Estimating Cumulative Traffic Loads, Volume II: Traffic Data Assessment and Axle Load Projection for the Sites with Acceptable Axle Weight Data, Final Report for Phase 2

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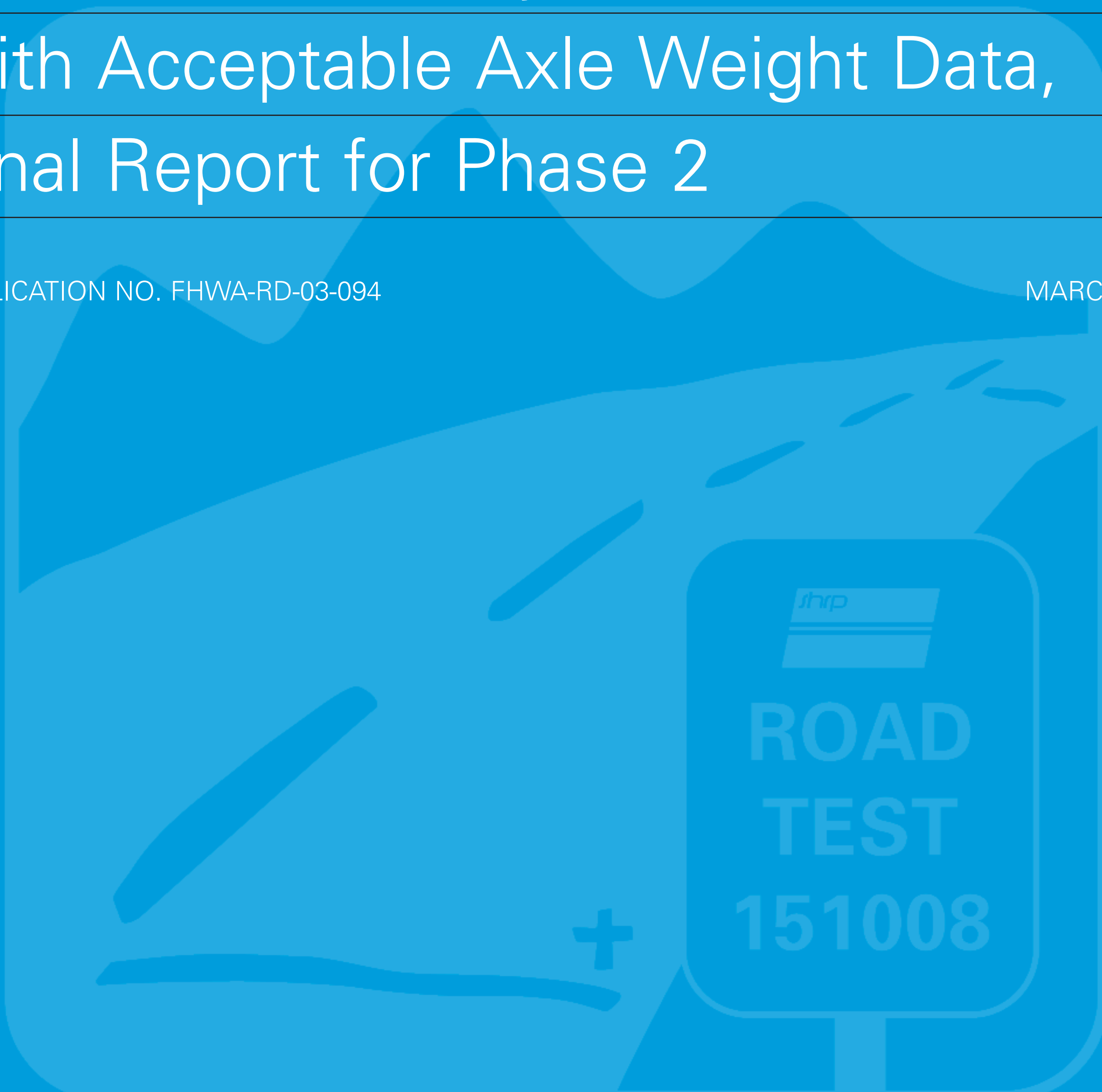

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Federal Highway Administration

Research, Development, and Technology
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LTPP

Foreword

In 1998, the Federal Highway Administration (FHWA) sponsored a two-phase study to develop traffic load estimates for Long-Term Pavement Performance (LTPP) sites. This report describes the results of the Phase 2 study. The Phase 1 study resulted in the development of methodology for estimating axle load spectra for all years the LTPP sites were in service. Phase 2 used this methodology to estimate axle loads for all LTPP sites that had acceptable site-specific axle weight data. In total, traffic load estimates were made for 558 LTPP traffic sites.

This report will be of interest to engineers involved in pavement management, design, maintenance, and rehabilitation and in traffic data collection and analysis.

T. Paul Teng, P.E.
Director, Office of Infrastructure
Research and Development

Notice

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16. Abstract

In 1998, the Federal Highway Administration sponsored a study to estimate traffic loads on Long-Term Pavement Performance (LTPP) sites. This report contains findings of the second phase of the study. Phase 1 encompassed the development of the estimation methodology, including numerical examples, and was documented in report FHWA-RD-00-054 issued in July 2000. Phase 2, described in this report, included the assessment of the overall quality of traffic data for all 890 LTPP traffic sites, and the projection of axle loads for all LTPP sites with adequate traffic data. Phase 2 also included the distribution of comprehensive traffic data reports to all participating agencies and the incorporation of comments regarding traffic projections received from the agencies.

Axle load projections were developed for all in-service years up to 1998 for 558 LTPP traffic sites that had adequate traffic monitoring data in the IMS database. The axle load projections were expressed as annual axle load spectra for single, tandem, and triple axles, and were placed into IMS computed parameter tables. The projection results for all LTPP sites are summarized in appendix A.

To overcome the difficulty of estimating traffic loads for the remaining 332 LTPP sites, it was proposed to develop the LTPP Pavement Loading Guide (PLG). The report contains a description of the purpose, design parameters, and functionality of the PLG, a blueprint for the development of the PLG, and two examples of using the PLG to obtain traffic load projections for LTPP sites without site-specific truck class and/or axle load data.

The recommended traffic analysis activities include the development of the LTPP PLG, completing traffic load projections for all LTPP sites, and the development of a comprehensive action plan for better utilization of the existing traffic data. The recommended components of the action plan include a comprehensive quality assurance process, use of monthly traffic data for estimating traffic loads, and regional traffic modeling utilizing both LTPP traffic data and other traffic data.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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CHAPTER 1. INTRODUCTION

In 1998, the Federal Highway Administration (FHWA) sponsored a two-phase study to develop traffic load estimates for Long-Term Pavement Performance (LTPP) sites. This report describes the results of the Phase 2 study. The Phase 1 study resulted in the development of a methodology for estimating axle load spectra for all years the LTPP sites were in service.[1] Phase 2 used this methodology to estimate axle loads for all LTPP sites that had acceptable site-specific axle weight data. In total, traffic load estimates were made for 558 LTPP traffic sites.

Objectives of Phase 2

The original goal of Phase 2 was to apply the methodology developed in Phase 1 to obtain annual axle load spectra for 500 LTPP sections. During the course of Phase 2, this goal was refined to encompass the following specific objectives:

- Review traffic data for all LTPP sites in terms of quality and quantity.
- Carry out initial truck volume projections for all LTPP sites and submit them for review by participating agencies.
- Carry out initial axle load spectra projections for all LTPP sites with monitoring site-specific axle loads and submit them for review by participating agencies.
- Modify the initial traffic projections according to the review comments provided by participating agencies.
- Develop computed parameter tables for storage of the projected axle load spectra and supplemental projection data in the LTPP Information Management System (IMS) and upload the traffic projections into the database.
- Develop a prototype Pavement Loading Guide (PLG).
- Develop reliability or variability indicators for the projected traffic loads.

Background

A principal objective of the LTPP program is to answer key questions about pavement design and rehabilitation characteristics that will help the States and Provinces achieve pavement performance that is both long lived and cost effective.[2] For interstate and other major highways, this objective is directly related to the need to quantify the relationship between pavement performance (deterioration of pavement structure with time) and traffic loads. Consequently, traffic data collection and analysis, required to obtain traffic loads, is the key activity within the LTPP program.

Since the inception of the LTPP program, traffic data collection has been the responsibility of the participating highway agencies, while the storage and analysis of traffic data have been done by LTPP program. Over the course of the program, participating agencies received a series of guidelines on how traffic data should be collected and reported to the LTPP. Briefly, the guidelines recommended that truck volume data should be collected using continuously operating automatic vehicle classifiers (AVC), and that truck axle weights should be collected using weigh-in-motion (WIM) scales or other scales operating during specified time periods.[3, 4]

Traffic data collected in the field are sent by the participating agencies to LTPP Regional Coordination Offices (RCOs) in an electronic format as individual vehicle records for processing and storage. The traffic data processing includes quality assurance (QA) checks and factoring. Factoring is used to obtain annual traffic data, such as annual average daily truck volumes, from the data collected during a portion of the year only. After processing by RCOs, data are stored in the Central Traffic Database (CTDB), and selected aggregated traffic data are also stored in the IMS.[5]

At some LTPP sites, traffic monitoring equipment was not installed, was not operational, or was not calibrated. Also, in spite of the best plans and intentions of the participating agencies, traffic data collection in the field has been prevented by such factors as equipment malfunction, power failure, inclement weather, lack of funding, and lack of personnel. As a result, the amount and quality of traffic data collected or measured in the field vary considerably from agency to agency, from site to site, and from year to year. Typically, the amount of measured traffic data (the number of trucks that have been classified and weighed) represents only a fraction of the traffic that a typical LTPP site carried during the course of the LTPP program, and an even a smaller fraction of the traffic that occurred over the entire time the pavements were in service.

To quantify the relationship between pavement performance and traffic loads, it is necessary to estimate the total amount of traffic loads that pavement sections carried since opening to traffic. The estimating process relies on: (a) traffic data provided by the participating agencies and (b) mathematical modeling procedures that utilize available traffic data to fill in gaps in data. This report describes the results of the modeling procedures applied to the 558 LTPP sites for which participating agencies supplied acceptable site-specific axle weight data.

Description of Traffic Variables and Terms

The following description of traffic variables and terms provides background information to facilitate understanding of this report.

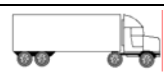
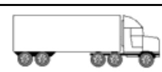
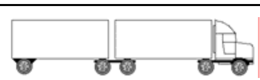
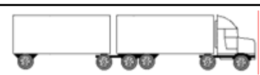
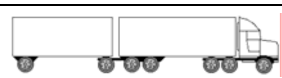
<u>Classification of Highway Vehicles</u>

LTPP uses the vehicle classification schema recommended by the *FHWA Traffic Monitoring Guide* and shown in table 1.[6]

Trucks are defined as highway vehicles having dual tires on one or more axles. *Buses* are defined as highway vehicles with two axles and six tires, or three or more axles, manufactured to carry passengers. Trucks and buses are called *commercial vehicles*. Because the proportion of buses in the traffic flow is usually small, traffic composition is expressed in the form of a *truck percentage* that also includes buses. Similarly, the term *truck volume* is assumed to include both trucks and buses.

Truck class distribution is the distribution of commercial vehicles into the vehicle classes defined in table 1.

Table 1. FHWA commercial vehicle classification schema.

Vehicle Class	Schema	Description
4		Buses
5		Two-axle, six-tire, single-unit trucks
6		Three-axle single-unit trucks
7		Four- or more than four-axle single-unit trucks
8		Four- or less than four-axle single trailer trucks
9		Five-axle single trailer trucks
10		Six- or more than six-axle single trailer trucks
11		Five- or less than five-axle multi-trailer trucks
12		Six-axle multi-trailer trucks
13		Seven- or more than seven-axle multi-trailer trucks

Classification of LTPP Sites by Highway Type

LTPP sites are classified according to the functional class of the highway on which they are located. At present, the LTPP sites are classified into six rural highway functional classes and five urban functional classes, listed below:

- Rural Principal Arterial—Interstate.
- Rural Principal Arterial—Other.
- Rural Minor Arterial.
- Rural Major Collector.
- Rural Minor Collector.
- Rural Local Collector.
- Urban Principal Arterial—Interstate.
- Urban Principal Arterial—Other Freeways or Expressways.
- Urban Other Principal Arterial.
- Urban Minor Arterial.
- Urban Collector.

Axle Loads and Axle Load Spectra

Equivalent single axle load (ESAL) is a quantity that is related to pavement damage caused by a standard axle load of 80 kilonewtons (kN) (18,000 poundforce (lbf)) carried by a single axle with dual tires. Because LTPP uses pounds (lb) as the unit for measurement and storage of axle weights, this unit is the primary unit used to report traffic projection results in this report.

Truck Factor (TF) is the number of ESALs per truck.

Axle load spectrum is defined as a frequency distribution of axle weights, of a given axle type, into weight ranges. Axle types are classified by the spacing between consecutive axles. Axles that are far apart (usually more than 2.44 meters (m) (8 feet (ft)) are called *single axles*. Two axles close together are called *tandem axles*; three axles spaced close together are *triple axles*; and four axles closely spaced are *quadruple axles*. Axle load spectrum is also referred to as *axle load distribution.*

Normalized axle load spectrum provides proportions of total axle loads that occur within designated load ranges. For example, the portion of 0.10 in the load range of 5,448 to 5,902 kilograms (kg) (12,000 to 12,999 pounds (lb)) for tandem axles means that 10 percent of all tandem axles are in the load range of 5,448 to 5,902 kg (12,000 to 12,999 lb). The normalized spectra (rather than actual spectra) are used to facilitate comparison of axle load spectra obtained for different truck volumes or sample sizes.

Axle-per-class coefficients provide the number of single, tandem, and triple axles for each vehicle class. Because the LTPP IMS database does not contain non-zero quadruple axle counts, no axle-per-class coefficients for the quadruple axles are discussed in this report. An example of axle-per-class coefficients for vehicle Class 9 (5-axle single trailer trucks) is presented in table 2.

Table 2. Example of possible axle-per-class coefficients for Class 9 vehicles.

Axle Type	**Axle-Per-Class Coefficient**	**Comments**
Single	1.1	The number is higher than 1 because some Class 9 vehicles may have, in addition to the ever-present steering axle, additional single load axles (on the semi-trailer or trailer).
Tandem	1.9	The number is less than 2 because of the presence of additional single axles or the presence of triple axles in place of tandems.
Triple	0.1	The number is small because the number of 5-axle single trailer trucks with triple axles is small.

Types of LTPP Traffic Data

The three main categories of LTPP traffic data are historical, monitoring, and supporting.

Historical data were estimated by the participating agencies for the LTPP sections before the use of monitoring equipment. Typically, historical data include annual average daily traffic (AADT) volumes, AADT truck volumes, TFs, and annual ESALs.

The years from the time the site was open to traffic to the time the site was included in the LTPP program are referred to as *historical years*. The years from the time a site was assumed by the LTPP program to present are referred to as *monitoring years*.

Monitoring data are data that have been submitted by the participating agencies for the years since the LTPP experiment began. There are two types of traffic monitoring data: measured and estimated. Measured monitoring data were obtained by field measurements using AVCs and WIM scales. Measured monitoring data are commonly referred to as monitoring data and typically include measured axle load data. Estimated monitoring data are data estimated by the participating agencies for monitoring years without measured monitoring data. Estimated monitoring data typically include annual truck volumes, TFs, and annual ESAL estimates.

Supporting data include site-specific characteristics such as site location, highway number, and pavement type.

Site-Specific, Site-Related, Regional, and Generic Data

Site-specific data are traffic data collected at or near the LTPP site using equipment that measures actual traffic that crosses the site. Site-specific data include truck class and axle load distributions.

Site-related data are traffic data collected on the same highway as the LTPP site but some distance from the site so that the collected data may be influenced by the presence of a major truck traffic generator (e.g., an intersection).

Regional data are traffic data collected on highways of the same functional class and located in the same region as the LTPP site. The site of the regional data and the LTPP site should be the subject of the same truck size and weight regulations.

Generic data are traffic data that represent typical traffic conditions, for example typical truck class distribution on rural interstates.

Projected Traffic Data

Traffic projection is a mathematical modeling process used to estimate traffic loads from samples of monitoring traffic data and other information. In the context of this study, the objective of traffic projection was to obtain axle load distributions for all years the LTPP sites were in service.

Projected traffic data are data that have been obtained by the projection process involving factoring or expanding sampled traffic data to obtain traffic data for an entire period. If the period used to factor or expand the data is a year, the result is *annual estimates*. If the period is the entire period the pavement was open to traffic, the result is *cumulative estimates*. In this report, the period for which traffic estimates were carried out is from the date the pavement was open to traffic to the end of 1998.

LTPP Traffic Data Structure

LTPP traffic data reside in two locations—the CTDB and the IMS.

The CTDB stores traffic data in five levels. Levels 1 through 4 store only measured monitoring data, whereas level 5 stores historical and supporting data. Level 1 features annual axle load spectra for all vehicle classes combined. Level 2 data contain annual axle load spectra for individual vehicle classes (FHWA Classes 4 through 13). Level 3 data feature daily axle load spectra for individual vehicle classes. Up to 365 tables (1 for each day of the year) may appear in level 3 for each of the 10 vehicle classes and for each monitoring year. Level 4 contains raw data submitted by the participating agencies. Level 5 contains supporting data.

The IMS contains level 1 data of the CTDB, including the monitoring axle load spectra for all vehicle classes combined, as well as annual ESALs.

Traffic Data Sources

Traffic data used in this report were obtained from the following IMS tables (first quarter of 2000, Level E release):

- TRF_BASIC _INFO (F01)—Basic information about site characteristics (sheet 1).
- TRF_EST_ANL_TOT_GPS_LN (F02)—Estimate of annual totals (volume and ESAL) in study lane when traffic monitoring equipment was not in service.
- TRF_MONITOR_BASIC INFO (F00)—Summary information concerning data collection and traffic characteristics (volume and ESAL) on a yearly basis.
- TRF_MONITOR_AXLE_DISTRIB (F04)—Annual axle load distribution by weight range and axle group from monitoring data, all vehicle classes combined.
- TRF_MONITOR_VEHICLE_DIST (F05)—Annual vehicle type distribution by FHWA vehicle class from monitoring data.
- TRF_MONITOR_AXLE_SUMMARY (F06)—Annual number of axles in each axle group from monitoring data.

In addition, CTDB level 2 data were utilized to investigate axle load spectra for individual vehicle classes.

The Challenge of Estimating Traffic Loads for All In-Service Years

Pavement damage caused by traffic loads is cumulative. Consequently, to quantify the relationship between pavement performance and traffic loads, all traffic loads imposed on the pavement during its service life must be taken into account. Estimating traffic loads for all the years the pavement was in service requires knowledge of both historical and monitoring traffic data.

The quantity and quality of available historical and monitoring data vary considerably between the LTPP sites and also between years for the individual LTPP sites. Historical data do not contain any truck class and axle load distribution data, and are unavailable for some sites for all or some of the historical years. Monitoring data are in the form of samples of uneven duration and quality taken during the monitoring years. To obtain axle loads for all years the pavement was in service (i.e., for both historical and monitoring years), appropriate mathematical modeling procedures must be used that fully utilize the available fragmented historical and monitoring data.

In addition, because emerging mechanistically based pavement performance models (such as the *2002 Pavement Design Guide*[7]) require knowledge of axle loads, axle loads must be estimated in terms of axle load spectra for all in-service years.

The estimation of cumulative axle loads for LTPP sites is done in two steps involving annual estimates and cumulative estimates.

1. *Annual estimates*—The sampled monitoring data are expanded or factored to obtain annual monitoring data. The shortest duration of a traffic sample that can be used to estimate annual monitoring data (e.g., annual axle load spectra) in the IMS database is 24 consecutive hours. The longest duration of a traffic sample is 365 days during the year. The quality and reliability of annual monitoring data depend on the quantity and quality of traffic samples and on the procedures used to expand the samples to obtain annual traffic data estimates. The procedure used to expand or project sampled data to obtain annual data is outlined in reference 5. The estimated annual data are stored in the CTDB and IMS databases.

2. *Cumulative estimates*—The annual monitoring data, available for some of the monitoring years, are combined with historical data and are projected for all the years the pavement was in service. Cumulative traffic estimates for any specified period expressed in number of years may be obtained by summation of the projected annual traffic data for these years.

Traffic data collection is essential to estimate traffic loads reliably. However, traffic data collection alone is not sufficient to obtain cumulative traffic loads because it is not possible to collect past data or to collect traffic data 100 percent of the time. To obtain pavement loads for all years the LTPP sections were in service, it is necessary to use a combination of traffic data (historical and monitoring) and traffic modeling procedures (traffic projection).

Results of Phase 1

The Phase 1 study encompassed preliminary assessment of the quantity and quality of LTPP traffic data.[1] Because of the large differences in the quantity and quality of traffic data available for the LTPP sites, the LTPP sites were divided into five projection categories based on available data:

- Category 1 was intended for LTPP sites that have sufficient truck class and axle weight distribution data to enable the projection of annual and monthly variation in traffic loads.
- Category 2 was intended for LTPP sites with both truck class and axle weight distribution data; however, compared to Category 1, the amount and quality of data is insufficient for projection of monthly variation in traffic loads.
- Category 3 represents sites with adequate truck class distribution data, but without site-specific axle weight data.
- Category 4 represents LTPP sites with truck volume data but without site-specific truck class and axle weight distribution data.
- Category 5 represents LTPP sites without traffic data or with unacceptable traffic data.

Traffic projection procedures for estimation of axle loads for all in-service years were developed for each projection category. Regardless of the projection category, the basic procedure for projecting axle load spectra for the LTPP was as follows:

1. All available annual historical and monitoring data were used to establish a model predicting annual truck volumes for all years the section was in service.
2. A base annual axle load spectrum, representing a typical annual axle load spectra, was established.
3. For the years with missing annual monitoring axle load spectra, the missing spectra were obtained by multiplying the base annual spectrum by a factor related to annual truck volumes.

The methodology for projecting axle load spectra was evaluated and demonstrated using case studies for specific LTPP sites. Altogether, 12 case studies were conducted (3 for each projection category except 5, where no data can be acquired).[1]

The main conclusions and recommendations of the Phase 1 study included the following:

- Proceed with Phase 2 study to develop and make available projected axle load spectra for selected LTPP sites using the projection methodology developed in Phase 1.
- Involving the participating agencies in the traffic projection process is crucial; many data problems cannot be resolved without input from local agencies.
- The projection of axle load spectra for LTPP sites without site-specific data (Categories 3 and 4) must be done judiciously and must be supported by a reference database source summarizing characteristic truck class and axle load distribution data. For this reason, the development of an LTPP PLG was proposed.
- Traffic projection and modeling is a highly cost effective and necessary process required to extend limited LTPP sampling traffic data and to compensate for the lack of measured traffic data in the past.

Report Overview

This report describes the findings and results obtained in Phase 2 of the FHWA study on the development of traffic loads for all years the LTPP sites were in service. It is organized into six chapters, including this one. Chapter 2 contains an outline of the projection procedure developed in Phase 1 and provides a detailed description of the process used to assess quality of traffic data, develop traffic projections in cooperation with the participating agencies, and assign projection confidence codes. It also includes the description of pilot studies that were used to develop procedures to involve participating agencies in the review of the initial projections and to facilitate the involvement of the regional LTPP data collection offices in the traffic data assessment and projection process. Chapter 3 summarizes the results of traffic data assessment and traffic load projection work. Chapter 4 describes the development of computed parameter tables used to store the projected traffic data in the IMS database. Chapter 5 describes the purpose, design parameters, and functionality of the proposed PLG. Finally, chapter 6 summarizes the study results and gives recommendations for future traffic analysis work.

This report also includes one appendix, appendix A, which tabulates traffic data assessment and projection results for all individual LTPP sites.

CHAPTER 2. PROCEDURES FOR TRAFFIC DATA ASSESSMENT AND PROJECTION

This chapter describes the procedures used to carry out the assessment of the quantity and quality of traffic data, and to estimate traffic loads for all years the LTPP sites were in service. The process of estimating traffic loads is referred to as *traffic projection*.

The assessment of the data quality and quantity was carried out for all LTPP sites. The projection of truck volumes was carried out for all sites with appropriate monitoring or historical truck volumes, and the projection of axle load spectra was done for all LTPP sites that had appropriate site-specific monitoring axle load data in the Level E release of the IMS database (first quarter of 2000).

The assessment of traffic data and the development of traffic projections have been carried out in two phases over the course of 30 months; they involved eight main activities (see figure 1).

Phase 1

1. Preliminary assessment of LTPP traffic data.
2. Development of LTPP traffic projection procedure.
3. Validation of LTPP traffic projection procedure using case studies.

Phase 2

4. Development of LTPP Traffic Feedback and Resolution Package.
    - a. Development of the content of the package.
    - b. Evaluation and testing of the package.
        - i. Review by RCO representatives and other parties.
        - ii. Review and enhancement by pilot studies.
5. Preparation of LTPP Traffic Feedback and Resolution Packages for all participating agencies.
    - a. Assessment of traffic data.
    - b. Projection of truck volumes.
    - c. Development of base annual spectra.
    - d. Assignment of initial projection codes.
    - e. Computation of annual axle load spectra.
6. Review of LTPP Traffic Feedback and Resolution Packages by RCOs.
7. Review of LTPP Traffic Feedback and Resolution Packages by participating agencies.
8. Implementation of review comments received from participating agencies.
    - a. Responding to agencies.
    - b. Preparation of revised traffic projections.
    - c. Placing projected traffic data into computed parameter tables.

Phase 3

Recommended phase
Recommendations for Phase 3 are provided in chapter 6.

Figure 1. Overview of main traffic data assessment and projection activities.

Of the eight traffic data assessment and projection activities, three were carried out in Phase 1 and five in Phase 2. In this chapter, the activities are described in the order they are listed in figure 1 as steps 1 to 8. To enable the reader to follow the traffic data assessment and projection process better, a general outline of the eight activities is provided first, followed by a more detailed description of the activities.

The main traffic data assessment and projection activities carried out in Phase 1, and described in Phase 1 report were:[1]

1. *Preliminary assessment of LTPP traffic data*—The objective of this activity was to obtain a basic understanding of the overall quantity and quality of traffic data. This understanding was necessary for the development of the traffic projection procedure.

2. *Development of LTPP traffic projection procedure*—The projection procedure developed in Phase 1 was designed to utilize fully all available historical and monitoring traffic data and to incorporate additional traffic information obtained from local agencies.

3. *Validation of LTPP traffic projection procedure using case studies*—The projection procedure was used to estimate axle loads for all in-service years of 12 LTPP sites with different amounts of historical and monitoring data. The objective was to validate the projection procedure using realistic examples.

The main traffic data assessment and traffic projection activities carried out in Phase 2, and described in here, were:

4. *Development of LTPP Traffic Feedback and Resolution Package*—The purpose of the LTPP Traffic Feedback and Resolution Package was to summarize and present historical and monitoring traffic data and the results of traffic data projections in a structured and user-friendly manner. The package, developed using a systematic procedure applied consistently to all LTPP sites, was the main means of communication and interaction with the participating agencies. The package contains traffic data summaries for the LTPP sites, easy-to-follow results of traffic projections, background information, and guidelines on how to assess traffic data and review traffic projections. During the development of the package, input and comments were received from the representatives of RCOs, members of the Expert Task Group (ETG) on Traffic Data Collection and Analysis, and others. To further evaluate suitability and ease of use, and to provide an opportunity for the RCOs to become familiar with the content and the purpose of the package, pilot studies involving four participating agencies were also carried out.

5. *Preparation of the LTPP Traffic Feedback and Resolution Packages for all participating agencies*—Altogether, 62 LTPP Traffic Feedback and Resolution Packages were produced (one for each participating agency). Each agency package addresses all LTPP traffic sites that belong to the agency, and each LTPP site was processed in terms of: (a) the assessment of the amount and quality of historical and monitoring traffic data, (b) the development of traffic projections, provided that appropriate traffic data were available, and (c) the assignment of confidence codes to the initial traffic projections.

6. *Review of LTPP Traffic Feedback and Resolution Packages by RCOs*—The responsibilities of RCOs include initial traffic data quality checks, as well as processing and storage of traffic data supplied by the participating agencies. Because of a long-standing involvement of the RCOs with traffic data issues on the local level and the knowledge of local traffic issues, the packages were sent to the RCOs for review prior to being sent to the participating agencies.

7. *Review of Traffic Feedback and Resolution Packages by participating agencies*—After the concerns of the RCOs were addressed, the updated packages were sent to the participating agencies for review. The involvement of the participating agencies has been crucial; many data problems cannot be resolved without local involvement.

8. *Implementation of review comments received from participating agencies*—To facilitate communication with the participating agencies on an individual section basis, a standardized questionnaire (Feedback and Data Resolution Sheet) for each LTPP site was developed, and the participating agencies were asked to complete it. Based on the responses we received from the participating agencies, the initial traffic projections were revised and the *initial* projection confidence codes were changed to *reviewed* projection confidence codes.

Step 1—Preliminary Assessment of LTPP Traffic Data

The Phase 1 report contains the results of the evaluation of LTPP traffic characteristics.[1] The results include examples of spatial and temporal variation in truck volumes; comparison of trends in historical and monitoring annual truck volumes and annual ESALs; the evaluation of the potential of Class 9 vehicles for prediction of axle loads; and the evaluation of axle load distribution characteristics: The Phase 1 report contains a review of several previous studies that used LTPP traffic data to: characterize seasonal variation in truck volumes;[8] evaluate the consequences of alternative sampling plans on the estimated annual traffic loads;[9] and assess the potential of LTPP traffic data to develop models for predicting axle load distributions.[10] The results of an exploratory analysis of trends in traffic data were presented in an interim report that preceded the Phase 1 report. [11]

The review of LTPP traffic data carried out during Phase 1 identified the following major issues, concerns, and recommendations regarding quality and quantity of traffic data and the projection of traffic loads.

- Trends in historical and monitoring data—The relationship between annual historical and monitoring ESALs, and between monitoring ESALs obtained for different years, investigated for all sites in the North Atlantic and North Central Regions, showed considerable variation. The differences between historical and monitoring ESALs, and between ESALs obtained for consecutive monitoring years, frequently exceeded 100 percent. Because truck volumes and axle loads on interstates and other major highways are expected to show relatively steady growth over the years, the observed differences indicated important data concerns requiring resolution.

- Involvement of participating agencies—Considering the available historical and monitoring data and the challenges involved in carrying out traffic projection, the involvement of participating agencies in the traffic projection process was identified as being essential for knowledge-based traffic data assessment and projection of traffic loads.
- Unavailability of monitoring data—Typically, only 3 or 4 years of monitoring axle load data are available for LTPP sites. Many sites do not have any axle load (WIM) or truck class distribution (AVC) data.
- Calibration of AVC and WIM equipment—AVC and WIM scale calibration concerns have not been studied in sufficient detail. For example, the CTDB does not contain any data on quadruple axles even though such axles regularly occur in several participating agencies, including Michigan and Ontario. For many sites, axle load spectra exhibited unexpectedly large year-to-year variations.
- Quality assurance—The QA techniques employed previously were characterized as an automated review to detect common equipment problems, rather than a comprehensive and detailed QA process. To ensure the integrity of the data used for traffic projections and for any subsequent analysis, the Phase 1 study recommended that a comprehensive QA process of underlying traffic data be carried out.
- Development of PLG—The data QA process would greatly benefit from the development of a knowledge base documenting typical values and ranges of traffic variables, particularly truck class and axle load distributions.

The knowledge gained during the preliminary assessment of the amount and quality of available historical and monitoring data was instrumental in the development of the LTPP traffic projection procedure.

Step 2—Development of LTPP Traffic Projection Procedure

This section outlines the LTPP traffic projection procedure. The detailed description of the procedure, including numerical examples in the form of case studies, is contained in the Phase 1 report.[1] To satisfy the following design requirements, the projection procedure was developed to ensure:

- The ability to estimate annual axle loads for the majority of LTPP sites and for all years the sites were in service.
- Compatibility with the available historical and monitoring traffic data and their full utilization.
- Transparency (to be understandable to the users of projected traffic data) and modularity (for ease of future enhancements of the projection procedure, and for ease of updating the projections if more data become available).

The procedure for projecting axle load spectra for the individual LTPP sites includes the following activities:

- All available annual historical and monitoring data were used to establish a model for estimating annual truck volumes for all years the site was in service.

- The model for estimating annual truck volumes was used to obtain annual projection factors.
- A base annual axle load spectrum, representing a typical axle load spectrum for the site, was established.
- The projected annual axle load spectra for all in-service years were obtained by multiplying the base annual spectrum by the annual projection factors.

Mathematically, the LTPP traffic load projection procedure is based on the following formula:

$$\text{Annual Axle Load Spectrum}_y = \text{Base Annual Spectrum} * \text{Annual Projection Factor}_y \quad (1)$$

Where:

Annual Axle Load Spectrum$_y$	=	Projected annual distribution of axle weights by load ranges for year *y*. Axle weights are reported separately for single, tandem, and triple axles.
Base Annual Spectrum	=	A typical annual axle load spectrum chosen to represent traffic loads on the site.
Annual Projection Factor$_y$	=	Annual truck volume adjustment factor for year *y* used to scale the *Base Annual Spectrum* according to the total volume of trucks in year *y*.

The above formula means that once the base annual spectrum was established, it was scaled using the annual projection factor corresponding to the annual truck volume for the given year. Consequently, it was assumed that the truck class distribution remained constant over the years and that only the amount of trucks changed.

Specific techniques, described in Phase 1 report, were developed to obtain base annual spectra for the five projection categories.[1] The five projection categories, classified by the amount of available monitoring data, are defined in chapter 1 of this report. Annual axle load spectra were projected also for the years with monitoring (measured) annual axle load spectra. For these years, both the monitoring and the projected axle load spectra will be available in the IMS database.

To obtain cumulative axle loads, annual axle spectra could be summed as shown in equation 2.

$$\text{Cumulative Axle Load Spectrum} = \sum_{y=1}^{y=n} \text{Annual Axle Load Spectrum} \quad (2)$$

Where:

Cumulative Axle Load Spectrum = Total amount of axle weights during *n* years. Axle weights are reported separately for single, tandem, and triple axles.

n = The number of years from the opening of highway to traffic through (and including) 1998.

Projections for Sites in Category 1 and 2

Category 1 and 2 sites have monitoring annual axle load spectra in the IMS database; these spectra were used to obtain the base annual spectrum. Traffic load projections carried out in Phase 2 were done for Category 1 and 2 sites only, and were in terms of annual axle load spectra. Typically, the base annual spectrum was an average of all acceptable annual spectra for the given site. Techniques used to establish base annual spectra for Category 1 and 2 sites are summarized as part of step 5 (figure 1) in the section titled "Development of Base Annual Spectra."

The Phase 1 report also contains the description of procedures developed for estimating base annual spectra for Category 3 and 4 sites, as well as numerical examples of traffic projections for these sites.[1] Even though these procedures were not used in this report, they are outlined below because they are important for the understanding of the subsequent recommendation to develop the LTPP PLG (discussed in chapter 5 of this report).

Projections for Sites in Category 3

Category 3 includes sites with site-specific monitoring truck class distribution data but without acceptable site-specific monitoring axle load distribution data. Because these sites do not have annual axle load spectra in the database, the base annual spectrum must be estimated. According to the Phase 1 report, it is proposed to accomplish this by combining the following two inputs:[1]

- Site-specific monitoring truck class distribution.
- Surrogate axle load spectra for individual truck types.

<u>Site-Specific Monitoring Truck Class Distribution</u>

If there are several years for which the site-specific monitoring truck class distributions are available, a typical truck volume distribution (called the *base truck distribution*) is established by plotting and assessing all annual truck class distributions using similar techniques as those used to obtain the base annual spectrum. The objective is to obtain the truck class distribution that best represents the given site.

<u>Surrogate Axle Load Spectra for Individual Truck Types</u>

The sources of surrogate axle load spectra include site-related data, regional data, and generic or typical data.

Projections for Sites in Category 4

Category 4 includes sites with annual truck volume data but without site-specific truck class and axle load distributions. Because these sites do not have annual axle load distribution in the database, the base annual axle load spectrum must be constructed. According to the Phase 1 report, it is proposed to accomplish this by combining the following three inputs:[1]

- Site-specific total truck volume.
- Surrogate monitoring truck class distribution.
- Surrogate axle load spectra for individual truck types.

The sources of surrogate truck class and axle load distribution data include site-related data, regional data, and generic or typical data.

Step 3—Validation of the LTPP Projection Procedure Using Case Studies

The methodology for projecting axle load spectra was evaluated and demonstrated in Phase 1 using case studies for selected LTPP sites. Case studies are numerical example applications of the traffic projection procedure for actual LTPP sites. All together, 12 case studies were carried out (3 case studies in each projection category except Category 5). The following observations were based on the results of the case studies:[1]

- The procedure for projecting traffic loads developed in the course of the Phase 1 study can be used to estimate axle load spectra for all LTPP sites.
- The involvement of participating agencies in the projection process is essential.
- The selection of truck class and axle load distributions required for Category 3 and 4 projections must be done judiciously and should be supported by a reference database summarizing characteristic truck class and axle load distribution data.
- The QA process would greatly benefit from developing a knowledge base or a catalog documenting typical or expected values and ranges of traffic variables, particularly axle load spectra for individual vehicle classes.

Step 4—Development of LTPP Traffic Feedback and Resolution Package

To meet the objectives of the Phase 2 study, it was necessary to work with all LTPP sites and with all participating agencies. The LTPP traffic database contains 890 unique traffic sites located in 62 agencies. Reflecting the objectives of the Phase 2 study, the objectives of the LTPP Traffic Feedback and Resolution Package were:

- To report back to the participating agencies the quantity and quality of the traffic data available for all LTPP traffic sites in their respective jurisdictions, using easy-to-understand graphic displays. Although the participating agencies had received traffic feedback reports in the past, the previous reports were limited in scope and did not contain all relevant traffic data for all historical and monitoring years, nor did they include long-term trends in traffic volumes and loads.

- To present traffic data in the format that would:
  - Facilitate the assessment of the quality and quantity of traffic data by the participating agencies, RCOs, and the project team.
  - Facilitate the understanding of the projection process, and the assessment of the initial traffic projections by the participating agencies and RCOs.

To efficiently assess traffic data and carry out traffic projections for all 890 LTPP sites, and to communicate the traffic projection results to participating agencies effectively, we developed a standardized package—the LTPP Traffic Feedback and Resolution Package (also referred to here as "the package"). The package combines graphic traffic data displays, information on how to interpret the data displays, and questionnaires addressing overall and site-specific traffic data issues. A separate package was prepared for each participating agency.

The rest of this section describes the content of the package and the involvement of the representatives of RCOs and others in its development and validation.

Content of the LTPP Traffic Feedback and Resolution Package

The package consisted of five items:

- Introductory letter.
- Outline of the LTPP traffic projection procedure.
- Initial overall feedback and resolution report.
- Initial site-specific feedback and resolution report.
- Site-specific reports for each LTPP site within the agency.

These five items are briefly described below. The package was quite bulky, particularly for agencies with many LTPP sites.

<u>Introductory Letter</u>

The introductory letter was prepared and signed by a representative of the RCO and was addressed to the State or Province LTPP contact engineer or other official. Typically, the letter outlined the purpose of the package and asked that a person within the agency who was familiar with the collection of traffic data for LTPP sites review the package and respond to the issues raised. Some letters also included additional information and comments regarding the traffic data availability for specific sites (e.g., if data submitted previously by the participating agencies were not yet included in the package).

<u>Outline of the LTPP Traffic Projection Procedure</u>

The outline of the LTPP traffic projection procedure was a 10-page report that explained the traffic projection procedure used to estimate traffic loads in straightforward language. The objective of the outline was to enable the reviewer to understand the relative importance of the different issues, potential discrepancies, and questions posed in the package. The outlined discussed:

- Objectives of the traffic projection procedure.
- Definition of key technical terms used in the outline.
- The need to estimate traffic loads in terms of axle load spectra. The outline also included a typical example of axle load spectra in graphic and tabular forms.
- Reasons for the involvement of participating agencies in the traffic estimation process.
- LTPP traffic projection procedure.

Initial Overall Feedback and Resolution Report

The initial overall feedback and resolution report was typically a 4- or 5-page report that contained a summary of traffic data assessment and traffic projection issues concerning more than one LTPP site. The report was called "initial" because it was concerned with the first traffic projections carried out for LTPP sites. The initial overall feedback and resolution report served two purposes:

- To summarize issues identified during the initial traffic data assessment and projection effort that required input from agency representatives.
- To seek additional traffic data and information from the agency representatives to improve traffic projections.

The issues and questions were grouped under the following headings:

- Overall review.
- Missing data.
- Location of sections.
- Traffic volumes.
- Vehicle classification—operation of AVC equipment.
- Axle weights—operation of WIM scales.

Overall review—The overall review included a table listing all LTPP sites for the agency and their corresponding LTPP experiment numbers and the initial projection confidence codes. The initial projection confidence codes were used to characterize the level of confidence associated with initial traffic projections. The assignment of the projection codes is described later ("Assignment of Initial Traffic Projection Codes" in step 5).

Missing data—This section provided a comprehensive listing of traffic data that were missing from the IMS database.

Location of sections—Particular attention was paid to the nearby sites located on the same highway, particularly if the sites were also located in the same direction of travel. The objective was to ascertain the existence of expected relationships between truck volumes and axle loads on related sites. Any potential discrepancies were brought to the attention of the agency representatives.

An example of the data assessment carried out under the heading of "Location of sections" is provided in table 3. As expected, nearby sites on the same highway in the same direction have similar truck volumes, truck percentages, and truck growth rates. The exception appears to be the two northbound sites on U.S. Route 93 in Arizona that have quite different truck percentages (15 versus 27) and quite different recent truck growth rates (1.0 versus 10.0 percent).

Traffic volumes—The objective of this part of the report was to emphasize the importance of trends in annual historical and monitoring truck volumes for the development of the traffic load projections. Sections with unexpected variation in annual truck volumes were identified and reviewers were asked to address truck volume discrepancies on a section-specific basis.

Vehicle classification—operation of AVC equipment—Typically, the main concern with vehicle classification was the number of vehicles that were not properly classified by the traffic monitoring equipment. These vehicles are identified in the IMS as Class 14 vehicles. Some agencies reported that the percentage of Class 14 vehicles in the total truck flow was, for the majority of sites and years, above 10 percent. Some agencies did not report any Class 14 vehicles. Questions posed to the agencies regarding vehicle classification were regarding: (a) distribution of Class 14 vehicles into "legitimate" vehicle classes; (b) reporting of vehicles that were not properly classified by AVC equipment; and (c) type of procedures used to ensure that the vehicles are properly classified.

Axle weights—operation of WIM scales—This segment of the overall report contained two parts.

The first part identified the LTPP sites with questionable axle load data and inquired about the procedures used to calibrate WIM scales and to review axle load data prior to their submission to RCOs. Questionable axle load distributions, for at least some sections and some monitoring years, were reported by all agencies that reported monitoring axle loads. Typically, the following questions were asked: *What type of procedure is used to ensure that WIM scales are calibrated? Is WIM calibration done routinely? Do you have resources to review traffic data prior to their submission to LTPP? If so, what procedures do you use?*

The second provided the results of analysis carried out to ascertain basic traffic loading patterns for all LTPP sites within the agency. The objective was to provide a summary of axle load characteristics and to identify sites that do not fit overall patterns. An example of such a summary is shown in tables 4 and 5.

Table 3. Arizona LTPP sites near other sites on the same highway and in the same direction.

Location, Hwy No. and Direction	Nearby Sites	1998 AADT Truck Volume	1998 Truck Percentage	Recent Truck Growth, %	Year or Years for which Axle Load Data are Available, Comments
93 N	0100	900	15	1.0	1997, axle load spectra are identical
	1036	800	27	10.0	
10 W	1001	2620	31	7.4	1995 and 1996
	1003	3400	52	7.0	1994
	1006	3160	45	6.7	1995
	1007	3530	44	7.4	1995, 1996, 1997
	7614	3490	35	9.0	1996
19 S	1015	620	7	7.0	None
	1016	470	8	6.0	1994
	1018	450	8	6.0	1993
	6054	570	8	2.0	1993
19 N	1017	540	10	4.0	1997
	6060	590	13	7.0	1996, 1997, 1999
40 W	1002	2210	49	8.0	1997, 1999
	1021	2240	50	11.0	None
	1022	2240	50	11.0	None
	1025	2130	47	7.0	1993, 1994
	1062	2190	58	9.0	1993
40 E	1024	2080	46	7.0	1993
	1065	2140	54	9.0	1993

The results in tables 4 and 5 indicate a similarity of traffic load characteristics with a few exceptions. For example, all TFs in table 4 are in the range of 0.9 to 1.3, except the TF of 0.6 for Mississippi site 1001. Consequently, the axle load data on this site need to be assessed to ascertain the reason for lower-than-expected axle loads.

Initial Site-Specific Feedback and Resolution Report

The purpose of this report was to:

- Describe the standardized displays of traffic data and the initial traffic projection results for individual LTPP sites.
- Provide guidelines for the assessment of traffic data and for the interpretation and evaluation of traffic projection results.

Table 4. Traffic loading parameters for Mississippi LTPP sites with axle weight projections.

Highway Functional Class	Site No. (Prefix of 28)	Flexible Pavement			Rigid Pavement		
		1998 Truck %	Average Unloaded/Loaded Peaks of Tandem Axle Load Spectra (kips)**	Average Truck Factor (ESALs/ Truck)	1998 Truck %	Average Unloaded/Loaded Peaks of Tandem Axle Load Spectra (kips)**	Average Truck Factor (ESALs/ Truck)
Urban Principal Arterial	1016	9	9/31	1.0	–	–	–
	5805*	–	–	–	15	11/27	1.1
Rural Principal Arterial	0500*	n/a	11/33	1.3	–	–	–
	1001	9	9/29	0.6	–	–	–
	1802	22	11/31	0.9	–	–	–
	2807	12	11/33	1.1	–	–	–
	3018	–	–	–	24	9/29	1.2
	3019	–	–	–	24	9/29	1.2
	3081	31	11/32	1.1	–	–	–
	3082	n/a	13/33	1.2	–	–	–
	3087	8.5	11/36	1.3	–	–	–
	3089	12	11/33	1.1	–	–	–
	3091	13	11/33	1.3	–	–	–
	3093*	20	11/31	0.9	–	–	–
	3094*	20	11/31	0.9	–	–	–
	3097*	–	–	–	14	11/27	1.7
	3099*	–	–	–	41	–/31	1.7
	5006	–	–	–	28	11/29	1.1
	5025	–	–	–	16	11/33	1.9
	5803	–	–	–	36	11/33	1.8
	7012*	–	–	–	29	–/31	1.8
	9030*	32	13/31	1.0	–	–	–

*Interstate; **1 kip = 4450 newtons

Table 5. Traffic loading parameters for Mississippi sites without axle weight projections.

