Dawson and others 2022, Nepal and others 2021). For many years, the Forest Products Lab has been engaged in mass timber research, with a variety of collaborators, addressing subjects of economics and sustainability, building science and durability, structural engineering of buildings and infrastructure, and quality assurance of manufactured components (Franca and Ross 2019; Kirker and others 2016; Nepal and Poudyal 2022a, 2022b; Pei and Zelinka 2017a, 2017b; van de Lindt and Rammer 2018; Wacker and others 2020). For a list of recent Forest Products Lab publications on mass timber research, please visit TreeSearch at https://www.fs.usda.gov/research/treesearch. Search on keywords “mass timber and CLT” and select “Forest Products Laboratory” as the station in the station drop down menu on the left.

Although research has provided some answers, ongoing research questions still need to be further investigated and new questions have come to light as the industry has grown (Penfield and others 2022, Zaman and others 2022, Zelinka and others 2019). In the United States, challenges and potential for widespread MTC are areas of constant assessment and refinement given the relative newness of MTC (Dawson and others 2022, Fernholz and others 2022). Historic changes to the most recent editions of the International Building Code have been made to include prequalified MTC structural systems for buildings up to 18 stories tall, based in major part on research highlighted by previous workshops (ICC 2020, Stegner and Fotheringham 2022). For the 2022 workshop, a group of MTC research and industry experts convened on September 20th through the 22nd in Madison, Wisconsin, USA, to evaluate and prioritize topics within the following subjects: (1) fire performance, (2) durability and building physics, (3) architectural and construction research, (4) structural system design and performance, (5) materials and manufacturing processes, (6) sustainability and economic analysis, and (7) infrastructure and nonbuilding applications. The results reported here represent the current research needs of the mass timber industry in North America.

Objective and Scope

The objective of this report is to present a comprehensive, prioritized list of the research needed to support the growing mass timber industry in North America. The scope of this needs assessment encompasses all aspects of mass timber utilization. The scope is broad—it includes nonbuilding applications for mass timber and, not just the engineering properties of mass timber use, but also the environmental and economic aspects.

Table 1—Subjects of mass timber workshop smaller group sessions listed in order of presentation

Order	Subject
1	Fire performance
2	Durability and building physics
3	Architectural and construction research
4	Structural system design and performance
5	Materials and manufacturing processes
6	Sustainability and economic analysis
7	Infrastructure and nonbuilding applications

Methodology

Similar to past workshops, the third mass timber research workshop solicited participant input via live discussions (Williamson and Ross 2016, Zelinka and others 2019). The objective of the first workshop at the Forest Products Lab in 2015 was to strategize a coordinated effort, because CLT research in North America was still relatively new. The objective of the second mass timber research needs workshop at the Lab in 2018 was to prioritize research topics in a ranked list, because CLT construction was burgeoning in the commercial marketplace and research institutions were building more robust strategies to keep pace with growth. The goal of the 2022 mass timber research needs workshop was to develop a more objective means of research prioritization than simple ranking. With this goal at the forefront, the planning committee developed an effort vs. impact method of prioritization. This Methodology section presents demographics of the workshop participants, the subjects of discussion, and methodology of the effort–impact prioritization.

During the two and a half days, 132 participants were divided into four groups to assess research needs organized by the subjects shown in Table 1. Other general-interest talks were given at different times during the workshop (see the agenda provided in Appendix A).

The time dedicated to each subject is shown in Figure 1. Equal two-hour times for each subject were generally allotted, except for two subjects, which had late afternoon sessions of one hour each. Workshop participants were briefly introduced to each subject in a plenary session, guided by a subject matter expert. Participants then headed to one of four assigned rooms for breakout discussions. While the participants were separated into the four smaller groups, moderators asked them to rank a list of study topics within each subject area that had been prepared before the workshop. These prepared topics were vetted with consideration of topics raised in the previous workshops. Participants were also encouraged to add new topics.

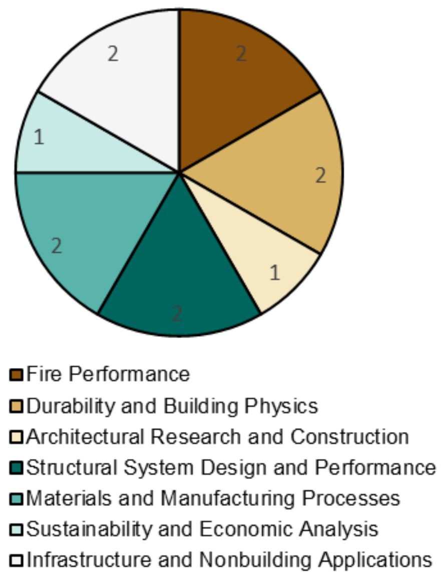


Figure 1—Hours dedicated to simultaneous smaller group discussion of each mass timber research subject.

Participant Population

Workshop organizers used information from the participant list (App. B) to evenly distribute members of industry, academia, government, and other research institutions but randomly assign members of each category to the four breakout sessions. While all participants in the workshop had expertise in mass timber, this semirandom grouping encouraged input from focused and peripheral experts in each of the seven topics. Figure 2 shows the organizational demographics of workshop participants. Participants from U.S. universities made up nearly a third of the workshop population (42 people). Researchers from the U.S. Forest Service (USFS) (32 people) and other government agencies (7 people) represented the next largest group, approximately a quarter of the workshop population (39 people). The manufacturing sector (Mfg) made up 15% of the workshop population (20 people) while another 17% of the workshop population came from the professional practitioner community of architects, engineers, contractors, and developers (23 people total). Nongovernmental organizations (NGO) that develop engineering design or sustainability standards for wood construction comprised another 10% of the workshop population (13 people). The remaining participants (2 people) came from the insurance industry and were primarily concerned with risk management of building facilities.

Figure 3 highlights the U.S. states and Canadian provinces of the participating organizations. Workshop participants traveled from the West Coast, Greater Mountain, Upper Midwest, Southeast, and East Coast regions of the United States. International participants mostly traveled from the Canadian provinces of British Columbia, Quebec, and Ontario. Therefore, it can be assumed that the views of the conference participants were largely driven by U.S. and Canadian market influences.

Most workshop attendees (60% or 79 people) were first-time participants. Approximately 9% of attendees had previously attended only the first research workshop (Williamson and Ross 2016), and 13% had previously attended only the second workshop (Zelinka and others 2019). About 18% of attendees had participated in both prior workshops. Figure 4 shows the number of participants whose first-time experience was at the first, second, or third mass timber research workshops. It also shows the number of participants who attended both the first and second workshops. Approximately 40% of 2022 workshop participants had attended at least one prior mass timber research workshop. Participation was analyzed using the participant list (App. B) and those of previous workshops.

Polling Method

Workshop participants were asked to rank a list of prepared research topics, many identified during the previous mass timber workshop (Zelinka and others 2019), by estimating the level of effort and impact. Prior to the workshop, links to a video (Consortium for Public Education 2021) and web article (Renahan 2021, Nwanne 2021) were shared with conference registrants via e-mail to familiarize them with the effort–impact method of prioritization. During the initial plenary session of the workshop, participants received further instruction of how to implement the effort–impact matrix methodology. The 0 to 100 scale of effort was calibrated by equating 50 with a 2-year and $500,000 total investment of research time and money. No other scaling was offered; therefore, participants had to judge lower and higher efforts as a multiple of the time and budget assigned to 50. Scaling for impact was much less certain, because workshop participants were instructed to consider a variety of criteria. High impact could be judged by moving large volumes of wood, making commercial construction more sustainable, or developing a technology that fulfills a niche that competing materials cannot satisfy.

The objective of the group evaluation was to plot effort vs. impact of each proposed topic in each of four sessions for later analysis and consolidation into one plot. Participants in each session were shuffled after each period of smaller group discussion, but the moderators and note takers were assigned to the same room for the entirety of the workshop. Moderators presented topics, encouraged discussion, and polled the room for notetakers to record comments and numerical scores in a spreadsheet. The polling method in one room asked participants to raise hands at the beginning of each polling period and then lower them when the level of effort that was called out seemed too high. Some hands were lowered early, whereas others remained up for the entirety of the topic scoring. The moderator, having the best

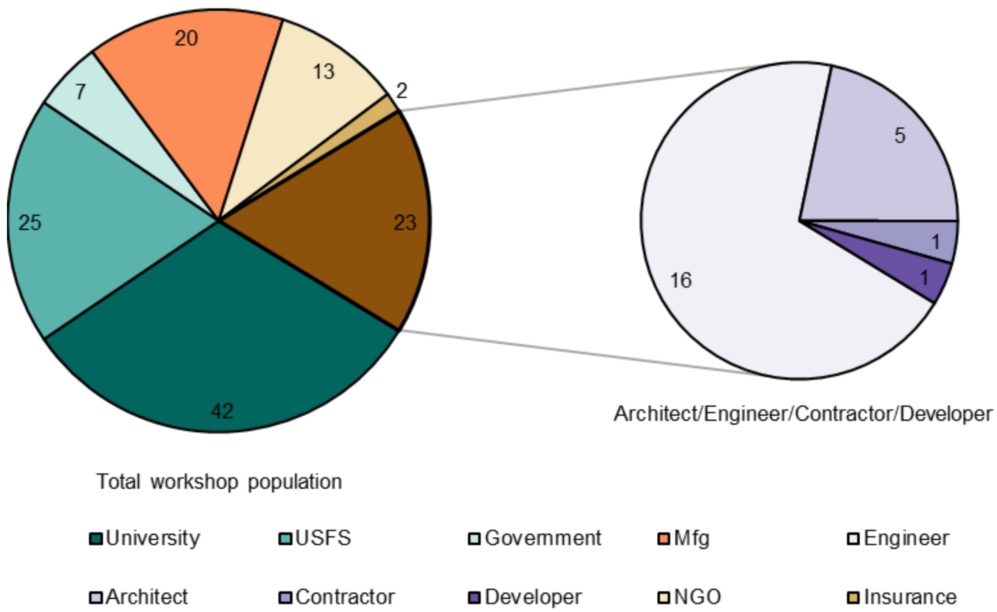


Figure 2—Demographic composition of workshop population, in number of participants and classification of organization.

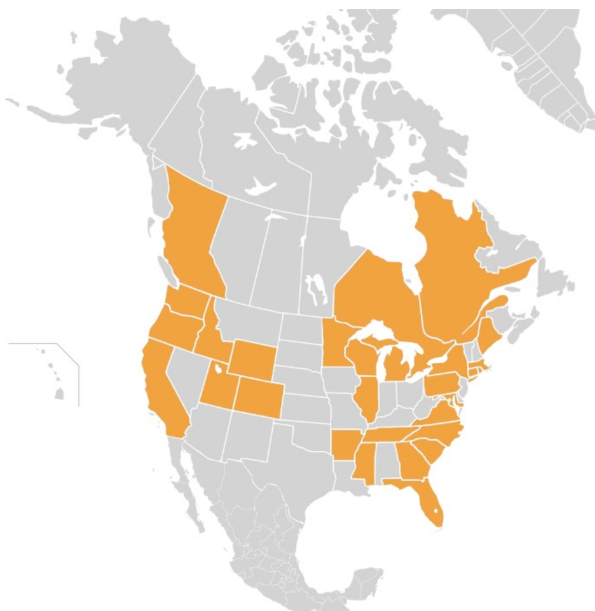


Figure 3—Geographic location of participating organizations.

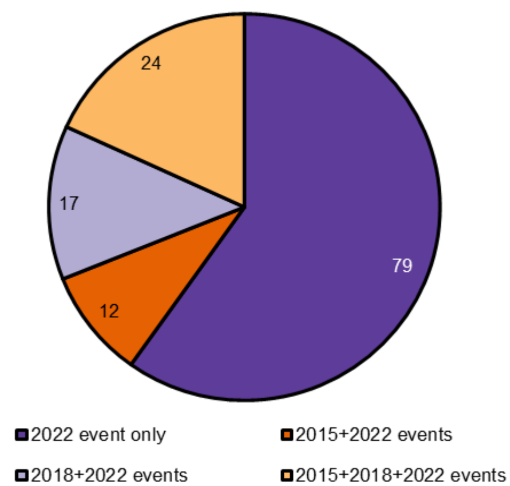


Figure 4—Number of workshop attendees grouped based on prior event attendance.

perspective of the entire room, had to judge the consensus score based on values when most participants lowered hands. In other rooms, vocal participants proposed an initial score and revised it higher and lower via debate. Because individual and anonymized input was not recorded during the live polling sessions, the consensus score may have been significantly influenced by moderator discretion and peer interactions within each room. During each session, the effort vs. impact plot was projected onto a screen for participants to see the results of live consensus scoring.

Proponents of the effort–impact matrix recommend this type of group evaluation because the results may be plotted and divided into four quadrants that may assist with prioritization (Helmke 2022). In this workshop, effort was deemed to be the input and was plotted on the *x* axis and impact was plotted as the output on the *y* axis. Figure 5 shows the scale and division of the plots into equal quadrants. According to the vernacular terms, the lower left (a), top left (b), top right (c), and lower right (d) quadrants represent incremental gains, easy wins, big bets, and money pits, respectively (Gilad 2022). Gilad critiques the standard effort–impact ranking system because people often underestimate effort and overestimate impact. To account for this bias, Gilad suggests using confidence values to redraw proportions of the chart quadrants, which typically

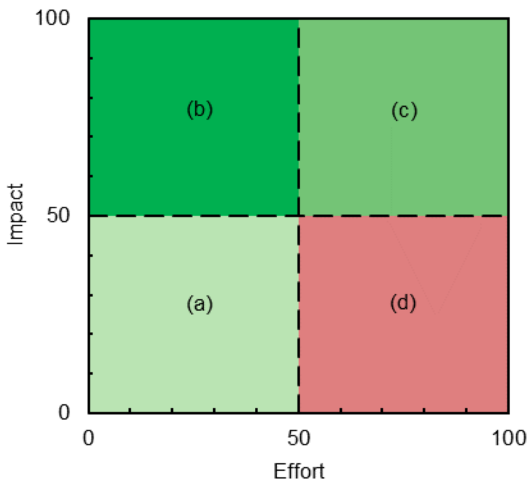


Figure 5. Effort versus impact matrix with (a) low effort, low impact, (b) low effort, high impact, (c) high effort, high impact, and (d) high effort, low impact quadrants.

renders the regions unequal in size. In addition, Gilad argues that negative impacts should be considered to identify potential loss generators in a fifth region of the plot.

