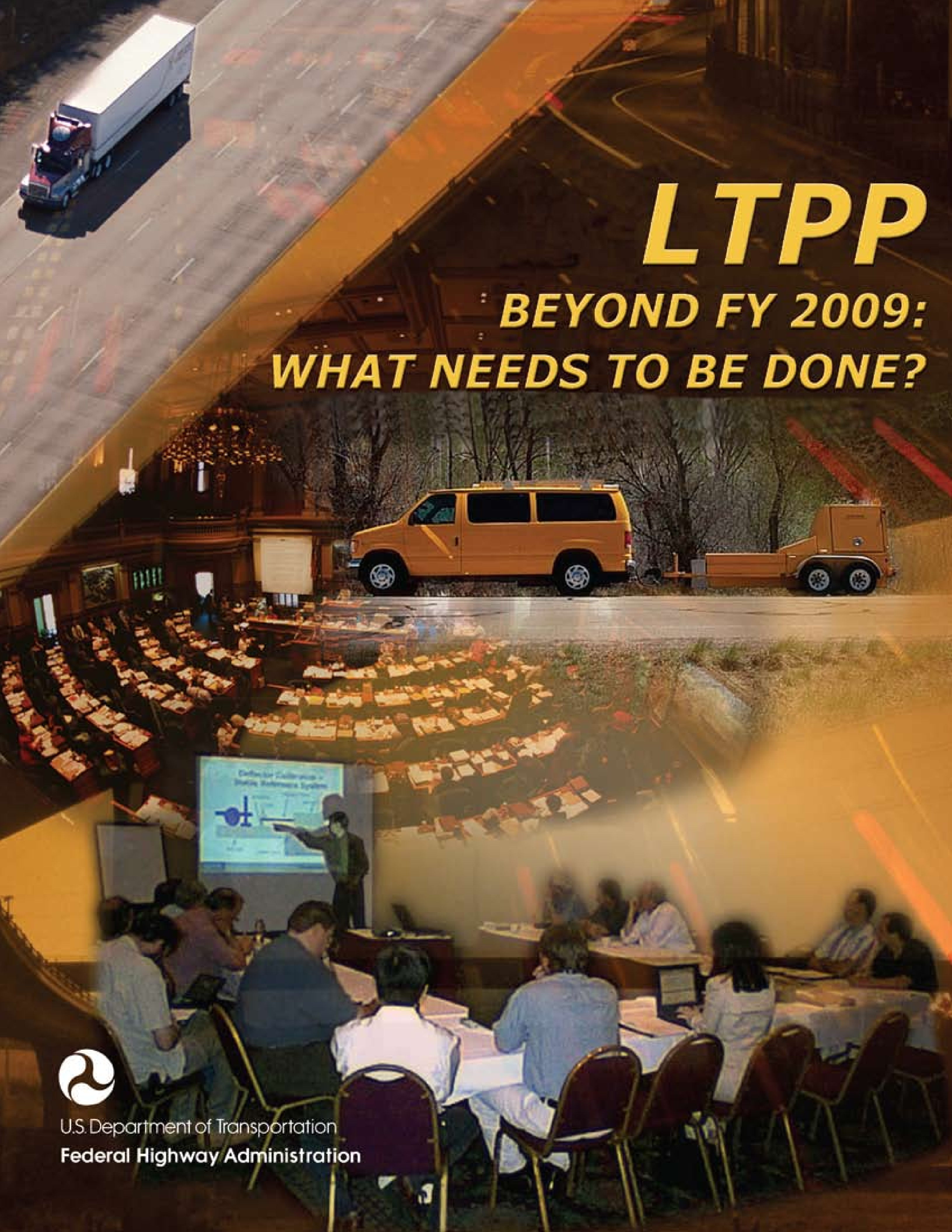
LTPP

BEYOND FY 2009: WHAT NEEDS TO BE DONE?



U.S. Department of Transportation
Federal Highway Administration

OVERVIEW

This report summarizes the current status of the Long-Term Pavement Performance (LTPP) program and its major activities—data collection, data storage, data analysis, and product development. It describes the work that will be needed beyond 2009 to realize the full potential of the world's most comprehensive pavement performance database and the benefits that will be accrued by capitalizing on the investment that has been made. The work that remains is as follows:

1. Provide ongoing security and maintenance of the LTPP database and manage the Materials Reference Library (MRL).
2. Continue to support LTPP database users.
3. Further develop the LTPP database including additional data collection and database refinements.
4. Continue data analysis and product development.

Addressing these needs is included in the Federal Highway Administration's (FHWA) planning for future infrastructure research and development as documented in *Highways of the Future—A Strategic Plan for Highway Infrastructure Research and Development* (FHWA-HRT-08-068).

The LTPP program is an ongoing and active program. To obtain more information, LTPP data users should visit the LTPP Web site at **http://www.fhwa.dot.gov/pavement/ltpp**. LTPP data requests, technical questions, and data user feedback can be submitted to LTPP customer service via e-mail at **ltppinfo@dot.gov**.

INTRODUCTION

The United States reaps a substantial return from investing approximately $40 billion a year in its pavements. As large as that figure seems, a recent article in *Roads & Bridges* puts the annual savings from the interstate system at $737 billion when considering "safety benefits, saved time, reduced fuel, and lower consumer costs."(1) The LTPP program, the most comprehensive pavement research program ever undertaken, addresses the issue of how to optimize this recurring investment.

