LTPP traffic database and its potential impact(s) on future pavement design

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The paper describes the Long-Term Pavement Performance Program (LTPP) objectives, Traffic Data requirements, status of Traffic Data Collection by the United States and Canadian participants and the LTPP Traffic Database. It concludes with a discussion of the Research potential and its impact on future Pavement Design.

BACKGROUND

One of the four primary elements of the Strategic Highway Research Program (SHRP) is the Long Term Pavement Performance Program. LTPP, as it is called, is a $50 million, five year research program designed to meet the following objectives:

- o Evaluate existing design methods.
- o Develop improved design methodologies and strategies for the rehabilitation of existing pavements.
- o Develop improved design equations for new and reconstructed pavements.
- o Determine the effects of (1) loading, (2) environment, (3) material properties and variability, (4) construction quality, and (5) maintenance levels on pavement distress and performance.
- o Determine the effects of specific design features on pavement performance.
- o Establish a national long-term pavement data base to support SHRP objectives and future needs.

The creation of the National Pavement Performance Data Base (Objective 6) is the first step toward achievement of the other five objectives. SHRP is gathering data for this data base through a number of carefully designed studies of in-service pavements. The studies have been designed to produce data of the type and range needed to satisfy Objectives 1 through 5.

The creation of the data base is complex, both technically and logistically. The data must be reliable; variability must be quantified; and the data must be collected through standardized, repeatable methods. Because data on actual, in-service roads is needed for the full range of climate, soil, and traffic conditions found in North America, the LTPP experiments require extensive coordination with state highway agencies throughout the United States and Canada.

The LTPP experiments are classified into two groups: the General Pavement Studies (GPS), and the Specific Pavement Studies (SPS).

GPS focuses on existing pavements. The designs under study are those most commonly used in the United States and Canada. The individual test sites have been selected to provide wide ranges of values for the key study variables, and significant co-variates. The almost 800 GPS sites are shown in Figure 1.

The SPS program involves specially constructed test sections, and will yield needed information about the cost-effectiveness of specific pavement design factors. Under the SPS program, SHRP is exploring options for construction of new pavements, the application of maintenance treatments to existing pavements, and rehabilitation of distressed pavements. SPS will require 336 test sites. As of April 30, 1992, 50% of the potential sites have been located, and Figure 2 shows the distribution of the 1/3 that have been constructed. Construction of all SPS sites should be completed in 1994.

There are 52 state highway agencies and 10 Canadian provinces included in the research effort. With Puerto Rico and Washington, D.C. also participating, there are a total

TABLE 1 GENERAL PAVEMENT STUDIES

GPS-1	Asphalt Concrete on Granular Base
GPS-2	Asphalt Concrete Bound Base
GPS-3	Jointed Plain Concrete
GPS-4	Jointed Reinforced Concrete
GPS-5	Continuously Reinforced Concrete
GPS-6A	Existing Asphalt Concrete Overlay on Asphalt Concrete
GPS-6B	New Asphalt Concrete Overlay on Asphalt Concrete
GPS-7A	Existing Asphalt Concrete Overlay on Jointed Concrete Pavements
GPS-7B	New Asphalt Concrete Overlay on Portland Cement Concrete Pavement
GPS-9	Unbonded Portland Cement Concrete Overlays of Portland Cement Concrete Pavement

