Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Forest Products Laboratory | General Technical Report FPL-GTR-310 | November 2026

An Assessment of Research Needs for Wood Transportation Structures

Justin Dahlberg
James P. Wacker



Citation

Dahlberg, Justin; Wacker, James P. 2026. An assessment of research needs for wood transportation structures. Gen. Tech. Rep. FPL-GTR-310. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 38 p. https://doi.org/10.2737/FPL-GTR-310.

Abstract

This report presents an updated assessment of national research needs for wood transportation structures. In the decades since the initial 1993 study, the U.S. Department of Agriculture, Forest Service; the U.S. Department of Transportation, Federal Highway Administration; and the National Center for Wood Transportation Structures have cultivated a robust program of research, demonstration, and technology transfer to advance the application of timber in transportation infrastructure. This assessment synthesizes feedback from public agencies, industry partners, researchers, and practitioners to identify and prioritize emerging research needs across the following categories: system development and design, material properties, preservatives and protective measures, other transportation system structures, inspection and rehabilitation, technology and information transfer, and historic timber bridges.

The findings emphasize continued and growing interest in enhancing the performance, longevity, and environmental compatibility of timber bridges and related structures. High-priority needs include advancing inspection technologies, developing environmentally acceptable preservative treatments, designing crashworthy timber rail systems, and expanding training resources for inspection and maintenance. The survey results provide direction for future investments and research efforts aimed at improving the viability and competitiveness of timber as a sustainable material for modern transportation systems. This work ensures that as the timber bridge industry evolves, research remains focused on addressing both longstanding challenges and new opportunities to strengthen rural infrastructure, promote sustainability, and safeguard historic structures.

Keywords: timber transportation structures, timber bridges, bridge inspection and rehabilitation, wood preservation, bridge design

Contents

Introduction 1
Objective and Scope 2
Methodology 2
Open-ended Responses 5
Results of Ranking Exercise 11
Analysis of Results for High-Priority Objectives 24
Concluding Remarks 26
Acknowledgments 27
Literature Cited 27
Appendix: Participant Survey 28

Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
MASH	Manual for Assessing Safety Hardware

Authors

Justin Dahlberg, director, Bridge Engineering Center, Iowa State University, Ames, Iowa

James P. Wacker, research general engineer, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, james.p.wacker@usda.gov

Cover photo: Backtrail Road, Monroe County, Wisconsin. Courtesy photo by Justin Dahlberg.

Published by

USDA Forest Service, Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53275
(608) 231-9200
November 2026

Visit the Forest Products Laboratory website at https://research.fs.usda.gov/fpl.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

Disclaimer

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Introduction

Interest in the area of wood transportation structures continues to increase. Much of this interest has resulted from the potential benefits of environmental sustainability and carbon sequestration. The U.S. Department of Agriculture, Forest Service, and the U.S. Department of Transportation, Federal Highway Administration, in partnership with the National Center for Wood Transportation Structures at Iowa State University, have maintained a centralized program for wood transportation structures. A primary goal of this initiative is to stimulate and enhance rural transportation systems by using locally available wood species for wood highway bridges and transportation-related structures. Additional research is needed further to develop wood as a material for transportation structures. New technology must be developed, adapted, and expanded to improve existing designs and develop new systems that allow for the efficient use of primary commercial wood species and previously underutilized species such as hardwoods.

This report of survey results builds on the efforts of previous timber bridge research needs surveys and completed studies. In the early 1990s, the Forest Service and the Federal Highway Administration initiated a comprehensive national research needs assessment in response to the growing interest in timber as a viable material for transportation structures. The resulting report by Wipf et al. (1993) captured input from a range of stakeholders—engineers, researchers, public agencies, and industry representatives—and identified and prioritized 118 research areas essential to advancing the use of timber in bridges and transportation infrastructure. Key focus areas included improving system design and standardization, enhancing inspection and maintenance methods, developing more effective preservative treatments, and evaluating economic impacts. The intent was to create a strategic roadmap that would stimulate local economies, optimize the use of underutilized wood species, and ensure that wood transportation structures could meet modern safety and performance standards.

In a follow-up report, Ritter and Duwadi (1998) highlighted the significant progress made over the subsequent 5 years. Substantial advancements were achieved in nearly every high-priority area, including the development of crashworthy timber bridge rails, standardized design aids, nondestructive inspection technologies, and improved preservative treatments with reduced environmental impact. Field testing and monitoring programs provided critical performance data for new bridge designs, and efforts to improve technology transfer and education expanded industry knowledge and adoption. Together, these efforts have substantially advanced the field, laying the groundwork for future innovation while addressing the initial priorities identified by the nationwide assessment. These two reports are a strong foundation upon which to update the research agenda and address evolving needs in wood transportation infrastructure.

The early Forest Service wood transportation program was grounded in four cornerstones: the promotion of underutilized, locally sourced wood species; the construction of demonstration bridges to showcase emerging technologies; a robust and coordinated research agenda; and proactive technology transfer to engage practitioners and stakeholders. As the program evolved into a formal joint research effort between the Forest Products Laboratory and the Federal Highway Administration, the focus shifted toward more conventional design methodologies and the use of traditional, readily available timber species to align more closely with mainstream bridge engineering practices. This strategic pivot allowed the program to broaden its impact by improving design consistency and fostering wider adoption in public infrastructure. The establishment of the National Center for Wood Transportation Structures in 2007, hosted by Iowa State University, further solidified this integrated approach by unifying research, outreach, and application under one

collaborative umbrella. Since then, the program has achieved substantial milestones in timber bridge innovation, including critical investigations into the behavior and preservation of historic covered bridges, the development of smart timber bridge concepts incorporating advanced monitoring technologies, and numerous advancements that have collectively elevated the safety, durability, and economic viability of timber as a bridge material.

In the coming years, it is anticipated that funding will be available for research and construction of wood transportation structures. Future research will include material properties, preservatives, system development design, maintenance, inspection, and economics. A comprehensive summary of potential and priorities must be developed based on national needs to effectively develop and execute a research program. This report presents potential research projects and priorities related to wood transportation structures.

Objective and Scope

The objective of this study was to develop a revised comprehensive summary of research needs and their relative priorities for wood transportation structures. This project's scope includes all aspects of wood utilization in application for transportation structures, from tree harvesting to bridge maintenance, rehabilitation, and replacement.

Methodology

Participant Identification

A multi-step methodology was developed to survey a wide range of participants. This methodology consisted of (1) identifying participants, (2) surveying participants, (3) assessing research needs in order of priority, and (4) analyzing data.

The survey was sent to an extensive list of organizations and potential respondents, including state departments of transportation (DOTs), wood industry organizations, wood-product manufacturers, county engineers, academics, and others. Following is a list of respondents by affiliation and location, and the distribution of respondents by entity is illustrated in Figure 1.

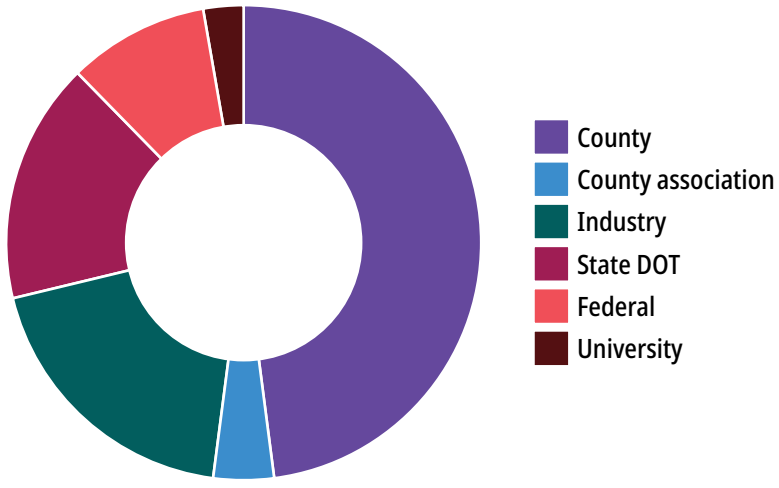

Figure 1.—General affiliations of survey respondents.

