PRESERVING AND MAXIMIZING THE UTILITY OF THE PAVEMENT PERFORMANCE DATABASE

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Long-Term Pavement Performance Committee

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Transportation Research Board
Washington, D.C.
2009
www.TRB.org

Transportation Research Board Miscellaneous Report

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study was sponsored by the Federal Highway Administration of the U.S. Department of Transportation.

Cover and inside design by Tony Olivis, Studio 2.

Library of Congress Cataloging-in-Publication Data

National Research Council (U.S.). Long-Term Pavement Performance Committee.
Preserving and maximizing the utility of the pavement performance database / Long-Term Pavement Performance Committee, Transportation Research Board of the National Academies, Transportation Research Board.
p. cm.
1. Pavements—Performance—United States—Data processing. 2. Pavements—Deterioration—United States—Data processing. I. Title.
TE251.5.N37 2009
625.8—dc22

2009005085

ISBN 978-0-309-12607-6

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PREFACE

The Long-Term Pavement Performance (LTPP) Committee is the second of two committees of the National Academies to provide advice pertaining to the LTPP studies. Initially, in the period from 1987 to 1992, when the studies were part of the Strategic Highway Research Program (SHRP) conducted by the National Research Council, oversight and guidance of the SHRP manager for LTPP were provided by the Pavement Performance Advisory Committee (PPAC). When SHRP ended in 1992, management and operation of the LTPP studies were transferred to the Federal Highway Administration (FHWA), and PPAC readdressed its advice to FHWA and the American Association of State Highway and Transportation Officials (AASHTO). In 1995, PPAC was retired and the LTPP Committee was established to provide advice on LTPP's programmatic planning, operations, and progress and to coordinate work on specific technical issues conducted by various subcommittees (expert task groups).

The Transportation Research Board's (TRB's) charge to the LTPP Committee is as follows:

> This committee, acting through the National Research Council, will advise the Federal Highway Administration and the American Association of State Highway and Transportation Officials on the planning and execution of the Long-Term Pavement Performance (LTPP) studies. The LTPP studies are a set of operational activities consisting of gathering and analyzing data that is being collected on more than 2500 in-service pavements in the United States and Canada. The principal objective of this data collection and analysis is to further the understanding of how and why pavements deteriorate when subjected to traffic loadings and environmental conditions. Data collection and analysis began in 1987 and will

> continue through 2009. The committee will also prepare reports, including letter reports, containing the committee's evaluations and suggested mechanisms to enhance the utility to the states of the studies' outcomes.

This report is the outgrowth of a series of letter reports to FHWA and AASHTO developed by the committee to convey its advice formally. To date, there have been 23 letter reports. Those written since 2006 have recommended the development of plans for preserving and implementing the outcomes of the LTPP studies in the post-LTPP period (commonly thought to begin in 2010). Of particular urgency to the committee was the need to plan for the safekeeping, management, and operation of the LTPP database before the legislation that succeeds the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) is fully developed.

As a result of subsequent deliberations, the committee decided to develop this statement of what it believes is needed to preserve the LTPP database, to facilitate its continued use for decades to come, and, through its use for data analysis and product development, to fulfill LTPP's promise of better roads.

Although the committee usually addresses its recommendations to the management and staff of FHWA, this report is addressed to a wider audience that includes all those in federal and state government, as well as in industry and academia, who will shape the future of highway pavement research.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published reports as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the committee's charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The committee wishes to thank the following individuals for their participation in the review of this report: John F. Conrad, CH2M Hill, Olympia, Washington; Jon A. Epps, Granite Construction, Inc., Sparks, Nevada; Sue McNeil, University of Delaware, Newark; Jorge A. Prozzi,

University of Texas, Austin; Michael M. Ryan, Michael Baker, Jr., Inc., Harrisburg, Pennsylvania; and Eugene L. Skok, Jr., G. A. Staus & Associates, White Bear Lake, Minnesota.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by C. Michael Walton, University of Texas, Austin. Appointed by NRC, he was responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

A. Robert Raab, who provides staff support to the LTPP Committee, drafted this report under the guidance of the committee and the supervision of Stephen R. Godwin, TRB Director of Studies and Special Programs. Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. The report was edited by Norman Solomon, TRB Senior Editor; Editorial Services Specialist Jennifer J. Weeks prepared the manuscript for editing and the prepublication PDF for web posting; and Production Manager Juanita Green coordinated the design, typesetting, and printing, under the supervision of Javy Awan, Director of Publications.

Special appreciation is expressed to James K. Cable, Iowa State University, and David Cebon, Cambridge University, who are, respectively, the chairs of the TRB Expert Task Group on LTPP Special Activities and the TRB Expert Task Group on LTPP Traffic Data Collection and Analysis, and who served as consultants to the committee during the development of this report.

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SUMMARY

In the 1980s, it was recognized in the transportation community that the causes of pavement deterioration were not well understood and that the cause-and-effect relationships between key factors governing pavement performance were largely unknown. Pavements were failing prematurely for reasons that could not be explained, although the ravages of weather, variability in materials and construction, and increased traffic loadings, or some combination of all of these factors, were thought to be responsible. Substantially more than $30 billion[1] was being invested annually in the design, construction, and maintenance of pavements using design methods based on tests that were more than 30 years old and that did not account for variations across the nation in traffic loadings, weather conditions, geology, paving materials, or construction practices.

The LTPP studies were designed to collect data on all these factors to resolve questions about how to account for them in design so that better, more cost-effective roads could be built. The LTPP studies are scientifically designed field experiments on more than 2,500 sections of in-service highways in the United States and Canada. Plans, procedures, and protocols for data collection, data analysis, and product development were created and implemented. The total federal investment in LTPP has been estimated to be $260 million, and the nonfederal (state and local) investment is probably two to three times as large. It is generally agreed that the total investment exceeds $800 million and that the lion's share of this amount is attributable to conducting the field experiments, the data from which were used to populate the LTPP database.

[1] http://www.fhwa.dot.gov/ohim/hs00/pdf/dischт.pdf.

Even though the LTPP studies, which were envisioned initially as a combined effort of data collection, data analysis, and product development over a 20-year period, are nearing the completion of their second decade, about 500 test sections will still be yielding important data at the end of FY 2009, and a large number of them will continue to do so for another decade.