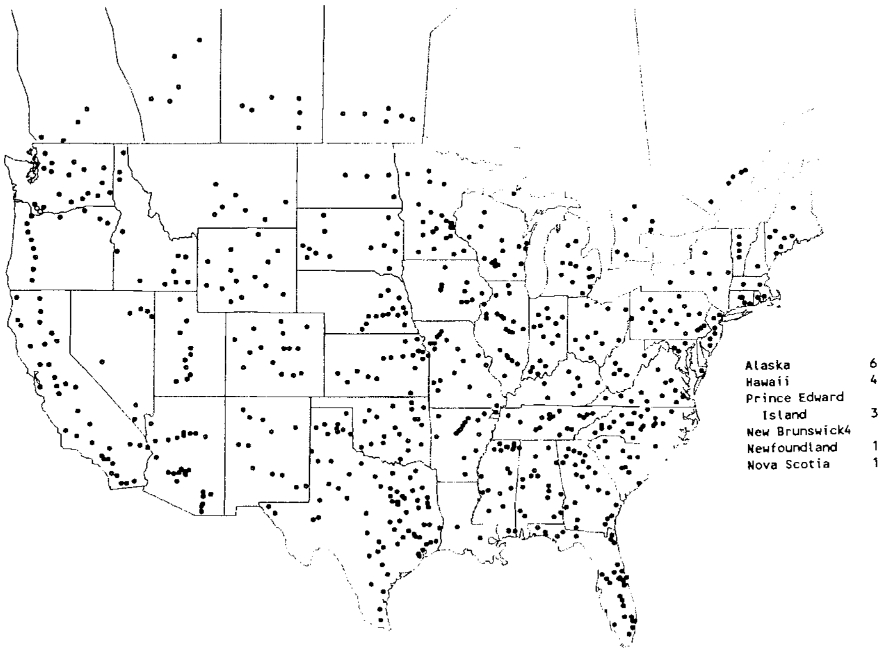

FIGURE 1 Location of constructed GPS sites.

TABLE 2 SPECIFIC PAVEMENT STUDIES

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 Asphalt Concrete Pavements
SPS-6	Rehabilitation of Jointed Portland Cement Concrete Pavements
SPS-7	Bonded Portland Cement Concrete Overlays of Concrete Pavements
SPS-8	Study of Environmental Effects in the Absence of Heavy Loads
SPS-9	SHRP Asphalt Research Field Verification

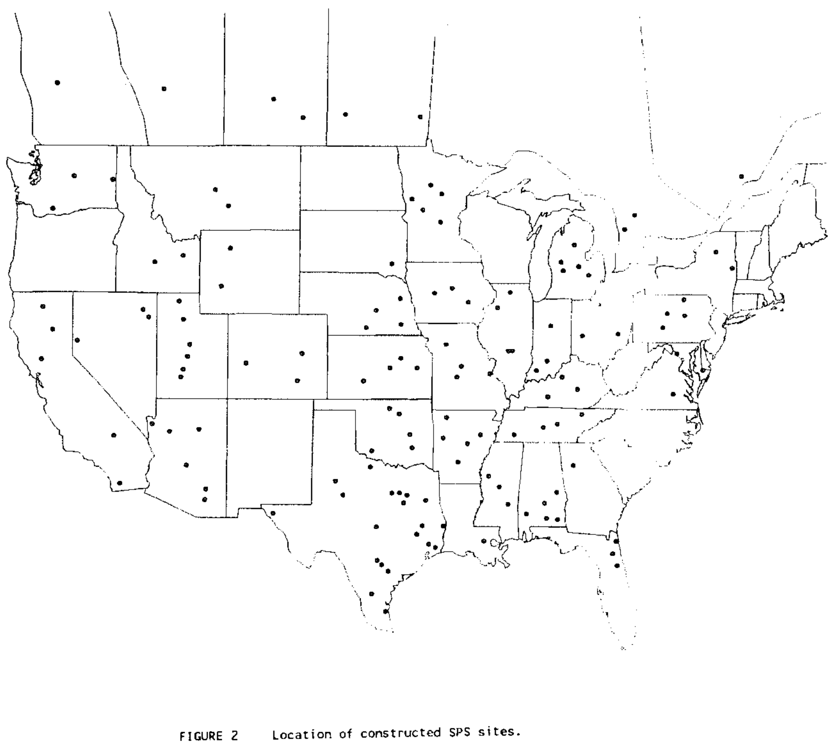

FIGURE 2 Location of constructed SPS sites.

of 62 state and provincial highway agencies (SHA) committed to the LTPP research. For planning and coordination of the research, the SHA are divided into four regions - Southern, Western, North Central, and North Atlantic shown in Figure 3. In each region there is a SHRP Regional Engineer and a SHRP LTPP Regional Coordination Office Contractor (RCOC).

