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TRB
TRANSPORTATION RESEARCH BOARD

January 2, 2020

Ms. Nicole Nason
Administrator
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

Dear Administrator Nason;

The Committee for the Review of Federal Highway Administration (FHWA) Infrastructure R&D Program met on November 6–7, 2019, in Washington, D.C., to review and discuss the progress of the Long-Term Infrastructure Program (LTIP). The committee members and other attendees of the meeting are listed in Attachment A. The charge to the committee is to "advise the Federal Highway Administration (FHWA) Infrastructure R&D Program regarding priorities in terms of the technical tools and products that state departments of transportation need to maintain and improve the performance of their pavements, bridges, and other structures." The committee was established to provide an ongoing review of the LTIP based on annual meetings with FHWA staff and stakeholders.

The committee's 2019 meeting was preceded by the meetings of two Expert Task Groups (ETGs) that support the work of the main committee—one each for the Long-Term Pavement Performance (LTPP) program and the Long-Term Bridge Performance (LTBP) program components of the LTIP. Members of the ETGs, along with attendees of their meetings, are listed in Attachment B. The ETG members reviewed and discussed the LTPP and the LTBP programs in depth and relayed summaries of their meetings to the main committee to inform its deliberations.

Members of the committee and its two ETGs extend their appreciation for the effective and informative presentations and discussion by David Winter, Acting Associate Administrator for Research, Development, and Technology; Cheryl Richter, Director of the Office of Infrastructure Research and Development; Jean Nehme, Team Leader, LTIP Team; and all of the other FHWA staff who participated in and supported the meetings that led to this report.

As described in the sections that follow, the committee believes the LTIP has made commendable progress over the past year. We also make a number of recommendations to further strengthen the program and offer some strategic considerations for the program to ensure future relevance to state departments of transportation (DOTs) and researchers.

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PROGRAM BACKGROUND

Authorized by Congress in 1987, the LTPP is by far the largest continuous pavement performance monitoring and data collection effort in history. It was designed with the expectation that "improved understanding of how pavement design, materials, construction techniques, maintenance practices, traffic loads, and climate affected the life cycle of pavements would lead to longer-lasting pavements and a more efficient use of public funds."[1] After the program was launched by the Strategic Highway Research Program, FHWA assumed management of the LTPP in 1992. At its peak, the program was monitoring the performance of 2,500 representative test sections to determine the performance of a variety of designs and materials while accounting for pavement loadings, climate, and other influences on pavement performance. Today, the LTPP records have reached roughly nine terabytes of data, which are made readily accessible to state DOTs and researchers through the FHWA InfoPave™ portal. In order to measure pavement performance accurately and consistently, the LTPP developed many data collection protocols and equipment specification and calibration standards, which have provided ancillary benefits to the states as they have embarked on performance measurement and asset management. The many benefits to state DOT pavement design and maintenance practice resulting from LTPP data and the tools have been thoroughly documented.[2] The LTPP program is still collecting data on about 400 test sections. Funding for the program from all sources, from inception in 1987 through 2014, averaged $11.5 million annually.[3] Funding available to the program fell sharply after 2015, after which time it has ranged between $4.2 and $6.5 million annually.

Originally authorized by Congress in 2005, the LTBP is modeled on the LTPP. The program intends to collect performance data on a sample of 500 to 700 nationally representative highway bridges over an extended period of time.[4] The bridges in the sample are the most common types of structures used by the states and are clustered in seven different climactic regions of the country. Initial data collection focuses on non-destructive evaluation (NDE) of untreated concrete bridge decks and visual inspection of coatings, joints, and bearings. Analogous to the LTPP InfoPave™ portal, the LTBP provides data collected on bridges through the InfoBridge™ portal. InfoBridge™ also contains state inspection data from the National Bridge Inventory (NBI) from more than 600,000 state and local highway bridges and National Bridge Element data from nearly 300,000 bridges on the National Highway System (NHS). The LTBP program design and sample size were developed when anticipated resources for data collection were higher than today. During the initial years of the program, authorized funding averaged $7.75 million annually and plans were made with assumptions of $10 million annually. Recent funding for LTBP data collection has been less than 70 percent of what was anticipated.