To facilitate implementation among approximately 30 participants in each of four sessions, a standard four-quadrant form of the effort vs. impact evaluation was presented to workshop participants. This form served as the primary method of analysis presented in the sections specific to each topic. The limitations of the polling method and determining consensus, therefore, were considered only in statistical analysis of the results and in planning to improve the prioritization process for future workshops. Generally, projects in all quadrants except the lower right, labeled (d) in Figure 5, merit consideration. Uncertainty in the polling and consensus scoring, however, should be considered before making any definitive conclusions about the worthiness of a research topic. And, prioritization of research needs, of course, may change with time as both the knowledge of and marketplace for mass timber structures continues to grow.

Analysis and Reporting

Notetakers, in each of four sessions (A, B, C, and D), recorded consensus scores and comments for topics in each of the seven subject areas listed in Table 1. The topics were organized into three categories: prepared, write-in, and honorable mention. Moderators began each breakout discussion by offering a uniform list of prepared topics for participants to evaluate. In addition, moderators encouraged participants to propose write-in topics pertinent to the subject. In many discussions, participants generated more topics than could be discussed in the time allotted for voting. In those cases, the unscored topics were recorded as honorable mentions.

The sample size, *n*, for averaging consensus scores typically varied by topic category. In most cases, $n = 4$ for standard prepared topics because each session typically chose to evaluate all topics on the uniform list. A few abstentions, however, happened when a session chose to replace a standard prepared topic in favor of a write-in topic, which decreased *n* to three. Write-in topics rarely matched across sessions, so *n* typically was less than four and most often equaled one or two for user-generated proposals. Even when write-in topics matched, the scope might not have aligned precisely across sessions and was subject to participants' interpretation of notes and patterns among sessions. When write-in topics were unscored because of time constraints, *n* was assumed zero and the topic was categorized as an honorable mention. All recorded consensus scores of effort and impact were greater than zero.

For each subject area shown in Table 1, workshop organizers tabulated a list of prepared and write-in topics to serve as a guide for the effort vs. impact matrix plot of consensus scores. Honorable mentions were tabulated separately because these topics did not receive scores. The effort vs. impact matrix plotted the average consensus score for each topic with a labeled point. Typically, the first ten topics of each subject were prepared and labeled with numbers, whereas subsequent topics were write-ins generated by workshop participants and were labeled with letters. In addition to the points representing averages, two-dimensional error bars were plotted to represent the variation associated with each topic. The length and slope of the error bars provided more insight. Short error bars indicated good consensus, in contrast to long error bars that indicated dissension, which caused more difficulty in reaching consensus. Error bars with a shallow slope, nearly horizontal, indicated variations in assessing effort but general agreement on impact. Error bars with a steep, nearly vertical slope indicated variations in assessing impact but general agreement on effort. Diagonal error bars of approximately one-to-one slope indicated differences in judging both impact and effort. The absence of an error bar typically indicated a write-in topic that was mentioned and scored in only one of the sessions.

Additional information to supplement the effort vs. impact plot for each subject is provided in tabular format. The numerical average and coefficient of variation (COV) of consensus scores is tabulated in the main body of discussion. Conference organizers synthesized these comments in a tabular summary for the main body of discussion.

Interpreting Results

In an industry context, the effort vs. impact matrix serves to prioritize projects and determine which projects are considered worthy of investment. Generally, only projects landing in the first three quadrants, (a) through (c) (Fig. 5), deserve consideration. Projects falling into the lower right quadrant (d) are typically deemed too costly and not worth doing. In a research context, however, investments must be made in all four quadrants of the effort–impact matrix plot to develop a comprehensive strategy. Research projects landing in lower right quadrant (d) should not be immediately ruled out but rather examined more carefully to mitigate the risk of time and cost overruns. The projects plotted in quadrant (d) may represent niche markets with an immediate need but limited scope of return relative to the larger construction market. Other projects landing in quadrant (d) may represent longer term needs that have a prolonged rate of return on investment. The purpose of using the effort–impact methodology, therefore, is to provide a relative sense of resources required to investigate the topics. The effort–impact methodology applied to research, however, is not intended to provide a pass/fail or go/no-go decision of whether a topic is worthy of investigation. Evaluations of research proposals should be made on an individual case-by-case basis.

Results

Subject 1: Fire Performance

Fire performance of mass timber products has been discussed at both previous research needs workshops. Since the first workshop, several major research objectives have been accomplished. The 2021 IBC both recognizes mass timber in the code and allows for mass timber buildings to be built up to 18 stories high if all mass timber elements are protected with noncombustible passive fire protection, such as gypsum wallboard (ICC 2020).

Table 2 presents the research topics discussed in the breakout sessions for this subject. There were 10 prepared topics. Five additional topics were generated in the four breakout sessions. These write-in topics are labeled A through E in this section. Rankings for the topics, including write-in topics, are displayed in Figure 6. The error bars indicate the range of scores for a given topic in both effort and impact. The mean scores and COVs for each topic are given in Table 3.

Overall, none of the prepared topics landed in the top left quadrant of the graph (low effort, high impact). Topic 2, “penetrations in CLT for fire protection”, was identified as an incremental gain (lower left quadrant). Only one prepared topic ended in the bottom right quadrant (high effort, low impact). That topic was number 7 “minimum separation distances for exposed mass timber surfaces column to wall/floor or corner”. Although there was small variation in the perceived effort of topic number 7 in the breakout sessions, there was large variation about the perceived value of this effort.

Subject 2: Durability and Building Physics

Table 4 summarizes the research topics discussed in the breakout sessions for this subject, and rankings are displayed in Figure 7. As in most of the other breakouts, there were 10 prepared topics. After the participants had reviewed and commented on this list of prepared topics, they suggested more than 20 additional topics. These were compared and analyzed to eliminate duplication and ultimately distilled down into 13 write-in topics. These write-in topics are labeled A through M in this section. Table 5 provides mean effort and impact scores for each topic and COVs for scoring of prepared topics. The high COVs reported for several topics revealed dissention that is captured in the notes of Table 4.

Subject 3: Architectural and Construction Research

Previous mass timber research needs symposia did not have a specific breakout session that focused on architectural issues or constructability of mass timber (Williamson and Ross 2016, Zelinka and others 2019).

Table 6 presents the research topics discussed in the breakout sessions for this subject. There were 10 prepared topics. Six additional topics were generated in the four breakout sessions. These write-in topics are labeled A through F in the remaining tables and figures in this section. Rankings for the topics, including write-in topics, are displayed in Figure 8. The error bars indicate the range of scores for a given topic in both effort and impact. The mean scores and COVs for each topic are given in Table 7.

Overall, only one of the prepared topics landed in the top left quadrant of the graph (low effort, high impact). This was topic 1, “biophilic advantages of exposed mass timber spaces”. However, the error bars indicate a large variability in the perceived effort. Only one prepared topic landed in the bottom right quadrant (high effort, low impact). That topic was number 8 “sequencing and installation of rocking wall components”. Although there was a large range of perceived efforts of this topic, the error bars remain mostly in the lower half of the graph.

Subject 4: Structural System Design and Performance

Ten prepared and 15 write-in topics were evaluated during discussions regarding structural system design and performance. The number of write-in topics, therefore, exceeded prepared topics by at least 50%.

Table 8 presents the research topics discussed in the breakout sessions for this subject, and results are plotted in the effort vs impact matrix of Figure 9. Although some topics distinctly landed in a quadrant, the error bars indicate that many topics could have crossed boundaries had there been more discussions. Table 9 provides the mean scores and COVs for each topic plotted in Figure 9. There was significant variation in the scoring of both prepared and write-in topics of the session. No topics had a COV less than 10% for both effort and impact. Only a couple of topics (4 and 6) had COVs greater than 50% for both effort and impact. For further understanding of the topics beyond scoring, Table 8 also summarizes the discussion notes. (Five honorable mentions listed in Table 10 were recorded but were not evaluated because of time constraints.)

Since the previous mass timber research workshop, recent editions of U.S. building codes have generally defined requirements for mass timber structures up to 18 stories in height (Showalter 2020). A CLT shear wall system (Amini and others 2018) was among the first cohort of structures to fulfill the rigorous FEMA P-695 seismic qualification process (FEMA 2009). This achieved another historic milestone as the first mass timber lateral system to be listed in ASCE/SEI 7-22 (ASCE 2022) for reference by the pending 2024 international building code (IBC). Despite these major technical and regulatory advances, many tall mass timber structures still rely on performance-based design for aspects beyond the scope of specific mass timber code provisions. The recently constructed 25-story Ascent building (Fernandez and others 2020) of hybrid concrete and mass timber construction provides an example. At the time of this workshop, the NHERI TallWood Project crew (Pei and others 2017) was constructing a 10-story mass timber structural assembly with interchangeable wall components, a variety of diaphragms, and nonstructural attachments in preparation for testing on the University of California-San Diego seismic shake table for development of performance-based seismic design standards.

Among the topics described in Table 8, consensus was reached in favor of developing a greater variety of these structural systems that cost-effectively target different levels of seismic performance because these prequalified systems are what practitioners reference first in design codes such as ASCE 7. Although there is valuable work to be done in wind and protective design topics, participants viewed these as lesser priorities because design provisions addressing these topics are often found in niche markets or geographic regions. In addition to adding code-listed prequalified systems, consensus formed around topics that would enable shallower structural floor depth such as point-supported mass timber panels and reinforcement of beam notches and openings.

During discussions of the structural system design and performance subject, workshop participants in four separate breakout sessions evaluated 10 prepared and 15 write-in topics. The average consensus scores of each topic were plotted on an effort vs. impact matrix to organize each research topic in quadrants. The upper right quadrant (c) contained the most topics, 12 of 25 or 48% of the total, which indicated that greater than average resources will typically be required to achieve significant advances in structural mass timber research. According to consensus, efforts toward standardization and diversified inclusion in structural building codes will require significant investment to transfer research findings into practice. Seismic performance—especially of shear walls, braced frames, diaphragms, and connections—remains a priority over other aspects of structural design. Workshop consensus suggests that wind and protective design performance of mass timber structures are niche topics, relative to seismic considerations, yet are important for comprehensive development of structural systems.

Subject 5: Materials and Manufacturing Processes

Table 11 summarizes the research topics discussed in the breakout sessions for this subject, Figure 10 displays rankings, and Table 12 provides average effort and impact with COV between rooms. These breakout sessions had 8 prepared topics. After the participants had reviewed and commented on this list of prepared topics, they suggested many additional topics. These were compared and analyzed to eliminate duplication and ultimately distilled down into 22 write-in topics. These write-in topics are labeled A through V in this section.

Subject 6: Sustainability and Economic Analysis

For this subject, there were 10 high-level topics for the participants to review and assess for prioritization (Table 13). Figure 11 shows the effort and impact of the 10 topics along with one write-in topic. Several topics were deemed to have relatively high impact and appeared in the upper two quadrants of the effort–impact matrix plot. Among the higher impact topics, topic 9 regarding end of life cycle generally scored highest in both effort and impact. The mean scores of effort and impact and COVs are provided in Table 14. Topic B regarding a repair manual to prolong service life did not receive a score but was recorded as an honorable mention.

Subject 7: Infrastructure and Nonbuilding Applications

Nonbuilding applications of mass timber products were discussed at the previous research needs workshops (Williamson and Ross 2016, Zelinka and others 2019). For this workshop, the subject was called infrastructure and nonbuilding applications. Since the previous workshops, many of the nonbuilding applications have been explored in various stages of detail.

Table 15 presents the research topics discussed in the breakout sessions for this subject. There were 10 prepared topics, and 12 additional topics were generated in the four breakout sessions. These write-in topics are labeled A through L in this section. Rankings for the topics, including the write-in topics, are displayed in Figure 12. The error bars indicate the range of scores for a given topic in both effort and impact. The mean scores and COVs for each topic are given in Table 16.

Overall, only four of the prepared topics landed in the top left quadrant of the graph (low effort, high impact). These were topic numbers 3, 5, 7, and 8 from the original 10 prepared topics and the write-in topics labeled D, F, H, I, and L. Topic numbers 9 and 10 and write-in topics labeled A and G were identified as incremental gains (lower left quadrant). Only the write-in topic labeled E ended in the bottom right quadrant (high effort, low impact). All other topics and write-ins were in the upper right quadrant or in between the two upper quadrants.

