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SHRP-LTPP Traffic Data Collection and Analysis: Five-Year Report

John L. German
Charlie R. Copeland, Jr.
William O. Hadley, editor

Texas Research and Development Foundation
Austin, Texas



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Project Manager: *H. K. (Kris) Gupta*
Five-Year Report Production Manager: *A. Robert Raab*
Program Area Secretary: *Cynthia Baker*
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Strategic Highway Research Program
National Research Council
2101 Constitution Avenue N.W.
Washington, DC 20418

(202) 334-3774

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SHRP-LTPP TRAFFIC DATA COLLECTION AND ANALYSIS 5-YEAR REPORT

INTRODUCTION

The planners of the Strategic Highway Research Program's Long-Term Pavement Performance (SHRP-LTPP) project identified the need to retrieve historical traffic volume and axle load data for each General Pavement Studies (GPS) test location before beginning the data monitoring phase and to collect traffic volume and axle load data at each GPS and Specific Pavement Studies (SPS) test location during the data monitoring phase of the LTPP research.

The development and evolution of the SHRP-LTPP traffic data collection methodology can best be portrayed by recounting the work and accomplishments of the SHRP Traffic Data Collection and Analysis Expert Task Group (ETG) since its inception in 1988. Summarizing the actions, recommendations, and achievements of the ETG reveals the evolutionary nature of the traffic data collection process. During the course of SHRP-LTPP, the ETG provided the impetus to overcome many obstacles in the development and implementation of the traffic data collection program. Without the contributions of the ETG, the LTPP program would not have the analytical foundation to fully realize its promise and potential.

An important feature of the traffic program was the role of the ETG in recommending and defining actions taken by SHRP in traffic data collection and analysis. This role evolved because the need for traffic load data for the GPS program had not been adequately considered in the research plans advocated before SHRP-LTPP began. This lack became evident early in the days of SHRP, and the ETG was established to address issues related to traffic load data.

To enhance the limited traffic experience of the SHRP staff, the LTPP program manager allowed the ETG to become more directly involved in the traffic data collection program, to provide direction to the SHRP staff, and to provide general guidance for the activities of the consultants and regional traffic representatives. The ETG met at least three times per year to consider progress made in all areas of traffic data collection and to make recommendations on policy matters.

It is important to note that traffic data collection for LTPP was actually a function of each of the 62 highway agencies (from the 50 states, the District of Columbia, Puerto Rico, and the 10 Canadian provinces) involved in the SHRP-LTPP program. (These agencies are called state highway agencies [SHAs] in this report.) For the most part, all other GPS data

collection activities were conducted directly by SHRP or the technical assistance contractors. The primary data collection agents for most data (distress, profile, deflections, material properties, etc.) were the regional coordination office (RCO) contractors. In the case of traffic data, the RCO contractors were responsible for working with the SHAs on traffic-related issues and on entering, checking, storing, processing, and summarizing the traffic and weight data collected by the SHAs. However, the responsibility for field data collection activities, including purchase and installation of traffic data collection equipment at each GPS test site, was assigned to the SHAs in the original planning and funding for SHRP.

The SHRP-LTPP planners initially, and incorrectly, assumed that the SHAs could accomplish the traffic data collection during their routine daily operations. The original premise was that the SHAs would collect traffic volume data and occasional truck weight data from the sites and forward it to the RCO for further processing. In later planning it was presumed that low-cost weigh-in-motion (WIM) devices, which could easily collect the data required for LTPP, were available. It was also generally believed that the traffic data collection procedures used by the SHAs were similar and would yield comparable data for use by SHRP. In reality, these assumptions were all found to be unrealistic, and the chore of directing the development of common standards and procedures fell to SHRP under the auspices of the ETG.

The Strategic Highway Research Program Research Plans final report (1) proposed a plan for traffic data collection that included a low-cost WIM device operating continuously at each GPS test site. The cost for the WIM equipment was estimated to be about \$5000 per site. SHRP was scheduled to pay half the cost, or \$2500. Therefore, a total of \$2 million was identified in the SHRP budget for the planned 800 GPS test locations. Since the SHAs had agreed to collect SHRP-LTPP traffic data, the funds were to be distributed to the SHAs to aid in the purchase of traffic data collection equipment for the GPS test locations.

TRAFFIC EXPERT TASK GROUP

Creation

In 1987, SHRP created two ETGs to assist in the development of standards, procedures, and methods for the traffic data collection effort. Experts were appointed to the Traffic Data Collection and Analysis ETG (commonly known as the Traffic ETG) and to the Weigh-in-Motion Equipment and Technology ETG (known as the WIM ETG). The WIM ETG was charged with determining the availability and cost of equipment necessary to fulfill the needs of the LTPP program. The Traffic ETG was given the broader responsibility of traffic data collection and analysis.

Early in the process, the WIM ETG concluded that the use of low cost piezoelectric cable WIM devices was not a viable option for truck weight studies but that the devices could be used for vehicle classification studies. Many SHA representatives believed that valid weight data could be obtained only if bending plates and load cells were included as elements of the WIM equipment. Cost estimates for these higher-quality WIM systems varied from \$50,000

to \$200,000, but some SHAs could not afford to install the sophisticated equipment at all their GPS sites. These concerns led SHRP to request that the Traffic ETG reevaluate the traffic data collection requirements and procedures and recommend revisions as appropriate.

The actions of the Traffic ETG are summarized in this report. The major achievements are cited in chronological order for historical purposes, but this report is intended neither to be a detailed description of all deliberations of the Traffic ETG nor to reflect all actions recommended by the Traffic ETG. Actions that were later revised or superseded are reported only in their final form unless the developmental process was particularly significant. A detailed summary report identifying all actions of the Traffic ETG was compiled (2).

Organization and Administration

The Traffic ETG was composed of representatives from throughout the United States and Canada. Most members were from SHAs. Other members represented the U.S. Federal Highway Administration (FHWA), academia, consulting firms, and research institutions. The ETG was supported in its work by SHRP staff, several consultants, and RCO contractor staff members. The RCO contractor staff were referred to as regional traffic representatives.

The diverse tasks faced by the ETG required that the members and consultants have expertise in a wide variety of areas, including traffic data collection and analysis, traffic monitoring, system design, database design and management, statistical analysis, software development, WIM operations, traffic engineering, pavement design, and research. The ETG was structured to include persons with these skills as members. When certain specialized skills were lacking, SHRP assigned other persons with the necessary skills and expertise to work with the Traffic ETG. The Traffic ETG addressed the needs of the greater traffic community, and substantial strides were made at the state and national level in the areas of traffic data collection and analysis.

The size of the ETG and its membership changed during SHRP-LTPP. There were originally eight ETG members supported by three SHRP staff members and consultants serving as advisers. By May 1992, only 3 of the 10 original members had served for the full term, but the membership had increased to 10 members supported by 10 staff members and consultants (Table 1). All members made contributions and helped the ETG achieve and exceed its goals.

DEVELOPMENT OF SHRP REQUIREMENTS (1987-1989)

Although the SHRP-LTPP program began in 1987, the work of the Traffic ETG did not begin until 1988. The ETG's first recorded meeting occurred in Washington, D.C., on June 15-16, 1988. This was a joint meeting of the WIM ETG and the Traffic ETG.

TABLE 1. Traffic ETG Membership (1988-1992)

NAME	AGENCY	TERM BEGAN	YEARS SERVED
MEMBERS			
David Albright	New Mexico	1988	4
Wiley Cunagin	Texas Transportation Institute	1988	2
Curtis Dahlin	Minnesota	1990	2
Ralph Folsum	North Carolina	1988	1
Jerry Hajek	Ontario	1988	4
John Hamrick	Idaho	1990	2
Andy Horosko	Saskatchewan	1990	2
B. Hutchison	Kentucky	1988	1
Ed Kashuba	FHWA	1988	4
Bill McCall	Iowa	1990	2
George Novenski	Wisconsin	1988	2
Alan Pisarski	Consultant (Virginia)	1990	2
Larry Schoenhard	South Dakota	1988	1
Ron Tweedie	New York	1991	1
Richard Weed	New Jersey	1990	2
SHRP STAFF AND ADVISERS			
Chuck Neissner	SHRP loaned staff (FHWA)	1988	1
Andy Horosko	SHRP loaned staff (Saskatchewan)	1988	2
Kris Gupta	SHRP staff	1990	2
Tony Esteve	Adviser (FHWA)	1988	4
Perry Kent	Adviser (FHWA)	1988	4
Ken Opiela	Transportation Research Board	1991	1
CONSULTANTS AND REGIONAL REPRESENTATIVES			
Mark Hallenbeck	Washington State Transportation Center (TRAC)	1988	4
Gary Elkins	Texas Research and Development Foundation (TRDF)	1988	2
John German	TRDF	1989	3
Wiley Cunagin	TRDF	1990	1
Charlie Copeland	TRDF	1990	2
Joe Wilkinson	Chaparral Systems	1990	2
Paul Irick	TRDF	1990	2
Bill Hadley	TRDF	1990	2
Mathew Huber	Braun Intertec	1990	2
Mark Gardner	Southern RCO (Brent Rauhut Engineering)	1990	2
Earl Laird	Western RCO (Nichols Engineering)	1990	2
Randy Plett	N. Atlantic RCO (Pavement Management Systems)	1990	2
Michael Marti	N. Central RCOC (Braun)	1990	2

The two ETGs met together initially for a briefing by the SHRP staff and consultants, after which they split and met separately. The WIM ETG discussed the types and quality of various WIM systems the uses of each system, and the cost and accuracy of each system, including sensors. The actions of the Traffic ETG over the 4-year period are summarized below.