The LTIP objectives are to (a) collect, manage, and provide easy access to data; (b) analyze data; and (c) develop tools for highway and bridge infrastructure management. Within the limited resources available, the LTIP is focusing most of its resources on the first objective of collecting, managing, and sharing data, and, with important exceptions noted below, is mostly relying on other parties for data analysis and the development of tools for infrastructure management.

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[1] FHWA. 2015. *The Long-Term Pavement Performance Program*. U.S. Department of Transportation. FHWA-HRT-15-049. P. 2. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/15049.

[2] See FHWA. 2015, Chapter 10.

[3] FHWA. 2015. Table 4.2, p. 47.

[4] FHWA. ND. About the Long Term Bridge Performance Program. https://highways.dot.gov/bridges-and-structure/long-term-bridge-performance/about-ltbp.

Although state DOTs have long been engaged in managing the condition of their assets, the outputs of the LTIP are particularly relevant in today's context. In the Moving Ahead for Progress in the 21st Century Act of 2012 and the Fixing America's Surface Transportation Act of 2015, Congress required that states set performance goals for NHS routes within their states; these requirements include measuring the performance of, and maintaining the condition of, NHS assets. Long-term performance data from the LTIP can be of great benefit to states in carrying out asset management, which includes assessing and predicting infrastructure performance and allocating resources accordingly.

RECENT ACCOMPLISHMENTS

Among the notable accomplishments of the LTIP over the past year, the LTPP and the LTBP programs added new data and tools; enhanced several features of InfoPave™ and InfoBridge™ to make data more easily interpreted, summarized, and downloaded; and conducted effective and extensive outreach to stakeholders. Listed in this section are specific recent accomplishments that the committee finds most noteworthy.

- The most recent LTPP data release includes new longitudinal transverse profile data, updated climate data, and pavement distress metrics and measured pavement loading that feed directly into pavement design software available through the American Association of State Highway and Transportation Officials (AASHTO).
- Completion of a number of LTPP data analysis projects addressing predictions of truck and axle loadings; guidance on the use of LTPP traffic data; computed parameters on top-down cracking; and other topics.
- After a lengthy period of technology development, testing, and calibration, the LTBP program is moving forward, to the extent possible with available resources, on NDE data collection on bridge decks.
- In concert with FHWA's NDE Laboratory, the program is actively exploring new techniques and technologies to collect NDE data more quickly and efficiently with drones, robots, and accelerated bridge testing.
- LTBP staff have developed a new set of bridge deck deterioration models based on NBI data.
- LTIP staff have proposed a new portal (InfoMaterials) for sharing the results of FHWA materials tests, which have previously been difficult for researchers to access.
- The LTIP engaged in effective and extensive outreach to key customers and stakeholders, including AASHTO committees and subcommittees, state and local highway engineers, and university professors across the country teaching the next generation of highway engineers.

In the following sections, the committee comments on and makes recommendations about a number of issues related to these accomplishments.

PROGRAM SUGGESTIONS, FINDINGS, AND RECOMMENDATIONS

LTPP Data Analysis

Ongoing analysis of LTPP data by federal and state agencies follows a data analysis plan most recently updated in 2010 by a forum of 50 highway pavement researchers and practitioners. The

forum added two new objectives and dozens of individual analysis projects to the existing seven research objectives to develop a comprehensive strategic plan for using LTPP data to improve the practice of designing and maintaining highway pavements.[5] This data analysis plan has been evolving since the 1990s as needs have arisen and technologies have developed. The forum held in 2010 was instrumental in reviewing and revising the pre-existing plan to take advantage of the data resources available through LTPP. The plan ultimately grew to contain more than 200 analysis projects, of which roughly 100 have been completed to date, including all of those identified as "high priority." Due to the LTPP's limited budget, the program is able to undertake only a single new analysis project each year. To assist the LTPP program, AASHTO's Special Committee on Research and Innovation has taken on several analysis projects recently through the National Cooperative Highway Research Program, but, even so, progress in completing the analysis projects has become halting, at best.