Table 2—Research topics for fire performance[a]

Topic	Description	Notes
1	Nongypsum methods of encapsulation/fire protection	There were considerable differences between how this item was perceived in different rooms. Some rooms assumed that the discussion was based upon existing fire protection technologies, such as mineral wool, whereas other rooms interpreted this item as a new intumescent coating or other technology. Other offered topics combined into this item included "Use of intumescent coatings to achieve fire resistance ratings" and "Clear coatings for encapsulation/fire protection."
2	Penetrations in CLT for fire protection	Challenges brought up with this topic focused on how many of the firestopping products are commercial and proprietary. While there is a need to characterize and develop a database of this information, it may be difficult to decide how to spend research dollars on which products to test. Additional work is needed on how char propagates around penetrations in beams. Other offered topics combined in this item include "shaft wall and curtain wall."
3	Char rates for CLT (linear/nonlinear models)—extending out to 3 hours	Comments in various rooms suggested that with PRG-320 compliant adhesives, delamination will have less impact on CLT char rates. As a result, NDS is more conservative than test data. Extending accepted NDS char model out past 2 hours may be helpful. Other offered topics combined into this item included "Expand accepted char models to 3 hours," "Differentiating CLT vs glulam char rates," and "Different char rates for different wood species/densities."
4	Safe amounts of exposed CLT	The change to 100% exposed mass timber on ceilings in the 2024 IBC was noted. However, existing data on exposed mass timber are limited to relatively small compartments. Future testing should focus on large compartments (see item 10). Other offered topics combined into this item included "Change Type IVA-IVB to allow more exposed timber."
5	Hybrid connections (steel + CLT)	Several rooms noted there is ongoing research on this topic. However, the scope is large. Firestopping products (item 2) may need to be combined with tested solutions to account for gaps that may occur between timber and steel during construction. Other offered topics combined into this item included "Wall application adhesives tying 2 adjacent wall panels."
6	Adhesives, lamella thicknesses, and delamination risk	Other offered topics combined into this item included "Mass timber to mass timber connections."
7	Minimum separation distances for exposed mass timber surfaces (column to wall/floor or corner)	Other offered topics combined into this item included "Effects of fire exposure on columns increasing eccentricity."
8	Fire spread in cavities and concealed spaces	Feedback collected on this topic noted that code changes are inherently difficult. However, code-accepted changes could reduce the cost of mass timber buildings
9	Construction fires in mass timber buildings	Several rooms noted there is a lot of data on this already, including work from Canada and FPInnovations. There was a consensus that mass timber construction fires are different from light-frame construction.
10	Traveling fires in open floorplans	This item applies to open offices and other commercial buildings. Most fire testing is smaller compartments. Integral to performance-based fire design (PBFD), has less of a place in prescriptive code.
A	Post fire impacts: insurance loss models and post-fire repair	This combined two offered topics focused on fire losses for insurance. One noted the need to develop new fire loss models for mass timber buildings as the current insurance practices are based off light-frame construction. A related topic combined with this was the post-fire assessment and repair of mass timber buildings.
B	Database development for approvals (prescriptive and performance-based design)	This item was suggested in two different rooms. The idea would be to summarize the state of the art for mass timber, including testing and precedents from around the country.
C	Fire retardant treated CLT	One room brought this up but noted that there would be extreme challenges in bonding FRT wood and that it may have high environmental costs
D	Exterior fire protection systems for mass timber buildings/infrastructure/structures	This could be a large effort but related to the protection of housing or infrastructure in wildland urban interface (WUI) zones.
E	Development of guidelines or tools for performance-based design	This item was suggested in two different rooms.

[a] Items 1–10 were preselected; items A–E were offered during the meeting.

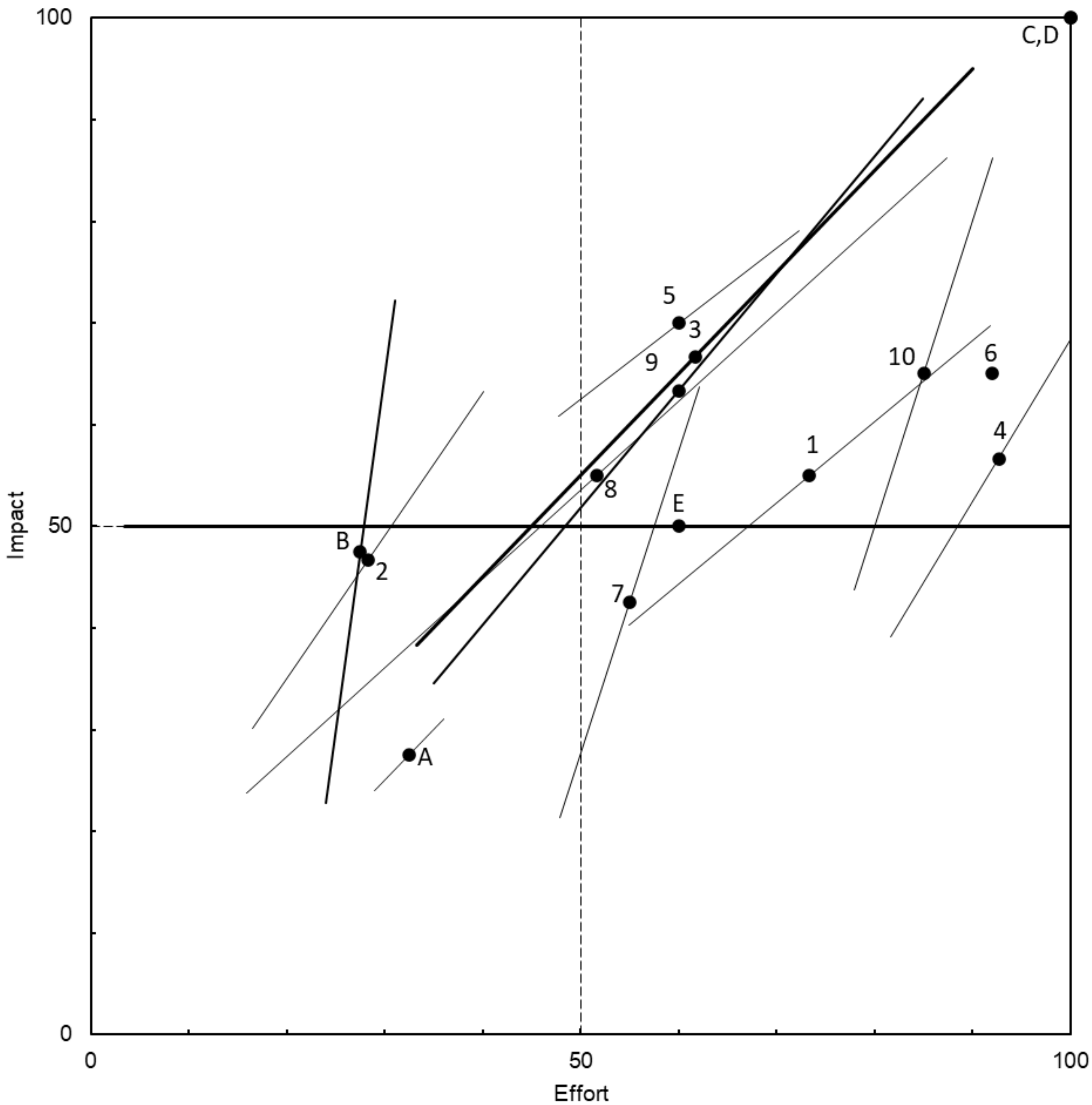


Figure 6—Effort vs impact matrix plot of fire performance breakout session.

Table 3—Average effort and impact for topics in fire research with coefficient of variation between rooms

	Average		COV	
Topic	Effort	Impact	Effort	Impact
1	73	55	25%	27%
2	28	47	42%	36%
3	62	67	46%	43%
4	93	57	12%	31%
5	60	70	20%	13%
6	92	65	–	–
7	55	43	13%	50%
8	52	55	69%	57%
9	60	63	42%	45%
10	85	65	8%	33%
A	33	28	11%	13%
B	28	48	13%	52%
C	100	100	–	–
D	100	100	–	–
E	60	50	94%	0%

Table 4—Research topics for durability

Topic	Description	Notes
1	Evaluate the effectiveness of protective coatings and membranes at limiting moisture uptake	Two of the four breakout sessions correlated relatively closely with the effort and impact scores, whereas the remaining two differed substantially in their impact scores (17 versus 80). Respondents identified moisture management during construction as their most critical area of concern. Users need empirical data on the effectiveness of sealers, coatings, waxes, tapes, and membranes. Because protective coatings are proprietary products that are regularly updated, an ongoing program of repeated testing is desirable. Any testing of moisture-proofing products should consider actual jobsite practices and, if possible, provide recommendations for how to use them. This overlaps somewhat with item 5 below. It was noted that FPL has an ongoing project on moisture and RDH has worked on this topic. Oregon State University has also done relevant research.
2	Determine how duration and severity of wetting affect mass timber products	Scores for impact ranged from a low of 35 to a high of 80, while effort ranged from 50 to 100 across the four sessions. Respondents are interested in the impact of moisture on creep of timber members; integrity of connectors and fasteners, and aesthetics, for both lumber-, strand-, and veneer-based mass timber products. It was noted that moisture impacts vary depending on the duration of exposure and whether they are due to condensation, envelope leaks, or internal issues such as burst or leaking plumbing. Workshop participants are interested in structural impacts, delamination, and mold/fungal growth, and noted that there would be greater uptake of moisture on CLT edges. This research was envisaged to play a role in allaying concerns from the insurance sector, which were seen as having a large impact on mass timber project viability (one participant noted that this is especially the case in the UK).

Table 4—Research topics for durability (continued)

Topic	Description	Notes
3	Preservative treatments/remedial treatments	Effort scores varied widely from a low of 25 to a high of 100. Impact also had a wide span, from a low of 34 to a high of 100. Research questions that participants suggested included "Can lumber be pre-treated to protect against moisture or termites, then laid up, or should coatings be applied after panels/beams are fabricated?" There is a desire for exposed timber to be used as exterior columns and also in balconies and parking structures. However, preservative treatments may be limited from a practical industrial standpoint due to the dimensions of treatment chambers. Some participants questioned whether it is viable from a cost perspective to treat all the mass timber products required for a whole building. There was also some interest in acetylation techniques, such as those used by the European company Accoya. There were also comments that this is an area in which manufacturers are taking care of the issue by developing proprietary products, and some people stated the opinion that preservatives are needed in the timber bridge market but not for buildings. Mississippi State University and Oregon State University were identified as working actively on research into preservative treatments and CLT.
4	Incorporation of naturally durable species into PRG 320 discussion	There was considerable difference of opinion about the level of effort required, ranging from 5 to 75. In terms of impact there was greater agreement, with two groups scoring 5 and two scoring 25. Demand for information on the properties of naturally durable species revolved around interest in its use for exterior applications. Species mentioned included Alaskan and Western Red Cedar, redwood, some hardwoods. It was noted that this would likely find more use in glulam than panel products, and that pressure-treated lumber would be more effective at resisting the effects of moisture and weathering. There was some interest in the use of thermally modified lumber in mass timber. Participants expected that there would be cost and supply challenges for the use of these kinds of products.
5	List of tested assemblies-acoustic performance of CLT	Scores for effort were extremely different, running from a low of 5 to a high of 100. Impact was similar, with a low score of 5 and a high score of 85. In each breakout the score each group gave for effort correlated closely with the score they gave for impact. This suggests that groups may have differing views about the number of assemblies that need to be tested to yield significant benefits for designers. Respondents expressed that there is a need for robust iterative acoustic testing of a wide range of mass timber assemblies to give designers access to the same kinds of data that exists for concrete and steel-based assemblies. This is a particular need in the multifamily residential and hospitality sectors, where acoustic performance can be a barrier and result in reputational damage even if assemblies meet the minimum standards according to code. Lab-based acoustic testing is expensive, but a body of testing has been done and Woodworks maintains a list on its website. Field testing of in-situ mass timber assemblies has also been done, but it has been difficult for researchers to obtain permission to publish the results publicly for private construction projects.
6	Moisture management during construction: guides, best practices, knowledge sharing, etc.	Groups were more aligned on their impact scores for this category than for many others (low of 10 to a high of 40). Impact varied from a low of 47 to a high of 100. Participants suggested that there is a need for a comprehensive guide on moisture management during construction and on how to dry out buildings prior to closing them up. Some construction guides exist, participants said, but they do not contain sufficient or detailed enough information on this topic. Information on the costs and benefits of different approaches and the associated risks were seen to be useful. In Europe, tenting the entire structure is sometimes done, but this adds considerable cost, impedes lifting of components onto the site, and extends the construction schedule. The risk associated with moisture intrusion is yet another factor that affects investor confidence. The degree of importance does vary from one region to another based on prevailing climatic conditions, so recommendations may need to be tailored to fit. Participants suggested that model contract language could be included in the guide. A guide by RDH was recommended by some participants.