June 15-16, 1988, Washington, D.C.

- A study conducted by the Wisconsin Highway Department in 1988 (3) showed that truck loads varied with the day of the week and in the vicinity of enforcement scales. Consequently, it was decided that site-specific traffic and loading data were needed at the GPS test locations.
- The ETG recommended that more of the SHRP-LTPP program's resources be allocated to traffic data collection and analysis. It was recommended that each region have a traffic expert on staff and that a traffic expert be designated at the national level to coordinate and maintain uniformity nationwide.
- The ETG agreed that historical data supplied by the SHAs would not be uniform and would vary in reliability and that the ETG must work to obtain reliable and consistent data.
- It was reported that the Canadian SHRP traffic data collection program required four manual traffic classification counts and four truck weight studies per year, the use of a minimum of four truck categories, and continuously recorded traffic volumes.
- Two reports were made available to the ETG members: "Presentation on Traffic Data Requirements" (4) and "Background on Traffic Data Considerations for LTPP" (5). In the first, the requirements for traffic data collection were presented. The recommendations included continuous traffic volume counts at each monitoring site by an automatic traffic recorder (ATR), quarterly vehicle classification counts (over a 48-hour period), and annual truck weight measurements (over a 48-hour period). The format identified in the FHWA Traffic Monitoring Guide (TMG) (6) was specified for the vehicle classification studies, and WIM devices were recommended for truck weight studies. A low-cost WIM system using piezoelectric cable was suggested. SHRP funding support of \$1250 per site was announced.
- In "Background on Traffic Data Considerations for LTPP" (5) several issues were offered for consideration by the Traffic ETG:
 - The high cost to the SHAs of installing WIM equipment at each site and operating it continuously for several years
 - The need to estimate the total traffic loading that has traversed a test site since the highway in its current configuration was opened to traffic

- The requirement to monitor the traffic loading during the life of the GPS experiments
- The quality of WIM equipment needed
- The accuracy, precision, durability, and cost of currently available equipment
- The reliability of systems that use piezoelectric cable sensors
- The appropriate sampling rate for traffic data

July 20, 1988, Irvine, California

In July 1988, the Traffic ETG considered a consultant report (7) that summarized the following recommendations made by the WIM ETG to SHRP:

- Because of the cost of WIM systems, participating SHAs should not be required to place WIM equipment at every site.
- Continuous vehicle classification counts should be made using ATRs.
- Existing ATR sites near GPS sites should be used to reduce the need for site-specific equipment at every site.
- SHRP should purchase automatic vehicle classifiers (AVCs) for the SHAs to install at a cost of \$7000 to \$8000 each.
- The equipment should be capable of classifying up to 20 vehicle classes and report data corresponding to the FHWA TMG 13-class structure.
- SHRP should use standards and procedures developed by ASTM, the Heavy Vehicle Electronic License Plate (HELP), and the National Cooperative Highway Research Program (NCHRP) rather than develop new standards.
- A chapter should be prepared for the Data Collection Guide describing the data to be collected, presenting the required forms, and establishing reporting requirements.
- SHRP should issue a document to the SHAs defining the data collection requirements and describing various aspects of WIM systems.

August 1, 1988, Washington, D.C.

Since SHRP was concerned about the recommendations of the WIM ETG, a meeting of the Traffic ETG was called to discuss the issues. There was strong disagreement with the WIM

ETG recommendations, especially those related to the use of weight and classification data from other sites to characterize the traffic loading at a GPS test site. The Traffic ETG confirmed that site-specific data were required.

As a result of its deliberations, the Traffic ETG recommended the following:

- As a minimum, AVC, rather than ATR, equipment should be installed at GPS sites because AVCs provide much more extensive data at minimal extra cost.
- SHRP should inform SHA chief administrative officers that the level of participation and costs were much higher than expected. The American Association of State Highway and Transportation Officials (AASHTO) was asked to help spread the word on traffic data needs and build support for the traffic data collection effort at the state level.
- SHRP should transmit the traffic data collection requirements, policies, and procedures to the SHAs.
- The technical assistance contractor should develop a position paper on the use and storage of traffic data.
- Cost information should be developed for several traffic data collection options.

September 15-16, 1988, Dallas, Texas

To resolve the differences between the two ETGs, a joint meeting of the Traffic ETG and the WIM ETG was held to consider a variety of issues. A report summarizing the costs of several alternative data collection strategies (8) was distributed and discussed at considerable length by participants from both groups.

After discussion of the various options, the Traffic ETG convened a separate meeting and recommended a modified traffic data collection program recognizing that it would not be possible to install a WIM device at every site and, further, that it would not be possible to operate WIM devices continuously at every site. The Traffic ETG also recommended that three levels of traffic data collection be identified:

- A preferred approach that relied on continuously operated WIM equipment at the GPS test location
- A desirable level that substituted AVCs for WIM devices and added portable WIM measurements for 7 consecutive days each quarter
- A minimum response that was similar to the desirable level but reduced time for the portable WIM counts to a 48-hour period each quarter during the week and a 48-hour period each quarter during the weekend.

A document summarizing the recommendations of the two ETGs was subsequently prepared. The published report, "SHRP Traffic Data Collection Plan," dated September 28, 1988, was revised on October 14, 1988, and subsequently published as "Summary Report of Traffic Data Collection and WIM ETG" (9).

INITIAL ACTIONS BY SHRP

Before March 1989

SHRP took several actions between September 1988 and March 1989 to address the issues raised by the two ETGs:

- The technical assistance contractor was authorized to hire a traffic expert to assist the regions with traffic data collection.
- The technical assistance contractor was instructed to develop a paper targeted for the SHRP state coordinators that outlined the traffic data collection requirements and provided information about WIM and AVC equipment and the cost of such equipment (December 1988).
- A SHRP staff person (Andy Horosko, loaned staff, Saskatchewan) was assigned the responsibility for traffic at SHRP headquarters.
- On the basis of the work of the technical assistance contractor, SHRP prepared an operational memorandum (10) for distribution to the SHAs at the meeting of the Transportation Research Board (TRB) in January 1989. The memorandum provided guidance on traffic data collection requirements and use of the traffic data, data collection plans, historical data requirements and forms, equipment descriptions and capabilities, and a schedule for action. The memorandum was updated in April 1990 and is the basis for traffic data collection by the SHAs for the GPS experiments.
- The SHRP executive director prepared a cover letter to the state and provincial coordinators that, among other things, announced the proposed regional traffic workshops to be held in each of the FHWA regions during March and April 1989. The letter also provided information about the types and brands of WIM and AVC equipment, axle sensors, suppliers, and costs of such equipment. The letter and the operational memorandum encapsulated the work of the staff and consultants and the recommendations of the two ETGs and "got the ball rolling" in traffic data collection for the LTPP program.
- SHRP regional engineers and FHWA regional engineers met together at TRB to brief each other on SHRP issues, including the proposed traffic data collection requirements and the upcoming regional traffic workshops. Both groups agreed to generate support

for and attendance at the regional workshops by representatives of SHAs and FHWA division offices.

- SHRP initiated a study of AVC equipment in Oregon to address issues about the use of AVC equipment and its applicability to the needs of LTPP. Castle Rock Consultants, with support and supervision from the Oregon DOT, was the firm selected to do this work.
- A paper describing the integration of the SHRP-LTPP traffic database with the FHWA Highway Performance Monitoring System (HPMS)/TMG database, and the FHWA truck weight tables was prepared (11).
- A meeting between SHRP personnel and representatives of the Georgia Highway Department was held on March 6, 1989, to resolve some major disagreements that Georgia had with the LTPP traffic data collection program.
- SHRP staff, consultants, and representatives of the technical assistance contractor met in Austin, Texas, on March 7-8, 1989, to develop a format for the traffic database and to establish procedures to process, store, and analyze traffic data.