General Affiliation and Location of Survey Respondents

County Governments and County Road or Highway Departments by State

- Alabama—Elmore County
- Arizona—Coconino County
- Florida—Polk County
- Illinois—Boone County
- Indiana—Brown County
- Iowa—Cedar County, Clinton County, Guthrie County, Humboldt County, Linn County, Marion County, Plymouth County, Washington County
- Michigan—Barry County, Muskegon County, Dickinson County
- Minnesota—Koochiching County, Otter Tail County, Rock County, St. Louis County
- New York—Ontario County
- North Dakota—Cass County, Walsh County
- Ohio—Logan County
- Oregon—Linn County
- South Dakota—Minnehaha County
- Washington—Snohomish County, Stevens County
- Wisconsin—Clark County, Columbia County

County Associations

- Arizona Association of County Engineers (AACE)
- National Association of County Engineers (NACE), North Carolina
- Wisconsin County Highway Association (WCHA)

State Departments of Transportation (DOT)

- Alaska
- Arkansas
- Minnesota
- Mississippi
- Missouri
- North Dakota
- South Carolina
- South Dakota
- Texas
- Vermont

Industry

- APA—The Engineered Wood Association (California and Washington)
- Conrad Wood Preserving Inc. (Oregon)
- Erickson Engineering (Minnesota)
- Hubbell, Roth & Clark, Inc. (HRC, Michigan)
- Natural Wood Solutions (Mississippi)
- Nisus Corporation (Tennessee)

- Southern Pressure Treaters Association (SPTA, Mississippi)
- Viance (Ohio)
- Koppers (Pennsylvania)
- Wood Preservation (Arizona)
- Western Wood Preservers Institute (WWPI, Washington)
- Wheeler (Minnesota)

Federal Agencies and Locations

- Federal Highway Administration—Delaware, North Carolina
- Forest Service—Montana, New Hampshire, Oregon, Wisconsin

Universities

- Clemson University, South Carolina
- Mississippi State University, Mississippi

Research Needs Assessment

The assessment was conducted by soliciting participants' feedback on research needs statements. Potential participants were contacted using electronic communication, which included a brief introduction to the survey and research needs and a link to access the online survey (see the appendix the survey questions). The electronic communication summarized the purpose of the study and the information requested. Participants were asked to respond to research needs in the following seven categories:

- System Development and Design
- Material Properties
- Preservatives and Protective Measures
- Other Transportation System Structures
- Inspection and Rehabilitation
- Technology and Information Transfer
- Historic Timber Bridges

The initial communication was sent to all study participants, and each participant was encouraged to solicit input from their respective organization. Additional participants were invited through a listserv, which the authors did not have direct access to. The survey was sent to approximately 350 unique email addresses. Of those, 84 responses (24 percent) were received, with varying degrees of completion.

Response Analysis

Each of the seven categories was prefaced by an open-ended question inviting participants to provide research topics of particular interest or requiring special attention. The open-ended questions appeared at the start of each category, ahead of the research needs statements, to capture respondents' thoughts on research needs without first being influenced by the prepared lists of potential research topics. A word study was completed from the received responses to identify recurring themes. The word study and full responses are given in the following section.

In addition to the open-ended questions, participants responded to 84 survey questions about research needs. These questions asked participants to assign a numerical value of 1, 2, 3, 4, or 5 to research needs statements (1 = low priority; 5 = high priority). Using these numerical values, the mean ranking for each

potential project was determined, and an overall ranking of projects was developed. Additionally, projects were ranked within the seven categories.

Open-ended Responses

Before ranking the research needs statements in each category, respondents were asked optional open-ended questions. The word cloud shows the full range of survey respondents' answers and indicates that the most important research topics are design, treatment, and materials (Fig. 2). Other words indicate topics of less but significant importance. The comparison to the numerical analysis of the research needs statements presented in the following section shows good agreement. Overall, the results indicate strong interest in future research on developing more durable timber bridge designs, improving preservative treatments, and advancing strategies to preserve and extend the service life of existing timber bridges.



Figure 2.—Word cloud created from responses to open-ended questions in each category.

The full responses to the open-ended questions at the beginning of each category are presented in this section. These responses are presented as written with minor editorial changes for brevity and consistency. The open-ended responses provide insight, yet the subjectivity of the exercise is clear and shows the value of the ranking exercise to assess the top priorities quantitatively.

System Development and Design

Question: What issue(s) would you like to see addressed with respect to system development and design of timber transportation structures (fastener design criteria and corrosion protection, structural glued laminated timber, structural composite lumber, design aids, timber bridge design criteria, timber bridge serviceability, design criteria for new bridge systems and components)?

Responses:

- Design criteria and serviceability.
- Structural glued laminated timber.
- All allowable stresses for timber design are too low. The allowable horizontal shear for timber pile caps is so low it controls virtually all timber bridge load ratings. I suspect existing values are based on tests of small samples. Our county has conducted its own research on full size new and used members. Our research shows that failure occurs at significantly higher values than the AASHTO allowable stresses.
- Product availability, design aids, service life, and cost benefit analysis.
- Potential use of glulam and engineered lumber materials.
- Approach transitions. Always a big settlement at end of bridge. This is a design issue. Need to also improve the approach.
- Corrosion protection, design aids, timber bridge design criteria, timber bridge serviceability.
- Structural details that enhance long-term performance of timber bridges.
- Timber bridge design criteria, especially incising and rail design.
- To keep timber bridges affordable, solid sawn materials should be considered where practical. There has been preference given to glulam and composites. While they serve a purpose for higher strength needs, they are twice the price of a raw material.
- In-service strengthening of timber girders, in-service FRP repairs of timber, railing design aides for timber to meet MASH TL1, TL2, and TL3 criteria, improvements to LRFD distribution models on timber-slab and timber-girder configurations.
- Standardized preservative treatment of all wood components of the structure.
- Design aids, application of treating industry best management practices in timber bridge specifying.
- Better information regarding lag screws used in timber design, deck connection hardware like deck screws or other, and a better sense of real design criteria for timber bridges with respect to AASHTO LRFD. The timber section of LRFD feels like timber was an afterthought, when it is still a viable material—in its many forms—for construction of both road and especially pedestrian bridges. Also, AASHTO LRFD needs to expand some of the design properties tables to include decay-resistant species such as Alaska Yellow Cedar.
- Structural glued laminated timber, structural composite lumber, and design aids.
- More options for durability and sustainability and carbon storage versus alternative materials.
- Fastener design: timber deck connectors to steel superstructure. Corrosion protection: methods and materials to eliminate corrosion between timber superstructure and timber wearing surface. Design aids: foundations for trail bridges (helical piles). Many modular steel bridges have channels for timber deck; however, designed to HS-20 and 10 mph, does not meet HL-93 for timber trucks, specifically with stringer spacing over 24 in. Replacement deck that will fit into 3.5 in. channels and meet codes. Transverse nail laminated decks work; however, contractors charge more than worth to replace or need high grade decking.
- Bridge design aids for new bridges. Load rating of timber bridges (take over the Forest Service Timber Bridge Analysis and Rating program). Composite action of timber decks and timber beams. Cupping of longitudinal glulam deck panel bridges over time (how to resolve problem).

- Additional protection needs to be incorporated into architectural and engineering principles to minimize decay, weathering, and insect attack. Based on FPInnovations research, there are basic principles to avoid being wood's worst enemy: 4Ds for decay—deflection, drainage, drying, and durable materials; 5Ps for weathering—preparing the surface, preserving against stain and decay, protecting from light, preventing moisture uptake, proactively re-finishing; and 6Ss for insects—suppression, site management, soil barrier, slab/foundation details, structural durability, surveillance and remediation (Stirling and Morris 2015). Innovations and understanding in these areas provide increased service life and safety of any material.
- Increased load capacity, flood plain effect, design examples for structures greater than 40 ft, cost comparison for 40 ft structures alternative materials, software design systems that have open source code to ensure wood is properly assigned design values, secondary remediation for wood and fasteners, inspection methods.

Material Properties

Question: What issue(s) would you like to see addressed with respect to material properties of timber transportation structures (external influences on wood properties, wood design values and properties, lumber grading and yield, composite materials)?

Responses:

- Sustainability.
- Composite materials.
- External influences, composite materials.
- Composite materials such as FRP glulam.
- Lumber grading and yield and composite materials.
- Wood design values and properties, lumber grading and yield.
- Wood design values and properties and composite materials.
- All wood design allowable stresses need to be re-evaluated by testing full size members.
- Material properties to be addressed include updates to LRFD timber design values, wood properties of material made from small-diameter young trees.
- Standards for lumber grade and density for bridge components and treatment quality.
- Update design and related information with respect to new southern pine design values and for copper naphthenate preservative if needed because pentachlorophenol is being phased out.
- Field guide to determine existing species and of timber bridges to help in load rating of bridges.
- Wood preservatives and glues.

Preservatives and Protective Measures

Question: What issue(s) would you like to see addressed with respect to preservative and protective measures of timber transportation structures (field treatment, preservative effects on material properties, environmental considerations for wood preservatives, preservation methods and chemicals, preservative application and use)?

Responses:

- Environmental considerations for preservatives.
- Field treatment, preservative application and use.

- Environmental considerations. Creosote has been banned by my agency due to concerns about impacts on fish.
- Preservation.
- Preservative treatment options.
- I would like to see different field treatments and preservation methods of timber piling.
- Effective preservative treatments that are acceptable to environmental agencies.
- Repair and preservation of existing timber piles. Specifically, preservation activities for timber piles (creosote treated) and at end of life appropriate repair treatments for piles used in bridge bents. The timber bridge inventory is challenging because once deterioration is detected, it may be too late, or the deterioration rate accelerates before funding can be put into place.
- Issues on preservative treatment include best management practices procedures for treating wood and applicability of use over aquatic environments, in-service applications of environmentally friendly treated wood retreatment, compatibility of materials for treatment corrosion against hardware.
- Mostly a comparison of the popular preservation chemical choices for environmental considerations for wood structures.
- Proper preservative for field conditions and quality control.
- Field treatments, environmental considerations.
- Wood preservative treatments.
- With respect to preservative treatment, a comprehensive look is needed to address many issues: (1) availability across the country, (2) use on broad species of timber, (3) impact on hardware from some treatments, (4) a real look at the impact of treatments on aquatic species when timber is used over open waterways—a comprehensive and professional study needed, (5) consideration and adoption of best management practices for the use of treated timber in aquatic environments to ensure standardized treatment practices to get the best materials.
- Field treatment with respect to environmental considerations for wood preservatives.
- Evaluate new preservatives as needed in the course of pentachlorophenol being phased out.
- Less expensive alternatives to fiber reinforced polymer or epoxy repairs/ treatment to piles specifically at fluctuating water lines. Treatment between timber superstructure and timber wearing planks.
- Effectiveness of preservation options versus environmental issues.
- The use of tools to look at impacts of preservatives on aquatic life. Look at different preservatives (waterborne versus oil-based) and how the use of dual treatments, which are popular for railways, can help protect bridges. Impacts of preservatives on glues.