In each SHA, a SHRP Coordinator and a LTPP Coordinator have been identified to provide liaison with SHRP and its contractors on LTPP activities. The SHA is responsible for assisting with site selection, marking and signing, inventory data collection, traffic control during operations, and traffic data collection at each of the LTPP test locations. For traffic data collection, the SHA have also designated a person to work with the SHRP Regional office to ensure that accurate traffic data is provided in the proper format and on a timely basis.

Traffic data is just one of many data elements included in the Pavement Performance Database. Profile, deflection, and distress data, along with climate, materials information, and lab test data, are being collected from the approximately 1,000 test sites. For the GPS, each site includes a 500 feet long section of pavement in the right hand lane or curb lane. This is the lane that over 90% of truck traffic travels at any given site. Study of these GPS sites will permit the researchers to eventually establish relationships between pavement performance, traffic loading, and climatological factors for various types of pavements, bases, and subgrade materials.

Data for the most part are collected using equipment owned by SHRP and operated by the regional contractors. There are four exceptions. The first is traffic data which are collected by the SHA. Two other data elements are collected by contractors, including distress data which are taken by a separate contractor using truck mounted video cameras, and climatological data that are being collected by one of the technical assistance contractors from national weather data. Data about the materials used in constructing the pavements are being provided by materials and sampling contractors and materials testing labs in each region. In all cases, the collection of data is accomplished using the guidelines and data formats set out in the LTPP Data Collection Guide prepared by the technical assistance contractor early in the SHRP LTPP process. These guidelines are published by SHRP, and are available to the public.

NATIONAL INFORMATION MANAGEMENT SYSTEM

The LTPP data are stored in the National Information Management System (NIMS). NIMS is PC based, uses the Oracle database management system, is located at Transportation Research Board, and is managed and operated by TRB personnel. Each region has an IBM compatible 80386 Microcomputer for the entry, storage and processing of data. This system is known as the Regional Information Management System (RIMS), was designed by Science Application International Corp., under contract to SHRP. Most data are initially processed at the RIMS and later are uploaded to the NIMS for archiving and release to the public.

Quality control and quality assurance checks are performed on the data prior to releasing the data from the NIMS for public use. After uploading the data to TRB and prior to public release, the data resides in the "Shadow Database." Only the regional offices, the technical assistance contractor, and TRB have access to the data. All data are subjected to computerized quality control programs and only that data that have met the high standards for quality control are cleared and made ready for public release. Any data that are suspect are checked again by the regional office and even referred back to the SHA, if necessary.

LTPP TRAFFIC DATABASE

Traffic data collection is a function of the SHA. The data are collected according to procedures, guidelines, standards, and principles established by SHRP based upon recommendations of the Traffic Data Collection and Analysis Expert Task Group (ETG). The Traffic ETG consists of traffic engineers, statisticians, data managers, and research specialists from across the U.S. and Canada. They represent state and federal highway agencies, research organizations, academia, equipment suppliers, and trade associations. The ETG has ten people who have over 200 years of collective experience in traffic data collection and analysis.

In the collection of traffic data, the ETG insists that the following principles be adhered to:

- Truth-in-data. Submit only real (or raw) data, not smoothed, factored, or massaged data. Clearly identify all data. Annotate any data sets that are known to have equipment malfunctions.