Budget cuts caused by reduced funding of LTPP under the Intermodal Surface Transportation Efficiency Act (1991), the Transportation Equity Act for the 21st Century (1998), and SAFETEA-LU (2005) have necessitated sacrifices in data collection and practically eliminated all data analysis and product development activity conducted with LTPP funds. Even with these compromises, a massive database has been created that could lead to fundamental improvements in the understanding of pavement performance and the future design of pavements.

The database has already contributed substantially to the development of a new pavement design guide that is being adopted by the states. While the database is LTPP's principal product, other outcomes are having far-reaching effects, especially in state agencies. Foremost among them are the testing protocols that were developed to bring consistency to the methods and equipment used to collect pavement and traffic data. As just one example, the *Distress Identification Manual* (FHWA 2003) has become a "best seller," and the pocket versions that are particularized to asphalt concrete (FHWA 2005a), jointed portland cement concrete (FHWA 2005c), and continuously reinforced concrete pavements (FHWA 2005b) are in high demand among field engineers.

The database will prove invaluable to individual states as they calibrate the models in the new pavement design guide to account for local conditions. However, the full benefits of LTPP cannot be realized until a commitment is made and fulfilled to complete the data collection that will be unfinished in 2009 and to analyze the data and develop the products that will help explain why, how, and to what extent pavements deteriorate in different situations. This will not happen without careful and comprehensive planning. The survival of the database as a significant tool for research, design, and management of pavements is at risk due to lack of a comprehensive plan to preserve it and enhance its future use.

To preserve the database and to maximize its use by the transportation community in the decades to come, the committee recommends, as priorities for the post-LTPP era, the following actions:

• Establishment of the National Pavement Performance Database (NPPD) to be the custodian and steward of the LTPP database, as a self-contained and fully funded entity within an existing agency, with the appropriate mandate and staffing resources to carry out the duties encompassed in this and the following three actions;

• Authorization of the NPPD to preserve the LTPP database and keep current its hardware and software as the technology of computers and data storage evolves, and to incorporate additional pavement performance data into the database as the data become available;

• Authorization of the NPPD to enhance the quality and ensure the completeness of data in the LTPP database where feasible, and to conduct LTPP data analysis and product development, to support those who seek to analyze the data to better understand the causes of pavement deterioration, and to develop new designs and maintenance procedures based on this improved knowledge; and

• Funding of the NPPD in the amount of $9 million annually during the next period of reauthorization of surface transportation research to enable the above actions.

1
BACKGROUND

The LTPP studies were originally a part of SHRP, which began as a consequence of the passage of the Surface Transportation and Uniform Relocation Assistance Act of 1987. The continuation of LTPP has been authorized by three succeeding acts of Congress, most recently SAFETEA-LU, which approves the continuation of LTPP research for 2005 to 2009. The end of this term is also the end of the 20-year period that is considered to be the nominal LTPP time frame.

The developers of SHRP recognized that about $400 billion (TRB 1984, 7) would be spent in the final decades of the 20th century to replace and rehabilitate Interstate and primary highway pavements as well as state, county, and local highways. Despite this huge cost, little was being invested in research, and major studies of the long-term performance of pavements had been lacking since 1960. Fundamental questions remained with regard to the effects of climate, maintenance, loads, materials variations, and construction practices on pavement performance.

As stated in SHRP's research plan (TRB 1986, TRA 2-6), LTPP's mission is to provide information and data to facilitate the improved design, construction, and maintenance of highway pavements by

- Evaluating existing design methods and developing new design methodologies;
- Determining the effects of loading, environment, materials, construction, and maintenance on pavement performance; and
- Establishing a national pavement performance database.

Fulfilling this mission entails the following activities:

- Collecting, processing, and storing performance data from a large number of in-service highways in the United States and Canada over an extended period;

- Analyzing these data to describe how pavements perform and to help explain the effects of climate and heavy load; and
- Translating these insights into products that can be used by state agencies for pavement design, rehabilitation, maintenance, and management.

The LTPP studies are a set of 17 scientifically designed field experiments conducted on more than 2,500 sections of in-service highways in the United States and Canada. The LTPP studies also include management and operation of the Materials Reference Library (MRL), which was established as a central storage facility for samples of the asphalt cements and aggregates that were used in the SHRP asphalt research program and of the pavement and subsurface materials and the 35-mm pavement surface distress films used in the LTPP studies.

Plans, procedures, and protocols for data collection, data analysis, and product development were created and implemented, but these activities have experienced peaks and valleys as LTPP's funding levels have fluctuated over the years. After a succession of budget cuts that reduced funding for LTPP from approximately $17 million per year to $7 million per year,[1] LTPP's remaining resource stream was redirected during the FY 2000–FY 2003 period to concentrate on collecting, processing, and storing pavement performance data. The total federal investment in LTPP has been estimated to be $260 million, and the nonfederal (state and local) investment is probably two to three times as large. The total investment is estimated to exceed $800 million (just 0.02 percent of anticipated expenditures on rehabilitation over a similar time frame), with the lion's share of this amount attributable to the conduct of field experiments, the data from which were used to populate the LTPP database.

SAFETEA-LU expires at the end of FY 2009. It is generally assumed in the highway community that LTPP, because it began approximately 20 years ago, has run its course.[2] This assumption prevails even though data collection is not complete on more than 500 test sections that, because of their young age, have not yet yielded the per-

[1] Technical corrections could increase funding for LTPP in 2008 and 2009 to more than $8 million annually.

[2] The committee's membership includes engineering professionals employed in state transportation agencies, industry, and academia. These individuals are active in their respective professional societies and associations and have often reported the expectations that they hear expressed at conferences and conventions concerning the conclusion of LTPP.

formance data for which they were designed, constructed, and entered into LTPP's testing program.

The committee was aware that many people assumed that LTPP would be completed by 2009, and it realized that definitive plans were needed for completion of the data collection and custody and utilization of the data beyond FY 2009. In October 2006, the committee concluded that high-priority LTPP activities that need to continue beyond the expiration of SAFETEA-LU should be identified and that plans for their continuation should be developed. In December 2006, the committee communicated these conclusions to the Administrator of FHWA and the Executive Director of AASHTO in a letter report.[3]

In subsequent deliberations, the programmatic efforts that need to be conducted through and beyond 2009 were identified, and a budget and management framework for this work were discussed. The committee concluded that LTPP's key core functions of data collection, data analysis, product development, database security and maintenance, and database user support should continue. Furthermore, the committee believed that these core functions should be conducted as a unified program and should be managed and directed by a dedicated staff in one basic organizational unit.