During the September 2019 Pavement ETG meeting, LTPP staff requested the ETG's assistance in sorting through the list of remaining analysis projects to identify priorities for the LTIP's next funded analysis projects. The ETG members, however, believed that they lacked the range of expertise to evaluate priorities across all nine research objectives. In addition, because the data analysis plan is now almost 10 years old, the ETG believes that the need for some of the analysis projects may have been supplanted by other research and changes in the priorities of highway asset owners and managers.

Finding 1: The LTPP data analysis plan needs a fresh look by a broad group with appropriate expertise to evaluate (a) the existing list of data analysis projects and (b) ways to help states with pavement preservation techniques, use of innovative materials, and other state DOT priorities for pavement performance in the future.

Recommendation 1: The LTIP should convene a new forum of pavement experts to assess how to make best use of LTPP data and identify how the LTPP can best serve the needs of state DOTs in the future. The Pavement ETG members volunteer to serve as the core of such a group, but the members would need to be supplemented with individuals with appropriate expertise and perspective. Should FHWA wish to fund such a forum, it should provide the members with the original research analysis rationales of the remaining topics in the LTPP data analysis plan, as well as literature reviews on them, in order to identify those that may no longer be necessary.

InfoBridge™ Enhancements

The LTBP program continues to add valuable enhancements to InfoBridge™. These enhancements include increased ease in visualizing and accessing data, creating tables, and exporting data. Of particular value over the past year was the addition of the history of changes in specifications for bridge loads and load combinations. This historical detail will allow for the development of bridge deterioration models that account for the design of the bridge. In response to a request from the LTBP program staff regarding the addition of the history of other specification changes, this committee endorses the Bridges ETG's suggestions, in priority order:

a. reinforced concrete shear design;
b. lightweight concrete;

[5] FHWA. 2015. Chapter 10. The matrix of research objectives and analysis projects under each objective grew to such a large size that it was referred to as the "tablecloth."

c. minimum/maximum reinforcement ratios;
d. confinement steel; and
e. cementitious materials.

Deck Deterioration Models

LTBP staff researchers are developing three different bridge deck deterioration models using NBI condition ratings, which are based on visual inspection.[6] These new models are using innovative techniques to predict future deck condition ratings. LTIP staff are adding documentation about these models to InfoBridge™ and, at some point, will add the ability to use these models to predict future bridge deck condition ratings.

Finding 2: The Bridge ETG and this committee are impressed with these novel approaches to deterioration modeling and believe that state bridge engineers and asset managers will be interested in comparing these models to those they are currently using for asset management.

Recommendation 2: The LTIP should ensure that its new bridge deck deterioration models are rigorously evaluated in peer-reviewed publications and results shared with state DOTs and other infrastructure asset owners. When FHWA adds the capability to use these models in InfoBridge™, it should cut off the prediction periods over 50 years due to the wide range between the upper and lower bounds of predicted deck ratings beyond that point in time.

NDE Data Collection

As noted above, collection of NDE measures of bridge deck condition has moved beyond the development phase to the production phase. The LTBP completed NDE data collection on 7 bridge decks in the Gulf region cluster of the LTBP sample of bridges and is moving on to the collection of data on an additional 33 bridge decks (17 under contract and 16 planned). These data will also be collected in the Gulf region to allow data collection to occur over the winter. The committee encourages LTBP staff to also begin collecting data in northern clusters subject to freeze-thaw cycles and winter maintenance as soon as conditions and resources permit.

Bridge deck NDE data are being collected using the robotics assisted bridge inspection tool (RABIT™), which collects multiple measures as it scans bridge decks.[7] This state-of-the-art robotic technology collects NDE data more efficiently, safely, and more completely than using individual handheld NDE technologies, but nonetheless requires about 1 hour to process 1,000

[6] The base model builds predictions by calculating the timespan that bridge decks maintain the same rating based on tens of thousands of decks of different bridge types for which continuous data are available. A second model adds survival periods with Markov-chain theory to develop predictions. A third model attempts to mimic bridge inspectors' ratings using pattern recognition/machine learning techniques and then adds uncertainty to a stochastic framework to make predictions of future ratings.