March 9-10, 1989, Albuquerque, New Mexico

The proposed five-level database structure was presented to the Traffic ETG at its March 9-10, 1989, meeting in Albuquerque, New Mexico. Several actions were undertaken and recommendations adopted:

- The ETG reviewed and discussed the response of various states to the SHRP traffic data requirements issued at TRB in January. The responses from Georgia, Oregon, Iowa, and Texas were identified as needing to be addressed. Georgia did not want to collect site-specific data but preferred to use statewide data and interpolate traffic volume and loading data to the GPS test locations. Oregon was not convinced that AVC equipment and axle sensors currently on the market could provide reliable classification data. Texas proposed collecting continuous AVC data for 1 week per month rather than 365 days per year. Iowa planned to use WIM/AVC data from sites on other routes or located considerable distance from the GPS sites to characterize the traffic loading data for the GPS sites. Minor problems in several other states were also discussed. A plan was developed to meet with representatives of each of the states to resolve these issues. An initial meeting with Georgia had been held the previous week, and progress was made in gaining support for the SHRP traffic program.
- The preliminary draft of the traffic chapter for the LTPP Data Collection Guide was presented. It included the revised historical data forms and the proposed process for collecting historical data from the SHAs. The ETG approved the document for interim use.

- The five-level structure for the traffic database was presented. The ETG recommended that the description of the traffic database be included in the workshop curriculum, along with the "Framework for Traffic Data Collection" (10). After extensive discussion on the processing of monitoring data, the ETG adopted the concept of retention of the raw data, not data that had been modified to smooth peaks and valleys or fill gaps. The ETG expressed concern over the difficulty that many SHAs would have in providing the monitoring data.
- The ETG discussed and adopted the schedule and curriculum for the regional workshops, which are described in more detail later in this report.
- The issue of data quality was raised, and a decision was made to recommend the following approach:
 - SHRP needs quality-equivalent and comparable traffic data for its LTPP research.
 - To reach that goal, it is imperative that each SHA adhere to the published SHRP traffic data collection requirements.
 - It is important that traffic loading data be site specific and that only the original data be submitted by the SHAs. Data that has been summarized, smoothed, or modified in any way should not be submitted.

In support of these recommendations, the Traffic ETG adopted a "truth-in-data" philosophy that would ensure that quality traffic data would be available for the LTPP program to produce the desired results. The ETG made several recommendations regarding truth-in-data, SHRP funding, submission of traffic data collection plans, review procedures for collection plans, need for collection of data on a continuing basis, consequences of not collecting the required traffic data, historical data collection forms, and traffic data needs for SPS. This was the first time that the principle of truth-in-data had been articulated in relation to traffic data. It was a turning point for AASHTO, ASTM, and FHWA in understanding traffic data.

Presentations were also made at the meeting about the use of traffic data in the LTPP program and the results of the Minnesota WIM data analysis study (12). The analysis of data from four continuously operated WIM stations in Minnesota showed the extreme variability in weight data from site to site and also demonstrated that weight data and loading data do not follow patterns normally displayed in traffic volume data. For example, the study documented that the equivalent single-axle load (ESAL) per truck factors were considerably higher on weekends than on weekdays even though the volume of trucks was less. The results of the Minnesota study were significant, and the presentation of that data at the regional workshops demonstrated the need for site-specific data collection.

The ETG recommended that the technical assistance contractor prepare a document outlining the requirements for traffic data collection plans that were to be developed by each SHA and submitted to the regional engineer for review and concurrence. The recommended funding plan for installation of WIM/AVC equipment at GPS test locations was also to be included in

that document. A plan for selecting approximately 50 regional WIM sites was also developed by Texas Research and Development Foundation (TRDF), the technical assistance contractor.

In addition, the ETG recommended delaying the adoption of a method for backcasting, or estimating previous traffic loading data at GPS sites until at least 2 years of monitoring data was available at each site.

In retrospect, this was a pivotal meeting for the ETG and for traffic monitoring practice. The decisions represented hallmark actions by the SHRP staff and consultants, since the basic principles of the traffic data collection program were established and the structure for the LTPP traffic database was formulated.

REGIONAL TRAFFIC WORKSHOPS (MARCH-JUNE 1989)

An important juncture was reached with the establishment and acceptance of the SHRP traffic data requirements by the SHAs. This development resulted from the nine regional traffic workshops, which were held during March to June 1989. FHWA afforded SHRP the opportunity to participate in a series of traffic-related workshops that were being planned for this period in each FHWA region. The workshops had been designed to discuss the TMG (4) and the HPMS. SHRP agreed to conduct a 1-day workshop in conjunction with these FHWA workshops to describe the SHRP traffic data requirements, traffic database, and other related information. SHRP staff, consultants, and representatives of the technical assistance contractor led the discussion.

At the workshops, SHA representatives were given opportunities to raise questions, express their concerns, and share their progress on the LTPP program with other participants. The workshops highlighted SHRP's traffic data needs and provided feedback to SHRP about SHA problems and issues. The workshops were an effective tool for communication and understanding between the SHAs and SHRP. Representatives from all but two SHAs participated in the workshops. The first workshop, held in Lenexa, Kansas, on March 20-23, 1989, was attended by 47 people representing 10 states and two FHWA regions. The schedule for the workshops is presented in Table 2.

During the workshops, SHRP announced that funds would be available to the SHAs to reimburse some of the expense of installing the traffic equipment. A reimbursement of \$2200 for the installation of WIM/AVC equipment and \$10,000 for regional WIM sites was announced. The \$10,000 reimbursement applied only to the 50 sites to be selected by SHRP.

DATA COLLECTION PROCEDURES (1989-1991)

With major advances in the development of principles and standards for traffic data collection assured, the second major phase of the SHRP Traffic Data Collection and Analysis Program

TABLE 2. SHRP/FHWA Regional Traffic Workshop Schedule

DATE	FHWA REGION	LOCATION
March 20-23, 1989	5 & 7	Lenexa, Kansas
April 10-12, 1989	9	Phoenix, Arizona
April 12-14, 1989	10	Portland, Oregon
April 18-19, 1989	3	Baltimore, Maryland
May 2-4, 1989	8	Denver, Colorado
May 9-10, 1989	1	Buffalo, New York
May 16-18, 1989	4	Frankfort, Kentucky
May 23-24, 1989	6	Austin, Texas
June 6-7, 1989	Canada	Winnipeg, Canada

was undertaken. These actions, activities, and reports can best be summarized chronologically from the minutes of the Traffic ETG meetings. In the following sections, organized by date and place of the meetings, the significant actions of the Traffic ETG are summarized.

October 12-13, 1989, Washington, D.C.

The following major recommendations were made:

- SHRP should apply the truth-in-data principles to the traffic data summary statistics and traffic adjustment factors.
- SHRP should attach a measure of variability or precision to each traffic data summary statistic.
- Regional WIM sites should not be used to characterize traffic loading data for a wide variety of sites in a geographic region. Vehicle classification and weight data represent the conditions at one site and do not necessarily relate to any other site. An analysis of the data from the regional WIM sites is required to determine whether there is any evidence of common patterns at multiple sites within the same region or on highways with similar traffic characteristics.
- SHRP should adopt the 13-class FHWA vehicle classification system for use in the LTPP program.
- The LTPP technical assistance contractor should be asked to prepare and distribute a report identifying the electronic edits that will be required for evaluation of the traffic data sets.
- SHRP should require the following for SPS projects:
 - SPS-1 and 2: Continuous WIM measurement
 - SPS-3 and 4: Same traffic data collection equipment as installed for the adjacent GPS section
 - SPS-5, 6, and 7: Same levels as required for GPS, but not less than the minimum requirement for GPS
 - SPS-8: Continuous AVC measurement supported as needed by portable WIM equipment
 - SPS-9: No recommendation at this time

- SHRP should implement the five-level traffic database system outlined in the report "SHRP-LTPP Traffic Database Design" (13) and make this traffic database available to researchers in the form of a national database.
- SHRP should ask the technical assistance contractor to prepare a report that describes the key summary statistics required for the pavement performance relationships. The report would also define methods for indicating variability in those summary statistics.
- The technical assistance contractor should be asked to add to the team, persons with expertise in traffic data variability and analysis and in traffic database management and computer programming.
- FHWA should be encouraged to provide lane identifiers in its volume count and truck weight record formats.