The committee believes that anything less than a centralized effort might result in the conduct of many small and disconnected activities in many separate research units within many organizations. LTPP is a large program with numerous interconnected parts, many of which entail close coordination of federal, state, and local officials and engineers in collecting, processing, and uploading pavement performance data. Related activities, such as test site preparation, installation and calibration of data collection equipment, and training and certification of performance surveyors, also require the coordination of diverse personnel and resources. Unless the central management and operation of these activities are maintained, the cohesion that proved effective for 20 years will be lost. Separating LTPP's activities into their component parts and dispersing them to wherever there are appropriate recipients willing to accept them might be possible, but it is likely that the "orphaned" activities would quickly lose their identities and connections to LTPP's objectives and be absorbed into the general mix of the recipients' operations.

[3] http://onlinepubs.trb.org/Onlinepubs/sp/ltpp_letter_22.pdf.

The committee discussed its conclusions with FHWA in October 2007. It decided to express its findings to FHWA and AASHTO in a new letter report[4] and to state its case to a wider audience through development of this report.

The committee seeks to protect the LTPP database from the fate experienced by the data collected at the American Association of State Highway Officials (AASHO) Road Test. These data provided the basis for pavement design, engineering, and education worldwide for 50 years. In the half century since the conclusion of that test, however, access to the data has been unreliable at best. Today, the data are generally inaccessible for technical research because only a few individuals have maintained personal copies of parts of the data for academic purposes.[5] The committee seeks a more secure future for the LTPP database. It would be a technical catastrophe if the LTPP database fell into inaccessibility and obsolescence through lack of adequate planning for its maintenance and use after the program ends.

This document is addressed to all those in federal and state government, as well as in industry and academia, who will shape the future of highway pavement research. In this document, the committee states its view of what is needed in the post-LTPP era to complete LTPP's data collection, data analysis, and product development and to take custody of the LTPP database and serve as its steward well beyond FY 2009.

[4] http://onlinepubs.trb.org/Onlinepubs/sp/ltpp_letter_23.pdf.

[5] The raw data consist of handwritten numbers, penciled into small boxes that fill columns that extend across pages too wide to fit into binders without folding. Nearly a dozen performance variables for two pavement types, 836 test sections, and 1.1 million test load applications over 2 years produced data filling many binders. The intention to preserve the data is evident from the trail of technology through the decades: field notebooks and data maps, microfilm, nine-track computer tape, punch cards, and recently a digital version. Images also were preserved: five boxes of photographs, glass slides, and color transparencies of pavement sections and test procedures. Through lack of a coordinated effort, several generations of research managers have wondered how to safeguard access to the data and artifacts, and the matter is still unresolved. Access to the original data will be necessary because many of the data maps were lost in the conversion from one technology to another. As a result, for scholarly research, the raw data from the tests will have to be supplemented by a yet-to-be-developed data user's guide or metadata.

2
Unfinished Work

The work of national importance that the committee sees remaining to be completed at the end of FY 2009 includes

- Completing data collection on all pavement test sections of prime value,
- Conducting data analysis according to the defined plan,
- Developing products in a disciplined manner, and
- Maintaining the database as both the custodian and steward of the data.

Data Collection

The collection of complete, high-quality pavement performance data has always been the primary goal and principal challenge of the LTPP Program.[1] Past budgetary constraints compromised this goal and challenge. Data gaps developed that had to be filled, and measurements of insufficient quality were collected that had to be repeated. Major efforts were undertaken to fill gaps, especially in the traffic and materials data, but some of these gaps and variations in quality remain and will require extra effort if they are to be remedied. At present, the gap that will be created if monitoring of some active test sections does not continue past FY 2009 is of most concern.

[1] LTPP's data collection plan was carefully designed to ensure collection of sufficient data of the types needed for analysis and product development. LTPP was organized as two sets of statistically designed experiments: (a) eight experiments that studied in-service pavements in common use across the United States incorporating materials and designs representing good engineering practice and (b) nine experiments to study specific design features or treatments that were constructed specifically for LTPP data collection. Guides developed by LTPP explicitly define the data elements to be collected at each test section, the sampling and testing protocols to be used, and the processes for assessing the quality of the data and for storing them in the LTPP database.

Approximately 1,200 of the original test sections still yield valuable performance data. Data collection on some of these sections only began in the mid-1990s, and a significant number were not built until 2000. Thus, it is important to continue the monitoring of these pavements, numbering approximately 500, that are still in the early or middle stages of their life cycle, to collect the performance data they were designed to yield when it is appropriate to do so, even if that is after FY 2009.

LTPP's data collection categories include climate, traffic volumes and loads, pavement layer type and thickness, material properties, and pavement condition (distress, longitudinal and transverse profile, and structural evaluation). The data collected through forensic evaluation of pavements at key points in their service life are also important. These data are essential in detecting the correspondence between observable surface deterioration and subterranean conditions caused by vehicle loads, climate, and aging—for example, between surface rutting and thickness changes of the various pavement layers. Lack of such detailed forensic information greatly degrades the value of the data already captured; it will be known that the pavement failed but not which layer or why.

Each component of the LTPP data collection plan can contribute to an understanding of the relationship among environment, pavement loading, and performance. Any portion of the performance data that is missing is a gap in the database that could hinder such understanding. It is necessary to complete performance monitoring on a schedule that identifies the onset and development of distress at each test section.

Much is still to be learned about the performance of these pavements as they age, especially of the pavements constructed as late as 2000, and data must be collected at each experimental site. Forensic studies as the pavements reach the end of their service life will add substantially to the knowledge base and provide valuable insight into failure mechanisms. In addition, individual state transportation departments are conducting their own limited pavement performance studies, and they should be evaluated, monitored, and included in the NPPD.