Highway Functional Class	Site No. (Prefix of 28)	1998 Projected AADT Truck Volume	1998 Truck %	1998 Annual Growth Rate %	Historical TF (ESALs/ Truck)
Rural Principal Arterial	3083	25	8	1.5	0.6–1.5
	3085	25	8	1.5	0.6–1.5
	3090	40	7	2.0	0.3–1.0
	4024	130	4	3.0	0.5–1.4

An example of the Initial Site-Specific Feedback and Resolution Report, prepared for the representatives of participating agencies assigned the task to review the initial traffic projections, is provided in figure 2. Specifically, figure 2 includes the entire site-specific feedback and resolution report prepared for the Mississippi Department of Transportation (DOT); the reports prepared for other agencies were similar.

The report in figure 2 refers to 26 site-specific reports (one for each of the 26 Mississippi LTPP sites that have traffic data in the IMS database). One of the 26 site-specific reports for Mississippi, report for site 285805 is presented in figures 3 through 10. To assist the reader in making the connection between the reports, figure 2 contains references to figures 3 through 10. The first data sheet of the site-specific report (figure 3) was on blue paper and is referred to as a "Blue Sheet."

Site-Specific Reports

The site-specific report for site 285805 (figures 3 through 10) consists of eight data sheets:

- Feedback and Data Resolution Sheet (figure 3).
- Site Map (figure 4).
- Annual Traffic Projection Sheet (figure 5).
- Projected AADT Truck Volumes (figure 6).
- Annual Vehicle Class Distribution (figure 7).
- Annual Load Spectra (figure 8).
- Average Annual Load Spectrum (figure 9).
- Projected Annual ESALs (figure 10).

The procedures used to develop site-specific reports are described in the Phase 1 report, and the content and purpose of the report are described in figure 2.[1] Subsequent sections will provide a description of techniques used to develop the initial projections shown in figures 6 and 10, and to assign projection confidence codes.

The Blue Sheet in figure 3 is shown as having been completed by the Mississippi Department of Transportation (MDOT) to avoid the need to show separate examples of uncompleted and completed Blue Sheets. The completion of Blue Sheets by participating agencies will be discussed in step 7 (Review of LTPP Traffic Feedback and Resolution Packages by Participating Agencies).

INITIAL SITE-SPECIFIC FEEDBACK AND RESOLUTION REPORT FOR MISSISSIPPI

November 2000

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INTRODUCTION

This report is about site-specific traffic projection issues concerning individual LTPP sites. The traffic projection issues that are applicable to more than one site are addressed in the *Initial Overall Feedback and Resolution Report for Mississippi*. The report is called "initial" because it comments on the first, or initial, traffic projections carried out for Mississippi sites.

The purpose of this report is twofold:

- To describe the standardized display of the results obtained during the initial traffic projection process for individual LTPP sites.
- To provide guidelines for the interpretation and evaluation of results.

Attached to this report are site-specific reports prepared for the 26 Mississippi LTPP sites that contain traffic monitoring data in the LTPP traffic database. Each report starts with a blue "Feedback and Data Resolution Sheet." Please review each report according to the guidelines provided herein.

In order for the reviewer to understand the relative importance of the different issues, potential discrepancies, and questions posed in this report, it is recommended that the reviewer become familiar with the overall traffic projection methodology. For this reason, an outline of the traffic projection methodology, entitled, *An Outline of the LTPP Traffic Projection Procedure*, is attached to this mailing.

How To Communicate with Us

Please use the blue Feedback and Data Resolution Sheet in front of the packages prepared for the individual sites. Handwritten notes are certainly sufficient. The sheets contain a number of questions and comments on a variety of issues, and seek input on these issues from the representatives of Mississippi DOT. In some situations, it may be appropriate to respond, in addition to using the blue sheet, by other means including telephone and e-mail.

Thank you very much for your help.

Figure 2. Initial site-specific report for Mississippi (page 1).

INSTRUCTIONS FOR THE REVIEWER

In order to facilitate the review of the projected traffic data, and the identification of site-specific issues (that need to be brought to the attention of the reviewer), a standardized format was developed to report and present traffic data (historical, monitoring, and projected) for the individual LTPP sites. Traffic data for each LTPP site that has WIM scale monitoring data are presented using a set of eight sheets. The eight-sheet set constitutes a standard package for the display and presentation of the projected traffic data and for their review by the representatives of State highway administrations (SHAs). The set contains the following sheets.

- Feedback and Data Resolution Sheet (figure 3).
- Site Map (figure 4).
- Annual Traffic Projection Sheet (figure 5).
- Projected AADT Truck Volumes (figure 6).
- Annual Vehicle Class Distribution (figure 7).
- Annual Load Spectra (figure 8).
- Average Annual Load Spectrum (figure 9).
- Projected Annual ESALs (figure 10).

The following briefly describes the purpose of each sheet and highlights typical features and concerns that usually require the review and assessment by SHA representatives.

Feedback and Data Resolution Sheet (Blue Sheet), figure 3

The purpose of this sheet is to summarize all major site-specific features that may influence traffic projection. This is the principal communication tool between the traffic team and the SHA reviewer.

It is expected that the reviewer will complete the blue sheet for each LTPP site under review. Additional comments and suggestions are encouraged. Please use additional sheets or the reverse side if needed.

Site Map, figure 4

The objective is to clearly identify the location of the site in question, as well as the location of nearby sites (which may serve as surrogate source of traffic data).

The location of each site should be verified.

Annual Traffic Projection Sheet, **figure 5**

The annual traffic projection sheet is used to summarize trends in historical and monitoring traffic data (AADT volumes, AADT truck volumes, average ESALs per day, and TFs).

It is expected that traffic volumes and ESALs will exhibit an increasing trend.
TFs (ESALs per truck) should be at a level or perhaps increasing (to reflect the increased cost-efficiency of the trucking industry).

Figure 2 continued. Initial site-specific report for Mississippi (page 2).

Projected AADT Truck Volumes, figure 6

This sheet shows historical and monitoring truck volumes and the suggested projection model—typically a smooth line or a curve—used to estimate truck volumes for all in-service years. This model is also used to project (estimate) axle load spectra. If needed, the model can exactly duplicate the reported historical data trends.

Are additional data available from other State sources?
Can a better model be developed and used? If so, please sketch the new model on the sheet.

Annual Vehicle Class Distribution, figure 7

The top half of the sheet shows actual axle counts for different truck classes. The bottom half of the sheet shows the distribution of trucks as a percentage of the total truck count. All available years are plotted to spot outliers and questionable results.

The unexpected truck distributions should be identified. This activity contributes to the judicious selection of the base spectra. Usually, for the same site, annual vehicle class distributions should be similar from year to year. It is expected that the number of Class 9 vehicles (5-axle tractor-semi-trailers) will predominate on rural interstates while, on the other hand, the number of 2-axle single-unit trucks will become significant on urban and semi-urban roads.

Annual Load Spectra, figure 8

Annual axle load spectra are plotted for all available years (the years with monitoring WIM scale data). The annual spectra are used to select/calculate a typical "base" spectrum. The base spectrum is then used to estimate axle load spectra (particularly for years without monitoring WIM data). In some instances, two base spectra are used for the projection: the first spectrum and the last spectrum.

If the site has reliable annual spectra for many years, two base annual spectra may be used for the projection. For example, the first base spectrum is used to represent traffic during the years before the installation of a WIM scale, and during the initial operation of the scale. The second spectrum is used to represent traffic levels for the most recent years, with and without WIM scale data. Both the first and the last spectra can be the averages of several annual spectra.

At most sites, and there are exceptions, most tandem axle loads are caused by Class 9 trucks (5-axle tractor-semi-trailers). Consequently, the distribution of tandem axles (shown in the middle of the sheet) usually has two peaks. The first peak corresponds to unloaded tandems, and the second peak to the fully loaded tandems. These two peaks are usually at 10 to 11 kips and 31 to 33 kips, respectively. (Federal regulations limit tandem axle weight to 34,000 lb.)

It is important to identify all incorrect and suspicious spectra, and to recommend which spectra should be used (averaged) to obtain the base spectrum. Usually, annual load spectra for the same site should be similar. It may be difficult, without inside knowledge, to judge the validity of spectra if there are just a few spectra available to define the expected pattern.

Figure 2 continued. Initial site-specific report for Mississippi (page 3).

Average Annual Load Spectrum, figure 9

The average annual load spectrum is obtained by calculating the average of the annual spectra, presented in figure 8, that are considered to be valid. It is also the base spectrum used for the projection.

Projected Annual ESALs, figure 10

This sheet provides a summary of equivalent single axle loads (ESALs) projected for all in-service years. ESALs are calculated using the site-specific pavement structure (type and thickness). It is recognized that the purpose of traffic collection and analysis is to obtain axle load spectra (and not ESALs). ESALs are used mainly for comparison and QA purposes.

Are the projected annual ESALs and the cumulative ESALs reasonable? Only pavement professionals can typically answer this question.

Figure 2 continued. Initial site-specific report for Mississippi (page 4).

GPS-5 **285805** ***Feedback and Data Resolution Sheet***

State/Province	Mississippi	**Direction**	West
Road Number	10	**Total No. of Lanes**	4
County/Town	HARRISON	**Pavement Structure**	D = 8.2
Functional Class	Urban Principal Arterial - Interstate	**Open to traffic**	1975

Please review the attached sheets (and any other information that you feel is applicable), and respond to the following questions. Please use the reverse side of this form if you need more space.

1. Were there any sudden changes that could have significantly and suddenly affected the amount of truck traffic on this site (e.g., opening or closing of parallel highways or the arrival of new industry)?
   [ ] Yes [✓] No If yes, please describe the changes and provide the dates when they occurred.
   ____
   ____

2. Is there predominant single-commodity traffic on this site (e.g., lumber, grain, gravel)?
   [ ] Yes [✓] No
   If yes, what is the commodity and which truck type is used to haul it? ______________

3. Are there any additional non-LTPP traffic data which could be useful for this site?
   [ ] Yes [✓] No If yes, please explain ______________

4. Do you find the following projected numbers to be reasonable?

		Yes	No	Comments
Recent truck traffic volume growth rate	*4.5%*	[✓]	[ ]	
1998 AADT truck volume (LTPP lane)	*2430*	[✓]	[ ]	
1998 Truck percentage	*15%*	[✓]	[ ]	
Average number of ESALs per truck	*1.1*	[✓]	[ ]	

5. Please comment below on the following site-specific observations and questions.
   Truck factor has increased from about 1.0 in 1992 to 1.5 in 1996. Is this expected? yes *The average of axle load spectra for 1992 to 1995 was used for the projection. Tandem loaded peak is lower than expected. Should we use 1996 axle loads to improve the projection?* NO
   ____
   ____

6. Using the rating below, please indicate your opinion about the accuracy of traffic data available for this site
   Rating: **1.** Excellent **2.** Very Good **3.** Good **4.** Fair **5.** Poor
   Historical truck volumes [3] Monitoring truck volumes [3]
   Historical truck loads (ESAL/truck) [3] Monitoring truck loads/axle load spectra [3]

7. What, in your opinion, should be done to improve the accuracy of traffic data for this site (e.g., the type of additional traffic monitoring, use of surrogate data, a more detailed look at past data)?
   ____
   ____

Completed by __________ Date: ________ Tel. No. __________ Email: __________

Thank you very much for your help.
ERES LTPP DATS Traffic Analysis Team

Figure 3. Feedback and Data Resolution Sheet for site 285805.

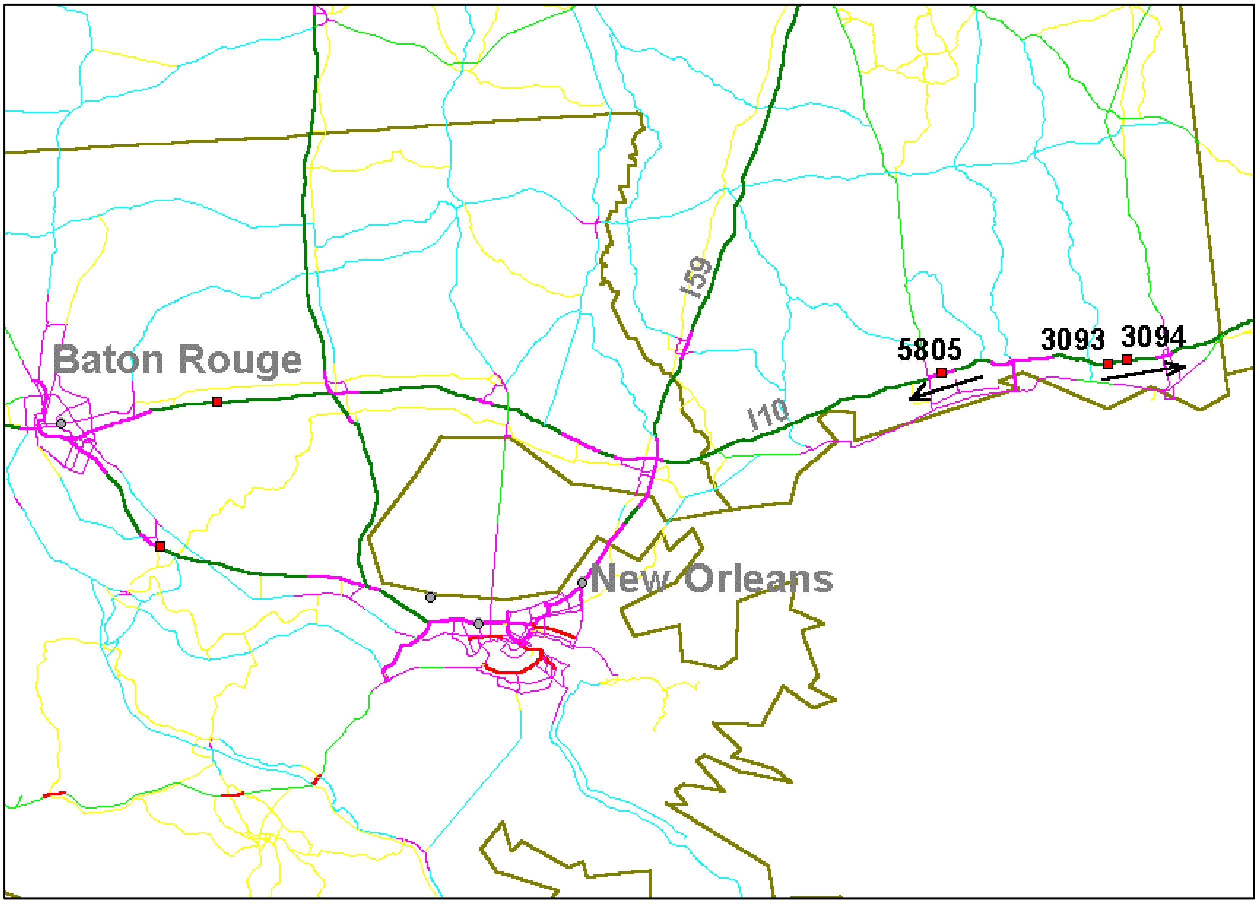
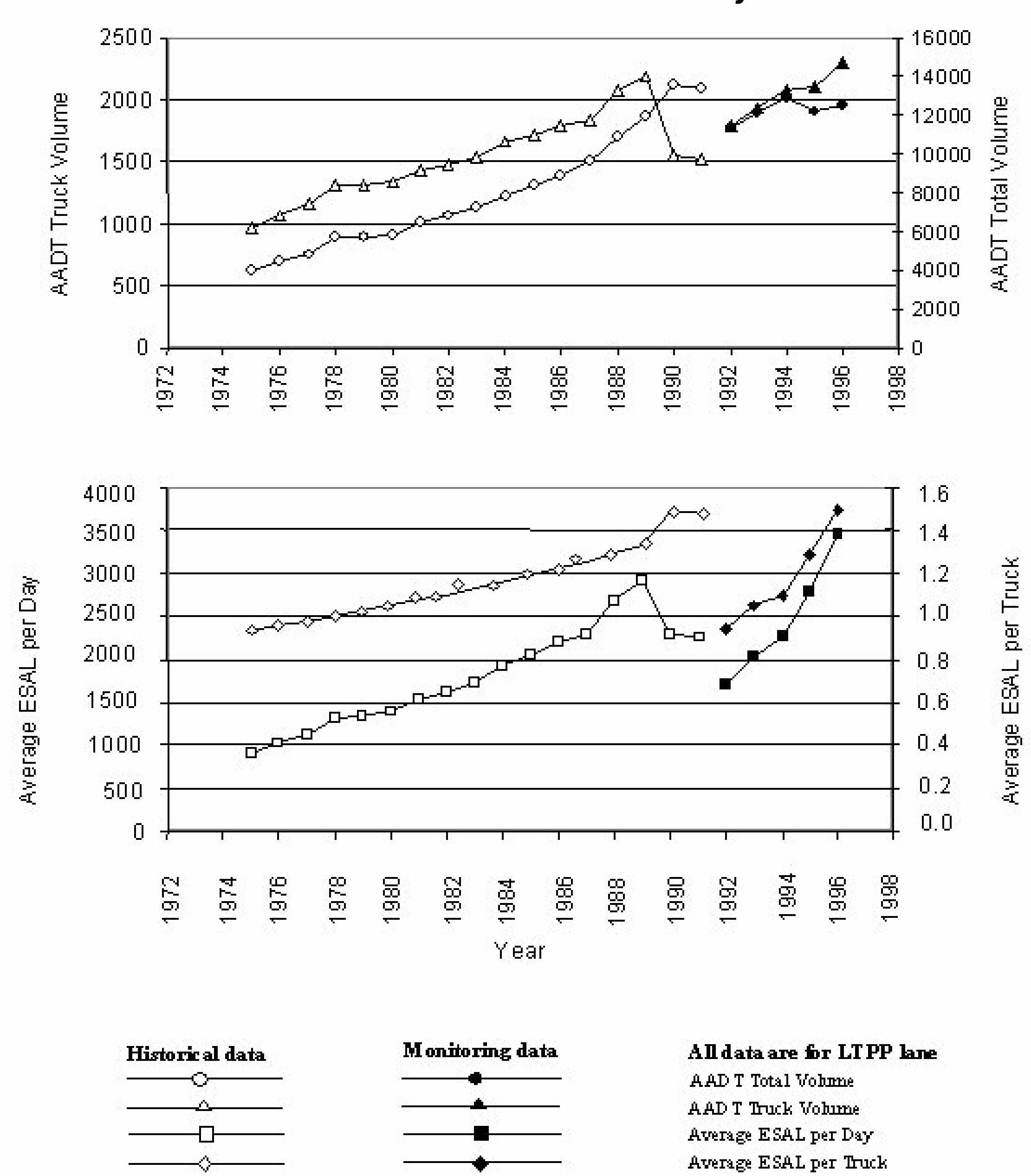


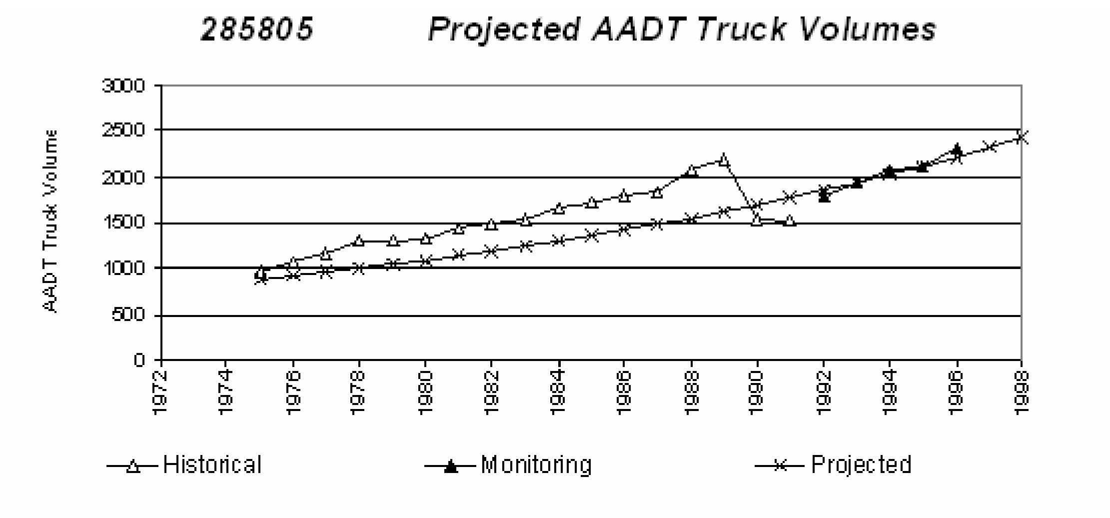
Figure 4. Site map for site 285805.

285805 Annual Traffic Projection Sheet



Data Type		Availability of Monitoring Data									
		1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
AVC	Days	–	–	266	361	351	363	160	–	–	1,501
	Month	–	–	9	12	12	12	–	–	–	45
WIM	Days	–	–	177	333	351	361	161	–	–	1,383
	Month	–	–	6	11	12	12	–	–	–	41

Figure 5. Annual Traffic Projection Sheet for Site 285805.



Year	AADT Truck Volumes			Projected Growth	
	Historical	Monitoring	Projected	Percentage	Factor
1975	970	–	885	–	0.45
1976	1060	–	923	4.2	0.47
1977	1160	–	962	4.2	0.49
1978	1310	–	1003	4.3	0.51
1979	1300	–	1046	4.3	0.53
1980	1330	–	1091	4.3	0.55
1981	1440	–	1139	4.4	0.58
1982	1480	–	1189	4.4	0.60
1983	1530	–	1241	4.4	0.63
1984	1660	–	1296	4.4	0.66
1985	1720	–	1354	4.5	0.68
1986	1790	–	1415	4.5	0.72
1987	1830	–	1479	4.5	0.75
1988	2070	–	1545	4.5	0.78
1989	2190	–	1616	4.5	0.82
1990	1544	–	1690	4.6	0.85
1991	1524	–	1767	4.6	0.89
1992	–	1789	1848	4.6	0.93
1993	–	1937	1934	4.6	0.98
1994	–	2079	2023	4.6	1.02
1995	–	2105	2118	4.7	1.07
1996	–	2307	2217	4.7	1.12
1997	–	–	2320	4.7	1.17
1998	–	–	2429	4.7	1.23

Figure 6. Projected AADT volumes for site 285805.

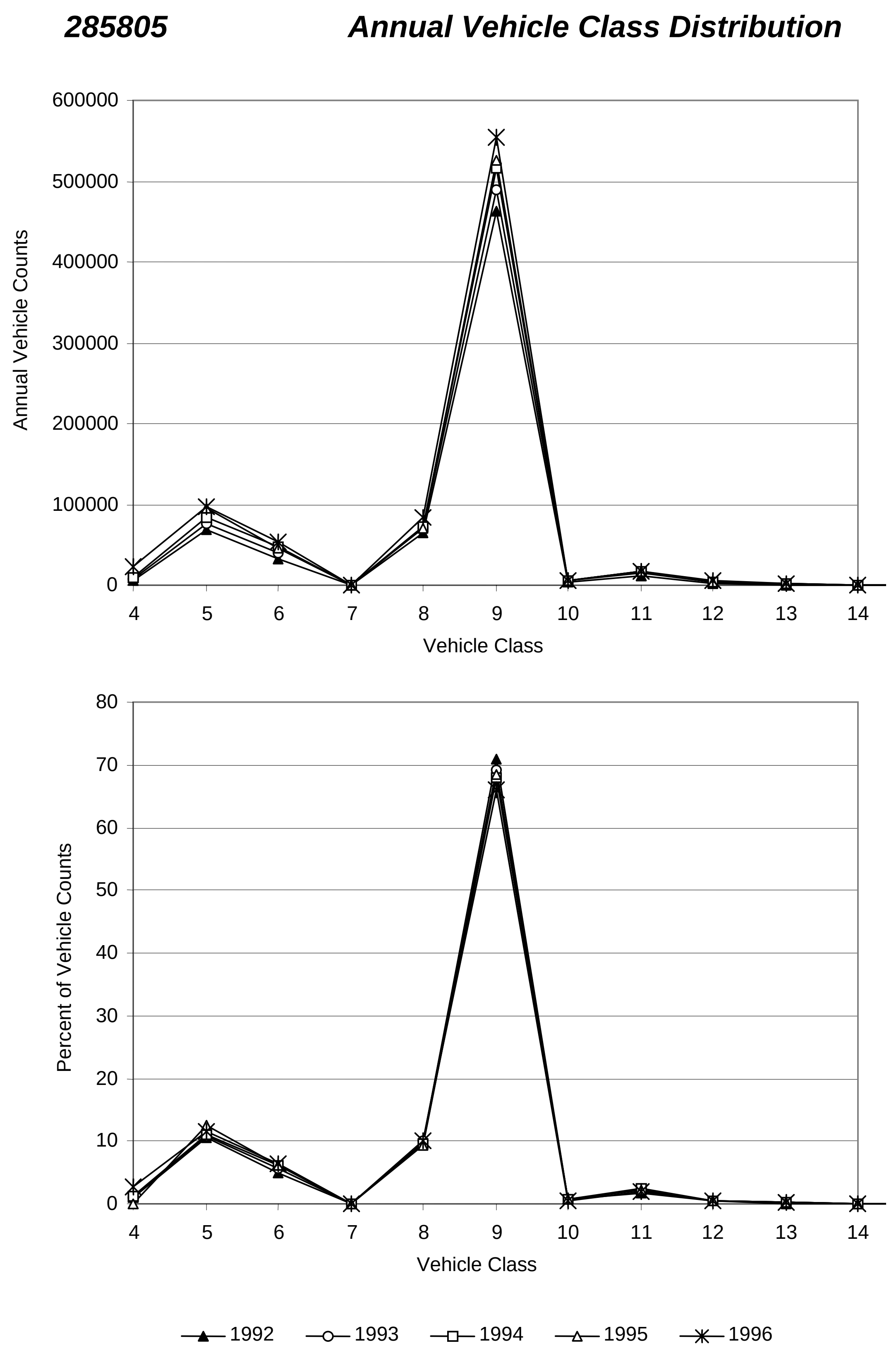


Figure 7. Annual vehicle class distribution for site 285805.

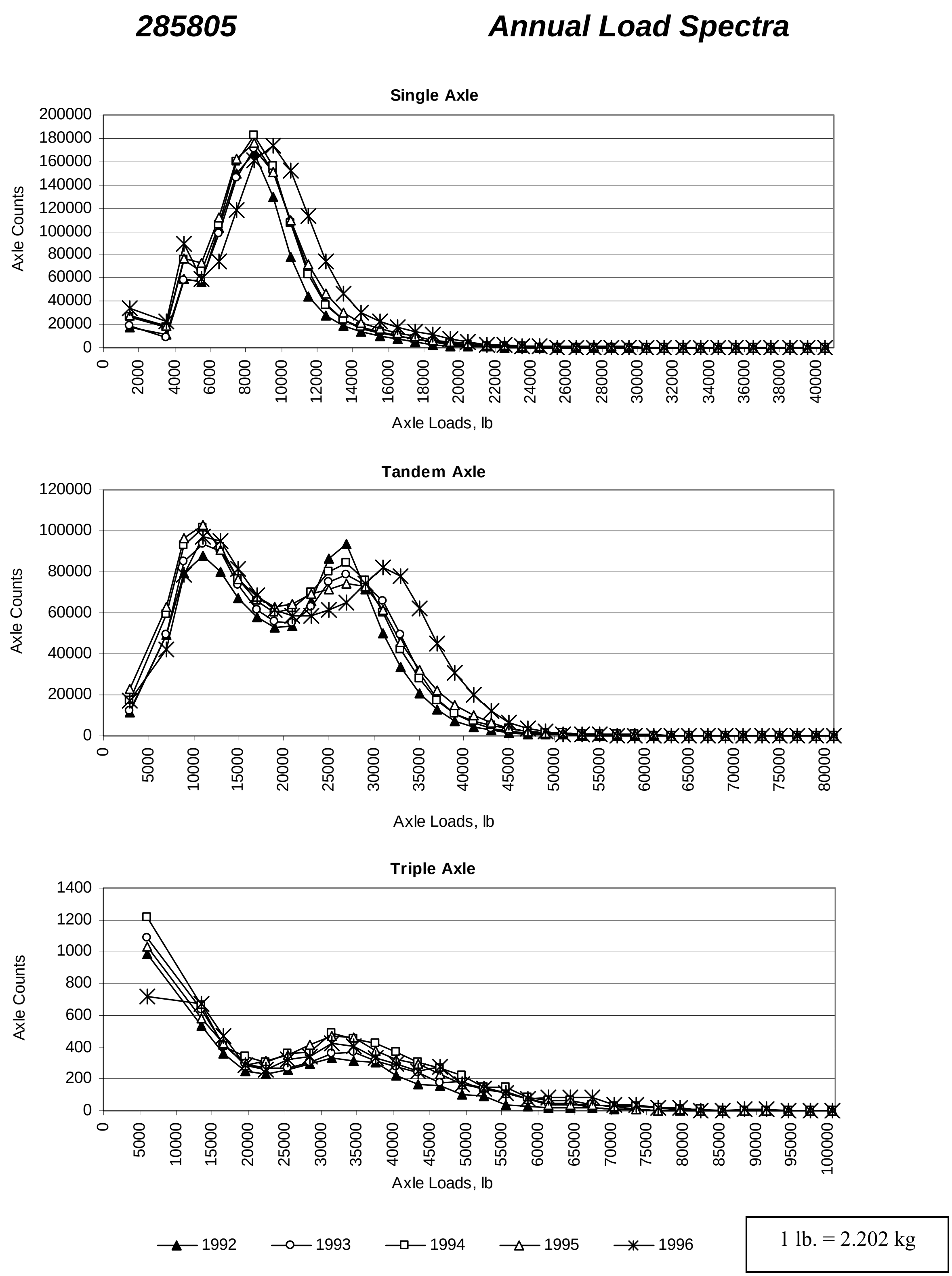


Figure 8. Annual load spectra for site 285805.

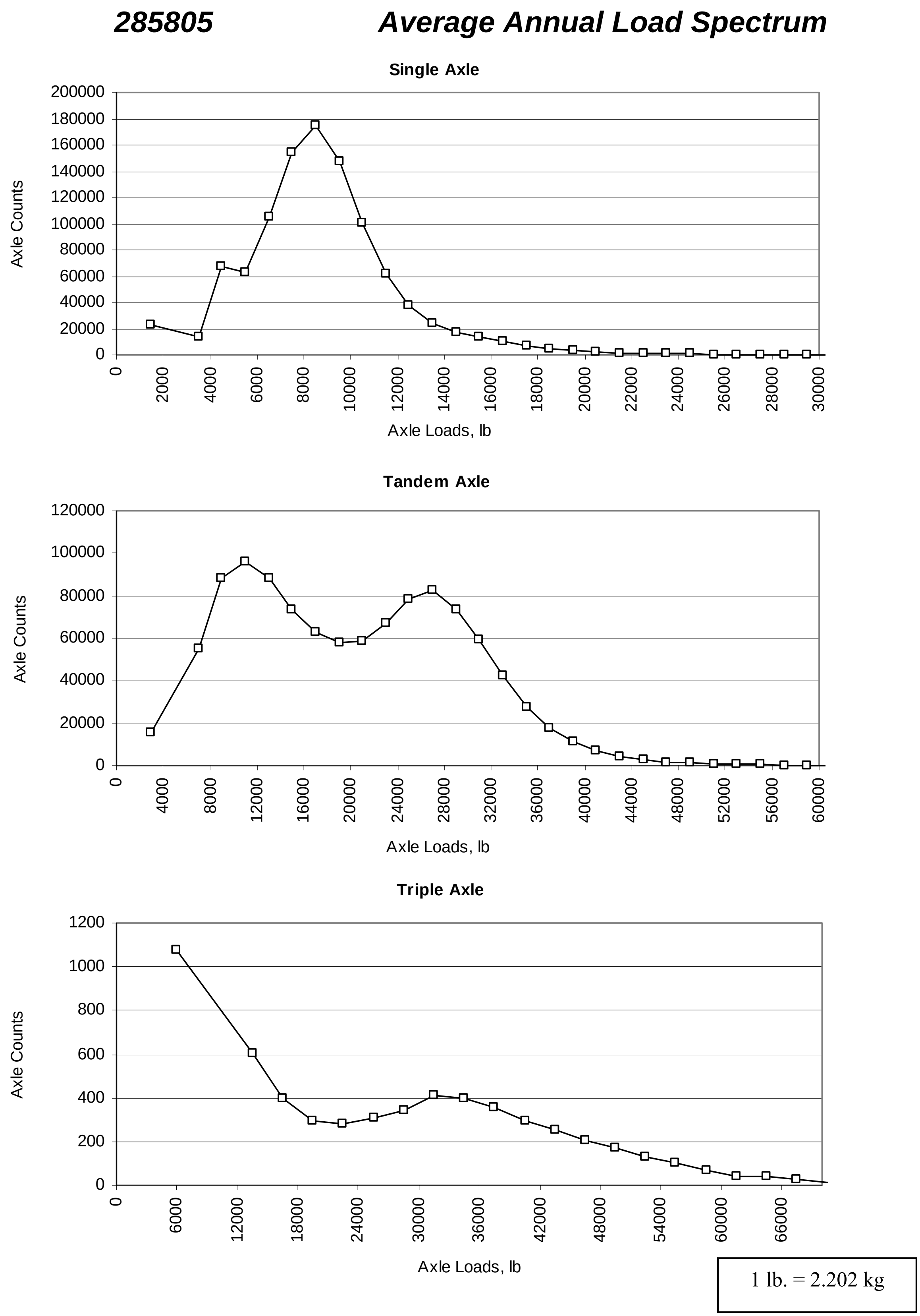
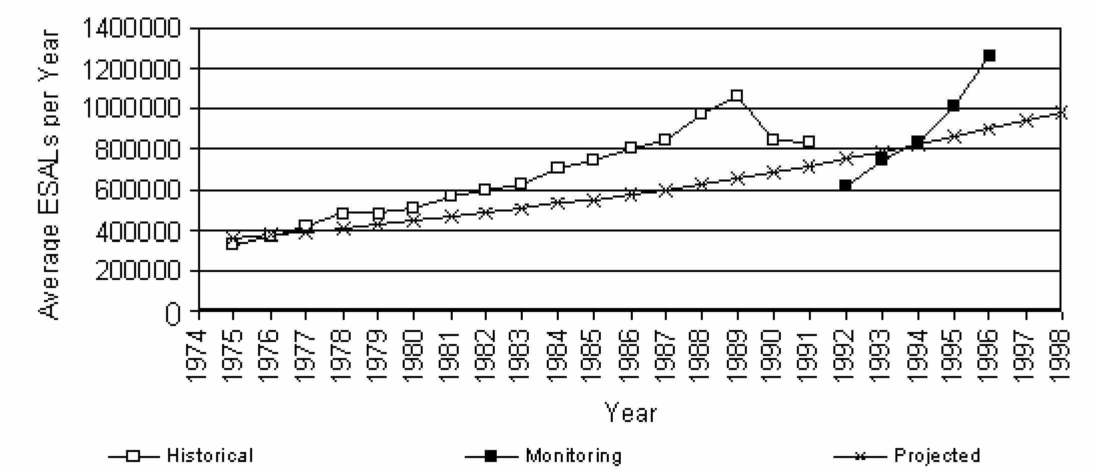


Figure 9. Average annual load spectrum for site 285805.

285805 Projected Annual ESALs (Initial)



Year	Annual ESALs		
	Historical	Monitoring	Projected
1975	330000	–	359237
1976	371000	–	374473
1977	414000	–	390386
1978	479000	–	407112
1979	486000	–	424689
1980	509000	–	443146
1981	565000	–	462405
1982	595000	–	482762
1983	631000	–	504029
1984	702000	–	526419
1985	748000	–	549829
1986	799000	–	574507
1987	840000	–	600428
1988	978000	–	627632
1989	1063000	–	656134
1990	837000	–	686160
1991	827000	–	717567
1992	–	618395	750656
1993	–	744923	785370
1994	–	833212	822124
1995	–	1017005	860362
1996	–	1256965	900519
1997	–	–	942662
1998	–	–	986994
Cumulative	–	–	14835602

Figure 10. Projected annual ESALs for site 285805.

Evaluation and Testing of LTPP Traffic Feedback and Resolution Package

The package described in the preceding section was the final version of the one that was distributed to the majority of the participating agencies. It was developed and refined over the course of several months through an interactive process involving reviews by interested parties and by representatives of several participating agencies. The two main review activities were:

- Review of the package by representatives of RCOs and by other interested parties.
- Review and enhancement of the package by pilot studies.

In addition, throughout the course of Phase 2 work, several small changes and enhancements to the package were instituted.

Review by Representatives of RCOs and Other Interested Parties

The important role of the RCOs in the projection process was recognized from the beginning of the study. Representatives of RCOs reviewed the first version of the LTPP Traffic Feedback and Resolution Package and subsequently reviewed agency-specific packages for all participating agencies in their respective regions.

The first package also was submitted to all members of the LTPP ETG on Traffic Data Collection and Analysis for review and comments, and a later version was presented during an ETG meeting in the spring of 2000. Reviews of an early version of the Package were also obtained from the representatives of the Technical Support Services Contractor and from the Minnesota Department of Transportation (Mn/DOT).

All reviewers provided valuable comments and suggestions on how to make the package more effective and user-friendly.

Review and Enhancement of the Package by Pilot Studies

During Phase 1 traffic projection work, it became apparent that it was necessary to involve representatives from the participating agencies in the traffic projection process because many data problems cannot be resolved without their involvement and help. The primary contact between the participating agencies and the LTPP program has been through RCOs. RCOs provide general technical support to the agencies regarding traffic data collection and analysis issues and are responsible for initial traffic data quality checks and for processing traffic data collected by the agencies. Consequently, the involvement of both the participating agencies and RCOs in traffic data assessment and projection is important. Pilot studies brought together the representatives of the participating agencies, RCOs, the project team, and others.

The main feature of the pilot studies was a 1-day meeting that was held at the participating agencies and attended by representatives of the participating agency (typically including an LTPP contact engineer, personnel responsible for traffic data management, field traffic data collection personnel, and others), RCOs (personnel responsible for traffic data), FHWA (representing the LTPP program, and FHWA Division Office), and two members of the project team.

The purpose of the pilot studies was to review and enhance the process of traffic data assessment and projection of traffic loads, including the content of the LTPP Traffic Feedback and Resolution Package, and to discuss specific issues concerning the agencies' LTPP sites. The pilot studies also provided an opportunity for the representatives of the RCOs to become better acquainted with the package and traffic data assessment and projection issues. For this reason, one pilot study took place in each of the four LTPP regions:

Agency	**Meeting Place**	**LTPP Region**
California DOT	Sacramento, CA	Western Region
Florida DOT	Tallahassee, FL	Southern Region
New Jersey DOT	Trenton, NJ	North Atlantic Region
Indiana DOT	Indianapolis, IN	North Central Region

During the course of the meeting, attendees discussed the LTPP package prepared for the agency. Agency representatives provided comments on specific LTPP sections following the format of the Feedback and Data Resolution Sheet (figure 3).

The pilot studies resulted in several improvements to the package, and in better communication among all interested parties, particularly between the representatives of the RCOs and the project team.

Step 5—Preparation of LTPP Traffic Feedback and Resolution Packages for All Participating Agencies

Once the package was developed through the review and consultative process outlined previously, a procedure was established to produce a package for each participating agency and to send it to RCOs for review. A substantial part of the package was produced as a customized printout of data stored in the IMS database. The assessment of data quality, the selection of data for projection, and the development of the projection models were done on a section-by-section basis using engineering and analytical judgment. The following activities were carried out to develop traffic projections:

- Assessment of traffic data.
- Projection of truck volumes.
- Development of base annual spectra.
- Assignment of initial projection confidence codes.
- Computation of annual axle load spectra.

These activities are described in the following sections under separate headings; however, the first four activities were intertwined.

The following principles applied to all traffic data assessment and projection work.

- Close attention was paid to whether the data and traffic projections encountered in the course of the work were reasonable. For example, when working with truck volumes, the corresponding highway classification, number of lanes, and AADT volumes reported for different years on the same site or on similar sites were noted to identify potential idiosyncrasies.

- All activities requiring engineering and analytical judgment were carried out by at least two members of the project team. Typically, one project team member carried out the task and the second member independently reviewed the outcome of the task. Any differences were discussed to reach a consensus.

- The initial projections were done with the understanding that they will be reviewed by the participating agencies. It was considered more constructive and beneficial for the projection if the project team were proactive and developed the initial traffic projection whenever possible, rather then to ask agencies first for more data or for directions. Consequently, for example, only meager data and engineering judgment were sometimes used to propose the truck volume projection model.

- The traffic data assessment and projection work was done for all sites belonging to an agency at the same time. This approach enabled the project team to cross-compare trends in data to identify data discrepancies and to develop solutions and for their resolution.

Assessment of Traffic Data

A general assessment of data quantity and quality for all LTPP sites within the agency was carried out as part of the preparation of the initial overall feedback and resolution report. Because traffic data for all LTPP sites within an agency were assessed at the same time, the process benefited from cross-comparison of trends observed on all sites. The site-specific assessment of data quantity and quality followed similar themes as those used to develop the initial overall feedback and resolution report: evaluation of missing data, location of sections, traffic volumes, vehicle classification (operation of AVC equipment), and axle weights (operation of WIM scales), and was based on the site-specific reports.

Observations regarding traffic data that were considered to be of interest to the participating agencies, or questions that the project team members had for the representatives of the participating agencies, were included in part 6 of the Blue Sheets (figure 3).

In some respects, the assessment of traffic data carried out as part of this study resembled the traffic data QA process recommended in the *LTPP Traffic QC User's Guide*.[12] However, there were fundamental differences between the quality control (QC) recommended by the guide and the traffic data assessment process carried out as part of the traffic projection process. The fundamental differences were in the timing and the outcome of the two activities, and in the length of the time period for which the traffic data were assessed.

The QC should be carried out a few days or weeks after traffic data are collected so that an appropriate corrective action (such as equipment calibration) can take place in a timely manner.

Traffic data assessment carried out in this study took place many years after the data were collected. The QC process may result in the removal of nonsensical data, but no data were removed from the database as part of this study. However, nonsensical data were identified and were not used for traffic projections. Finally, the previous QC process evaluated traffic data for only relatively short time periods, such as day, week, month, or quarter, without examining long-term trends. Traffic data assessment done in this study evaluated only annual data, but evaluated trends in annual data for all in-service years.

The type of traffic data assessment done in this study is not a replacement for the appropriate QC process. The assessment process used was necessitated by the quality of available traffic data and the need to provide the initial traffic projection for the development and calibration of the *2002 Pavement Design Guide*.[7] Traffic data used in this study still need to be evaluated using a basic QA process.

Projection of Truck Volumes

To estimate traffic loads for all in-service years, it was necessary to estimate the AADT volumes for all years the pavement was in service. The available historical and monitoring truck volume data had to be "backcasted" (to years before the sites became part of the LTPP program), interpolated (for the interim monitoring years without monitoring data), and forecasted (for years after the data are no longer collected), as shown schematically in figure 11.

The AADT volumes for all in-service years were estimated using a projection model. The AADT projection model was also used to obtain annual projection factors required for the calculation of the annual axle load spectrum (see equation 1).

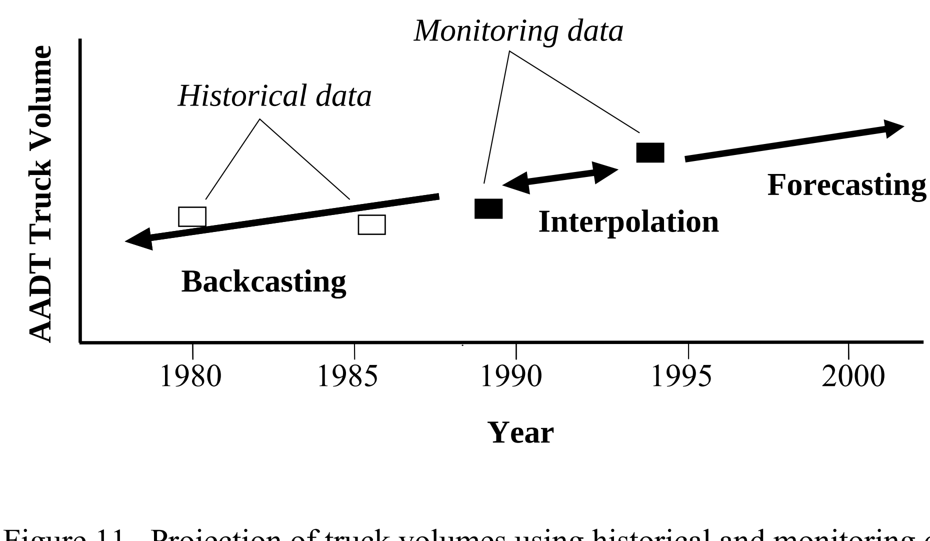


Figure 11. Projection of truck volumes using historical and monitoring data.

Figure 6 provides an example of the AADT truck projection model for site 285805. Twelve other examples of the projection model were provided in the Phase 1 report.[1] The table in figure 6 lists historical, monitoring, and projected AADT volumes from 1975 when the pavement was open to traffic to 1998. Also listed are the projected growth percentage and the projected growth factor. The projected growth percentage, indicating the historical rate of growth in truck volumes, was provided to facilitate the review of the projection models by the participating agencies. The projected growth factor, also referred to as "Annual Projection Factor" in equation 1, is a multiplier that was applied to the base annual spectrum to obtain projected annual axle load spectra for each year the section was in service. Projected growth factors were used to scale overall truck volumes up or down compared to base conditions and to account for traffic growth for different years.

The development of the AADT truck projection model followed the procedures developed in Phase 1 and documented in reference 1. Briefly, the available historical and monitoring annual truck volumes were plotted separately for each site and analyzed to determine their statistical characteristics. Plots of annual volumes often revealed considerable variation. Typically, simple regression models would fit the data best. However, least square regressions were not carried out because the technique cannot accommodate many considerations that were used to develop the projection model, and would not provide more meaningful results.