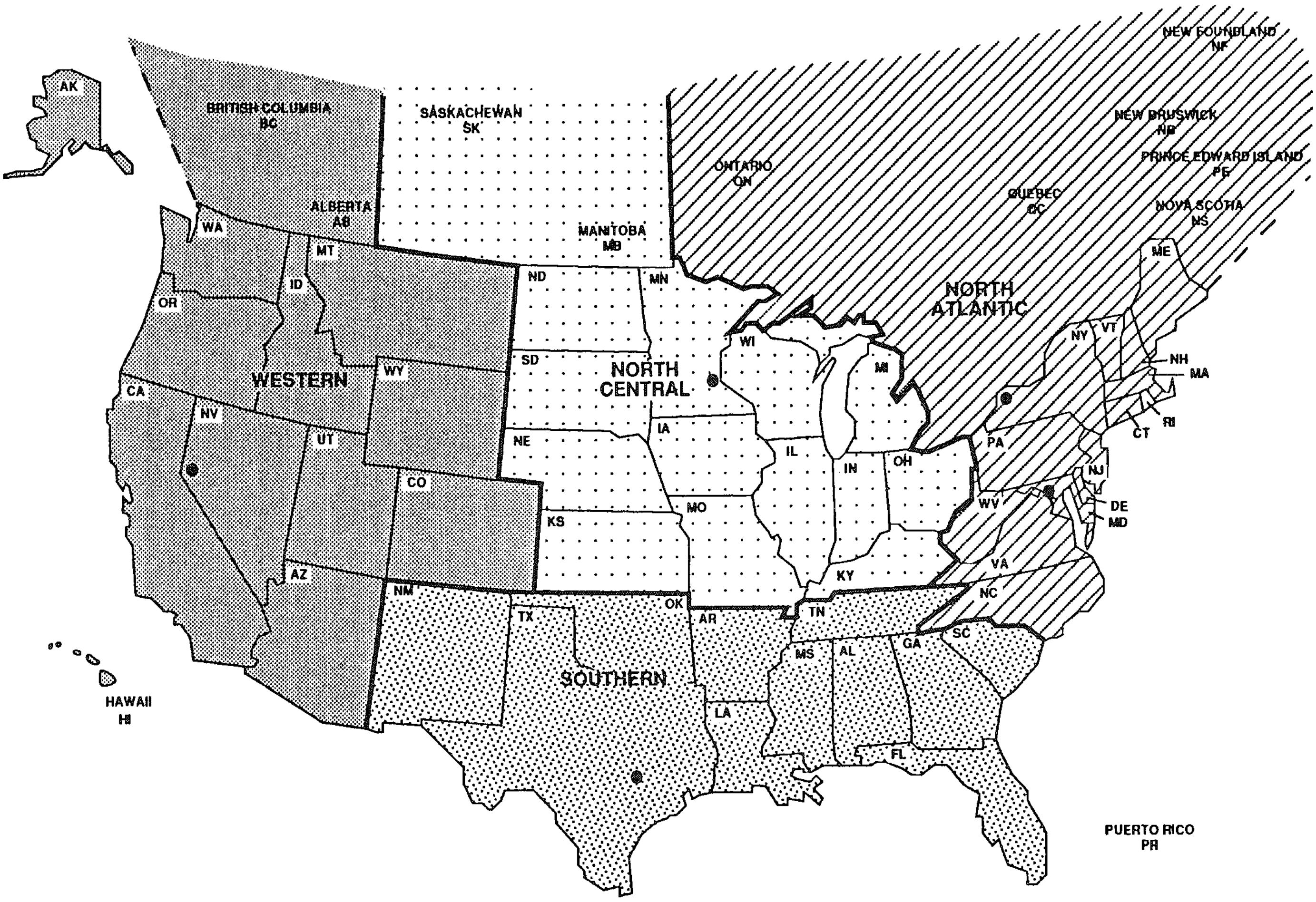

FIGURE 3 SHAs in SHRP four regions.

- Only site specific data can be used to characterize traffic conditions at a given site, especially vehicle classification and truck weights.