The need for the LTPP program was first identified in the Transportation Research Board's (TRB) *America's Highways: Accelerating the Search for Innovation.*(2) This report, prepared by a panel of senior leaders in the transportation community, noted that highway pavements do not always live up to design expectations and recommended a "long-term field test that systematically covered a wide range of climate, soil, construction, maintenance, and loading conditions…."(2) In 1986, based on this recommendation, the American Association of State Highway and Transportation Officials (AASHTO) developed the plan for such a program to be included in the 5-year Strategic Highway Research Program (SHRP). The mission of the program, known now as the LTPP program, was to promote increased pavement life through the following:

- Collecting and storing performance data from a large number of in-service highways in the United States and Canada over an extended period to support analysis and product development.
- Analyzing these data to describe how pavements perform and to explain why they perform as they do.
- Translating these insights into knowledge and usable engineering products related to pavement design, construction, rehabilitation, maintenance, preservation, and management.

Congress funded SHRP which was managed by the National Academy of Sciences as part of Federal-aid highway authorizing legislation in 1987. LTPP field data collection began in 1989. It was always understood that the achievement of the program's objectives required that the program be continued over the long term. The long term, as originally envisioned, was a period of 20 years—the minimum duration necessary to establish a path to better roads. Therefore, as SHRP began to diminish, continuation of LTPP under the FHWA was formally authorized by Congress in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. In 1992, the FHWA assumed management and administrative responsibilities to continue LTPP and complete the planned pavement performance monitoring.

In 2009, the LTPP program is reaching its 20-year monitoring milestone—a critical milestone in this national pavement research initiative similar to the end of the first 5-year SHRP program. A dataset reflecting two decades of data collection is available. Analysis results derived from the application of the data are also available to support advances in pavement engineering science, to provide valuable insights and innovations, and to form the basis for the products needed by State transportation departments and local and municipal agencies.

The LTPP database is the program's most important product; however, LTPP has produced or contributed to many other products that have

benefited pavement engineering and pavement management practices. Other LTPP products that have been developed range from standardized data collection methods, to new engineering tools, to new pavement design methods. These advances are only the beginning as many significant activities, real benefits, and innovative products remain to be performed and developed after 2009.

This report briefly summarizes the current status of LTPP and describes the work needed after 2009 to capitalize on the investment made in developing the world's most comprehensive pavement research database. The purpose of this report is to provide LTPP's stakeholders with a look ahead to the critical activities and products that need to be pursued beyond 2009 in order to reap the high return rewards of this unique and critical program that has and will continue to influence the way pavements are designed, built, and maintained.

LTPP IN 2009

LTPP requires activities in four main areas: data collection, data storage, data analysis, and product development. These activities are conducted in accordance with a well-defined plan developed in collaboration with LTPP's primary stakeholders, the States, Canadian Provinces, academia, and industry. Accomplishments in each area derived from the substantial investment to date are discussed below.

DATA COLLECTION

The performance data collection effort is the largest and most comprehensive ever undertaken on in-service highway pavements. The LTPP experiment plan was developed in a collaborative manner to address the data analysis needs for various pavement types and was extensively peer reviewed by experts and highway agency practitioners.

Data collection guides developed by SHRP and kept current by the FHWA explicitly define the data elements to be collected for each experiment and test section, the sampling and testing protocols to be employed, and the processes used to assess data quality and store records in the LTPP database. Data collection categories include climate, traffic volumes and loads, pavement layer types and thicknesses, material properties, and pavement condition (distress, longitudinal and transverse profile, and structural response). Some data are collected centrally, while others are the responsibility of the participating States or Provinces. Regardless of the collecting agency, a high priority is placed on the accuracy and completeness of the measurements.

Of the 2,512 LTPP test sections located throughout the United States and Canada, 950 test sections are currently active. Figure 1 shows the geographic distribution of the test sections, while figure 2 shows the number of active test sections over time.

Prior to 2005, most data collection activities occurred on a yearly cycle for each test section. However, data collection on in-service test sections was reduced from annual surveys to one round of testing between 2006 and 2008 due to budget constraints of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This reduction in testing frequency, while a setback to the program, can be partially overcome with a return to more frequent data collection in the future. The remaining sections are those that are of most interest to pavement engineers, including many sections in the rehabilitation and structural factor experiments of the program.

DATA STORAGE

The LTPP database is the central facility for assembly, storage, maintenance, and dissemination of the collected data. The pavement performance database is LTPP's principal operational tool, its most strategic product, and its legacy to its stakeholders and future generations of highway researchers and practitioners. The LTPP pavement performance database is supported by a traffic database and a large amount of ancillary information including test section photographs, videos, reports, raw data files, construction plans, data collection protocols, data processing guides, and other program documentation.

The LTPP database is the largest and most comprehensive pavement performance research database ever created. At present, the database includes approximately 150 million records of data comprising

Figure 1. Geographic distribution of LTPP test sections.