Data Analysis

Analysis of LTPP data began in earnest in 1992 with the evaluation of the then-current version of the *AASHTO Guide for Design of Pavement*

Structures (AASHTO 1986). That analysis confirmed that the guide had outlived its usefulness and contributed to the decision to develop a new guide based more closely on an understanding of the relationships between the stresses and strains of a pavement's constitutive materials, and between the loads and deformations of a pavement's structural elements composed of these materials, when the pavement is subjected to in-service loads and environmental influences. Since then, more than 400 published analysis reports have referenced LTPP data, and each year the use of LTPP data in analysis has increased significantly. Highlights of LTPP-funded reports can be found in *Key Findings from LTPP Analysis* (FHWA 2000; FHWA 2004). These analyses test the quality and completeness of the data, support the search for answers to questions about how pavements perform, and provide the technical basis for pavement design and management tools.

A strategic plan was then developed for the further analysis of LTPP data. The plan was designed to achieve the seven strategic objectives of the LTPP program:

- To characterize the traffic loading of pavements,
- To characterize the materials properties of pavement layers,
- To monitor the effects of environment on pavement performance,
- To evaluate pavement condition and its use in pavement management,
- To support the development of improved pavement performance models,
- To support the development of pavement maintenance and rehabilitation strategies, and
- To study the impact of specific pavement design features (such as drainage and prerehabilitation preparations) on subsequent performance.

Individual analysis projects, as well as sequences of projects, have been identified and defined in support of each of the seven objectives in the plan. For each project, the specific analytical effort, scope, time frame, and budget have been described. The descriptions identify the data needed; the availability of the data; and the analytical efforts either completed, under way, or yet to be undertaken that are necessary for the success of the project. Overall, the plan is a coordinated set of

interrelated analyses, with the outcomes of some becoming inputs to others. Although each analysis has the potential to produce insights leading directly to products, equally important is the potential for the results of one analysis to provide needed information for subsequent analyses.

The plan has served to chart the course of LTPP-funded data analyses and to guide other analysts by suggesting directions for their efforts along paths of inquiry that would supplement LTPP's efforts. The plan is limited in the sense that it seeks to achieve programmatic objectives. It does not define all possible uses of the database.

To date, 63 of the 97 projects defined in this plan have been completed with the use of LTPP, National Cooperative Highway Research Program, and FHWA non-LTPP funds. They have contributed substantially to improvements in pavement technology. Analysis findings have already led to the development of products such as LTPPBind[2] and software for predicting minimum pavement temperatures, which have been incorporated into the Superpave®[3] system of hot-mix asphalt materials design. Other data analyses contributed to the development of the 1998 Supplement to the *AASHTO Guide for Design of Pavement Structures*.

Product Development

The true benefit of the LTPP database will come from its use in developing new pavement designs and methods for building and maintaining pavements. While individual researchers and organizations from around the world are likely to continue to apply the LTPP data on an ad hoc basis for as long as the data remain accessible, the most immediate impact will be achieved if data analysis is pursued in an organized and programmatic fashion, accompanied by a similarly organized program of product development.

[2] LTPPBind is a Windows-based software program developed by LTPP to help highway agencies select the most suitable and cost-effective Superpave® asphalt binder performance grade for a particular site. http://www.fhwa.dot.gov/pavement/ltpp/ltppbind.cfm.

[3] The Superpave (SUperior PERforming Asphalt PAVEments) system was developed to give highway engineers and contractors the tools they need to design asphalt pavements that will perform better under extremes of temperature and heavy traffic loads. The system primarily addresses two pavement distresses: permanent deformation and low-temperature cracking. The system consists of three interrelated elements: asphalt binder specification, volumetric mix design and analysis system, and mix analysis tests and a performance prediction system that includes computer environmental and performance models.

Product development activity began in earnest in the late 1990s, when standardized procedures for collecting and processing the data had been developed and implemented throughout the LTPP experiments and data collection was maturing but far from complete. State agencies recognized the benefits that they would derive from incorporating these procedures into their own operations and requested LTPP's testing protocols, distress identification aids, analysis reports, and related information. In many instances, the information, software, and hardware requested by the states—from internal operational aids to tools suitable for external use by unknown third parties—had to be developed further.

Product development was greatly diminished by budget cuts necessitated by SAFETEA-LU's reduced funding for LTPP. The activity continues because LTPP's product potential extends far beyond tools and techniques for data collection and processing. The states continue to request decision-making aids and information with regard to the deployment of limited resources for pavement repair, rehabilitation, and reconstruction. It is fortunate that FHWA has found ways to keep this activity alive by using non-LTPP funds. However, the activity has been kept alive by "picking low-hanging fruit," rather than by executing a disciplined plan of product development, and by using small increments of unallocated funds from other related programs.

FHWA has developed a plan (FHWA 2001) for the development and delivery of LTPP products. The plan identifies the needs expressed by the states and provinces and tracks the development and delivery of products to meet those needs.

Database Maintenance

The LTPP database is the central repository for assembly, storage, and maintenance of the data collected at the program's test sections. It is LTPP's principal operational tool, its principal product, and its principal legacy to future highway researchers and practitioners. The database currently contains approximately 300 gigabytes of data. Additional data, including more than 450 gigabytes of scanned data sheets and electronic raw data and more than 200 billion records of traffic classification and weight data, are stored off-line.

The database is a continually expanding and improving repository of data about in-service highway pavements in North America. It

is the most comprehensive source of pavement performance data ever assembled and will continue to be a primary source of data for analysts around the world. It will be used more extensively and will have more impact on highway pavement research than the data collected at the AASHO Road Test,[4] which was conducted from 1958 to 1960 and was the last major road test in the United States prior to LTPP.

The ultimate success of LTPP can only be estimated now but will be evaluated by its future impact on engineers, researchers, and teachers of pavement technology. The committee is convinced that the database itself will be a major component of that legacy, since it will be the basis of analyses investigating how pavements perform as a function of their environment, design, materials, traffic, and age, and new design procedures will use this knowledge.

The NPPD will be the most comprehensive source of pavement performance data ever assembled. The data will provide the basis for understanding how pavements perform. The database will be the primary source of data for pavement studies and analysis throughout the United States for years to come. The impact and usefulness of the database will grow with creation of the NPPD by preserving what exists and improving on it with additional extended performance data, technical data analysis, interpretive reports, performance predictive models, software programs, user manuals, and countless other products.