Some considerations used to develop the AADT truck projection models are summarized here.

- The monitoring AADT truck volumes, based on measured data, should be more reliable than historical volumes based on estimated data. In situations where historical and monitoring truck volumes did not match, the projection model placed more emphasis on the monitoring data and followed the monitoring data more closely than the historical data. The emphasis on the measured truck volumes is shown in the projection model in figure 6.

- Monitoring annual truck volumes based on measurements carried out during a substantial portion of the year should be more reliable than monitoring annual volumes based on short-duration measurements. The number of days and months during which AVC and WIM data were collected was known for all monitoring years up to 1998 and was listed on the bottom of Annual Traffic Projection Sheet (figure 5).

- The development of the projection model considered not only the trends in AADT truck volumes, but also the trends in AADT vehicle volumes, truck factors (TFs), and ESALs summarized in the Annual Traffic Projection Sheet (figure 5).

- Consistency of the historical estimates and the relationship between the historical and monitoring volumes for all sites within the agency. For example, if the historical truck volume estimates matched the subsequent monitoring volumes well for the majority of the sites within the agency, the historical volumes would be given greater weight for the sites where the match between the historical and monitoring volumes was poor.

- To initiate the traffic projection process and to provide a concrete example of the initial model for consideration and comments by the participating agencies, the AADT truck projection models were developed for all LTPP sites with at least some truck volume information. For example, if the AADT truck volume was available for only one monitoring year in 1998 and the section was opened to traffic in 1991, we would still provide truck volume estimates for all years between 1991 and 1998. The volume reported for 1998 would be assessed for reasonableness by considering other available data, such as AADT volumes, traffic volumes on similar sites in the same agency, the number of lanes, and highway classification. The projected growth in truck volumes between 1991 and 1998 would be based on the growth rate at similar sites in the same jurisdiction. Because this information was unavailable for a few sites, we used a 5 percent historical growth rate in truck traffic for interstates and major highways and a 2 percent rate for other highways. These rates were established by examining vehicle travel statistics available at FHWA's Web site, www.fhwa.dot.gov/ohinstat.htm. Subsequent analysis of LTPP data (presented in table 13, later in this report) confirmed that the selected growth rates are reasonable. It needs to be emphasized that the growth rate estimates were made to initiate the projection process and to submit a concrete projection for the review and comment by the participating agencies. Agencies were asked to verify the proposed growth rates using local information.

- Specific attention was paid to the influence of unclassified vehicles reported as Class 14 vehicles. The number of Class 14 vehicles strongly influenced total truck volumes on many sites in several agencies. After analysis of trends in truck volumes, Class 14 vehicles were usually attributed to passenger cars. Example of such analysis for three Minnesota LTPP sites is shown in figure 12. The treatment of Class 14 vehicles used in this study should be considered to be an interim measure. For some agencies and sites, consideration should be given to re-processing raw traffic data to distribute the Class 14 vehicles among the 13 vehicle classes.

Development of Base Annual Spectra

The objective of the development of base annual spectra was to obtain the annual axle load distribution or distributions that best reflect the axle loads on the site. The development of base annual spectra was the most challenging part of the entire projection process. The shape of the base annual spectrum (i.e., the normalized base annual spectrum) remained the same for all years. To obtain annual axle load spectra for all in-service years, the base annual spectrum was multiplied by a scale factor (annual projection factor) to reflect the historical changes in truck volumes (equation 1).

The annual axle load spectra showed a large variation in the amount and quality of monitoring axle load data. For example, some spectra had unexpected shapes with very few loaded axles, others had a large proportion of apparent axle overloads. Annual spectra also varied considerably from year to year. Reasons for the variation in and unusual shape of the spectra include:

- *Length of the sampling period*—The number of days per year during which the WIM scales were operating varied from site to site and year to year. The length of the WIM data-collection period for monitoring years up to 1998 was reported on the bottom part of the Annual Traffic Projection Summary Sheet (figure 5). The shortest period necessary for obtaining annual axle loads spectra was 24 consecutive hours. A spectrum based on several months of data may be quite different from one based on only a few days of data.

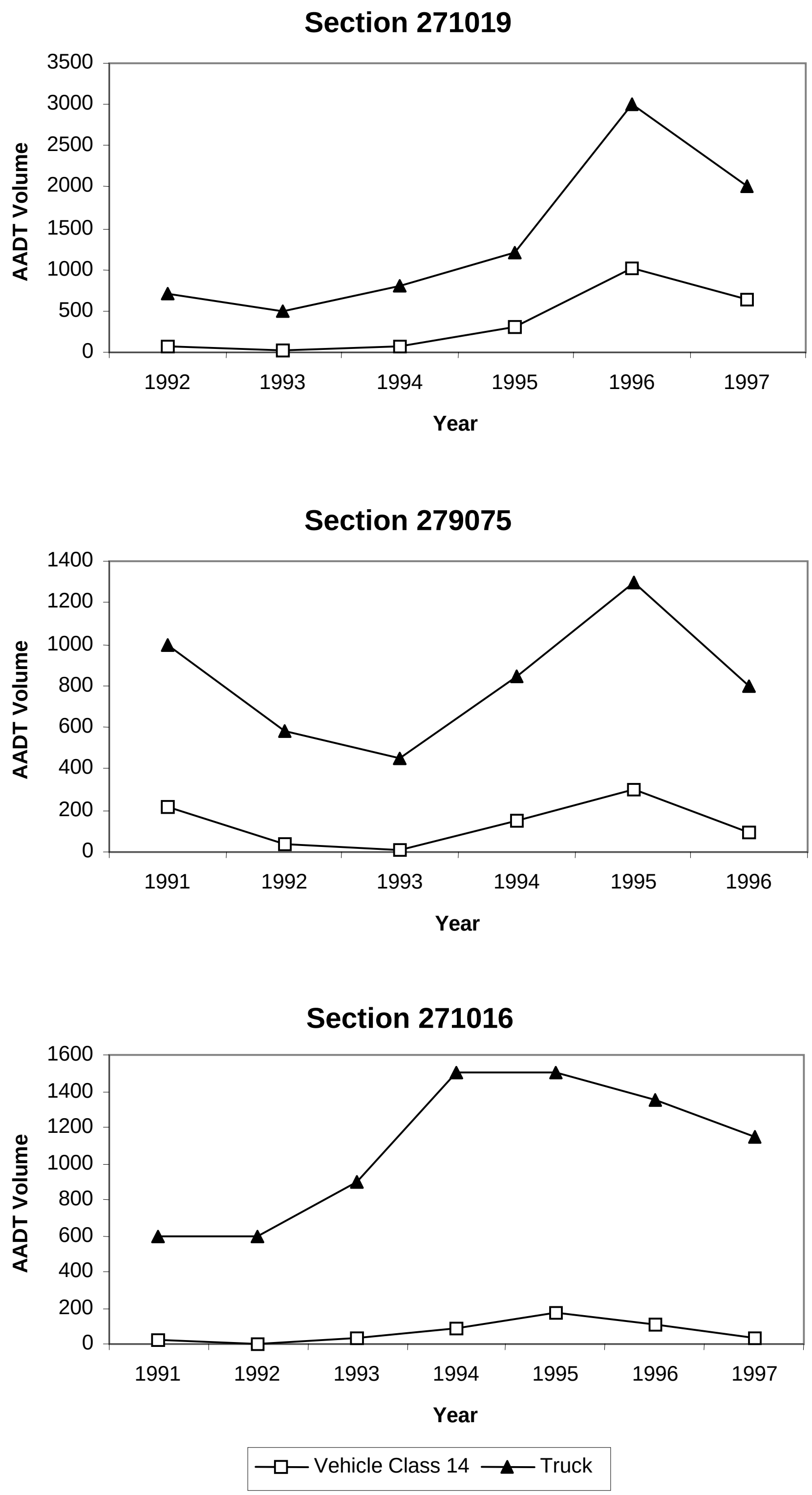


Figure 12. Comparison of AADT volumes for Class 14 vehicles with AADT volumes for all trucks.

- *Equipment errors*—These errors, caused by equipment limitations, can result in bias and cannot be remedied without changes to the equipment. It is possible that some occurrences with the large numbers of Class 14 vehicles were due to equipment errors.

- *Calibration errors*—These errors are caused by inaccuracies resulting from the way the physical response of the equipment to the passing vehicles is transformed into units of weight. After the initial calibration, the scales may have been allowed to drift. Thus, the axle load spectrum based on the first year of operation may be different from the spectra obtained for the subsequent years. Automatic calibration based on the weight of steering axles of Class 9 vehicles is not always reliable.

- *Changes in traffic patterns*—Annual axle load spectra for sites with low truck volumes may be significantly influenced by changes in the location and operation of nearby large truck traffic generators (e.g., by the construction of a large subdivision or by opening of new industry).

- *Natural variation*—Traffic loads naturally vary from year to year due to economic and other factors.

Selection of the base annual spectra was carried out by examining all available monitoring data for a given site, including all available truck class and axle load distributions. Graphic displays of traffic data, contained in the site-specific reports, were used for this purpose. The assessment considered the shape of the spectra (e.g., presence and location of peaks in the tandem axle spectra) and the differences and trends among the available spectra.

The main technique used to assess axle load spectra was the expectation that many large trucks operate either fully loaded or empty. The loaded peak is usually below the maximum allowable load because shippers may not know the exact weight of the empty trucks that will transport shipments. Consequently, they prepare or partition shipments with a margin of safety (so that the shipment and the weight of the truck will not exceed the allowable axle weight and gross vehicle weight limits). For example, if the allowable axle load on tandem axles is 15,436 kg (34,000 lb), the majority of fully loaded trucks should have tandem axle loads in the range of 14,074 to 14,982 kg (31,000 to 33,000 lb). Typical values for unloaded and fully loaded axles, together with Federal axle load regulations, are summarized in table 6.[13]

Table 6. Characteristic values of axle load spectra.

Axle Type		Federal Regulation for Maximum Allowable Axle Weight, lb	Expected Guideline Value, lb	
			Unloaded	Loaded[a]
Single	Class 5	20,000	3,000–4,000	16,000–18,000
	Steering Axles[b]	n/a	10,000–12,000	10,000–12,000
	Load Axles[c]	20,000	3,000–4,000	16,000–18,000
Tandem		34,000	7,000–12,000	31,000–33,000
Triple		42,000[d]	8,000–14,000	35,000–40,000

[a] Loaded to achieve maximum allowable weight.
[b] For vehicle classes 7 to 13
[c] Single payload carrying axles for all vehicle classes
[d] Depends on Bridge Gross Weight Formula
1 lb = 2.202 kg

As outlined in the Phase 1 report, there are many exceptions to the Federal vehicle weight regulations on the State and Provincial levels.[1] The enforcement of vehicle weight regulations also plays an important part. The values provided in table 6, therefore, are only typical guideline values.

The basic procedures used to obtain the base annual spectrum included:

- Computing the mean of all available annual axle load spectra.
- Computing the mean of selected annual axle load spectra.
- Selecting one or two annual axle load spectra.
- Rejecting all available annual axle load spectra.

An additional computational provision was made for sites with many years of reliable annual axle load spectra. It is possible to utilize two base annual spectra for the traffic load projection on one site. The first base spectrum can be used to represent traffic loads during the years before the installation of a WIM scale and during the initial operation of the scale; the second spectrum can be used to represent traffic loads for the most recent years with and without WIM scale data. Both the first and the second base annual spectra can be the averages of several annual spectra. However, this provision was not used for any LTPP site because its use was not warranted by quality of available axle load data.

<u>Mean of all Available Annual Axle Load Spectra</u>

A mean of all available annual axle load spectra was used if the mean spectrum was considered to be the best representation of traffic loads for the given site. An example of annual axle load spectra that were averaged to obtain the base annual spectrum is shown in figure 13 (for California site 063042, located on Interstate 5 south of Sacramento, CA). The base annual spectrum was obtained as a mean value of the annual spectra for 1990 to 1998, inclusively.

Mean of Selected Annual Axle Load Spectra

A mean of selected annual axle load spectra was used if some of the available annual spectra were considered to be outliers (for example, because of the large percentage of very excessive loads, or because the expected loaded and unloaded peaks were not present) and could not be used to determine the base annual spectrum. The base spectrum was calculated as the mean of the remaining spectra. An example of establishing the base annual spectrum as a mean of selected annual spectra is shown in figure 14 (for site 185518 on a rural interstate in Indiana).

The base annual spectrum for the site in figure 14 was calculated as the mean of annual axle load spectra for three years (1991, 1992, and 1995). The truck class distribution for the site was examined and was considered to be stable throughout the monitoring years. Consequently, the annual spectra were expected to be similar for all monitoring years.

Specific reasons that several of the annual axle load spectra shown in figure 14 were not used for calculating the base annual spectrum were:

- 1993 spectrum: The spectrum is flat and contains a relatively large number of overloaded tandem axles; the spectrum for single axle loads has no peak.
- 1994 spectrum: The spectrum is on the margin of being acceptable, and it is possible that other analysts would include this spectrum in the calculation of the base annual spectrum. However, it includes a relatively large number of tandem axle overloads (tandem axle weights exceeding 15,436 kg (34,000 lb)). Adding the 1994 spectra—to the already selected spectra for 1991, 1992, and 1995—would have only a small influence on the resulting base annual spectrum and on the cumulative axle loads.
- 1996, 1997, and 1998 spectra: The peak for single axles is below 4,540 kg (10,000 lb), and there are no peaks for tandem axles corresponding to the loaded and unloaded axles.

Another example of establishing the base annual spectrum as a mean of selected spectra is provided in figure 8, showing five annual axle load spectra for Mississippi site 285805. Initially, the base spectrum was calculated as the mean of 1992, 1993, 1994, and 1995 spectra. The 1996 spectrum was not used for the initial projection because it was considered to be an outlier. Its peak for the loaded tandem axles was about 2,270 kg (5,000 lb) higher than the peaks of the other four annual spectra (14,528 kg (32,000 lb) compared to 12,228 kg (27,000 lb)). However, in response to a subsequent review carried out by a representative of the Mississippi DOT, the 1996 annual spectrum was included in the calculation of the reviewed base annual spectrum. The utilization of review comments received by the participating agencies is discussed in step 8 ("Implementation of Review Comments Received from Participating Agencies").

<u>Selection of One or Two Annual Axle Load Spectra</u>

Many sites had only one or two annual axle load spectra that were considered suitable for the development of base annual spectrum. An example of such a situation is provided in figure 15 for site 124057, located on a rural Interstate 75 east of Tampa, FL. From the eight annual spectra available for this site, only axle load spectra for 1991 and 1992 were used for the projection. The reasons for the rejection of the remaining spectra (for years 1993 through 1998) were similar to those given for the rejection of the spectra in figure 14.

The 1991 and 1992 spectra have similar shapes but have different magnitudes: the 1992 spectrum is based on a much smaller number of trucks than the 1991 spectrum. Because the projection process utilizes the normalized spectra, the difference in magnitude does not influence the calculation of annual base spectra. It should be pointed out that the allowable tandem axle load in Florida is 19,976 kg (44,000 lb)even though the maximum allowable gross vehicle weight is still 36,320 kg (80,000 lb). Consequently, the 1991 and 1992 spectra (given in figure 15) used for the development of base annual spectra do not contain many overloads.

<u>Rejection of All Available Annual Axle Load Spectra</u>

For many sites, all available monitoring annual axle load spectra were judged to be inappropriate for the development of base annual spectra, and thus for the projection of traffic loads. The main consideration in not using the available monitoring data was the possibility that their use would result in a larger error in the projected traffic loads than the use of surrogate data such as site-related, regional, or generic axle load spectra. See figure 16 for an example of a site for which all available spectra were rejected.

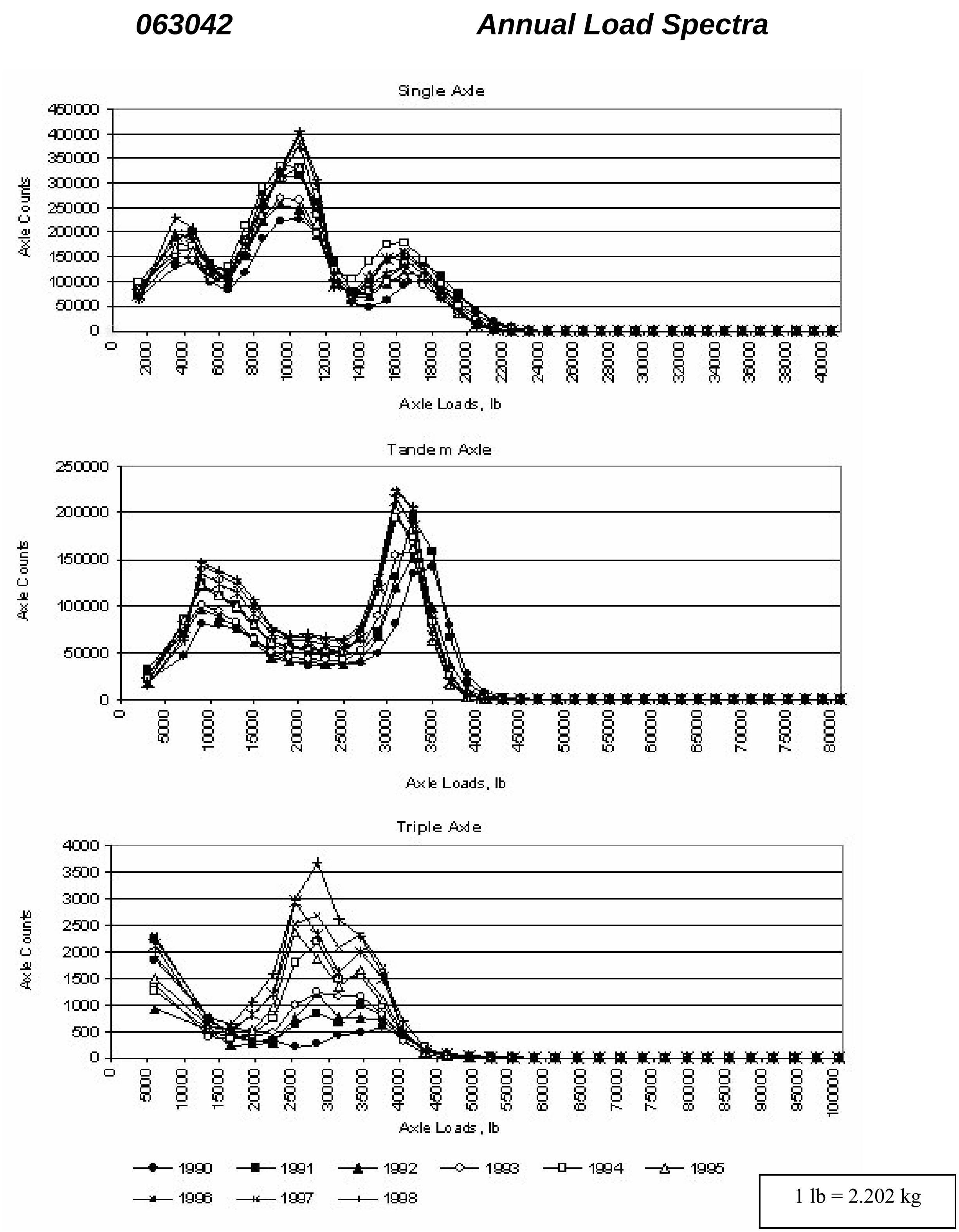
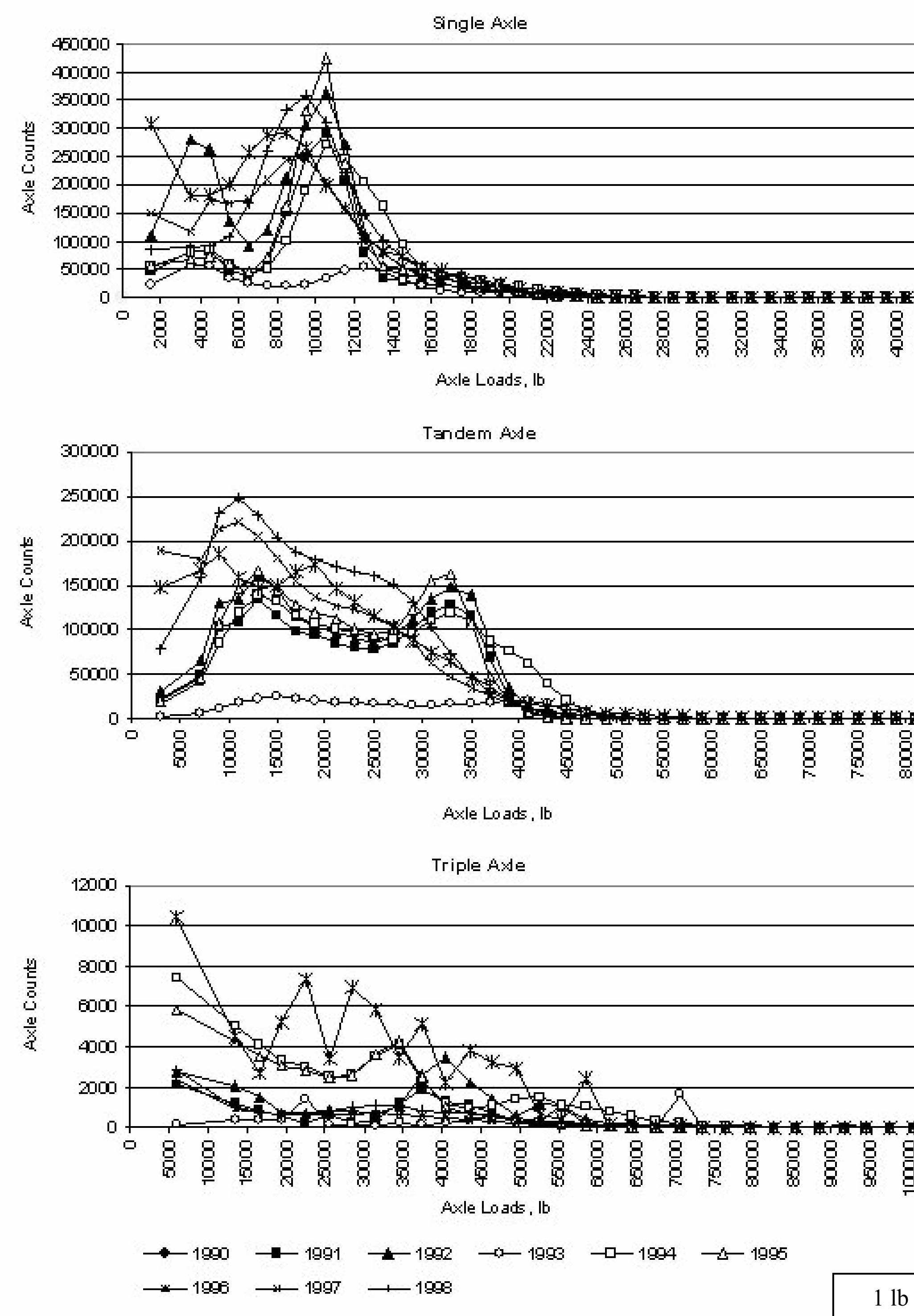


Figure 13. Use of the mean of all annual axle load spectra to obtain base annual spectrum.

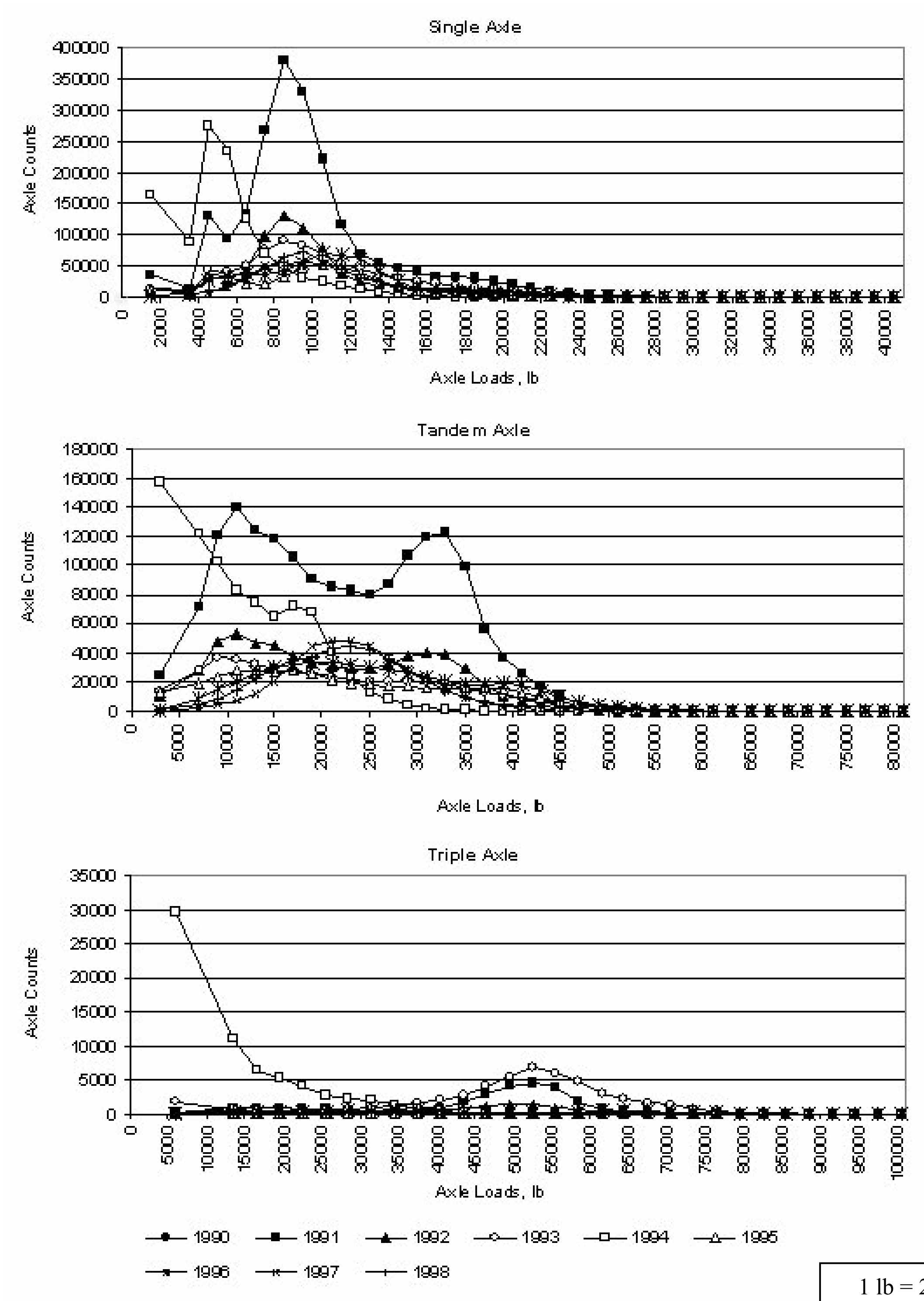
185518 Annual Load Spectra



1 lb = 2.202 kg

Figure 14. Use of the mean of 1991, 1992, and 1995 annual axle load spectra to obtain base annual spectrum.

124057 *Annual Load Spectra*



1 lb = 2.202 kg

Figure 15. Use of the mean of 1991 and 1992 annual axle load spectra to obtain base annual spectrum.

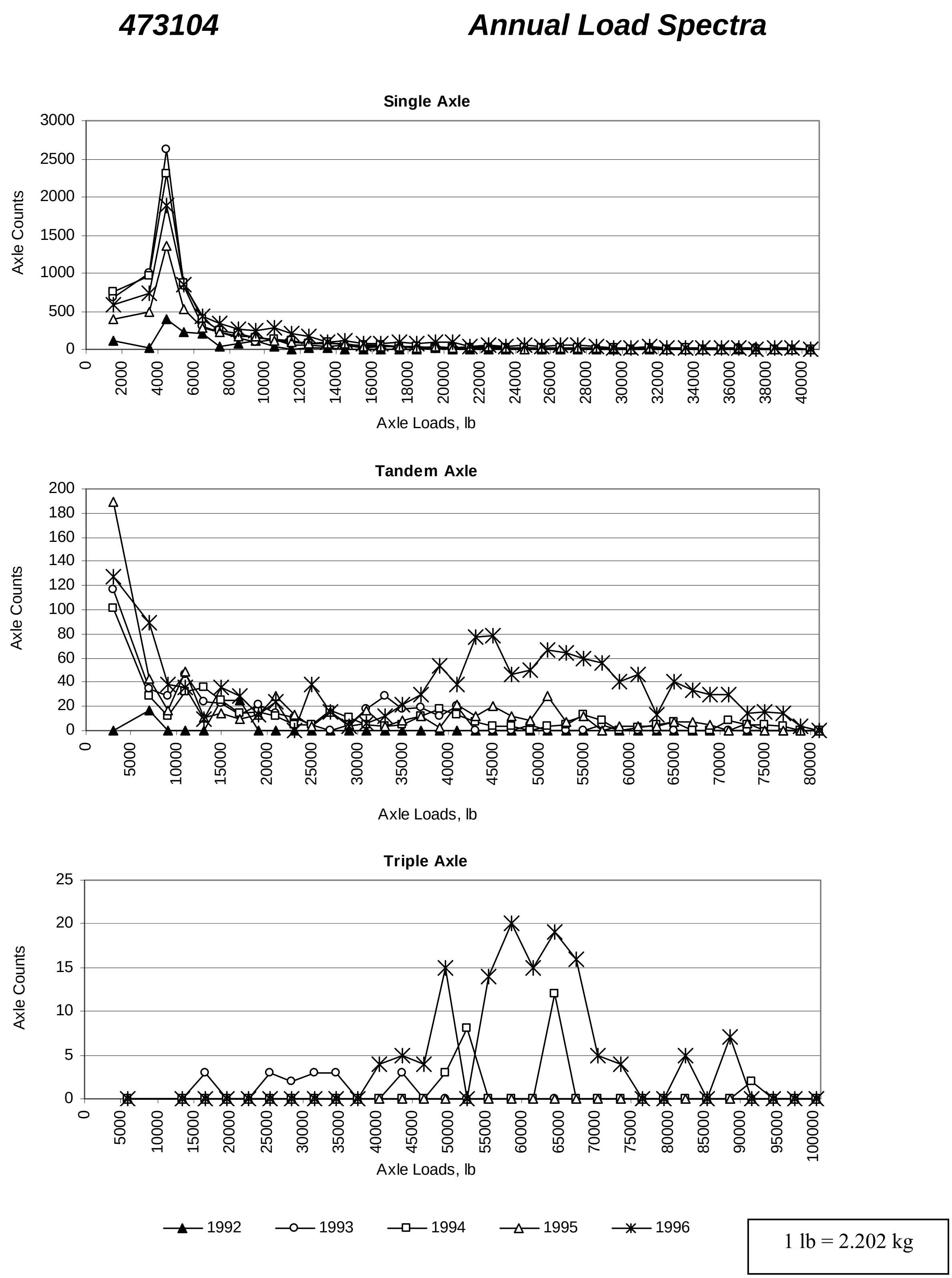


Figure 16. Rejection of all available annual axle load spectra.

Figure 16 shows five annual axle load spectra for site 473104 in Tennessee located on a rural major collector highway. The 1995 and 1996 spectra contain an unreasonable number of overloaded tandem axles. The main problem with the 1992, 1993, 1994, and 1995 spectra is probably the small number of observations (weighted trucks) used to develop the spectra.

Additional information on the indicators used to decide whether individual axle load spectra were suitable for the projection of traffic loads is discussed next.

Assignment of Initial Projection Confidence Codes

The purpose of developing projection confidence codes was to characterize the uncertainty associated with traffic load projections. Such characterization is useful for the development of pavement performance models and for the development of pavement design procedures that incorporate reliability concepts.

The level of confidence in the initial traffic projections has been expressed in the form of initial traffic projection codes that have been assigned to all LTPP sites. The following three codes were used to characterize the level of confidence associated with initial traffic projection results:

- IA—Initial acceptable projection results.
- IQ—Initial questionable projection results.
- IN—Initial not available projection results.

The traffic projections were classified according to the confidence codes to provide guidance to the pavement analyst regarding overall *expected* accuracy of traffic projections. However, the *actual* accuracy of traffic projections is unknown because the actual traffic loads that went over the sites during the time the pavement was in service is not known. To provide guidance to the pavement analyst, the following approximate interpretation of the initial projection confidence codes has been provided:

- IA—Cumulative ESAL estimates are probably within ±50 percent of the actual cumulative ESAL values.
- IQ—Cumulative ESAL estimates are probably off by more than ±50 percent from the actual cumulative ESAL values, but are probably better than the estimates based entirely on surrogate (regional or generic) data. Cumulative ESAL estimates are probably within ±100 percent of actual ESAL values.
- IN—Axle load estimates could not be provided at this time.

The initial traffic projection codes were assigned subjectively using engineering judgment and considering:

- Site-specific historical and monitoring traffic data.
- Agencywide historical and monitoring traffic data.
- Other data such as highway location, functional class, and total number of lanes.

Only three traffic projection codes were used because of uncertainties inherent in the traffic projection process caused by the amount and quality of traffic data. Traffic data available for the projection of traffic loads received only a cursory QC and QA review, and include good, marginal, and erroneous data.

The initial projection of traffic loads and the assignment of the projection codes were carried out for all sites within the agency at the same time. The projection process utilized agencywide trends and similarities in historical and monitoring data. This was achieved, for example, by comparing traffic loads reported for nearby sites (as shown in table 3) and similar sites, or by comparing the match between historical and monitoring truck volumes, or between historical and monitoring TFs, for all sites. When weighing the information provided by historical and monitoring data, the extent, consistency, and quality of the agency's historical monitoring data were taken into account.

An agency's consistency and reliability in providing historical traffic load estimates, particularly estimates that were in good agreement with the subsequent monitoring data, imparted additional confidence in the traffic projections. For many sites, the number of historical years exceeded the number of monitoring years, so the reliability of historical traffic estimates played an important role in assigning projection confidence codes. For example, figure 5 shows that for site 285805 there were 17 historical years (1975 to 1991) and 7 monitoring years (1992 to 1998, even though 1997 and 1998 had no monitoring data). The reliability of cumulative traffic load estimates (from 1975 to 1998) at this site depends also on the reliability of historical data.

The level of confidence was linked to the accuracy of traffic projections even though the accuracy of traffic projections cannot be determined and will remain unknown. It is believed that the comparison of the projected traffic loads with the actual expected traffic loads is more meaningful than the comparisons of the projected traffic loads with a relative reference, such as the estimated traffic loads based on monitoring data, because the relative reference also may be subject to error.

The level of confidence was related to the cumulative ESALs. Cumulative rather than annual ESALs were used to avoid the influence of annual variation in traffic loads that can occur by chance alone, or can be caused by other reasons, such as special events.

The assignment of the initial projection codes using judgment was a complex task that used subjective interpretation of all relevant information provided by historical and monitoring data. To minimize the subjectivity involved in assigning the confidence codes for the initial traffic projections, researchers ensured that:

- The assignment of codes was based on guidelines.
- At least two project team members were involved in assigning codes for each section. The experience with pavement condition rating (which is also done subjectively using guidelines) indicates that the use of multiple raters has a positive influence on the variability of pavement condition rating.[14]

The guidelines for assigning projection confidence codes described in the following section are organized under the main headings of "Guidelines for Assigning IA, IN, and IQ Codes," respectively, and under the subheadings of "Location, Truck Volumes, Truck Classification, and Axle Weights." However, the assignment of the projection confidence codes considered simultaneously all traffic data characteristics and was done simultaneously with the traffic data assessment and traffic projection activities. The guidelines reflect the knowledge acquired during the course of this study and information obtained from the feedback on the initial traffic projections received from the participating agencies. The feedback information received from the participating agencies is discussed in step 7 ("Review of LTPP…Packages by Participating Agencies").

Guidelines for Assigning IA Codes

The IA code was assigned to LTPP sections with site-specific traffic volume and axle weight data where it was judged that the cumulative ESALs were probably within ±50 percent of the actual cumulative ESALs. Typical requirements for assigning IA codes included the following conditions.

Location—There was an agreement between the description of the site location and the position of the site when plotted on a highway map. Ambiguity regarding the site location did not play a decisive role in assigning the projection codes for any of the LTPP sites because any ambiguity was addressed during the traffic data assessment process.

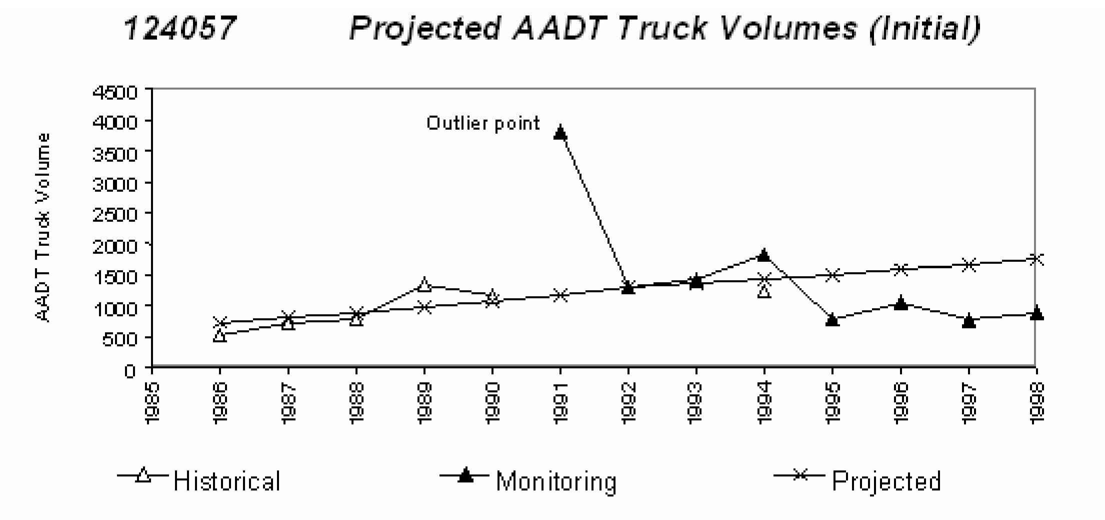
There was a logical agreement between traffic characteristics (e.g., truck volumes, TF, and truck growth) on nearby sites. For example, truck volumes on nearby sites were similar and tended to increase with the proximity to large cities. An example comparing traffic characteristics for nearby sites is provided in table 3.

Truck Volumes—There were no large discrepancies between the historical and monitoring trucks volumes. The truck volume projection model—the model estimating the total annual number of trucks for each year since the highway was opened to traffic—fit the annual historical and monitoring truck volumes within a typical range of about ±50 percent. Outliers were permitted where it was felt that the historical or monitoring data were probably in error. An example of a truck volume projection model that contains an outlier is shown in figure 17.

Truck Classification—the distribution of trucks into the 13 FHWA vehicle classes appeared to be reasonable considering:

- The functional class of the highway. For example, it was expected that about 50 to 80 percent of all trucks on rural interstates would consist of five-axle single trailer trucks (vehicle Class 9).
- Monitoring truck class distribution obtained for different years. It was expected that the truck class distribution for the major truck classes such as Class 5 and Class 9 vehicles (table 1) would not vary by more than about ±25 percent from year to year (particularly on highways with daily truck volumes exceeding about 300 trucks).

- Relatively small number of unclassified vehicles. Typically, the number of unclassified vehicles did not exceed about 15 percent of all vehicles.



Year	AADT Truck Volumes			Projected Growth	
	Historical	Monitoring	Projected	Percentage	Factor
1986	529	–	735	–	0.29
1987	716	–	808	10.0	0.32
1988	780	–	889	10.0	0.35
1989	1348	–	978	10.0	0.38
1990	1162	–	1076	10.0	0.42
1991	–	3812	1183	10.0	0.46
1992	–	1302	1302	10.0	0.51
1993	–	1417	1367	5.0	0.53
1994	1234	1813	1435	5.0	0.56
1995	–	792	1507	5.0	0.59
1996	–	1061	1582	5.0	0.62
1997	–	770	1661	5.0	0.65
1998	–	889	1744	5.0	0.68

Figure 17. Projected AADT truck volumes for site 124057.

Axle Weights—The distribution of axle weights appeared to be reasonable considering:

- There was a basic correspondence between the truck class distribution and the truck axle load spectra. For example, for the sites with many two-axle trucks, the predominant component of the axle load spectra was expected to be single axles.
- There was at least one year for which axle load spectra were considered to be appropriate. Typical characteristics of acceptable axle load spectra are summarized in table 6, and included:
    - *Single axles* had a predominant peak at about 4,540 to 5,448 kg (10,000 to 12,000 lb), and a secondary peak (when warranted by the truck classification data indicating the presence of vehicles with single axles carrying payload) at about 7,264 to 8,172 kg (16,000 to 18,000 lb).
    - *Tandem axles* had the loaded peak at about 14,074 to 14,982 kg (31,000 to 33,000 lb) for agencies with the allowable axle weight for tandem axles of 15,436 kg (34,000 lb). The unloaded peak was about 3,178 to 5,448 kg (7,000 to 12,000 lb).
    - *Triple axles* had the peak at about 18,160 kg (40,000 lb), and their number was commensurable with the occurrence of six-and-more axle trucks. Based on the Bridge Gross Weight Formula, for the triple axle spacing exceeding 2.44 m (8 ft), the allowable axle weight is 19,068 kg (42,000 lb).[13]
- If the axle load spectra were available for more than 2 years, the requirements for the peak axle weights to reach the specific ranges were relaxed because the base annual spectra were calculated as an average of all annual spectra that were considered acceptable.
- For agencies that provided apparently good estimates of historical truck volumes and TFs, the monitoring TFs were typically within ±50 percent of the historical TFs.

For a few sites, the quality of axle weight data was also evaluated by examining the distribution of gross vehicle weights (GVW) for Class 9 vehicles (5-axle single trailer trucks). The logic underlying the QC process utilizing the GVW distribution is that many Class 9 trucks operate either unloaded or loaded, and if loaded their GVW is close to the maximum allowable GVW of 36,320 kg (80,000 lb). Thus, a typical distribution of the GVW of Class 9 vehicles is expected to have two peaks, the first peak, associated with unloaded vehicles, at about 12,712 to 16,344 kg (28,000 to 36,000 lb), and the second peak, associated with loaded vehicles, at 31,780 to 35,412 kg (70,000 to 78,000 lb).

The reasons for not using GVW of Class 9 vehicles more extensively included:

- For sites where Class 9 vehicles predominate (for example on rural interstates and on other major rural highways), the plots of single and tandem axle load distributions are governed by the presence of the Class 9 vehicles already (and convey similar information as the GVW plots).
- For sites where Class 9 vehicles do not dominate (for example on some urban highways and minor rural roads), the knowledge of the GVW distribution of Class 9 vehicles is not critical for assessing the quality of axle weight data.
- The weights of the individual vehicles are not stored in the IMS database and the production of the GVW plots would require considerable additional analytical effort.

The use of the GWV distribution of Class 9 vehicles is recommended in the *LTPP Traffic QC User's Guide* as the basic QA process for the operation of WIM scales.[12]

Regardless of the use of the GVW of Class 9 vehicles, there are fundamental differences between (a) the QA process using the GVW of Class 9 vehicles recommended by the user's guide and (b) the traffic data assessment process used to carry out traffic projection and the assignment of the projection confidence codes. The fundamental differences are in the timing, outcome, and length of the time period for which the data were assessed as outlined previously. It appears that the many axle load data stored in the IMS have not been subjected to the QC process recommended by the *LTPP Traffic QC User's Guide*.

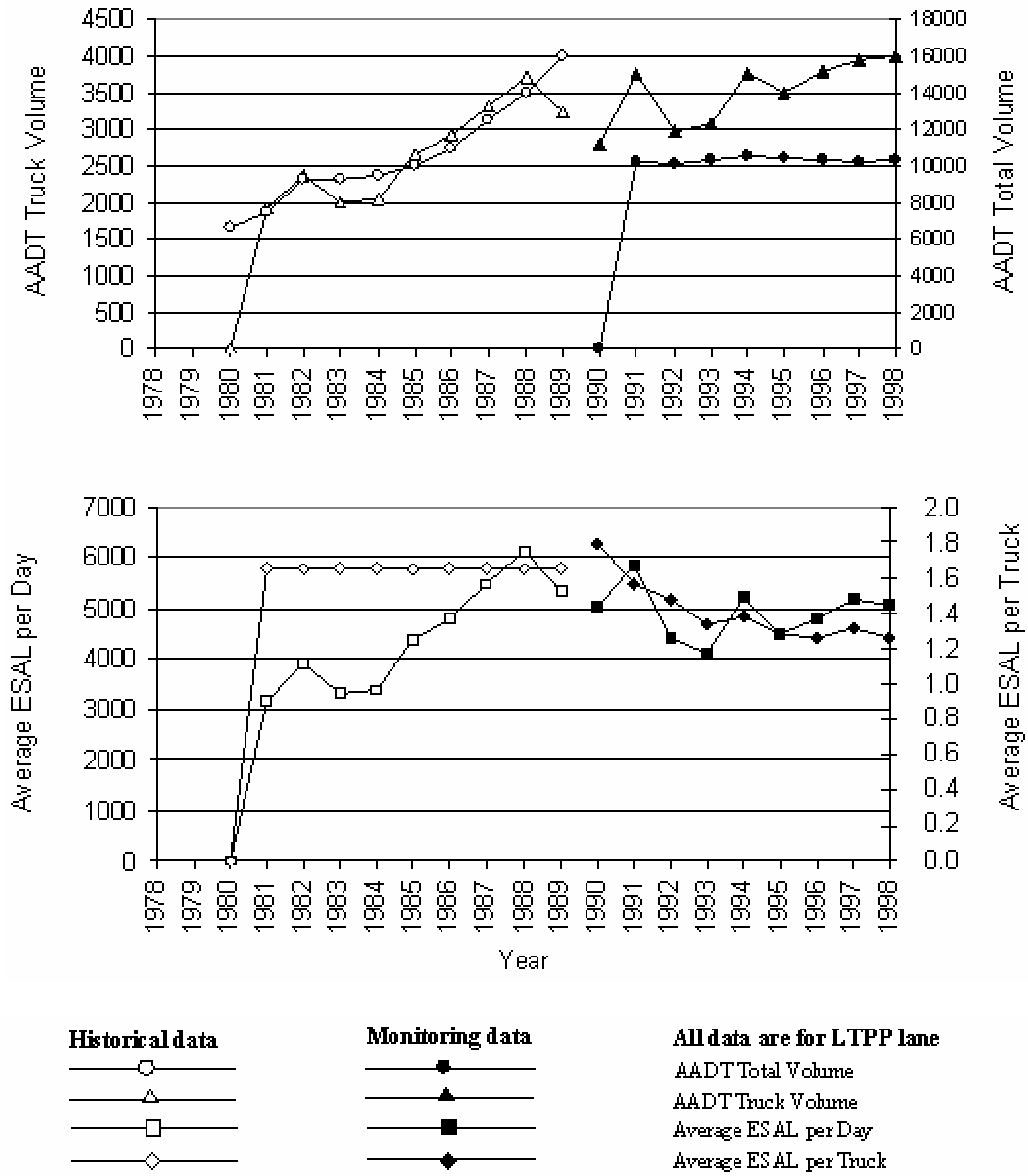
Example of Assigning IA Code—The following example summarizes some considerations involved in assigning IA codes. Many considerations also apply to traffic data assessment and traffic projection activities done in unison with the assignment of projection confidence codes.