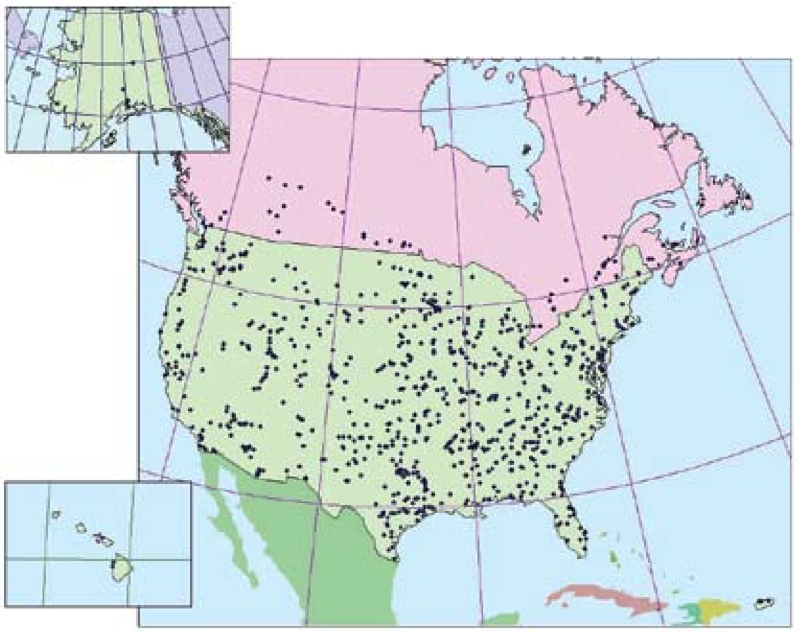
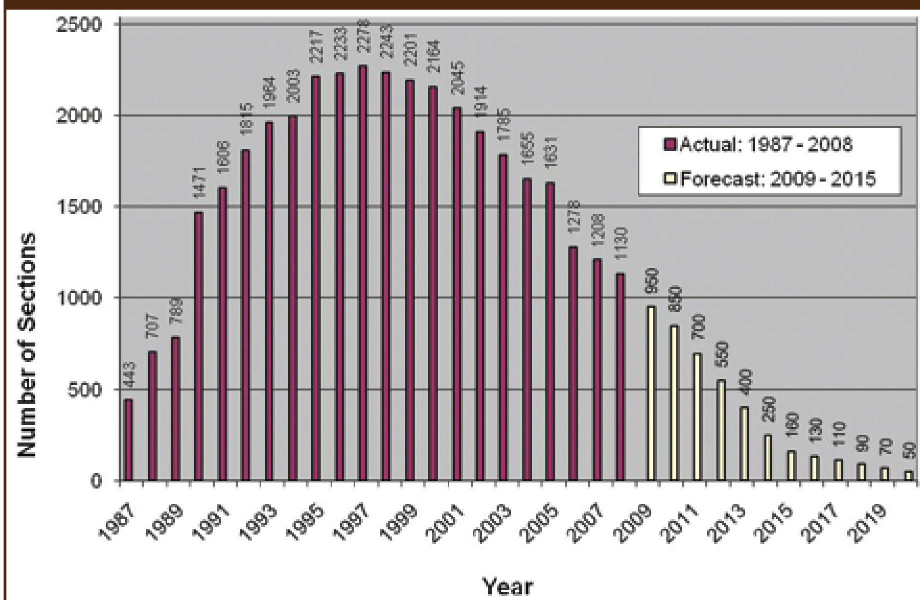


Figure 2. Variation in number of active test sections over time.



11,000 individual data elements stored in 460 tables. By virtue of its size and the evolutionary nature of its development, the database can be characterized as a complex data warehouse.

Plans to simplify the database structure, add more commonly used computed parameters,[1] improve access, and create a ready-for-analysis data structure have been deferred due to budget constraints. Therefore, in 2009, LTPP is delivering a data warehouse that is somewhat cumbersome to use properly and efficiently without extensive training and experience. Providing technical support to data users has been and will continue to be an important activity.

The ancillary data and information are even more voluminous than the pavement performance database. The traffic database presently contains more than 1.5 billion raw traffic classification and weight measurement records. The central electronic ancillary information consisting of data and images not in the pavement performance or traffic databases currently includes 10,000 files. Over 12,000 35-mm black and white, high-quality film-strips of LTPP test sections are stored in the MRL. In addition, FHWA has created a central LTPP library at the Turner-Fairbank Highway Research Center (TFHRC) to store the more than 600 physical documents associated with the program, many of which have yet to be converted into a searchable electronic format. Plans to create an indexed electronic library containing all of this information were canceled due to program budget constraints.

DATA ANALYSIS

Analysis of LTPP data, the key to producing benefits and products, began in earnest in 1992 with the evaluation of the then-current version of the *AASHTO Guide for the Design of Pavement Structures*.[(3)] That analysis confirmed the need for a new guide because it showed large discrepancies between predicted and actual performance. Since that initial analysis, a total of 90 LTPP data analysis reports have been published by SHRP, FHWA, and the National Cooperative Highway Research Program (NCHRP). Highlights of these reports can be found in the 2000 and 2004 *Key Findings from LTPP Analysis*, and many are available on the LTPP Web site **http://www.fhwa.dot.gov/pavement/ltpp/index.cfm.**[(4,5)] In addition, States, Provinces, and universities have published countless reports, theses, and dissertations based on analysis of LTPP data.

Data analysis serves several important functions. First, it provides the technical basis for identifying and developing tools and products that engineers and managers can use to design more cost-effective and better-performing pavements. It ensures that the data being collected are of the quality and completeness needed to find answers about how and why pavements perform as they do. It is also used to fill in data gaps, for example estimating cumulative traffic loads from short-term traffic monitoring measurements. Another major function of data analysis is to have experts centrally compute

[1] Computed parameters are values derived from the raw data that are stored in the LTPP database for use in subsequent analysis. Examples of computed parameters include International Roughness Index (IRI) values computed from longitudinal profile data as a measure of pavement roughness, backcalculated pavement layer moduli derived through analysis of pavement deflection data to characterize the structural characteristics of the pavement layers, and moisture content estimates derived from interpretation of raw data from Time Domain Reflectometry (TDR) probes.

common parameters from the raw measurements so that future researchers do not have to expend limited research resources performing these same computations.