[4] The AASHO Road Test was a series of experiments conducted by what is now AASHTO to determine how traffic contributed to the deterioration of highway pavements. The study was carried out in the late 1950s and is the primary source of experimental data when vehicle damage to highways is considered. The test consisted of six two-lane loops along the future alignment of Interstate 80. Each lane was subjected to repeated loading by a specific vehicle type and weight. The pavement structure within each loop was varied so that the interaction of vehicle loads and pavement structure could be investigated. The results of the test were used to develop a pavement design guide, which was issued in 1961.

3
RECOMMENDATIONS

The committee recommends that an NPPD be established to serve as the custodian and steward of the LTPP database; that it be charged with keeping the LTPP database hardware and software current as the technology of computers and data storage evolves and with incorporating additional pavement performance data into the database as such data become available; and that it be charged further with conducting LTPP data analysis and product development to support those seeking to better understand the causes of pavement deterioration and to develop new designs and maintenance procedures based on this improved knowledge.

To ensure the long-term survival and viability of the NPPD, the committee recommends that the NPPD be established as an entity with a stated mission similar to that of the National Highway Institute (NHI)[1] or the Highway Performance Monitoring System (HPMS).[2] Both the NHI and the HPMS were established as a result of federal legislation, and both entities have survived for decades despite changes of administration, retirements of key individuals, reprioritization of programs, and reassignments of staff. The committee hopes that the

[1] Established by Congress in 1970, NHI provides training that addresses the full life cycle of the highway transportation system to professionals and the public. The purpose is to train the current and future transportation workforce and to aid in the quick and effective transfer of knowledge among transportation professionals.

[2] The HPMS is a federally mandated inventory system and planning tool designed to assess the nation's highway system. The HPMS provides data that reflect the extent, condition, performance, use, and operating characteristics of the nation's highways. It was developed in 1978 as a national highway transportation system database. It includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and certain statewide summary information. The HPMS data form the basis of the analyses that support the biennial Conditions and Performance reports to Congress on the condition of the nation's highways. These reports provide a comprehensive, factual background to support development and evaluation of the administration's legislative, program, and budget options. They provide the rationale for requested Federal-Aid Highway Program funding levels and are used for apportioning federal-aid funds back to the states; both of these activities ultimately affect every state that contributes data to the HPMS.

NPPD, as an entity with a mission, will survive similarly and preserve and maximize the use of the LTPP database.

The committee further recommends the following:

- The NPPD should be a self-contained and fully funded entity. It should be a unit of an existing agency with the appropriate mandate and associated resources, not a collateral activity of an existing office.
- The managers of the NPPD should create an advisory committee consisting of a representative cross section of pavement stakeholders and data users, including other federal agencies, state transportation departments, local governments, nonprofit entities, academia, and the private sector, to review and recommend improvements in the plans and operations of the NPPD.
- Data analysis and product development contracts should be awarded through open competition and merit review conducted on a regular basis, as is done in programs such as the National Cooperative Highway Research Program and SHRP 2.
- Contract findings should be disseminated through conferences and seminars, field demonstrations, workshops, training programs, the World Wide Web, publications for the general public, and other appropriate means.
- The NPPD should include an operations agenda and a multiyear strategic plan for the following purposes:
  - To ensure the quality and completeness of the data and to fill data gaps and establish a more consistent level of data quality throughout the database where possible;
  - To maintain the database by keeping its hardware and software current and by incorporating additional data as they become available;
  - To maintain the Materials Reference Library as a central storage facility for asphalt cements and aggregates used in the SHRP asphalt research and for pavement and subsurface materials and 35-mm pavement surface distress films used in the LTPP studies;
  - To ensure the accessibility of the database to support those seeking to understand why some pavements deteriorate rapidly while others do not;
  - To continue the collection, processing, and uploading of pavement performance data from in-service highway test sections

identified as LTPP test sections;

- To continue the execution of data analysis projects according to existing plans for strategic analysis of LTPP data; and
- To continue, in accordance with existing plans, translating analytical results into tools, techniques, and other products that can be used by state agencies for pavement design, rehabilitation, maintenance, and management.

• The operations agenda should include data analysis and product development in the following areas:

- Highway traffic characterization and prediction,
- Pavement materials characterization,
- Determination of environmental effects on pavement design and performance prediction,
- Evaluation and use of pavement condition data in pavement management,
- Development of pavement response and performance models applicable to pavement design and performance prediction,
- Pavement maintenance and rehabilitation strategy selection and performance prediction, and
- Quantification of the performance impact of specific pavement design features.

4
The National Pavement Performance Database

Establishment

In the committee's opinion, establishment of a centralized NPPD would be the most effective and efficient means of securing the future of the database. Data would be collected and analyzed and products would be developed in a manner consistent with the original statement of LTPP's objectives.

As a single entity with centralized management and a dedicated staff, the NPPD will be responsible for

- Maintaining the LTPP database as an easily accessible compilation of information and data about the design, materials, traffic, environment, age, and deterioration of more than 2,000 test sections across the United States;
- Analyzing these data to investigate how pavements deteriorate; and
- Providing state agencies with results of these analyses in the form of tools for better design, maintenance, rehabilitation, and reconstruction of the nation's highway pavements.

Establishing the NPPD requires agreement of federal, state, and private stakeholders of LTPP. Doing this as quickly as possible is important; however, any such agreements should be enduring and survive changes of agency administrations or incumbents. Establishing and funding the NPPD when surface transportation research is next authorized would be appropriate.

In addition, the duties of the custodian and steward logically include the responsibility for the MRL. The MRL is a central storage

facility for asphalt cements and aggregates that were used in the SHRP Asphalt Research Program and for pavement and subsurface materials used in the LTPP studies. The MRL also stores LTPP's 35-mm films recording test site surface distresses. Materials from other FHWA and national pavement research activities have also been stored at the MRL over time, and material from other research work will be stored there in the near future. The materials samples housed there will yield information about the nature and performance of pavement materials when new theories and test methods pertaining to materials science are developed. The information will be a valuable addition to the results of analyses of the LTPP database that will be conducted in the future.