[7] FHWA has purchased four RABIT-CE™ devices that simultaneously collect high-resolution photographic images of surface cracking; electrical resistivity to assess the corrosive environment of the concrete; ground penetrating radar using electromagnetic waves to identify potential flaws and deterioration; impact echo to evaluate concrete delamination; ultrasonic surface waves to assess concrete strength; and global positioning system locations to identify exactly where measurements are taken. See https://highways.dot.gov/bridges-and-structure/long-term-bridge-performance/products.

square feet of deck (or roughly two 8-hour shifts to assess the average bridge deck on principal arterial highways), not including equipment set up and down time.[8] Deck assessment using the RABIT™ therefore requires lane closures and maintenance of traffic that add to collection costs and delays to highway users.

Data Quality Assurance and Control

NDE data collection is highly sensitive to a variety of influences such as moisture and environmental conditions. The LTBP developed protocols and technologies for its contractors to use onsite to avoid the collection of spurious data. These approaches allow for recollection whenever issues of concern are identified during data collection. After data are submitted, the LTBP relies on its resident staff expert to conduct quality assurance/quality control (QA/QC).

Finding 3: The LTIP is developing appropriate and rigorous processes for ensuring that LTIP NDE data are of research quality.

Recommendation 3: To avoid over-reliance on individual expertise and judgment, the LTBP should develop a standard set of metrics and procedures for QA/QC, which should be shared with the community of bridge data users.

Data Posting

Once data have been accepted, FHWA will post the NDE data in InfoBridge™, possibly including the LTBP interpretations or computations based on the raw data.

Finding 4: The posting of raw NDE data, rather than computed metrics, will be essential for researchers who wish to develop their own interpretations of NDE data.

Recommendation 4: The LTIP should develop, use, and share an open source code for interpretation of all raw data using a standard format that tags each bridge deck by structure number, x/y coordinates on the deck surface, and metadata, and using a uniform image coding (coloring) scheme. The LTBP should develop a protocol for the latter, as needed.

Alternative Approaches

LTIP staff realize that NDE data collection, even with the RABIT™, is expensive and time consuming. They are therefore exploring alternative NDE measurements and methods of collection. In addition to using Small Business Innovation Research funds to test promising concepts proposed by entrepreneurs, LTBP staff are partnering with the FHWA NDE Laboratory to conduct an accelerated test of a full-scale bridge superstructure (deck). Although not a substitute for field data collection, this valuable project illustrates the LTBP program's interest in exploring different approaches for determining bridge performance. Over a roughly 2-year period, this project will test a deck until it is deteriorated enough to require overlay and will then evaluate the performance of various overlay materials. The deck will be fully instrumented and will be subject to repeated NDE data collection. This project also provides a unique opportunity

[8] The pace of data collection per deck can be accelerated by operating two RABIT™ devices at the same time.

to begin developing meaningful deck deterioration models that are based on NDE data and would be an opportunity to also develop uniform and accessible formats for raw NDE data that can be used later in InfoBridge™.

Revised NDE Data Collection Plan

Although the committee hopes that Congress will provide ample resources for field bridge performance data collection, funding may be more limited in the future than when the sample size and data collection plans were established several years ago. Some state DOTs are assisting by contributing the cost of traffic control during data collection and others may be willing to take cores of decks and contribute them to the LTBP to assist in interpreting NDE results. Nonetheless, resource constraints and the cost of data collection indicate that the specific purposes for collecting NDE data need to be determined. Doing so will help define the minimum number of bridges for which NDE data collection is required, as well as the extent and frequency of data collection, which will drive the overall cost. One purpose for collecting NDE data would be for the development of improved deterioration models, but the models that states rely on for asset management do not require the greater precision that NDE-based deterioration models might provide. Deterioration models based on NBI ratings may be adequate for asset management. NDE data, however, may help validate ratings based on visual inspection or improve understanding about how quickly unseen internal deterioration begins before it shows up in NBI ratings.

Finding 5: With current funding being less than anticipated, and in light of anticipated future resource constraints, a revised plan for NDE data collection is needed.