These recommendations were all accepted and acted on affirmatively by SHRP.

February 14-15, 1990, Austin, Texas

At this meeting, the ETG initiated the effort of refining the traffic database structure and prescribing the procedures for collecting, transmitting, recording, storing, processing, summarizing, and retrieving traffic data, both historical and monitoring data. Again, significant recommendations were made:

- SHRP should continue to collect traffic data at the GPS test sites beyond the initial 5-year period.
- SHRP should conduct an analysis of the inherent variability of the traffic summary statistics and the variability added by the data collection practices.
- SHRP should develop procedures for selecting the 50 regional WIM sites that are based on geographic distribution but define a range of traffic loading as measured in KESAL (thousands of ESAL) biased toward the lower-volume sections. This traffic loading criterion was adopted because SHAs tend to install WIM sites at higher-volume locations. Four ranges were set:
 - Less than 100 KESAL
 - 100-500 KESALs
 - 500-1000 KESALs
 - Greater than 1000 KESALs
- The ETG should review the weight categories used by FHWA and recommend what weight ranges SHRP should adopt.

- SHRP should transfer ESAL data from the traffic database to the pavement performance database.
- SHRP should develop a method for calculating ESAL for triple- and quadruple-axle groups.
- The pavement performance database should include standard deviation and sample size data along with each traffic summary statistic.

The ETG also took action to better define the traffic database and how it will function:

- The ETG adopted the format for displaying traffic summary statistics in the pavement performance database (14).
- The ETG adopted the concepts for tracking traffic data as they are entered, processed, and stored in the database as recommended in TRDF technical memorandum entitled, "Traffic Data Tracking System" (15).
- The ETG accepted the reports entitled "SHRP National Traffic Database: Description of the Required Computer System" (16) and "Procedures for Manipulating SHRP-LTPP Traffic Data" (11).
- The ETG agreed to the editing procedures outlined in the TRDF technical memorandum "Automated NTDB Traffic Data Edit" (17).
- The ETG recommended that a log and reporting forms be developed to record information about the type of equipment installed at GPS sites and to enter information about methods used and the timing of WIM devices calibration.
- The ETG recommended that SHRP adopt the AASHTO method of calculating ESAL.
- The ETG discussed traffic monitoring problems associated with the placement of WIM/AVC devices at locations separated from the GPS site by major traffic generators such as other highways, commercial areas, urbanized areas, and interchanges. A code was suggested to distinguish traffic data collected at the GPS site ("site specific") from that collected at locations separated by major traffic generators ("site related") or on a completely different road ("off site"). More study was requested.
- A list of traffic-related products of SHRP was prepared. (These products are discussed in more detail later in this report.)

June 21-22, 1990, San Francisco, California

Representatives from each of the four regions attended to provide input and improve communication with the SHAs on traffic data issues. Several significant recommendations were made to SHRP:

- The principle of base data integrity was formally adopted by the ETG, recommended to the LTPP Advisory Committee, and adopted by the committee. This second principle was just as important as the truth-in-data principle adopted by AASHTO and ASTM.
- SHRP should investigate the use of optical disks for the transfer and storage of traffic data.
- SHAs need more information about WIM and AVC equipment. The FHWA representative agreed to distribute pertinent information to the SHAs.
- SHRP should encourage each RCO to designate a traffic representative to be responsible for all traffic data activities in the region and to participate regularly in the ETG meetings.
- Each region reported to the ETG on the status of traffic data collection in each state or province in the region. At future meetings, a standard format will be developed for the regional reports.
- SHRP should develop software for entering and processing traffic data at the RCOs. Editing software should be a part of that package. The work was estimated to cost about \$80,000.
- SHRP should create a data availability code to define whether data is collected on or off site and whether they are gathered continuously or periodically.
- The ETG accepted a report, "ESALs for Triple and Quadruple Axles" (18) that provided a method for calculating ESAL for triple- and quadruple-axle groups.
- The ETG adopted the technical assistance contractor's recommendations for the format for recording the traffic data collection equipment installed at each GPS test site and for recording changes made to the equipment over time, including calibration. These formats are known as Sheet 14 and Sheet 15 and are found in Chapter 4 of the LTPP Data Collection Guide (19).
- A report describing the capabilities and limitations of the computers being used by the RCOs was reviewed. The report was titled "Traffic Data Processing Capabilities of the Computers at the SHRP Regional Coordinating Office: Analysis and Recommended Alternatives" (20).

September 19-20, 1990, Washington, D.C.

The following significant actions were taken or recommended by the Traffic ETG:

- The regions should determine how many GPS sites in each state or province fall into the categories of site specific, site related, and off site. This information should be included in the regional status reports.
- The ETG appointed a subcommittee to develop a report on variability of traffic summary statistics.
- The SHRP-LTPP data analysis contractor asked for assistance to secure as much traffic data as possible for early analysis. Annual and cumulative ESAL information is needed for each site. A procedure is needed to calculate the cumulative ESAL from available historical data.
- A meeting was planned for October in Santa Fe, New Mexico, to develop the detailed outline for the traffic data software.
- Until a better option is available, the data availability code will be used as a surrogate for the variability of traffic summary statistics. Later, when more site-specific data are available, statistical data will be used.
- SHRP should establish a national contract for the purchase and distribution of optical disks for the SHAs, and the SHAs should be given the opportunity to use the SHRP traffic equipment installation reimbursement funds to pay for the optical disks.
- SHRP should closely monitor the progress of NCHRP Project 3-39, which is studying WIM calibration procedures, and review a copy of the report when it is available.
- SHRP should actively participate in ASTM, AASHTO, the Institute of Traffic Engineering, the American Society of Civil Engineering, and related professional organizations to increase the visibility of the LTPP traffic data collection program and to encourage the adoption of national standards and specifications.
- The regional reports focused on the status of traffic data collection plans in each state and province. Guidelines for the development of traffic data collection plans were prepared by the technical assistance contractor and distributed to the SHAs in March 1990. (21)
- The regional WIM plans for each region were accepted. Revisions were needed in some cases. The technical assistance contractor prepared guidelines for selecting regional WIM sites in June 1990 (22).
- The technical assistance contractor developed a package of materials to be distributed during the International Traffic Workshop on October 29, 1990 (23).

- A report dated September 17, 1990 (24), was presented that described the traffic data analyses required for LTPP in the future.
- It was reported that the software for data editing and entry of historical data had been completed.
- The ETG accepted a report, "Implementation of the National Traffic Database" (25), that updated previous work and provided cost estimates and timing for creating a central traffic database. The total cost was estimated to be \$149,000, and the final action involved the purchase of the central computer in 1992.
- A report, "A Generalized Algorithm for Identifying Vehicles from Axle Spacing" (26) was also accepted.

February 25-26, 1991, Washington, D.C.

The major actions were as follows:

- A total of 57 SHAs have submitted traffic data collection plans.
- Meetings were held in each RCO to install the new traffic data processing software and discuss a variety of traffic data issues with regional engineers and contractor staff members.
- A meeting was held in Santa Fe, New Mexico, on October 7-9, 1990, to develop a plan for the development of the Level 3-2-1 software. The work was broken down into 22 tasks, or milestones, and a schedule was proposed for implementation.
- An optical disk purchase program is being implemented by SHRP.
- The ETG discussed the report "Algorithms for the Estimation of Traffic Data Variability" (27) and requested major revisions before the next meeting.
- The ETG recommended that a blue ribbon panel be established to address the requirements for a national traffic database.
- The data availability code was adopted along with two "SRO" codes: Each indicates whether the AVC and WIM device locations are site specific (S), site related (R), or off site (O). The three codes in combination describe the level of traffic data collection at each site and the location of the traffic data equipment.
- A subcommittee was appointed to develop a comprehensive listing of the traffic data analyses anticipated for the next 5 years. The subcommittee would also assist in the preparation of NCHRP problem statements.

- The Florida Department of Transportation's experience with WIM equipment and its methods of data processing were examined.
- The ETG recommended that SHRP develop procedures for conducting profile measurements at each WIM site to understand the effect that adjacent pavement roughness could have on traffic loading characteristics. These measurements would be made at the same time the SHRP profilometers measure the roughness of the GPS site.
- The International Traffic Data Collection Handbook (23) prepared by the technical assistance contractor was distributed at the recent international coordinators' conference.
- The ETG reviewed the report "Determination of Cumulative Loading Estimates from Historical Data" (28) and found that the methodology seemed sound. However, the ETG preferred that this data be provided by the SHAs rather than estimated mathematically by the RCO offices, if at all possible.
- The ETG recommended that SHRP provide funding of about \$40,000 to \$50,000 to enhance the traffic data processing software.
- SHRP authorized the purchase for each RCO one additional personal computer with an 80386 microprocessor to be used for traffic data processing and storage.
- The ETG was briefed on the 1990 Kummer Lecture presented to ASTM in San Antonio, Texas, in December. The paper "The Development of ASTM Highway Traffic Monitoring Standards" (29), summarized the work under way in SHRP and emphasized the need for high standards in the traffic data practices.