Operations

The committee believes that all six LTPP activities (data collection, data analysis, product development, database security and maintenance, and database user support) are of the utmost importance and need to continue beyond the conclusion of LTPP as key operational components of the NPPD. Teaming with other groups pursuing compatible programs might bring additional resources to bear on NPPD's objectives, but the NPPD must be responsible for the conduct and coordination of all of these activities if the continued effort is to succeed. While the immediate focus is on planning for the next authorization period of FY 2010 to FY 2015, the committee's recommendations concerning the NPPD are not limited to this 6-year period. The LTPP database will be a valuable national asset, and the NPPD will be its custodian and steward until the database is rendered obsolete by more comprehensive databases in the distant future.

Supporting Advances in Pavement Technology

The NPPD is the premier product of LTPP and its principal legacy to the highway pavement community. Collecting and compiling the data into the database have been the core activities. Completing the collection of performance data from test sites that have not yet yielded all of the data that they were designed to produce and providing those data to analysts are the committee's key objectives as it looks beyond FY 2009.

LTPP data have been available since the first public release of data in May 1999, and the database will remain an important resource for pavement performance research. However, this expectation can be realized only if the database and supporting information remain accessible. Accomplishing this will require

- Identification of a permanent custodian and steward for the database,
- Secure storage of the database,
- Software and hardware updates to keep pace with changing data storage technology, and
- Maintenance of the MRL.

Providing for security and maintenance of the NPPD will ensure that it remains accessible to all potential users. This is the minimum level of functionality needed to ensure progress toward achievement of the NPPD's potential. Absent investment in these activities, the NPPD's ability to contribute to advancements in pavement engineering will be gradually eroded and eventually lost.

Facilitating Wide Use

The principal function of the NPPD is the compilation and analysis of pavement data. Information is produced from the data and disseminated to state departments of transportation so that they can make informed decisions with regard to the design, construction, and maintenance of their pavements. Continued research must be conducted to improve the quality and usefulness of the data. The data must be continually reviewed and updated for relevance to ensure that current needs for decision making and analysis are being met and that future needs are being anticipated. This will require maintaining contact with a broad spectrum of users in academia, state and local highway agencies, and private industry.

The NPPD will require staff to conduct user support activities to ensure easy access to and effective use of the database. The following are examples of such support activities:

- Data preservation and maintenance;
- Data table consolidation and quality labeling enhancements;
- Creation of ready-to-use data sets;

- Program documentation enhancements;
- Maintenance and materials management of the MRL and associated pavement distress materials currently in storage; and
- Collection, preservation, and maintenance of the ancillary data that have already been developed and stored in various ways and locations.

The NPPD will be the primary source of data in the use of the *Guide for Mechanistic–Empirical Design of New and Rehabilitated Pavement Structures* (MEPDG),[1] whose performance prediction models were calibrated by using LTPP data. However, it is necessary to perform additional calibrations against a wider range of local variables to achieve a practical design procedure for a particular road, and these calibrations are also likely to rely on this database.

Strategically, the NPPD is required to fulfill the need for long-term monitoring of pavement performance. The 1978 Surface Transportation Assistance Act, long-term monitoring studies of the early 1980s (FHWA 1985; Rauhut et al. 1986), and a TRB special report in 1984 (TRB 1984) clearly established the need for long-term or continuous pavement monitoring. New construction technologies and new materials reinforce the need for long-term monitoring of pavement performance. The database could serve as the starting point for such an initiative. Performance information and other data from test sections in various states that were used to calibrate the MEPDG, as well as from other test sections, could be added to the database.

Issuance of reports and development of tools of analysis are integral activities of any statistical center or bureau, and that should be the case for the NPPD. An example of such a report is *Highway Statistics 2006*.[2]

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[1] The MEPDG is a part of the output of National Cooperative Highway Research Program Project 1-37A, which produced a guide for mechanistic–empirical design and analysis, companion software with documentation and a user manual, and implementation and training materials. The guide includes procedures for the analysis and design of new and rehabilitated flexible, rigid, and semirigid pavements. It uses mechanistic–empirical numerical models to analyze input data for traffic, climate, materials, and structure to estimate damage accumulation and predict performance in terms of distress and smoothness. http://www.trb.org/mepdg/AASHTO_memorandum.pdf.

[2] http://204.68.195.102/policy/ohim/hs06/index.htm. FHWA collects information necessary to support its responsibilities to Congress and the public from the states and publishes the information in Highway Statistics. It is used in the development of highway legislation at both the federal and the state levels. The information is also used in preparing legislatively required reports to Congress; in calculating and evaluating federal fund apportionments; in keeping state governments informed; in aiding highway planning, programming, budgeting, forecasting, and fiscal management; and in evaluating federal, state, and local highway programs.

Funding

The table below provides what the committee considers to be an appropriate set of activities for the newly established NPPD and corresponding funding needs for the period from FY 2010 to FY 2015. These needs are based on estimates that appear in the committee's earlier report (TRB 2001),[3] as well as on information provided to the committee by FHWA concerning LTPP's costs in the years prior to FY 2008.

Activity	*6-Year Budget ($ millions, in 2008 dollars)*
Data collection	**6**
Data analysis	**14**
Product development	**14**
Database security and maintenance	**4**
Database refinements	**6**
Database user support	**2**
Ancillary (nondigital) data maintenance	**2**
Staff operations	**6**
Total	**54**

In sum, the committee's refined estimate of the cost to operate the NPPD in the 6-year period from FY 2010 to FY 2015 is $54 million, or $9 million per year in 2008 dollars with no adjustment for inflation in future years.

[3] The column headed "FY 2009" in Table 2-1 on page 22 of that report contains the earlier cost estimates that have been referenced.

5
The Road Ahead

As FY 2009 and the expiration of SAFETEA-LU approach, a growing number of groups are following the committee's lead in realizing that LTPP's promise of better roads is still to be achieved and that the extra effort needed is well worth the investment. TRB's Committee for Pavement Technology Review and Evaluation,[1] TRB's Research and Technology Coordinating Committee (TRB 2008, 99), and AASHTO's Standing Committee on Research[2] have already reached this conclusion and issued public statements to this effect. In concert with them, the TRB LTPP Committee calls for this additional effort and recommends the establishment of the NPPD as the means to carry it out.