The FHWA worked with the Data Analysis Expert Task Group (ETG) of the TRB to develop a strategic plan for LTPP data analysis. This plan was subsequently expanded and maintained with support of all of the TRB LTPP committees supporting the ETG. The plan lays out a long-term strategy for data analysis that recognizes both internal and external analytical needs, the current or anticipated data availability, and the building block process through which the major products of LTPP will be developed. The plan is a coordinated set of interrelated analyses, with some outcomes being inputs to others. FHWA maintains the plan by tracking analytical efforts completed, currently underway, and yet to be undertaken.[2] To date, 66 of 116 identified projects have been completed through FHWA, NCHRP, or pooled fund projects.

Due to funding limitations under SAFETEA-LU, only two formal data analysis projects have been supported with LTPP program funds for fiscal years 2005 to 2009. Over 40 LTPP analysis projects identified in the plan remain to be funded.

PRODUCTS AND BENEFITS

Documented outcomes of the LTPP program include many positive and wide ranging impacts. Long lasting and quality pavements contribute to the following:

- **Country**—Expanded economy.
- **Public**—Increased safety, decreased congestion, and reduced user costs.
- **Environment**—Reduced pollution.
- **Highway agencies**—New and improved engineering practices and savings.
- **Education**—Real world data for university curricula.
- **Industry**—New equipment, manuals, calibrations, and lab procedures.
- **Research community**—A national pavement performance database.

Products derived from LTPP have been flowing to State transportation departments and other segments of the highway community since the early years of the program. Initially, these were methods, guidelines, and procedures for standardized testing and performance data collection. While these procedures were developed to meet LTPP data collection needs, their conversion into standard practices has been an AASHTO activity. Some products and benefits from LTPP already implemented in practice are based on best-practice construction specifications developed for the pavement experiments requiring new construction, while other products were developed from early analysis of LTPP data.

The products and benefits derived from the LTPP program include improved data collection techniques, better data quality and quality assurance tools, new materials, testing protocols, software for selecting the most suitable and cost-effective asphalt

[2] See the Strategic Plan for LTPP Data Analysis (**http://www.fhwa.dot.gov/pavement/ltpp/stratplan/strategic.cfm**).

binder for a particular site, pavement maintenance and repair manuals, a more efficient method for asphalt pavement layer temperature measurements, rigid pavement design software, the implementation of wider Portland cement concrete (PCC) slabs and narrower joints, and discontinued use of skewed joints. Also, the developers of the *Mechanistic-Empirical Pavement Design Guide* (M-E PDG), developed under the NCHRP 1-37A project and adopted by AASHTO in 2008, stated that it would have been impossible to develop the guide and nationally calibrate its prediction models without LTPP data.[5,6]

Throughout the life of the LTPP program, significant efforts have been made to improve data accessibility for all potential users. At least once a year for more than a decade, standard data releases containing data from the LTPP database have been made available on CDs and/or DVDs. Since March 2003, DataPave Online has also made available a significant portion of the data contained in the LTPP database via the Web at **http://www.ltpp-products.com.**

Another significant benefit of the LTPP program has been the introduction and use of LTPP data in university engineering curricula. Many engineering schools with pavement engineering classes have developed course curricula around the LTPP data and database. In addition to challenging students with computational problems based on real field data, this provides the benefit of introducing both professors and students to database manipulation tools, which is an emerging need for future engineers that is not presently provided in most engineering programs. Hundreds of undergraduate and graduate students have used the LTPP database as part of their pavement engineering coursework. More than 75 engineering graduates with advanced degrees based on analysis of LTPP data are now working in the profession.

The funding dedicated to LTPP in SAFETEA-LU has not been sufficient to support both the development of LTPP-based products and the completion of the needed data collection. For this reason, LTPP product development activities are funded as part of FHWA's broader Pavement Technology Program.

In economic terms, the 2001 study *An Investment Benefiting America's Highways: The Long Term Pavement Performance Program* (FHWA-RD-01-094) estimated that the use of just one LTPP product, the LTPPBind software for selection of the SuperPave® binder grade, can save as much as $50 million per year. Estimates of the value of this and other products of the program to date give the program annual benefit-to-cost ratios ranging from 5 to 10. The overall rate of return could be much greater with an appropriate investment in data analysis and product development.

LESSONS LEARNED TO DATE

LTPP is a unique national research program whose operations model consists of providing research quality data for analysis. Data quality has been a prime concern in the development and operation of the LTPP program. LTPP is also unique in its magnitude and duration. Full documentation of the many lessons learned over the course of the last 20 years is beyond the scope of this report. However, within the context of planning for LTPP after 2009, the most important lessons learned to date are as follows:

- Continued involvement of stakeholders is vital to the ultimate success of the LTPP program. Routine coordination and communication with participating highway agencies, for example, are of paramount importance. Without support

from the States and Provinces, performance monitoring and other data collection activities on the LTPP test sections would not be possible. Furthermore, the program cannot afford to lose priority test sections due to a lack of interest by the highway agencies.

- Central management of core LTPP functions is required to achieve consistent, high-quality data.

- Efficient execution of a program, such as LTPP, requires considerable planning and a predictable, uninterrupted stream of funding. While LTPP has received continued funding, there has been considerable disruption and uncertainty as to how much money would be available and when it would be available. This was the case, for example, over the nearly 2-year period of extensions and continuing resolutions under the TEA-21 highway legislation immediately prior to the SAFETEA-LU highway legislation. The adjustments in short- and long-term plans and priorities made necessary by funding uncertainties and shortfalls led to missed opportunities, as is the case with pavement performance monitoring and the delay of critical activities.