Other Transportation System Structures

Question: What issue(s) would you like to see addressed with respect to other timber transportation system structures (bridge rails, retaining structures, noise barriers)?

Responses:

- Bridge rails, noise barriers.
- Bridge rails.

- Noise barriers.
- Crash tested bridge railing options.
- Crash test different types of timber bridge and curb rails. Details (CAD drawings) for crash tested bridge rails.
- The retaining structures and noise barriers.
- Bridge railing and retaining structures.
- There should be a comprehensive study done on guardrail systems constructed of timber. I was involved in the concept report that secured the use of timber guard structures along the edge of a roadway at Mines of Spain State Recreation Area in Iowa, in 1990 and 1991. The visual effect was noted in the announcement for the Iowa ASCE Civil Engineering Project of the Year award announcement (around 1991) for this roadway project, as well as the in the nomination for the ASCE National Civil Engineering Project of the Year. While the timber guard structures were a product that had been in use previously along roadways, more study of the system would be beneficial for roads in parks and recreation areas, and in national and state forest areas.
- Need to do some MASH testing.
- Need MASH-compliant bridge rail systems for bridges with timber decks.
- Crash-testing of bridge rails to meet MASH criteria for TL-2 and TL-4 needs to be a top priority.
- Crash tested timber rails meeting MASH criteria as well as consideration for low volume railings that are realistic for use in remote settings. With respect to retaining structures, considerations for options that are more constructible, especially where roadway templates are narrow and access is challenging.
- To my knowledge there is not a timber MASH rated bridge rail that has been developed.
- Bridge railing connections for box culverts and modular steel bridges.
- Issues related to other structures to be addressed include barrier selection guide for varying test levels and structure types, applicability for use of timber as headwalls to buried structures.
- Develop standard that is TL2 and TL3 compliant.
- We need to help wood take back these markets, such as retaining walls, noise barriers, and guardrail posts.

Inspection and Rehabilitation

Question: What issue(s) would you like to see addressed with respect to inspection and rehabilitation of timber transportation structures (construction, inspection and in-place evaluation, structural strength and property assessment, maintenance and rehabilitation)?

Responses:

- Maintenance and rehabilitation.
- Inspection of structural strength evaluation of decaying timber pile.
- Issues of property assessment and maintenance and rehabilitation.
- Inspections and structural evaluation of in-service structures.
- Inspection of in-place timber members using nondestructive methods.
- Load rating of timber structures.

- Better methods for assessing remaining structural section for in-service timber members.
- We have a PD400 RESI micro drill from IML. The micro drill can measure the drill resistance and the feed force (force required to penetrate the wood). I would like to see a correlation developed between the data from our micro drill and pile capacity for a bridge. Looking for an equation that could give an estimate of the remaining pile capacity.
- Nationally recognized standards for inspection of timber piles that identify testing methods and frequencies. With many timber piles deteriorating from the inside out, it is difficult to assess the condition of the pile without using a resistograph or other technology. Not many agencies know of this technology, and even fewer require it or something similar. Many agencies want to limit the testing because of concern for creating problems by providing access to the interior of the pile (like an incremental borer). Also, appropriate analysis methods to determine the capacity of piles, especially when there is rot in the center of the pile. It appears agencies may be just doing a P/A analysis.
- Issues of inspection to address include improvement to descriptors on evaluating severity of defects, tips and techniques for normalizing inspection coding, in-service determination of design values to support load rating or permit-overload assessment of existing structures, methods for in-service repair or strengthening of existing structures.
- Identification of new and existing innovative nondestructive evaluation techniques.
- In-service inspection and remediation.
- Concern about ASTM D3737 requiring strength reductions of pre-1970s glulam members. The evaluation of these reductions is in the hands of owners, and it can be costly to evaluate whether it is reasonable to take this reduction. This can decrease the overall strength of bridges by 25 percent when they have been performing for many years at full capacity with no signs of distress. Would also be good to have a better understanding of and ability to apply results of nondestructive testing such as resistograph readings to apply to strength of wood for use in load ratings. Want to see timber considered as a viable construction material instead of being overlooked versus steel and concrete.
- Field guide for determining species and grade of existing timber bridges.
- Oregon State Utility Pole Research Cooperative has a lot of information on remedial treatments. We need to expand this and determine how to help simplify and perform maintenance on wood bridges and other infrastructure including identifying rot in the structure.

Technology and Information Transfer

Question: What issue(s) would you like to see addressed with respect to technology and information transfer of timber transportation structures (information distribution, design software)?

Responses:

- Distribution of resources and potentially some form of basic design software for some spans.
- Issues to address include availability of design stresses and timber assessment in design software, centralized distribution of information resources.
- Software in line with AASHTO LRFD with respect to timber that comprehensively considers needed reduction factors, traffic levels, and other factors affecting and complicating timber design and evaluation.

- Design software.
- Information distribution, especially carbon sequestration.
- Infrared analysis of existing timber structures and relative deterioration.

Historic Timber Bridges

Question: What issue(s) would you like to see addressed with respect to historic timber bridges (covered bridges, historical documentation)?

Responses:

- Develop maintenance and rehabilitation guidelines for replacing deteriorated timber members while still maintaining the original character of the structure.
- Impact damage and prevention.
- Documentation and sharing of resources amongst peer owners.
- The Forest Service has historic timber bridges that would add to the conversation.
- Covered bridges and historic wood inspection, treatment, and maintenance.

Results of Ranking Exercise

The results obtained from the ranking exercise of the 84 research needs statements are presented in three formats based on priorities assigned by participants. The first format is the overall priority rank of all research needs without regard to categories (Table 1). The second format is the relative ranking of each research need within the original seven research categories (Tables 2 through 8). The third format uses the same ranking values as the second format and shows more clearly the overall ranking of the high-priority research needs (Tables 9 through 15).

Ranking of Research Needs by Overall Priority

Table 1 gives the rankings for each of the 84 research needs statements in all categories combined. Rankings are based on the numerical value for each research need, ranging from 5 (high priority) to 1 (low priority). The participants' responses ranged from 4.43 to 2.70.

Table 1.—All research needs statements ranked by score

Rank	Research needs statement	Score
1	Investigate methods for determining the post-decay strength of timber components.	4.43
2	Development of new railing systems for timber bridge decks (and approach guardrails) that meet current crash-testing criteria standards.	4.40
3	With increasing restrictions on the preservative creosote, investigate new alternative creosote formulations suitable for bridge applications.	4.39
4	Develop training courses on timber bridge inspection/rehabilitation.	4.36
5	Develop new inspection techniques for detecting internal deterioration with scanning technologies.	4.29
6	Develop and test new wood preservative chemicals that do not pose adverse environmental hazards.	4.18
7	Develop guide for timber bridge long-term performance evaluation.	4.13

(continued on next page)

Table 1.—*(continued)*

Rank	Research needs statement	Score
8	Develop guidance for timber substructure designs.	4.09
9	Prepare a comprehensive manual on maintenance practices for timber bridges.	4.07
10	Develop preservatives that enhance the aesthetics of timbers and provide 100 years of life while being economical and environmentally acceptable.	4.05
11	Evaluate the life cycle assessment (LCA) of timber bridges which focuses on the overall environmental impacts.	4.03
12	Evaluate how timber bridges can be used in accelerated bridge construction projects.	4.00
13	Explore new surface coatings, claddings, or encapsulation techniques to prevent deterioration due to elevated moisture contents.	4.00
14	Develop methods and comprehensive guidelines for restoring, increasing the capacity of, and replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.	3.98
15	Evaluate performance of modern, conventional wood preservatives (e.g., CCA, copper naphthenate, ACQ, copper azole, etc.) in structural composite lumbers.	3.95
16	Develop a density gauge to identify interior areas of decay or rotten timber.	3.95
17	Develop a comprehensive inspection manual specific to timber bridge superstructure type.	3.95
18	Summarize method of construction for various timber superstructures and substructures, including case histories.	3.95
19	Develop and evaluate economical, long lasting methods for sealing and protecting wood against moisture (especially end grain) when prolonged moisture exposure is likely to occur.	3.92
20	Develop educational materials for use in colleges and trade schools.	3.91
21	Update comprehensive bridge manual to meet AASHTO LRFD specifications.	3.91
22	Develop standard designs, details, and specifications for timber bridge substructures and culverts.	3.90
23	Develop schemes and details for increasing the load carrying capacity of existing and new timber bridges.	3.88
24	Investigate the use of mass timber (laminated timber, CLT, mass plywood) materials for new and existing timber bridges.	3.87
25	Improve specifications for timber bridge construction in AASHTO LRFD.	3.87
26	Investigate the use of wood-based composites and their long-term performance in bridge structures.	3.85
27	Develop design aids for various timber bridge superstructure designs for bridge owners and decision makers.	3.84
28	Develop guidelines for economically optimized material requirements for specific timber bridge types.	3.81
29	Develop design properties needed for modeling the structural behavior of CLT materials in bridge deck applications.	3.81
30	Investigate and determine methods for evaluating the residual bending strength of beams that have split or failed horizontal shear.	3.79
31	Develop a database of timber bridges, by type and material, that have been constructed in the United States and Canada over the past 30 years.	3.73