The establishment of the NPPD must be planned carefully and comprehensively, and the planning must start now. When discussion of the content of the next highway bill begins, establishment and funding of the NPPD should be given full consideration.

[1] Letter Report #2, http://onlinepubs.trb.org/onlinepubs/reports/PavTecComm_feb_2008.pdf.

[2] http://www.transportation.org/sites/policy_docs/docs/ix.pdf, page 13.

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
FHWA	Federal Highway Administration
TRB	Transportation Research Board

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Study Committee Biographical Information

Victor M. Mendez (*Chair*) is Director of the Arizona Department of Transportation (ADOT). He has held that position since 2002 and is responsible for more than 6,100 miles of roadway statewide, motor vehicle titling and registration, and aircraft registration. He manages more than 4,800 employees, organized into divisions including the Intermodal Transportation Division, the Motor Vehicle Division, the Transportation Planning Division, and the Aeronautics Division. Mr. Mendez was named Deputy Director of ADOT in 1999. Throughout his professional career, Mr. Mendez has worked on a variety of engineering projects and has managed several programs. From 1997 until late 1999, he was the Deputy State Engineer for the Valley Transportation Group at ADOT. He was responsible for the life-cycle programming, design, construction, and maintenance of the freeways and highways in the Phoenix metropolitan area (Maricopa County). Throughout his 15-year career with ADOT, Mr. Mendez has supervised several offices with responsibility for managing projects on a statewide basis, implementing quality initiatives, providing program management support, implementing management information systems, and providing project scheduling expertise and support. Early in his professional career, he worked in Oregon and northern Arizona. He planned, designed, managed, and constructed a multitude of civil engineering public works projects, including roadways, buildings, and water supply projects. In 1980 he graduated from the University of Texas at El Paso with a bachelor of science degree in civil engineering. He received a master's degree in business administration from Arizona State University in 1994. Mr. Mendez is a Registered Professional Engineer in civil engineering in the state of Arizona and a member of the AASHTO Standing Committee on Research.

William H. Temple (*Vice Chair*) was selected to fill the position of Chief Engineer, Office of Highways, of the Louisiana Department of Transportation and Development (LADOTD) in January 2001. From July 1999 to January 2001 he served LADOTD as Assistant Secretary, Operations, which is an administrative position over the nine district offices and the New Orleans Bridge Authority program. From May 1996 to July 1999 he served as LADOTD Chief Maintenance Engineer and was active with the AASHTO Subcommittee on Maintenance, serving as Task Force Leader in the pavements area. Mr. Temple served as Director of Research for the Louisiana Transportation Research Center from 1990 to 1996; in this capacity he worked to serve the research needs of LADOTD in a program involving approximately 50 in-house staff and seven Louisiana universities. Mr. Temple has authored four TRB technical papers on such topics as pavement serviceability, life-cycle cost analysis, and nondestructive testing of pavements, and he has made numerous presentations on similar topics. He graduated from Louisiana State University in 1971 with a BS in civil engineering and is currently a member of the AASHTO Joint Task Force on Pavements and the Standing Committee on Highways.

Michael E. Ayers is Director of Pavement Technology Services for the American Concrete Pavement Association (ACPA) in Skokie, Illinois. He has held that position since November 2001 and is responsible for technical issues relating to pavements and technology transfer. In that capacity, Dr. Ayers was also appointed as a Task Leader for several Innovative Pavement Research Foundation–Federal Highway Administration Cooperative Agreement contracts. In addition, his responsibilities include management and dissemination of research conducted though ACPA and its affiliates. Before joining ACPA, Dr. Ayers was Director of Technology Transfer at ERES Consultants in Champaign, Illinois. In that capacity, he was responsible for development and delivery of training courses for the Federal Highway Administration, state agencies, and private industry. He was active in research and served as Principal Investigator for numerous federally and state-funded research projects. Before joining ERES in 1996, Dr. Ayers was an Associate Professor of Civil Engineering for Oklahoma State University.

Thomas E. Baker is State Materials Engineer for the Washington State Department of Transportation. Mr. Baker manages 130 engineers and technicians in the performance of testing and engineering services for the state and for local agencies. His laboratory performs services in construction materials testing, pavement design and management, and geotechnical engineering services. Mr. Baker serves as Vice Chair for the National Transportation Product Evaluation Program (NTPEP), which is administered through AASHTO. He also serves as Vice Chair for the Plastic Pipe Product Panel and as Vice Chair of the Administrative Task Force, both within NTPEP. In 2001, Mr. Baker was selected as Chair for the Technical Section on Asphalt–Aggregate Mixtures of the AASHTO Subcommittee on Materials. Mr. Baker serves on the State Pavement Technology Consortium, which comprises four states' pooled efforts on improving pavements and pavement technology (the consortium includes the departments of transportation of Washington State, California, Texas, and Minnesota). Mr. Baker was a member of the Expert Task Group on LTPP Materials Data Collection and Analysis from 2002 to 2007.

Donald H. Freeman is currently president of Freeman's Consulting Services, Inc., a company that was formed after his retirement from the South Carolina Department of Transportation in January 2005. The firm specializes in project management, facilitation, mediation, and resolution of construction claims as related to highway and bridge projects. He is also a principal of LPA Group, Inc. Mr. Freeman began his career as a permanent employee with the South Carolina Department of Transportation in 1975 and held various positions within the department, ranging from Resident Construction Engineer to Director of Construction. Mr. Freeman was named Deputy Director/State Highway Engineer in 1997. In that capacity he also served as Assistant Executive Director, and as State Highway Engineer, he was responsible for the planning, development, construction, and maintenance of a 42,000-mile highway system. Mr. Freeman earned bachelor's and master's degrees in civil engineering from the University of South Carolina. He is a Registered Professional Engineer in South Carolina and was active in AASHTO as Chairman of the Transport Technical Review Team for Site Manager and as a member of the Subcommittee on Construction, the Transport Task Force, and the Standing Committee on Highways.