The appearance of annual axle load spectra shown in figure 13 was one reason the IA code was assigned to the traffic projections carried out for site 063042. The nine annual axle load spectra for this site (for 1990 to 1998, inclusive) show a consistent downward trend, illustrated by the plot of average ESALs per truck (figure 18).

According to figure 18, the average ESALs per truck gradually declined between 1990 and 1998 from 1.8 to about 1.3 per truck. However, because there has been a significant increase in truck volume at the same time, the total annual number of ESALs has remained relatively constant. The reason the decline appears to be real (not caused by a WIM scale calibration drift) is based on the observation that axle weights that are not sensitive to payload have remained relatively unchanged, whereas the weight of loaded axles has gradually declined. For example, the second peak of the single axle load spectra (top chart in figure 13) can be attributed principally to the steering axle of heavy trucks. The load on the steering axle of these trucks is relatively insensitive to the load carried and has remained substantially unchanged over recent years. Similarly, the first peak for tandem axles (middle chart in figure 13), which corresponds to unloaded tandem axles, has also remained unchanged. On the other hand, the second peak for tandem axles, corresponding to loaded payload-carrying tandem axles, gradually declined.

It is possible that the historical decline in axle weights reflected in the decline in ESALs per truck is the result of deregulation process of the motor carrier industry and the emergence of low-weight high-value freight.[15]

063042 Annual Traffic Projection Sheet



Data Type		Availability of Monitoring Data									
		1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
AVC	Days	0	153	127	79	78	161	170	163	135	931
	Month	12	8	10	11	–	–	–	–	–	41
WIM	Days	34	185	66	85	85	164	174	165	140	958
	Month	5	12	10	11	–	–	–	–	–	38

Figure 18. Annual Traffic Projection Sheet for site 063042.

Additional considerations that lead to the assignment of the IA code included:

- Three well-defined peaks for annual load spectra for single axles (first part of figure 13). The first peak at about 1,816 kg (4,000 lb) corresponds to Class 5 vehicles (2-axle single unit trucks), the second peak at about 4,994 kg (11,000 lb) to steering axles of Class 9 vehicles, and the third peak corresponds to load axles of Class 9 vehicle consisting of a 3-axle single unit truck pulling a 2-axle trailer (a truck type common on some highways in California).
- Clearly defined and logical trend in historical and monitoring AADT truck volumes (first part of figure 18).
- Correspondence between historical and monitoring TFs (second part of figure 18).
- Relatively small number of triple axles that had been gradually increasing over the years.

Guidelines for Assigning IN Codes

The IN code means that the axle load projections were not carried out at this time because of lack of site-specific axle load data. For some sites, the IN code was assigned because there were no site-specific axle load data. For other sites, there were axle load data, but the data were questionable to the degree that it appeared probable that better traffic load estimates could be provided by using surrogate (regional or generic) axle load data rather than by using the available site-specific axle load data. However, for all sites with historical or monitoring truck volume data, but without axle weight data, annual truck volume projections were still carried out for all in-service years. The exceptions were four Specific Pavement Section (SPS)-8 sites (environmental sites with little or no truck traffic).

Because both truck volumes and axle load data were used for the projection of traffic loads, a site could be assigned the IN code due to inadequacies in: (a) truck volume data alone; (b) axle load data alone; or (c) the combination of truck volume and axle load data. However, the situations where the IN code was assigned primarily because of inadequacies in truck volume data were rare. The typical reason for assigning the IN code was the combination of truck volume and axle load data inadequacies, with the inadequacies in axle load data predominating.

The guidelines for assigning IN code do not enumerate all possible combinations of truck volume, truck distribution, and axle load data inadequacies. The principal consideration in assigning the IN code was the judgment whether the traffic projection using the available site-specific data would be likely to provide better results than could be obtained using surrogate traffic data.

Truck Volume—Typical problems encountered included large differences between historical and monitoring truck volumes and/or large variation in monitoring truck volumes, making the estimates of annual truck volumes unreliable.

Truck Classification—The truck distribution could exhibit any combination of the following problems:

- Unexpected truck distribution considering the highway functional type. For example, a higher percentage of four-or-less-axle single trailer trucks (class 8) than of five-axle single trailer trucks (class 9) on a rural interstate.
- Highly variable annual truck distributions, with no single annual distribution that could be identified as being correct or expected.
- A large number of unclassified vehicles, sometimes exceeding 50 percent.

Axle Weights—Conditions that characterized axle load spectra that were considered to be inadequate, and that were not used for the projection, included:

- Disjointed truck class distribution and axle load distribution data. For example, axle load spectra for single and tandem axles would appear as flat lines while the truck class distribution would indicate that the predominant truck type was Class 9.
- A large variation in annual axle load spectra, but without a year for which the annual axle load spectrum could be considered appropriate. For example, for a 4-lane highway, an annual tandem axle load spectrum would have only 10 percent of axles weighing more than 6,810 kg (15,000 lb) one year, whereas the next year 50 percent of tandem axles would be more than 15,463 kg (34,000 lb).
- Monitoring TFs appeared to be unreasonable judging by (a) historical TFs and (b) TFs obtained on similar sites. For example, a monitoring TF for an interstate would be less than 0.2, while the corresponding historical TF would be 1.2 (reported by an agency that provided historical TFs that have been, in general, in good agreement with monitoring TFs), and the monitoring TFs obtained for similar sites (for the same agency and the same pavement type) were in the range of 0.8 to 1.3.

Example of Assigning IN Code—The shape of the annual axle load spectra presented in figure 16 was the main reason the IN code was assigned to site 473104 and no axle load projections were done for this site. The annual axle load spectra shown in figure 16 exhibit considerable variation. For example, the 1992 TF was about 0.1, while the 1996 factor was about 4.0. Truck volume projections were still carried out and are shown in figure 19.

Guidelines for Assigning IQ Codes

The IQ code was assigned to sites with traffic data characteristics falling between IA and IN characteristics. In other words, the projected traffic loads were probably better than the estimates based entirely on surrogate axle load data but not as good as the IA results. Cumulative ESAL estimates were probably typically within ±100 percent of the actual ESALs.

Example of Assigning IQ Code—The assignment of IQ codes is illustrated using examples for sites 285805 (figure 8) and 124057 (figure 15).

The main reason for assigning the IQ code to site 285805 was inconsistencies in annual axle load spectra. The peak of single axle load spectra for all years was below 4,540 kg (10,000 lb) (figure

8), even though about 65 percent of all trucks were Class 9 trucks (figure 7). It was unclear whether the 1996 tandem axle load spectra were better than the spectra for the remaining years (1992 to 1995). The annual truck traffic projection model followed the trend set by the monitoring truck volumes (figure 6).

The shape of the annual axle load spectra for site 124057, presented in figure 15, was not the main reason the IQ code was assigned to this site. The 1991 and 1992 spectra appear to be reasonable even though their peaks for single axle loads at about 3,632 kg (8,000 lb) were lower than expected. The main reason was the uncertainty regarding the projection of truck volumes (see figure 17). According to figure 17, the initial truck volume projection was based on historical data and on estimated monitoring data only. The monitoring truck volumes show a decline between 1992 and 1998.

Concluding Remarks

The projection confidence codes are subjectively assigned indicators of the reliability of traffic load estimates. The codes may change if more data become available, or a different interpretation of the data is made. The initial codes may also change after the initial traffic projections are reviewed by the agencies. For example, the initial IQ code for site 285805 was changed to IA based on the review of the initial projection provided by a representative of the Mississippi DOT. The review confirmed the legitimacy of 1996 axle load spectra (figure 8) and the appropriateness of the initial truck volume projection (figure 6).

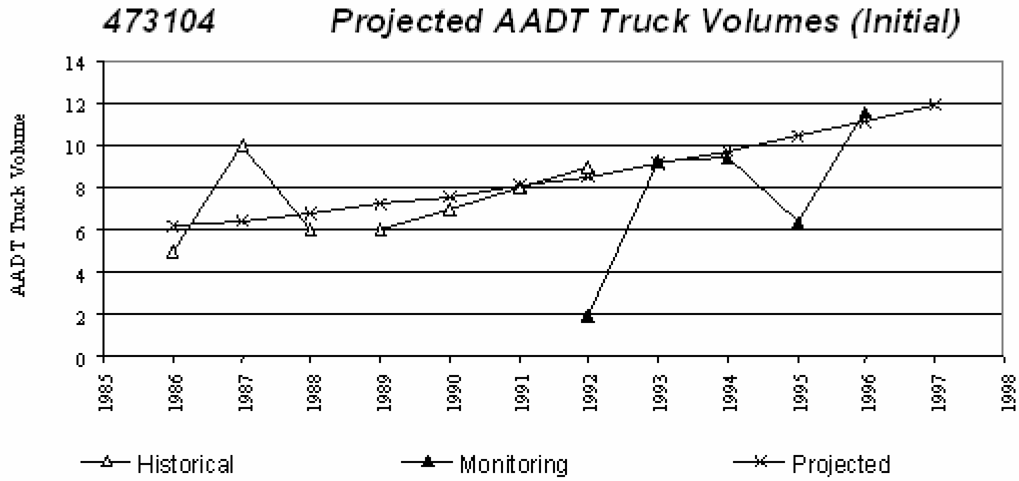
<u>Computation of Annual Axle Load Spectra</u>

The computation of annual axle load spectra was carried out using a procedure outlined by equation 1. In addition, for QC purposes, annual ESALs and cumulative ESALs were also calculated using projected axle load spectra and compared with historical and monitoring ESALs, as shown in figure 10.

Step 6—Review of LTPP Traffic Feedback and Resolution Packages by RCOs

The collection of traffic data on LTPP sites has been the responsibility of the participating agencies. However, throughout the LTPP program, RCOs have been responsible for many activities concerning traffic data, such as:

- Communicating the LTPP traffic data collection requirements to the participating agencies.
- Providing technical assistance to the agencies regarding traffic data collection and traffic data handling and reporting.
- Providing QA for traffic data supplied by the participating agencies.
- Inputting and storing traffic data in the regional traffic database.



Year	AADT Truck Volumes			Projected Growth	
	Historical	Monitoring	Projected	Percentage	Factor
1986	5	–	6	–	0.91
1987	10	–	6	5.1	0.96
1988	6	–	7	5.3	1.01
1989	6	–	7	5.6	1.07
1990	7	–	8	5.8	1.13
1991	8	–	8	6.0	1.20
1992	9	2	9	6.3	1.27
1993	–	9	9	6.5	1.36
1994	–	9	10	6.7	1.45
1995	–	6	10	6.9	1.55
1996	–	12	11	7.1	1.66
1997	–	–	12	7.3	1.78
1998	OUT OF STUDY: 02/07/1997				

Figure 19. Projected AADT truck volumes (initial) for site 473104.

Because RCOs are responsible for communicating with participating agencies and have detailed knowledge of local traffic data and issues acquired through long-standing cooperation with local agencies, the LTPP Traffic Feedback and Resolution Packages were first sent to RCOs for review and comments. Representatives of RCOs reviewed the packages, often providing written comments to the project team, and chose one of the following alternatives:

- Sending the package to the agency with a standard introductory letter that asked the agency to review the package and respond to questions. The introductory letter became part of the package as outlined in the section describing the content of the package. About 60 percent of the packages were sent this way.
- Sending the package to the agency using an introductory letter that provided additional information to the agency regarding traffic data. Typically, this information was about traffic data that were not included in site-specific reports (because the data had not yet reached the IMS database). Some RCOs also included handwritten notes on the packages.

- Asking the project team for explanation or for modifications in the package before sending it to the agencies. Typically, modifications requested by RCOs concerned the initial overall feedback and resolution report. About 15 percent of the packages were modified by the project team after initial submission to the RCOs. Once the explanation and modifications were provided to the satisfaction of the RCOs, the RCOs sent the packages to the participating agencies for review.

Step 7—Review of LTPP Traffic Feedback and Resolution Packages by Participating Agencies

It was recognized early in Phase 1 that the involvement of the participating agencies in the traffic data assessment and traffic load projection process would be essential for meeting the project objectives. Specific issues requiring local agency involvement included trends in annual historical and monitoring truck volumes, changes in local traffic patterns due to changes in highway network, influence of predominant single-commodity traffic, existence of local truck weight and size regulations and truck operating permits, and the availability of local QA/QC information.

All LTPP Traffic Feedback and Resolution Packages were sent to the participating agencies by the end of March 2001. By the end of May 2001, the project team received responses from about 40 percent of participating agencies. These responses varied considerably. Some reviews may not have been as useful as was originally anticipated, while others were very useful, insightful, and even included additional supplemental traffic data.

Representatives of the participating agencies were asked specifically to respond to two items of the LTPP Traffic Feedback and Resolution Package: the initial overall feedback and resolution report and the Blue Sheet (figure 3) that was part of the initial site-specific report.

The initial overall feedback and resolution report contained general questions regarding the procedures used to classify vehicles and to measure axle loads; responses varied considerably. Regarding vehicle classification, some agencies assigned unclassified vehicles proportionally to all vehicle classes unless there was a clear indication that a Class 14 vehicle belonged to a particular class. Other agencies simply reported the existence of Class 14 vehicles. Regarding WIM calibration procedures, some agencies attempt to carry out periodic verification of the accuracy of WIM scales, while others had not calibrated their scales beyond the initial calibration. Some agencies reviewed traffic data before their submission to RCOs and some did not.

The Blue Sheet was the main means of communication between the participating agencies and the project team; it contains seven parts (figure 3):

- The first part solicits additional information on truck volumes.

- The second part concerns the existence of single commodity traffic on the LTPP site. With very few exceptions, the LTPP sites were not exposed to single or predominant commodity traffic.

- The third part enquires about the existence of additional traffic data, other than the one submitted to LTPP, that may be useful for traffic data assessment and projection of traffic loads. This question was probably not specific enough because most respondents answered that no additional data existed. However, most agencies have extensive traffic databases that may yield useful information.

- The fourth part asked the agencies to comment on four specific traffic data characteristics. These characteristics were selected to provide an overall assessment of traffic loads and to motivate the reviewer to compare the reported LTPP data with data from other sources. The question regarding the 1998 truck percentage was included to obtain verification of truck volumes based on AADT volumes.

- The fifth part was used to solicit an agency's response to specific observations and questions. For some sites, the responses to the observations and questions were used to change the initial projection confidence codes.

- The sixth part asked the reviewer to provide an opinion regarding the accuracy of historical and monitoring traffic data. The respondent for site 285805 (figure 3) felt that the accuracy of both the historical and monitoring traffic data were similar (good).

- The seventh part solicited the reviewer's opinion for improving the quality of traffic data. Typical responses included the installation of new traffic data collection equipment and the calibration of WIM scales.

Step 8—Implementation of Review Comments Received from Participating Agencies

This last activity consisted of three tasks:

- Responding to agencies.
- Preparation of revised projections.
- Placing traffic data into computed parameter tables.

Responding to Agencies

A response letter was prepared for each agency that provided a review of the LTPP Traffic Feedback and Resolution Package. The response letter included a listing of specific changes, if any, that were made to the initial projections based on the agency's recommendations.

Preparation of Revised Projections

The preparation of revised projections also included the assignment of revised projection confidence codes. The revised projection confidence codes were assigned using the same guidelines as those used for the assignment of the initial projection confidence codes, but also utilized information supplied by the participating agencies.

Based on the comments received from the agencies, about 10 percent of the initial projections were revised and about 15 percent of the initial projection confidence codes were changed. Typically, the change was from “questionable” to “acceptable” code.

Placing Projected Traffic Data into Computed Parameter Tables

The projected traffic data that were placed into the computed parameter tables (these tables will become a part of the IMS database) included traffic projections with both acceptable and questionable projection confidence codes, whether or not they had been reviewed by the participating agencies. The projection confidence code and the review status information were included in the database. The description of computed parameter tables used to store the projected traffic data is provided in chapter 4.

CHAPTER 3. RESULTS OF DATA ASSESSMENT AND TRAFFIC PROJECTION

This chapter describes the results of traffic data assessment and traffic projection activities carried out using the procedures presented in chapter 2. The following are provided:

- *Projected axle load spectra for all in-service years*. The main product of the study is traffic axle load projections that were developed for all in-service years for 558 of the 890 LTPP traffic sites processed during the study. The axle load projections were expressed as annual axle load spectra for single, tandem, and triple axles, and were placed into the IMS computed parameter tables. Storage of the projected axle load spectra in the computed parameter tables and computational procedures used to generate the spectra are described in chapter 4.
- *Summary results*. Summary results of the traffic data assessment and projection process are described in this chapter. The objective of presenting the summary results is to provide information on the overall scope and quality of LTPP traffic data, to summarize the availability of traffic projections for different categories of sites, and to describe historical trends regarding the amount and quality of monitoring traffic data.
- *Summary results for individual sites*. Summary results for each of the 890 LTPP traffic sites processed during the study are provided in appendix A. Appendix A contains a table that provides, for each of the 890 LTPP traffic sites, site-specific information on the availability of traffic data, traffic projection results, and traffic characteristics.

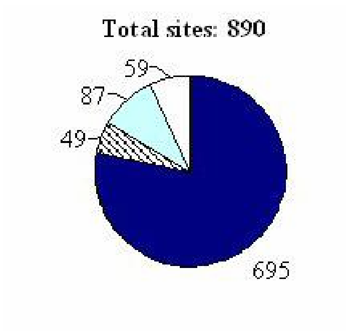
Availability of Traffic Projections

The traffic data assessment process distinguished between the traffic data that were included in the IMS database and the traffic data that were of sufficient quality to be used for the projection. Figure 20 compares the distribution of the 890 sites according to: (a) data presence in the database; (b) data availability for the projection; and (c) data quality. For the total of 890 LTPP sites, 695 (78 percent) had some monitoring axle weight, vehicle class, and truck volume data in the database. However, of the 695 sites, only 543 (61 percent of the total of 890 sites) had data of sufficient quality to be used for the projection of axle loads. Of these 543 sites, only 194 sites (21.8 percent of the total 890 sites) had traffic load projections that were assigned an acceptable projection confidence code.

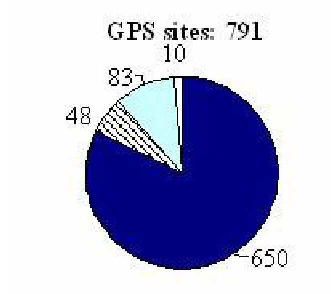
For 650 General Pavement Section (GPS) sites, 650 sites had monitoring axle weight data in the database, and 511 sites had data suitable for the projection. Of the 99 SPS sites, 45 had monitoring axle weight, vehicle class, and truck volume data in the database; 32 had data of sufficient quality to be used for the projection of axle loads; and only 10 sites (of the 99 total SPS sites) were judged to have an acceptable projection confidence code.

For 15 LTPP sites without axle load data in the database, axle load projections were carried out using data from adjacent sites. Thus, altogether, axle load projections were carried out for 558 sites: the 543 sites with their own data of sufficient quality for projections plus the 15 sites for which data from adjacent sites were used.

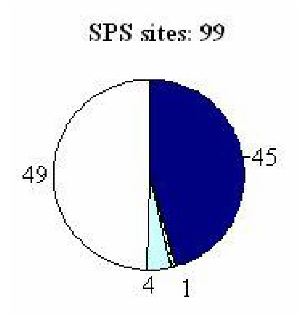
Data Presence



a. Data presence total sites.

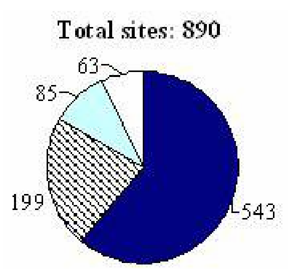


b. Data presence GPS sites.

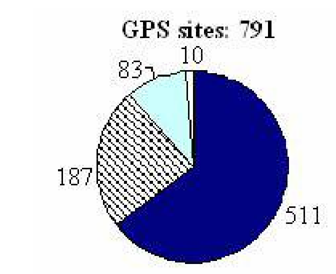


c. Data presence SPS sites.

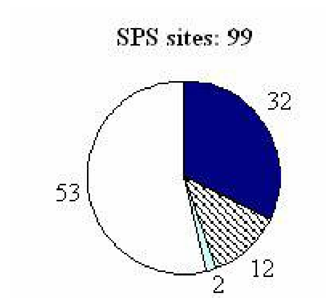
Data Usability for Projection



d. Data usability total sites.

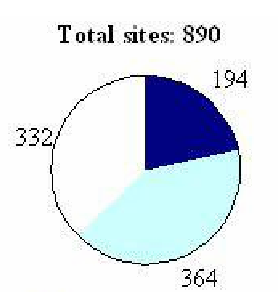


e. Data usability GPS sites.



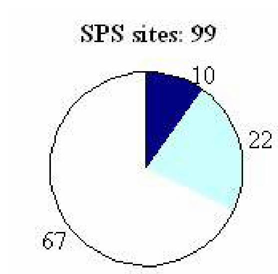
f. Data usability SPS sites.

Data Quality for Projection



g. Data quality total sites.

h. Data quality GPS sites.



i. Data quality SPS sites.

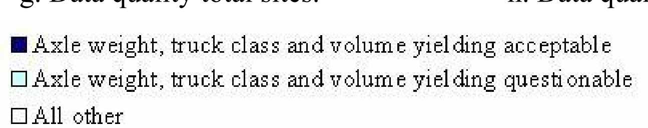


Figure 20. Summary of LTPP sites sorted by data presence and data usability for projection.

The availability of traffic projections for the LTPP sites is also summarized in table 7. Of the 890 sites, 194 (21.8 percent) were assigned an acceptable projection confidence code and 364 (40.9 percent) were assigned a questionable projection confidence. For 269 sites (30.2 percent), only the projection of annual truck volumes was provided, and for 63 sites (7.1 percent), no traffic projections were carried out because of lack of data.

Table 7. Availability of traffic projections.

Projection Result	**All Sites**		**All Sites**		**GPS**		**SPS**	
	No. of Sites	**%**	**No. of Sites**	**%**	**No. of Sites**	**%**	**No. of Sites**	**%**
Acceptable	194	21.8	558	62.7	184	23.3	10	10.1
Questionable	364	40.9			342	43.2	22	22.2
Truck Volume	269	30.2	332	37.3	255	32.2	14	14.1
None	63	7.1			10	1.3	53	53.5
TOTAL	890	100	890	100	791	100	99	100

Projection Results:

Acceptable = projection confidence code was "Initial Acceptable" or "Reviewed Acceptable";
Questionable = projection confidence code was "Initial Questionable" or "Reviewed Questionable";
Truck Volume = only the projection of annual truck volumes was carried out;
None = no traffic projection was carried out.

Considering that only about 23 percent of all GPS sites and about 10 percent of all SPS sites had acceptable axle load estimates, greater attention should be paid to the quality of traffic data. About 37 percent (332 sites) of all sites had insufficient site-specific truck class and/or axle weight distribution data to carry out axle load projections. To obtain axle load estimates for these 332 sites, new traffic monitoring data must be collected or surrogate data must be used. Chapter 5 outlines the proposed LTPP PLG that would facilitate the projection of traffic loads for these sites.

The projection results provided here are for LTPP sites with unique traffic identification numbers. The total number of all LTPP *sections* is larger than the number of the LTPP *sites* because one site may provide traffic data for several sections.

Table 8 shows the availability of traffic projections by the experiment type and the projection confidence code. For the GPS experiment types with more the 10 sites, the percentage of sites without axle load projections (projection confidence code N) ranges from 16.1 percent for GPS-7B to 40.8 percent for GPS-6A. As already indicated in figure 20, the percentage of sites without traffic projections is higher for SPS experiments than for GPS experiments.

Table 8. Availability of traffic projections by experiment type and projection confidence code.

Experiment Type	Total Number of Sites	Projection Confidence Code					
		A		Q		N	
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	Number of Sites	Percent of Sites
GPS-1	161	29	18.0	69	42.9	63	39.1
GPS-2	90	11	12.2	43	47.8	36	40.0
GPS-3	129	42	32.6	46	35.7	41	31.8
GPS-4	53	14	26.4	29	54.7	10	18.9
GPS-5	72	21	29.2	31	43.1	20	27.8
GPS-6A	49	8	16.3	21	42.9	20	40.8
GPS-6B	83	12	14.5	38	45.8	33	39.8
GPS-6C	14	5	35.7	5	35.7	4	28.6
GPS-6D	4	1	25.0	1	25.0	2	50.0
GPS-6S	43	12	27.9	17	39.5	14	32.6
GPS-7A	22	7	31.8	11	50.0	4	18.2
GPS-7B	31	11	35.5	15	48.4	5	16.1
GPS-7C	1	1	100.0	–	–	–	–
GPS-7D	2	–	–	2	100.0	–	–
GPS-7S	11	4	36.4	4	36.4	3	27.3
GPS-9	26	6	23.1	10	38.5	10	38.5
SPS-1	18	2	11.1	5	27.8	11	61.1
SPS-2	13	2	15.4	5	38.5	6	46.2
SPS-4	2	–	–	–	–	2	100.0
SPS-5	12	2	16.7	4	33.3	6	50.0
SPS-6	12	3	25.0	5	41.7	4	33.3
SPS-7	4	1	25.0	2	50.0	1	25.0
SPS-8	16	–	–	–	–	16	100.0
SPS-9	22	–	–	1	4.5	21	95.5
TOTAL	890	194	21.8	364	40.9	332	37.3

The availability of traffic projections for LTPP sites according to the highway functional classification is presented in table 9. Of the 890 total sites, 635 (71.3 percent) are located on rural interstates or on rural principal arterial highways. Typically, highway functional classes that are expected to have large truck volumes have the higher percentage of sites with the acceptable projection confidence code. For example, 34.8 percent of all sites on rural interstates had an acceptable projection confidence code, while only 6.9 percent of the sites on rural minor arterial highways were in the acceptable category. This trend is likely caused by larger samples of trucks weighted on major highways, and by the inclination of the participating agencies to install traffic monitoring equipment on major highways rather than on local highways.

The presence of different types of traffic data for sites located in the four LTPP regions is summarized in table 10. More than 70 percent of sites for all LTPP regions had monitoring axle weight, truck class, and truck volume data. The availability of traffic projections in the four regions is shown in table 11. The highest percentage of sites with acceptable axle load projections was in the Western region (29.4 percent); the lowest percentage (12.1 percent) was in the Southern region. The percentage of sites without traffic load projection ranged from about 30 in the North Central region to 45 in the Southern region.

Table 9. Availability of traffic projections by highway functional class and projection confidence codes.

FHWA Highway Functional Class	Total Number of Sites	Projection Confidence Code					
		A		Q		N	
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	Number of Sites	Percent of Sites
Rural Principal Arterial—Interstate	282	98	34.8	104	36.9	80	28.4
Rural Principal Arterial—Other	353	62	17.6	157	44.5	134	38.0
Rural Minor Arterial	72	5	6.9	43	59.7	24	33.3
Rural Major Collector	19	2	10.5	8	42.1	9	47.4
Rural Minor Collector	3	–	–	1	33.3	2	66.7
Rural Local Collector	8	–	–	–	–	8	100.0
Urban Principal Arterial—Interstate	56	13	23.2	23	41.1	20	35.7
Urban Principal Arterial—Other Freeways or Expressways	24	6	25.0	8	33.3	10	41.7
Urban Other Principal Arterial	42	7	16.7	19	45.2	16	38.1
Urban Minor Arterial	4	1	25.0	1	25.0	2	50.0
Urban Collector	2	–	–	–	–	2	100.0
Unclassified	25	–	–	–	–	25	100.0
TOTAL	890	194	21.8	364	40.9	332	37.3

Table 10. Presence of traffic data by LTPP region.

LTPP Region	Total Number of Sites	Sites with Traffic Data				Sites with No Traffic Data
		Weight, Class, and Truck Volumes		Only Class and Truck Volumes	Only Historical Truck Volumes	
		Number	%			
North Atlantic	149	117	78.5	2	21	9
North Central	247	207	83.8	6	12	22
Southern	290	230	79.3	30	8	22
Western	204	141	69.1	11	46	6
TOTAL	890	695	78.1	49	87	59

Table 11. Availability of traffic projections by LTPP region and projection confidence codes.

LTPP Region	Total Number of Sites	Projection Confidence Code					
		A		Q		N	
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	Number of Sites	Percent of Sites
North Atlantic	149	39	26.2	57	38.3	53	35.6
North Central	247	60	24.3	114	46.2	73	29.6
Southern	290	35	12.1	125	43.1	130	44.8
Western	204	60	29.4	68	33.3	76	37.3
TOTAL	890	194	21.8	364	40.9	332	37.3

The availability of traffic projections for all participating agencies, in terms of projection confidence codes, is summarized in table 12. For agencies with 10 or more LTPP sites, the percentage of sites with the acceptable projection confidence code ranged from 1.1 percent in Texas to 79.3 percent in Arizona.

Table 12. Availability of traffic projections by participating agencies and projection confidence codes.

State/Province	Total Number of Sites	Projection Confidence Code					
		A		Q		N	
		Number of Sites	Percent of Sites	Number of Sites	Percent of Sites	Number of Sites	Percent of Sites
Alabama	19	3	15.8	10	52.6	6	31.6
Alaska	6	–	–	6	100.0	–	–
Arizona	29	23	79.3	5	17.2	1	3.4
Arkansas	19	7	36.8	7	36.8	5	26.3
California	38	9	23.7	12	31.6	17	44.7
Colorado	20	1	5.0	8	40.0	11	55.0
Connecticut	5	1	20.0	2	40.0	2	40.0
Delaware	7	–	–	–	–	7	100.0
District of Columbia	1	–	–	–	–	1	100.0
Florida	33	–	–	21	63.6	12	36.4
Georgia	24	–	–	1	4.2	23	95.8
Hawaii	4	–	–	–	–	4	100.0
Idaho	13	3	23.1	10	76.9	–	–
Illinois	19	10	52.6	7	36.8	2	10.5
Indiana	18	6	33.3	9	50.0	3	16.7
Iowa	16	1	6.3	7	43.8	8	50.0
Kansas	19	–	–	10	52.6	9	47.4
Kentucky	7	2	28.6	4	57.1	1	14.3
Louisiana	4	–	–	2	50.0	2	50.0
Maine	8	–	–	–	–	8	100.0
Maryland	6	1	16.7	–	–	5	83.3
Massachusetts	3	–	–	1	33.3	2	66.7
Michigan	17	2	11.8	13	76.5	2	11.8
Minnesota	36	21	58.3	8	22.2	7	19.4
Mississippi	28	14	50.0	8	28.6	6	21.4
Missouri	27	1	3.7	20	74.1	6	22.2
Montana	10	–	–	–	–	10	100.0
Nebraska	17	10	58.8	6	35.3	1	5.9
Nevada	11	6	54.5	4	36.4	1	9.1
New Hampshire	1	–	–	–	–	1	100.0
New Jersey	10	3	30.0	4	40.0	3	30.0
New Mexico	16	2	12.5	7	43.8	7	43.8
New York	7	1	14.3	3	42.9	3	42.9
North Carolina	27	5	18.5	17	63.0	5	18.5
North Dakota	5	–	–	3	60.0	2	40.0
Ohio	14	3	21.4	6	42.9	5	35.7

Table 12. Availability of traffic projections by participating agencies and projection confidence codes (continued).

State/Province	Total Number of Sites	Projection Confidence Code					
		A		Q		N	
		Number Of Sites	Percent of Sites	Number Of Sites	Percent of Sites	Number of Sites	Percent of Sites
Oklahoma	23	7	30.4	8	34.8	8	34.8
Oregon	12	7	58.3	4	33.3	1	8.3
Pennsylvania	21	11	52.4	9	42.9	1	4.8
Rhode Island	1	–	–	1	100.0	–	–
South Carolina	9	–	–	7	77.8	2	22.2
South Dakota	16	1	6.3	2	12.5	13	81.3
Tennessee	16	1	6.3	10	62.5	5	31.3
Texas	95	1	1.1	44	46.3	50	52.6
Utah	15	–	–	–	–	15	100.0
Vermont	5	3	60.0	2	40.0	–	–
Virginia	13	6	46.2	5	38.5	2	15.4
Washington	21	9	42.9	9	42.9	3	14.3
West Virginia	5	3	60.0	–	–	2	40.0
Wisconsin	22	3	13.6	11	50.0	8	36.4
Wyoming	14	2	14.3	10	71.4	2	14.3
Puerto Rico	4	–	–	–	–	4	100.0
Alberta	7	–	–	–	–	7	100.0
British Columbia	4	–	–	–	–	4	100.0
Manitoba	6	–	–	4	66.7	2	33.3
New Brunswick	4	–	–	3	75.0	1	25.0
Newfoundland	3	–	–	–	–	3	100.0
Nova Scotia	1	1	100.0	–	–	–	–
Ontario	7	1	14.3	3	42.9	3	42.9
Prince Edward Island	3	–	–	2	66.7	1	33.3
Quebec	11	3	27.3	5	45.5	3	27.3
Saskatchewan	8	–	–	4	50.0	4	50.0
TOTAL	890	194	21.8	364	40.9	332	37.3

The geographical distribution of the LTPP sites with the acceptable projection confidence code is shown in figure 21. In addition, the sites in figure 21 were identified as “Urban” or “Rural,” depending on their highway functional class. Because there were no sites with the acceptable projection confidence code in Alaska, Hawaii, Puerto Rico, and most of the Canadian provinces, these jurisdictions were not included in the figure 21.

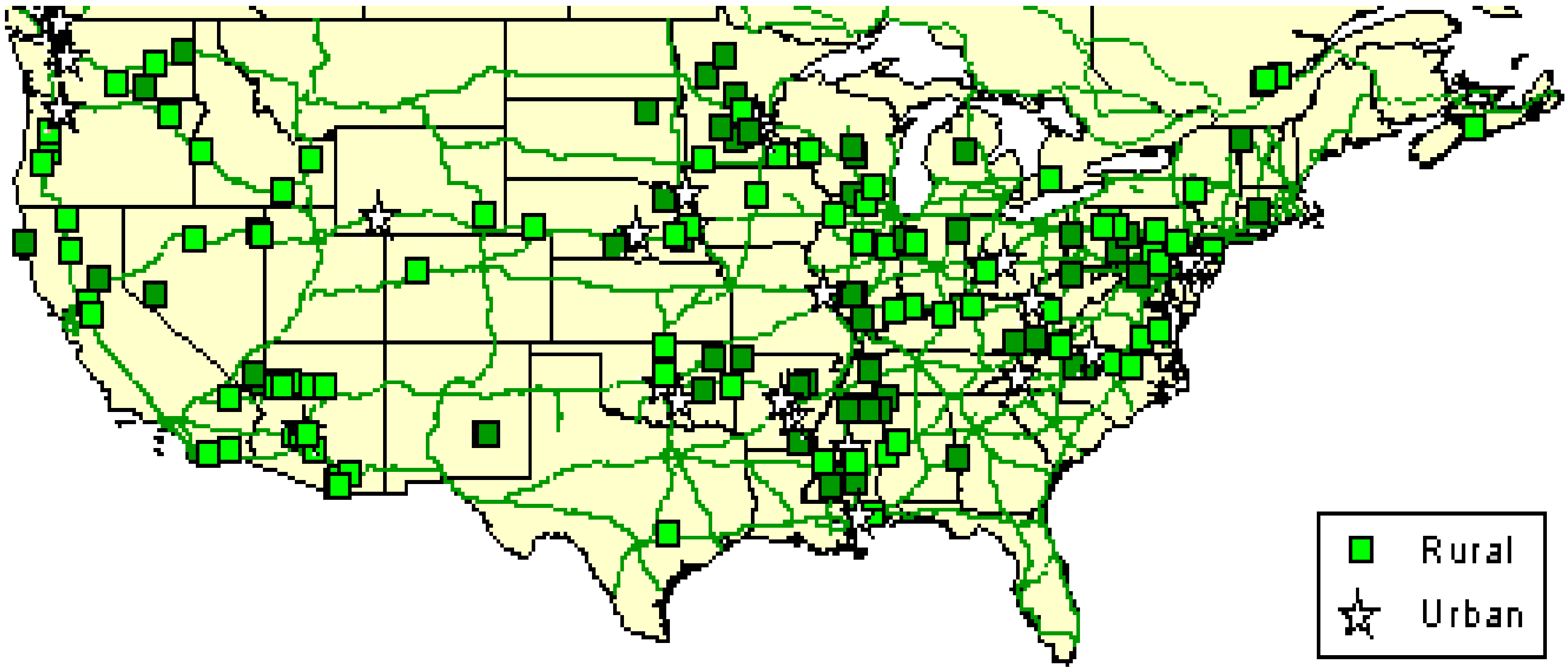


Figure 21. Geographical distribution of LTPP sites with acceptable projection confidence codes.

Scope of the LTPP Traffic Data

Table 13 provides an overview of the traffic characteristics for the 558 LTPP sites with the acceptable and questionable projection confidence codes.

The minimum AADT truck volume ranges from 30 trucks per day for a site located on rural minor collector highways to 6310 trucks per day for a site located on an urban interstate. The mean annual growth of truck volumes during the period of 1994 to 1998, disregarding one site on rural minor collector highway, ranged from 6.5 percent for urban freeways and expressways to 3.0 percent for rural minor arterial highways.

The TFs provided in table 13 show considerable variation within different highway functional classes, particularly for interstates and principal arterial highways. A part of the variation in TFs can be attributed to the influence of the site-specific pavement type and pavement thickness used in the ESAL calculation.

The vehicle class distribution for LTPP sites with acceptable and questionable projection confidence codes for different highway functional classes is shown in table 14 and in figures 22 and 23. (Vehicle classes were defined in table 1.) As expected, Class 9 vehicles (5-axle single trailer trucks) dominate vehicle class distribution on interstates and other major highways. On rural major collector and rural minor arterial highways, the dominant truck class is 5 (2-axle single unit trucks).

Of the 10 vehicle classes representing buses and trucks, classes 5, 6, 8, and 9 typically account for more than 90 percent of all vehicles. Vehicles in the remaining classes (4, 7, 10, 11, 12, and 13) are typically less than 3 percent, on average.

Table 14 also shows the mean and standard deviation (SD) for unclassified vehicles (Vehicle Class 14). The mean number of unclassified vehicles has not exceeded 7 percent for any functional class. However, the percentage of unclassified vehicles on some individual sites and for some years was considerably higher. Also, data presented in table 14 are only for sites with acceptable and questionable projection confidence codes.

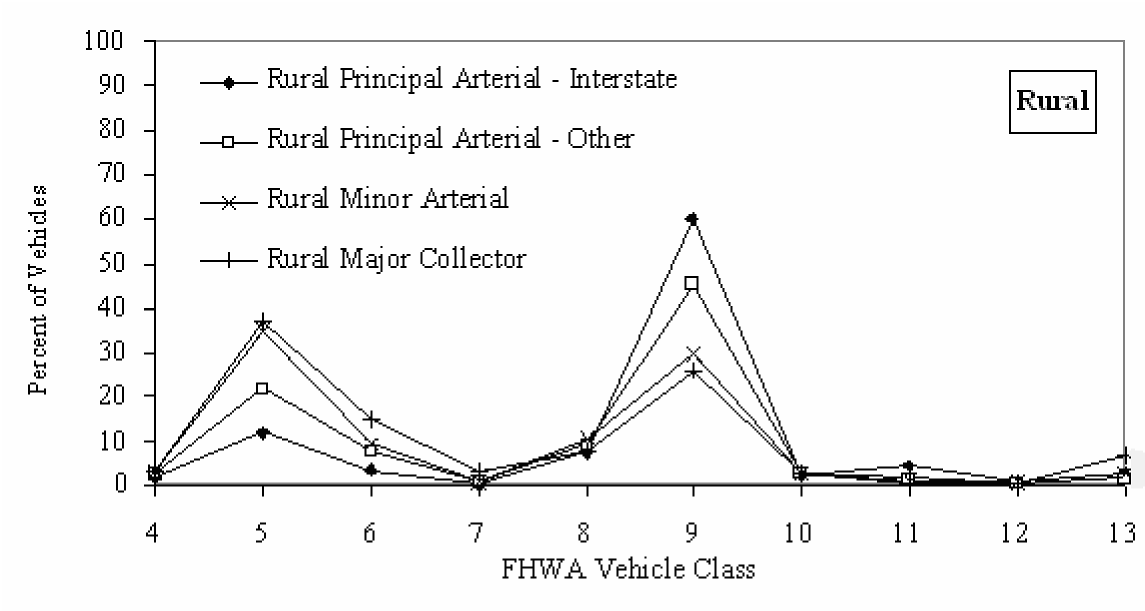
Vehicle classification data presented in table 14 and in figures 22 and 23 are useful for assessing whether the truck distribution data are reasonable and for estimating truck class distributions if site-specific data are not available.

Table 13. Traffic characteristics of LTPP sites with acceptable and questionable projection confidence codes.

AADT Truck Volumes (1998 or Last Projection Year)					
FHWA Highway Functional Class	**Number of Sites**	**Mean**	**Standard Deviation (SD)**	**Min.**	**Max.**
Rural Principal Arterial—Interstate	202	1921	1027	160	5340
Rural Principal Arterial—Other	219	558	467	50	4320
Rural Minor Arterial	48	338	274	30	1100
Rural Major Collector	10	178	151	50	540
Rural Minor Collector	1	90	n/a	90	90
Urban Principal Arterial—Interstate	36	1821	1155	390	6310
Urban Principal Arterial—Other Freeways or Expressways	14	925	407	270	1490
Urban Other Principal Arterial	26	775	654	138	2920
Urban Minor Arterial	2	225	n/a	190	260
Annual Growth Rate in Truck Volumes (1994 to 1998)					
FHWA Highway Functional Class	**Number of Sites**	**Mean**	**SD**	**Min.**	**Max.**
Rural Principal Arterial—Interstate	202	4.6	3.8	-17.2	17.0
Rural Principal Arterial—Other	219	3.9	3.9	-10.8	21.2
Rural Minor Arterial	48	3.0	4.2	-13.8	14.1
Rural Major Collector	10	3.8	3.2	0.0	11.4
Rural Minor Collector	1	0.0	n/a	0.0	0.0
Urban Principal Arterial—Interstate	36	4.6	3.2	0.0	12.0
Urban Principal Arterial—Other Freeways or Expressways	14	6.4	5.3	1.2	22.0
Urban Other Principal Arterial	26	3.3	4.4	-7.5	11.4
Urban Minor Arterial	2	3.5	n/a	2.0	5.1
Truck Factor					
FHWA Highway Functional Class	**Number of Sites**	**Mean**	**SD**	**Min.**	**Max.**
Rural Principal Arterial—Interstate	202	1.3	0.5	0.4	3.0
Rural Principal Arterial—Other	219	0.9	0.5	0.2	4.8
Rural Minor Arterial	48	0.7	0.3	0.3	1.7
Rural Major Collector	10	0.8	0.4	0.3	1.5
Rural Minor Collector	1	0.8	n/a	0.8	0.8
Urban Principal Arterial—Interstate	36	1.1	0.4	0.5	2.1
Urban Principal Arterial—Other Freeways or Expressways	14	0.9	0.4	0.4	1.6
Urban Other Principal Arterial	26	0.9	0.4	0.2	2.5
Urban Minor Arterial	2	0.5	n/a	0.5	0.6

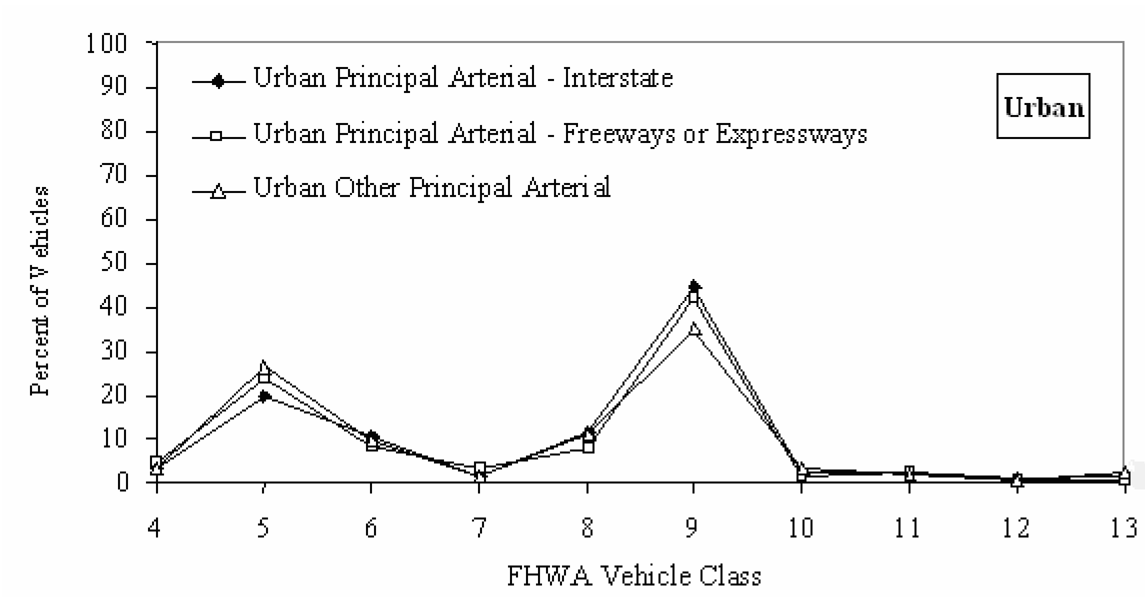
Table 14. Truck class distribution by highway functional classes for LTPP sites with acceptable and questionable projection confidence codes.