Recommendation 5: LTIP staff should begin developing a revised plan for data collection that accounts for

- **a. The specific purposes for collecting NDE data and the necessary sample size;**
- **b. A nationally representative sample;**
- **c. Building on data already collected at selected bridges for trend analysis;**
- **d. Appropriate cycles for repeating data collection on sampled bridges (2, 4, or 6 years, perhaps based on deck age or condition); and**
- **e. State participation for/support in data collection.**

The pending reauthorization of surface transportation legislation may bring new resources to the program, which may justify the delay in developing a formal plan. It would, nonetheless, be useful for FHWA to present the LTBP program progress and begin discussing the elements of a revised plan with the states through the AASHTO Committee on Bridges and Structures (COBS) or other venues with substantial state bridge engineering expertise and perspective. The committee would like to hear a presentation on a revised plan at its next annual meeting.

Stakeholder Outreach

LTIP staff have been reaching out effectively to key stakeholder communities to build awareness of, and support for, long-term infrastructure performance data collection. LTBP staff have carried out appropriate and useful outreach to the subcommittees of AASHTO's COBS, state DOT staff gathered at AASHTO regional meetings, various meetings of state and county bridge

engineers, university professors teaching bridge engineering, and to the community of bridge researchers and practitioners participating in the Transportation Research Board (TRB) Annual Meeting.

It would be useful to reinvigorate the state coordinators' meetings for the LTPP and the LTBP, but the old model of meeting with these groups at the TRB Annual Meeting is no longer viable given restrictions on state DOTs' travel budgets and ability to allow multiple employees to attend the TRB Annual Meeting. It may be better for LTIP staff to interact with state bridge and pavement staff at the regional and national meetings they are able to attend. In addition to the state DOT pavement, materials, and bridge engineers who participate in state coordinators' meetings, the committee encourages LTIP staff to reach out to state DOT staff responsible for asset management.

The committee also encourages LTIP staff to continue to make key constituents aware of its data collection programs and products. High-priority groups to reach out to include the AASHTO Board of Directors, Highways and Streets Council, Chief Engineers, COBS, and Committee on Materials and Pavements. Committee members will readily volunteer to assist in getting the LTBP program on the agendas for upcoming meetings and in making presentations.

STRATEGIC CONSIDERATIONS FOR THE FUTURE

The infrastructure management context and resources available for research and development have changed since the LTPP and the LTBP programs were authorized by Congress. The LTPP was developed to answer questions about how pavements of various designs and materials perform over time and how designs could be improved to maximize life-cycle costs. However, even as the LTPP's data collection experiments wind down, most states are designing much less new pavement than before. They are, instead, much more focused on preservation techniques, use of innovative materials to extend pavement life, and optimizing infrastructure life-cycle costs through asset management. Indeed, many states are relying on data gathered from their own test sections to evaluate alternative preservation techniques and materials. Moreover, as connected and automated vehicles emerge that navigate, in part, using pavement markings, understanding how to optimize the performance of these materials has become a subject of heightened interest by state and local infrastructure owners. As noted above, it may be the case that the LTBP will not be able to collect bridge performance data on the scale expected and to the degree helpful to the states. Whereas the InfoPave™ and InfoBridge™ portals are extremely valuable for making infrastructure performance data accessible to state DOTs and researchers, aside from publishing NBI and NDE data, they mostly focus on federal data.

Finding 6: State DOT interest in managing infrastructure performance, as well as states' need for performance data for both performance measurement and asset management, provide the basis for greater future collaboration between state DOTs and FHWA in data collection. Such collaboration would build awareness of and support for the LTIP.

Recommendation 6: LTIP staff should begin considering how to partner with state DOTs in the future to collect and make infrastructure performance data available. For example, states using LTPP and LTBP data collection protocols could gather and report results on (a) states' own pavement test sections in the LTPP formats and (b) NDE and other data collection on bridge elements, which the LTIP could make accessible to all states and the research community through its data portals.

CONCLUDING COMMENTS

The committee wishes to again commend LTIP staff on its accomplishments over the past year and thank FHWA for the opportunity to review and comment on this important program. We hope that our suggestions and recommendations will allow the LTIP to improve on an already strong set of activities that are of great value to state DOTs.

Sincerely,

Paul Ajegba

Committee Chair and Director, Michigan Department of Transportation

Attachments

A. Committee Members and Meeting Participants

B. ETG Members and Meeting Participants

Attachment A: Committee Members and Meeting Participants

Committee for the Review of Federal Highway Administration (FHWA) Infrastructure R&D Program
November 6–7, 2019
Keck Building, Washington, D.C.