(continued on next page)

Table 1.—*(continued)*

Rank	Research needs statement	Score
32	Evaluate the life cycle cost assessment (LCCA) of timber bridges which focuses solely on financial costs.	3.71
33	Evaluate AASHTO LRFD design specifications for timber slab type bridges.	3.68
34	Develop updated standard superstructure plans to meet AASHTO LRFD specifications.	3.68
35	Develop and evaluate alternative methods of wood preservation, other than chemical preservatives, which protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).	3.66
36	Develop an informational summary on the restrictions, use recommendations, and use of wood preservatives.	3.65
37	Evaluate the compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives before gluing.	3.61
38	Establish the relationship between age, traffic volume, exposure to water and pollution, other factors, and the load carrying capacity for various structural systems.	3.59
39	Evaluate the effect of preservatives in contact with steel components.	3.57
40	Evaluate current AASHTO LRFD live load deflection criteria for various timber superstructure and deck types based on structural behavior, wearing surface performance, and human response.	3.52
41	Develop techniques for the easy retrofit/repair of damaged timber bridge rails.	3.52
42	Develop new treatment options for mass timber products (CLT) both before and after gluing.	3.51
43	Study the means of improving composite action between timber beams and timber decks.	3.48
44	Develop aesthetically pleasing timber (and/or combination of timber and steel) roadside barrier systems that meet safety performance guidelines.	3.47
45	Develop standardized methods for load testing and load rating historic timber bridges.	3.47
46	Develop methods for determining the embedment length of timber piles.	3.45
47	Develop standard designs for timber retaining walls and evaluate their field performance.	3.43
48	Evaluate the suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.	3.42
49	Develop models for long-term behavior of mechanical connections for glulam bridge components.	3.41
50	Develop methods to retrofit and strengthen timber piles (possibly with FRP) that are prone to debris-hit damage.	3.40
51	Perform more testing of various species and sizes of wood to determine the flat-wise use factors.	3.37
52	Develop methods for reducing live load deflection of AASHTO-approved timber bridges.	3.35
53	Investigate the feasibility of gluing wood treated with creosote or other oil-borne preservatives to improve treatment and durability of large glulam members.	3.35
54	Investigate and revise existing treating standards to limit the quantity of untreatable heartwood and restate moisture content requirements to reflect maximum values rather than average values.	3.33
55	Evaluate the suitability of timber connections subjected to dynamic loading.	3.29
56	Develop underwater and under-earth inspection equipment.	3.29

(continued on next page)

Table 1.—*(continued)*

Rank	Research needs statement	Score
57	Develop and field-evaluate new methods for shear transfer between glulam deck panels.	3.26
58	Improve timber glulam deck-to-steel girder installation procedures with a more effective connection system.	3.26
59	Establish methods to determine the residual capacity of structural wood members in historic covered bridges.	3.26
60	Evaluate the structural behavior and field performance of historic timber arch and/or timber truss bridges that remain in service.	3.26
61	Develop portable timber bridges for temporary needs (road closures, disasters, etc.).	3.24
62	Determine the level of lateral support provided for steel beams by different timber deck systems.	3.23
63	Investigate the use of FRP with timber (e.g., economic viability, effect of FRP on structural stiffness, etc.).	3.23
64	Develop effective drainage detailing by timber bridge superstructure type and bridge curb/rail system.	3.23
65	Assess the value/effectiveness of existing NDE devices (particularly around connection).	3.22
66	Develop structural health monitoring systems for timber bridges using smart technologies.	3.22
67	Develop a design guide for the replacement of historic short-span timber bridges using glulam components.	3.21
68	Develop new methods of protecting bridges from fire damage.	3.13
69	Develop technical guidance for load rating historic short-span timber bridges based upon on-site inspection and live load testing data.	3.11
70	Develop design criteria for timber arches and trusses for submission to AASHTO.	3.06
71	Develop supplementary inspection data for timber bridges using drone-based technologies.	3.05
72	Evaluate the structural behavior and field performance of historic timber-concrete-composite (TCC) bridges that remain in service.	3.05
73	Develop new methods of providing corrosion protection for steel hardware and stress-laminated bridge stressing bars, including mechanical protection, epoxy coatings, galvanizing, and cathodic protection.	3.05
74	Develop improved/specific grading rules for timber guardrail posts.	3.03
75	Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.	3.00
76	Develop round post roadside guardrail systems and investigate market opportunity.	3.00
77	Develop methods for fastening wood decks to steel and concrete stringers for both new construction and for replacement of decks.	3.00
78	Develop lightweight floor replacement systems for covered bridges.	3.00
79	Develop methods and design criteria for longitudinally stress laminating transverse timber decks.	2.94
80	Develop prefabricated sound barriers/retaining walls.	2.90
81	Develop standard designs and evaluate the field performance of noise barriers constructed of timber, and of timber with other materials.	2.80

(continued on next page)

Table 1.—*(continued)*

Rank	Research needs statement	Score
82	Develop durable field sensors to measure in-situ wood moisture content and performance information for load-carrying members on covered bridges.	2.80
83	Investigate the effectiveness of using different kind of post-tensioning rods (e.g., graphite or other composite materials).	2.77
84	Study the applicability of composite materials made of wood and other materials to resist the effects of vessel or vehicle impacts (e.g., bridge pier protection systems, fender components in docks, guardrails, etc.).	2.70

Ranking of Research Needs Within Each Category

Tables 2 through 8 show the research needs statements ranked within each of the seven categories using the same numerical values used in Table 1. The numerical rankings of each of the individual categories ranged from 4.43 to 2.70.

Table 2.—Research needs statements in the System Development and Design category, ranked by score

Rank	Research needs statement	Score
1	Develop guide for timber bridge long-term performance evaluation.	4.13
2	Evaluate the life cycle assessment (LCA) of timber bridges which focuses on the overall environmental impacts.	4.03
3	Evaluate how timber bridges can be used in accelerated bridge construction projects.	4.00
4	Develop standard designs, details, and specifications for timber bridge substructures and culverts.	3.90
5	Investigate the use of mass timber (laminated timber, CLT, mass plywood) materials for new and existing timber bridges.	3.87
6	Improve specifications for timber bridge construction in AASHTO LRFD.	3.87
7	Develop design aids for various timber bridge superstructure designs for bridge owners and decision makers.	3.84
8	Develop guidelines for economically optimized material requirements for specific timber bridge types.	3.81
9	Evaluate the life cycle cost assessment (LCCA) of timber bridges which focuses solely on financial costs.	3.71
10	Evaluate AASHTO LRFD design specifications for timber slab type bridges.	3.68
11	Evaluate the compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives before gluing.	3.61
12	Evaluate current AASHTO LRFD live load deflection criteria for various timber superstructure and deck types based on structural behavior, wearing surface performance, and human response.	3.52
13	Study the means of improving composite action between timber beams and timber decks.	3.48
14	Develop methods for reducing live load deflection of AASHTO-approved timber bridges.	3.35
15	Evaluate the suitability of timber connections subjected to dynamic loading.	3.29
16	Develop and field-evaluate new methods for shear transfer between glulam deck panels.	3.26

(continued on next page)

Table 2.—*(continued)*

Rank	Research needs statement	Score
17	Improve timber glulam deck-to-steel girder installation procedures with a more effective connection system.	3.26
18	Determine the level of lateral support provided for steel beams by different timber deck systems.	3.23
19	Investigate the use of FRP with timber (e.g., economic viability, effect of FRP on structural stiffness, etc.).	3.23
20	Develop effective drainage detailing by timber bridge superstructure type and bridge curb/rail system.	3.23
21	Develop new methods of protecting bridges from fire damage.	3.13
22	Develop design criteria for timber arches and trusses for submission to AASHTO.	3.06
23	Develop new methods for providing corrosion protection for steel hardware and stress-laminated bridge stressing bars, including mechanical protection, epoxy coatings, galvanizing, and cathodic protection.	3.03
24	Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.	3.00
25	Develop methods and design criteria for longitudinally stress laminating transverse timber decks.	2.94
26	Investigate the effectiveness of using different kind of post-tensioning rods (e.g., graphite or other composite materials).	2.77

Table 3.—Research needs statements in the System Development and Design category, ranked by score

Rank	Research needs statement	Score
1	Explore new surface coatings, claddings, or encapsulation techniques to prevent deterioration due to elevated moisture contents.	4.00
2	Investigate the use of wood-based composites and their long-term performance in bridge structures.	3.85
3	Develop design properties needed for modeling the structural behavior of CLT materials in bridge deck applications.	3.81
4	Establish the relationship between age, traffic volume, exposure to water and pollution, other factors, and the load carrying capacity for various structural systems.	3.59
5	Develop models for long-term behavior of mechanical connections for glulam bridge components.	3.41
6	Perform more testing of various species and sizes of wood to determine the flat-wise use factors.	3.37

Table 4.—Research needs statements in the Preservatives and Protective Measures category, ranked by score