IMPLEMENTATION PHASE (1991-1992)

During the implementation phase, the Traffic ETG focused attention on a myriad of issues related to implementing the traffic data collection plans in each state and to forming the traffic database. During a series of meetings, the ETG developed procedures and programs to make the traffic database operational.

August 5-6, 1991, Washington, D.C.

The following major actions occurred:

- The meeting began with a presentation by the new FHWA-LTPP division chief. He addressed a variety of issues related to the transfer of the LTPP program to FHWA in July 1992. His group will have eight members. The RCOs will continue, but new requests for proposals will be solicited and new contracts awarded. The same will occur for the technical assistance contractor. The Traffic ETG will continue through

TRB under a program known as SHRP Monitoring and Research Transfer. The ETG asked that more details be presented at the next meeting.

- A blue ribbon panel meeting was scheduled for August 7, 1991, in Washington, D.C.
- It was reported that 62 percent of the historical data had been completed and submitted to the regions. The ETG asked that greater emphasis be given to this activity by the regional traffic representatives. In recognition of the significant progress made to date, the ETG asked that SHRP commend the regional staff members for their accomplishments in the traffic data collection effort.
- Final revisions to Sheets 14 and 15 of Chapter 4 of the LTPP Data Collection Guide (19) were approved. Other changes to Chapter 4 were also made.
- The ETG made several decisions to further the development of the traffic database and the traffic data processing software. Many details require that the ETG provide guidance to ensure that the principles of truth-in-data and base data integrity are maintained.
- The upcoming international coordinators' meeting in Göteborg, Sweden, on September 17-20, 1991, was discussed. On the first day, there will be a meeting on SHRP traffic data collection requirements.
- A review was conducted to define the availability of FHWA truck weight data for GPS sites. From this review it was ascertained that truck weight data are available for only 21 GPS sites---fewer than expected.
- It was reported that the meeting SHRP convened with TRB, ASTM, and AASHTO at the ASTM meeting in Atlantic City, New Jersey, was productive. SHRP staff, consultants, RCO contractors, and ETG members made presentations at the meeting.

November 5-6, 1991, Washington, D.C.

The actions of the Traffic ETG are described below:

- The ETG decided to encourage NCHRP to fund three traffic data projects previously identified as high-priority projects by the ETG. The earliest they can be funded is 1994.
- The FHWA-LTPP division director provided further information about the transfer of LTPP to FHWA. The chairman expressed appreciation for his continued updates and his concern for traffic in the process.

- Reports from the regional traffic representatives' meeting in St. Paul, Minnesota, in October 1991 were heard. Operational issues were discussed and resolved at that meeting.
- The ETG again considered several traffic database and traffic data processing software matters and systematically make recommendations for each. Ultimately, these decisions will be evident in the database and in the software.
- The ETG took action on a report describing the requirements for profiling measurements at WIM installations. The ETG accepted the report and asked SHRP staff to develop a final version. It is important that profile measurements be made soon at each WIM site.
- Nine countries participated in the international traffic meeting. The International Traffic Data Collection Handbook (23) was distributed as planned. The meeting was productive, but many new issues were raised. SHRP will be working with the SHRP international coordinators to address these problems and needs.
- "National Traffic Data Collection and Monitoring Standards" (ASTM E 1442-91) (30) was approved October 15, 1991, and is available from ASTM. FHWA will distribute more than 500 copies to FHWA regional and division offices. The AASHTO standards are also progressing through the review and development process. Many SHRP-related people are working on these two sets of standards.
- The blue ribbon panel report was received and recommended for immediate implementation by SHRP. The report cites a need for \$110,000 to create a central traffic database and operations center at TRB parallel to the pavement performance database.
- The ETG was alerted that progress had been made since the last meeting to address the issue of traffic variability. A panel of experts had met in Austin, Texas, to address the matter in early October. As a result of extensive discussions and detailed analysis of the subject, a working outline was prepared and assignments were made. The group then proceeded during the next few weeks to prepare two reports for consideration by the ETG.
- The ETG considered the two reports. One report (31) defined the process for determining ESAL from available data and related it to the work done on the AASHTO road test. One important factor considered was that the same traffic stream affects concrete and asphalt pavements differently because of the load equivalency factors developed as a result of the AASHTO road test. An improved method for defining the effect of loading is needed.
- The other report (32) outlined the procedures employed by SHRP to process monitoring data and to summarize that data to calculate the annual traffic summary statistics for use in the pavement performance studies. The report also presented a method for determining the precision of that process for each site. The ETG asked

that the previous report be merged with this one. ETG members recommended several enhancements to the combined report. A special meeting was planned for that evening to develop a unified report and present the results the next day. These goals were accomplished.

- Although more work is needed, the ETG complimented the panel of experts for bringing the matter to final consideration. The work of the Variability Subcommittee was also recognized. The ETG urged swift action to finish the revised report, which is to be entitled "Procedures for Assessing the Precision of Annual Traffic Statistics" (32). This reference will be included in the AASHTO guidelines for traffic data programs. One member volunteered to conduct a statistical study to verify some of the equations cited in the reports and present the results at the next meeting. Also, a plan is being developed to work with FHWA, New Mexico State University, and the New Mexico Department of Highways and Transportation to test the statistical procedures outlined in the report.
- The regional representatives again reported good progress toward installing traffic data collection equipment at GPS test locations. There continue to be problems, but generally speaking the SHAs are working positively to collect the traffic data SHRP needs.
- An initiative to evaluate WIM/AVC equipment on Interstate 95 near the Delaware, Pennsylvania, and New Jersey borders was noted.
- The ETG identified a list of additional software development activities that require funding, including conversion to the AASHTO standards, study of traffic variability and precision, and the central traffic database. SHRP was urged to fund these needs. A panel was appointed to meet November 14, 1991, to discuss these needs in more detail.
- Priorities were set for the use of time by the software development contractor. Operational issues were discussed, including implementation of the SRO codes and the proposed Canadian vehicle classification system.
- The program to purchase optical disks for the SHAs has been very positive for SHRP and the SHAs, and it provides a common medium for recording, storing, and transferring traffic data. SHRP is providing technical advice and assistance to the regions and to the states as requested.
- Future needs in traffic data collection and analysis were discussed, and a comprehensive list was generated. All present offered their thoughts and ideas. The results of this process are presented under "Pending Issues" later in this report.
- The ETG decided to prepare a report summarizing its actions over the past 4 years. The ETG developed an outline and made assignments to the members, staff, and consultants.

- The ETG encouraged the regional representatives to meet with each of the SHAs that have not submitted the historical data and to encourage them to complete it by the end of the year.

February 10-11, 1992, Washington, D.C.

These actions were taken:

- Further information about the transfer to FHWA was provided. The additional funding (\$80,000) for the central traffic database had been approved by the SHRP Executive Committee, and the technical assistance contractor would be asked to submit a proposal. Work should begin on the software in the next few weeks.
- It was noted that the report on precision, "Procedures for Assessing the Precision of Annual Traffic Statistics" (32), dated November 1991, had been completed, reviewed, and finalized. The statistical analysis and evaluation of the two equations was also completed by one of the members. The SHRP-LTPP program manager stated that the report will be published by SHRP as a working paper.
- A plan to analyze the SHRP-LTPP WIM data was presented and accepted.
- The meeting held with equipment manufacturers under the sponsorship of ASTM was described. The group met before the TRB meeting on January 10-12, 1992, to consider equipment issues. An ASTM task force was established to develop standards for traffic monitoring devices. The first meeting will be in Monterey, California, in March 1992.
- Historical traffic data collection results were analyzed by the ETG. Many problems were noted and actions recommended. About 82 percent of the data have been submitted to date, and it is important to have these data for the data analysis contractor. The regional representatives agreed to pursue this matter aggressively in the next few weeks.
- The regional reports were presented. Operational issues were raised and discussed and recommendations offered as a consequence of the reports.
- Problems in the development of LTPP traffic data processing software were identified and discussed. Changes to Chapter 4 of the Data Collection Guide (19) were recommended to resolve these problems.

May 14-15, 1992, Washington, D.C.