- The LTPP database is the program's principal operational tool, its most strategic product, and its legacy to future generations of highway researchers and practitioners. LTPP's efforts over the past two decades have focused primarily on the collection and efficient storage of high-quality data in the database. The database is a large data warehouse, not an analysis database. Successful navigation requires in-depth knowledge that requires a substantial investment of time to develop. In addition, the database contains many raw data elements that must be combined or processed in some way to derive data sets suitable for analysis. In some cases, significant effort is required to extract and prepare the data for analysis. Therefore, refinements and enhancements to the database to significantly improve its accessibility are viewed high-priority needs to address after 2009.

- More than 20 years are required to fully document and understand the performance of high-performing in-service pavement structures. To understand why some pavements provide superior service beyond a 20-year design life, monitoring must be extended beyond 20 years.

LTPP BEYOND 2009

The LTPP database that is delivered in 2009—the culmination of the originally-planned 20-year monitoring period for the LTPP test sections—has enormous potential as the foundation for improvement in pavement engineering and management procedures and practices. While some of that potential has already been realized, full realization will require work beyond 2009. The additional work currently identified as necessary to take full advantage of the investment already made in LTPP is as follows:

1. Provide ongoing security and maintenance of the LTPP database and manage the MRL.
2. Continue to support LTPP database users.
3. Further develop the LTPP database including additional data collection and database refinements.
4. Continue data analysis and product development.

SECURITY AND MAINTENANCE OF THE LTPP DATABASE

The LTPP data have been available to all potential users since the first public release of data in May 1999. The LTPP database is expected to remain an important resource for pavement performance research for decades to come. However, this expectation can only be realized if mechanisms are put into place to ensure that the database and supporting information remain accessible to all. Accomplishing this will require the following:

- Arrangements for secure storage of backup copies of the database and updates of the database software and hardware needed to keep pace with changing data storage technology, newly discovered data issues, and new ways to characterize data. This work includes expansion and development of the auxiliary information management system.
- Maintenance of the MRL established as part of the SHRP Asphalt Research Program. Although not solely an LTPP activity, the MRL is an important component of the work required to secure the LTPP data by virtue of the fact that it is the repository for material samples and 35-mm film distress records from LTPP test sections.

History offers an important lesson in this regard. The 1957 American Association of State Highway Officials (AASHO) Road Test data were used by researchers and engineers in the Federal Government, State transportation departments, and industry associations for many years after the completion of the test. However, a majority of its data were lost due to a fire at the public university that volunteered to house the data. Avoiding a similar loss of the LTPP data will require positive action to secure continued access to LTPP data and information after 2009.

Providing for security and maintenance of the LTPP database will assure that it remains accessible to any and all potential users. This is the minimum level of functionality needed to assure progress toward full achievement of the potential of LTPP. Without adequate investment in these activities, the potential of the LTPP database to contribute to advancements in pavement engineering will be gradually eroded and eventually lost.

Materials Reference Library

The original MRL was established in the late 1980s in Austin, TX, as part of the original SHRP. The purpose of the MRL was to create a central storage/warehouse facility for asphalt cements and aggregates selected for use by the Asphalt Research Program of SHRP and pavement and subsurface materials from both the General Pavement Studies (GPS) and Specific Pavement Studies (SPS) experiments of the LTPP program. This has made it possible to link the results of past, present, and future research of national significance.

Over time, materials from other FHWA and national pavement research activities such as the FHWA Crumb Rubber Modifier Project, Accelerated Loading Facility (ALF), and the WesTrack Project were also stored in the MRL. Material from the National Center for Asphalt Technology (NCAT) and the Western Research Institute (WRI) research work will be stored there in the near future.

From 2003 to 2006, materials from the MRL have been used to support 32 national highway research projects. Samples from the LTPP test sections added to the MRL enable the application of as-yet undeveloped test methods to LTPP materials, thereby enabling updates of the LTPP data to reflect new technologies. These samples have and will continue to make it possible to clearly understand the relationships among studies including LTPP through its use of common materials.

SUPPORT USERS OF THE LTPP DATABASE

For the past decade, researchers throughout the world have successfully applied LTPP data to address a broad array of pavement engineering problems. Among the keys to their success has been the availability of technical support to answer their questions, point them to the documentation they need to understand the data applicable to their problem, and otherwise help them successfully navigate and manipulate the LTPP database to obtain the appropriate data. Over 5,000 requests for LTPP data or technical assistance have been processed by LTPP. Given the complexity of the LTPP database, continuing to provide technical support to data users is important to maximize the success and efficiency of those who apply the LTPP data to address pavement engineering problems.

User support may take several different forms and the level of support provided may depend on the intended use of the data as illustrated below through the following sample scenarios:

- For studies of national significance, such as the NCHRP 1-37 effort that developed the new M-E PDG, user support may entail: (1) face-to-face meetings with the contract team to clearly understand their data needs and required format as well as to suggest the best source of those data within the LTPP database, (2) custom extractions from the LTPP database to provide the needed data in the appropriate format, and (3) ongoing technical support to ensure a clear understanding of the LTPP data by the contractor team and to clarify issues that may arise from their usage.
- In the case of State and local highway agencies, user support could focus on the generation of custom data extraction routines that would generate data sets for selected location(s) that could be used to calibrate the M-E PDG for local conditions. User support would also likely entail general technical support to ensure a clear understanding of the LTPP data provided and to clarify issues that may arise from their usage.