Table 4—Research topics for durability (continued)

Topic	Description	Notes
7	Mold curtailment, both internally and externally	Effort scores were relatively well aligned in the range from 0 to 35. Impact scores were similar, at 0 to 40. This was seen as an important topic for exterior applications and in the building envelope. One area of concern was thermal bridges in locations where steel meets timber. A question was asked about pre-treatments that could be applied to mass timber elements prior to construction to inhibit mold development. There is some overlap between this and item 3.
8	Termite/pest management	There was a reasonable correlation of effort scores across the four breakouts, from a low of 50 to a high of 70. This was similar for impact, ranging from 35 to 75. It was pointed out that there are regional variations in the kinds of pests that threaten wood structures beyond just termites. In terms of existing solutions, glulam was seen as being fairly simple to treat, and elevating timber above the ground was another common strategy. The question was posed, "Has the risk to mass timber been evaluated relative to other wood products?" The development of monitoring techniques was seen as challenging for mass timber compared to structural light-frame, though some nondestructive testing techniques based on the use of sonic waves are being trialed. This research topic was seen as most pertinent in the southern coastal states and Hawaii.
9	Is mass timber suitable for all climates?	One group did not score this topic for the reasons outlined below, whereas the others scored both effort and impact from a low of 5 to a high of 25. Participants generally expressed the view that this was a very broad question that was too general to constitute a research question in and of itself. There was broad consensus that mass timber could be made suitable for any climate, with some specific variations needed in design, construction, and moisture management to cope with the unique challenges of different regions and climates. A question was asked about whether there were any special challenges or impacts on service life for mass timber arising in arid climates due to excessive drying. Similarly, questions were asked about how to design for situations in which floods and power outages occurred simultaneously and for extended periods.
10	Surveys of indoor air quality of mass timber buildings	Effort scores ranged from a low of 10 to a high of 30, while impact received a low score of 10 and a high score of 60. With the rise in interest in healthy indoor environments and the increased airtightness that comes with more energy-efficient structures, indoor air quality is becoming an important topic. There are many preconceived ideas about the emission of formaldehyde and volatile organic compounds (VOCs) from building components and finishes, but nonwood fixtures such as carpeting, furniture, and flooring often play a bigger role than structural mass timber. Product manufacturers test their own products when required to by standards such as CARB. There is rising interest in using mass timber in medical and institutional buildings, and participants asked whether mechanical systems need to be designed differently because of mass timber behaving differently from other materials. Another key question revolves around microbial buildup on wood and how easy mass timber surfaces are to clean (a University of Oregon study is currently underway on this, looking at both unsealed wood surfaces and finished ones). It was noted that mass timber's impacts on air quality can be inferred to some degree from existing data on engineered wood products, though these comparisons depend upon the type and concentration of adhesives used in the products. Participants were also interested in air quality impacts of bio-based versus petroleum-derived adhesives. Lab/bench testing versus field testing are two possible strategies for gaining greater insight into this topic.
A	Quantify the adverse effects of penetration of fasteners through acoustic mats on acoustic performance	Though related to item 5, this topic constitutes a specific additional research project.
B	Development and testing of high-performing exterior mass timber structural walls	Key questions were seen to be the effects of wind-driven rain, long-term durability, and resistance to leaks. The experimental design and specific areas of focus would be influenced by regional climatic factors.
C	Design guidance and design life for exposed mass timber structures (e.g., pedestrian bridges)	A participant asked, "How do you design for a 75-year service life. What does that mean?"

Table 4—Research topics for durability (continued)

Topic	Description	Notes
D	Bridges using pressure-treated mass timber products (from item 3)	Although this topic is related to the previous one and both are somewhat covered under item 3, it is reiterated here to signal that many participants considered bridges to be an area of potential market growth for mass timber, primarily glulam, and therefore identified this as an important research topic.
E	Long-term wood checking/noise/cracking	Although the technical reasons for this phenomenon are widely understood, building owners who are new to mass timber have expressed some concern about the causes. Educational materials were seen as desirable so that these stakeholders can be assured that it does not signal any underlying technical issue.
F	Performance standard for vapor permeability and moisture absorption for mass timber	No comments.
G	Modify durability tests for mass timber (e.g., soil block tests)	No comments.
H	How do we correlate between accelerated testing and real-world testing?	In the context of moisture-related durability, degradation effects of mass timber products can be measured via lab-based accelerated weathering simulators or by weathering trials in which the products are left exposed in an outdoor test site for an extended period of time. Insufficient data have been gathered on how the results from one type of experiment can be correlated to the other.
I	Field decay testing of mass timber	The participant suggested that although some testing has been/is being done for mass timber, there is a need for more comprehensive data. Note however that this experimental technique would be applicable to many of the research questions listed above when considering exterior applications (items 1, 2, 3, 7, & 8).
J	Self-adhered acoustical mat (development and testing)	No comments.
K	Publish lessons learned from mass timber failures that consultants know but can't share	It was noted that (a) this would be extremely difficult from a confidentiality standpoint and (b) it would need to be done with extreme care to avoid conveying the impression that these rare failures are commonplace.
L	Would preservatives affect engineering design standards for glued timbers or veneers	The inherent research question posed here is whether treating timber prior to layup and pressing has an adverse impact on bond strength and therefore on the strength and design values for the products concerned. This is related to item 3, and some work is underway on the topic.
M	Efficacy of tapes and membranes in reducing moisture-related degradation	No comments.

[a] Items 1–10 were preselected; items A–M were offered during the meeting.

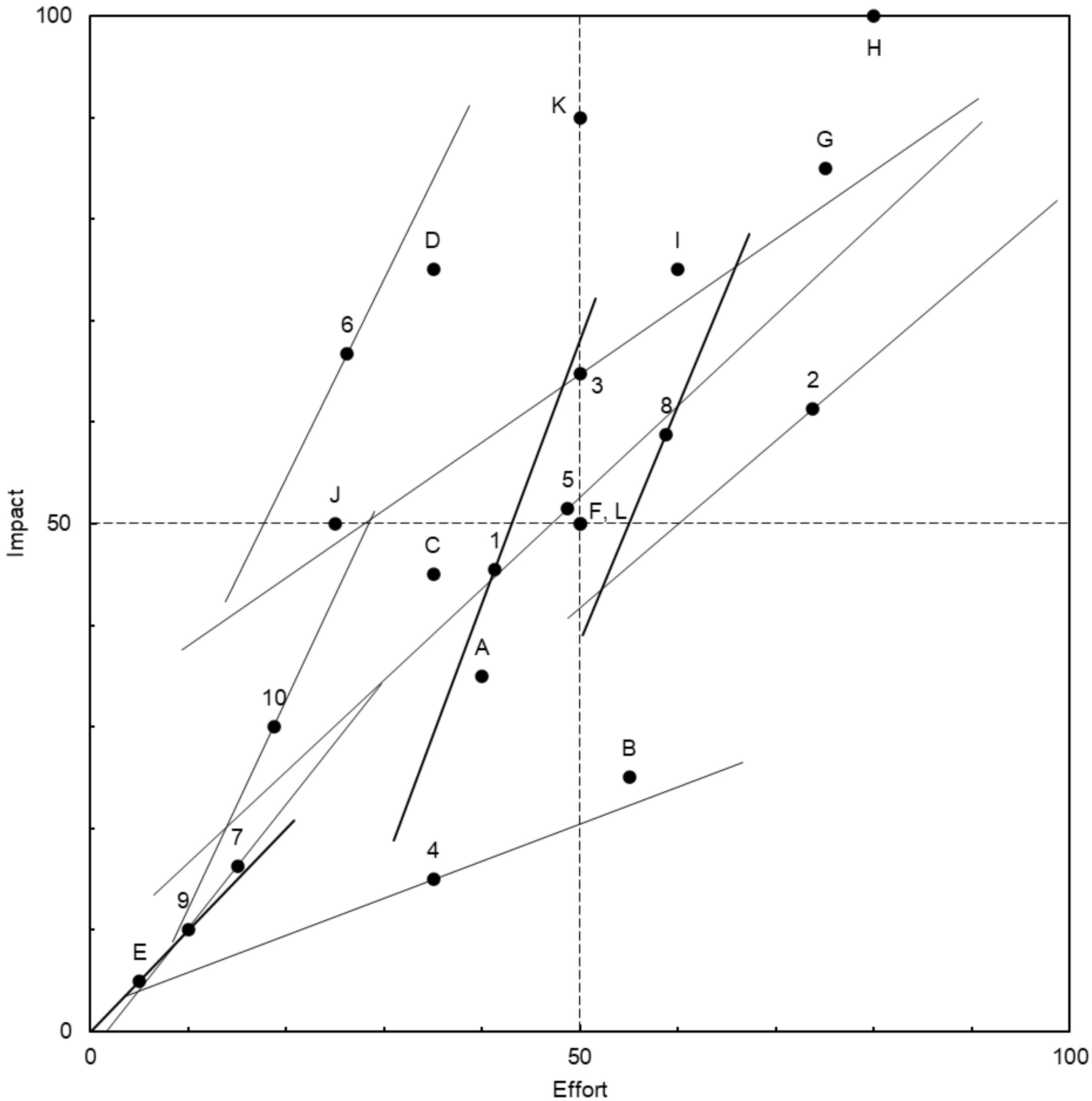


Figure 7—Effort vs impact matrix plot of durability breakout session.

Table 5—Average effort and impact for topics in durability with coefficient of variation between rooms

	Average		COV	
Topic	Effort	Impact	Effort	Impact
1	41	46	25%	59%
2	74	61	34%	34%
3	50	65	81%	42%
4	35	15	90%	77%
5	49	52	87%	74%
6	26	67	48%	37%
7	15	16	98%	111%
8	59	59	15%	34%
9	10	10	108%	108%
10	19	30	55%	71%
A	40	35	–	–
B	55	25	–	–
C	35	45	–	–
D	35	75	–	–
E	5	5	–	–
F	50	50	–	–
G	75	85	–	–
H	80	100	–	–
I	60	75	–	–
J	25	50	–	–
K	50	90	–	–
L	50	50	–	–

Table 6—Research topics for architectural and/or construction

Topic	Description	Notes
1	Biophilic advantages of exposed mass timber spaces	Several groups mentioned that the wording is ambiguous. Data are already available from InnoRenew, FPInnovations, and German institutions. The difficulty comes from which metrics to measure and report.
2	Vibration design and criteria for different building types	Groups talked about resources that are already available. Woodworks (vibration) design guide. Canadian code equation, APA also has a guide. However, more details on an "intermediate difficulty" approach would be useful. This approach was offered as a new topic (item B) in one group.
3	Acoustics assemblies, especially for higher performance (matching or exceeding concrete)	This was looked at as a continual need, you can always add more assemblies to a database.
4	Insulative qualities and humidity mitigation of CLT walls	The energy codes do not recognize the insulative properties of mass timber even though the thermal conductivity of wood/mass timber are well known. Other related questions include the following: Does CLT act as a moisture barrier? How does mass timber affect MEP/HVAC systems?
5	Repair methodologies—in-situ lamination and replacement	
6	Repair methodologies—dowel-fastener reinforcement	Many groups suggested that topics 5–7 be combined into one topic. Little work has been done in this area.
7	Repair methodologies—advanced techniques (polymer injection, FRP applications, etc.)	
8	Construction: Sequencing and installation of rocking wall components	Rocking walls will be necessary if we want to build mass timber buildings without concrete cores. Work at Oregon State Univeristy and University of California–San Diego shake table has answered these questions related to sequencing and installation. The problems are not sequencing but rather code approval of rocking wall systems.
9	Construction: Beam to column connections and column to column connections	Two groups suggested that standardizing connections would address constructability issues or bottlenecks.
10	Difficulty and added costs of solid walls in regard to outlets/switches/conduits/junction boxes coordination	Only one group scored this topic with no comments.
A	Repairs are unsufficient, replacement MT products required	See items 5–7.
B	Vibration guidelines medium difficulty	See item 2.
C	Research on constructability of mass timber	No comments.
D	Create content to train workforce so that it is easier to assemble the proper teams to do mass timber construction.	No comments.
E	Design: Getting rocking wall into code, getting literature on how to design rocking wall and other MT lateral systems	No comments.
F	Design: Beam to column connections and column to column connections	This would include a complete design that accounts for deformation compatibility, biaxially stress states, fire design

[a] Topics 1–10 were preselected. Topics identified with a letter were offered during the meeting.

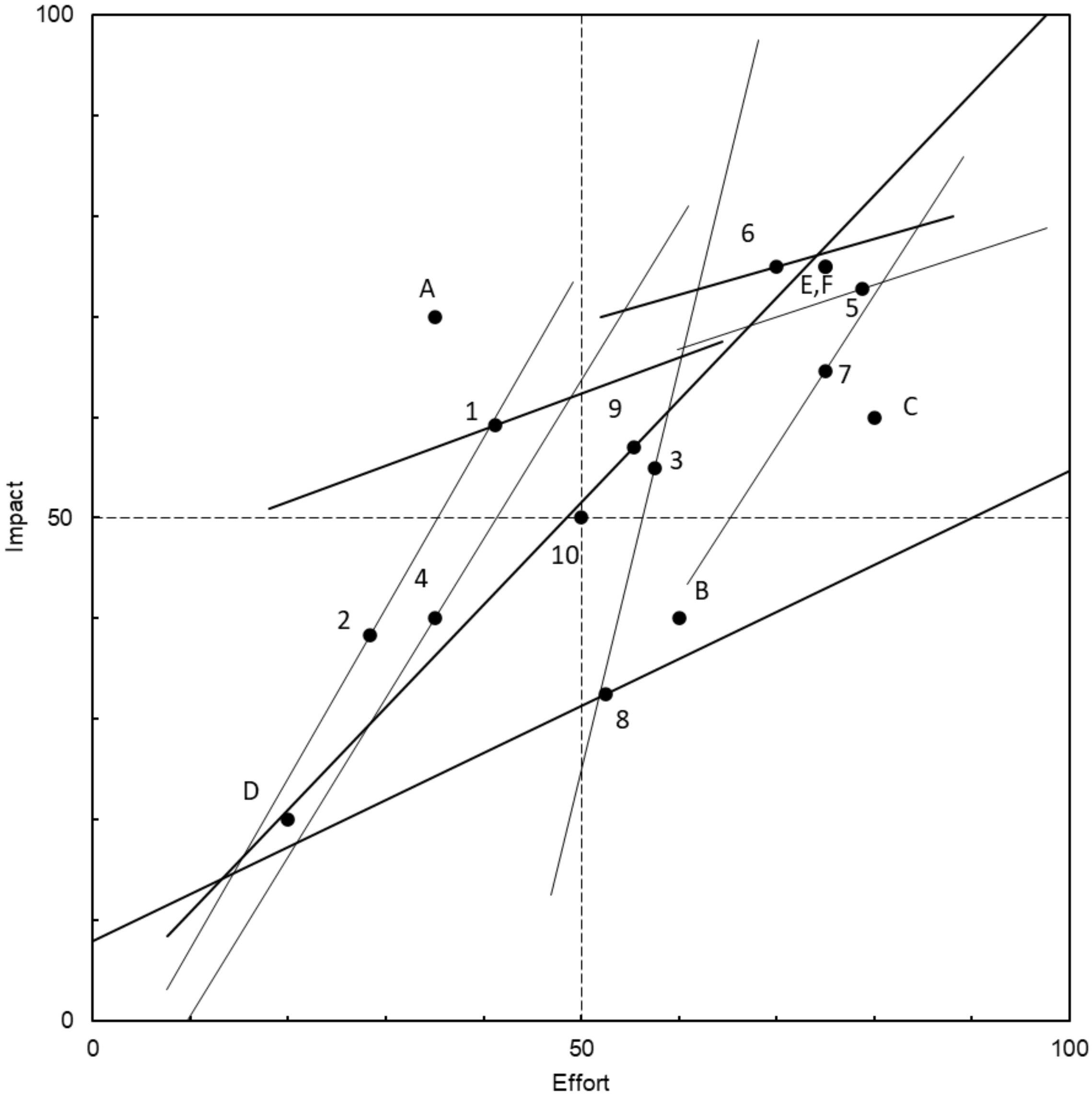


Figure 8—Effort vs impact matrix plot of architectural and/or construction breakout session.