The Traffic ETG's final meeting under the SHRP banner was held in Washington, D.C., on May 14-15, 1992. The following actions were recorded:

- The ETG agreed with the proposal that it be continued as a TRB committee under the new FHWA-LTPP structure.
- A report was presented on the successful meeting of the regional traffic representatives in Santa Fe, New Mexico.
- Chapter 4 of the LTPP Data Collection Guide (19) was accepted, and the ETG recommended that it be published by SHRP.
- A report was presented on the status of the traffic data processing software and on the plans to develop software to activate the LTPP central traffic database. The Level 3-2-1 software will be completed by September 30, 1992, and the central traffic database will be complete and operational by October 31, 1992.
- The ETG reviewed the progress report on the WIM data analysis and provided guidance to the technical assistance contractor.
- The ETG agreed to the revised profiling standards for WIM locations.
- The ETG reviewed the report "Applications of Weigh-in-Motion Data in Transportation Planning" (Ref 33).
- The ETG accepted the reports of each of the regional traffic representatives and commended them for reaching the level of 95 percent complete for historical data. The summary report included the following statement of progress to date (34):
 - 273 continuous WIM installations planned (35 percent)
 - 485 continuous AVC installations planned (62 percent)
 - 671 site-specific installations (86 percent)
 - 62 SHA traffic data collection plans received
 - Traffic equipment now in place at 50 percent of GPS test sites; another 20 percent of sites under construction
- It was recommended that traffic data collection plans be developed in each state for SPS test locations in that state. The regional traffic representatives are to follow up on this recommendation.
- It was recommended that the traffic database be modified as necessary to receive data from SPS test locations.
- The ETG commended FHWA for making funds available to the SHAs for traffic data collection activities at SPS test locations.
- The ETG reviewed the compilation of minutes recording its actions since its inception in 1988 and asked that the Traffic ETG 5-year report be finalized and published by SHRP (2).

- The ETG reviewed and accepted the issues report (35) and asked that it be incorporated into the ETG 5-year report.
- The ETG asked that copies of the draft final report for NCHRP Project 3-39 be distributed to the ETG members for individual review and comments.
- The ETG urged NCHRP to give high priority to funding for the traffic data analysis projects as previously defined by the ETG and now under consideration by AASHTO committees.
- It was recommended that SHRP ask FHWA to establish a National Highway Institute course providing training about the ASTM/AASHTO national traffic monitoring standards, as well as hands-on training in the use of the SHRP-LTPP traffic data processing software.
- The ETG supported the work related to incorporating international traffic data into the LTPP traffic database.
- It was recommended that SHRP and FHWA take a strong role in the planning of the National Data Acquisition Conference in Sacramento, California, in October 1992. Regional meetings are planned, and several speakers will address SHRP traffic issues.
- The ETG extended its appreciation to the SHRP staff, regional traffic representatives, and consultants who had provided valuable assistance over the past 4 years. The ETG chairman expressed his appreciation to current and past ETG members for their dedicated and significant achievements during the tenure of the Traffic ETG. He envisioned that the ETG's work would significantly affect traffic data collection and analysis for many years to come.

LTPP CENTRAL TRAFFIC DATABASE

The concept of a national traffic database originated at a meeting in Austin, Texas, in March 1989, at which SHRP staff, consultants, and the technical assistance contractor staff were in attendance. The group concluded that the volume of traffic and load data that would be collected over the 20 years of LTPP was far more than could be handled as part of the national pavement performance database. The traffic data would be very valuable for the LTPP project and related future research in the future.

The initial framework for the national traffic database was developed at the Austin meeting, including the five levels of traffic data and the computer capabilities required to handle the data. These concepts were summarized in two reports: "SHRP-LTPP Traffic Database Design" (13), the most recent version of which is dated August 1990, and "SHRP National Traffic Database: Description of the Required Computer System," also dated August 1990 (16). Another report, "Procedures for Manipulating SHRP-LTPP Traffic Data" (11), dated August 1990, outlined the procedures for collecting, formatting, processing, storing, reporting,

and summarizing traffic data. The traffic database was initially developed at the regional level. Later, the national traffic database was established at TRB to make access to the traffic data more efficient.

The national traffic database will be available for research studies and analysis on a general issue basis, a state-specific, or a site-specific basis. Traffic data from more than 775 GPS sites on key highway routes throughout the United States and Canada will be extremely valuable to policy planners at the national and state levels for both highway pavement issues and national traffic planning issues. The creation of the national traffic database in cooperation with the 62 participating SHAs is certainly a major achievement for the SHRP-LTPP program.

One important aspect of the traffic database is the estimation of annual traffic loading (ESAL). In summarizing the available traffic and weight data to estimate the total annual loading, errors or bias' may be introduced into the data. Algorithms for estimating the variability of the traffic summary statistics have been developed (32). Data variability parameters will be incorporated in the traffic database in Level 1 and also in the pavement performance database.

ANALYSES CONDUCTED

During the tenure of the ETG, several studies were conducted that were beneficial to the ETG's work. The results were also significant in transforming the traffic data collection procedures used by the SHAs. These studies were summarized in a memorandum dated April 3, 1992 (36), for consideration by the Traffic ETG. The report was accepted by the ETG, and the various studies are briefly described below:

- Evaluation of the Tridem and Quadruple Axles. This study defined tridem and quadrem axles for purposes of the LTPP studies (18).
- Analysis of Truck Editing Schemes. This study evaluated the use of the observed patterns of 3S2 trucks as a traffic editing device for SHAs.
- Data Variability. This study led to the development of the document "Procedures for Assessing the Precision of Annual Traffic Statistics" (32). The report, dated November 1991, will be published as a stand-alone document by SHRP.
- Analysis of Piezo-Electric Cable for Vehicle Classification. This work was done by Oregon State University, and the results are summarized in the report "Pilot Project: Piezo-Electric Automatic Vehicle Classification System" (37). AVC specifications were also developed as a result of this pilot project in Oregon.
- Minnesota WIM Data Analysis. A study was conducted using WIM data from four sites in Minnesota to determine patterns and trends of 3S2 trucks (12). The results were significant. The patterns were quite varied for each site, and the trends showed

that the volume of trucks on weekends was lower than on other days of the week but the loads being carried were much heavier. The trends established in this study persuaded many SHAs that site-specific WIM equipment was crucial to the GPS program. The results of this study were incorporated into a paper delivered at the Denver midterm conference of SHRP in August 1990, entitled "The SHRP Traffic Database: What It Really Is" (38).

- Preliminary WIM Data Analysis for Selected SHRP GPS Sites. This study was conducted by the technical assistance contractor. It evaluated the use of time series analysis to determine trends and patterns in data from three continuously monitored GPS test sections. The traffic and weight data were converted to daily ESAL values with specially developed software. Time series analysis techniques (39, 40, 41) were used to develop mathematical relationships from the daily ESAL values. The results of this preliminary study are described in the report "Preliminary WIM Data Analysis for Selected SHRP GPS Sites: Final Report" (42), dated July 1992. Insufficient data were available in the time allowed for the study to establish definitive results, but the technique is promising. Many lessons were learned about the processing of SHRP WIM data. The following section provides more detail about this analysis.

SOFTWARE DEVELOPMENT

The SHRP regions required computer software to receive and process the traffic data from the SHAs. The development of the traffic data processing software was generally guided by the actions of the Traffic ETG and the SHRP staff, with the technical assistance of various consultants. The technical assistance contractor developed a series of reports defining the filing system, the reporting formats, and the basic design for the software. The final design and initial coding was begun in the fall of 1989, and software for data entry, edit checks, and processing of historical data was completed in 1990. Software for entry, processing, and summarization of monitoring data was completed during the summer of 1992. The software is called Level 3-2-1. Problems with the initial version of the software have since been rectified, and the system is in place and being used by the regional offices. Additional software designed for use in the LTPP central traffic database located at TRB was released in September 1992. The LTPP central traffic database was acquired and installed at TRB in November 1992.

Several technical documents and user manuals have been prepared to guide this software development effort. User manuals have been developed to explain the two software programs and how they function (42, 43).

OTHER IMPORTANT PROGRAMS

Data Formats

The Traffic ETG focused on developing procedures for formatting, receiving, storing, processing, summarizing, and reporting traffic data collected at GPS test locations. The SHRP traffic data consultant, a traffic data specialist working with the SHRP staff and the Traffic ETG, developed a series of reports summarizing the actions and decisions of the ETG, SHRP staff, and consultants (11, 13, 16, 38). These reports provided the structure for the traffic database and led to further work by the consultants and staff in the development of Chapter 4 of the Data Collection Guide (19), "Guidelines for Traffic Data Collection Plans" (21), related computer software (42, 43), and various other technical memorandums and reports. SHRP consultants advised the Traffic ETG and SHRP staff members as the traffic data collection plans and database were developed during the 5 years of SHRP and the 4 years of the Traffic ETG.