Highway Functional Class	Number of Sites	Statistic	Vehicle Class 4	5	6	7	8	9	10	11	12	13	14
Rural Principal Arterial—Interstate	202	Mean	1.7	12.3	3.7	0.4	7.8	60.3	2.4	4.6	1.1	2.9	1.9
		SD	1.6	8.7	3.4	0.7	4.8	17.0	4.4	3.7	1.6	5.1	5.9
Rural Principal Arterial—Other	219	Mean	2.6	21.9	7.5	0.8	9.3	45.2	2.8	1.8	0.5	2.0	5.4
		SD	3.4	12.3	5.6	1.3	6.0	17.9	4.3	4.5	0.8	4.0	11.8
Rural Major Collector	48	Mean	3.2	36.7	15.0	3.4	7.5	25.8	2.6	0.5	0.3	6.7	0.1
		SD	4.1	19.3	8.9	3.5	4.4	13.1	2.6	0.7	0.6	19.8	0.6
Rural Minor Arterial	10	Mean	3.2	35.2	9.2	1.0	10.6	29.5	2.5	1.3	1.1	2.8	4.7
		SD	3.8	21.5	5.9	1.0	8.3	16.7	3.2	2.8	6.6	5.1	8.1
Rural Minor Collector	1	Mean	2.0	22.2	7.2	0.0	13.9	54.2	0.5	0.0	0.0	0.0	0.0
Urban Principal Arterial—Interstate	36	Mean	3.2	19.6	10.3	1.3	11.3	44.6	2.3	2.1	0.8	1.3	3.2
		SD	2.6	12.2	8.1	1.7	10.0	16.8	2.6	1.9	1.8	2.8	9.4
Urban Principal Arterial—Other Freeways or Expressways	14	Mean	4.5	23.8	8.3	3.2	7.9	41.6	1.5	2.5	0.3	0.4	3.1
		SD	7.3	9.7	3.3	5.0	4.0	17.3	1.9	2.5	0.6	1.7	6.7
Urban Other Principal Arterial	26	Mean	3.0	26.5	9.6	1.3	11.0	35.2	3.0	1.8	0.5	2.4	4.8
		SD	2.6	15.1	5.5	1.5	8.0	15.5	3.4	2.0	0.8	3.4	10.9
Urban Minor Arterial	2	Mean	4.9	31.3	9.6	0.1	9.0	23.4	6.3	0.5	1.1	6.9	6.9



Note: Not included are rural minor collector and rural local collector because of insufficient data.

Figure 22. Mean vehicle class distribution for LTPP sites with acceptable and questionable projection confidence codes located on rural highways.



Note: Not included is urban minor arterial because of insufficient data.

Figure 23. Mean vehicle class distribution for LTPP sites with acceptable and questionable projection confidence codes located on urban highways.

Historical Trends in LTPP Traffic Data Quantity and Quality

A historical perspective on the availability of monitoring axle load data is provided in table 15 and figure 24. Table 15 shows the number of sites for which axle load distributions are stored in the IMS database for specific years, and the corresponding number of sites with axle load distributions that were used for the projection. For example, in 1993, there were 446 sites in the IMS database that had (monitoring) annual axle load spectra. Of these 446 sites, 94 (21.1 percent) have axle load spectra that could be used for projections yielding the acceptable projection confidenece code and 137 (30.7 percent) have axle load spectra yielding traffic projections with the Questionable projection confidence code. In total, 231 sites (51.8 percent) had axle load spectra yielding acceptable or questionable traffic projections.

Data given in table 15 are plotted in figure 24 to illustrate the overall historical trend in the available axle load spectra. After the peak of 446 sites was reached in 1993, the number of sites with existing axle load spectra declined to 287 sites in 1998. These numbers refer to the existence of the spectra only. The number of spectra that could be used for the projection of axle loads declined from the peak of 231 sections in 1993 to 150 sections in 1998. In other words, in 1998, of the 890 sites, only 150 (16.8 percent) had axle load spectra that could be used for projection of axle loads yielding acceptable or questionable projections. Only 51 sites in 1998 (5.7 percent of all sites) had axle loads yielding acceptable axle load projections.

The ratio between axle load spectra available in the database and the axle load spectra that were used for the projection has been relatively constant over the years and was in the range of about 52 to 56 percent. For example, in 1991, 201 sites had axle load spectra in the database; of these, 109 sites (54.2 percent) were used for the projection of axle loads. The corresponding percentage in 1998 was 52.3. In other words, just over 50 percent of annual axle load spectra obtained by WIM scale measurements could be used in the projection. That this percentage is not improving with time indicates the need to improve the quality of traffic data.

According to figure 20, 543 of 890 sites (61 percent) had axle load spectra yielding acceptable or questionable projections. This percentage is higher than the percentages reported in table 15. The higher percentages reported in table 7 resulted from combining several annual axle load spectra to obtain traffic projections for one site.

For the sites with acceptable and questionable projection confidence codes, the number of years with annual axle load data per site varied from 1 to 8. On average, about 4.5 years of annual data were available for each site, and about 2.8 years of annual data were used for the computation of the base annual spectra.

The steady decline in the amount of monitoring axle load data shown in figure 24 highlights the need for renewed data collection efforts. It also highlights the importance of traffic modeling and projections, and the need for the proposed LTPP PLG for estimating traffic loads on LTPP sites without site-specific truck class and axle load distributions.

Table 15. Availability of annual axle weight data and their use for projection.

Annual Axle Load Spectra		Number of Sites									
		1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**Total**
Available in IMS		58	201	314	446	410	412	383	370	287	2881
Used for Projection	Conf. Code A	9	33	76	94	109	106	88	82	51	648
	Conf. Code Q	17	76	93	137	120	124	112	121	99	899
	Total	26	109	169	231	229	230	200	203	150	1547
Total Percent Used for Projection		*44.8*	*54.2*	*53.8*	*51.8*	*55.9*	*55.8*	*52.2*	*54.9*	*52.3*	*53.7*

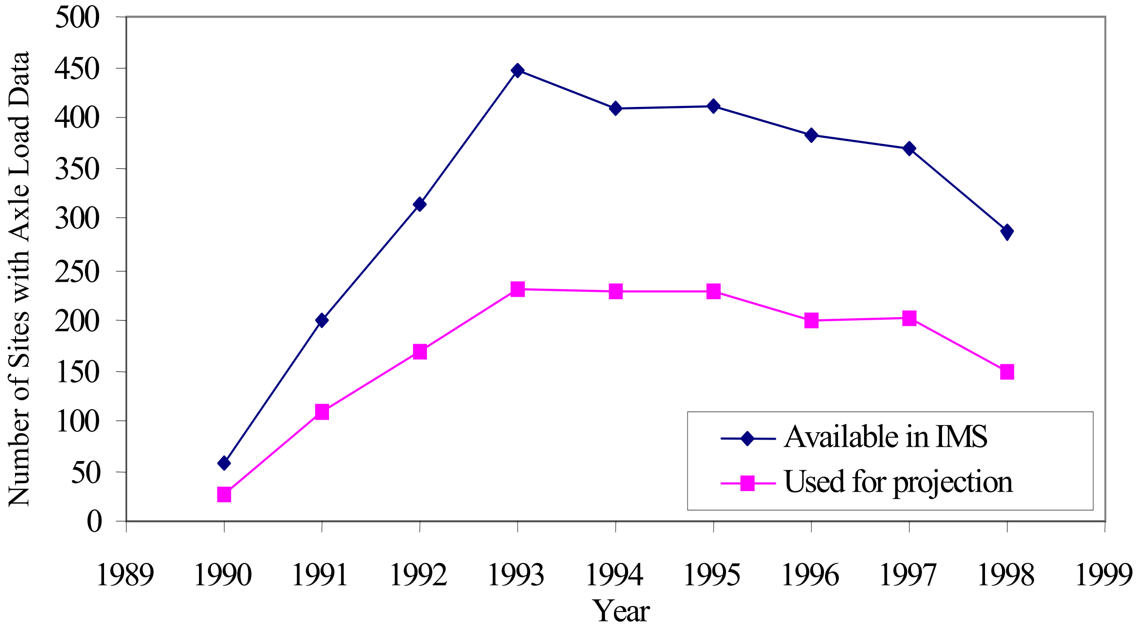


Figure 24. Trends in the number of monitoring axle load spectra.

Data Analysis/Operations Feedback Reports

Questionable or missing data identified during the study were reported to FHWA using data analysis/operations feedback reports. The feedback reports are not concerned with engineering validity of the data, but only with issues connected with data storage and operations. Table 16 provides a list of data analysis/operations items identified in the course of the study and provides recommendations to resolve problems.

Table 16. Summary of data analysis/operations feedback reports prepared during the study.

Report Number	Subject	Recommended Action
ERES_BW_82	"Zero" data in table TRF_MONITOR_AXLE_DISTRIB	(1) Use "null" data type for future data processing when no axle count data are available; (2) review records that are already in the IMS table TRF_MONITOR_AXLE_DISTRIB and eliminate years where all axle count records are set to "zero" or change data type from "zero" to "null."
ERES_BW_99	Multiple monitoring traffic data entries for the same year	The identified records with multiple entries should be deleted. Only records with the highest modification numbers should be left in IMS data tables.
ERES_BW_100	Missing data in the TRF_MONITOR_BASIC_INFO table	The identified records should be reviewed and either added to the TRF_MONITOR_BASIC_INFO table or excluded from the TRF_MONITOR_AXLE_DISTRIB and TRF_MONITOR_VEHICLE_DISTRIB tables.
ERES_BW_101	All-zero traffic data entries in the TRF_MONITOR_* tables	The identified records should be reviewed and either added to the TRF_MONITOR_BASIC_INFO table or excluded from the TRF_MONITOR_AXLE_DISTRIB and TRF_MONITOR_VEHICLE_DISTRIB tables.
ERES_BW_102	Missing records in TRF_EST_ANL_TOT_LTPP_LN table	RCOs should review the identified records and the TRF_EST_ANL_TOT_LTPP_LN table should be updated.
ERES_BW_103	Missing records in TRF_BASIC_INFO table	The identified GPS sites and SPS experiments should be reviewed by RCOs and the TRF_BASIC_INFO table should be updated.
ERES_BW_107	Sites with questionable pavement types in 1998 in table TRF_MONITOR_BASIC_INFO	The identified records should be reviewed and the IMS table TRF_MONITOR_BASIC_INFO should be updated.
ERES_BW_108	Sites with questionable class distribution in TRF_MONITOR_VEHICLE_DISTRIB table	The identified records should be reviewed and updated or deleted from the IMS table TRF_MONITOR_VEHICLE_DISTRIB.
ERES_BW_109	Sites with extremely low axle load counts in IMS table TRF_MONITOR_AXLE_DISTRIB	The identified records should be reviewed and updated or deleted from the IMS table TRF_MONITOR_VEHICLE_DISTRIB.

CHAPTER 4. COMPUTED PARAMETER TABLES FOR PROJECTED TRAFFIC DATA

This chapter describes computational procedures used to generate projected annual axle load spectra, explains how the projected data are stored in the computed parameter tables in the IMS Traffic Module, and describes relationships between computed traffic parameters and other data elements in the IMS database. The computational procedure described here applies only to sites with site-specific annual axle load data.

Description of Computed Parameter Tables

The projection of traffic loads for all in-service years for the LTPP traffic sites resulted in the five computed parameter tables. These tables contain both the projected annual axle load spectra and the intermediate variables. The intermediate variables carry important information documenting how the projected axle load spectra were calculated. The following list represents a set of the projected traffic computed parameter tables. Each table is named twice: the descriptive name is first, and the proposed IMS name follows in **bold type**.

Main Table:

- Projected Annual Axle Load Spectra (**TRF_PRJ_YR_AXLE_DISTRIB**).

Intermediate Tables:

- Normalized Base Annual Axle Load Spectra **(TRF_PRJ_BAS_ANL_PCT_AXLE)**.
- Base Annual Axle Load Summary (**TRF_PRJ_BAS_ANL_AXLE_SUM**).
- Annual Projection Factors (**TRF_PRJ_YR_MULTIPLIER**).
- Projection Summary Table (**TRF_PRJ_MASTER**).

Figure 25 presents an overview of the IMS Traffic Module that includes historical, monitoring, and projected traffic data. The relationship between the projected and other traffic tables stored in IMS is shown in figure 26. Figure 26 also provides a flowchart used for the calculation of variables stored in the computed parameter tables. The main computed parameter table is highlighted by heavy borderlines. Below the main table, in the oval shape, is the provision for calculating “cumulative axle loads.” The cumulative axle load spectra are not available in the IMS database; they can be obtained by adding up annual axle load spectra for any combination of in-service years.

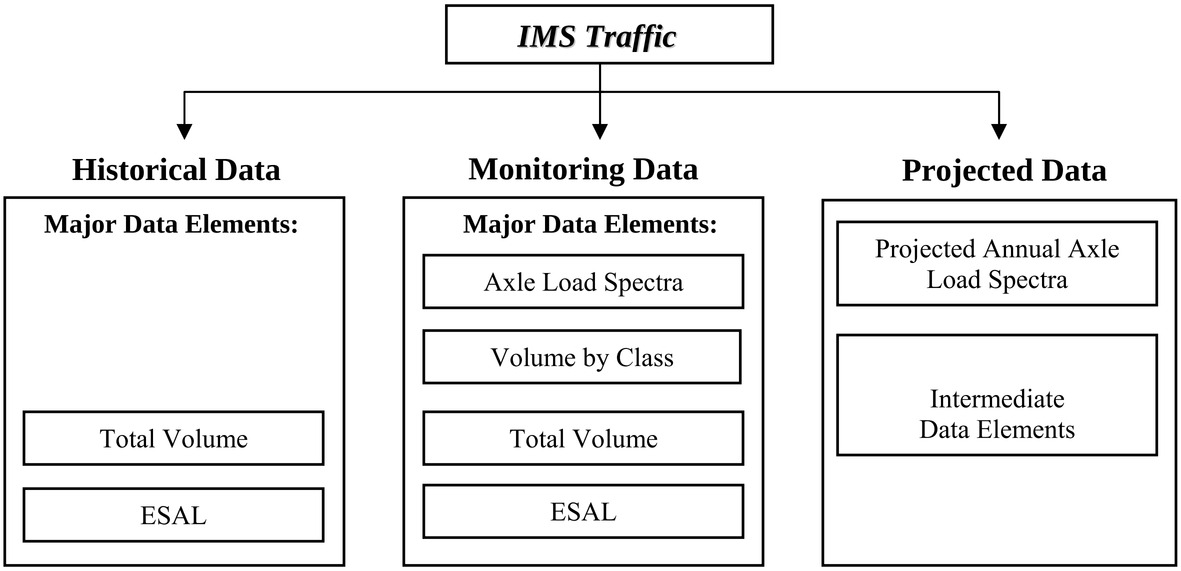


Figure 25. Overview of the IMS Traffic Module showing the proposed addition of projected traffic data.

Generation of Projected Annual Axle Load Spectra

This section describes the computational procedure used to generate projected annual axle load spectra for all in-service years, and the relationships among the variables in the computed parameter tables. The description builds on the outline of the traffic projection procedure provided in chapter 2. Since only traffic projections for Category 1 and 2 sites were carried out during the study, the description herein is based on methodology developed for Category 1 and 2 projections (see p. 8 of this report for descriptions of the categories).

Computation of the projected annual axle load spectra for all in-service years and preparation of the computed parameter tables involves the following major steps:

1. Computation of normalized base annual axle load spectra (table **TRF_PRJ_BAS_ANL_PCT_AXLE**).
2. Computation of base annual axle load summary (table **TRF_PRJ_BAS_ANL_AXLE_SUM**).
3. Computation of annual projection factors (table **TRF_PRJ_YR_MULTIPLIER**).
4. Computation of projected annual axle load spectra (table **TRF_PRJ_YR_AXLE_DISTRIB**).
5. Reporting projection summary (table **TRF_PRJ_MASTER**).

These steps are described in more detail in the following sections.

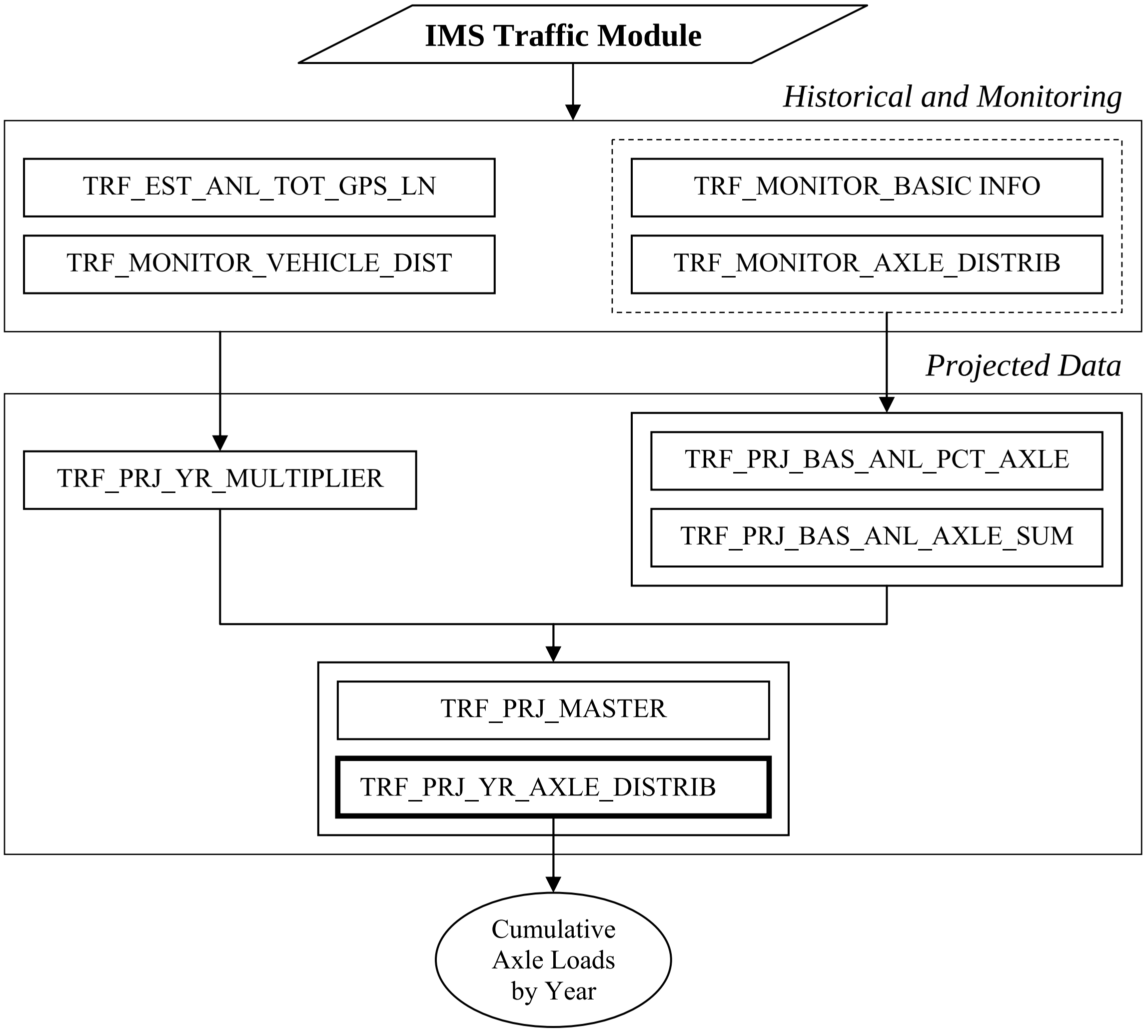


Figure 26. Flowchart used for calculating computed parameter tables.

Computation of Normalized Base Annual Axle Load Spectra

Normalized base annual axle load spectra for single, tandem, triple, and quad axle groups are given in table **TRF_PRJ_BAS_ANL_PCT_AXLE**. The normalized base annual axle load spectrum is the base annual load spectrum with the axle load counts for a given weight range (and axle type) expressed as percentages of the total axle counts for the given axle type. This spectrum is computed for the same set of weight ranges that are used in table **TRF_MONITOR_AXLE_DISTRIB**. Normalized spectrum provides a characteristic shape of axle weight distribution for each LTPP traffic site.

To develop normalized base annual spectrum, available monitoring annual spectra from the IMS table **TRF_MONITOR_AXLE_DISTRIB** were critically assessed and base annual spectrum was computed by averaging annual axle load data for selected years as described in chapter 2. Then, the computed base annual spectrum was normalized with respect to the total annual axle load counts for each axle type. The computational procedure for obtaining normalized base annual axle load spectrum is shown in figure 27.

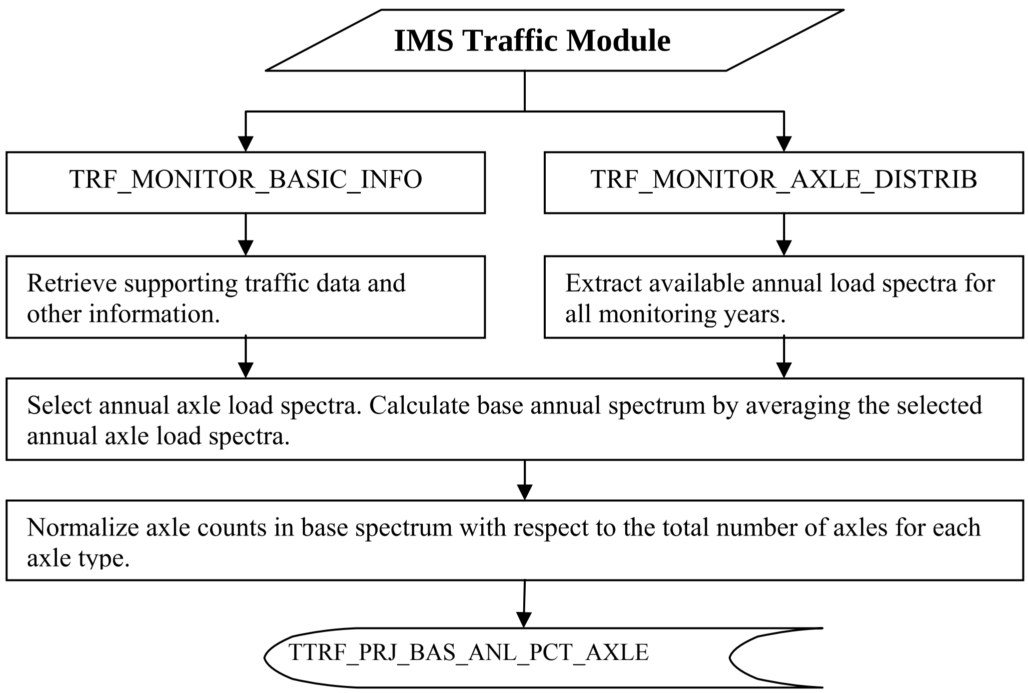


Figure 27. Flowchart for computation of the normalized base annual load spectra.

Computation of Base Annual Axle Load Summary

The base total annual numbers of axles for single, tandem, and triple axle groups contained in the base annual spectrum are given in table **TRF_PRJ_BAS_ANL_AXLE_SUM** (base annual axle load summary). The base total annual number of axles is associated with normalized base number of axles from **TRF_PRJ_BAS_ANL_PCT_AXLE** and is used to calculate projected annual axle load spectra. The base total annual number of axles provides information about overall truck volume (in terms of total axle counts) that is representative for each LTPP traffic site.

The total base annual number of axles was computed (see figure 28) by summing axles from the computed base annual spectrum across all weight ranges. This summation was done separately for each axle type.

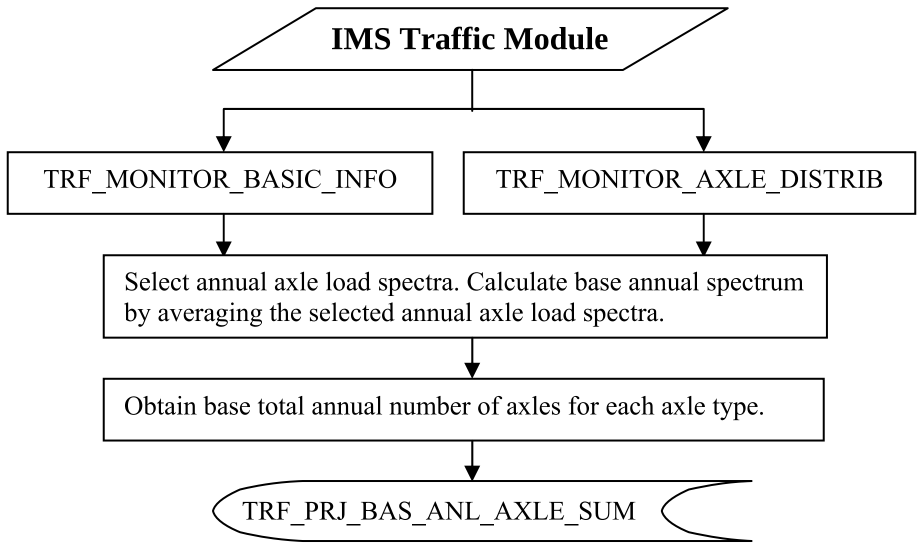


Figure 28. Flowchart for computation of the base annual axle load summary.

Computation of Annual Projection Factors

Annual projection factors, calculated for each in-service year for LTPP sites, are given in table **TRF_PRJ_YR_MULTIPLIER**. These factors define an annual truck traffic growth pattern and adjust the base total annual axle counts up or down to fit the selected projection model. Annual projection factors are used to compute projected annual axle load spectra.

The annual projection factors are selected based on critical review of the available historical and monitoring traffic data for all available years from the following IMS tables:

- **TRF_MONITOR_BASIC INFO**.
- **TRF_EST_ANL_TOT_GPS_LN**.
- **TRF_MONITOR_AXLE_DISTRIB**.
- **TRF_MONITOR_VEHICLE_DIST**.

The computational procedure for the annual projection factors is shown in figure 29.

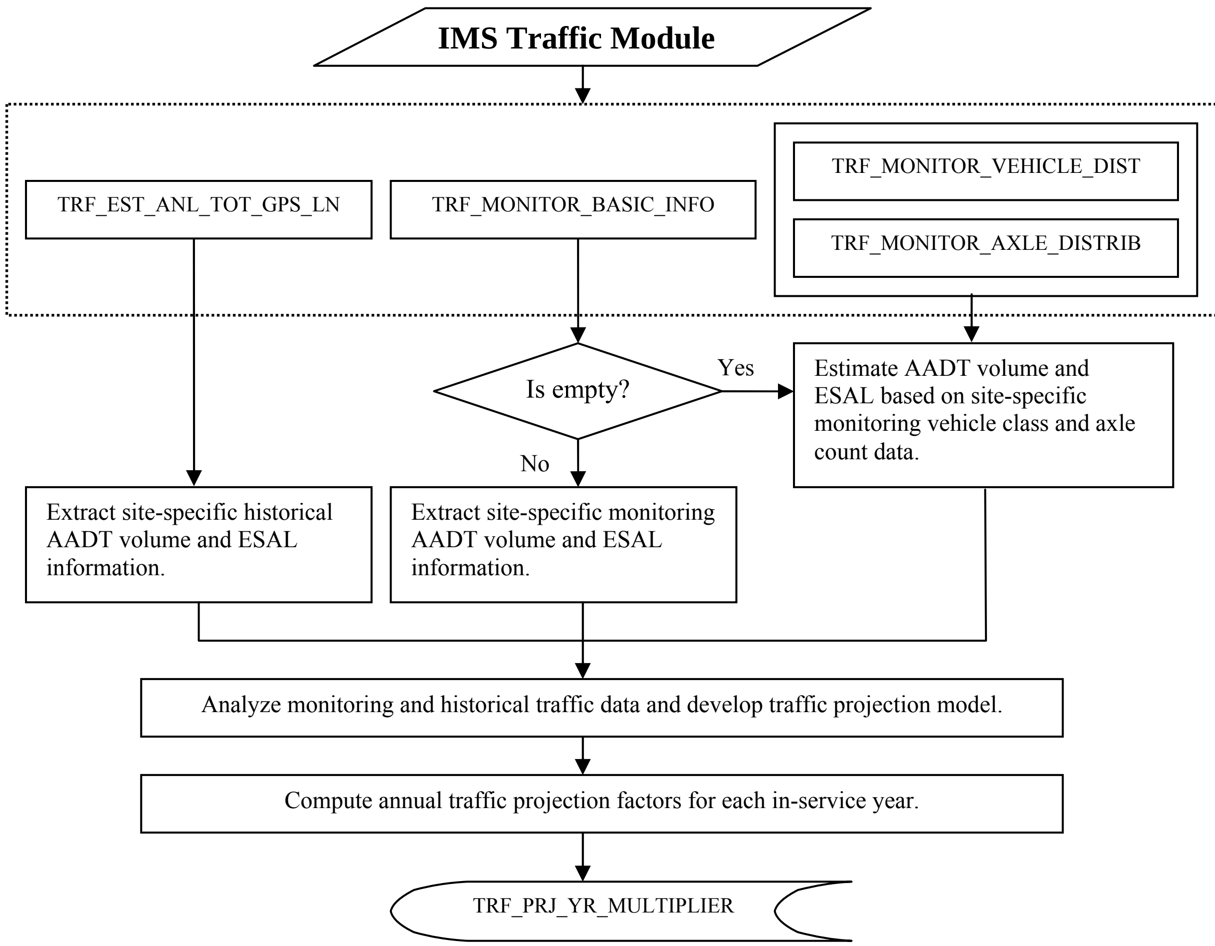


Figure 29. Flowchart for computation of the annual projection factors.

Computation of Projected Annual Axle Load Spectra

Projected annual axle load spectra (for single, tandem, and triple axle groups) are the main product of the LTPP traffic projection process. These results are presented in the table **TRF_PRJ_YR_AXLE_DISTRIB**. Projected annual load spectra for each year are computed (see figure 30) by multiplying the base annual load spectrum with annual traffic projection factors from table **TRF_PRJ_YR_MULTIPLIER**. The base annual load spectrum is computed by multiplying the normalized base annual axle load spectrum for single, tandem, and triple axle groups from the table **TRF_PRJ_BAS_ANL_PCT_AXLE** with the total base annual number of axles for single, tandem, and triple axle groups from the table **TRF_PRJ_BAS_ANL_AXLE_SUM**. The projected load spectra are reported in terms of annual axle counts for the same set of load ranges used in table **TRF_MONITOR_AXLE_DISTRIB**.

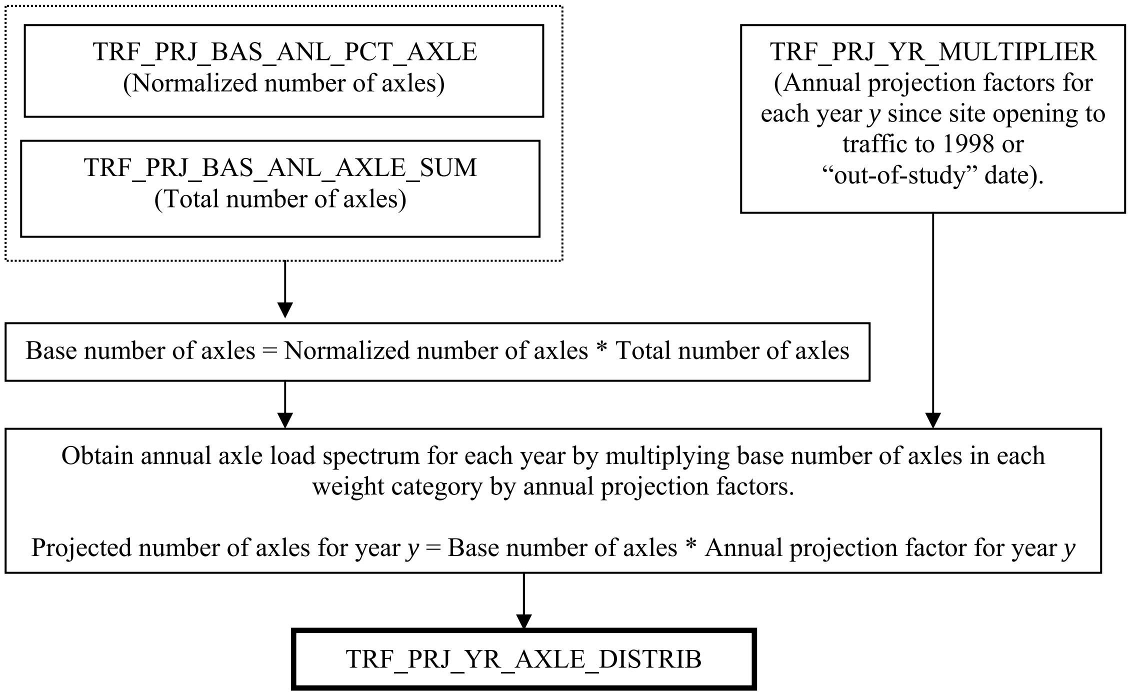


Figure 30. Flowchart for computation of projected annual axle load spectra.

Reporting Projection Summary

The summaries of projection results (including applicable traffic projection interval; information about traffic projection category used for each LTPP traffic site; the assigned traffic projection codes; and any specific traffic characteristic for each LTPP site) are stored in the table **TRF_PRJ_MASTER.**

To assign projection confidence codes and for QA purposes, the projected annual axle load spectra were used to calculate ESALs. Calculated ESALs were then compared with the available historical ESAL trends. Also, TFs were computed and compared with historical TFs and with typical TFs based on FHWA functional highway classification. Analysts assigned initial projection confidence codes to the results using the guidelines described in chapter 2. After the traffic projection results were reviewed by the participating highway agencies, the changes were made to the initial projections, and reviewed projection confidence codes were assigned to each site.

CHAPTER 5. PROTOTYPE LTPP PAVEMENT LOADING GUIDE

This chapter describes the purpose, design parameters, and functionality of the proposed PLG. It contains a blueprint for the development of the PLG and examples of using the PLG to obtain traffic load projections for LTPP sites without site-specific truck class or axle load data.

The need for the PLG was identified during the Phase I work and was reinforced by the traffic prediction work carried out in Phase 2. The process of estimating, selecting, or assessing truck class and axle weight distributions for LTPP sites needs to be supported by a reference database summarizing characteristic truck class and axle load distribution data. This reference database should contain not only traffic characteristics encountered on the LTPP sites, but also typical benchmark characteristics for truck class and axle load distributions. The PLG would fulfill:

- The need to estimate missing truck class and axle load distributions for Category 3 and 4 sites.
- The need to assess the quality of monitoring traffic data used for traffic projection.

The Need to Estimate Missing Traffic Data

The traffic data assessment and traffic projection work summarized in this report processed all 890 LTPP sites. Of the 890 sites, axle load projections were carried out for 558 sites. Of the 558 sites with axle load projections, the projections for 194 sites were assigned an acceptable projection confidence code and 364 sites were assigned a questionable projection confidence code. No traffic load estimates were provided for 332 LTPP sites for which the required site-specific traffic data (truck class distributions or axle loads) were not available. Yet many of the 332 sites without the site-specific data contain a wealth of information regarding pavement materials, environment, and pavement performance. For example, pavement materials were subjected to a battery of laboratory tests, and the pavement performance has been evaluated using a series of profile, distress, and falling weight deflectometer (FWD) measurements over the years. Without the corresponding traffic data, this wealth of information cannot be utilized for developing load-related pavement performance models.

The additional traffic data that need to be estimated depend on the traffic load projection category of the site:

- For Category 3 sites, axle load spectra for the individual truck.
- For Category 4 sites, truck class distribution and axle load spectra for the individual truck classes.

The estimation of missing truck class and axle weight distributions can have significant consequences on the reliability of the resulting traffic load estimates and must be done judiciously.

The estimating process should consider data collected in the vicinity of the site on the same highway (site-related data) and data collected on similar highway links in the same area or jurisdiction (regional data). In many cases, applicable site-related or regional traffic data may not be available. To facilitate the task of estimating traffic data for a variety of sites, and to make the estimating process consistent, a database containing traffic values for a variety of sites, as well as typical benchmark values, is required. Such a database will be developed as part of the proposed PLG.

There is no substitute for site-specific traffic data. However, to utilize the large amount of pavement-related data collected on the 332 LTPP sites with missing traffic data for the prediction of pavement performance, some traffic data need to be estimated. Research shows that it is possible to use estimated traffic data to carry out basic calibration and verification of pavement design models.[16] Without traffic estimates, it would not be possible to utilize many LTPP sections for the development and verification of load-dependent pavement performance models.

The Need to Assess the Quality of Monitoring Traffic Data

As discussed in chapter 2, traffic data stored in the LTPP databases exhibit considerable variation in quality. Consequently, the annual truck class and axle load distributions need to be examined and verified before they can be used for traffic projection. The assessment and verification of truck class and axle weight distributions requires the development of software that displays and compares data.

In addition, it has become a common practice to assess the quality of axle weight data by examining the GVW distribution of Class 9 vehicles (5-axle single trailer trucks).[12] However, the data necessary to plot the GVW of Class 9 trucks against the frequency of occurrence are not stored in the IMS database, and the retrieval of the necessary data from the CTDB and the development of appropriate graphical displays require considerable effort and specialized skills. Computational software that can facilitate the development of graphical displays showing the GVW distribution of Class 9 vehicles exists, but is not readily available and would need to be adapted to process annual data.

For the efficient verification and QC of traffic data used for the projection, it is desirable to compare axle load and other data obtained for a specific site with corresponding data obtained for similar sites and with typical or expected data. By facilitating the comparison of axle load spectra and other traffic data, and by providing typical values and ranges for traffic variables, the proposed PLG will facilitate the QA process.

Scope of Pavement Loading Guide: LTPP PLG or General PLG

A catalogue containing validated truck class and axle load distributions, and with additional capabilities to display and compare data graphically, would be useful not only for the projection of LTPP traffic data, but also for estimating traffic loads for general pavement design purposes. The need for such tool is highlighted by the emergence of mechanistic-based pavement design procedures that require axle load spectra. The use of axle load spectra in pavement design is relatively new. Many pavement designers may benefit from information on typical values of truck class and axle load distributions that are expected to occur on different classes of highways. Consequently, the LTPP PLG has the potential for wider applicability beyond the needs of the LTPP program.

The main purpose of the LTPP PLG is to facilitate traffic loading projections for LTPP sites without site-specific traffic loading data, and the work summarized in this chapter has been directed toward the development of the PLG that would serve this need. Only a limited amount of work has been done to prepare groundwork to enhance the LTPP PLG to serve general pavement design needs.

There are many similarities between a PLG serving LTPP's needs and a PLG serving general pavement design needs. Of course, the two versions also have several differing characteristics.

Characteristic Features of LTPP PLG

- The LTPP PLG is concerned mainly with backcasting of traffic loads using historical and monitoring data.
- Data input and output functions need to be compatible with the LTPP databases (IMS and CTDB).
- The number of potential active users is limited, and the majority of users are expected to have a research background. Consequently, user-friendliness of the software and application guidelines may not be of paramount importance.
- Traffic projections need to be carried out only in terms of axle load spectra. The LTPP traffic projection process uses ESALs for QC purposes only.

Characteristic Features of General PLG

- The general PLG is concerned with forecasting of future traffic loads.
- Data input functions need to be flexible to accommodate user data; data output functions and formats should match the input format requirements of common pavement design methods (e.g., 1993 AASHTO guide[17] or the not-yet-finalized National Cooperative Highway Research Program (NCHRP) 2002 guide[7].
- The number of potential users is large, and they may have quite diverse backgrounds. User-friendly software and application guidelines are important.
- The majority of pavement designers currently need axle loads in ESALs. Axle load spectra will be required by the NCHRP 2002 guide and by other mechanistic-based pavement design methods.

This chapter concentrates on describing the development of the LTPP PLG to facilitate the projection of traffic loads on LTPP sites. However, the concepts for the development of the LTPP PLG described in this chapter also apply to the development of a general PLG.

Objectives of the PLG and Purpose of This Chapter

It is necessary to make a distinction between the objectives of the PLG and the purpose of this chapter. The objectives of the PLG refer to the functionality and potential use of the proposed PLG, its software and guidelines, and include the following:

- Provide tools for projecting traffic loads for LTPP sites without site-specific truck class and axle loads distribution data.
- Facilitate the assessment and QA of LTPP traffic data.
- Facilitate understanding of traffic load characteristics, such as truck distributions and axle load spectra, and provide educational and training opportunities.
- Provide groundwork for a PLG that can be used for forecasting traffic loads for pavement design.
- Promote the use of LTPP traffic data for other applications.

This chapter describes the functionality of the proposed PLG and the methodology for its development. Some specific objectives of this chapter are to:

- Develop design criteria and functional features required to meet the objectives of the PLG.
- Describe data, information, and data analysis needed to develop the engineering underpinnings for the PLG, such as typical characteristics of axle load spectra for different highway functional classes.
- Describe the use of the PLG to obtain LTPP traffic projections for sites without site-specific data using practical examples.
- Illustrate the operation of the PLG software using prototype demonstration software.

Working with axle load spectra involves working with large data sets that are best handled by a computer. To illustrate some features of the proposed PLG, particularly how axle load spectra can be compared, combined, or selected using graphical displays, prototype PLG software was developed. The operation of the software is described briefly in this chapter.

The prototype demonstration software contained several functions of the proposed PLG but lacked many of the analytical and engineering underpinnings that still need to be developed. The main purpose of the prototype software was to illustrate the overall concept and functionality of the proposed PLG.

Role of PLG in Traffic Projection

Traffic data collected in the field are typically in the form of samples that are uneven in duration and quality. The samples of collected traffic data are used to calculate cumulative traffic loads through an analytical process involving factoring and traffic modeling referred to as traffic projection. The LTPP traffic projection is done in two steps. First, the monitoring data collected during a given year are projected (or factored up) to obtain annual monitoring data (this factoring step is required because traffic monitoring equipment seldom operates all the time). Second, the annual monitoring data (available for some of the years) are combined with historical data and are projected to all years the pavement was in service.

Traffic data collection alone is not enough to obtain cumulative traffic loads. The data that were not collected in the past will remain missing, and it is not possible (nor it is necessary) to collect traffic data all the time. To obtain cumulative traffic loads for all years the pavement has been in service, it is necessary to use both the traffic data (historical and monitoring data) and the traffic projection procedures.

The PLG is not a substitute for the site-specific collection of traffic data, which is required to obtain reliable estimates of traffic loads and needs to be encouraged and promoted. However, traffic data alone, without traffic projection procedures, will not provide the required results, either. Both the data collection and the data projections activities have undeniable roles and need to be n balance. The role of the PLG is to strengthen and facilitate the traffic data projection. The use of PLG, together with guidelines for selecting missing data, can be instrumental in alleviating some uncertainty resulting from the unavoidable need to factor up and estimate traffic data.

Conceptual Outline of PLG

This section outlines how the concept of estimating ESALs using TFs can be modified to apply to estimating axle load spectra.

The AASHTO *Guide for Design of Pavement Structures 1993*, the most common pavement design method in North America, uses ESALs to characterize traffic loads.[17] Consequently, many pavement professionals are familiar with the concept of estimating ESALs for pavement design. In the following, the procedure of estimating traffic loads using ESALs is described to demonstrate its similarity with the procedure, utilized by the PLG, of estimating traffic loads using axle load spectra.

Estimating ESALs typically starts with the division of the average annual daily traffic volume into a car volume and a truck volume. Truck volume is then subdivided into several classes, and each truck class is assigned a representative TF defined as the number of ESALs per truck. For example, the computerized version of the 1993 AASHTO guide (the DARWin® 3.1 pavement design software) encourages the user to classify vehicles into 13 vehicle classes and to provide TFs for each vehicle class.

To obtain the daily number of ESALs for a base year, it is necessary to sum the product of the daily truck volumes in different classes and their corresponding TFs. To obtain the annual number of ESALs, the average daily number of ESALs is multiplied by 365. Mathematically, the process of calculating ESALs can be expressed by equation 3.

$$ESALs_{year} = \sum_{i=1}^{i=n} ADTV_i * TF_i * 365 \qquad (3)$$

Where:

$ESALs_{year}$	=	Total annual number of ESALs for a base year.
i	=	Truck class number.
n	=	Number of truck classes.
$ADTV_i$	=	Average daily volume of truck class i.
TF_i	=	Truck factor for truck class i.
365	=	Constant to convert daily traffic to annual traffic.

To obtain the number of ESALs for an entire pavement design period, the annual number of ESALs estimated for a base year is factored to account for traffic that will occur during the entire design pavement service period.

For LTPP traffic projection purposes, the projection is not done in terms of ESALs but in terms of axle load spectra. Thus, instead of the representative TFs for different truck classes used in equation 3, we need to use the representative axle load spectra for different truck classes. The overall concept of classifying trucks into classes, assigning a representative load-related factor to each truck class (i.e., axle load spectra or TFs), and combining the result remains the same.

Using the axle load spectra instead of TFs, equation 3 can be written as follows.

$$ALS_{year} = \sum_{i=1}^{i=n} ADTV_i * RTS_i * 365 \tag{4}$$

Where:

ALS_{year}	=	(Annual) combined axle load spectra (for single, tandem, triple axles) for a base year.
i	=	Truck class number.
n	=	Number of truck classes.
$ADTV_i$	=	Average daily volume of truck class i.
RTS_i	=	Representative axle load spectrum for truck class i.
365	=	Constant to convert daily traffic to annual traffic.

To obtain annual axle load spectra for the entire pavement design period, the annual axle load spectra estimated for the base year are factored to account for traffic that will occur during the entire pavement design period.

Equation 4 is an abbreviated expression intended to demonstrate the similarity between the use of ESALs and TFs on the one hand, and the use of axle load spectra on the other. The variable ALS_{year} represents three separate arrays for single, tandem, and triple axle spectra. (There is no array for quadruple axles\ spectrum because the LTPP traffic data do not contain any data for quadruple axles.) RTS_i represents three arrays for each truck class i, as shown in equation 5.

$$RTS_i = \begin{bmatrix} S_i \\ D_i \\ T_i \end{bmatrix} \tag{5}$$

The S_i, D_i, and T_i are arrays for single, tandem, and triple axle spectra, respectively. They are defined for each truck class *i* according to equations 6, 7, and 8.

$$S_i = s_i a_i \tag{6}$$

$$D_i = d_i b_i \tag{7}$$

$$T_i = t_i c_i \tag{8}$$

Where:

S_i	=	Adjusted normalized axle load spectrum for single axles (an array containing the number of single axles belonging to each of the pre-defined load categories for single axles).
s_i	=	Array containing normalized single axle load spectra for vehicles class i.
a_i	=	Single-axle coefficient (number of single axles per vehicle) for vehicle class i.
D_i, T_i	=	Adjusted normalized axle load spectra for tandem and triple axles, respectively.
d_i, t_i	=	Arrays containing normalized tandem and triple axle load spectra, respectively.
b_i, c_i	=	Tandem and triple axle coefficients, respectively.