Rank	Research needs statement	Score
1	With increasing restrictions on the preservative creosote, investigate new alternative creosote formulations suitable for bridge applications.	4.39
2	Develop and test new wood preservative chemicals that do not pose adverse environmental hazards.	4.18
3	Develop preservatives that enhance the aesthetics of timbers and provide 100 years life while being economical and environmentally acceptable.	4.05
4	Evaluate performance of modern, conventional wood preservatives (e.g., CCA, copper naphthenate, ACQ, copper azole, etc.) in structural composite lumbers.	3.95
5	Develop and evaluate economical, long lasting methods for sealing and protecting wood against moisture (especially end grain) when prolonged moisture exposure is likely to occur.	3.92
6	Develop and evaluate alternative methods of wood preservation, other than chemical preservatives, which protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).	3.66
7	Develop an informational summary on the restrictions, use recommendations, and use of wood preservatives.	3.65
8	Evaluate the effect of preservatives in contact with steel components.	3.57
9	Develop new treatment options for mass timber products (CLT) both before and after gluing.	3.51
10	Evaluate the suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.	3.42
11	Investigate the feasibility of gluing wood treated with creosote or other oil-borne preservatives to improve treatment and durability of large glulam members.	3.35
12	Investigate and revise existing treating standards to limit the quantity of untreatable heartwood and restate moisture content requirements to reflect maximum values rather than average values.	3.33

Table 5.—Research needs statements in the Other Transportation System Structures category, ranked by score

Rank	Research needs statement	Score
1	Development of new railing systems for timber bridge decks (and approach guardrails) that meet current crash-testing criteria standards.	4.43
2	Develop aesthetically pleasing timber (and/or combination of timber and steel) roadside barrier systems that meet safety performance guidelines.	3.47
3	Develop standard designs for timber retaining walls and evaluate their field performance.	3.43
4	Develop portable timber bridges for temporary needs (road closures, disasters, etc.).	3.24
5	Develop improved/specific grading rules for timber guardrail posts.	3.03
6	Develop round post roadside guardrail systems and investigate market opportunity.	3.00
7	Develop prefabricated sound barriers/retaining walls.	2.90
8	Develop standard designs and evaluate the field performance of noise barriers constructed of timber, and of timber with other materials.	2.80
9	Study the applicability of composite materials made of wood and other materials to resist the effects of vessel or vehicle impacts (e.g., bridge pier protection systems, fender components in docks, guardrails, etc.).	2.70

Table 6.—Research needs statements in the Inspection and Rehabilitation category, ranked by score

Rank	Research needs statement	Score
1	Investigate methods for determining the post-decay strength of timber components.	4.43
2	Develop new inspection techniques for detecting internal deterioration with scanning technologies.	4.29
3	Prepare a comprehensive manual on maintenance practices for timber bridges.	4.07
4	Develop methods and comprehensive guidelines for restoring, increasing the capacity of, and replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.	3.98
5	Develop a density gauge to identify interior areas of decay or rotten timber.	3.95
6	Develop a comprehensive inspection manual specific to timber bridge superstructure type.	3.95
7	Develop schemes and details for increasing the load carrying capacity of existing and new timber bridges.	3.88
8	Investigate and determine methods for evaluating the residual bending strength of beams that have split or failed horizontal shear.	3.79
9	Develop techniques for the easy retrofit/repair of damaged timber bridge rails.	3.52
10	Develop methods for determining the embedment length of timber piles.	3.45
11	Develop methods to retrofit and strengthen timber piles (possibly with FRP) that are prone to debris-hit damage.	3.45
12	Develop underwater and under-earth inspection equipment.	3.40
13	Assess the value/effectiveness of existing NDE devices (particularly around connection).	3.22
14	Develop structural health monitoring systems for timber bridges using smart technologies.	3.22
15	Develop supplementary inspection data for timber bridges using drone-based technologies.	3.05
16	Develop methods for fastening wood decks to steel and concrete stringers for both new construction and for replacement of decks.	3.00
17	Develop durable field sensors to measure in-situ wood moisture content and performance information for load-carrying members on covered bridges.	2.70

Table 7.—Research needs statements in the Technology and Information Transfer category, ranked by score

Rank	Research needs statement	Score
1	Develop training courses on timber bridge inspection/rehabilitation.	4.36
2	Develop guidance for timber substructure designs.	4.09
3	Summarize method of construction for various timber superstructures and substructures, including case histories.	3.95
4	Develop educational materials for use in colleges and trade schools.	3.91
5	Update comprehensive bridge manual to meet AASHTO LRFD specifications.	3.91
6	Develop a database of timber bridges, by type and material, that have been constructed in the United States and Canada over the past 30 years.	3.73
7	Develop updated standard superstructure plans to meet AASHTO LRFD specifications.	3.68

Table 8.—Research needs statements in the Historic Timber Bridges category, ranked by score

Rank	Research needs statement	Score
1	Develop standardized methods for load testing and load rating historic timber bridges.	3.47
2	Evaluate the structural behavior and field performance of historic timber arch and/or timber truss bridges that remain in service.	3.26
3	Establish methods to determine the residual capacity of structural wood members in historic covered bridges.	3.26
4	Evaluate the structural behavior and field performance of historic timber-concrete-composite (TCC) bridges that remain in service.	3.26
5	Develop a design guide for the replacement of historic short-span timber bridges using glulam components.	3.21
6	Develop technical guidance for load rating historic short-span timber bridges based upon on-site inspection and live load testing data.	3.11
7	Develop lightweight floor replacement systems for covered bridges.	3.00

Ranking of Research Needs by Category Based on High Priority Objectives

The data were further analyzed, and individual research needs were regrouped as needed into one of the seven categories. The rankings within each category were organized from high priority to low and include the 84 values shown in Table 1. Tables 9 through 15 show more clearly the distribution of the high-priority objectives within each category.

Table 9.—Research needs statements in the System Development and Design category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	Develop guide for timber bridge long-term performance evaluation.	7
2	Evaluate the life cycle assessment (LCA) of timber bridges which focuses on the overall environmental impacts.	11
3	Evaluate how timber bridges can be used in accelerated bridge construction projects.	12
4	Develop standard designs, details, and specifications for timber bridge substructures and culverts.	22
5	Investigate the use of mass timber (laminated timber, CLT, mass plywood) materials for new and existing timber bridges.	24
6	Improve specifications for timber bridge construction in AASHTO LRFD.	25
7	Develop design aids for various timber bridge superstructure designs for bridge owners and decision makers.	27
8	Develop guidelines for economically optimized material requirements for specific timber bridge types.	28
9	Evaluate the life cycle cost assessment (LCCA) of timber bridges which focuses solely on financial costs.	32

(continued on next page)

Table 9.—*(continued)*

Category rank	Research needs statement	Overall priority rank
10	Evaluate AASHTO LRFD design specifications for timber slab type bridges.	33
11	Evaluate the compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives before gluing.	37
12	Evaluate current AASHTO LRFD live load deflection criteria for various timber superstructure and deck types based on structural behavior, wearing surface performance, and human response.	40
13	Study the means of improving composite action between timber beams and timber decks.	43
14	Develop methods for reducing live load deflection of AASHTO-approved timber bridges.	52
15	Evaluate the suitability of timber connections subjected to dynamic loading.	55
16	Develop and field-evaluate new methods for shear transfer between glulam deck panels.	57
17	Improve timber glulam deck-to-steel girder installation procedures with a more effective connection system.	58
18	Determine the level of lateral support provided for steel beams by different timber deck systems.	63
19	Investigate the use of FRP with timber (e.g., economic viability, effect of FRP on structural stiffness, etc.).	64
20	Develop effective drainage detailing by timber bridge superstructure type and bridge curb/rail system.	65
21	Develop new methods of protecting bridges from fire damage.	69
22	Develop design criteria for timber arches and trusses for submission to AASHTO.	71
23	Develop new methods for providing corrosion protection for steel hardware and stress-laminated bridge stressing bars, including mechanical protection, epoxy coatings, galvanizing, and cathodic protection.	73
24	Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.	75
25	Develop methods and design criteria for longitudinally stress laminating transverse timber decks.	79
26	Investigate the effectiveness of using different kind of post-tensioning rods (e.g., graphite or other composite materials).	82

Table 10.—Research needs statements in the Material Properties category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	Explore new surface coatings, claddings, or encapsulation techniques to prevent deterioration due to elevated moisture contents.	13
2	Investigate the use of wood-based composites and their long-term performance in bridge structures.	26

(continued on next page)

Table 10.—*(continued)*

Category rank	Research needs statement	Overall priority rank
3	Develop design properties needed for modeling the structural behavior of CLT materials in bridge deck applications.	29
4	Establish the relationship between age, traffic volume, exposure to water and pollution, other factors, and the load carrying capacity for various structural systems.	38
5	Develop models for long-term behavior of mechanical connections for glulam bridge components.	49
6	Perform more testing of various species and sizes of wood to determine the flat-wise use factors.	51

Table 11.—Research needs statements in the Preservatives and Protective Measures category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	With increasing restrictions on the preservative creosote, investigate new alternative creosote formulations suitable for bridge applications.	3
2	Develop and test new wood preservative chemicals that do not pose adverse environmental hazards.	6
3	Develop preservatives that enhance the aesthetics of timbers and provide 100 years life while being economical and environmentally acceptable.	10
4	Evaluate performance of modern, conventional wood preservatives (e.g., CCA, copper naphthenate, ACQ, copper azole, etc.) in structural composite lumbers.	15
5	Develop and evaluate economical, long lasting methods for sealing and protecting wood against moisture (especially end grain) when prolonged moisture exposure is likely to occur.	19
6	Develop and evaluate alternative methods of wood preservation, other than chemical preservatives, which protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).	35
7	Develop an informational summary on the restrictions, use recommendations, and use of wood preservatives.	36
8	Evaluate the effect of preservatives in contact with steel components.	39
9	Develop new treatment options for mass timber products (CLT) both before and after gluing.	42
10	Evaluate the suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.	48
11	Investigate the feasibility of gluing wood treated with creosote or other oil-borne preservatives to improve treatment and durability of large glulam members.	53
12	Investigate and revise existing treating standards to limit the quantity of untreatable heartwood and restate moisture content requirements to reflect maximum values rather than average values.	54