Table 7—Average effort and impact for topics of architectural and/or construction with coefficient of variation between rooms

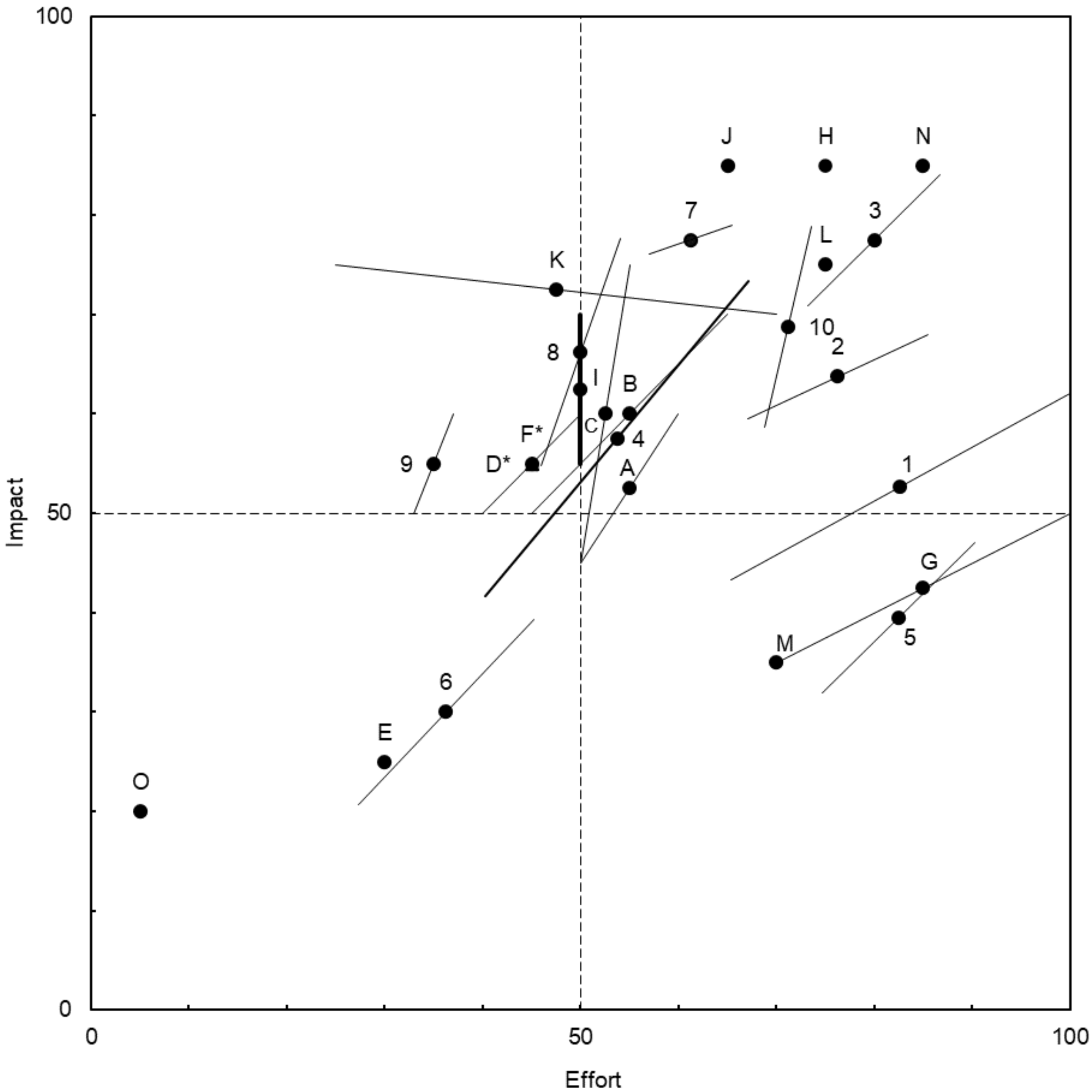
	Average		COV	
Topic	Effort	Impact	Effort	Impact
1	41	59	56%	14%
2	28	38	73%	92%
3	58	55	18%	77%
4	35	40	74%	102%
5	79	73	24%	8%
6	70	75	26%	7%
7	75	65	19%	33%
8	53	33	101%	76%
9	55	57	86%	85%
10	50	50	–	–
A	35	70	–	–
B	60	40	–	–
C	80	60	–	–
D	20	20	–	–
E	75	75	–	–
F	75	75	–	–

Table 8—Research topics for structural systems design and performance

Topic		Notes
1	Full-scale validation testing of structural assemblies (seismic, wind, blast, or progressive collapse simulations)	Clear consensus supported 10-story seismic shake-table tests underway but dismissed needs for testing of this magnitude to address wind. Support for full-scale tests to mitigate progressive collapse exists among a minority engaged in protective design.
2	Braced frame development of various configurations (BRBs, specially detailed, concentric, range of ductility R = 3 to R = 6, etc.)	After prototype testing, code qualification of timber-braced frame systems requires major effort and sustained investment. Though braces are essential vertical elements of the lateral system, the low volume of wood used in braces limits impact.
3	Shear wall development of various configurations (rocking post-tensioned or passive, conventional, hybrid, stiff R = 1.5 vs ductile R = 6, etc.)	Though innovative, the first code-qualified CLT shear-wall option restricts panel aspect ratios, which makes assembly uncompetitive in “ordinary,” low-seismic-design-category applications. Large investments should be prioritized to fulfill the FEMA P-695 process for “ordinary” shear walls because of the potential impacts for multi-unit housing and school building markets.
4	Diaphragm development of various configurations (simple span, cantilever, service, failure, load and displacement capacity, chord and fastener details)	Based on the volume and versatility of mass timber decking systems, design guidance for panelized diaphragms would have high impact. To date, efforts to develop diaphragm details have been disjointed, lacking communications, and need organization for a strategic effort, commensurate with the potential impact.
5	Moment-frame development of beam-to-column connections (post-tensioned or passive systems)	Despite international precedents, the effort required to develop and qualify lateral moment-resisting frames is high and with lower impact than shear walls and braced frames. Moment connections for non-lateral system applications have greater potential.
6	Protective performance for multi-hazard resilience (wind-launched debris, blast and ballistics, disproportionate/progressive collapse)	Lack of emphasis in standard building codes limits the impact of addressing these hazards. Wind debris impact is important in geographic regions subject to frequent storms, and federal agencies are developing updates to protective design standards to acknowledge the enhance performance of CLT mass timber products.
7	Two-way slab development (post-tensioning, punching shear, load distribution, etc.)	Point-supported CLT has been built internationally but with no standardization of engineering models. Risks of point-supported CLT include uncertain effects of load interactions, punching shear, quality of cross-layers, and reinforcement strategies that permit greater column spacing. The potential market gain is large but unquantified.

Table 8—Research topics for structural systems design and performance (continued)

Topic		Notes
8	Glued-in and cast-in connection development for improved force transfer in panelized and hybrid assemblies	Private industry has developed products, but design standardization of glued-in rods is needed. Quality control of in-situ applications, with greater range of ambient conditions than a factory setting, presents unique challenges. Glued-in rods are critical to hybrid construction but only offer incremental change where alternative mechanical fasteners may suffice.
9	Perp to grain bearing capacity and characterization of deformations under uniform and varying loads	Current design values for limiting compression perpendicular to grain may be too conservative for mass timber products. Reinforcement strategies, such as compression screws, have been developed but not standardized in codes. Better models would bring welcome but incremental change, because other structural details may circumvent compression perpendicular to grain.
10	Mass timber slab development for composite action, enhanced stiffness, and vibrational characteristics	Concrete over timber floors improves vibrational and acoustical performance, by adding mass and stiffness, yet the development of composite floor systems has focused on strength and lacked standardization. Economic, sustainability, and construction safety objectives provide reasons to exclude concrete, but other solutions addressing vibrations and acoustics need to emerge.
A	Standardization of mass timber rocking walls	No comments.
B	Compare panelized SCL alternatives to CLT (e.g., GLT, NLT, DLT, LVL, MPP)	No comments.
C	Mass timber moment connections	Room A focused on panel-to-panel connections, while Room D proposed a generalized approach for non-seismic, static-load architectural applications.
D	Screw reinforcement of mass timber	Topic focuses on screw reinforcement but more broadly applies to notches, shear, compression perpendicular to grain, and openings, mentioned in other topics.
E	Edgewise bending of CLT beams	No comments.
F	Penetrations and holes through mass timber panels and beams	Openings impact bending performance of beams and panels (oriented edgewise and flatwise). Results will need to be coordinated with research of fire effects on the penetrations.
G	Full-scale progressive collapse testing	Analysis may demonstrate conformance with progressive collapse provisions, but proof-of-concept testing showing that mass timber connections may undergo extreme rotations and maintain integrity is scarce. The testing gap is a hindrance to mass timber use in government facilities that require high levels of protection but not most housing/hospitality buildings.
H	Connection details for seismic displacement compatibility	Engineers currently lack models for rotations and displacements of connection details, used to assess compatibility. This could be a two-phase project, organized by low and high seismic categories.
I	Period estimation via vibrations monitoring for seismic and wind design	Natural periods of tall wood buildings need to be determined by a combination of wind-tunnel testing, modeling connection stiffness, and vibration monitoring of existing buildings. Access to privately owned buildings and data sharing is not incentivized, though it reduces risk of serviceability-related insurance claims.
J	Intermediate shear wall—ordinary with ductile hold downs	Specific shear wall development for use in the majority of the United States.
K	Reinforcing at notches/openings of mass timber panels and beams	To manage story heights from growing too tall, MEP penetrations through mass timber beams are common. Guidance on reinforcing openings and mitigating fire damage at the penetration is necessary for mass timber floor framing systems to be competitive.
L	Timber-to-timber composites and built-up structural members	Develop stiff mass timber floors with structural box beams that provide spaces to conceal and route utilities, while mitigating vibrations and acoustic transmission.
M	Full-scale blast testing—windows, connector system	Specific to protective requirements most typically applied to federal facilities and other governmental agencies, part of a niche market.
N	Seismic tests of 4- to 8-story buildings with fully wood systems	No comments.
O	CLT tornado saferooms	Technical solutions are available but require economic analysis and outreach to educate homeowners and encourage implementation.



* Coincident points. Error applies only to point D.

Figure 9—Effort vs impact matrix plot of structural system design and performance breakout session.

Table 9—Averages and variation of consensus scores for topics of structural systems design and performance

	Average		COV[a]	
Topic	Effort	Impact	Effort	Impact
1[b]	83	53	36%	31%
2	76	64	24%	13%
3	80	78	17%	17%
4	54	58	50%	55%
5	83	40	19%	38%
6	36	30	50%	62%
7	61	78	14%	4%
8	50	66	16%	35%
9	35	55	12%	18%
10	71	69	7%	29%
A	55	53	13%	20%
B	53	60	26%	24%
C	53	60	7%	35%
D	45	55	–	–
E	30	25	–	–
F	45	55	16%	13%
G	85	43	25%	25%
H	75	85	–	–
I	50	63	0%	17%
J	65	85	–	–
K	48	73	67%	5%
L	75	75	–	–
M	70	35	–	–
N	85	85	–	–
O	5	20	–	–

[a] COV, coefficient of variation; no COV reported if $n = 1$; unless noted otherwise, $n = 4$ for topics labeled with numbers, $n = 2$ for topics labeled with letters.
[b] For topic 1, $n = 3$.