The adjusted normalized load spectra used in arrays S_i, D_i, and T_i are expressed as the product of normalized spectra and axle-per-class coefficients. The normalized spectra contain proportions of axle loads that occur within designated load ranges. The axle-per-class coefficients are required to obtain actual axle load spectra from the normalized spectra. The calculation procedure embodied in equations 3 through 8 corresponds to the calculation procedure developed for Category 3 and 4 sites in Phase 1.[1]

The use of axle load spectra as the basic traffic characteristics for pavement design is relatively new and presents several challenges:

- Axle load spectra are large. They consist of many values representing axle load distributions for single, tandem, triple, and quadruple axles for different vehicle classes. Because of the voluminous nature of axle load spectra, their manipulation requires the development of computerized procedures.
- There is little information available on the characteristics of axle load spectra. A novice user of axle load spectra would have difficulties judging whether the spectra reported for different vehicle classes or for the total traffic flow are reasonable. Guidelines on the typical spectra for different vehicle classes on different highway classes are required for QA purposes and for promoting confidence in the use of axle load spectra. The guidelines may include information on the location of typical peaks and valleys of the axle load distribution, and on the temporal and spatial variability of spectra.
- The easiest way to compare spectra rapidly and to evaluate their reasonableness and interpret their meaning is by using graphical displays of spectra and summary characteristics such as ESALs. This also requires the development of computerized procedures.

The PLG is intended to overcome these challenges to computation and data comparison. The PLG will also contain a catalogue of typical benchmark values and characteristics of axle load spectra, as well as software to display, compare, and combine axle load spectra, and to calculate annual cumulative axle load spectra.

Functionality of PLG

This section contains a detailed description of the main functions and features of the proposed PLG. The functionality of the PLG and its design parameters have been formulated to meet the objectives of the PLG presented previously. Briefly, the main purpose of the PLG is to facilitate traffic loading projections for LTPP sites without site-specific traffic data. To meet the objectives of the PLG, the PLG will support the following main functions:

- Database management, including:
  - Data storage.
  - Selection, sorting, and retrieval.
  - Importing and exporting data.
- Data comparison and assessment.
- Development of pavement loading estimates for LTPP sites in Categories 3 and 4.
- Development of combined axle load spectra and cumulative traffic estimates.

An overview of the PLG functions is presented in figure 31.

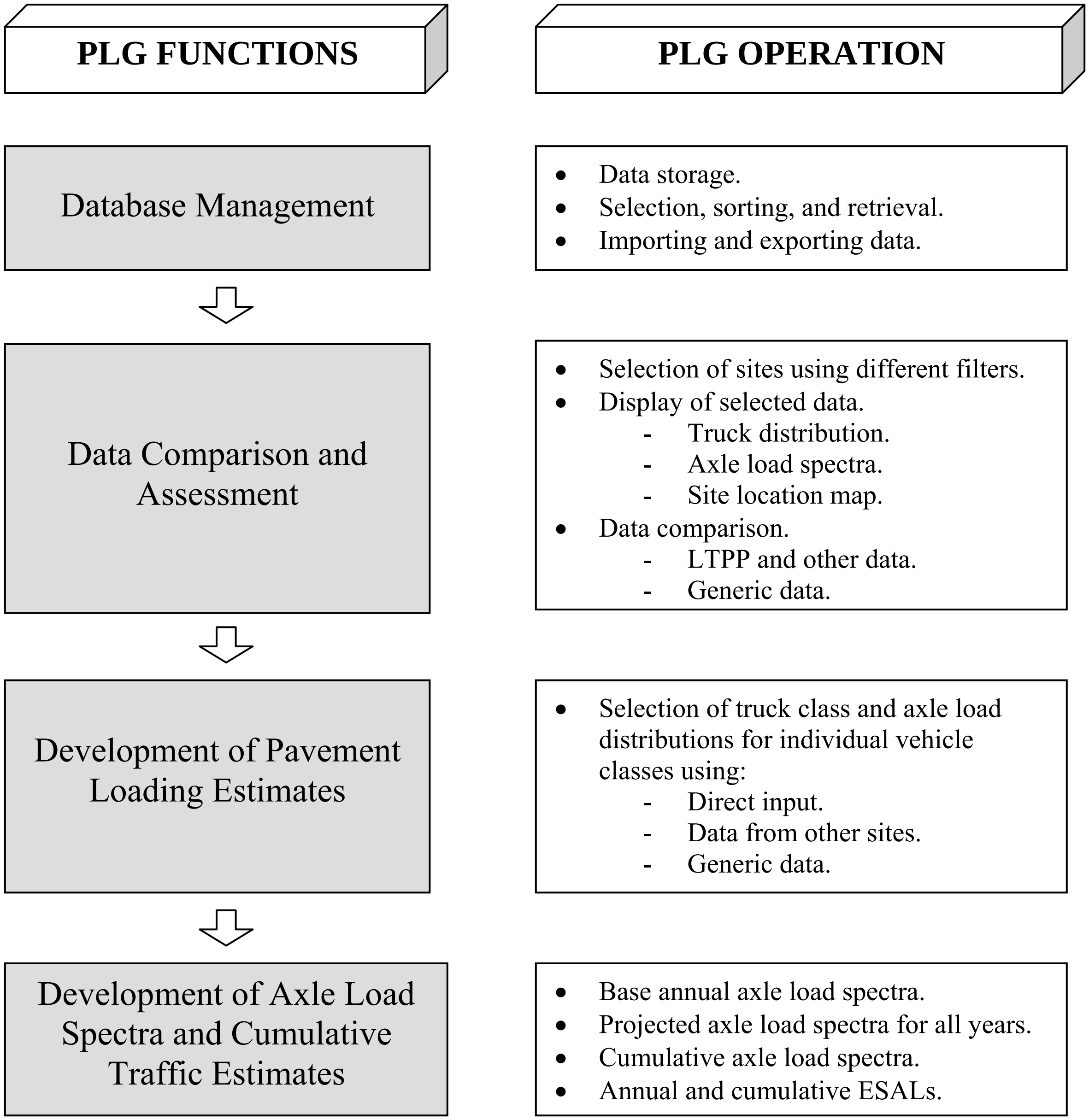


Figure 31. Overview of PLG functions.

Data Storage

The LTPP databases (IMS and CTDB) contain all LTPP traffic data submitted by participating agencies that have passed basic data QA checks. During the course of this project, large amounts of traffic data stored in the IMS were identified by the project team and by the participating agencies as being of dubious quality. Consequently, not all IMS and CTDB data should be part of the PLG, as the PLG data will be used for the estimation of traffic loads at other LTPP sites and need to be of high quality. All traffic data stored in the LTPP databases should be verified using a comprehensive QA process that would identify and remove dubious and nonsensical data. In the absence of such QA process, the only data that should be included in the PLG database at present (that is, if the development of the PLG were to commence prior to the proposed comprehensive traffic data QA process) are those that were used to produce traffic load projections assigned the acceptable projection confidence code. The inclusion of only verified or "acceptable" data in the PLG is one of the main distinctions between the PLG and the DataPave software.[18]

The data stored in the PLG will be of two origins:

- LTPP data obtained or derived from IMS and CTDB databases.
- User-supplied data.

Regardless of the origin, the data stored in the proposed PLG will be of four types: supporting data, monitoring traffic data, projected traffic data, and generic or typical traffic data.

Variables that will be stored in the PLG to support its functionality are described below and summarized in table 17.

Supporting Data

Supporting data are non-traffic data required for the identification and retrieval of traffic data. Supporting data stored in the PLG will include:

- Site identification data.
- Data describing the physical properties of the site: pavement structure, number of lanes, direction of travel, etc.
- Highway functional class.

Monitoring Traffic Data

Monitoring traffic data are data derived from AVC and WIM measurements, and are typically annual data reported for a specific year. Monitoring traffic data stored in the PLG will include:

- Annual truck volume distribution into the 10 classes.
- Annual axle load spectra for all trucks combined (normalized spectra plus axle counts).
- Annual axle load spectra for individual truck classes (normalized spectra plus axle counts).
- Annual TFs for all trucks combined.
- Annual TFs for individual truck classes.
- Annual axles-per-truck coefficients for single, tandem, and triple axle types, and for individual truck classes.
- Truck percentage.
- Annual AADT truck volumes.

Table 17. List of main variables stored in PLG.

FHWA Highway Functional Type	**Truck Traffic Classification (TTC) of Highways**	**FHWA Vehicle Classes 4 through 13**		**Classes 4 through 13 Combined**
		Class 4	**Classes 5, 6, 7–13**	
Rural Interstates	**TTC 1**	• Axle load spectra for single and tandem axles (normalized). • Axle per vehicle class coefficients. • Load spectra coefficients. • ESAL/truck.	Same for other vehicle classes (including triple and quad axle groups, if appropriate)	• Truck volume distribution (normalized). • Annual load spectra for single and tandem axles (normalized). • AADT volume. • Truck percentage. • Load spectra coefficients. • ESAL/truck.
	TTC 2 through TTC 17	**Repeated for other TTC categories**		
Repeated for other highway functional types				
Urban Collector	**TTC 1 through TTC 17**	[As Above]	[As Above]	[As Above]

Projected Traffic Data

Projected traffic data are data derived from monitoring data. Projected traffic data stored in the PLG will include:

- Base annual truck distribution.
- Base annual axle load spectra for all trucks (normalized spectra plus axle counts).
- Base annual axle load spectra for individual trucks (normalized spectra plus axle counts).
- Base annual axles-per-truck coefficients for single, tandem, and triple axle types and for individual truck classes.
- TF for base axle load spectra for all trucks.
- TF for base axle load spectra for individual trucks.
- Truck growth rate, typical for the past 5 years.

Generic Traffic Data

Generic traffic data are typical or default traffic data. Unlike monitoring and projected traffic data that are tied to the specific LTPP and other traffic sites, generic data will be provided only for highway functional classes. For the purposes of the PLG, the 11 highway functional classes (6 rural and 5 urban) currently used by the LTPP may need to be further subdivided.

Generic traffic data items stored in the PLG will be similar to the projected traffic data items listed above. However, generic traffic data will not be "base" data but "typical" data.

Notes on Data Storage

The following notes apply to monitoring, projected, and generic traffic data stored in the proposed PLG:

- To facilitate comparisons and mathematical operations, all truck class distributions and axle load spectra will be stored as normalized distributions or spectra. Normalized axle load spectra will be accompanied by axle-per-class coefficients.
- TFs should be calculated using the AASHTO load equivalency factors.[17]
- Data on monthly variation in traffic loads may also be stored in the PLG. However, substantial research effort will be required to identify monthly variation in traffic loads using LTPP traffic data.

Selection, Sorting, and Retrieval

In many respects, the selection, sorting, and retrieval functions of the PLG will be similar to corresponding functions in DataPave.[18] In view of the popularity of DataPave software, and of similar needs to select, sort, and retrieve LTPP data, the user interface of the PLG software and DataPave will be similar. This will make it easier for users to become proficient in using either software package.

Basic site and data selection, sorting, and display functions will include the following modules:

- *Section Selection Module.* Selection of any number of LTPP traffic sites from the PLG database, based on user-selected filtering and sorting criteria such as participating agency, highway functional class, pavement type, and experiment type.
- *Select by Map Module.* Selection of any number of LTPP traffic sites from the database using an interactive map option.
- *View by Map Module.* Selection of traffic data from the PLG database using interactive selection of sites from a map display combined with additional filtering/sorting criteria.
- *Presentation Module*. Presentation of detailed traffic data (e.g., annual axle load spectra for the individual vehicle types) for single sites in tabular and graphical formats.
- *Data Extraction and Retrieval Module.* Retrieval of traffic data from the PLG database using a variety of filtering and sorting criteria.

Importing and Exporting Data

To supplement the resident PLG data with the user-supplied data, the user will have the option to import additional data into the PLG. User-supplied data may be particularly useful if site-specific LTPP data are missing. For example, some highway agencies have reported monitoring axle weight data that were collected on the LTPP sites during time periods shorter than 24 consecutive hours. Such data have not been included in the LTPP database and, consequently, will not be transferred from the LTPP to the PLG. Yet the use of this type of site-specific data is probably preferable to the use of site-related or regional data.

The storage of user-supplied data may be temporary or permanent. The permanent storage of user-supplied data has the advantage of customizing the PLG with local data that can be used in the future. The PLG database will distinguish between the LTPP and user-supplied data.

Appropriate functions will be developed to export data stored in the PLG, as well as traffic projections developed through the PLG, for subsequent use.

Data Comparison and Assessment

The comparison and assessment function facilitates cross-comparison and evaluation of axle load spectra, and other traffic data. It builds on the PLG's data-storage, selection, sorting, and retrieval functions. Whereas the retrieval function will typically display data for one section at the time, the comparison and assessment function will display data for several sections simultaneously. The comparison and assessment function is unique to the PLG, and will enhance the traffic data assessment and projection by helping the user to:

- Compare the measured or projected site-specific truck class and axle load distributions with expected or typical distributions or spectra.
- Select surrogate truck class or axle load distributions for sites without the site-specific distributions (Category 3 and 4 sites).
- Obtain a better understanding of the spatial and temporal variability of traffic data characterized by truck class and axle load distributions.

The comparison and assessment function should include the following capabilities:

- The option to provide graphical and tabular displays of several data sets at the same time. The typical data sets to be displayed will include monitoring and projected truck class and axle load distributions.
- The ability to display multiple data sets of different origins (LTPP, generic, and user-supplied) and of different types (monitoring, projected, and generic). For example, one could compare axle load spectra for vehicle Class 9 measured on an LTPP site in 1994 with the generic axle load spectra for Class 9 vehicles that are characteristic of rural interstates.
- The option to display statistical measures such as means, ranges, and standard deviations for selected traffic data sets.

- The option of displaying not only multiple data sets, but also multiple data types. For example, in addition to displaying axle load spectra in a graphical format, the screen would also display, at the same time, the corresponding TFs.

Many features of the data-selection, sorting, retrieval, and comparison and assessment functions were implemented in the prototype PLG demonstration software.

Development of Pavement Loading Estimates for LTPP Sites in Categories 3 and 4

The PLG will contain guidelines for developing missing truck class distributions (required for Category 4 sites) and axle load spectra for individual truck classes (required for Category 3 and 4 sites), and a mechanism for calculating base annual and cumulative axle load spectra.

Developing Truck Class Distribution

The user will have several options to develop truck class distributions required for Category 4 sites: direct input of truck class distributions, use of truck class distributions for the selected LTPP sites, and use of generic truck class distributions.

Direct Input of Truck Class Distribution—For some LTPP sites, additional truck class distribution data (i.e., data not included in the LTPP traffic database) may be available. Also, in some situations, it may be preferable to modify truck distributions developed by analyzing truck distributions on similar sites or suggested by the generic truck class distribution data. Table 18 provides an example of truck class distribution and contains a provision to accommodate an additional truck type designated as "special."

Table 18. Example of truck class distribution.

FHWA Vehicle Class Number										
4	5	6	7	8	9	10	11	12	13	Special
Fraction of Commercial Vehicles										
0.01	0.11	0.06	0.00	0.10	0.65	0.01	0.03	0.02	0.01	0.00

Truck Class Distributions for Selected Sites—The estimation of a missing truck class distribution would typically utilize site-related data or data on similar sites in the same agency. The user will be able to employ the comparison and assessment function to display the data for the selected sites graphically, and to calculate the means of the selected truck class distributions.

Generic Truck Class Distribution—The use of generic truck class distributions is an option if there are no suitable surrogate truck class distribution data from other (nearby or regional) sites. Generic truck class distributions will be provided for all highway functional classes.

Development of Axle Load Spectra for Individual Truck Classes

The user will have three options to develop axle load spectra for the individual truck classes required for Category 3 and 4 sites: direct input of axle load spectra, use of axle load spectra for selected sites, and use of generic axle load spectra. The direct input of axle load spectra and the use of axle load spectra for selected sites would use similar procedures to select and modify surrogate data as outlined for the selection of truck class distributions. Development of the axle load spectra will be also facilitated by the comparison and assessment function of the PLG.

It is important to allow the user to make adjustments to the truck class and axle load distributions using data from other sites or using generic data. Users may have various bits of information about the composition of traffic stream that could improve the estimates (for example, the proportion of short and long trucks, or the number of buses using an urban highway).

Development of Combined Axle Load Spectra and Cumulative Traffic Load Estimates

The calculation of the projected traffic data, such as the annual base spectra or cumulative axle load estimates, can be accomplished by using the existing LTPP traffic projection procedures. However, before exporting the projected traffic data from the PLG for subsequent use, the user may want to see the overall results of the traffic projection process expressed in terms of ESALs, and have the option of carrying out sensitivity analysis by quantifying the consequences of selecting different truck class and axle load distributions.

In addition, the knowledge of the overall traffic projection results (for example the average TF or the annual number of ESALs) will provide valuable feedback to the process of selecting truck class and axle load distributions, and provide additional assurance to the analyst that the traffic projection results are sound. Consequently, the option to calculate the projected traffic data within the PLG is required and should be implemented.

Development of Generic Truck Characteristics and Data-Selection Guidelines

Extensive additional statistical and engineering analyses are needed to develop generic truck characteristics (in terms of truck class and axle load distributions), and guidelines for the use of the generic and other non-site specific truck characteristics in the projection procedure. These analyses will use LTPP and other traffic data.

The main features of this effort may include the development of: a new highway classification system; generic truck class distributions and generic axle load spectra for individual truck classes; and guidelines for judicious selection of missing truck class and axle load distributions for Category 3 and 4 sites.

Highway Classification System

Generic traffic data will be defined for typical highway functional classes. At present, the LTPP sites are classified into the six rural highway functional classes and five urban functional classes listed below:

- Rural Principal Arterial—Interstate.
- Rural Principal Arterial—Other.
- Rural Minor Arterial.
- Rural Major Collector.
- Rural Minor Collector.
- Rural Local Collector.
- Urban Principal Arterial—Interstate.
- Urban Principal Arterial—Other Freeways or Expressways.
- Urban Other Principal Arterial.
- Urban Minor Arterial.
- Urban Collector.

These classes are broad and have a universal applicability. However, they may not be specific enough for the projection of traffic loads. The development of LTPP functional classes for the projection of traffic should be based on the assessment of commonalities in truck class and axle load distributions among LTPP sites. Consideration should also be given to the development of regional highway functional classes.

The number of functional classes for which the generic traffic data will need to be developed may be different from the existing LTPP functional highway classes. For example, the *2002 Pavement Design Guide* is expected to use 17 distinct highway classification groups, called Truck Traffic Classifications (TTC):

- TTC 1: Major Single-Trailer Truck Route (Type I).
- TTC 2: Major Single-Trailer Truck Route (Type II).
- TTC 3: Major Single- and Multi-Trailer Truck Route (Type I).
- TTC 4: Major Single-Trailer Truck Route (Type III).
- TTC 5: Major Single- and Multi-Trailer Truck Route (Type II).
- TTC 6: Intermediate Light and Single-Trailer Truck Route (I).
- TTC 7: Major Mixed Trailer Truck Route (Type I).
- TTC 8: Major Multi-Trailer Truck Route (Type I).
- TTC 9: Intermediate Light and Single-Trailer Truck Route (II).
- TTC 10: Major Mixed Trailer Truck Route (Type II).
- TTC 11: Major Multi-Trailer Truck Route (Type II).
- TTC 12: Intermediate Light and Single-Trailer Truck Route (III).
- TTC 13: Major Mixed Trailer Truck Route (Type III).
- TTC 14: Major Light Truck Route (Type I).

- TTC 15: Major Light Truck Route (Type II).
- TTC 16: Major Light and Multi-Trailer Truck Route.
- TTC 17: Major Bus Route.

Generic Truck Class and Axle Load Distributions

The development of generic truck class distributions should start with the evaluation of the truck class distributions on all LTPP sections to identify commonalities in the distribution for various highway functional categories.

The development of generic axle load spectra may draw on the parallel between TFs (number of ESALs per truck) and the axle load spectra. The relationship between TFs and axle load spectra for individual truck classes was discussed in the section titled "Conceptual outline of PLG."

There is a body of knowledge dealing with truck axle loads in terms of TFs. Several highway agencies have evaluated the temporal and spatial variation of TFs, and many highway agencies use generic and other TFs in the pavement design process.[19,20] The variation in TFs is to some degree indicative of the variation in the corresponding axle load spectra. However, our current understanding of the expected axle load spectra on different class highways is limited and will need to be developed by an in-depth analysis of LTPP and other traffic data.

The understanding of the variation of truck class and axle load distributions will affect the division of the highway network into highway functional classes. Consequently, the enhancement of the existing LTPP highway functional classes, or the development of new classes, and the development of generic truck class and axle load distributions will need to be interactive.

Guidelines for Data Selection

Guidelines for selecting surrogate truck class and axle load distributions for Category 3 and 4 sites will help a user who is estimating missing data. The guidelines will use new information on the characteristics of truck flows (expected or generic truck class and axle load distributions on characteristic highway links) and the PLG comparison and assessment functions.

Prototype Demonstration Software

To cope with the large amount of traffic data, the proposed PLG will function as a stand-alone software product operating as a relational database with many additional built-in computational and reporting features. Prototype software was developed to illustrate the operation of the PLG.

The development of final PLG software will require, in addition to the programming effort, considerable engineering and analytical effort to develop generic truck class and axle load distributions and provide guidelines for their use. For this reason, the prototype PLG software demonstrated only data-management, comparison, and assessment functions.

Example Use of PLG

This section contains two examples of estimating annual axle loads for all in-service years for LTPP sites using the proposed PLG. One is for Category 3 sites that lack axle load data, the other for Category 4 sites that lack axle load data and truck class distribution data. These examples:

- Describe the traffic projection procedure for sites lacking site-specific data (Category 3 and 4 sites) using realistic examples.
- Illustrate how the proposed PLG can facilitate and improve the projection process and the functionality of the PLG.
- Estimate the consequences of using surrogate traffic data instead of site-specific data.

These two examples use the LTPP traffic projection procedure outlined in chapter 2 of this report (and documented in the Phase 1 report), and they assume the existence of the proposed PLG.[1] To estimate the consequences of using surrogate data, the sites selected for the examples actually had site-specific monitoring truck class and axle load distribution data; however, it was assumed that the site-specific data were missing and had to be estimated using surrogate data. Thus, it was possible to compare traffic loads estimated using surrogate data with traffic loads based on site-specific monitoring data. The comparison was done in terms of the annual axle load spectra and the cumulative number of ESALs.

Use of PLG for Category 3 Sites

The example of traffic projection for Category 3 sites was based on California LTPP site 068150, located on a two-lane rural minor arterial highway east of Los Angeles, CA. It was assumed that the site had truck class distribution data (annual number of trucks that belong to different vehicle classes) but lacked axle load data. The task was to develop (select) surrogate axle load spectra for individual truck classes and combine them with the known (site-specific) number and type of trucks to calculate annual axle load spectra.

The PLG database can be queried to facilitate the selection of axle load data. This can be done by searching the database for similar sites in California (for example, all sites on rural minor or principal arterial highways) or in other jurisdictions. The search of the prototype PLG database identified two similar California sites with monitoring axle load data (site 062040 located on a two-lane rural principal arterial highway east of San Francisco, CA, and site 066044 located on a four-lane principal arterial highway south of Eureka, CA). The truck class distributions on the three California sites are compared in figure 32, which was produced by the prototype PLG software; it indicates that the truck distributions on the three sites are similar. While the similarity of truck class distributions does not mean the similarity in axle loads, it does provide assurance that the sites serve similar traffic flows and are on highways with similar functional classification.

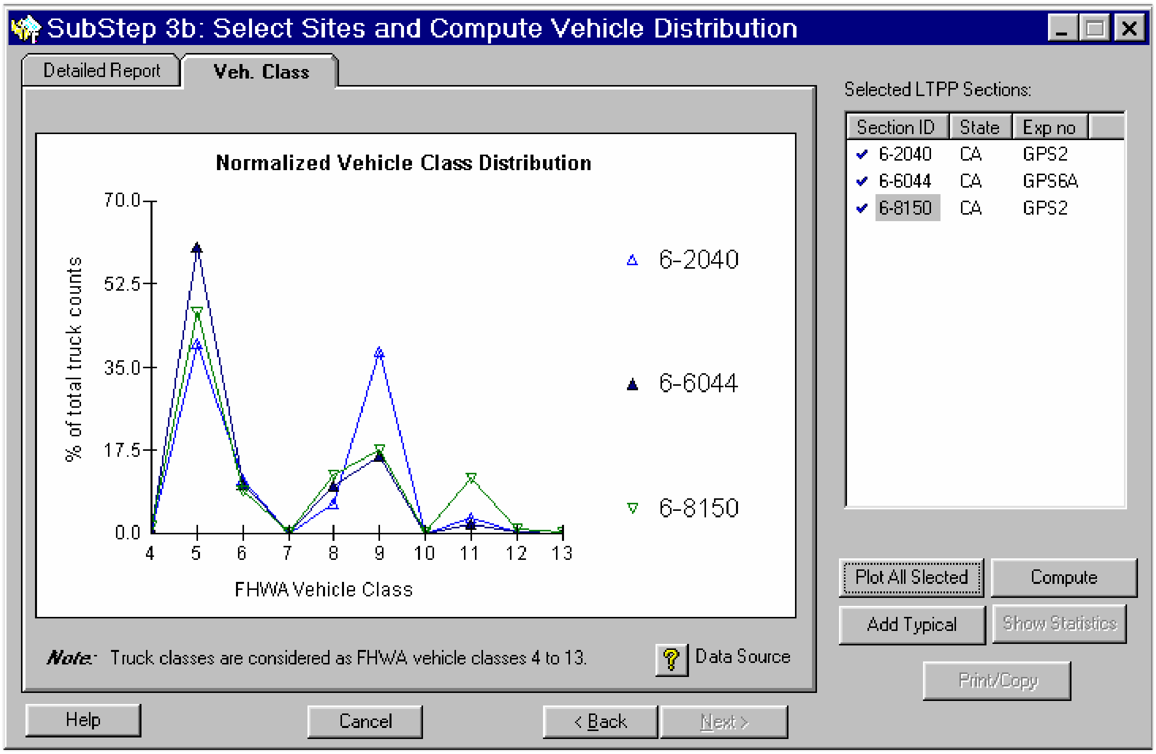


Figure 32. Comparison of truck class distributions for sites 062040, 066044, and 068150.

The required surrogate axle load data are needed as axle load distributions (spectra) for individual truck types. The prototype PLG database was used to compare axle load spectra on nearby sites. An example of the spectra comparison for sites 062040 and 066044 is provided in figures 33 and 34 for single and tandem axles for Class 9 vehicles (5-axle single-trailer trucks), respectively. Also shown in figures 33 and 34 is the surrogate (computed) axle load spectrum for site 068150 obtained as the mean spectrum for sites 062040 and 066044. It should be noted that figures 33 and 34 show the example of axle load spectra for only 1 of the 10 truck types for which the surrogate spectra are required.

The process of assessing available data and selecting surrogate data would benefit from the comparison of the selected spectra (shown in figures 33 and 34) with generic or typical spectra. However, the generic spectra are not available in the prototype PLG.

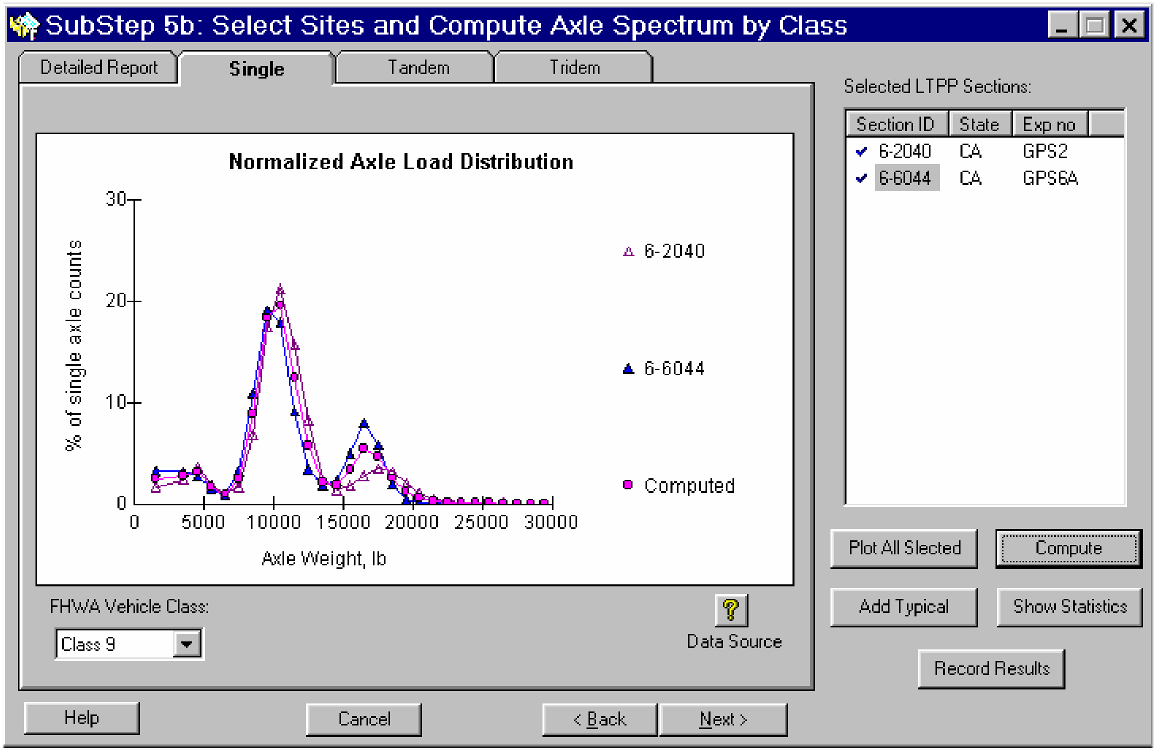


Figure 33. Comparison of single axle load distributions for vehicle Class 9 for sites 062040 and 066044 with computed mean distribution.

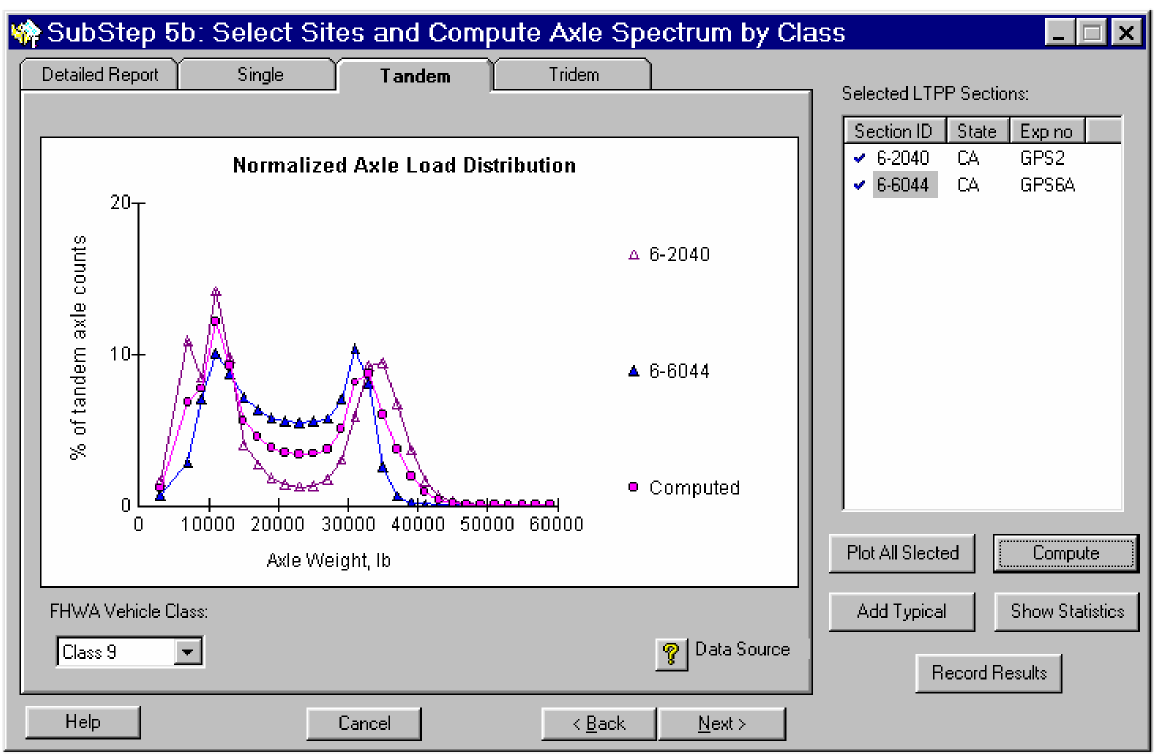


Figure 34. Comparison of tandem axle load distributions for vehicle Class 9 for sites 062040 and 066044 with computed mean distribution.

The annual axle load spectrum for site 068150 was obtained by combining the surrogate axle load spectra for the individual truck classes (expressed as normalized spectra) and the site-specific (classified) annual truck volumes. The resulting estimated annual spectrum for site 068150 is presented in figure 35. The spectrum was obtained by calculations done outside the prototype PLG. Such calculation should be done by the PLG, and the PLG can then be used to compare the calculated annual spectra using surrogate data with annual spectra obtained for nearby sites or with typical spectra. It should be noted that the site-specific spectrum for site 068150 would not exist for Category 3 sites. This is the spectrum that is to be estimated using surrogate data. It has been included in figure 35 for comparison purposes.

The comparison of annual axle load spectra for site 068150 in figure 35 indicates that the actual monitoring spectrum and the estimated surrogate spectrum are quite similar. For example, the three peaks of the single axle load distribution are duplicated quite well. The annual axle load spectrum for site 068150 in figure 35 is for all vehicle classes combined and represents, using the LTPP projection terminology, the base annual spectrum, or surrogate base annual spectrum.

To quantify the consequences of using the surrogate base annual spectrum, the surrogate base annual spectrum was used to calculate the number of cumulative ESALs. The annual base spectrum was combined with the projected growth factor (established previously as part of traffic load projection for site 068150) to obtain annual axle load spectra, and then the annual spectra were expressed in terms of ESALs. The result of this calculation is presented in figure 36, which also shows the corresponding results obtained for monitoring site-specific axle load spectra (labelled Site-Specific Category 2). Figure 36 include a "Projected Annual ESALs" sheet (which was part of site-specific reports described in chapter 2) for site 068150 adapted to also display ESALs estimated using surrogate data.

As already indicated by the similarity of the base annual spectra for Class 9 vehicles (figures 33 and 34), ESALs are also similar. The cumulative number of ESALs using surrogate spectra was 2.06 million, while the corresponding number of ESALs for site-specific spectra was 2.2 million (figure 36).

Use of PLG for Category 4 Sites

Arizona site 041017, located in the northbound direction on a four-lane rural interstate south of Tucson, AZ, was used to illustrate the use of the PLG to obtain traffic projection for Category 4 sites. Even though site-specific axle load data were available for this site, it was assumed that these data were not available and that both truck class and axle load distributions had to be estimated. It was assumed that the only available information about truck loads on this site were AADT truck volumes (assumed to be 540 in 1998).

The site selected to obtain surrogate data for the subject site was another Arizona site, 041007, located in the westbound direction of a rural interstate west of Phoenix, AZ. The 1998 annual AADT truck volume on this site, 3525, was approximately 7 times larger than the corresponding truck volume on the subject site. Thus, the two sites are located on different interstates and carry different truck volumes. While it is possible to use data for other sites, or to use a combination of data obtained for several sites, this example demonstrates the use of a single site.

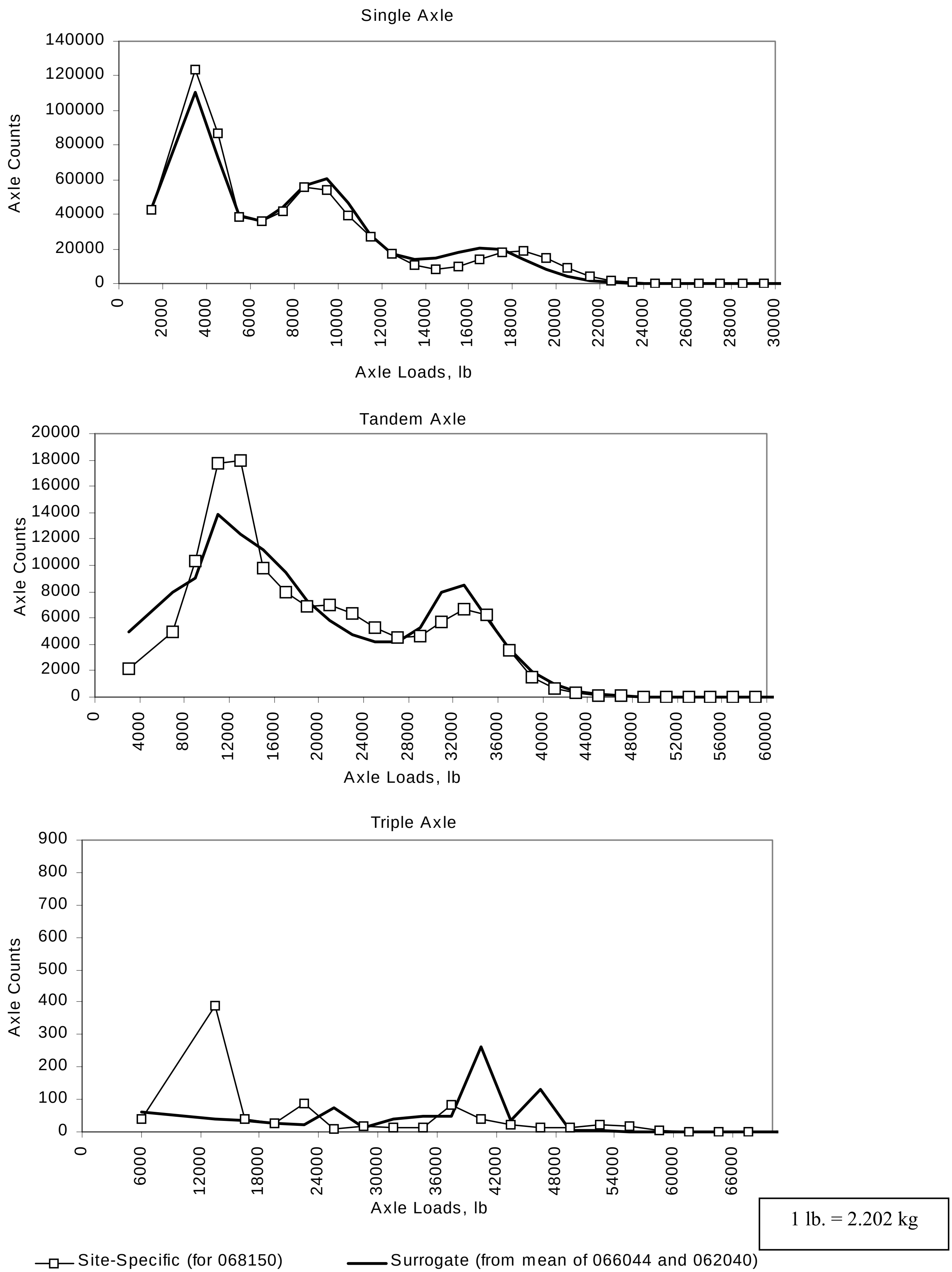
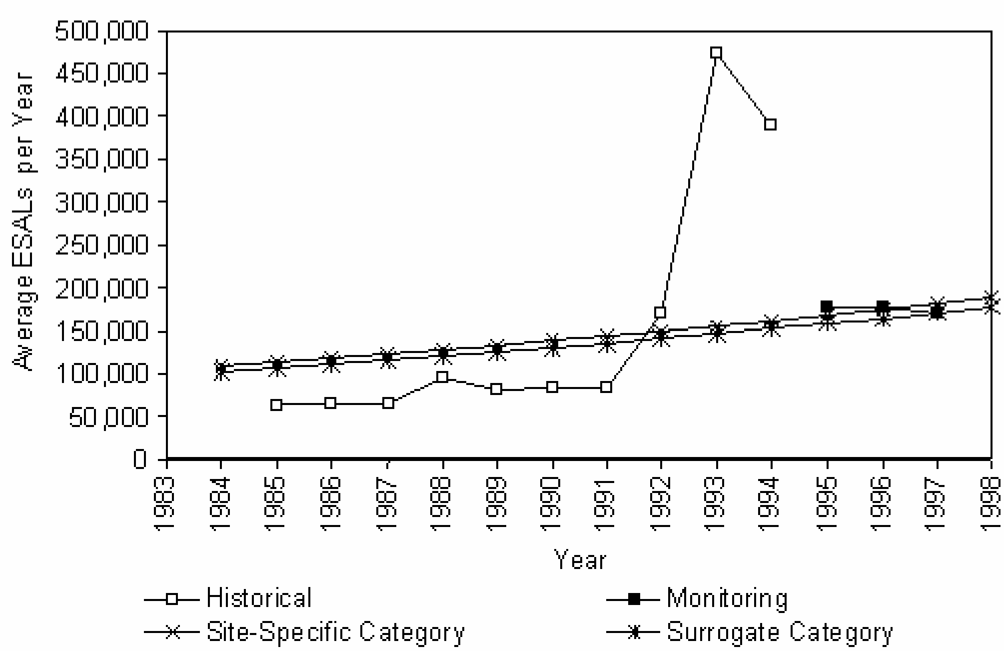


Figure 35. Comparison of site-specific and surrogate base annual spectra for site 068150.



Year	Annual ESALs			
	Historical	Monitoring	Projected	
			Site-Specific Spectra Category 2	Surrogate Spectra Category 3
1984	–	–	108,789	102,577
1985	63,000	–	113,118	106,714
1986	67,000	–	117,675	111,000
1987	67,000	–	122,388	115,443
1988	96,000	–	127,274	120,124
1989	81,000	–	132,356	124,930
1990	83,000	–	137,657	129,895
1991	83,000	–	143,154	135,134
1992	171,000	–	148,921	140,544
1993	473,000	–	154,887	146,211
1994	389,000	–	161,068	152,068
1995	–	176,297	167,491	158,168
1996	–	177,884	174,487	164,528
1997	–	169,527	181,354	171,104
1998	–	–	188,601	177,975
Cumulative ESALs			**2,179,220**	**2,056,415**

Figure 36. Comparison of projected, historical, and monitoring annual ESALs for site 068150.

The truck class distribution for the two sites is compared in figure 37. The data for the subject site shown in figure 37 would not exist for a Category 4 site and are included for comparison purposes only. To determine whether the selected surrogate truck distribution is typical, the PLG will contain not only truck class distributions for other Arizona sites, but also generic or typical truck class distributions for typical highway functional classes.

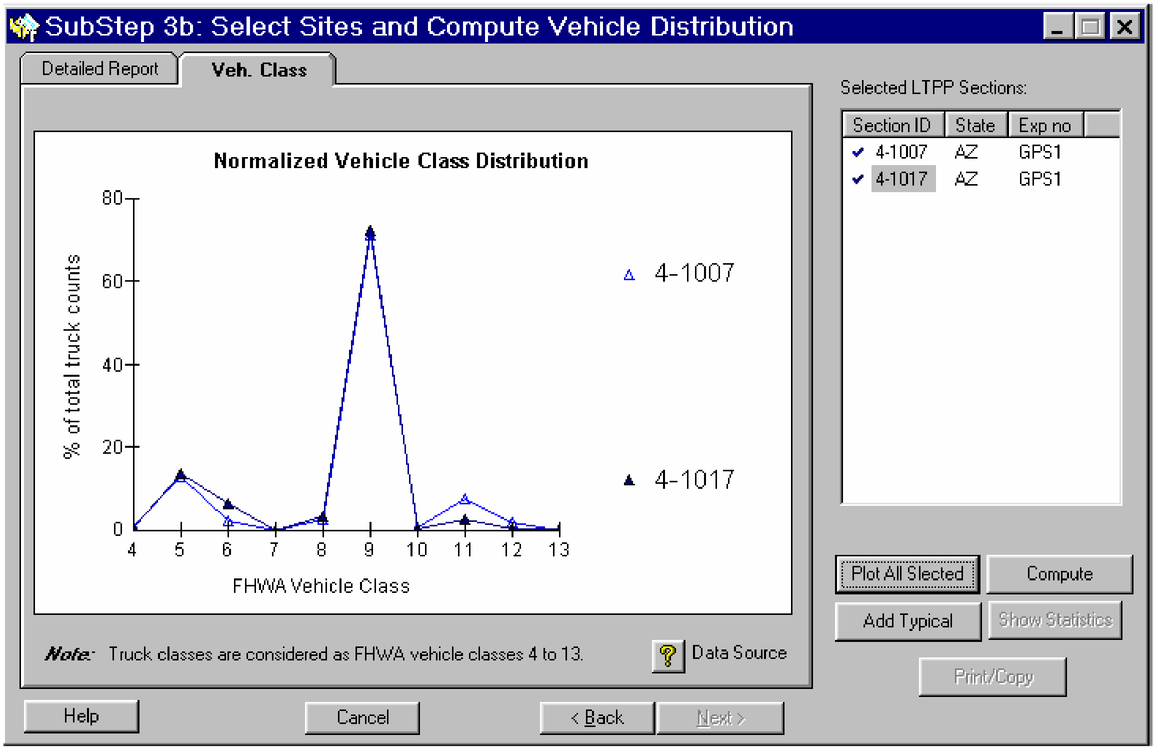


Figure 37. Comparison of truck class distributions for sites 041007 and 041017.

The base annual spectrum for site 041017 was obtained by combining the site-specific annual truck volumes with surrogate truck classification and axle load spectra (for individual vehicle types) obtained from site 041007. The resulting surrogate base annual axle load spectrum is compared with the spectrum obtained using site-specific monitoring axle load data in figure 38.