- There is an inherent variability to traffic data and summary statistics, and as such the data should be annotated with information depicting that variability as well as the precision of the annual estimates.

- Use standard formats for WIM/AVC as specified in the FHWA Traffic Monitoring Guide and Chapter 4 of the LTPP Traffic Data Collection Guide.

- Classify vehicles into the FHWA 13 class vehicle classification system.

- Traffic data collection is a function of the SHA and as such will only be collected by the SHA. SHRP will never intervene nor generate any traffic data. Filling gaps in data will be the responsibility of the SHA.

The LTPP Traffic Database is specifically designed to meet the needs for traffic data for pavement performance studies. It is structured in five levels for storage and processing purposes. The lowest level, or fifth level, contains basic information about traffic characteristics in the area of a particular LTPP test location. The individual test location is the basic unit of the database. All data are referenced to and stored by LTPP test location. Usually, Level 5 information is not site specific, but rather represents data from other sites in the area with similar traffic characteristics. System wide factors used to determine AADT and other summary or mean statistics are also stored at this level.

Data and related information at this level may not be available in the database. Some of this information may only be available in LTPP files.

Site specific hourly vehicle classification and traffic volume data are found in Level 4, along with individual truck weight records. Equipment calibration information and log of activities from each GPS site are also stored at this level. This is the level at which the basic traffic volume, classification, and truck weight is stored. At higher levels, this basic information is summarized to daily and annual summary statistics using procedures specifically developed by SHRP through the assistance of the Traffic ETG.

The third level includes site specific daily traffic volume, vehicle classification, and truck weight data. The data at Level 3 are a summary of the available hourly data found in Level 4.

Annual traffic summary statistics are located in Level 2. Axle weight data arranged in the FHWA W-4 Table format and summarized by vehicle class; vehicle volume and classification data; calculated loading data in ESAL; and annual average daily traffic (AADT) are also stored at this level.

The primary level, or Level 1, of the Traffic Database contains the annual traffic summary statistics for each year since the road was opened to traffic in its present configuration. These include test lane volumes, axle weight distribution by type of axle grouping (single, tandem, tridem, and quad axle groups) and weight range (usually 1,000 or 2,000 pound categories), calculated ESAL, and an indication of the error of estimate.

Early in the program it is difficult to estimate the error without any traffic data from the site to make such determinations. In the interim period, a coding system has been devised to provide the researcher a fairly accurate picture of the quality of the available traffic data. This code, known as the Data Availability Code, provides information about the type of equipment used to collect the traffic data and the amount of data collection accomplished at the site over the course of a year. Each year the regional office enters the Data Availability code into the database for each site.

There is also a code to depict the location of the traffic data equipment in proximity to the GPS test location. If it is on site, it is given an (S) for site specific. If it is close by but not at the site, it given an (R) for site related; and if completely off site it is given an (O) for off site. This coding scheme is referred to as the SRO code. This information is also added to the database for each site once per year.

Data from Level 1 are transferred to the Pavement Performance database on an annual basis. These are the only traffic and loading data that are available without accessing the LTPP Traffic Database. The data are provided as annual ESAL and cumulative ESAL for each site. In addition, the numbers of axles counted by each type of axle and weight category are included in the pavement performance database.

TRAFFIC DATA PROCESSING SOFTWARE

Software has been developed to enter the traffic data into the database and to process it to the appropriate level in the database. The historical data from over 95% of the GPS sites has already been collected by the SHA from old records and recorded on forms designed for that purpose. That data has been entered into the traffic database manually by the regional office personnel. All other traffic data will be entered electronically, and processed automatically using a IBM Compatible 80486 Microcomputer housed in each regional office. Traffic data are stored and transferred on optical disks. The optical disk drives were acquired by SHRP for its contractors, regional offices, and the interested SHA through centralized purchase contracts. The cost of the units was about $5500.