Table 10—Honorable mentions of structural systems design and performance

Topic	Description
P	Architectural/nonstructural component compatibility with rocking systems
Q	Composite timber–concrete diaphragms
R	Sustainable alternatives to concrete for composite floors
S	Protection from wind debris impacts. Tests of light-framed wood structures were mentioned in Room B discussion.
T	Volumetric module (Type III) hybrid designs related to connections

Table 11—Research topics for materials and manufacturing processes[a]

Topic	Description	Notes
1	Develop nondestructive evaluation techniques that evaluate bond line integrity in CLT panels (in-plant)	Existing certification requires destructive testing, and new processes would be put in place if a NDE solution existed. Several techniques exist for other products and would need to be applied to inline verification.
2	Develop nondestructive evaluation techniques to evaluate the structural condition of CLT panels in service	Solutions have been used for glulam/timber bridges and could be used on the newer mass timber buildings to look for potential issues. Range of needs from understanding moisture to checking for structural integrity after a fire event or recognizing a possible post-occupation issue.
3	Develop models to predict properties of CLT that can minimize the need for physical testing of multiple species–grade–adhesive options	Very expensive to add species and grades. Glulam has had a model approach, but CLT does not. This item would look at ways of documenting the analysis and streamlining the required tests. Models exists, including one in the *CLT Handbook*.
4	Develop CLT stress grades that are based on assembled panels rather than the constituent lumber properties.	The ability to optimize fiber basket and optimize species into products could be valuable. Could use different grades without grading/analyzing lumber components.
5	Develop improved estimates of panel strength in the minor strength direction	Minor axis testing being done. Two sides of this issue: current estimates are too conservative and need more historical MT products in service before changing any safety values. Utilize data from PRG 320 panel tests for statistical variations. Interaction guidance within PRG320 would be useful.
6	Conduct indoor air quality tests to evaluate off-gassing of CLT panels, not just the adhesives.	Mostly a messaging issue around EWP. Formaldehydes are not used in CLT/glulam, but general public is still uneducated.
7	Evaluate the feasibility of utilizing reclaimed lumber in the manufacture of CLT panels	Qualification and grading are a major gap in this item. Very challenging logistically and would be very boutique operation. The risks might outweigh the benefits.
8	Quantify volume and/or system effects on flatwise bending properties of CLT	Not all rooms understood this item and the benefit. Two rooms suggest there is something to look into on this item. Wider panels demonstrate slightly higher strength per foot than 12-in. strip current values are based on. Potential 10% to 15% increase in bending strength. Also look to Europeans for volume effect results.
A	Hardwood/alternative species	Bonding issues with mixed species can be tough, but process covered by glulam standard(s). Several options and studies.
B	Mixed species layup issues	Currently allowed, provided laminations meet PRG 320 (e.g., $G = 0.32$).
C	Alternative layups (no adhesives)	Mechanical or dowel-based layups
D	Design for manufacturing and assembly in mass timber	Mass timber volumetric modular.
E	Cross-platform interoperability of digital tools	No comments.
F	Diagonal layers in layups	No comments.
G	How to improve competitiveness of domestic mass timber	Several factors around different markets and market maturity.
H	Challenges with bottleneck in CNC	Do we have enough CNC capability? What quality is needed?
I	Sanitize CLT for potential pests	Sanitize, heat treatment, fumigation to eliminate potential pests, regional variations around importance.
J	Bio-resins	Potential cost, sustainability, and adhesive performance.
K	Volume from topic 8	Consider loading, depth; benefits are unclear for volume factor compared to repetitive; who's looking for this information; we could make it cheaper (less wood).
L	Supply chain issue—need more ANSI 405 adhesives	Need more volume of ANSI 405 adhesives because less adhesive manufacturers are ANSI 405 qualified; very expensive and long process (1 year) for adhesive manufacturers to be qualified and barrier to scaling up
M	Supply chain issue—regional CLT fabrication	Matching up all supply chain capacities. Will require maturity.
N	Rolling shear values	Research shows that rolling shear values are higher than actual listings. Updating to PRG method and ASTM standards would need to follow testing.
O	Two-way bending	Add into PRG320.

Table 11—Research topics for materials and manufacturing processes[a] (continued)

Topic	Description	Notes
P	Variable lumber/ply thickness for CLT	What is prohibiting U.S. manufacturers? Sourcing is difficult. No cost-savings over 2x. Bidding process can also hinder the use. Finger jointing is more difficult.
Q	What is the next EWP that can use small diameter?	Any type of MT that can use small wood would have a huge impact. Concerns around quality of the small diameter wood. Can it be planed?
R	Block gluing in glulam/larger glulam	Currently can be produced only in Europe. ANSI standard has this in it. Mostly a manufacturing/production issue in NA. Most of CNC machines are not geared towards these sizes. Will be needed if we are building TWB in the United States and want to use NA lumber.
S	MSR rated/electronic rated stock (rather than lam-stock) for glulam columns	Would bring the cost of the same size glulam members (specifically columns) down. Could end up with a weaker column but could have biggest effect on low-rise (3–5 stories). May not be allowed—would require change in ANSI standard. If cost savings aren't there, then the impact would not be significant.
T	In-plane values for CLT	More information in in-plane bending, shear, torsion, and stiffness would be beneficial. If shear wall CLT systems are going to be used, more information is needed. Applicable to both intermediate shear walls and specialty shear walls.
U	Does CLT have a size effect similar to glulam?	Could this be modeled? Model may increase impact. Could bring cost down.
V	CLT built with a camber	Many comments on the pros/cons of this item. How to get longer spans is the big question—does camber make this possible and would it even be possible to press, CNC, and ship cost effectively?

[a] Items 1-8 were preselected. Items with a letter were offered during the meeting

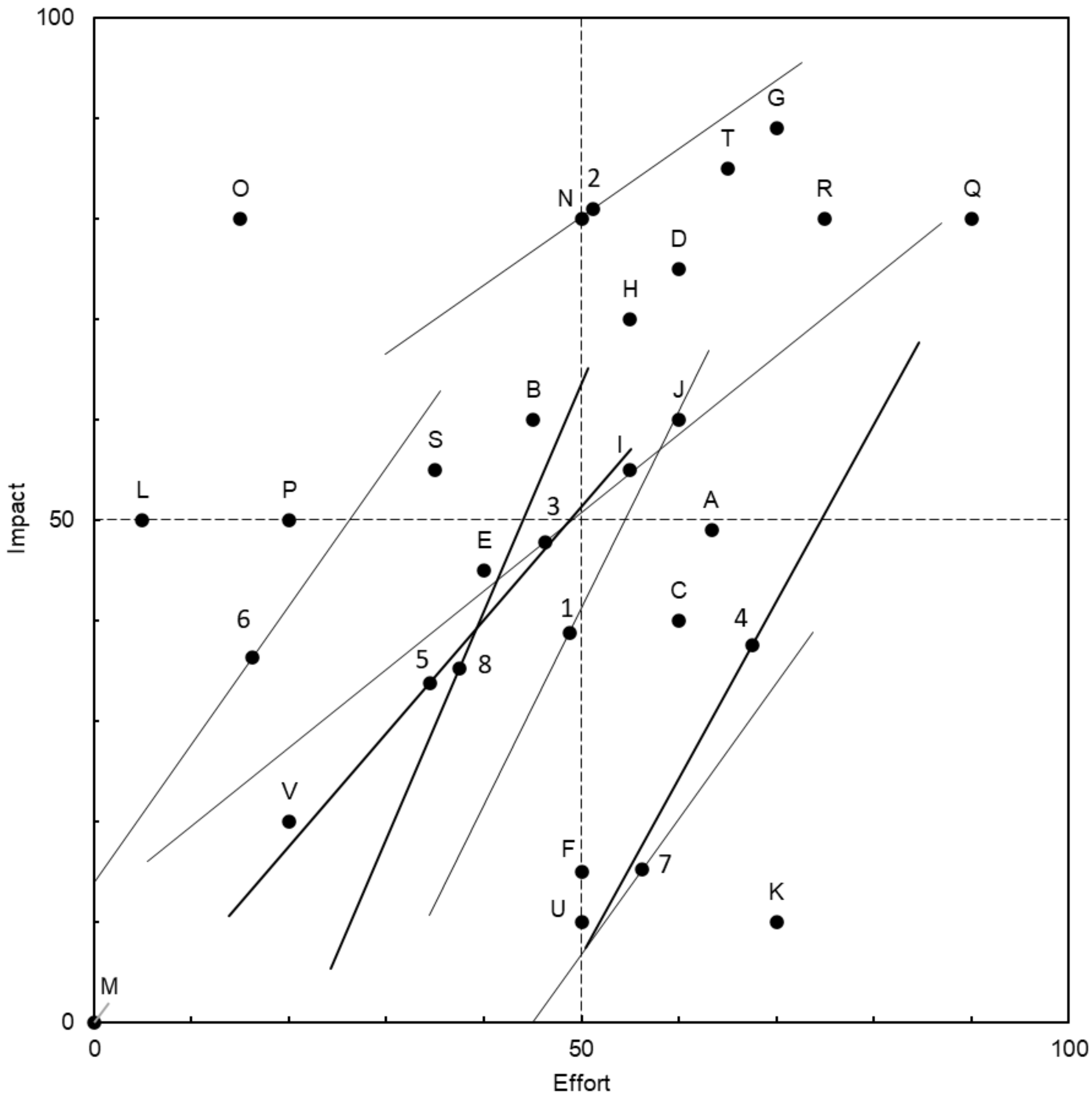


Figure 10—Effort vs impact matrix plot of materials and manufacturing breakout session.

Table 12—Average effort and impact for the topics in the materials and manufacturing with coefficient of variation between rooms

	Average		COV	
Topic	Effort	Impact	Effort	Impact
1	49	39	29%	73%
2	51	81	42%	18%
3	46	48	88%	67%
4	68	38	25%	80%
5	35	34	60%	69%
6	16	36	119%	73%
7	56	15	31%	155%
8	38	35	35%	85%
A	63	49	40%	51%
B	45	60	–	–
C	60	40	–	
D	60	75	–	–
E	40	45	–	–
F	50	15	–	–
G	70	89	–	–
H	55	70	–	–
I	55	55	–	–
J	60	60	–	–
K	70	10	–	–
L	5	50	–	–
M	0	0	–	–
N	50	80	–	–
O	15	80	–	–
P	20	50	–	–
Q	90	80	–	–
R	75	80	–	–
S	35	55	–	–
T	65	85	–	–
U	50	10	–	–
V	20	20	–	–

Table 13—Research items for sustainability and economic analysis

Topic	Description	Notes
1	Develop and maintain MT materials and buildings for Building Information Modeling databases	Report medium effort and relatively high impact. New government funding for GSA on federal buildings may be used. WBLCA tools exist and need to harmonize underlying MT LCI data and approaches/standards for rigor and consistency.
2	Incorporate LCI databases as part of whole-building LCA tools and green purchasing initiatives	Report medium effort and relatively high impact. CLT life-cycle inventory data does exist but not yet widely available in WBLCA tools or LCA modeling software.
3	Regionalize harvested wood product carbon models/tools while adding MT products	Report relatively high effort and medium impact. Government role would be helpful. USFS and states like California have developed their own HWP C estimation tools and are or will be publicly available.
4	Support development of sustainable metric standards through ASTM and ISO	Report relatively high effort and medium impact. Need to specify what other sustainable metrics are needed. Wood product PCRs use current standards to list what metrics are required for building products EPDs.
5	Meta-analysis synthesizing the current state of knowledge on economics, market, social science, and public policy	Report relatively high effort and low impact. Research topic is too broad and need to be broken down into smaller components under a single umbrella.
6	Develop projections of long-range regional outlook of building construction and estimation of associated long-range demand for MT in those constructions	Report low effort and medium impact. FPL has project underway through the USFS Resource Planning Act (RPA) Assessment. Softwood Lumber Board developed a MT demand forecasting approach.
7	Conduct updates of wood LCA data and reports using online surveys to meet demands of the marketplace and to reduce the statistical variation	Report low effort and medium impact. A joint U.S./Canadian effort has made great progress on implementing an online survey mechanism for both countries for non-CLT wood products.
8	Use A4 (product transport) lifecycle results to link to new EPD-type products and WBLCA tools	Report low effort and a relatively low impact. Softwood lumber A4 module project completed. Other WBLCA tools are planning to incorporate the above outcomes into their tools.
9	De-construction of mass timber buildings and carbon effects of alternative end-of-life treatment options	Report medium effort and high impact. Assess marketplaces on reusing MT products. Develop deconstruction guidelines to help reuse industry.
10	Conduct techno-economic analysis and life-cycle assessment of utilizing small-diameter trees for current and new mass timber product manufacturing	Report medium effort and medium impact. Costs for harvesting small-diameter trees need to be found to help MT manufacturing and construction industry make the right choices. What incentives if any are needed?
A	Baseline (life-cycle assessment) LCA	As an add-on item, report medium effort and medium impact. This item closely aligns with items 2 and 7. Creating a U.S. version of the Canadian WBLCA guidelines would be useful to develop a baseline for architects and developers.
B	Mass timber repair guide to help prolong service life	Honorable mention topic did not receive score.