The projected annual spectra for all in-service years are compared, in terms of ESALs, in figure 39. Figure 39 is a "Projected Annual ESALs" sheet for site 041017 also adapted to display ESALs estimated using surrogate data. The results in figures 38 and 39 show a very good agreement between traffic loads estimated using surrogate data and site-specific data. For example, the number of ESALs estimated using site-specific axle load data was 2.1 million, while the number of ESALs estimated using surrogate data was 2.9 million.

Example Summary

The two examples provided in this section indicate that reasonable traffic loading estimates can be obtained by judiciously selecting surrogate data (in the absence of site-specific truck class and axle load data). The relatively close agreement between the site-specific and surrogate projections may leave a false impression that the site-specific axle load data are not important because they can be estimated using surrogate data. While the judicious selection of surrogate data is important, and the proposed PLG can facilitate and guide the selection, surrogate data can never replace site-specific data. Also, the greater the amount of site-specific data, the easier it is to develop appropriate surrogate data.

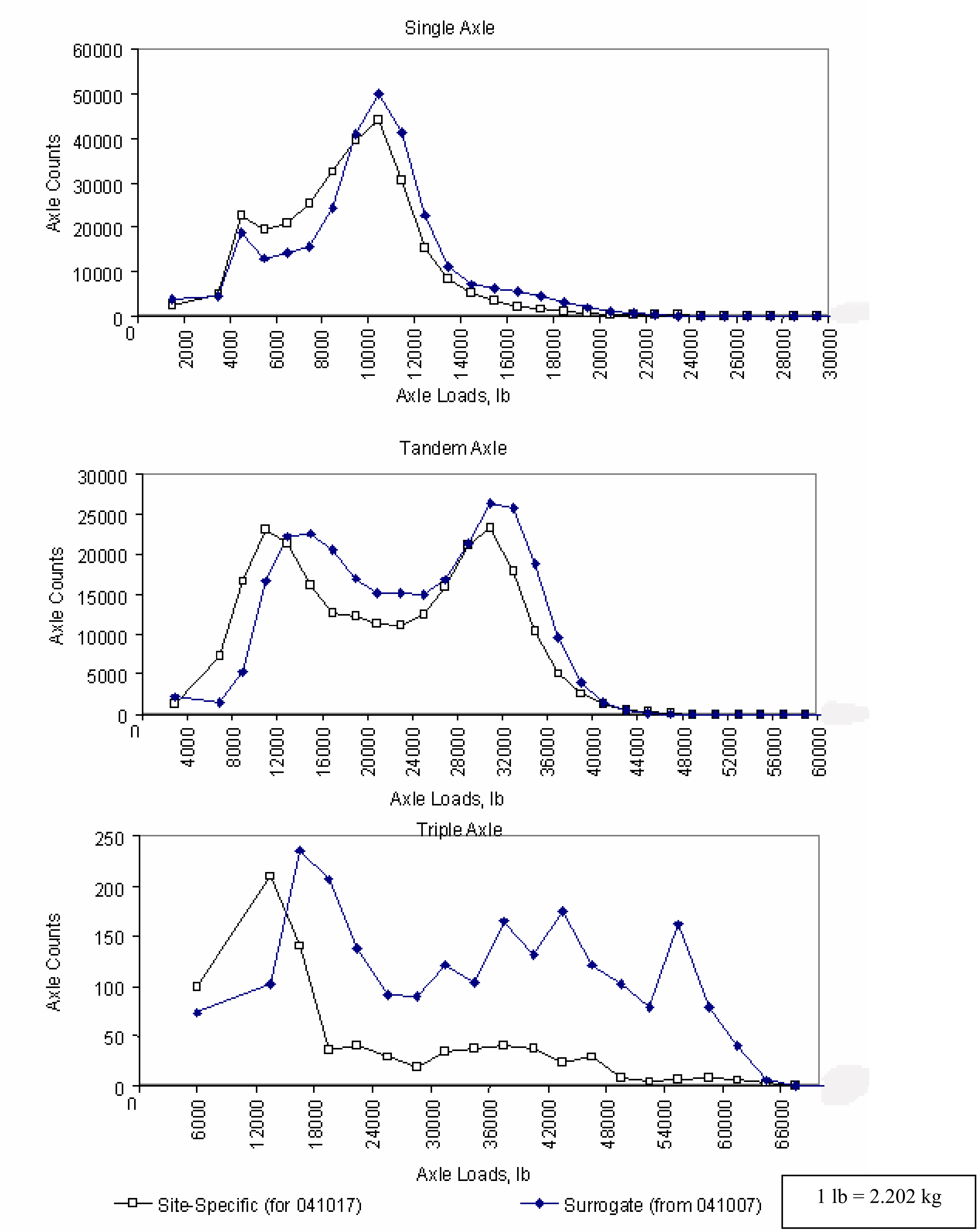
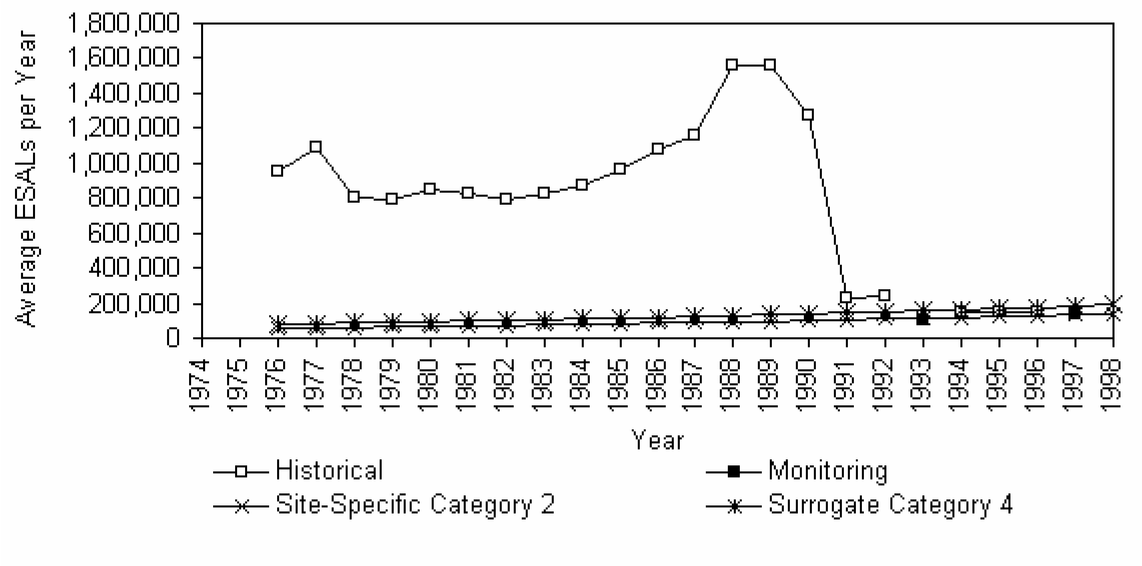


Figure 38. Comparison of site-specific and surrogate base annual spectra for 041017.



Year	Annual ESAL			
	Historical	Monitoring	Projected	
			Site-Specific Spectra Category 2	Surrogate Spectra Category 4
1976	948,000	–	58,254	80,142
1977	1,089,000	–	60,593	83,384
1978	806,000	–	63,011	86,725
1979	792,000	–	65,514	90,192
1980	849,000	–	68,209	93,802
1981	821,000	–	70,925	97,594
1982	792,000	–	73,740	101,483
1983	821,000	–	76,717	105,564
1984	877,000	–	79,785	109,804
1985	962,000	–	82,964	114,213
1986	1,075,000	–	86,276	118,801
1987	1,160,000	–	89,785	123,561
1988	1,556,000	–	93,361	128,539
1989	1,556,000	–	97,104	133,668
1990	1,273,000	–	100,986	139,034
1991	230,000	–	105,026	144,581
1992	240,000	–	109,220	150,414
1993	–	102,230	113,585	156,450
1994	150,000	–	118,142	162,729
1995	150,000	–	122,857	169,267
1996	150,000	–	127,755	176,025
1997	–	132,850	133,030	183,091
1998	–	–	138,279	190,454
Cumulative			**2,135,118**	**2,939,517**

Figure 39. Comparison of projected, historical, and monitoring annual ESALs for site 041017.

CHAPTER 6. SUMMARY AND RECOMMENDATIONS

Summary

A principal objective of the LTPP program is to quantify the relationship between pavement performance and traffic loads. Consequently, traffic data collection and analysis, required to obtain traffic loads, is the key activity within the LTPP program.

In 1998, the FHWA sponsored a study to estimate traffic loads on LTPP sites. Phase 2, described in this report, included the assessment of the overall quality of traffic data for all 890 LTPP traffic sites, the distribution of summary traffic data reports to all participating agencies describing what traffic data are available for the sites in their jurisdictions, and soliciting their input regarding traffic projections and the projection of axle loads for all LTPP sites with adequate traffic data.

Axle load projections were developed for all in-service years for 558 LTPP traffic sites that had adequate traffic monitoring data in the IMS database. The axle load projections were expressed as annual axle load spectra for single, tandem, and triple axles, and were placed into IMS computed parameter tables.

The main traffic data assessment and traffic projection activities carried out during the course of the Phase 2 study were:

- Data assessment and traffic projection carried out for all individual LTPP traffic sites.
- Preparation of the LTPP Traffic Feedback and Resolution Packages for all participating agencies; these summarized traffic data assessment and traffic projection results.
- Review of LTPP Traffic Feedback and Resolution Packages by RCOs.
- Review of LTPP Traffic Feedback and Resolution Packages by participating agencies.
- Implementation of review comments received from participating agencies.

Because of the large variation in the quality of traffic data and the uncertainty associated with traffic load projections developed for individual sites, traffic projections were assigned projection confidence codes to characterize the level of confidence associated with projected traffic loads:

- A: *Acceptable* projection results. Cumulative ESAL estimates are probably within ±50 percent of the actual cumulative ESAL values.
- Q: *Questionable* projection results. Cumulative ESAL estimates are probably within ±100 percent of actual cumulative ESAL values.
- N: *Not available* projection results. Axle load estimates could not be provided at the time.

Of the 890 LTPP traffic sites, 194 (21.8 percent) were assigned the acceptable projection confidence code and 364 (40.9 percent) were assigned the questionable projection confidence code. For 269 sites (30.2 percent), only the projection of AADT truck volumes was provided because of the unavailability of adequate site-specific axle load data. Many of these 269 sites had site-specific axle load data in the database, but the data were considered inadequate to be used for the projection of axle loads. No traffic projections were carried out for 63 sites because of lack of traffic data. The projection results for all 890 sites are summarized in appendix A.

The projection results were provided for the LTPP sites with unique traffic identification numbers. The total number of all LTPP sections is larger than the number of the LTPP sites because one traffic site may provide traffic data for several sections.

No axle load projections could be developed for 332 LTPP sites because of inadequate or missing data. Nonetheless, the 332 sites, representing 37 percent of all LTPP sites, contain a wealth of information regarding pavement materials, environment, and pavement performance. Without the required traffic data, this information cannot be utilized for the development of load-related pavement performance models. In order to provide traffic projections for these sites, truck classification and axle load distributions must be estimated in lieu of missing site-specific data. Any such estimates must be done judiciously. However, no guidelines exist for the estimation of truck class and axle load distributions, and the knowledge of typical or characteristic distributions is widely dispersed.

To overcome the difficulty of estimating the missing traffic data, it was proposed to develop the LTPP PLG. This report contains a description of the purpose, design parameters, and functionality of the PLG, a blueprint for the development of the PLG, and two examples of using the PLG to obtain traffic load projections for LTPP sites without site-specific truck class or axle load data.

Conclusions

- Traffic data collection in the field is essential for obtaining reliable traffic load data but not sufficient to obtain traffic loads for all years the pavement was in service because it is not possible to collect past traffic data or to collect traffic data all the time. To obtain pavement loads for all years the LTPP sites were in service, it is necessary to use the combination of traffic data (both historical and monitoring) and mathematical modeling referred to as traffic projection.

- The projection procedure used to estimate traffic loads reflects the quantity and quality of available historical and monitoring data. However, the projection procedure cannot fully overcome limitations caused by the presence of questionable data in the database and the use of data that has been factored to annual values. Recommendations to overcome the limitations caused by data quality concerns and factoring of data to annual values are presented in the next section.

- Considering that only about 23 percent of all GPS sites, and about 10 percent of all SPS sites, have acceptable axle load estimates, greater attention should be paid to the quality of traffic data. About 37 percent of all sites (332 sites) had insufficient or missing site-specific truck class or axle weight distribution data to carry out axle load projections. To obtain traffic load estimates for those 37 percent, replacement traffic data will need to be used.

- The LTPP traffic database provides good representation of traffic flows on major highways. Of the 558 sites with traffic projections assigned the acceptable or questionable projection confidence codes, 471 sites (84.4 percent) are located on rural or urban interstates and principal arterial highways. The minimum annual average daily truck volume on LTPP sites ranged from 30 trucks per day for a site located on rural minor collector highway to 6310 trucks per day on a site located on an urban interstate.

- The mean annual growth in truck volumes between 1994 and 1998 ranged from 6.5 percent for urban freeways and expressways to 3.0 percent for rural minor arterial highways. The mean annual growth in truck volumes on rural interstates was 4.6 percent.

- Since 1993, there has been a steady decline in the amount of monitoring axle load data available for traffic projection. The number of annual axle load spectra that could be used for the projection declined from 231 sections in 1993 to 150 sections in 1998. In other words, in 1998, of the 890 sites, only 150 (16.8 percent) had axle load spectra that could be used for projection of axle loads that yielded acceptable or questionable confidence codes. Only 51 sites in 1998 (5.7 percent of all sites) had axle loads yielding acceptable axle load projections. The decline in the amount of acceptable traffic data highlights the need for a renewed data-collection effort. It also highlights the importance of traffic modeling to extend limited sampling data and to compensate for the lack of data, and the need for the proposed LTPP PLG.

Recommendations

This section describes recommended future analytical, modeling, and traffic data-management activities needed to improve traffic load estimates for LTPP sites. There is an obvious need to collect more traffic data and, particularly, to collect high-quality traffic data; however, the activities recommended in this section are concerned only with traffic data analysis and management and not with data collection. The recommendations are divided into:

- Short-term activities required to carry out traffic projection, initiated in Phase 2, to completion.
- Long-term activities that go beyond the scope and methodology of Phase 2 work and are needed for better utilization of the existing traffic data.

Short-Term Activities

Responding to Participating Agencies

At the conclusion of Phase 2, approximately 60 percent of the participating agencies had not yet completed the review of the initial traffic projections. When the agencies' reviews of the initial traffic projections are completed, the reviews should be clarified and discussed with the participating agencies, and utilized to develop reviewed projections.

Developing the LTPP PLG

The LTPP PLG is essential for the estimation of pavement loads for the LTPP sites that do not have site-specific traffic monitoring data. Of 890 LTPP sites, 332 are without traffic load projections. To provide traffic load projections for these sites, axle load spectra and/or truck classification volumes must be estimated in lieu of missing data. The proposed PLG will provide a knowledge base, guidelines, and computational software to facilitate the estimation of traffic loads for the LTPP sites without site-specific traffic data. It will also be a very useful product emerging from the LTPP program for estimating traffic loads for general pavement design purposes. For these reasons, it is recommended to proceed with the development of the proposed PLG on a priority basis.

Completing Traffic Projection for all LTPP Sites

After the development of the LTPP PLG, the initial traffic projection for the remaining 332 LTPP sites without traffic load projections should be carried out, sent to the participating agencies for review, and included in the database. The completion of the initial traffic projections for all LTPP sites will enable pavement performance analyses that require the knowledge of traffic loads for the additional 334 LTPP sites. Potentially, the number of additional LTPP sections that could be used in the load-dependent performance modeling could be even greater because more than one LTPP section could use traffic data from a single LTPP traffic site.

Traffic projections carried out in Phase 2 were done for the period from the time the pavement was open to traffic to 1998. The projections should be updated to incorporate additional traffic data when the data become available.

Long-Term Activities

The recommended long-term activities include:

- Development of an action plan.
- QA of traffic data.
- Use of monthly traffic data.
- Regional traffic modeling.

Development of an Action Plan

The action plan should identify all issues facing LTPP traffic data collection and analysis and recommend specific actions for their resolution. Several components of such an action plan are recommended here.

Quality Assurance of Traffic Data

The previous traffic data QA process has resulted in traffic data that cannot be used without reservations. As documented in chapter 3, about 50 percent of all annual axle load spectra stored in the IMS database were judged unacceptable for estimating traffic loads.

The scope and effectiveness of the original LTPP traffic data QA process faced several limitations:

- The previous LTPP traffic data QA reports were carried out for periods equal to, or less than, 1 year. Consequently, it was not possible to assess long-term trends in historical and monitoring traffic data, such as annual differences in monitoring truck volumes (e.g., to compare AADT truck volumes for two consecutive years) and axle load spectra.
- Comparisons between historical and monitoring traffic data were not carried out, and no long-term assessment of trends in traffic data (spanning the entire time the pavement sections were in service) was performed.
- When the original traffic data QA work started, monitoring traffic data was available for only a few years, and often the amount of data was insufficient to establish trends and to obtain an understanding of what type of data are expected on a particular site. This paucity of data has made it difficult to screen data and reject suspect data confidently.
- Vehicles that could not be properly classified by the monitoring equipment (usually referred to as Class 14 vehicles) were typically not included in the traffic data QA process.

These barriers have been removed through: the development of the computerized procedure to display and summarize long-term trends in traffic data developed under this project; better understanding of trends and variation in traffic data; and the availability of additional traffic data. The anticipated development of the LTPP PLG will also contribute to the body of knowledge that can be used to assess and verify traffic data.

In summary, there is a fundamental need to carry out a basic traffic data QA process to better use traffic data that have been collected in the field. The traffic data QA process is necessary to provide reliable traffic load estimates. The collection of traffic data in the field is very expensive considering the cost of purchasing, installing, and maintaining AVC or WIM system equipment, and data collection and processing. The QA process will help agencies obtain a return on this investment and enhance the LTPP data.

The following activities may be required to carry out the basic traffic data QA process and to remove nonsensical data from the database:

- Reprocessing of some of the raw traffic data (for example, for agencies that have reported a large percentage of Class 14 vehicles).
- Improvements in the software used to produce LTPP traffic data QA reports so the graphs displaying traffic data are more user-friendly and understandable to representatives of participating agencies.

- Preparation of new LTPP traffic data QA reports (or re-examination of the old reports) and identification of erroneous data.
- Purging erroneous data.

Use of Monthly Traffic Data

If an annual axle load spectrum were judged to be unacceptable, all axle loads constituting the annual spectrum were rejected and not used in the projection. Yet annual axle loads may consist of an amalgam of both valid and questionable axle load data collected at different times of the year. Rejecting the entire annual spectrum from the projection process could have serious consequences for sites for which only a few monitoring annual axle load spectra are available.

Using shorter time periods, such as a month, enables a better utilization of available traffic data because axle load spectra are accepted or rejected as monthly, not annual, chunks. Consequently, a portion of the annual axle load data that would have been rejected as part of the annual data could be utilized as monthly data. Monthly axle load spectra are not available and need to be calculated from the raw binary files. Because of the large computational requirements, the monthly axle load spectra can be calculated only through CTDB data managers.

The use of annual data for the projection of traffic loads has been appropriate as the starting point. However, to overcome the disadvantages of using annual data, it is recommended to develop software to calculate monthly traffic data and, in particular, monthly axle load spectra, and to use the monthly axle load spectra for the projection of axle loads. The availability of monthly data will also provide a measure of seasonal variation in traffic loads.

Regional Traffic Modeling

Regional traffic modeling may be the best and most cost effective way to extend limited LTPP data and supplement them with data that are not part of the LTPP database. This situation specifically applies to agencies such as Florida and Texas that have a large corporate traffic database containing extensive WIM-type data but relatively little LTPP data. The feasibility of this approach (utilizing both LTPP and non-LTPP data for LTPP traffic projection) should be investigated using a pilot study in one or two agencies.

The proposed PLG, with its database management, display, and comparison features, will also facilitate the utilization of regional traffic data in lieu of missing LTPP data.

APPENDIX A. SUMMARY OF RESULTS

This appendix provides summary of traffic projection results for all 890 sites with unique traffic ID numbers that are currently in the LTPP program and are included in the IMS database. The summary results are given in table 21. Traffic and other data were not available for several sites; a hyphen in a cell in table 21 indicates the unavailability of the data. The listing contains the following 14 variables:

1. **Agency:** Postal abbreviation for the State or Province of the participating agency.
2.
3. **SHRP ID:** Site identification number assigned by LTPP program (SHRP stands for Strategic Highway Research Program).
4. **Traffic ID:** Unique ID obtained by the combination of STATE_CODE (a 2-digit code assigned to each participating agency) and SHRP ID.
5. **GPS/SPS:** Code indicating whether the section is a GPS (G) or SPS (S) section.
6. **Exp. No.:** Code indicating to which LTPP experiment (exp.) the pavement section is assigned.
7. **Highway Functional Class:** Code indicating functional classification of the highway site.

Table 19. Codes in the IMS database.

Highway Functional Class	Description
1	Rural Principal Arterial—Interstate
2	Rural Principal Arterial—Other
6	Rural Minor Arterial
7	***Rural Major Collector***
8	Rural Minor Collector
9	Rural Local Collector
11	Urban Principal Arterial—Interstate
12	Urban Principal Arterial—Other Freeways and Expressways
14	Urban Other Principal Arterial
16	Urban Minor Arterial
17	Urban Collector
19	Urban Local

8. **Projection Cat.**:

Table 20. Code indicating projection category (2 to 5).

Projection Category	Description
2	Sites with truck class and axle weight distribution data.
3	Sites with truck class distribution data but without site-specific axle weight data.
4	Sites with truck volume data but without site-specific truck class and axle weight distribution data.
5	Sites without traffic data.

Note: Projection Category 1 is reserved for the sites with truck class and axle weight distribution data that can be used for the projection of monthly variation in traffic loads. The adequacy of data to project monthly variation in axle loads was not assessed.

9. **Projection Code:** Projection confidence code:
- **A**—Acceptable.
- *Q**—Questionable.***
- *N**—Not available.***

10. **Projection Status:** Code indicating projection status:
- **I**—Initial.
- *R**—Reviewed.***

11. **Pav. Type:** Code indicating pavement type:
- **F**—Flexible.
- *R**—Rigid.***

12. *Last Pr. Year:* ***Last year for which traffic projections (pr.) are provided in the last three columns of table 21.***

13. *Truck Volume:* ***Projected average annual daily truck volume (in the LTPP traffic lane) in the last year (item 11, above) for which the projection is provided (trucks per day rounded to the nearest 10).***

14. **Annual Growth Rate:** Projected average annual growth rate (for the average daily truck volume) for the last 5 years for which the projection is provided.

15. **ESALs:** Projected total annual ESALs (in the LTPP traffic lane) for the last year for which the projection is provided (rounded to the nearest 10).

Table 21. Summary of traffic projection results.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
AL	0100	010100	S	1	2	5	N	I	–	–	–	–	–
AL	0600	010600	S	6	–	5	N	I	–	–	–	–	–
AL	1001	011001	G	6B	2	2	A	I	F	1998	680	1.60	268,740
AL	1011	011011	G	2	6	3	N	I	F	1998	190	0.49	–
AL	1019	011019	G	6S	2	2	Q	I	F	1998	440	0.77	194,420
AL	1021	011021	G	2	6	2	Q	I	F	1998	390	4.12	197,910
AL	3028	013028	G	3	11	2	Q	I	R	1998	1,550	8.86	668,160
AL	3998	013998	G	7C	1	2	A	I	R	1994	2,350	3.81	1,088,600
AL	4007	014007	G	4	11	2	Q	I	R	1998	960	4.22	743,190
AL	4073	014073	G	2	2	2	Q	I	F	1998	500	6.52	159,830
AL	4084	014084	G	4	11	2	Q	I	R	1998	3,170	4.00	2,271,870
AL	4125	014125	G	2	14	2	Q	I	F	1998	750	2.00	358,400
AL	4126	014126	G	1	1	2	Q	I	F	1998	3,030	3.00	876,890
AL	4127	014127	G	6B	2	3	N	I	F	1998	310	0.42	–
AL	4129	014129	G	6B	2	2	Q	I	F	1997	460	0.00	137,070
AL	4155	014155	G	6B	2	3	N	I	F	1998	770	6.00	–
AL	5008	015008	G	5	1	2	Q	I	R	1998	3,120	6.14	2,226,460
AL	6012	016012	G	6A	1	2	A	I	F	1998	2,780	3.90	1,482,520
AL	6019	016019	G	6D	1	3	N	I	–	1998	2,320	5.57	–
AK	1001	021001	G	1	2	2	Q	I	F	1998	200	0.68	26,360
AK	1002	021002	G	6B	2	2	Q	I	F	1998	200	0.68	26,960
AK	1004	021004	G	6B	14	2	Q	I	F	1998	360	3.77	86,040
AK	1008	021008	G	6A	6	2	Q	I	F	1998	120	2.00	38,440
AK	6010	026010	G	6A	1	2	Q	I	F	1996	320	1.87	58,140
AK	9035	029035	G	6B	2	2	Q	I	F	1998	100	6.00	33,300
AZ	0100	040100	S	1	2	2	A	R	F	1998	900	9.27	272,650
AZ	0200	040200	S	2	1	2	A	R	R	1998	3,290	6.00	1,706,650
AZ	0500	040500	S	5	1	2	A	R	F	1998	720	3.00	283,870
AZ	0600	040600	S	6	1	2	A	R	R	1998	2,620	5.00	1,917,230
AZ	1001	041001	G	1	1	2	A	R	F	1996	2,620	7.17	913,190
AZ	1002	041002	G	1	1	2	A	R	F	1998	2,200	7.77	841,830
AZ	1003	041003	G	6S	1	3	A	R	F	1998	3,400	7.05	1,231,890
AZ	1006	041006	G	6S	1	2	A	R	F	1998	3,160	6.62	1,216,480
AZ	1007	041007	G	6S	1	2	A	R	F	1998	3,530	-11.25	1,308,390
AZ	1015	041015	G	1	1	3	A	R	F	1998	620	7.42	253,850

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
AZ	1016	041016	G	1	1	2	A	R	F	1998	540	7.37	219,680
AZ	1017	041017	G	1	1	2	Q	R	F	1998	540	4.00	138,280
AZ	1018	041018	G	1	1	3	A	R	F	1998	520	5.23	219,040
AZ	1021	041021	G	1	1	3	A	R	F	1998	2,240	11.25	1,400,330
AZ	1022	041022	G	1	1	3	A	R	F	1998	2,240	11.25	1,348,000
AZ	1024	041024	G	1	1	2	A	R	F	1998	2,080	6.70	1,156,220
AZ	1025	041025	G	1	1	2	A	R	F	1998	2,130	7.35	1,305,460
AZ	1034	041034	G	1	6	2	Q	R	F	1998	460	3.81	73,190
AZ	1036	041036	G	1	2	3	A	R	F	1998	800	12.15	252,190
AZ	1037	041037	G	1	2	3	N	R	F	1998	300	7.49	–
AZ	1062	041062	G	6S	1	2	A	R	F	1998	2,190	8.75	1,494,820
AZ	1065	041065	G	6S	1	2	A	R	F	1998	2,140	9.28	762,300
AZ	6053	046053	G	6A	1	2	A	R	F	1997	2,080	4.00	1,003,140
AZ	6054	046054	G	6A	1	2	Q	R	F	1998	570	1.63	164,270
AZ	6055	046055	G	6A	2	2	Q	R	F	1998	790	1.40	167,870
AZ	6060	046060	G	6A	1	2	A	R	F	1998	590	6.68	223,870
AZ	7079	047079	G	5	12	2	A	R	R	1998	660	13.10	193,680
AZ	7613	047613	G	3	14	2	Q	R	R	1998	2,000	9.86	502,380
AZ	7614	047614	G	3	1	2	A	R	R	1998	1,700	4.58	777,360
AR	0100	050100	S	1	2	2	Q	I	F	1998	820	5.29	217,740
AR	0200	050200	S	2	1	3	N	I	R	1998	3,490	0.00	–
AR	0800	050800	S	8	17	5	N	I	–	–	–	–	–
AR	0900	050900	S	9	–	5	N	I	–	–	–	–	–
AR	2042	052042	G	6S	2	2	A	I	F	1998	180	0.00	45,280
AR	3011	053011	G	3	2	2	A	I	R	1998	690	4.18	303,190
AR	3048	053048	G	2	2	2	Q	I	F	1998	110	5.00	31,440
AR	3058	053058	G	2	12	2	Q	I	F	1998	1,120	22.00	320,510
AR	3059	053059	G	4	11	2	Q	I	R	1998	660	6.00	260,080
AR	3071	053071	G	2	2	2	A	I	F	1998	1,770	8.12	478,440
AR	3073	053073	G	4	11	4	N	I	–	1998	6,570	8.00	–
AR	3074	053074	G	4	1	2	Q	I	R	1998	3,210	0.00	1,921,590
AR	4019	054019	G	4	12	2	A	I	R	1998	1,220	8.00	551,030
AR	4021	054021	G	4	14	2	A	I	R	1998	990	-7.54	390,970
AR	4023	054023	G	4	2	2	A	I	R	1998	1,320	6.00	442,060
AR	4046	054046	G	4	2	2	Q	I	R	1998	790	6.78	357,540

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
AR	5803	055803	G	5	11	2	A	I	R	1998	720	10.85	122,810
AR	5805	055805	G	5	11	2	Q	I	R	1998	1,870	7.21	450,270
AR	A600	05A600	S	6	2	5	N	I	–	–	–	–	–
CA	0500	060500	S	5	1	2	Q	I	F	1998	2,040	6.50	821,640
CA	1253	061253	G	1	2	2	Q	I	F	1998	90	2.56	9,700
CA	2002	062002	G	2	2	4	N	I	–	1998	610	0.80	–
CA	2004	062004	G	2	1	4	N	I	–	1998	4,500	10.00	–
CA	2038	062038	G	2	2	4	N	I	–	1998	400	0.50	–
CA	2040	062040	G	2	2	2	A	I	F	1998	840	-10.78	201,420
CA	2041	062041	G	6B	2	4	N	I	–	1998	840	6.35	–
CA	2051	062051	G	6B	12	3	N	I	F	1998	1,080	4.00	–
CA	2053	062053	G	2	1	2	Q	I	F	1998	520	5.00	71,220
CA	2647	062647	G	2	2	2	Q	I	F	1998	530	2.88	200,330
CA	3005	063005	G	3	1	2	A	I	R	1998	2,920	4.61	1,711,740
CA	3010	063010	G	3	11	4	N	I	–	1998	3,600	7.50	–
CA	3013	063013	G	3	1	4	N	I	–	1998	2,600	7.00	–
CA	3017	063017	G	3	12	4	N	I	–	1998	890	3.07	–
CA	3019	063019	G	3	1	4	N	I	–	1998	4,500	6.73	–
CA	3021	063021	G	3	1	2	A	I	R	1998	700	-16.11	180,780
CA	3024	063024	G	3	1	3	N	I	R	1998	2,290	7.00	–
CA	3030	063030	G	3	1	2	A	I	R	1998	2,850	4.16	1,468,130
CA	3042	063042	G	3	1	2	A	I	R	1998	3,990	3.50	2,034,110
CA	6044	066044	G	6A	2	2	A	I	F	1998	390	2.00	42,580
CA	7452	067452	G	2	6	2	Q	I	F	1998	230	3.42	21,600
CA	7454	067454	G	1	6	2	Q	I	F	1998	110	2.00	22,830
CA	7455	067455	G	5	1	2	A	I	R	1998	2,260	7.58	809,980
CA	7456	067456	G	3	1	4	N	I	–	1998	1,850	7.00	–
CA	7491	067491	G	6S	1	4	N	I	–	1998	1,360	4.58	–
CA	7493	067493	G	3	1	4	N	I	–	1998	2,800	6.43	–
CA	8149	068149	G	6S	1	4	N	I	–	1998	1,770	7.31	–
CA	8150	068150	G	2	6	2	Q	I	F	1998	890	-0.78	188,600
CA	8151	068151	G	2	1	2	A	I	F	1998	2,220	6.68	937,730
CA	8153	068153	G	6B	6	2	Q	I	F	1998	250	1.38	27,240
CA	8156	068156	G	1	6	2	Q	I	F	1998	250	2.30	94,070
CA	8201	068201	G	2	6	2	Q	I	F	1998	230	3.00	36,330

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
CA	8202	068202	G	2	2	2	Q	I	F	1998	570	3.34	93,550
CA	8534	068534	G	6B	1	2	Q	I	F	1998	730	5.24	128,700
CA	8535	068535	G	6B	1	2	A	I	F	1998	960	4.00	196,790
CA	9048	069048	G	9	1	4	N	I	–	1998	1,100	5.80	–
CA	9049	069049	G	9	12	4	N	I	–	1998	3,080	6.13	–
CA	9107	069107	G	9	1	4	N	I	–	1998	1,460	3.48	–
CO	0200	080200	S	2	1	2	Q	I	R	1998	960	0.00	346,050
CO	0500	080500	S	5	1	2	Q	I	F	1998	1,150	5.00	536,060
CO	0800	080800	S	8	9	5	N	I	–	–	–	–	–
CO	1029	081029	G	6B	2	2	Q	I	F	1998	100	1.00	14,480
CO	1047	081047	G	6B	7	2	Q	I	F	1998	150	0.00	38,210
CO	1053	081053	G	1	2	3	N	I	F	1998	450	2.94	–
CO	1057	081057	G	1	14	3	N	I	F	1998	310	3.00	–
CO	2008	082008	G	2	2	3	N	I	F	1994	260	0.00	–
CO	3032	083032	G	3	1	2	A	I	R	1998	820	5.34	381,890
CO	6002	086002	G	6C	1	2	Q	I	F	1998	1,530	3.88	264,700
CO	6013	086013	G	6A	14	3	N	I	F	1998	370	12.00	–
CO	7035	087035	G	7S	1	3	N	I	R	1998	1,640	3.73	–
CO	7036	087036	G	7A	1	4	N	I	–	1997	1,580	5.32	–
CO	7776	087776	G	3	1	3	N	I	R	1998	1,700	4.93	–
CO	7780	087780	G	6B	2	3	N	I	F	1998	340	0.51	–
CO	7781	087781	G	6B	2	3	N	I	F	1998	260	0.00	–
CO	7783	087783	G	6A	1	2	Q	I	F	1998	770	3.00	305,640
CO	9019	089019	G	9	1	2	Q	I	R	1998	2,610	5.76	667,800
CO	9020	089020	G	9	1	2	Q	I	R	1998	2,810	6.15	882,360
CO	A400	08A400	S	4	–	5	N	I	–	–	–	–	–
CT	0900	090900	S	9	–	5	N	R	–	–	–	–	–
CT	1803	091803	G	1	2	3	N	R	F	1998	210	7.00	–
CT	4008	094008	G	4	1	2	Q	R	R	1998	2,700	5.23	1,444,240
CT	4020	094020	G	7B	2	2	A	R	R	1998	800	2.84	119,860
CT	5001	095001	G	7B	1	2	Q	R	R	1998	3,780	4.73	1,734,800
DE	0100	100100	S	1	2	5	N	R	–	–	–	–	–
DE	0200	100200	S	2	2	5	N	R	–	–	–	–	–
DE	1201	101201	G	4	2	4	N	R	–	1998	720	6.50	–
DE	1450	101450	G	6C	2	4	N	R	–	1998	1,200	1.48	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
DE	4002	104002	G	7B	2	4	N	R	–	1998	480	11.23	–
DE	5004	105004	G	5	1	4	N	R	–	1996	4,730	16.23	–
DE	5005	105005	G	7B	2	4	N	R	–	1998	620	5.06	–
DC	1400	111400	G	6B	11	4	N	I	–	1996	1,110	5.00	–
FL	0100	120100	S	1	2	3	N	I	F	1998	800	5.00	–
FL	0500	120500	S	5	2	5	N	I	–	–	–	–	–
FL	0900	120900	S	9	–	5	N	I	–	–	–	–	–
FL	1030	121030	G	1	2	3	N	I	F	1998	400	10.00	–
FL	1060	121060	G	1	12	3	N	I	F	1998	160	10.00	–
FL	1370	121370	G	1	6	2	Q	I	F	1998	110	3.00	53,380
FL	3804	123804	G	3	1	2	Q	I	R	1998	1,430	8.50	1,156,350
FL	3811	123811	G	3	1	2	Q	I	R	1998	1,620	6.00	784,160
FL	3995	123995	G	1	11	2	Q	I	F	1998	1,960	7.00	713,630
FL	3996	123996	G	1	2	2	Q	I	F	1998	220	2.00	69,400
FL	3997	123997	G	6B	2	3	N	I	F	1998	510	5.17	–
FL	4000	124000	G	3	2	2	Q	I	R	1998	560	2.00	257,460
FL	4057	124057	G	3	1	2	Q	I	R	1998	1,740	5.00	956,430
FL	4059	124059	G	3	2	2	Q	I	R	1998	130	6.00	40,200
FL	4096	124096	G	2	6	2	Q	I	F	1998	100	-13.83	24,980
FL	4097	124097	G	2	1	2	Q	I	F	1998	1,630	6.00	467,340
FL	4099	124099	G	1	14	2	Q	I	F	1998	250	2.00	144,540
FL	4100	124100	G	2	14	2	Q	I	F	1998	140	3.00	30,180
FL	4101	124101	G	6B	12	3	N	I	F	1998	1,150	4.00	–
FL	4102	124102	G	1	12	5	N	I	–	–	–	–	–
FL	4103	124103	G	1	12	3	N	I	F	1998	620	10.00	–
FL	4105	124105	G	1	14	2	Q	I	F	1998	670	3.19	259,830
FL	4106	124106	G	1	1	2	Q	I	F	1998	1,390	7.00	534,520
FL	4107	124107	G	1	2	2	Q	I	F	1998	200	6.00	119,960
FL	4108	124108	G	2	6	2	Q	I	F	1998	320	3.51	67,320
FL	4109	124109	G	3	2	3	N	I	R	1998	130	4.00	–
FL	4135	124135	G	6B	2	2	Q	I	F	1998	1,050	2.00	456,530
FL	4136	124136	G	6B	2	2	Q	I	F	1998	1,050	2.00	450,900
FL	4137	124137	G	6B	2	2	Q	I	F	1998	1,050	2.00	428,700
FL	4138	124138	G	3	2	2	Q	I	R	1998	560	2.00	274,360
FL	4153	124153	G	1	6	5	N	I	–	–	–	–	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
FL	4154	124154	G	1	6	3	N	I	F	1998	22,040	171.58	–
FL	9054	129054	G	1	6	2	Q	I	F	1998	430	2.00	174,670
GA	0500	130500	S	5	1	5	N	I	–	–	–	–	–
GA	1001	131001	G	1	2	3	N	I	F	1998	910	5.09	–
GA	1004	131004	G	1	6	3	N	I	F	1998	500	8.56	–
GA	1005	131005	G	1	7	4	N	I		1998	620	5.39	–
GA	1031	131031	G	6S	2	3	N	I	F	1998	480	11.30	–
GA	3007	133007	G	3	2	3	N	I	R	1998	640	14.88	–
GA	3011	133011	G	3	1	3	N	I	R	1998	1,420	12.56	–
GA	3015	133015	G	3	1	3	N	I	R	1998	1,350	12.50	–
GA	3016	133016	G	3	1	4	N	I	–	1998	3,120	6.14	–
GA	3017	133017	G	3	1	3	N	I	–	1998	4,710	9.16	–
GA	3018	133018	G	3	1	3	N	I	R	1998	4,710	9.16	–
GA	3019	133019	G	3	2	3	N	I	R	1998	1,110	0.00	–
GA	3020	133020	G	3	2	2	Q	I	R	1998	300	0.00	95,000
GA	4092	134092	G	2	2	3	N	I	–	1998	380	5.08	–
GA	4093	134093	G	2	2	3	N	I	–	1998	380	5.08	–
GA	4096	134096	G	2	8	3	N	I	–	1998	40	0.00	–
GA	4111	134111	G	1	7	3	N	I	F	1998	270	0.00	–
GA	4112	134112	G	6S	1	3	N	I	F	1998	3,600	4.70	–
GA	4113	134113	G	6S	1	3	N	I	F	1998	3,600	4.70	–
GA	4118	134118	G	9	1	3	N	I	R	1998	3,970	3.72	–
GA	4119	134119	G	2	1	3	N	I	F	1998	4,760	1.89	–
GA	4420	134420	G	6B	2	3	N	I	F	1998	570	3.00	–
GA	5023	135023	G	5	1	3	N	I	R	1998	4,050	6.00	–
GA	7028	137028	G	7S	1	3	N	I	R	1998	4,150	5.28	–
HI	1003	151003	G	1	14	3	N	I	F	1998	190	6.61	–
HI	1006	151006	G	1	14	3	N	I	F	1998	220	3.90	–
HI	1008	151008	G	1	14	3	N	I	F	1998	270	2.35	–
HI	7080	157080	G	1	2	4	N	I	–	1998	320	8.42	–
ID	1001	161001	G	1	2	2	Q	R	F	1998	580	3.92	174,380
ID	1005	161005	G	1	2	2	Q	R	F	1998	120	2.45	25,080
ID	1007	161007	G	6B	2	2	Q	R	F	1998	110	0.00	32,400
ID	1009	161009	G	1	1	2	A	R	F	1998	1,040	7.00	497,320
ID	1010	161010	G	1	1	2	A	R	F	1997	610	5.80	257,190

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
ID	1020	161020	G	1	2	2	Q	R	F	1998	170	0.00	55,190
ID	1021	161021	G	1	2	2	Q	R	F	1998	470	1.50	153,040
ID	3017	163017	G	3	1	2	Q	R	R	1998	960	3.89	640,120
ID	3023	163023	G	3	1	2	A	R	R	1998	1,380	0.00	816,360
ID	5025	165025	G	5	1	2	Q	R	R	1998	600	5.85	210,110
ID	6027	166027	G	6A	2	2	Q	R	F	1997	400	0.00	282,890
ID	9032	169032	G	1	2	2	Q	R	F	1998	190	0.00	28,080
ID	9034	169034	G	1	2	2	Q	R	F	1998	250	0.00	111,820
IL	0600	170600	S	6	1	2	Q	R	R	1998	1,670	-5.39	1,080,600
IL	1002	171002	G	1	2	2	A	R	F	1998	400	3.50	101,910
IL	1003	171003	G	1	2	2	A	R	F	1998	340	4.07	66,310
IL	4074	174074	G	4	2	2	Q	R	R	1998	450	4.00	180,370
IL	4082	174082	G	4	2	2	A	R	R	1998	180	4.00	39,880
IL	5020	175020	G	5	2	2	A	R	R	1998	220	4.00	51,840
IL	5151	175151	G	7B	1	2	A	R	R	1998	2,630	2.50	1,671,520
IL	5217	175217	G	7B	1	2	Q	R	R	1998	1,950	3.92	558,900
IL	5423	175423	G	7A	1	2	A	R	R	1998	1,830	2.50	769,070
IL	5453	175453	G	7A	1	2	Q	R	R	1998	4,820	5.47	3,075,630
IL	5843	175843	G	5	1	2	A	R	R	1998	3,040	3.60	1,697,030
IL	5849	175849	G	5	1	2	A	R	R	1998	1,350	2.00	721,120
IL	5854	175854	G	5	2	2	Q	R	R	1998	570	5.74	120,880
IL	5869	175869	G	5	12	2	Q	R	R	1998	690	5.39	156,730
IL	5908	175908	G	5	2	2	A	R	R	1998	340	2.00	88,260
IL	6050	176050	G	6A	7	3	N	R	F	1998	50	1.00	–
IL	7937	177937	G	7D	6	2	Q	R	R	1998	120	6.00	32,000
IL	9267	179267	G	5	1	2	A	R	R	1998	2,520	2.50	1,602,540
IL	9327	179327	G	7B	1	3	N	R	R	1998	1,820	4.00	–
IN	1028	181028	G	6S	1	2	A	R	F	1998	1,980	7.00	602,030
IN	1037	181037	G	6B	6	2	Q	R	F	1998	470	6.53	106,780
IN	2008	182008	G	2	2	2	A	R	F	1998	1,330	2.50	358,920
IN	2009	182009	G	2	6	2	Q	R	F	1998	980	3.99	181,860
IN	3002	183002	G	3	2	2	A	R	R	1998	830	3.03	474,930
IN	3003	183003	G	7B	2	2	Q	R	R	1998	1,360	2.11	623,630
IN	3030	183030	G	3	7	3	N	R	R	1998	650	5.45	–
IN	3031	183031	G	3	6	2	A	R	R	1998	830	2.03	236,450