- Support may include training for government agencies, industry, academia, and local agencies. For example, LTPP has developed a professor training workshop that familiarizes and engages professors who teach pavement engineering courses with the LTPP database and real pavement analysis problems.

- For university students working on their theses, dissertations, or other university or State-sponsored research projects, user support could include: (1) provision of the standard LTPP database release along with the required documentation, (2) recommendations on where to find the needed data within the database structure, and (3) clarification of data-related questions and issues.

The above examples are just a few of many possible scenarios, but they illustrate that the actual form and level of user support will depend on the nature of the request and from where it originates. In addition to the above, keeping track of data requests and suggestions made by data users to improve either the customer support functions or the database itself is also a vital function associated with user support (i.e., the feedback mechanism).

FURTHER DEVELOP THE LTPP DATABASE

While the LTPP database is already an unprecedented resource for deriving answers about how and why pavements perform, its value could be improved significantly through targeted investment in its further development. Two areas of investment warrant consideration: (1) additional monitoring of selected LTPP test sections to improve its potential for answering the most critical performance questions facing pavement engineers and (2) refinement of the database to make it easier to use. More details concerning these opportunities are listed below.

Test Section Monitoring

A total of 950 LTPP test sections remain in active service in 2009 (see figure 2). Among these test sections, some have been constructed or rehabilitated within the past decade in several of the SPS-2 projects, while some are long-lived structures still in good condition, and others are monitored as LTPP test sections both before and after rehabilitation. Continued performance monitoring of these sections will be needed to fully answer the questions they were selected to address.

For example, many of the SPS-2 experimental sites have been in service for fewer than 15 years as of 2009. In addition, 172 of the original 207 (83 percent) SPS-2 test sections are still active in 2009. Similarly, 155 of the presently active GPS-6 and -7 (asphalt concrete (AC) overlay on AC and PCC pavements, respectively) experimental test sections have been in service for 10 years or less as of 2009.

An opportunity for continued monitoring that warrants consideration is the collection of permanent distress records for those test sections that remain in service. This activity was highly recommended by the TRB LTPP Committee for pursuit prior to 2009, but it was not completed due to budgetary constraints.

One area where continued LTPP test section monitoring is already provided for to some degree is the continued collection of traffic data for selected SPS test sections. This work is part of the LTPP SPS Traffic Data Collection Pooled Fund Study. Table 1 provides more specifics as to the benefits that may be derived through additional monitoring of several

subsets of the LTPP test sections that remain in service as well as what will be lost if monitoring is not continued.

Database Refinements

The LTPP database that is delivered in 2009 is best described as a large data warehouse. While the LTPP database is well documented, successful navigation requires in-depth knowledge that develops only after a substantial investment of time. In addition, the LTPP database contains many raw data elements that must be combined or processed to derive data sets suitable for analysis. Several activities have been identified as having the potential to make the LTPP database easier to use, which include the following:

- Creating a consolidated pavement surface distress time history dataset.
- Developing consolidated transverse profile indices.
- Consolidating data tables.
- Generating additional computed parameters (e.g., layer moduli derived from deflection data, hot mix asphalt dynamic modulus values from existing laboratory test results, etc.).
- Creating ready-to-use analysis datasets.
- Improving the data quality labeling system.

Table 1. Summary of economic analysis results.

Monitoring of LTPP Test Sections	Benefits of Additional Data Collection	What Is Lost if Monitoring is Not Continued
SPS-1 and -2	Improved ability to derive definitive results concerning the impact of design features on pavement performance.	Research conclusions that are drawn will be founded on incomplete performance histories, and the results may be misleading in relation to long-term performance.
SPS-8	Assessment of the effects of loading and environment on pavement life. This work cannot begin until sufficient distress (serviceability loss) has accumulated on the SPS-8 test section pavements.	The opportunity to quantitatively evaluate the performance impact of environmental factors absent of heavy loads, which is critical for pavement design and performance models.
GPS-6 and -7 SPS-5, -6, and -9 (AC overlay)	Improved design, construction, and maintenance procedures for AC overlays, which will result in longer and/or more economical renewed pavement life.	Knowledge required for improving the design, construction, and maintenance of AC overlays.
GPS-1, -2, -3, -4, and -5 (long life)	Performance data required to develop, verify, and calibrate designs for long-life, high-performance pavements and to manage and maintain those new pavements.	Knowledge required for designing, managing, and maintaining long-life, high-performance pavements.
Permanent distress records for LTPP	Future analysts will have the opportunity to revisit test section condition on the basis of objective records. Potential for interpretation/reinterpretation of images based on improved distress definitions/criteria.	No objective record of pavement distress condition will exist for dates after 2005.

- Interpreting test section images.
- Enhancing electronic documentation for the program.

Pursuit of these enhancements would significantly improve the accessibility of the LTPP database to those not intimately involved in its development and bring the LTPP database into better compliance with section 515 of the Treasury and General Government Appropriations Act for fiscal year 2001 (Public Law 106-554; H.R. 5658). Section 515 directs the Office of Management and Budget (OMB) to issue governmentwide guidelines that "provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies." Funding restrictions preclude pursuit of these enhancements prior to 2010.