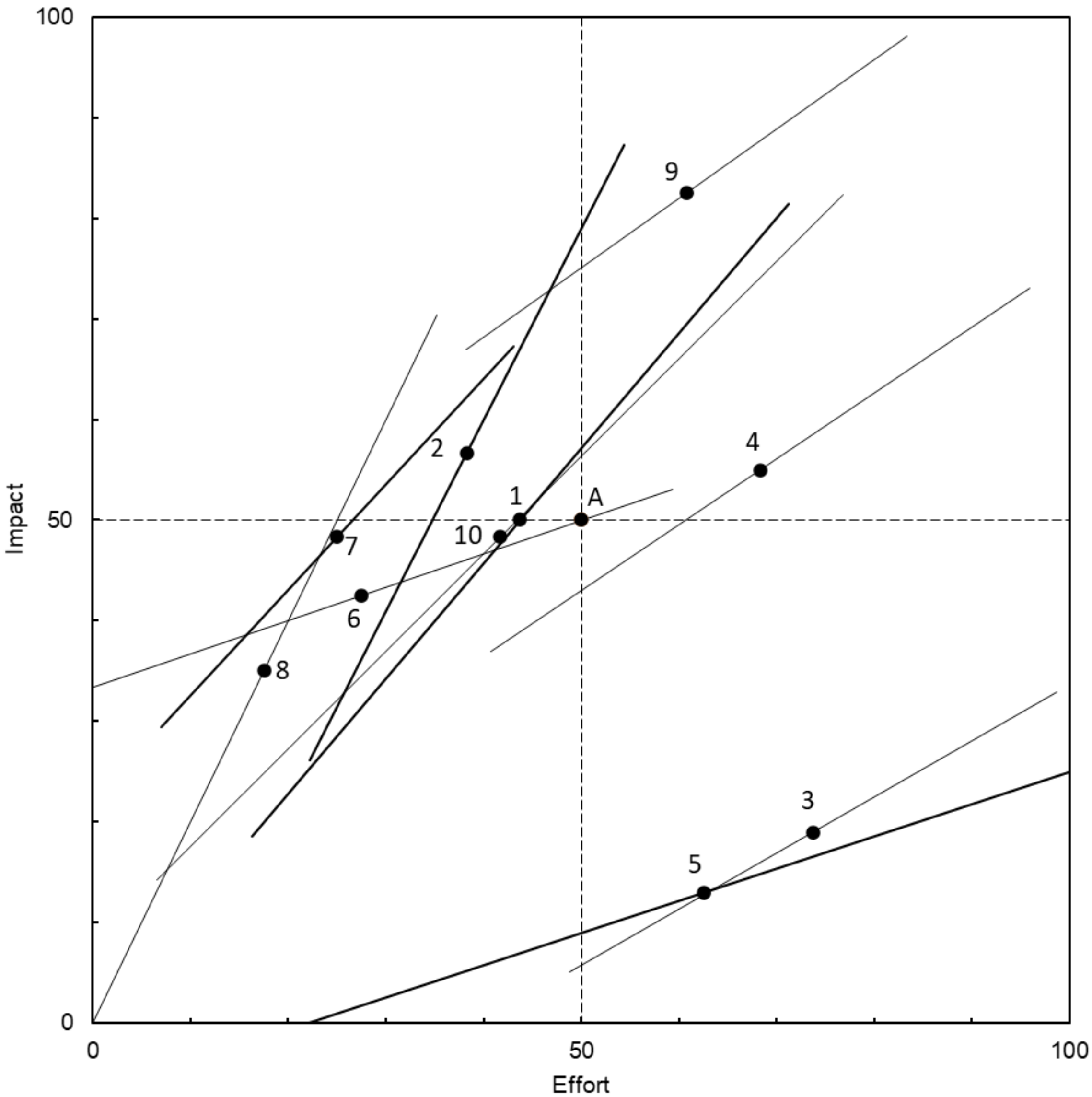


Figure 11—Effort vs impact matrix plot of sustainability and economic analysis breakout session.

Table 14—Average effort and impact for topics in sustainability and economic analysis with coefficient of variation between rooms

	Average		COV	
Topic	Effort	Impact	Effort	Impact
1	44	50	63%	63%
2	38	57	42%	54%
3	74	19	34%	73%
4	68	55	40%	33%
5	62	13	85%	131%
6	28	42	116%	25%
7	25	48	72%	39%
8	18	35	101%	101%
9	61	82	37%	19%
10	42	48	84%	7 0%
A	50	50	–	–
B	–	–	–	–

Table15—Research items for infrastructure/nonbuilding applications

Topic	Description	Notes
1	Research use of CLT for bridges for stream crossings in lieu of culverts and how to expand knowledge to other states	State, local, private use for bridges/water crossing. Potential to reduce environmental impacts by not using culverts. Use/length of service duration needs to consider different solutions, preservatives, adhesives, etc. Short-term bridge/crossing material for logging operations or repair of bridge. S&RF WIG, SLB, Sterling currently researching aspects of topic.
2	Small and large CLT for bridge decks to reduce joints and understand weathering properties, preservatives, moisture effects (e.g., creep, strength reductions, long-term durability, cupping, panel deformations), etc. Potential for market opportunity	Can research develop 30- to 50-year bridge? No-joint bridges preferred (i.e., CLT for short spans). Species effect on bridge lifespan. Small vs large bridges—load requirement, span, durability. State DOT for outreach efforts.
3	Full-scale testing to evaluate loads on bridge deck panels	CLT testing currently underway. Testing needed on encapsulated CLT/glulam decking. AASHTO specifications on loadings. Small vs large bridge testing. Assessment plan on best approach to package/share best management practices based on research results.
4	Fatigue testing for connections in bridges with CLT decking	Fatigue testing to meet AASHTO requirements (e.g., full scale, panel, component testing). Glulam testing has been done, so expand on this if additional testing needed. Montana has timber bridge inspection guide (i.e., wet, salt effect). Maine did research with FRP bridge stringers. Difference between CLT in building and exposed outside (i.e., weather cycling, moisture, load).
5	Investigate the use of concrete and/or steel materials for developing composite behavior with timber (i.e., CLT) components	Composite/hybrid materials discussed (e.g., timber–concrete, timber–timber, timber–steel). Need to expand on current building construction and long-term European studies. Possible AASHTO requirements.
6	What types of treatments are needed for mass timber panels	Normal to extreme exposure studies to include ground contact, marine environment, salt/deicing—current test plots exist for CLT (e.g., MSU, FPL). From no treatment to fully encapsulated and what to treat (lumber or CLT). Does PRG-320 apply to for non-structural applications? LCA for treatments?

Table15—Research items for infrastructure/nonbuilding applications (continued)

Topic	Description	Notes
7	Best moisture management (e.g., drainage, protection) for mass timber systems needs to be evaluated	Adapt best management practices for bridges to other mass timber systems—see USFS (1992) timber bridge guide. Address fears and concerns of using wood outside. Ongoing projects in Europe and United States (e.g., Iowa State and FPL moisture management project to prevent trapping within bridge superstructure and contact with wood).
8	Nondestructive evaluation (NDE) techniques	Good existing NDE techniques that can be adapted to other areas (i.e., beyond bridges to powerline structures, mats, guardrail posts). Additional research needed to: decrease wide range of scoring, structural health monitoring, better NDE data interpretation guidance, remote sensing (i.e., LIDAR), long-term monitoring sensors, schedules, strike studies. Research tech transfer to practitioners.
9	Fire testing on mass timber bridges, as a result of additional wildfires	Installation decisions may be made locally depending on fire-prone areas/risk. Potential BMP—let char, inspect, and replace as necessary. Look at railroad wood bridges, treatment, and BMPs.
10	Evaluate shoring design using CLT as temporary shoring for concrete buildings	Is it shoring or formwork? Leave in place form discussed as potential secondary or tertiary use of CLT. Market analysis may be needed to determine use of scrap CLT cutoffs.
A	General operations and inspections of timber bridges	Glulam and other products have been used in bridges, but difficulty in approval in many places. AASHTO requirements may direct research. Bridge inspections and training module to include post bridge-vehicle collision.
B	Temporary vs permanent bridges	Create two bridge categories: (1) temporary (e.g., forest access, DOD) and (2) permanent (AASHTO/DOT). Include protected and unprotected wood elements, specialized elements, service life. Full-scale testing of large sections/bridges.
C	Research for noise barriers and sound walls	Durability issues need to be researched, developed, and transitioned to include durability, rain cap, [wax] coating, preservation treatments, end grain exposure, glued vs non-glued options. Need long service life (i.e., 30+ years). LCA on barriers to look at: potential cost savings, wood vs pre-cast concrete comparison, treating costs.
D	Excavation shoring—retaining walls/wood foundations	Large market for retaining walls, but likely concerns with durability.
E	Maritime structures	Dock, piers, etc.
F	Economic and market analysis of all exterior applications	What is the value of this group of exterior applications? What is important research to start based on market impact?
G	Bridge and roadway repair and maintenance	Develop repair methods for all externally used mass timber, education of maintenance crews. Cost analysis.
H	Decking and mats	Use of domestic hardwoods to replace tropical hardwoods. How does timber behave as/with composites? How to increase the life of matting/outrigger pads.
I	CLT panels used for emergency/homeless shelters	Build on emergency shelter work already done post-disaster portable, rapidly deployable shelters.
J	Potential MT uses wind turbines, solar arrays, shipping containers, glulam power poles, parking garages and then education of users, impact of EV fires in MT parking garages.	Need to understand the life-span requirements of municipalities (30 years? 50 years?). Keeping money in the state is desired (local timber resource). What are the best exterior uses for different MT materials (a lot of glulam in bridges already, power poles, etc.)? Robust traffic coatings that are lightweight to go on top of CLT. One in Sweden, several in Switzerland. Lithium-ion batteries create a unique fire challenge.
K	Railway Ties	15–18M ties per year = huge market. Disposal/develop MT ties from a less desirable species.
L	Salt effects on CLT and connections	Salt effects on CLT and connections

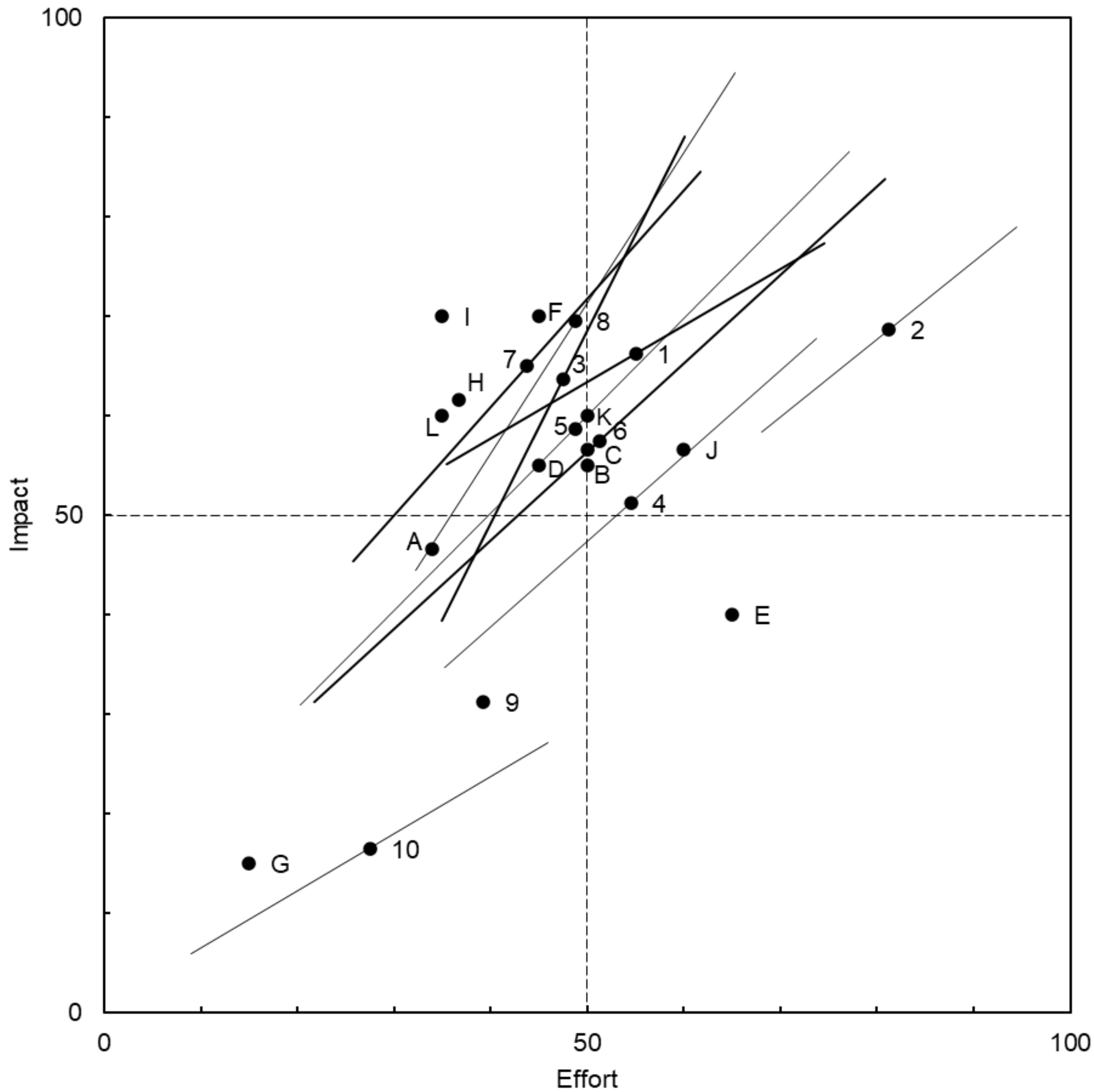


Figure 12—Effort vs impact matrix plot of infrastructure/nonbuilding applications breakout session.

Table 16—Average effort and impact for the topics in infrastructure nonbuilding applications along with coefficient of variation between rooms

	Average		COV	
Topic	Effort	Impact	Effort	Impact
1	55	66	36%	17%
2	81	69	16%	15%
3	48	64	26%	38%
4	55	51	35%	32%
5	49	59	58%	47%
6	51	58	58%	46%
7	44	65	41%	30%
8	49	70	34%	36%
9	39	31	67%	60%
10	28	17	67%	64%
A	34	47	–	–
B	50	55	–	–
C	50	57	–	–
D	45	55	–	–
E	65	40	–	–
F	45	70	–	–
G	15	15	–	–
H	37	62	–	–
I	35	70	–	–
J	60	57	–	–
K	50	60	–	–
L	35	60	–	–

Summary

Mass timber represents an exciting potential market for wood products. In recent years, the mass timber industry has achieved notable milestones in both building code qualification and construction applications. As of December 2022, nearly 1,700 mass timber projects were either completed or in the construction phase in the United States; these projects encompassed all 50 states and were in the multifamily, commercial, or institutional categories of construction (Woodworks 2023). Also, more than 10 new mass timber panel plants have been constructed in the United States since 2015 (Dawson and others 2022, Section 4.3.1). Within the last year, the 25-story Ascent building in Milwaukee, Wisconsin, was declared the tallest hybrid mass timber and concrete building in the world (Safarik and others 2022). These accomplishments signal growth in the mass timber industry in North America. The 3rd mass timber research needs assessment workshop was an opportunity for key industry stakeholders to work together to identify the most critical research needs to further advance adoption of mass timber and CLT in North America. The conversations and research topics generated in this workshop have been summarized in this report.