Table 12.—Research needs statements in the Other Transportation System Structures category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	Development of new railing systems for timber bridge decks (and approach guardrails) that meet current crash-testing criteria standards.	2
2	Develop aesthetically pleasing timber (and/or combination of timber and steel) roadside barrier systems that meet safety performance guidelines.	44
3	Develop standard designs for timber retaining walls and evaluate their field performance.	47
4	Develop portable timber bridges for temporary needs (road closures, disasters, etc.).	62
5	Develop improved/specific grading rules for timber guardrail posts.	74
6	Develop round post roadside guardrail systems and investigate market opportunity.	76
7	Develop prefabricated sound barriers/retaining walls.	80
8	Develop standard designs and evaluate the field performance of noise barriers constructed of timber, and of timber with other materials.	81
9	Study the applicability of composite materials made of wood and other materials to resist the effects of vessel or vehicle impacts (e.g., bridge pier protection systems, fender components in docks, guardrails, etc.).	83

Table 13.—Research needs statements in the Inspection and Rehabilitation category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	Investigate methods for determining the post-decay strength of timber components.	1
2	Develop new inspection techniques for detecting internal deterioration with scanning technologies.	5
3	Prepare a comprehensive manual on maintenance practices for timber bridges.	9
4	Develop methods and comprehensive guidelines for restoring, increasing the capacity of, and replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.	14
5	Develop a density gauge to identify interior areas of decay or rotten timber.	16
6	Develop a comprehensive inspection manual specific to timber bridge superstructure type.	17
7	Develop schemes and details for increasing the load carrying capacity of existing and new timber bridges.	23
8	Investigate and determine methods for evaluating the residual bending strength of beams that have split or failed horizontal shear.	30
9	Develop techniques for the easy retrofit/repair of damaged timber bridge rails.	41
10	Develop methods for determining the embedment length of timber piles.	46

(continued on next page)

Table 13.—*(continued)*

Category rank	Research needs statement	Overall priority rank
11	Develop methods to retrofit and strengthen timber piles (possibly with FRP) that are prone to debris-hit damage.	50
12	Develop underwater and under-earth inspection equipment.	56
13	Assess the value/effectiveness of existing NDE devices (particularly around connection).	66
14	Develop structural health monitoring systems for timber bridges using smart technologies.	67
15	Develop supplementary inspection data for timber bridges using drone-based technologies.	72
16	Develop methods for fastening wood decks to steel and concrete stringers for both new construction and for replacement of decks.	77
17	Develop durable field sensors to measure in-situ wood moisture content and performance information for load-carrying members on covered bridges.	84

Table 14.—Research needs statements in the Technology and Information Transfer category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	Develop training courses on timber bridge inspection/rehabilitation.	4
2	Develop guidance for timber substructure designs.	8
3	Summarize method of construction for various timber superstructures and substructures, including case histories.	18
4	Develop educational materials for use in colleges and trade schools.	20
5	Update comprehensive bridge manual to meet AASHTO LRFD specifications.	21
6	Develop a database of timber bridges, by type and material, that have been constructed in the United States and Canada over the past 30 years.	31
7	Develop updated standard superstructure plans to meet AASHTO LRFD specifications.	34

Table 15.—Research needs statements in the Historic Timber Bridges category, ranked by category and overall priority

Category rank	Research needs statement	Overall priority rank
1	Develop standardized methods for load testing and load rating historic timber bridges.	45
2	Evaluate the structural behavior and field performance of historic timber arch and/or timber truss bridges that remain in service.	59
3	Establish methods to determine the residual capacity of structural wood members in historic covered bridges.	60

(continued on next page)

Table 15.—*(continued)*

Category rank	Research needs statement	Overall priority rank
4	Evaluate the structural behavior and field performance of historic timber-concrete-composite (TCC) bridges that remain in service.	61
5	Develop a design guide for the replacement of historic short-span timber bridges using glulam components.	68
6	Develop technical guidance for load rating historic short-span timber bridges based upon on-site inspection and live load testing data.	70
7	Develop lightweight floor replacement systems for covered bridges.	78

Analysis of Results for High-Priority Objectives

The possible average score for any research needs statement could be as high as 5.0 or as low as 1.0. A score of 4.0 or higher was in the upper 25 percent of possible scores. Using 4.0 as an arbitrary score for high-priority consideration, Figure 3, Table 16, and Table 17 were developed to show the research needs statements with an average score of 4.0 or higher. Of the 84 topics identified, 13 had a score of 4.0. At least one needs statement from six of the seven categories had an average score of 4.0 or higher; only the Historic Timber Bridges category had no topics that scored 4.0 or higher.

Figure 3 shows the range of scores in each category. The threshold line highlights scores above 4.0. Table 16 lists the research needs statements with an average score of 4.0 or higher ranked by overall score. Table 17 lists the statements with an average score of 4.0 or higher ranked by overall score and grouped into categories.

Review of the highest-priority objectives reveals that stakeholders' priorities include the immediate needs of inspection and rehabilitation as well as forward-looking strategies to enhance durability and environmental compliance. These dual priorities reflect the current balance in the industry between preserving existing infrastructure and advancing the design and materials for future projects. Additionally, the strong emphasis on technology transfer and training underscores the importance of equipping engineers and practitioners with the knowledge and tools needed to implement emerging solutions effectively. These insights provide clear guidance for structuring a well-rounded, responsive research agenda moving forward.

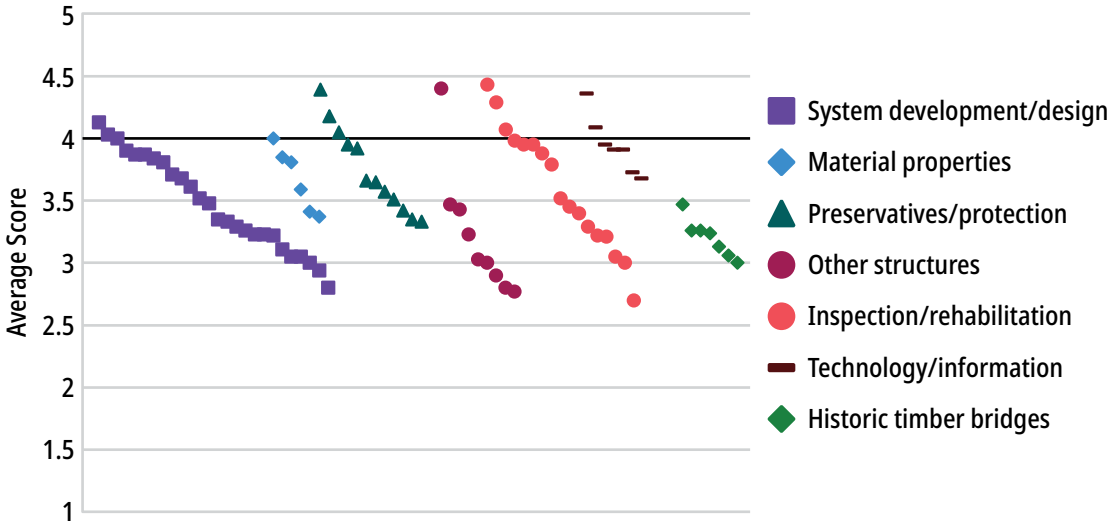

Figure 3.—Range of scores by category. The threshold line at 4.0 highlights the upper 25 percent of possible scores.

Table 16.—Research needs statements in all categories with an average score of 4.0 or higher, ranked by score

Rank	Research needs statement	Category	Score
1	Investigate methods for determining the post-decay strength of timber components.	Inspection and Rehabilitation	4.43
2	Development of new railing systems for timber bridge decks (and approach guardrails) that meet current crash-testing criteria standards.	Other Transportation System Structures	4.40
3	With increasing restrictions on the preservative creosote, investigate new alternative creosote formulations suitable for bridge applications.	Preservatives and Protective Measures	4.39
4	Develop training courses on timber bridge inspection/rehabilitation.	Technology and Information Transfer	4.36
5	Develop new inspection techniques for detecting internal deterioration with scanning technologies.	Inspection and Rehabilitation	4.29
6	Develop and test new wood preservative chemicals that do not pose adverse environmental hazards.	Preservatives and Protective Measures	4.18
7	Develop guide for timber bridge long-term performance evaluation.	System Development and Design	4.13
8	Develop guidance for timber substructure designs.	Technology and Information Transfer	4.09
9	Prepare a comprehensive manual on maintenance practices for timber bridges.	Inspection and Rehabilitation	4.07
10	Develop preservatives that enhance the aesthetics of timbers and provide 100 years life while being economical and environmentally acceptable.	Preservatives and Protective Measures	4.05
11	Evaluate the life cycle assessment (LCA) of timber bridges which focuses on the overall environmental impacts.	System Development and Design	4.03
12	Evaluate how timber bridges can be used in accelerated bridge construction projects.	System Development and Design	4.00
13	Explore new surface coatings, claddings, or encapsulation techniques to prevent deterioration due to elevated moisture contents.	Material Properties	4.00