DATA ANALYSIS AND PRODUCT DEVELOPMENT

The greatest way to derive benefit—the real payoff—from the LTPP database is to first apply the data and then develop products from what is learned through its application. While it is likely that individual researchers and organizations around the world will continue to apply the LTPP data on an ad hoc basis for as long as it remains accessible to them and applicable to questions of interest, the greatest and most immediate impact will be achieved if an integrated and programmatic approach to analysis (such as that defined in the Strategic Plan for LTPP Data Analysis) is pursued in an organized fashion and accompanied by a similarly coordinated and organized program of product development. More specifics concerning the work that is needed are provided next.

Data Analysis

The Strategic Plan for LTPP Data Analysis provides the framework, organization, and classification matrix for LTPP-related research projects. The plan identifies the following seven strategic objective areas:

- Traffic characterization and prediction.
- Materials characterization.
- Determination of environmental effect in 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.
- Maintenance and rehabilitation strategy selection and performance prediction.
- Quantification of the performance impact of specific design features such as drainage and prerehab surface preparation.

More than 60 analysis projects defined in the plan have been completed, and over 300 research papers have been submitted to the TRB using LTPP data. Numerous agencies have initiated follow-up research and/or implementation activities within their jurisdictions to take advantage of the LTPP efforts. However, 40 defined research projects remain to be performed, and some analysis outcomes are not ready for development of research problem statements since the underlying research will not have been performed. In addition, second looks at early findings from LTPP data are recommended to determine if the short-term trends were correct.

It is also important to recognize that while national needs drove the analysis program defined in the Strategic Plan for LTPP Data Analysis, the plan does not encompass all of the needs to which the data are applicable. LTPP data, for example, are also applicable to some of the needs identified in the Concrete Pavement (CP) Roadmap, the National Asphalt Roadmap, and, to a lesser degree, the Pavement Preservation Roadmap.[7–9] Many of the studies outlined in these strategic roadmaps will be difficult to perform without the use of LTPP data.

Product Development

The LTPP program was established to enable the development of new pavement engineering and pavement management products. While LTPP has created many products during the course of its mission, the most significant products will be derived after the full performance history of the test sections has been documented and complete suites of quality data are available in the LTPP pavement performance database. As noted by the TRB LTPP Committee in its 2001 report *Fulfilling the Promise of Better Roads*:

> The fact that LTPP data are being used does not indicate that the job is complete. Pavement distresses observed in the studies so far are primarily confined to the lighter duty test sections. To learn the lessons required to design long-life, high-performance pavements, we must continue to track the performance of the more structurally robust test sections. It is their performance that will yield the requisite knowledge to develop, verify, and calibrate designs demanded by 21st century highway networks; their performance that will teach us how to manage and maintain these new pavements. If LTPP stops now, we will have only learned how to build and maintain 20th century pavements better.[10]

OTHER CONSIDERATIONS

The post-2009 activities described in the preceding paragraphs are critical activities to fully complete the LTPP program. Those activities can be expanded to further extend the usefulness of the LTPP program.

The value of the LTPP database could be enhanced through the addition of new materials test data and other inputs required by the M-E PDG, in particular the level 1 inputs. Dynamic modulus testing of asphalt mixes and asphalt binder characterization testing in accordance with the M-E PDG input requirements, for example, would facilitate the calibration of the existing performance models at the State and local level while at the same time providing the necessary data for future calibration and validation of the existing models or the development of improved performance models. Also, improved traffic loading and volume estimates from the LTPP test sections could contribute to M-E PDG implementation.

At a higher level, completion of LTPP does not fully address the need for long-term monitoring of pavement performance. *America's Highways: Accelerating the Search for Innovation*, Special Report 202, the 1978 Surface Transportation Act and the FHWA Long-Term Monitoring Study of the early 1980s clearly established the need for long-term or continuous pavement monitoring.[2] The fulfillment of that need began with the LTPP program. However, many new technologies have evolved over the past two decades, including SuperPave®, the new M-E PDG, new construction technologies, and new materials. As a result, further long-term monitoring of pavement performance is warranted. The LTPP processes, procedures, and database could certainly serve as the spring board for such long-term monitoring programs.

SUMMARY

The first 20 years of data collection, data storage, data analysis, and product development have already provided LTPP stakeholders with a number of high priority outcomes from the program. However, the work is not yet complete.

Working with stakeholders, FHWA has identified the work that remains to be done and estimated the cost of completing that work. The required activities fall under the following four strategic work areas:

1. Provide ongoing security and maintenance of the LTPP database and manage the MRL.
2. Continue to support LTPP database users.
3. Further develop the LTPP database including additional data collection and database refinement.
4. Continue data analysis and product development.

Some of the benefits to be reaped through these activities will include the following:

- Improved ability to derive definitive results concerning the impact of design features on pavement performance.
- Ability to assess the effects of loading and environment on pavement life.
- Improved design, construction, and maintenance procedures for AC overlays, which will result in longer and/or more economical renewed pavement life.
- Increased knowledge required to develop, verify, and calibrate designs for long-life, high-performance pavements and to manage and maintain those new pavements.

Stakeholders of the LTPP program can be assured that plans to continue the program are a prime consideration of FHWA's future research and technology strategy. The Long-Term Infrastructure Performance Strategy outlined in *Highways of the Future—A Strategic Plan for Highway Infrastructure Research and Development* (FHWA-HRT-08-068) is intended to build upon the foundation that has been established through the LTPP program.(11) LTPP, as well as the continuation of the recently initiated Long-Term Bridge Performance program authorized under SAFETEA-LU and pursuit of infrastructure performance data collection needs, are central to FHWA's strategies for fulfilling the mission of better roads for our Nation.