Ralph Haas is the Norman W. McLeod Engineering Professor and Distinguished Professor Emeritus at the University of Waterloo. He is a National Associate of the National Research Council of the National Academies and has been elected to the Canadian Academy of Engineering as well as the Royal Society of Canada. The author of 10 books and more than 400 technical papers on pavements and infrastructure, Dr. Haas has lectured and consulted worldwide. He has been involved in numerous TRB activities for more than four decades. He served as Chair or Cochair of the 1994 and 1998 International Pavement Management Conferences and as Chair of TRB's Pavement Management Committee, and he is an Emeritus Member of the committee. Dr. Haas is an Honorary Life Member of the International Society for Asphalt Pavements, the Transportation Association of Canada, and the Association of Asphalt Paving Technologists. In 2000, Dr. Haas received his country's highest civilian honor, Member of the Order of Canada.

Carl L. Monismith is Robert Horonjeff Professor of Civil Engineering, Emeritus, at the University of California, Berkeley, and Director of the Pavement Research Center, Institute of Transportation Studies at Berkeley. He is internationally recognized for his work in the fields of pavement design and rehabilitation and asphalt paving technology. Professor Monismith has served as Chair of the Pavement Design Section and has been a member of a number of committees and task forces of TRB. He was the first Distinguished Lecturer (1992) and the recipient of the K. B. Woods Award (1972) and the Roy W. Crum Award (1995) from TRB. He is a Member of the National Academy of Engineering and an Honorary Member of the American Society of Civil Engineers and the Association of Asphalt Paving Technologists. He is a Registered Civil Engineer in California.

David E. Newcomb joined the National Asphalt Pavement Association (NAPA) in October 1999 as Vice President–Research and Technology. Before joining NAPA, Dr. Newcomb was an Associate Professor in the Department of Civil Engineering at the University of Minnesota and had been Technical Director of the Minnesota Road Research Project since 1989. Before that, he taught at the University of Nevada, Reno, for 2 1/2 years. He received his PhD from the University of Washington in

1986 after working at the New Mexico Engineering Research Institute for 3 years. Dr. Newcomb received his BS and MS degrees at Texas A&M University in 1977 and 1979, respectively. He has published more than 90 papers and reports related to the characterization and behavior of bituminous materials and the structural evaluation of pavement systems. Dr. Newcomb has been Chair of TRB's Pavement Rehabilitation Committee and is a member of the Pavement Maintenance Committee, the Pavement Monitoring Committee, the Evaluation and Data Storage Committee, and the Flexible Pavement Design Committee. He is a member of the American Society for Testing and Materials, the American Society of Civil Engineers, the International Society for Asphalt Pavements, and the Association of Asphalt Paving Technologists. He is a Registered Professional Engineer in the state of Minnesota.

Robert L. Sack is Deputy Chief Engineer, Technical Services Division, with the New York State Department of Transportation (NYSDOT). He is responsible for the technical and administrative management of a division charged with providing materials engineering and testing, geotechnical engineering and testing, highway-use data services, and targeted transportation research in a timely and cost-effective manner for the department and other governmental agencies. The division manages the quality assurance program for materials incorporated into department projects, manages the department's testing laboratories, and is responsible for the department's pavement management program. Prior positions with NYSDOT include assignments in the Offices of Engineering, Legal Affairs, Operations, and Regional Affairs; he also served in the Office of the Commissioner. Mr. Sack holds master of public administration, master of science in civil engineering, bachelor of science in civil engineering, and associate in science degrees. He is a Licensed Professional Engineer in New York State. Mr. Sack is a member of the AASHTO Subcommittee on Materials and the American Society of Civil Engineers.

Ted M. Scott II is Director of Special Projects with the American Trucking Associations (ATA) in Alexandria, Virginia. He received a BS in civil engineering from the University of New Mexico and an MBA from Boston University. Before returning to ATA, he was Executive Director of Government Relations for Roadway Express and then

Yellow Roadway Corporation. He also served as an officer in the U.S. Army Corps of Engineers for 24 years, with overseas service in Panama, Vietnam, England, and Germany, and with U.S. assignments in the Engineer Topographic Laboratory, the Vicksburg Engineer District, and the Office of the Chief Engineers. He is a graduate of the U.S. Army Command and General Staff College.

Gary C. Whited is Program Manager of the Construction and Materials Support Center in the Department of Civil and Environmental Engineering, University of Wisconsin, Madison. Mr. Whited is responsible for managing operations of the center; conducting research activities; performing engineering studies for federal, state, and local transportation agencies; consulting on materials engineering and construction management projects; and classroom teaching. He has 35 years of experience in managing transportation programs and providing technical oversight of engineering projects and policy development in highway construction management, pavement design and construction, and materials use and testing for the Wisconsin Department of Transportation. He has a BS from Iowa State University and an MS from the University of Wisconsin, Madison. Mr. Whited has served on a number of National Cooperative Highway Research Program project oversight committees dealing with construction, pavements, and geotechnical engineering. He has served on a variety of TRB committees on soils, materials, pavement, and construction topics. He is a Licensed Professional Engineer in the state of Wisconsin and is a member of the American Society of Civil Engineers, the Association of Asphalt Paving Technologists, and the Midwest Concrete Consortium.

James McFarland Yowell served as State Highway Engineer for the Kentucky Transportation Cabinet from 1992 to 2005. In January 2003, he was appointed by Governor Paul E. Patton to his second term on the Board of Licensure for Professional Engineers and Land Surveyors in Kentucky. In addition, he has served as Chair of the Civil Engineering Industry Advisory Committee of the University of Kentucky, as a member of the Engineering Advisory Board of Western Kentucky University, and as a member of the Executive Committee for Construction Management at the University of Kentucky. After graduating from the University of Kentucky in 1959, Mr. Yowell worked for 6 years with the

Kentucky Department of Highways as an Assistant Resident Engineer and Resident Engineer on the construction of Interstate highways. After that, he spent 27 years working for various construction companies in Kentucky and Tennessee building bridges, roads, and water and sewer lines. A member of the National Society of Professional Engineers for 32 years, he served two terms as Vice President of the Kentucky Society of Professional Engineers and in 1984 was named the Outstanding Professional Engineer in Construction in Kentucky. He is also a member of the American Society of Civil Engineers and is a Licensed Professional Engineer in Kentucky, Tennessee, Georgia, South Carolina, and Florida. Since retiring, he has worked as a transportation consultant and currently is Engineering Group Manager for the City–County Planning Commission in Bowling Green, Kentucky.

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ISBN 978-0-309-12607-6