Table 17.—Research needs statements with an average score of 4.0 or higher grouped by category and ranked by score within each category

Rank	Research needs statement	Category	Score
7	Develop guide for timber bridge long-term performance evaluation.	System Development and Design	4.13
11	Evaluate the life cycle assessment (LCA) of timber bridges which focuses on the overall environmental impacts.	System Development and Design	4.03
12	Evaluate how timber bridges can be used in accelerated bridge construction projects.	System Development and Design	4.00
13	Explore new surface coatings, claddings, or encapsulation techniques to prevent deterioration due to elevated moisture contents.	Material Properties	4.00
3	With increasing restrictions on the preservative creosote, investigate new alternative creosote formulations suitable for bridge applications.	Preservatives and Protective Measures	4.39
6	Develop and test new wood preservative chemicals that do not pose adverse environmental hazards.	Preservatives and Protective Measures	4.18
10	Develop preservatives that enhance the aesthetics of timbers and provide 100 years life while being economical and environmentally acceptable.	Preservatives and Protective Measures	4.05
2	Development of new railing systems for timber bridge decks (and approach guardrails) that meet current crash-testing criteria standards.	Other Transportation System Structures	4.40
1	Investigate methods for determining the post-decay strength of timber components.	Inspection and Rehabilitation	4.43
5	Develop new inspection techniques for detecting internal deterioration with scanning technologies.	Inspection and Rehabilitation	4.29
9	Prepare a comprehensive manual on maintenance practices for timber bridges.	Inspection and Rehabilitation	4.07
4	Develop training courses on timber bridge inspection/rehabilitation.	Technology and Information Transfer	4.36
8	Develop guidance for timber substructure designs.	Technology and Information Transfer	4.09

Concluding Remarks

Research related to the development of wood transportation structures has historically lagged behind that of other materials. However, through sustained collaboration among the Forest Service, the Federal Highway Administration, and numerous public and private partners, substantial progress has been made in advancing timber bridge technologies and expanding their application across rural and urban infrastructure. The findings of this updated research needs assessment demonstrate both the depth and breadth of opportunities to further enhance the performance, durability, and sustainability of wood transportation structures.

The priorities identified in this study reflect not only longstanding challenges, such as wood preservation and structural performance, but also emerging themes including accelerated bridge construction, smart monitoring technologies, and environmental considerations associated with material selection and maintenance. These evolving priorities underscore the need for continued research investments that align with national goals for sustainable infrastructure, climate resilience,

and rural economic development. Importantly, the preservation of historic timber structures remains a unique opportunity to safeguard cultural heritage while applying modern engineering solutions.

The information compiled through this assessment will directly inform the Forest Service and Federal Highway Administration in shaping future research programs. As the industry evolves, new high-priority projects will undoubtedly surface, and this living roadmap will continue to be refined through ongoing engagement with stakeholders. By fostering an open exchange of ideas and maintaining close collaboration between researchers, practitioners, and policymakers, the wood transportation community can maximize the impact of its efforts, ensuring that wood remains a viable, forward-thinking material for the nation's transportation infrastructure.

Acknowledgments

The authors of this report wish to thank all the participants in the study.

Literature Cited

Wipf, T.J.; Ritter, M.A.; Duwadi, S.R.; Moody, R.C. 1993. Development of six-year research needs assessment for timber transportation structures. Gen. Tech. Rep. FPL-GTR-74. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 44 p. https://doi.org/10.2737/FPL-GTR-74.

Ritter, M.A.; Duwadi, S.R. 1998. Research accomplishments for wood transportation structures based on a national research needs assessment. Gen. Tech. Rep. FPL-GTR-105. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 30 p. https://doi.org/10.2737/FPL-GTR-105.

Appendix: Participant Survey

Introductory Email to Potential Participants

The survey linked below is being completed as part of the ongoing study, Timber Transportation Structures Research Needs Assessment, conducted through a cooperative agreement between Iowa State University and the USDA Forest Products Laboratory. With your input we will be able to identify, describe, and prioritize a list of research needs that will serve as a basis for developing and funding research related to the use of timber in transportation structures.

The needs statements have been categorized into seven individual categories. Please complete the survey for the category or categories you are most closely tied and/or interested.

Thank you for your participation.

Online Survey Questions

2021 Timber in Transportation Research Needs

Introduction

This survey is being completed as part of the ongoing study. "Timber Transportation Structures Research Needs Assessment," conducted through a cooperative agreement between Iowa State University and the USDA Forest Products Laboratory. With your input we will be able to identify, describe, and prioritize a list of research needs that will serve as a basis for developing and funding research related to the use of timber in transportation structures.

The needs statements have been categorized into 7 individual categories.

1. **System Development and Design** (fastener design criteria and corrosion protection, structural glued laminated timber, structural composite lumber, design aids, timber bridge design criteria, timber bridge serviceability, design criteria for new bridge systems and components)
2. **Material Properties** (external influences on wood properties, wood design values and properties, lumber grading and yield, composite materials)
3. **Preservatives and Protective Measures** (field treatment, preservative effects on material properties, environmental considerations for wood preservatives, preservation methods and chemicals, preservative application and use)
4. **Other Transportation System Structures** (bridge rails, retaining structures, noise barriers)
5. **Inspection and Rehabilitation** (construction, inspection and in place evaluation, structural strength and property assessment, maintenance and rehabilitation)
6. **Technology and Information Transfer** (information distribution, design software)
7. **Historic Timber Bridges** (covered bridges, historical documentation)

Please complete the survey for the category or categories you are most closely tied and/or interested. Rank the needs on a scale of 1 to 5, with 1 indicating a low priority and 5 a high priority.

Thank you for your participation.

1. Contact Information (optional)

   Name:
   Affiliation:
   City/Town:
   State/Province:
   Email Address:
   Phone Number:

System Development and Design

System Development and Design Intro

2. Would you like to respond to research needs statements regarding **System Development and Design** (fastener design criteria and corrosion protection, structural glued laminated timber, structural composite lumber, design aids, timber bridge design criteria, timber bridge serviceability, design criteria for new bridge systems and components)?

   ☐ Yes ☐ No

3. **Optional response:** What issue(s) would you like to see addressed with respect to system development and design of timber transportation structures (fastener design criteria and corrosion protection, structural glued laminated timber, structural composite lumber, design aids, timber bridge design criteria, timber bridge serviceability, design criteria for new bridge systems and components)?

   Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

4. Evaluate the suitability of timber connections subjected to dynamic loading.

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Develop new methods of providing corrosion protection for steel hardware and stress-laminated bridge stressing bars, including mechanical protection, epoxy coatings, galvanizing, and cathodic protection.

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. Evaluate the compatibility and relative bond strength of various adhesives used for glulam timber treated with different wood preservatives before gluing.

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. Develop guidelines for economically optimized material requirements for specific timber bridge types.

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

8. Study the means of improving composite action between timber beams and timber decks.

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

9. Determine the level of lateral support provided for steel beams by different timber deck systems.

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

10. Develop and field-evaluate new methods for shear transfer between glulam deck panels.

☐1 ☐2 ☐3 ☐4 ☐5

11. Develop design criteria for timber arches and trusses for submission to AASHTO.

☐1 ☐2 ☐3 ☐4 ☐5

12. Evaluate current AASHTO LRFD live load deflection criteria for various timber superstructure and deck types based on structural behavior, wearing surface performance, and human response.

☐1 ☐2 ☐3 ☐4 ☐5

13. Develop methods for reducing live load deflection of AASHTO-approved timber bridges.

☐1 ☐2 ☐3 ☐4 ☐5

14. Develop methods and design criteria for longitudinally stress laminating transverse timber decks.

☐1 ☐2 ☐3 ☐4 ☐5

15. Investigate the use of FRP with timber (e.g., economic viability, effect of FRP on structural stiffness, etc.).

☐1 ☐2 ☐3 ☐4 ☐5

16. Investigate the use of mass timber (laminated timber, CLT, mass plywood) materials for new and existing timber bridges.

☐1 ☐2 ☐3 ☐4 ☐5

17. Investigate the effectiveness of using different kind of post-tensioning rods (e.g., graphite or other composite materials).

☐1 ☐2 ☐3 ☐4 ☐5

18. Develop design aids for various timber bridge superstructure designs for bridge owners and decision makers.

☐1 ☐2 ☐3 ☐4 ☐5

19. Develop guide for timber bridge long-term performance evaluation.

☐1 ☐2 ☐3 ☐4 ☐5

20. Improve timber glulam deck-to-steel girder installation procedures with a more effective connection system.

☐1 ☐2 ☐3 ☐4 ☐5

21. Develop appropriate guidelines for fabrication, transportation, and storage of timber components and bridge systems.

☐1 ☐2 ☐3 ☐4 ☐5

22. Develop new methods of protecting bridges from fire damage.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

23. Develop standard designs, details, and specifications for timber bridge substructures and culverts.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

24. Improve specifications for timber bridge construction in AASHTO LRFD.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

25. Develop effective drainage detailing by timber bridge superstructure type and bridge curb/rail system.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

26. Evaluate AASHTO LRFD design specifications for timber slab type bridges.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

27. Evaluate how timber bridges can be used in accelerated bridge construction projects.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

28. Evaluate the life cycle assessment (LCA) of timber bridges which focuses on the overall environmental impacts.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

29. Evaluate the life cycle cost assessment (LCCA) of timber bridges which focuses solely on financial costs.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Material Properties

Material Properties Intro

30. Would you like to respond to research needs statements regarding Material Properties (external influences on wood properties, wood design values and properties, lumber grading and yield, composite materials)?