Multiple agencies are funding research on mass timber in North American. To make the most effective use of these resources, consensus should be established on the most critical research needs facing the mass timber industry and communication among the agencies should be encouraged.

This report presents matrices plotting effort versus impact of possible research endeavors across a range of construction industry disciplines. These matrices can be used to evaluate and develop calls for proposals. Furthermore, they can be used as a benchmark of the current state of knowledge of mass timber. It is hoped that in future years, many of the current research needs will have been accomplished and that potential research topics will have evolved. Over the course of the three research needs workshops, the progress is clear. Comprehensive, significant, and strategic investments need to be made in research and development to support the burgeoning mass timber industry in the near term and establish a solid basis for continued growth while improving the sustainability and performance of construction.

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Appendix A—Workshop Agenda

WOODWORKS
WOOD PRODUCTS COUNCIL

Mass Timber Research Workshop
September 20–22, 2022—Madison, WI

Day 1 – September 20, 2022

7:30 AM – 8:00 AM	CHECK-IN/REGISTRATION
8:00 AM – 9:00 AM	***Inspiration*** – main session room Ameche ▪ Workshop Kickoff – Andy Martin, USDA Forest Service; Tracy Tophooven, USDA Forest Service; Jennifer Cover, WoodWorks ▪ Ascent Project – Jason Korb, Korb + Associates Architects
9:00 AM – 11:00 AM	***Fire Performance*** – impact/effort discussions—preassigned break out rooms • Breakout Intro – Bill Parsons, WoodWorks and David Barber, Arup
11:00 AM – 12:00 PM	***Major Institutional Progress Report*** – main session room Ameche ▪ Wood Innovation Grant Summary – Brian Brashaw, USDA Forest Service ▪ Mississippi State University – Rubin Shmulsky ▪ Karagozian & Case – Mark Weaver
12:00 PM – 1:00 PM	LUNCH – main session room Ameche
1:00 PM – 3:00 PM	***Durability and Building Physics*** – impact/effort discussions—preassigned break out rooms ▪ Breakout Introduction – Tammy Siliznoff, RDH Building Science
3:00 PM – 4:00 PM	***Major Institutional Progress Report*** – main session room Ameche ▪ University of Arkansas – Peter MacKeith ▪ Michigan State University – George Berghorn ▪ Clemson University – Patricia Layton
4:00 PM – 5:00 PM	***Architectural Research and/or Construction*** – impact/effort discussions—preassigned break out rooms ▪ Breakout Introduction – Jennifer Hardy, Payette
5:00 PM	***DAY 1 ENDS/***RECEPTION – main session room Ameche

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Mass Timber Research Workshop

September 20–22, 2022—Madison, WI

Day 2 – September 21, 2022

8:00 AM – 9:00 AM	***Mass Timber Successes, Pinch Points and A Look Ahead: Insights from Leading A&E Firms*** – main session room Ameche ▪ Panel Discussion: Carla Dickof, Fast + Epp; Tom Chung, Leers Weinzapfel Associates; Greg Kingsley, KL&A Engineers and Builders
9:00 AM – 11:00 AM	***Structural System Design & Performance*** – impact/effort discussions—preassigned break out rooms • Breakout Introduction – Tanya Luthi, Entuitive
11:00 AM – 12:00 PM	***Major Institutional Progress Report*** – main session room Ameche ▪ Forest Products Lab – Andy Martin, USDA Forest Service ▪ Natural Hazards Engineering Research Infrastructure (NHERI) Shake Table Test – Shiling Pei, Colorado School of Mines ▪ Consortium for Research on Renewable Industrial Materials (CORRIM) – Elaine Oneil, CORRIM
12:00 PM – 1:00 PM	**LUNCH** – main session room Ameche
1:00 PM – 3:00 PM	***Materials and Manufacturing Processes*** – impact/effort discussions—preassigned break out rooms ▪ Breakout Introduction – Todd Beyreuther, Mercer Mass Timber
3:00 PM – 4:00 PM	***Major Institutional Progress Report*** – main session room Ameche ▪ Oregon State University – Iain Macdonald ▪ University of Washington – Indroneil Ganguly ▪ The Nature Conservancy – Yangyang Wang
4:00 PM – 5:00 PM	***Sustainability and Economic Analysis*** – impact/effort discussions—preassigned break out rooms ▪ Breakout Introduction – Bill Parsons, WoodWorks
5:00 PM	***DAY 2 ENDS***

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Day 3 – September 22, 2022

8:00 AM – 9:00 AM	***Major Institutional Progress Report*** – main session room Ameche ▪ State University of New York College of Environmental Science and Forestry – Paul Crovella ▪ University of Tennessee – Adam Taylor ▪ Yale School of the Environment – Yuan Yao
9:00 AM – 11:00 AM	***Infrastructure/Nonbuilding Applications*** – impact/effort discussions–preassigned break out rooms • Breakout Introduction – Michaela Harms, Sterling Structural
11:00 AM – 12:00 PM	***Major Institutional Progress Report*** – main session room Ameche ▪ University of Maine – Ling Li ▪ University of Utah – Chris Pantelides ▪ Michigan Technological University – Mark Rudnicki ▪ FPInnovations – Samuel Cuerrier-Auclair
12:00 PM	***DAY 3 ENDS***

Appendix B—List of Participants

Last name	First name	Occupation	Company
Abbott	Greg	Building Owner/Developer	Dept of Public Safety Communications
Adler	Brandon	Architect	Angus Young
Ahn	Namhyuck	Student	Oregon State University
Amini	Mohammad Omar	Wood Industry	American Wood Council
Arango	Rachel	Government	Forest Products Lab
Barber	David	Engineer	Arup
Barbosa	Andre	Educator	Oregon State University
Bechle	Nathan	Government	USDA Forest Service Forest Products Laboratory
Becker	Charlie	Government	USDA Forest Service
Berghorn	George	Educator	Michigan State University
Bergman	Richard	Government	USDA Forest Service Forest Products Laboratory
Beyreuther	Todd	Wood Industry	Mercer Mass Timber LLC
Bickel	Matt	Architect	Wold Architects and Engineers
Blomgren	Hans-Erik	Engineer	Timberlab
Boubacar	Inoussa	Wood Industry	Forest Service
Brashaw	Brian	Other	USDA Forest Service
Breneman	Scott	Engineer	WoodWorks
Brown	Nathan	Educator	Penn State University
Brown	Justin	Engineer	StructureCraft Builders
Cagle	Ashley	Engineer	WoodWorks
Chung	Tom	Architect	Leers Weinzapfel Associates
Clark	Hannah	Engineer	StructureCraft Builders
Congleton	Tyler	Wood Industry	Boise Cascade
Cover	Jennifer	Engineer	WoodWorks
Crovella	Paul	Educator	SUNY-ESF
Cuerrier Auclair	Samuel	Engineer	FPInnovations
Daniels	Ellie	Government	Forest Products Lab
Deliman	Patrick	Engineer	USACE - ERDC
Dickof	Carla	Engineer	Fast + Epp Structural Engineers Inc.
Farkas	Natalia	Government	FS-FPL
Farrell	Patrick	Wood Industry	Freres Engineered Wood
Flom	Ryan	Softwood Lumber Check-Off Supporter	Softwood Lumber Board
Folan	John	Educator	University of Arkansas
Freres	Kyle	Wood Industry	Freres Engineered Wood
Frost	Levi	Wood Industry	Sterling Structural
Ganguly	Indroneil	Educator	University of Washington
Gareis	Bill	Adhesive	Bostik
Gerard	Robert	Engineer	Coffman Engineers
Gines	Jacob	Educator	Mississippi State University
Glass	Sam	Government	USDA Forest Products Laboratory
Goergen	Michael	Other	U.S. Endowment for Forestry and Communities
Gourabi	Mahboobeh	Student	University of Arkansas
Gu	Hongmei	Government	USDA Forest Products Laboratory
Hanna	David	Engineer	Nordic Structures
Hardy	Jennifer	Architect	Payette
Harms	Michaela	Wood Industry	Sterling Structural
Harwood	Matthew	Engineer	Holmes
Hasburgh	Laura	Government	USDA Forest Products Laboratory
Helbach	Nate	Building Owner/Developer	The Neutral Project
Heymsfield	Ernie	Educator	University of Arkansas / Dept. of Civil Engineering
Hsu	Kevin	Wood Industry	Sterling Structural

Jakes	Joseph	Government	USDA FS Forest Products Laboratory
Johnson	Benton	Engineer	Skidmore, Owings & Merrill
Johnson	Dave	Wood Industry	Smartlam
Jones	Bevan	Engineer	Holmes Fire
Kallakas	Heikko	Educator	Tallinn University of Technology
Kazer	Alex	Other	Forest Service
Khademibami	Laya	Educator	Sustainable Bioproducts, MSU
Khatri	Poonam	Government	USDA Forest Products Laboratory
Kingsley	Greg	Engineer	KL&A
Kirker	Grant	Other	USDA FS FL
Kjolsing	Eric	Engineer	Karagozian & Case, Inc.
Korb	Jason	Architect	Korb and Associates Architects
Kumar	Vaibhav	Government	USDA Forest Product Laboratory
Landreman	Archie	Wood Industry	Sterling Structural
Layton	Patricia	Educator	Clemson University
Leach	Michael	Wood Industry	Element5
Li	Ling	Educator	University of Maine
Line	Philip	Engineer	American Wood Council
Lo Ricco	Marco	Engineer	USDA, Forest Service, Forest Products Laboratory
Lupien	Sandra	Educator	Michigan State University
Luthi	Tanya	Engineer	Entuitive
Macdonald	Iain	Educator	TallWood Design Institute
Machuca	Jose	Engineer	Holmes US
MacKeith	Peter	Educator	University of Arkansas - Fay Jones School of Architecture and Design
Martin	Andy	Government	USDA FS FPL
McDonnell	Eric	Engineer	Holmes US
McLain	Ricky	Engineer	WoodWorks
Messadi	Tahar	Educator	University of Arkansas
Miyamoto	Byrne	Educator	Tallwood Design Institute
Mohammadabadi	Mostafa	Educator	Sustainable Bioproducts, MSU
Morrow	Jeff	General Contractor/Framer	Timberlab
Moser	Robert	Engineer	US Army Corps of Engineers - ERDC
Mostafaei	Hossein	Insurance	FM Global
Nelson	Keith	Engineer	US Department of State
Nepal	Prakash	Government	US Forest Products Lab
Ogorzalek	Kenneth	Engineer	KPFF
Oneil	Elaine	Other	CORRIM
Pang	Weichiang	Educator	Clemson University
Pantelides	Chris	Educator	University of Utah
Parsons	Bill	Engineer	WoodWorks
Paul	Nathan	Wood Industry	Boise Cascade
pei	shiling	Educator	Colorado School of Mines
Potter	Frank	Engineer	Boise Cascade
Pryor	Steve	Engineer	Simpson Strong-Tie
Rammer	Douglas	Engineer	USDA Forest Service
Richards	Steve	Project Manager	Dane County Public Works
Rodrique	Timothee	Insurance	FM Global
Rudnicki	Mark	Educator	Michigan Technological University
Sadoughi	Arezou	Educator	Sustainable Tecnology and The Built Environment
Schmidt	Evan	Educator	TallWood Design Institute
Senalik	Christopher	Engineer	USDA Forest Service Forest Products Laboratory
Shi	Michele	Wood Industry	Hasslacher Timber Inc.
Shmulsky	Rubin	Educator	Sustainable Bioproducts, MSU
Siliznoff	Tammy	Educator	RDH Building Science Inc.
Simpson	Barbara	Educator	Stanford University
Sinha	Arijit	Educator	Oregon State University
Smart	Jason	Engineer	AWC
Spinelli Correa	Laurice Mara	Educator	Mississippi State University/USDA-FPL
Stewart	Lauren	Engineer	Georgia Institute of Technology

Stoner	Michael	Educator	Clemson University
Stringer	Megan	Engineer	Holmes
Stynoski	Peter	Engineer	USACE ERDC-CERL
Swinea	Juliet	Student	Georgia Institute of Technology
Taylor	Adam	Educator	University of Tennessee
Taylor	Robert	Wood Industry	Boise Cascade
Timmer	Alex	Educator	University of Wisconsin Milwaukee
Tophooven	Tracy	Other	USDA FPL
van de Lindt	John	Educator	Colorado State University
Vega	Patricia	Other	Wood-Based Composites Center / WSE-OSU
Wang	Xiping	Government	USDA Forest Service Forest Products Laboratory
Wang	Yangyang	Other	The Nature Conservancy
Warren	Mitch	Wood Industry	Kalesnikoff Mass Timber
Weaver	Mark	Engineer	Karagozian & Case, Inc.
Whitman	Tony	Building Official	PCS
Williamson	Tom	Engineer	Timber Engineering LLC
Xie	Xinfeng	Educator	Michigan Technological University
Yao	Yuan	Educator	Yale University
Yedinak	Kara	Government	Forest Products Laboratory
Yeh	Borjen	Engineer	APA - The Engineered Wood Association