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THE LONG-TERM PAVEMENT PERFORMANCE (LTPP) PROGRAM

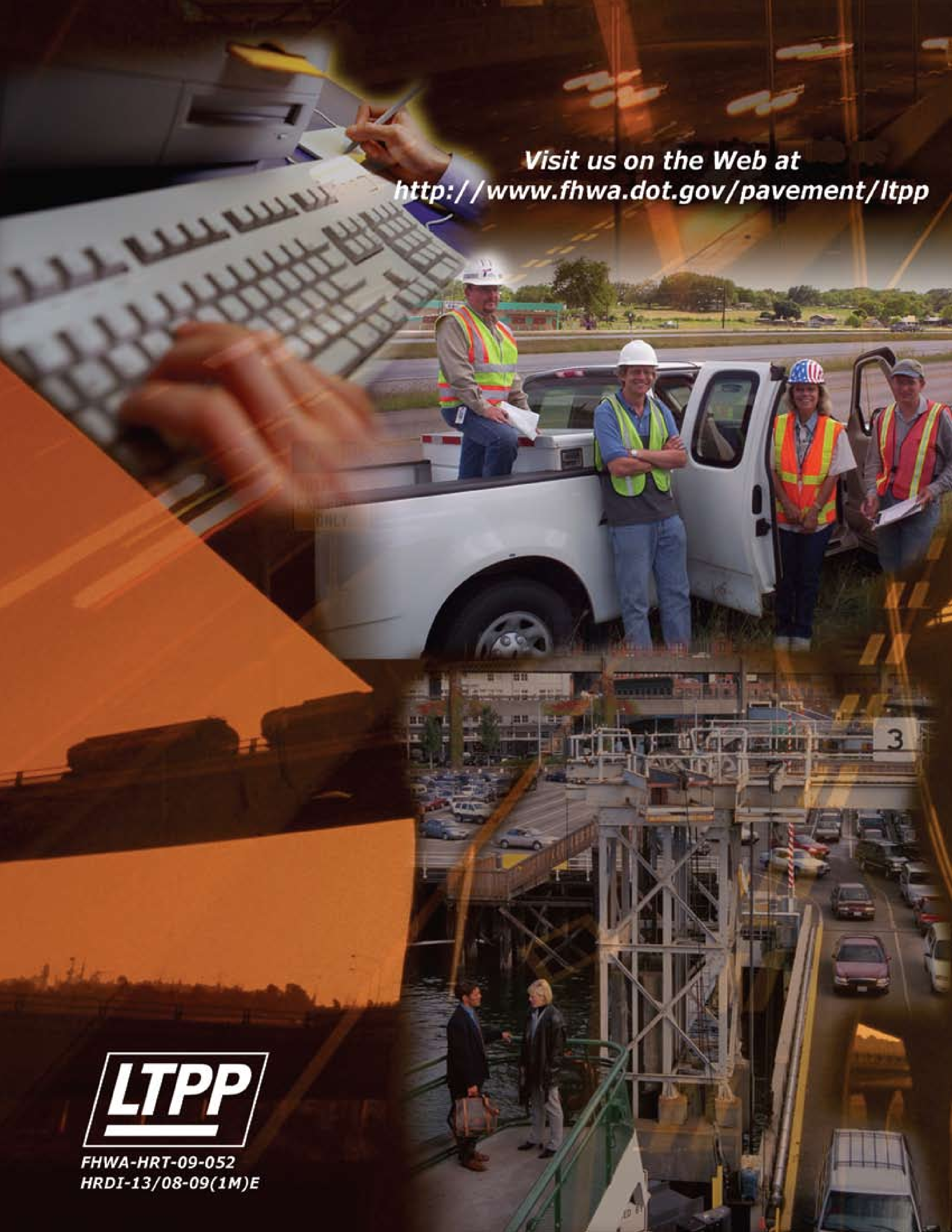
The LTPP program incorporates two major studies—SPS and GPS. The primary goal of SPS experiments is to conduct detailed analysis of specific performance factors of newly constructed pavements and overlays. In contrast, the primary goal of GPS experiments is to analyze performance factors of existing pavements and overlays.

Table 2. SPS experiment analyses of newly constructed pavements and overlays.

SPS Test	Experiment Analyses of Newly Constructed Pavements and Overlays
SPS-1	Strategic Study of Structural Factors for Flexible Pavements
SPS-2	Strategic Study of Structural Factors for Rigid Pavements
SPS-3	Preventive Maintenance Effectiveness of Flexible Pavements
SPS-4	Preventive Maintenance Effectiveness of Rigid Pavements
SPS-5	Rehabilitation of AC Pavements
SPS-6	Rehabilitation of Jointed Portland Cement Concrete (JPCC) Pavements
SPS-7	Bonded PCC Overlays of Concrete Pavements
SPS-8	Study of Environmental Effects in the Absence of Heavy Loads
SPS-9P/ SPS-9A	Validation and Refinements of SuperPave® Asphalt Specifications and Mix Design Process/ SuperPave® Asphalt Binder Study

Table 3. GPS experiment analyses of existing pavements and overlays.

GPS Test	Experiment Analyses of Existing Pavements and Overlays
GPS-1	AC Pavement on Granular Base
GPS-2	AC Pavement on Bound Base
GPS-3	Jointed Plain Concrete Pavement (JPCP)
GPS-4	Jointed Reinforced Concrete Pavement (JRCP)
GPS-5	Continuously Reinforced Concrete Pavement (CRCP)
GPS-6	AC Overlay on AC Pavement
GPS-7	AC Overlay on PCC Pavement
GPS-9	Unbonded PCC Overlay on PCC Pavement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