☐ Yes ☐ No

31. **Optional response:** What issue(s) would you like to see addressed with respect to material properties of timber transportation structures (external influences on wood properties, wood design values and properties, lumber grading and yield, composite materials)?

Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

32. Establish the relationship between age, traffic volume, exposure to water and pollution, other factors, and the load carrying capacity for various structural systems.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

33. Investigate the use of wood-based composites and their long-term performance in bridge structures.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

34. Perform more testing of various species and sizes of wood to determine the flat-wise use factors.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

35. Develop models for long-term behavior of mechanical connections for glulam bridge components.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

36. Develop design properties needed for modeling the structural behavior of CLT materials in bridge deck applications.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

37. Explore new surface coatings, claddings, or encapsulation techniques to prevent deterioration due to elevated moisture contents.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

Preservatives and Protective

Preservatives and Protective Measures Intro

38. Would you like to respond to research needs statements regarding Preservatives and Protective Measures (field treatment, preservative effects on material properties, environmental considerations for wood preservatives, preservation methods and chemicals, preservative application and use)?

☐ Yes | ☐ No

39. **Optional response:** What issue(s) would you like to see addressed with respect to preservative and protective measures of timber transportation structures (field treatment, preservative effects on material properties, environmental considerations for wood preservatives, preservation methods and chemicals, preservative application and use)?

Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

40. Investigate the feasibility of gluing wood treated with creosote or other oil-borne preservatives to improve treatment and durability of large glulam members.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

41. Investigate and revise existing treating standards to limit the quantity of untreatable heartwood and restate moisture content requirements to reflect maximum values rather than average values.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

42. Develop preservatives that enhance the aesthetics of timbers and provide 100 years of life while being economical and environmentally acceptable.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

43. Evaluate performance of modern, conventional wood preservatives (e.g., CCA, copper naphthenate, ACQ, copper azole, etc.) in structural composite lumbers.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

44. Evaluate the effect of preservatives in contact with steel components.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

45. With increasing restrictions on the preservative creosote, investigate new alternative creosote formulations suitable for bridge applications.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

46. Develop and test new wood preservative chemicals that do not pose adverse environmental hazards.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

47. Develop and evaluate alternative methods of wood preservation, other than chemical preservatives, which protect bridge components from moisture exposure and deterioration (coatings, shielding, composite materials, etc.).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

48. Develop an informational summary on the restrictions, use recommendations, and use of wood preservatives.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

49. Develop and evaluate economical, long lasting methods for sealing and protecting wood against moisture (especially end grain) when prolonged moisture exposure is likely to occur.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

50. Evaluate the suitability of wearing surface materials and geotextile fabrics to provide moisture protection to timber bridge decks.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

51. Develop new treatment options for mass timber products (CLT) both before and after gluing.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Other Transportation System Structures

Other Transportation System Structures Intro

52. Would you like to respond to research needs statements regarding Other Transportation System Structures (bridge rails, retaining structures, noise barriers)?

☐ Yes ☐ No

53. **Optional response:** What issue(s) would you like to see addressed with respect to other timber transportation structures (bridge rails, retaining structures, noise barriers)?

Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

54. Study the applicability of composite materials made of wood and other materials to resist the effects of vessel or vehicle impacts (e.g., bridge pier protection systems, fender components in docks, guardrails, etc.).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

55. Develop round post roadside guardrail systems and investigate market opportunity.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

56. Develop improved/specific grading rules for timber guardrail posts.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

57. Develop aesthetically pleasing timber (and/or combination of timber and steel) roadside barrier systems that meet safety performance guidelines.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

58. Develop standard designs for timber retaining walls and evaluate their field performance.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

59. Develop prefabricated sound barriers/retaining walls.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

60. Develop portable timber bridges for temporary needs (road closures, disasters, etc.).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

61. Develop standard designs and evaluate the field performance of noise barriers constructed of timber, and of timber with other materials.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

62. Development of new railing systems for timber bridge decks (and approach guardrails) that meet current crash-testing criteria standards.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Inspection and Rehabilitation

Inspection and Rehabilitation Intro

63. Would you like to respond to research needs statements regarding Inspection and Rehabilitation (construction, inspection and in place evaluation, structural strength and property assessment, maintenance and rehabilitation)?

☐ Yes ☐ No

64. **Optional response:** What issue(s) would you like to see addressed with respect to inspection and rehabilitation of timber transportation structures (construction, inspection and in place evaluation, structural strength and property assessment, maintenance and rehabilitation)?

Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

65. Develop schemes and details for increasing the load carrying capacity of existing and new timber bridges.

☐1 ☐2 ☐3 ☐4 ☐5

66. Develop durable field sensors to measure in-situ wood moisture content and performance information for load-carrying members on covered bridges.

☐1 ☐2 ☐3 ☐4 ☐5

67. Develop methods for determining the embedment length of timber piles.

☐1 ☐2 ☐3 ☐4 ☐5

68. Investigate methods for determining the post-decay strength of timber components.

☐1 ☐2 ☐3 ☐4 ☐5

69. Investigate and determine methods for evaluating the residual bending strength of beams that have split or failed horizontal shear.

☐1 ☐2 ☐3 ☐4 ☐5

70. Prepare a comprehensive manual on maintenance practices for timber bridges.

☐1 ☐2 ☐3 ☐4 ☐5

71. Develop methods and comprehensive guidelines for restoring, increasing the capacity of, and replacing deteriorated timber components and piles used in bridges with an emphasis on accuracy and minimizing traffic disruption.

☐1 ☐2 ☐3 ☐4 ☐5

72. Assess the value/effectiveness of existing NDE devices (particularly around connection).

☐1 ☐2 ☐3 ☐4 ☐5

73. Develop underwater and under-earth inspection equipment.

☐1 ☐2 ☐3 ☐4 ☐5

74. Develop a density gauge to identify interior areas of decay or rotten timber.

☐1 ☐2 ☐3 ☐4 ☐5

75. Develop methods to retrofit and strengthen timber piles (possibly with FRP) that are prone to debris-hit damage.

☐1 ☐2 ☐3 ☐4 ☐5

76. Develop techniques for the easy retrofit/repair of damaged timber bridge rails.

☐1 ☐2 ☐3 ☐4 ☐5

77. Develop methods for fastening wood decks to steel and concrete stringers for both new construction and for replacement of decks.

☐1 ☐2 ☐3 ☐4 ☐5

78. Develop new inspection techniques for detecting internal deterioration with scanning technologies.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

79. Develop structural health monitoring systems for timber bridges using smart technologies.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

80. Develop supplementary inspection data for timber bridges using drone-based technologies.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

81. Develop a comprehensive inspection manual specific to timber bridge superstructure type.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Technology and Information Transfer

Technology and Information Transfer Intro

82. Would you like to respond to research needs statements regarding Technology and Information Transfer (information distribution, design software)?

☐ Yes ☐ No

83. **Optional response:** What issue(s) would you like to see addressed with respect to technology and information transfer of timber transportation structures (information distribution, design software)?

Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

84. Develop updated standard superstructure plans to meet AASHTO LRFD specifications.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

85. Develop guidance for timber substructure designs.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

86. Develop educational materials for use in colleges and trade schools.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

87. Develop training courses on timber bridge inspection/rehabilitation.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

88. Update comprehensive bridge manual to meet AASHTO LRFD specifications.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

89. Summarize method of construction for various timber superstructures and substructures, including case histories.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

90. Develop a database of timber bridges, by type and material, that have been constructed in the United States and Canada over the past 30 years.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

Historic Timber Bridges

Historic Timber Bridges Intro

91. Would you like to respond to research needs statements regarding Historic Timber Bridges (covered bridges, historical documentation)?

☐ Yes | ☐ No

92. **Optional response:** What issue(s) would you like to see addressed with respect to historic timber bridges (covered bridges, historical documentation)?

Answer:

Please rank the research needs statements in order of importance with 1 being low and 5 being high.

93. Establish methods to determine the residual capacity of structural wood members in historic covered bridges.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

94. Evaluate the structural behavior and field performance of historic timber-concrete-composite (TCC) bridges that remain in service.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

95. Develop lightweight floor replacement systems for covered bridges.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

96. Evaluate the structural behavior and field performance of historic timber arch and/or timber truss bridges that remain in service.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

97. Develop a design guide for the replacement of historic short-span timber bridges using glulam components.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

98. Develop technical guidance for load rating historic short-span timber bridges based upon on-site inspection and live load testing data.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

99. Develop standardized methods for load testing and load rating historic timber bridges.

☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

SURVEY COMPLETION

Your participation is greatly appreciated.

If you'd like to suggest other research needs statements not listed in the survey or if you have other comments or suggestions, please provide those in the boxes below.

100. Other suggested research needs.

    Suggestion 1:
    Suggestion 2:
    Suggestion 3:

101. Other comments or suggestions:

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the State or local Agency that administers the program or contact USDA through the Telecommunications Relay Service at 711 (voice and TTY). Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at How to File a Program Discrimination Complaint and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Mail Stop 9410, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.



FOREST PRODUCTS LABORATORY

https://research.fs.usda.gov/fpl