The traffic data processing software was developed by Chaparral Systems, Inc. under the direction of the SHRP staff and its consultants, the technical assistance contractor, and the Traffic ETG. The software was patterned after similar software developed by Chaparral for the New Mexico Department of Highways and Transportation. Although the software will run initially at the regional level, it will eventually be made available to each of the SHA involved in LTPP for use in pre-processing traffic data.

SHRP TRAFFIC DATA COLLECTION REQUIREMENTS

SHRP established the requirements for traffic data collection in an operational memorandum issued in January, 1989, entitled "Traffic Data Requirements for General Pavement Studies Test Locations." At each site, the expectation was that either a WIM or an AVC device would be installed in the outside lane to measure the traffic volume, classification, and weight of vehicles crossing over that site. The equipment would be operated continuously for at least one year to determine the patterns of truck traffic and the variation of total ESAL over the course of a full year. If AVC equipment is used, a further expectation is that truck weight data will be collected on site at least four times per year, generally quarterly, and that either permanent or portable WIM devices will be used for those weight measurements. The weight sessions would preferably be a week in duration but as a minimum would be 48 hours in duration during the week and 48 hours during the weekend. Automatic traffic recorders measuring only traffic volumes are not acceptable. AVC equipment must segregate vehicles into the FHWA 13 class vehicle classification. The Specific Pavement Studies, employing test sections specially constructed to meet study parameters, has a similar set of Traffic Data Collection requirements. For some SPS, all traffic monitoring is to be done with continuously operating weigh-in-motion devices.

CURRENT STATUS OF TRAFFIC DATA COLLECTION

There are 779 GPS sites in service at this time. The SHA have developed traffic data collection plans laying out the type of equipment to be installed at each site in the state. They have also established an installation schedule for all sites. The latest status report reflects that WIM equipment will be installed at 273 sites, or 35% of the total, and that AVC will be put in at 485 sites, or 62% of the total. Of the 273 WIM sites, 175 or 63%, will utilize piezo cable sensors. Other types of sensors being used include bending plates (18%), bridge WIM devices (5%), capacitance strips (3%), load cells (2%), and various other types or undecided (9%). The traffic data collection equipment will be located at the site at 671 locations, or 86% of the time. The equipment will be located at nearby sites (site related) 9% of the time, and either off site or no equipment will be provided on 5% of the sites.

The typical cost for a piezo based WIM installation is $50,000. Other WIM systems can range in cost up to $150-250,000. AVC installations can be made for $20,000-25,000. SHRP is participating in the cost of the traffic equipment installations at LTPP sites by reimbursing the SHA $2200 per site. In addition, SHRP pays $10,000 toward the cost of a site that is designated a Regional WIM site.

There are 50 of these regional WIM sites distributed throughout the United States and Canada. These sites were selected by the Regional Engineers based upon nominations from the SHA in the region. The regional WIM sites will provide an opportunity to compare traffic volume, classification, and weight data among locations with a variety of traffic conditions, highway types, environmental conditions, and settings.

To date, traffic data collection equipment has been installed at approximately one-half of the GPS test locations, and 40% more will be installed or substantially complete by the end of calendar year 1992. However, at this time, data for more than one year on a continuous basis are only available at one site.

Therefore, extensive results from data analysis are not yet available.

A very detailed and scientific WIM Data Analysis Plan has been developed by TRDF, the technical assistance contractor. The analysis relies on time series analysis to evaluate the data and to demonstrate trends, patterns, and mathematical relationships among the data. The daily ESAL estimate is used as a basis for the analysis. Preliminary analysis indicates that trends can be noticed, cyclical patterns are visible, and mathematical relationships can be established. However, considerably more data analysis must be accomplished before any real results can be announced.