FHWA Monitoring Procedures

Another major action by the ETG was to recommend the adoption of the FHWA HPMS user manual and TMG (6) as basic documents for the development of a SHRP-LTPP traffic database, including the adoption of the FHWA 13-class vehicle classification system and the FHWA formats for reporting traffic volume, classification, and weight data. These documents provided a standard that was known to all states. With the adoption of the FHWA procedures, FHWA committed to provide funding support, personnel support, and assistance at all levels of the organization in the development and implementation of the LTPP traffic data collection program.

TRAFFIC DATA COLLECTION PLANS

Because of the variety of options available to the SHAs in installing traffic data collection equipment and measuring traffic and axle load data, the Traffic ETG requested that each SHA prepare a traffic data collection plan. The technical assistance contractor developed a set of guidelines for preparing traffic data collection plans, and the guidelines were issued to the SHAs in November 1989 (21). Each SHA was asked to submit to the RCO outlines of specific plans for collecting traffic data at each GPS test section in its state. Location, type of equipment, frequency of operation, SHRP funds required, persons responsible, and method of transmitting the data were summarized in the plan. Maps and installation schedules were also included along with other pertinent information. All SHAs prepared and turned in traffic data collection plans.

Traffic data collection plans were reviewed by the technical assistance contractor and the RCO staff to ensure that they met the standards established by SHRP. If problems were

noted, they were discussed with the SHA and resolved. After all issues had been addressed, the SHRP regional engineer issued a letter of concurrence authorizing the SHA to receive SHRP funds and encouraging the SHA to begin implementation. The initial activity involved retrieving and reporting historical data and was followed by the installation of traffic data collection equipment at each site.

Historical Data

The requirements for retrieving and reporting historical data for each GPS test location were specified in Chapter 4 of the Data Collection Guide (19), which was issued by SHRP in an interim format in May 1990. This document provided background information, an explanation of the historical and monitoring traffic data requirements, historical data forms, monitoring data formats, and baseline information about collecting and processing traffic data.

Historical data were initially retrieved from the files for two sites in each state and submitted to the RCO for review and verification of the output. After receiving feedback from the RCO, the SHA collected the historical data for all other GPS sites in the state. To date, historical traffic data from more than 400 GPS test locations have been collected and turned into the RCOs. These data will be important in the early analysis studies to be conducted by the data analysis contractor.

Role of the Regional Coordination Offices

The SHRP-LTPP traffic database is housed at the four RCOs. At the regional level, the data is received, entered, checked, summarized, processed, reported, and stored. The regional representatives work directly with the SHAs in obtaining traffic and load data for the GPS experiments. This process includes reviewing and approving data collection plans, verifying the installation of traffic data collection equipment at each site, and receiving and entering traffic data from the SHAs every month.

National Standards

SHRP has provided leadership throughout the nation in the development of traffic data collection procedures and standards. The first evidence of this leadership is found in the adoption of the ASTM WIM specifications (E 1318-90) (40). Although the proposed WIM specifications had been previously drafted, it was the push by SHRP and the Traffic ETG for a common standard for the SHAs to use at GPS test locations that expedited the review and balloting for the ASTM WIM specifications.

SHRP also stimulated the need for ASTM standards for AVC, which are being considered for adoption by ASTM. Similarly, AASHTO also developed standards for traffic monitoring patterned after the work of ASTM and SHRP (45). Improvements in traffic data collection

and analysis techniques are evident in highway departments throughout the United States and Canada because of the programs and policies instituted by SHRP.

International Traffic Data Requirements

After some deliberation, the Traffic ETG recommended that the traffic data requirements for international GPS test locations be the same as those established for U.S. and Canadian sites. To facilitate understanding of these requirements by the coordinators from the various countries, an International Traffic Data Collection Handbook (23) was compiled incorporating the most important technical memorandums, reports, and documents. The handbook was distributed initially at the international coordinators' meeting in England in November 1990.

A paper was presented in July 1992 to the Third International Symposium on Heavy Vehicle Weights and Dimensions in Cambridge, England. The paper summarized the LTPP Traffic Data Collection Program and its role in the future design of highway pavements (46).

PENDING ISSUES

In a report to the SHRP Executive Committee dated January 23, 1992, the Traffic ETG identified the most prominent issues that need attention over the next 5 years (35). These issues had been identified at the previous ETG meeting and summarized by the SHRP consultant for ETG consideration. The ETG accepted the report and authorized its submission to SHRP.

The issues were divided into five categories:

- WIM equipment concerns
- Management of the traffic data function
- Analysis needs
- Database issues
- Funding and staffing needs

These categories are examined in detail in the following sections.

WIM Equipment Concerns

The SHAs are purchasing and installing WIM vehicle classification equipment required for LTPP data collection. This equipment represents the state of the art in traffic monitoring devices, and many states are experiencing more difficulty in installing, calibrating, and maintaining the equipment than expected. In addition, the cost of these devices has been considerably higher than anticipated in the initial SHRP planning documents (1). The staffing requirements at the state and regional level for handling the large volume of traffic data necessary to support the LTPP effort were also underestimated. Finally, the state of the art in

WIM has not progressed as rapidly as expected in the original SHRP documents. Some technical issues, such as weighing vehicles on rough roads and calibrating WIM devices independently from the traffic stream, have yet to be resolved by the professional community.

Because of differences between the original expectations for SHRP and the actual operating characteristics of the equipment, the ETG has the following concerns:

- An unexpectedly large number of WIM devices may fail prematurely (primarily because of sensor failure but also because of failure of electronic components).
- The cost of replacing sensors may be too high for many SHAs, significantly delaying the replacement of failed sensors and resulting in a loss of data important to the LTPP analyses.
- Calibration procedures for WIM equipment in locations inaccessible to static scales are poorly defined and inconsistently performed by SHAs. In addition, some research has shown that equipment calibration changes over time with changes in environmental and roadway conditions. Both these situations increase the uncertainty associated with vehicle weights collected and incorporated into the SHRP database. SHRP has not been able to adequately define how to reduce the number of instances when these situations occur, how to reduce the effects when they occur, or how to adequately incorporate these situations into the existing SHRP databases.

The ETG recommends the following measures as initial steps toward resolving these issues:

- SHRP should continue to monitor the functioning of WIM equipment purchased and operated by the SHAs. Information on successful WIM installations and procedures should be distributed to the SHAs whenever possible so that all SHAs may reduce their WIM expenditures without loss of data or data quality. SHRP should also distribute information on techniques and equipment that do not work so that SHAs do not repeat mistakes made by others.
- SHRP should support the continuing evolution and improvement of WIM technology through improvements in equipment, through research to address the above issues, and through technology transfer among the SHAs.

SHRP support in these areas will require some funding but mostly a concerted, publicly expressed emphasis on these topics by the SHRP management.

Management of the Traffic Data Function

The original SHRP research design and staffing plan underestimated the effort required to collect the traffic data for the LTPP program. Partly because of this underestimation, resources at the beginning of the LTPP effort were inadequate to manage traffic data collection. While additional staff and resources were later allocated to the traffic effort,

several major issues have yet to be resolved. The ETG is concerned that sufficient management attention be allocated to the traffic data portion of the LTPP project as part of the new SHRP organization. Issues that need management attention or otherwise relate to ETG concerns with upcoming project management include the following:

- The technology assumptions and policies of the SHRP Traffic ETG are more advanced than many of those the SHAs currently use. The SHRP successor organization must continue to help the SHAs advance the state of the art in procedures for installing and maintaining equipment and collecting, processing, storing, and manipulating data.
- Given the structure and staffing levels of the FHWA office, scheduled to continue the LTPP project, the ETG recommended that FHWA provide staffing necessary to handle the administrative functions related to the LTPP traffic data effort.
- The ETG is also concerned that inadequate funding has been provided for staff responsible for traffic data collection at the RCOs and that staffing levels at the SHAs are too low for basic traffic needs, let alone the effort needed to collect, verify, and transmit the SHRP traffic data. If these resource limitations materialize, a significant SHRP management effort will be needed either to adapt the LTPP project to the lack of data or to provide assistance to the SHAs and regions that lack those resources.
- SHRP must produce some traffic-oriented products that demonstrate to the SHAs the value of continuing the LTPP traffic collection effort. These products need not relate directly to pavements if they help maintain support among the SHAs for continuing the data collection effort.
- In several ETG meetings, SHRP staff have stressed the importance of products that demonstrate the benefits from SHRP. However, the traffic analyses that produce those benefits have often been caught in a no-win situation. Since SHRP emphasizes products, anything not directly related to pavement research is not considered part of the SHRP research funding commitment. (Note that the central traffic database was renamed the "LTPP Traffic Database" to avoid giving it connotations outside the LTPP project, despite its utility outside the LTPP effort.) Similarly, outside funding sources often express interest in topics that would benefit SHRP, but stop short of funding these studies because the database is a SHRP function and it is assumed that SHRP analyses should be funded by SHRP.
- The ETG is also concerned that the successor organization maintain careful control over the entry and use of data in the LTPP traffic database. Historically, traffic data have often been misused by researchers unaware of the variability inherent in the data, and the likelihood of such misuse of the LTPP database is quite high.
- Finally, the ETG recommends that FHWA maintain a group similar to the ETG to address the LTPP needs in light of the changing facets of traffic data collection. These tasks include determining the appropriate SHRP responses to the technical advances that will affect data collection during the life of the LTPP project, converting the SHRP database from English units of measure to Système Internationale (SI) units,

addressing issues of compatibility with the foreign LTPP databases, and responding consistently to comments and questions from the SHAs.

Analysis Needs

Limitations of the current SHRP budget have postponed the conduct of several important analyses involving traffic data. The results of most of these analyses will significantly affect either the quality of the loading estimates incorporated into the LTPP databases or the volume of data that must be entered into the LTPP databases. The most important of these analyses are the following:

- The reasonability of the historical traffic volume and loading estimates (backcasting) should be analyzed. This study will compare the estimates with current traffic patterns, as measured with the continuous AVC and WIM devices installed for the LTPP project.
- Researchers should also analyze the effect of road roughness on the distribution of vehicle weights, as collected by WIM scales, and the effect of that variation on ESAL (or other) load estimates made with those weights. (This process should take into account the profile and falling-weight deflectometer measures in the LTPP Information Management System database and may help resolve the issues of WIM scale bias, calibration difficulties, and calibration drift.)
- In addition, researchers should examine the basic issue of how dynamic forces (as measured by available WIM technology) should be converted to estimates of standard load for use in pavement performance equations. This study would include a careful review of how the traffic stream should be characterized for pavement analyses.
- An analysis is needed of the variability in the vehicle class and weight data at each site so that the existing data collection plan can be replaced by a smaller sample of data that produces a loading estimate of known precision that is acceptable for the LTPP research.
- The volume of traffic data collected for SHRP prevents cost effective manual review of the data. Faster, more automated, and more accurate methods of validating the data produced by field equipment are needed to reduce the cost of data collection, to help SHAs identify malfunctioning equipment, and to improve the quality of the data incorporated into the LTPP database.
- A related issue is the need to periodically review the validity of assumptions and procedures used in SHRP to collect and manipulate the traffic data. This process might be termed "truth in analysis" and is required to ensure that generally accepted assumptions about the nature of traffic and load distributions are true and do not reduce the reliability of the traffic estimates used in SHRP.

- Last, SHRP needs to review and determine how best to use the "extraneous" information it is requesting from the SHAs and storing in Level 5 of the traffic database. These data include the site-related traffic counts that describe the effect of the roads between the traffic data collection site and the LTPP test section, the profile information for the WIM scale, and the calibration data for each scale.

Database Issues

Because of the scarcity of funds, the LTPP traffic database lacks many features it should have. These features, listed in previous ETG working papers, should be added as quickly as possible to reduce the workload of the RCO contractors and improve the quality of the data in the LTPP database.

The ETG is concerned that SHRP has not adequately addressed the need for long-term storage and handling of the LTPP databases. While the ETG's primary concern is for the handling of the voluminous traffic information, they are also aware of the need to store pavement cores, profilometer data, falling-weight deflectometer data, and a large number of other sets of raw information.

The ETG is concerned about the compatibility of data among SHAs as well as between U.S. and international LTPP participants. While the ETG has worked hard to quantify the reliability of traffic estimates in the database through the principal of truth in data, there are still several concerns in this area:

- Differences in vehicle classification algorithms
- Differences in WIM devices
- Differences in the way axle weights are recorded (SI versus English units)
- Environmental effects

These differences are not always obvious to researchers using the database and may well be overlooked by researchers trying to manipulate the large volumes of data stored in the LTPP databases.

Some of these differences can be addressed by expanding the LTPP traffic database to better incorporate WIM calibration information, ongoing changes in the vehicle classification schemes the SHAs use, and the development of simple methods for retrieving and using information stored in Level 5. Additional attention must be paid to these items as more researchers begin to use the SHRP database.

Last, operational experience with the traffic monitoring data is quite limited. Consequently, the relationship between the regional traffic databases and the central traffic database requested by the ETG is still conceptual. SHRP must pay close attention to the entire traffic data entry, manipulation, storage, and retrieval process and be prepared to refine those procedures to maintain a cost-effective system. Refinement may include shifting some traffic database responsibilities between the regional and central facilities.

Funding and Staffing Needs

As indicated above, the ETG is concerned that most SHAs have not allocated sufficient resources to continue the SHRP traffic data collection effort. This problem is particularly apparent in current staffing levels. It will become even more significant if equipment and sensor failures continue at the rates observed so far and if automated data editing procedures are not developed and transferred to the SHAs. SHRP must continue to press the SHAs to adequately fund and staff these efforts. One key point for SHRP to make is that these data will result in improvements to SHA databases and design information as well as the SHRP-LTPP effort.

The ETG also recommends that FHWA provide appropriate staffing to continue the LTPP traffic data collection program at 1992 levels. This staffing is important to ensure support for the regional contractors and, consequently, for the collection of data by the SHAs.

SHRP must develop an image of an organization that gives things back to the SHAs. This image can be developed through the analyses and technical assistance described above, through the development and dissemination of products that benefit the SHAs, and through the provision of funds to assist the SHAs in traffic data collection.

SUMMARY

This report provides a summary of the SHRP-LTPP 5-year effort to better understand traffic's effect on pavement performance. The report also reviews the traffic data collection program over an intensely developed 4 years. It also provides a connection with the reports and publications issued during the period by providing an extensive reference list.

The format portrays the history of action by the Traffic ETG and reflects the ETG's active role in the traffic data collection and analysis program. The actual SHRP traffic data requirements are specifically defined in a report prepared in August 1991 (47). Because of the role that each of the 62 SHAs had in the process, this program was a highly developed cooperative effort, and the Traffic ETG, consisting of representatives from several SHAs, was the bridge between SHRP and the SHAs.

The LTPP traffic database developed by this program will benefit state and federal highway agencies for many years to come. By establishing the LTPP central traffic database at TRB parallel to the national pavement performance database, the two will be readily accessible and usable for intellectual research for years to come. At some point in the future, the relative effect of traffic loading on pavement performance will clearly be known, and a process will be available to collect traffic and loading data on a sampling basis and project the total ESAL on a highway over a given time frame accurately and effectively. When that occurs, it will be because of this research work, and many of the basic objectives of the SHRP-LTPP program will be met.

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Strategic Highway Research Program
National Academy of Sciences
2101 Constitution Avenue N.W.
Washington, DC 20418

(202) 334-3774

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Transportation Research Board

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Federal Highway Administration

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Marcus Williams
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Indiana Department of Transportation

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W.J. MacCreery, Inc.

David Albright
Alliance for Transportation Research

Richard Barksdale
Georgia Institute of Technology

James L. Brown
Pavement Consultant

Robert L. Clevenger
Colorado Department of Transportation

Ronald Collins
Georgia Department of Transportation

Guy Doré
Ministere des Transports de Quebec

Charles E. Dougan
Connecticut Department of Transportation

McRaney Fulmer
South Carolina Department of Highways & Public Transportation

Marlin J. Knutson
American Concrete Pavement Association

Hans Jorgen Ertman Larsen
Danish Road Institute

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Consultant Civil Engineer

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University of Kansas

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Pennsylvania Department of Transportation

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University of Minnesota

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National Stone Association

Cesar A.V. Queiroz
The World Bank

Rolands L. Rizenbergs
Kentucky Transportation Cabinet

Gary K. Robinson
Arizona Department of Transportation

Frederic R. Ross
Wisconsin Department of Transportation

Ted M. Scott
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University of Illinois

Kenneth R. Wardlaw
Exxon Chemical Corporation

Marcus Williams
H.B. Zachry Company

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USAE Waterways Experiment Station

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