Committee Members[9]

Paul Ajegba, *Chair,* Michigan Department of Transportation
Courtney Drummond, Florida Department of Transportation
Matthew Farrar, Idaho Department of Transportation
Daniel Frangopol, Lehigh University
Mostafa Jamshidi, Nebraska Department of Roads
Patricia Leavenworth, Massachusetts Department of Transportation
Rebecca McDaniel, Purdue University
James Nelson, Iowa Department of Transportation
Kumares Sinha, NAE, Purdue University
Carman Swanwick, Utah Department of Transportation
Joyce Taylor, Maine Department of Transportation
James Williams, Mississippi Department of Transportation

Meeting Participants

Shrinivas Bhide, FHWA
Amir Hanna, National Cooperative Highway Research Program
Jean Nehme, FHWA
Glenn Page, AASHTO
Cheryl Richter, FHWA
Larry Scofield, National Concrete Pavement Association
Deborah Walker, FHWA
Richard Willis, National Asphalt Pavement Association
David Winter, FHWA
Larry Wiser, FHWA
Robert Zobel, FHWA

[9] Members in attendance shown in bold font.

Attachment B: ETG Members and Meeting Participants

Pavements Expert Task Group Meeting
September 29–30, 2019
National Academy of Sciences Building, Washington, D.C.

Expert Task Group[10]

Rebecca McDaniel, *Chair*, Purdue University
Kim Alexander, Washington State Department of Transportation
Bouzid Choubane, Florida Department of Transportation
Eshan Dave, University of New Hampshire
Mark Hallenback, University of Washington
Moussa Issa, Georgia Department of Transportation
Zheng (Jenny) Li, Texas Department of Transportation
Tommy Nantung, Indiana Department of Transportation
Tom Pyle, California Department of Transportation
Shelley Stoffels, The Pennsylvania State University
Julie Vandenbosshe, University of Pittsburgh
Ben Worel, Minnesota Department of Transportation

Meeting Participants

Todd Copenhaver, Texas Department of Transportation (by teleconference)
Amir Hannah, National Cooperative Highway Research Program (by teleconference)
Jamie Harris, FHWA
Jane Jiang, FHWA
Jean Nehme, FHWA
Glenn Page, American Association of Transportation Officials
Larry Scofield, American Concrete Pavement Association (by teleconference)
Leif Wahtne, American Concrete Pavement Association
Deborah Walker, FHWA
Brett Williams, National Asphalt Pavement Association (by teleconference)
Larry Wiser, FHWA
Jack Youtcheff, FHWA

[10] Members in attendance shown in bold font.

Bridges Expert Task Group Meeting
October 24–25, 2019
Keck Building, Washington, D.C.

Bridges Expert Task Group[11]

George Hearn, *Acting Chair*, University of Colorado Boulder
Alexander Bardow, Massachusetts Department of Transportation
George Conner, Alabama Department of Transportation
Zhengzheng (Jenny) Fu, Louisiana Department of Transportation
Cheryl Hersh Simmons, Utah Department of Transportation
Thomas Macioce, Pennsylvania Department of Transportation
Anne-Marie H. McDonnell, Connecticut Department of Transportation
Soheil Nazarian, The University of Texas at El Paso
John Popovics, University of Illinois at Urbana-Champaign
Anne M. Rearick, Indiana Department of Transportation
Sarah Wilson, Illinois Department of Transportation

Meeting Participants

Anwar Ahmhad, FHWA
Hoda Azari, FHWA
Shrinivas Bhide, FHWA
Patricia Bush, AASHTO
Wassem Dekelbab, National Cooperative Highway Research Program
Raka Goyal, FHWA
Jamie Harris, FHWA
Frank Jalinoos, FHWA
Brian Kozy, FHWA
Heng Liu, FHWA
Ping Lu, FHWA
William Nickas, Precast/Prestressed Concrete Institute
Cheryl Richter, FHWA
Deborah Walker, FHWA
Robert Zobel, FHWA

[11] Members in attendance shown in bold font.