TRAFFIC DATA AND PAVEMENT DESIGN

The need for this extensive traffic database as part of the LTPP studies is simply stated. Pavements are load bearing structures! The basic design equations for pavement structures contained in the AASHTO Guide for the Design of Pavement Structures (the GUIDE) [ref. 2], relate the volume of standard axle applications to loss of pavement serviceability. The AASHTO equation for flexible pavements is:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where

W_{18} = predicted number of 18-kip equivalent single axle load applications,

Z_R = standard normal deviate,

S_o = combined standard error of the traffic prediction and performance prediction,

ΔPSI = difference between the initial design serviceability index, p_o, and the design terminal serviceability index, p_t, and

M_R = resilient modulus (psi).

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where

a_i = i^{th} layer coefficient,

D_i = i^{th} layer thickness (inches) and

m_i = i^{th} layer drainage coefficient.

The current version of the GUIDE estimates that 20-25% of the uncertainty in the service predictions of the design equations is related to traffic prediction variance. In as much as there has been no large scale attempt to relate traffic loadings to pavement performance in rigorous fashion since the AASHO Road Test of 1958-60, the actual traffic related variance is unknown. Clearly, any attempt to improve or replace the current design procedures must have accurate traffic data or reasonable precision. Those data must be site specific if they are to be related to other data collected in the study. The term M^r in the equation shown is the resilient modulus value for the subgrade soils at the design site. Determination of this value requires measurements to 10,000ths of an inch. The misfit with currently accepted standards for the estimation of traffic loadings is obvious.

The GUIDE went on to note, that as there are very large differences among reported values for traffic prediction variance "it appears that further definitive research should be performed, perhaps in the context of long-term monitoring studies." The state and provincial monitoring efforts in support of LTPP are just such studies.

The significance of accurate traffic data for pavement design cannot be overemphasized. A reduction of 50% in the uncertainty related to traffic estimates would result in a reduction of materials cost alone of $100 million dollars in the United States each year. Savings related to reduced user costs and improved budgeting efficiency as "early failures" are reduced, will probably be even more substantial.

OTHER APPLICATIONS OF THE LTPP TRAFFIC DATABASE

The breadth and long term nature of the LTPP Pavement Database lends itself to applications far removed from pavement design research. At the 1992 Annual Meeting of the Transportation Research Board in Washington, D.C., Hajek, Billing and Kennepohl [ref. 3] described the application of these and similar data to transportation planning.

Among these applications are the monitoring of compliance with regulations regarding vehicle weights, axle configuration and length. While the WIM and AVC devices installed in support of SHRP are insufficiently accurate for enforcement purposes, their number, distribution and full-time operation will provide large volumes of data regarding general compliance with such regulations.

Geometric design standards also require knowledge of the distribution of vehicle sizes and weights. Radii of curvature, superelevations, lane widths, particularly at intersections, and the provision of climbing lanes are all standards influenced by realistic estimates of vehicle size, weight and related tracking characteristics.

The SHRP traffic monitoring installations will also yield information significant to safety and capacity analyses including vehicle speed distributions and headway. Distributions of maximum truck weights and weights by configuration will be valuable in bridge design and the assessment of the impact of bridge restrictions on a particular network.

This is by no means an exhaustive list of potential applications of the LTPP traffic data. For this reason, the data contained in the National Pavement Performance Database and the LTPP Traffic Database will be generally available to researchers and operating highway agencies. The data will be available through the Transportation Research Board.

SIGNIFICANCE FOR THE FUTURE

The LTPP studies and the strong emphasis on traffic and load data have broken down barriers that formerly isolated the various components of highway engineering from one another. These data are valuable not just to pavement research, but to rational highway planning, design, operation and maintenance functions and are a key element in the development of future highway management systems. Within the United States, the recently enacted Intermodal Surface Transportation Efficiency Act [ref. 4], requires that the SHAs develop management systems for highway pavements, traffic congestion, bridges, highway safety and intermodal transportation. All of these systems will benefit from the data, data collection and data management techniques pioneered by SHRP LTPP.

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