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
IN	4021	184021	G	4	14	2	Q	R	R	1998	930	4.00	235,240
IN	4042	184042	G	4	6	2	A	R	R	1998	830	4.12	226,700
IN	5022	185022	G	7B	11	2	Q	R	R	1998	6,310	4.79	2,470,400
IN	5043	185043	G	5	2	3	N	R	R	1998	180	2.86	–
IN	5518	185518	G	7B	1	2	A	R	R	1998	4,500	4.70	1,940,110
IN	5528	185528	G	7B	6	2	Q	R	R	1998	550	2.00	134,150
IN	5538	185538	G	7B	6	2	Q	R	R	1998	470	2.30	104,280
IN	6012	186012	G	6S	1	2	Q	R	F	1998	2,170	7.22	793,950
IN	9020	189020	G	9	1	2	Q	R	R	1998	3,670	7.99	1,136,320
IN	A900	18A900	S	9	–	5	N	I	–	–	–	–	–
IA	0100	190100	S	1	2	2	Q	I	F	1998	170	0.00	34,060
IA	0200	190200	S	2	12	3	N	I	R	1998	550	13.27	–
IA	0600	190600	S	6	1	2	Q	I	R	1998	1,890	3.16	670,760
IA	0700	190700	S	7	1	2	A	I	R	1998	1,960	2.69	977,240
IA	1044	191044	G	1	2	2	Q	I	F	1998	290	0.96	107,570
IA	3006	193006	G	3	2	2	Q	I	R	1998	380	2.43	145,710
IA	3009	193009	G	3	11	3	N	I	R	1998	1,100	7.00	–
IA	3028	193028	G	3	2	2	Q	I	R	1998	940	2.58	345,010
IA	3033	193033	G	3	2	3	N	I	R	1998	760	7.09	–
IA	3055	193055	G	3	2	2	Q	I	R	1998	610	6.75	194,270
IA	5042	195042	G	5	1	3	N	I	R	1998	1,550	3.63	–
IA	5046	195046	G	5	1	3	N	I	R	1998	1,550	3.63	–
IA	6049	196049	G	6A	1	3	N	I	F	1998	3,000	2.41	–
IA	6150	196150	G	2	7	3	N	I	F	1998	60	0.00	–
IA	9116	199116	G	7B	1	2	Q	I	R	1998	1,410	4.92	509,100
IA	9126	199126	G	7B	1	3	N	I	R	1998	2,470	4.71	–
KS	0100	200100	S	1	2	2	Q	I	F	1998	480	0.00	197,440
KS	0200	200200	S	2	1	2	Q	I	R	1998	1,200	6.00	1,069,450
KS	1005	201005	G	1	6	3	N	I	F	1998	180	0.82	–
KS	1006	201006	G	6A	2	2	Q	I	F	1998	200	0.00	19,400
KS	1009	201009	G	1	2	2	Q	I	F	1998	170	0.80	23,610
KS	1010	201010	G	1	2	3	N	I	F	1997	310	2.76	–
KS	3013	203013	G	3	11	3	N	I	R	1998	820	10.00	–
KS	3015	203015	G	3	2	2	Q	I	R	1998	760	4.00	244,690
KS	3060	203060	G	3	11	3	N	I	R	1998	500	10.57	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
KS	4016	204016	G	4	2	3	N	I	R	1998	270	3.04	–
KS	4052	204052	G	4	2	2	Q	I	R	1998	390	5.11	120,540
KS	4053	204053	G	4	11	3	N	I	R	1998	820	1.24	–
KS	4054	204054	G	4	1	2	Q	I	R	1998	1,150	3.00	880,380
KS	4063	204063	G	4	1	2	Q	I	R	1998	820	10.00	352,880
KS	4067	204067	G	7D	14	2	Q	I	R	1998	600	2.90	224,620
KS	6026	206026	G	6D	2	3	N	I	F	1998	410	5.00	–
KS	7073	207073	G	7S	1	3	N	I	R	1994	1,030	3.06	–
KS	7085	207085	G	7S	2	2	Q	I	R	1997	350	3.00	57,750
KS	9037	209037	G	9	12	3	N	I	R	1994	450	4.11	–
KY	1010	211010	G	1	7	2	Q	I	F	1994	60	4.49	16,420
KY	1014	211014	G	1	2	2	Q	I	F	1998	400	5.00	181,180
KY	1034	211034	G	6S	2	2	Q	I	F	1998	590	12.96	114,820
KY	3016	213016	G	3	1	2	A	I	R	1998	3,410	2.35	1,507,820
KY	4025	214025	G	4	1	2	A	I	R	1995	2,050	4.27	930,340
KY	6040	216040	G	6A	12	2	Q	I	F	1993	1,000	4.78	563,140
KY	6043	216043	G	6A	2	3	N	I	F	1998	360	1.09	–
LA	0100	220100	S	1	2	5	N	I	–	–	–	–	–
LA	0700	220700	S	7	1	5	N	I	–	–	–	–	–
LA	3056	223056	G	2	1	2	Q	I	F	1998	630	4.01	262,170
LA	4001	224001	G	4	1	2	Q	I	R	1998	1,800	4.01	849,480
ME	1001	231001	G	6S	1	4	N	I	–	1998	650	3.30	–
ME	1009	231009	G	6B	2	4	N	I	–	1998	420	2.39	–
ME	1012	231012	G	1	1	4	N	I	–	1998	1,550	2.41	–
ME	1026	231026	G	6B	2	4	N	I	–	1998	260	2.26	–
ME	1028	231028	G	6B	2	4	N	I	–	1998	360	2.46	–
ME	3013	233013	G	3	1	4	N	I	–	1998	1,350	7.26	–
ME	3014	233014	G	3	1	4	N	I	–	1998	1,340	7.26	–
ME	7023	237023	G	7A	1	4	N	I	–	1998	1,740	2.45	–
MD	0500	240500	S	5	2	2	A	R	F	1998	830	0.00	224,760
MD	1632	241632	G	2	2	4	N	R	–	1998	620	7.14	–
MD	1634	241634	G	6C	2	4	N	R	–	1998	170	0.00	–
MD	2401	242401	G	2	2	4	N	R	–	1998	880	8.45	–
MD	2805	242805	G	6C	1	4	N	R	–	1998	1,500	0.00	–
MD	5807	245807	G	5	11	4	N	R	–	1998	640	6.64	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
MA	1002	251002	G	1	1	2	Q	I	F	1998	490	1.66	74,770
MA	1003	251003	G	1	2	3	N	I	F	1998	200	4.08	–
MA	1004	251004	G	1	1	3	N	I	F	1998	1,040	5.23	–
MI	0100	260100	S	1	2	2	Q	R	F	1998	100	0.00	12,290
MI	0200	260200	S	2	2	2	Q	R	R	1998	4,320	15.50	2,040,510
MI	0600	260600	S	6	2	2	Q	R	R	1998	890	2.44	330,140
MI	0900	260900	S	9	–	5	N	R	–	–	–	–	–
MI	1001	261001	G	1	6	2	Q	R	F	1998	160	14.09	22,760
MI	1004	261004	G	1	14	2	Q	R	F	1998	150	0.00	41,130
MI	1010	261010	G	1	6	2	Q	R	F	1998	340	13.36	67,960
MI	1012	261012	G	1	2	2	Q	R	F	1998	850	7.77	166,360
MI	1013	261013	G	1	2	3	Q	R	F	1998	1,040	8.00	202,250
MI	3068	263068	G	3	2	2	A	R	R	1993	320	8.49	92,570
MI	3069	263069	G	3	2	2	A	R	R	1998	560	8.69	151,450
MI	4015	264015	G	4	1	2	Q	R	R	1998	1,640	10.49	606,580
MI	5363	265363	G	5	1	2	Q	R	R	1998	1,940	8.53	1,010,520
MI	6016	266016	G	6A	1	2	Q	R	F	1998	350	0.00	78,320
MI	7072	267072	G	7A	1	2	Q	R	R	1998	1,840	11.21	417,080
MI	9029	269029	G	9	1	3	N	R	R	1998	1,910	2.00	–
MI	9030	269030	G	9	2	2	Q	R	R	1998	2,270	2.32	976,200
MN	0700	270700	S	7	1	2	Q	R	R	1998	1,200	4.16	358,990
MN	1003	271003	G	1	1	2	A	R	F	1998	2,370	6.02	603,260
MN	1004	271004	G	1	1	2	A	R	F	1998	2,370	6.02	663,090
MN	1016	271016	G	1	2	2	A	R	F	1998	180	4.84	36,240
MN	1017	271017	G	1	1	5	N	R	–	–	–	–	–
MN	1018	271018	G	1	2	2	A	R	F	1998	300	3.66	79,580
MN	1019	271019	G	1	2	2	Q	R	F	1998	300	4.50	64,700
MN	1020	271020	G	1	1	5	N	R	–	–	–	–	–
MN	1023	271023	G	1	2	2	A	R	F	1998	400	4.15	142,250
MN	1028	271028	G	1	2	2	A	R	F	1998	350	-2.06	86,950
MN	1029	271029	G	1	6	2	Q	R	F	1998	210	0.55	50,660
MN	1085	271085	G	1	6	2	A	R	F	1998	100	1.00	19,080
MN	1087	271087	G	1	14	2	A	R	F	1998	340	1.27	24,960
MN	2018	272018	G	1	1	5	N	R	–	–	–	–	–
MN	2023	272023	G	2	1	5	N	R	–	–	–	–	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
MN	3003	273003	G	3	2	2	A	R	R	1998	200	2.02	74,230
MN	3005	273005	G	3	1	3	A	R	R	1998	2,370	6.02	939,660
MN	3007	273007	G	3	1	2	A	R	R	1998	2,370	6.02	1,051,670
MN	3009	273009	G	3	1	2	A	R	R	1998	2,370	6.02	1,051,660
MN	3010	273010	G	3	1	2	A	R	R	1998	2,370	6.02	1,080,010
MN	3012	273012	G	3	1	2	A	R	R	1998	2,370	6.02	1,080,020
MN	3013	273013	G	3	12	2	A	R	R	1998	380	1.21	54,910
MN	4033	274033	G	4	11	2	Q	R	R	1998	700	4.12	171,640
MN	4034	274034	G	4	11	4	N	R	–	1998	1,320	4.15	–
MN	4037	274037	G	4	11	2	Q	R	R	1998	500	3.59	127,800
MN	4040	274040	G	4	2	2	Q	R	R	1998	430	1.50	109,020
MN	4050	274050	G	4	2	2	Q	R	R	1998	160	-5.63	39,950
MN	4054	274054	G	4	1	2	A	R	R	1998	1,410	7.00	909,290
MN	4055	274055	G	4	1	2	A	R	R	1998	2,190	5.50	1,273,080
MN	4082	274082	G	4	2	3	N	R	R	1998	450	2.00	–
MN	5076	275076	G	7B	11	2	Q	R	R	1998	1,500	4.56	412,460
MN	6064	276064	G	6S	1	5	N	R	–	–	–	–	–
MN	6251	276251	G	1	2	2	A	R	F	1998	600	6.50	86,030
MN	6300	276300	G	9	1	2	A	R	R	1998	550	3.59	153,980
MN	7090	277090	G	7A	2	2	A	R	R	1998	900	1.50	349,860
MN	9075	279075	G	9	2	2	A	R	R	1998	130	0.00	42,870
MS	0500	280500	S	5	1	2	Q	R	F	1998	1,550	5.00	726,370
MS	0800	280800	S	8	2	5	N	R	–	–	–	–	–
MS	0900	280900	S	9	–	5	N	R	–	–	–	–	–
MS	1001	281001	G	6S	2	2	Q	R	F	1998	380	5.23	86,400
MS	1016	281016	G	2	14	2	A	R	F	1997	240	9.49	91,960
MS	1802	281802	G	2	2	2	A	R	F	1998	240	0.44	77,840
MS	2807	282807	G	6S	2	2	A	R	F	1998	360	3.00	140,450
MS	3018	283018	G	3	2	2	A	R	R	1998	650	9.62	282,410
MS	3019	283019	G	3	2	2	A	R	R	1998	660	9.61	285,180
MS	3081	283081	G	6S	2	2	A	R	F	1998	1,860	11.12	714,120
MS	3082	283082	G	2	2	2	Q	R	F	1998	460	7.67	204,110
MS	3083	283083	G	2	2	3	N	R	F	1998	20	1.66	–
MS	3085	283085	G	2	2	3	N	R	F	1998	20	1.66	–
MS	3087	283087	G	6C	2	2	Q	R	F	1998	170	0.00	80,580

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
MS	3089	283089	G	2	2	2	A	R	F	1998	360	3.00	140,440
MS	3090	283090	G	2	2	3	N	R	F	1998	40	1.84	–
MS	3091	283091	G	6S	2	2	Q	R	F	1998	290	1.00	137,040
MS	3093	283093	G	6B	1	2	A	R	F	1998	2,400	4.88	818,290
MS	3094	283094	G	6B	1	2	A	R	F	1998	2,400	4.88	818,470
MS	3097	283097	G	7A	1	2	Q	R	R	1994	1,390	2.60	847,660
MS	3099	283099	G	7B	1	2	A	R	R	1998	2,260	6.65	1,422,470
MS	4024	284024	G	4	14	3	N	R	R	1998	120	3.01	–
MS	5006	285006	G	5	2	2	A	R	R	1998	1,950	7.80	765,280
MS	5025	285025	G	5	2	2	A	R	R	1998	380	4.40	261,050
MS	5803	285803	G	5	2	2	Q	R	R	1998	1,830	5.83	1,205,250
MS	5805	285805	G	5	11	2	A	R	R	1998	2,430	4.67	986,990
MS	7012	287012	G	9	1	2	Q	R	R	1998	2,620	6.00	1,725,340
MS	9030	289030	G	9	1	2	A	R	R	1998	2,880	5.75	1,072,640
MO	0500	290500	S	5	–	5	N	I	–	–	–	–	–
MO	0600	290600	S	6	2	2	Q	I	R	1998	2,030	4.06	1,169,210
MO	0700	290700	S	7	14	2	Q	I	R	1998	740	-7.22	261,450
MO	0800	290800	S	8	9	5	N	I	–	–	–	–	–
MO	0900	290900	S	9	–	5	N	I	–	–	–	–	–
MO	1002	291002	G	1	7	2	Q	I	F	1998	100	11.41	15,800
MO	1005	291005	G	1	2	2	Q	I	F	1998	500	3.58	84,410
MO	1008	291008	G	1	6	3	N	I	F	1998	250	2.94	–
MO	1010	291010	G	1	1	2	Q	I	F	1998	2,800	6.24	1,046,880
MO	4036	294036	G	4	11	2	Q	I	R	1998	1,610	9.90	1,064,270
MO	4069	294069	G	7B	11	2	Q	I	R	1998	1,220	7.34	585,200
MO	5000	295000	G	4	1	2	Q	I	R	1998	1,470	4.79	419,400
MO	5047	295047	G	5	12	2	A	I	R	1998	1,250	5.14	748,870
MO	5058	295058	G	4	1	3	Q	I	R	1998	1,470	4.79	420,730
MO	5081	295081	G	4	1	3	Q	I	R	1998	1,470	4.79	422,300
MO	5091	295091	G	4	1	3	Q	I	R	1998	1,470	4.79	421,030
MO	5393	295393	G	7B	6	2	Q	I	R	1998	300	2.79	48,530
MO	5403	295403	G	6B	6	2	Q	I	F	1998	510	6.85	245,560
MO	5413	295413	G	6B	6	2	Q	I	F	1998	470	6.75	127,400
MO	5473	295473	G	4	1	2	Q	I	R	1998	3,660	7.12	2,076,000
MO	5483	295483	G	7B	2	2	Q	I	R	1998	470	2.32	174,280

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
MO	5503	295503	G	4	2	2	Q	I	R	1998	1,200	4.96	437,130
MO	6067	296067	G	6A	2	2	Q	I	F	1998	300	-0.53	128,320
MO	7054	297054	G	7S	1	2	Q	I	R	1998	3,350	6.32	1,874,510
MO	7073	297073	G	7A	2	2	Q	I	R	1998	350	1.46	79,600
MO	A600	29A600	S	6	–	5	N	I	–	–	–	–	–
MO	A800	29A800	S	8	9	5	N	I	–	–	–	–	–
MT	0100	300100	S	1	1	5	N	R	–	–	–	–	–
MT	0800	300800	S	8	9	5	N	R	–	–	–	–	–
MT	0900	300900	S	9	–	5	N	R	–	–	–	–	–
MT	1001	301001	G	1	2	3	N	R	F	1998	200	2.43	–
MT	6004	306004	G	6A	2	3	N	R	F	1998	40	1.81	–
MT	7066	307066	G	6B	1	3	N	R	F	1998	910	4.39	–
MT	7075	307075	G	6A	1	3	N	R	F	1998	1,400	4.50	–
MT	7076	307076	G	6B	1	3	N	R	F	1998	470	5.40	–
MT	7088	307088	G	6B	1	3	N	R	F	1998	960	4.70	–
MT	8129	308129	G	1	2	3	N	R	F	1998	160	5.37	–
NE	0100	310100	S	1	2	2	Q	I	F	1998	330	0.00	110,120
NE	0900	310900	S	9	2	5	N	I	–	–	–	–	–
NE	1030	311030	G	1	2	2	Q	I	F	1998	100	0.00	28,470
NE	3018	313018	G	3	1	2	A	I	R	1998	5,340	4.46	1,397,190
NE	3023	313023	G	3	1	2	Q	I	R	1998	2,350	4.40	2,031,850
NE	3024	313024	G	3	1	2	Q	I	R	1998	2,450	3.98	1,258,810
NE	3028	313028	G	3	2	2	A	I	R	1998	400	10.65	151,220
NE	3033	313033	G	3	2	2	A	I	R	1998	330	6.53	155,830
NE	4019	314019	G	4	11	2	A	I	R	1998	790	1.50	356,690
NE	5052	315052	G	5	11	2	A	I	R	1998	890	2.50	444,710
NE	6700	316700	G	6B	2	2	A	I	F	1998	110	0.50	35,920
NE	6701	316701	G	9	14	2	A	I	R	1998	210	0.50	76,110
NE	6702	316702	G	7B	1	2	A	I	R	1998	1,770	5.00	1,321,520
NE	7005	317005	G	7S	1	2	A	I	R	1998	2,380	4.00	1,639,440
NE	7017	317017	G	7A	2	2	Q	I	R	1998	150	0.45	78,270
NE	7040	317040	G	7S	2	2	Q	I	R	1998	280	8.00	145,730
NE	7050	317050	G	7S	1	2	A	I	R	1998	2,750	4.08	1,724,620
NV	0100	320100	S	1	1	2	A	R	F	1998	1,430	17.00	595,460
NV	0200	320200	S	2	1	2	A	R	R	1998	1,430	17.00	958,890

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
NV	1020	321020	G	1	2	2	A	R	F	1998	280	7.82	138,120
NV	1021	321021	G	1	14	2	Q	R	F	1998	140	4.00	40,070
NV	1030	321030	G	6B	12	2	Q	R	F	1997	660	7.47	165,690
NV	2027	322027	G	2	1	3	A	R	F	1997	940	5.00	468,610
NV	3010	323010	G	3	1	2	Q	R	R	1998	1,260	4.42	772,350
NV	3013	323013	G	3	1	2	A	R	R	1998	1,050	4.50	689,480
NV	7000	327000	G	2	1	2	A	R	F	1997	940	5.00	478,580
NV	7084	327084	G	3	1	2	Q	R	R	1998	2,270	6.44	1,686,480
NV	B400	32B400	S	4	–	5	N	R	–	–	–	–	–
NH	1001	331001	G	1	1	3	N	R	F	1998	890	4.48	–
NJ	0800	340800	S	8	–	5	N	I	–	–	–	–	–
NJ	1003	341003	G	6S	6	2	Q	R	F	1998	1,100	3.00	177,500
NJ	1011	341011	G	1	1	2	A	R	F	1998	1,330	5.04	368,560
NJ	1030	341030	G	1	14	3	N	R	F	1998	480	1.00	–
NJ	1031	341031	G	6S	12	2	Q	R	F	1998	1,380	3.00	472,270
NJ	1033	341033	G	2	2	2	Q	R	F	1998	320	1.47	45,080
NJ	1034	341034	G	2	12	2	Q	R	F	1998	1,480	5.00	282,930
NJ	1638	341638	G	2	12	2	A	R	F	1998	1,490	5.00	564,670
NJ	4042	344042	G	4	11	2	A	R		1998	2,610	2.30	1,698,690
NJ	6057	346057	G	6A	11	3	N	R	F	1998	1,850	3.33	–
NM	0100	350100	S	1	1	3	N	I	F	1998	380	3.96	–
NM	0500	350500	S	5	1	3	N	I	F	1998	2,360	4.00	–
NM	0800	350800	S	8	9	5	N	I	–	–	–	–	–
NM	0900	350900	S	9	–	5	N	I	–	–	–	–	–
NM	1002	351002	G	6A	2	2	A	I	F	1998	940	21.20	274,430
NM	1003	351003	G	1	2	2	A	I	F	1998	940	21.20	277,680
NM	1005	351005	G	1	1	3	N	I	F	1998	770	2.40	–
NM	1022	351022	G	1	2	2	Q	I	F	1998	460	8.34	147,610
NM	1112	351112	G	1	2	2	Q	I	F	1998	260	0.63	77,850
NM	2006	352006	G	2	2	2	Q	I	F	1998	310	5.05	108,810
NM	2007	352007	G	6S	2	2	Q	I	F	1998	460	8.34	149,950
NM	2118	352118	G	2	1	3	N	I	F	1998	2,390	6.00	–
NM	3010	353010	G	3	2	2	Q	I	R	1998	260	0.00	102,820
NM	6033	356033	G	6A	1	3	N	I	F	1998	620	3.09	–
NM	6035	356035	G	6A	1	2	Q	I	F	1998	2,080	3.47	978,900

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
NM	6401	356401	G	6A	1	2	Q	I	F	1998	2,080	3.47	669,890
NY	0800	360800	S	8	–	3	N	I	F	1998	10	6.68	–
NY	1008	361008	G	6B	14	2	Q	I	F	1998	920	11.38	120,890
NY	1011	361011	G	6B	1	2	Q	I	F	1998	700	7.38	157,770
NY	1643	361643	G	6B	2	2	Q	I	F	1998	700	0.96	262,050
NY	1644	361644	G	6S	6	3	N	I	F	1998	100	5.00	–
NY	4017	364017	G	4	2	3	N	I	R	1998	1,360	5.24	–
NY	4018	364018	G	4	1	2	A	I	R	1998	1,130	5.05	403,790
NC	0200	370200	S	2	2	2	Q	R	R	1998	1,230	7.61	835,310
NC	0800	370800	S	8	–	5	N	R	–	–	–	–	–
NC	0900	370900	S	9	–	5	N	R	–	–	–	–	–
NC	1006	371006	G	6S	11	2	Q	R	F	1998	2,740	7.00	633,650
NC	1024	371024	G	6S	6	2	Q	R	F	1998	240	5.75	24,250
NC	1028	371028	G	1	2	2	Q	R	F	1998	220	2.26	55,290
NC	1030	371030	G	1	2	2	Q	R	F	1998	260	2.71	74,410
NC	1040	371040	G	6B	2	2	Q	R	F	1998	300	3.64	31,610
NC	1352	371352	G	6S	2	2	Q	R	F	1998	260	2.00	82,780
NC	1645	371645	G	2	2	2	Q	R	F	1998	670	7.21	254,860
NC	1801	371801	G	6S	11	2	A	R	F	1998	2,250	5.52	715,720
NC	1802	371802	G	6B	16	3	N	R	F	1998	140	1.45	–
NC	1803	371803	G	6B	2	2	Q	R	F	1998	580	1.17	41,880
NC	1814	371814	G	1	2	3	N	R	F	1998	120	3.96	–
NC	1817	371817	G	6C	2	2	Q	R	F	1998	520	19.91	116,410
NC	1992	371992	G	1	2	2	Q	R	F	1998	750	10.34	169,760
NC	2819	372819	G	6C	2	2	A	R	F	1998	1,090	11.93	182,630
NC	2824	372824	G	6C	2	2	Q	R	F	1998	760	5.54	187,530
NC	2825	372825	G	2	16	3	N	R	F	1998	140	6.08	–
NC	3008	373008	G	3	14	2	Q	R	R	1998	630	3.79	358,720
NC	3011	373011	G	3	1	2	A	R	R	1998	2,820	5.75	1,395,750
NC	3044	373044	G	3	1	2	A	R	R	1995	2,090	2.00	1,079,280
NC	3807	373807	G	3	2	2	A	R	R	1998	1,220	8.52	489,890
NC	3816	373816	G	3	2	2	Q	R	R	1998	1,030	1.17	284,950
NC	5037	375037	G	5	11	2	Q	R	R	1998	2,160	5.00	951,620
NC	5826	375826	G	7B	1	2	Q	R	R	1998	3,150	7.84	1,727,060
NC	5827	375827	G	5	2	2	Q	R	R	1998	1,010	6.29	429,660

Table 21. Summary of traffic projection results, continued

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
ND	0200	380200	S	2	1	5	N	I	–	–	–	–	–
ND	2001	382001	G	2	2	3	N	I	F	1998	290	3.00	–
ND	3005	383005	G	3	2	2	Q	I	R	1998	290	3.83	115,800
ND	3006	383006	G	3	2	2	Q	I	R	1998	220	4.46	85,320
ND	5002	385002	G	5	1	2	Q	I	R	1998	480	-17.25	118,090
OH	0100	390100	S	1	2	3	N	I	F	1998	210	6.00	–
OH	0200	390200	S	2	2	3	N	I	R	1998	1,460	6.00	–
OH	0800	390800	S	8	9	3	N	I	F	1998	140	6.00	–
OH	0900	390900	S	9	2	3	N	I	F	1998	210	6.00	–
OH	3013	393013	G	7B	6	2	Q	I	R	1998	160	0.00	68,560
OH	3801	393801	G	3	14	2	Q	I	R	1998	620	5.25	556,770
OH	4018	394018	G	4	11	2	A	I	R	1998	1,510	12.00	627,350
OH	4031	394031	G	4	11	2	A	I	R	1998	2,800	0.36	884,990
OH	5003	395003	G	5	2	2	Q	I	R	1998	800	3.16	388,330
OH	5010	395010	G	7B	1	2	Q	I	R	1998	570	4.38	242,890
OH	5569	395569	G	9	12	2	Q	I	R	1998	540	1.91	137,410
OH	7021	397021	G	7A	11	2	Q	I	R	1998	2,660	0.00	1,063,620
OH	9006	399006	G	9	1	2	A	I	R	1998	3,780	5.00	1,786,940
OH	9022	399022	G	9	11	4	N	I	–	1998	1,500	0.00	–
OK	0100	400100	S	1	2	5	N	I	–	–	–	–	–
OK	0500	400500	S	5	2	5	N	I	–	–	–	–	–
OK	0600	400600	S	6	1	2	A	I	R	1998	1,700	2.31	749,730
OK	1015	401015	G	2	6	3	N	I	–	1998	210	0.00	–
OK	1017	401017	G	2	2	3	N	I	F	1996	1,140	3.38	–
OK	3018	403018	G	3	11	2	A	I	R	1998	850	3.84	167,610
OK	4086	404086	G	6B	6	2	Q	I	F	1998	310	1.17	69,990
OK	4087	404087	G	6C	2	3	N	I	F	1998	280	3.07	–
OK	4088	404088	G	2	2	4	N	I	–	1995	240	0.00	–
OK	4154	404154	G	2	6	2	Q	I	F	1998	300	1.14	141,220
OK	4155	404155	G	9	2	3	N	I	R	1998	340	0.00	–
OK	4157	404157	G	3	2	2	Q	I	R	1998	1,170	1.13	455,200
OK	4158	404158	G	5	2	2	Q	I	R	1998	400	0.00	116,680
OK	4160	404160	G	3	12	2	A	I	R	1998	270	3.21	49,980
OK	4161	404161	G	2	2	2	Q	I	F	1998	300	5.00	84,570
OK	4162	404162	G	3	2	2	Q	I	R	1998	200	1.00	45,520

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
OK	4163	404163	G	2	2	2	Q	I	F	1998	270	0.00	60,260
OK	4164	404164	G	6B	6	2	Q	I	F	1998	240	2.73	77,340
OK	4165	404165	G	2	2	3	N	I	F	1998	230	4.00	–
OK	4166	404166	G	5	2	2	A	I	R	1998	1,630	7.51	622,320
OK	5021	405021	G	5	2	2	A	I	R	1998	680	2.86	232,140
OK	6010	406010	G	6A	7	2	A	I	F	1998	300	2.38	111,590
OK	7024	407024	G	7A	1	2	A	I	R	1998	2,020	5.58	815,130
OR	2002	412002	G	6S	2	2	Q	R	F	1998	680	5.98	191,350
OR	5005	415005	G	5	1	3	A	R	R	1998	3,830	4.72	2,509,200
OR	5006	415006	G	5	1	2	Q	R	R	1998	1,950	7.28	1,451,930
OR	5008	415008	G	5	1	2	A	R	R	1998	1,720	6.36	1,101,920
OR	5021	415021	G	5	1	2	A	R	R	1998	3,370	4.00	1,854,410
OR	5022	415022	G	5	1	2	A	R	R	1998	3,280	3.66	2,090,380
OR	6011	416011	G	6S	1	2	A	R	F	1998	3,630	5.00	1,619,800
OR	6012	416012	G	6A	1	4	N	R	–	1991	1,130	4.49	–
OR	7018	417018	G	7S	1	2	A	R	R	1998	4,040	3.57	2,550,930
OR	7019	417019	G	7A	2	2	Q	R	R	1998	950	2.66	187,620
OR	7025	417025	G	7A	1	2	A	R	R	1997	2,600	6.00	1,687,410
OR	7081	417081	G	5	1	2	Q	R	R	1998	1,400	10.14	1,003,580
PA	0600	420600	S	6	1	2	Q	R	R	1998	2,810	2.00	2,324,180
PA	1597	421597	G	1	6	2	Q	R	F	1998	100	0.31	19,030
PA	1598	421598	G	5	1	2	A	R	R	1998	4,020	-11.35	1,597,610
PA	1599	421599	G	1	7	2	A	R	F	1998	250	0.00	92,880
PA	1605	421605	G	1	6	2	A	R	F	1998	1,100	2.95	358,190
PA	1606	421606	G	4	2	2	A	R	R	1998	540	3.60	240,870
PA	1608	421608	G	6A	7	2	Q	R	F	1998	50	5.29	5,900
PA	1610	421610	G	7A	1	2	A	R	R	1998	2,120	5.01	710,520
PA	1613	421613	G	7B	11	2	A	R	R	1998	2,580	2.00	997,750
PA	1614	421614	G	7B	2	2	A	R	R	1998	970	3.98	384,890
PA	1617	421617	G	7B	11	4	N	R	–	1998	3,730	2.00	–
PA	1618	421618	G	6B	7	2	Q	R	F	1998	80	3.97	26,220
PA	1623	421623	G	3	1	2	Q	R	R	1998	1,060	1.62	511,360
PA	1627	421627	G	9	1	2	A	R	R	1998	3,640	2.12	2,647,030
PA	1690	421690	G	4	1	2	Q	R	R	1998	980	1.60	463,640
PA	1691	421691	G	7B	2	2	A	R	R	1998	450	8.00	143,190

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
PA	3044	423044	G	3	1	2	A	R	R	1998	3,460	5.39	1,886,830
PA	5020	425020	G	5	11	2	Q	R	R	1998	3,510	9.85	1,219,130
PA	7025	427025	G	7A	2	2	Q	R	R	1998	500	0.00	194,780
PA	7037	427037	G	7S	1	2	A	R	R	1998	3,000	2.91	1,644,700
PA	9027	429027	G	9	1	2	Q	R	R	1998	3,480	6.16	2,092,660
RI	7401	447401	G	7A	2	2	Q	R	R	1998	870	5.19	1,535,220
SC	1008	451008	G	1	6	2	Q	I	F	1998	70	1.00	12,850
SC	1011	451011	G	1	14	2	Q	I	F	1998	1,400	2.82	335,990
SC	1024	451024	G	1	17	3	N	I	F	1998	20	0.00	–
SC	1025	451025	G	6B	2	3	N	I	F	1998	150	7.91	–
SC	3012	453012	G	3	1	2	Q	I	R	1998	2,010	3.84	934,880
SC	5017	455017	G	5	1	2	Q	I	R	1998	1,470	6.96	637,890
SC	5034	455034	G	5	1	2	Q	I	R	1998	1,750	9.00	1,056,970
SC	5035	455035	G	5	1	2	Q	I	R	1998	1,840	9.00	879,660
SC	7019	457019	G	7A	2	2	Q	I	R	1998	450	4.33	64,760
SD	0600	460600	S	6	2	2	A	I	R	1998	280	5.00	104,690
SD	0800	460800	S	8	7	3	N	I	F	1998	20	0.00	–
SD	3009	463009	G	3	1	4	N	I	–	1998	640	3.94	–
SD	3010	463010	G	3	1	4	N	I	–	1998	480	5.42	–
SD	3012	463012	G	3	1	2	Q	I	R	1998	670	2.26	361,100
SD	3013	463013	G	3	1	3	N	I	R	1998	400	2.59	–
SD	3052	463052	G	3	1	2	Q	I	R	1998	160	0.99	63,930
SD	3053	463053	G	3	6	3	N	I	R	1998	170	4.56	–
SD	5020	465020	G	5	1	4	N	I	–	1998	560	2.31	–
SD	5025	465025	G	5	1	4	N	I	–	1998	690	4.00	–
SD	5040	465040	G	5	1	4	N	I	–	1998	910	3.00	–
SD	6600	466600	G	3	2	4	N	I	–	1998	320	7.00	–
SD	7049	467049	G	7A	6	4	N	I	–	1998	190	2.52	–
SD	9106	469106	G	6B	6	4	N	I	–	1998	60	6.00	–
SD	9187	469187	G	1	6	4	N	I	–	1998	40	2.63	–
SD	9197	469197	G	6B	6	4	N	I	–	1998	110	8.93	–
TN	0600	470600	S	6	–	5	N	I	–	–	–	–	–
TN	1023	471023	G	6B	1	2	Q	I	F	1998	2,990	1.99	750,440
TN	1028	471028	G	2	2	2	Q	I	F	1998	350	4.26	138,900
TN	1029	471029	G	6S	2	3	N	I	F	1998	400	12.30	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
TN	2001	472001	G	6B	2	2	Q	I	F	1998	800	3.34	365,960
TN	2008	472008	G	6B	2	2	A	I	F	1998	430	2.50	121,200
TN	3075	473075	G	1	2	3	N	I	F	1998	170	6.31	–
TN	3101	473101	G	6B	2	2	Q	I	F	1998	100	4.34	40,580
TN	3104	473104	G	1	7	3	N	I	F	1997	10	6.91	–
TN	3108	473108	G	6B	1	2	Q	I	F	1998	3,010	2.05	715,930
TN	3109	473109	G	6B	2	2	Q	I	F	1998	180	2.00	24,000
TN	3110	473110	G	6B	2	2	Q	I	F	1998	190	4.12	94,520
TN	6015	476015	G	6A	1	2	Q	I	F	1998	3,580	3.79	1,434,860
TN	6022	476022	G	6A	2	2	Q	I	F	1993	300	4.03	82,970
TN	9024	479024	G	6B	2	3	N	I	F	1998	80	6.00	–
TN	9025	479025	G	6B	2	2	Q	I	F	1998	100	4.34	50,260
TX	0001	480001	G	1	11	2	Q	I	F	1998	390	5.82	134,880
TX	0100	480100	S	1	2	5	N	I	–	–	–	–	–
TX	0800	480800	S	8	9	5	N	I	F	–	–	–	–
TX	0900	480900	S	9	2	5	N	I	–	–	–	–	–
TX	1039	481039	G	6B	2	3	N	I	F	1998	690	4.50	–
TX	1046	481046	G	6A	1	2	Q	I	F	1998	2,620	7.00	1,208,890
TX	1047	481047	G	1	1	2	Q	I	F	1998	2,410	7.00	1,662,560
TX	1048	481048	G	2	16	2	Q	I	F	1998	190	2.00	33,660
TX	1049	481049	G	2	14	3	N	I	F	1996	1,250	2.00	–
TX	1050	481050	G	1	6	3	N	I	F	1996	240	5.28	–
TX	1056	481056	G	1	2	3	N	I	F	1998	150	1.00	–
TX	1060	481060	G	1	2	2	Q	I	F	1998	1,040	7.00	242,720
TX	1061	481061	G	1	2	5	N	I	–	–	–	–	–
TX	1065	481065	G	1	2	3	N	I	F	1997	180	2.08	–
TX	1068	481068	G	1	2	2	Q	I	F	1998	440	5.00	111,130
TX	1069	481069	G	2	2	2	Q	I	F	1998	610	8.00	139,330
TX	1070	481070	G	2	2	3	Q	I	F	1998	670	8.00	139,330
TX	1076	481076	G	1	14	2	Q	I	F	1998	310	0.00	78,310
TX	1077	481077	G	1	2	3	N	I	F	1998	800	3.40	–
TX	1087	481087	G	1	14	3	N	I	F	1998	170	2.00	–
TX	1092	481092	G	1	2	2	Q	I	F	1998	400	6.00	74,890
TX	1093	481093	G	6B	1	2	Q	I	F	1998	1,230	6.00	265,360
TX	1094	481094	G	6B	2	3	N	I	F	1998	190	7.00	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
TX	1096	481096	G	1	2	2	Q	I	F	1998	430	4.86	95,520
TX	1109	481109	G	2	2	2	Q	I	F	1998	340	5.00	72,080
TX	1111	481111	G	1	2	3	N	I	F	1998	330	2.50	–
TX	1113	481113	G	6B	2	3	N	I	F	1998	520	4.00	–
TX	1116	481116	G	6S	2	3	N	I	F	1998	930	5.00	–
TX	1119	481119	G	6B	2	3	N	I	F	1998	310	4.00	–
TX	1122	481122	G	1	2	2	Q	I	F	1998	270	6.19	52,970
TX	1123	481123	G	1	1	2	Q	I	F	1993	750	6.00	274,850
TX	1130	481130	G	6B	6	2	Q	I	F	1998	170	4.50	24,610
TX	1168	481168	G	1	8	3	N	I	F	1998	20	10.00	–
TX	1169	481169	G	1	6	3	N	I	F	1998	460	3.50	–
TX	1174	481174	G	1	2	3	N	I	F	1998	280	1.80	–
TX	1178	481178	G	1	2	3	N	I	F	1995	480	10.00	–
TX	1181	481181	G	1	1	2	Q	I	F	1998	1,200	5.00	392,790
TX	1183	481183	G	1	2	3	N	I	F	1994	410	0.00	–
TX	2108	482108	G	2	2	2	Q	I	F	1998	140	0.00	32,930
TX	2133	482133	G	2	6	2	Q	I	F	1998	340	10.00	86,450
TX	2172	482172	G	2	1	2	Q	I	F	1995	1,560	3.00	381,640
TX	2176	482176	G	2	7	3	N	I	F	1998	70	2.00	–
TX	3003	483003	G	3	14	3	N	I	R	1998	360	4.00	–
TX	3010	483010	G	3	14	2	Q	I	R	1998	750	7.60	153,460
TX	3559	483559	G	2	2	2	Q	I	F	1998	220	5.50	40,440
TX	3569	483569	G	9	1	3	N	I	R	1998	2,450	3.00	–
TX	3579	483579	G	6B	6	3	N	I	F	1998	360	6.00	–
TX	3589	483589	G	3	2	3	N	I	R	1998	1,100	3.40	–
TX	3609	483609	G	1	2	3	N	I	F	1991	100	0.00	–
TX	3629	483629	G	7A	1	3	N	I	R	1996	2,020	6.00	–
TX	3669	483669	G	2	6	3	N	I	F	1998	140	4.00	–
TX	3679	483679	G	2	6	3	N	I	F	1997	180	4.00	–
TX	3689	483689	G	2	2	3	N	I	F	1998	180	0.00	–
TX	3699	483699	G	4	14	2	Q	I	R	1998	1,850	6.00	435,380
TX	3719	483719	G	5	2	3	N	I	R	1998	680	4.00	–
TX	3729	483729	G	1	2	2	Q	I	F	1998	880	2.50	110,190
TX	3739	483739	G	1	2	3	N	I	F	1998	650	5.00	–
TX	3749	483749	G	1	2	3	N	I	F	1997	210	3.00	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
TX	3769	483769	G	1	2	2	Q	I	F	1998	250	2.86	57,500
TX	3779	483779	G	5	11	3	N	I	R	1998	980	6.00	–
TX	3835	483835	G	1	2	2	Q	I	F	1998	840	10.00	186,510
TX	3845	483845	G	9	1	2	Q	I	R	1998	2,450	5.74	1,374,970
TX	3855	483855	G	6B	2	3	N	I	F	1998	480	6.00	–
TX	3865	483865	G	1	2	2	Q	I	F	1998	210	4.00	54,830
TX	3875	483875	G	6B	2	3	N	I	F	1998	560	4.84	–
TX	4142	484142	G	4	2	3	N	I	R	1998	590	5.00	–
TX	4143	484143	G	4	2	2	Q	I	R	1998	370	6.00	116,460
TX	4146	484146	G	4	6	2	Q	I	R	1998	330	6.00	155,940
TX	4152	484152	G	4	2	2	Q	I	R	1998	290	4.00	85,750
TX	5024	485024	G	5	2	2	Q	I	R	1998	580	6.50	218,460
TX	5026	485026	G	5	6	2	Q	I	R	1998	240	10.50	57,630
TX	5035	485035	G	5	11	3	N	I	R	1998	1,130	0.00	–
TX	5154	485154	G	5	1	2	A	I	R	1998	2,030	6.00	734,970
TX	5274	485274	G	5	1	3	N	I	R	1998	1,510	5.50	–
TX	5278	485278	G	5	7	3	N	I	R	1998	190	0.00	–
TX	5283	485283	G	5	11	3	N	I	R	1998	1,090	6.00	–
TX	5284	485284	G	5	11	3	N	I	R	1998	490	0.00	–
TX	5287	485287	G	5	11	3	N	I	R	1998	1,130	6.50	–
TX	5301	485301	G	5	11	3	N	I	R	1998	400	4.00	–
TX	5310	485310	G	5	2	3	N	I	R	1998	700	8.00	–
TX	5317	485317	G	5	12	3	N	I	R	1998	940	4.00	–
TX	5323	485323	G	5	1	2	Q	I	R	1998	2,280	7.00	2,152,650
TX	5328	485328	G	5	2	2	Q	I	R	1998	1,400	6.00	787,190
TX	5334	485334	G	5	1	2	Q	I	R	1998	2,530	7.00	656,970
TX	5335	485335	G	5	1	2	Q	I	R	1998	2,570	7.00	1,994,090
TX	5336	485336	G	5	1	2	Q	I	R	1998	800	4.00	445,310
TX	6079	486079	G	6A	1	3	N	I	F	1998	2,250	6.00	–
TX	6086	486086	G	6A	1	2	Q	I	F	1998	840	5.00	192,730
TX	6160	486160	G	6A	2	3	N	I	F	1993	410	1.25	–
TX	6179	486179	G	6A	2	3	N	I	F	1998	240	1.31	–
TX	7165	487165	G	7S	11	2	Q	I	R	1998	530	0.00	277,000
TX	9005	489005	G	1	8	2	Q	I	F	1998	90	0.00	27,390
TX	9167	489167	G	9	1	2	Q	I	R	1998	2,460	6.00	1,388,120

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
TX	9355	489355	G	9	11	2	Q	I	R	1998	2,700	3.00	1,023,730
TX	A500	48A500	S	5	2	2	Q	I	F	1998	640	9.00	124,920
UT	0800	490800	S	8	6	5	N	I	–	–	–	–	–
UT	1001	491001	G	1	6	4	N	I	–	1998	150	2.00	–
UT	1004	491004	G	6A	6	4	N	I	–	1998	190	1.84	–
UT	1005	491005	G	6A	14	4	N	I	–	1998	430	2.16	–
UT	1006	491006	G	6A	2	4	N	I	–	1998	480	2.52	–
UT	1007	491007	G	6A	2	4	N	I	–	1995	680	5.02	–
UT	1008	491008	G	1	2	4	N	I	–	1998	560	2.81	–
UT	1017	491017	G	1	6	4	N	I	–	1998	150	1.00	–
UT	3010	493010	G	3	1	4	N	I	–	1998	1,140	3.65	–
UT	3011	493011	G	3	1	4	N	I	–	1998	700	2.45	–
UT	3015	493015	G	3	11	4	N	I	–	1998	850	10.00	–
UT	7082	497082	G	3	1	4	N	I	–	1998	510	6.00	–
UT	7083	497083	G	3	11	4	N	I	–	1998	160	4.45	–
UT	7085	497085	G	3	2	4	N	I	–	1998	360	8.24	–
UT	7086	497086	G	3	14	4	N	I	–	1998	350	4.66	–
VT	1002	501002	G	1	2	2	Q	R	F	1998	350	2.50	86,920
VT	1004	501004	G	1	2	2	Q	R	F	1998	250	3.33	26,250
VT	1681	501681	G	6B	2	2	A	R	F	1998	580	3.50	155,680
VT	1682	501682	G	7B	2	2	A	R	R	1998	610	3.50	225,700
VT	1683	501683	G	6B	2	2	A	R	F	1998	610	3.50	146,120
VA	0100	510100	S	1	2	3	N	I	–	1998	750	5.91	–
VA	1002	511002	G	6B	6	3	N	I	F	1998	110	0.00	–
VA	1023	511023	G	6C	1	2	A	I	F	1998	2,600	3.69	1,141,360
VA	1417	511417	G	6D	2	2	Q	I	F	1998	1,200	3.00	401,040
VA	1419	511419	G	6D	2	2	A	I	F	1998	290	0.00	70,930
VA	1423	511423	G	6B	2	2	A	I	F	1998	270	2.00	132,710
VA	1464	511464	G	6S	1	2	A	I	F	1998	1,810	-1.38	519,010
VA	2004	512004	G	6C	14	2	A	I	F	1998	860	8.24	304,590
VA	2021	512021	G	6C	6	2	A	I	F	1998	420	5.25	151,400
VA	2564	512564	G	5	11	2	Q	I	R	1998	1,660	0.00	663,760
VA	5008	515008	G	5	11	2	Q	I	R	1998	800	0.00	150,900
VA	5009	515009	G	5	7	2	Q	I	R	1998	540	4.31	300,440
VA	5010	515010	G	5	1	2	Q	I	R	1998	1,580	6.36	1,493,440

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
WA	0200	530200	S	2	12	2	Q	I	R	1998	810	6.00	470,550
WA	0800	530800	S	8	9	5	N	I	F	–	–	–	–
WA	1002	531002	G	1	2	2	Q	I	F	1998	200	2.90	82,920
WA	1005	531005	G	6B	1	2	A	I	F	1998	1,000	3.37	399,300
WA	1006	531006	G	1	2	3	N	I	F	1998	340	2.66	–
WA	1007	531007	G	6B	6	2	Q	I	F	1998	280	3.00	173,420
WA	1008	531008	G	6B	2	2	A	I	F	1998	360	1.97	71,490
WA	1501	531501	G	1	2	4	N	I	–	1998	60	3.46	–
WA	1801	531801	G	1	16	2	A	I	F	1998	260	5.11	52,670
WA	3011	533011	G	3	11	2	A	I	R	1998	1,200	3.49	431,930
WA	3013	533013	G	3	2	2	A	I	R	1998	360	1.97	72,770
WA	3014	533014	G	3	2	2	A	I	R	1998	1,050	3.66	551,740
WA	3019	533019	G	3	11	2	Q	I	R	1998	1,330	3.40	641,670
WA	3812	533812	G	3	11	2	Q	I	R	1993	1,340	4.16	389,760
WA	3813	533813	G	3	14	2	A	I	R	1998	990	6.59	272,320
WA	6020	536020	G	6A	2	2	Q	I	F	1998	740	3.07	119,730
WA	6048	536048	G	6C	2	2	Q	I	F	1998	1,050	6.00	167,480
WA	6049	536049	G	6A	14	2	A	I	F	1998	2,920	4.23	706,580
WA	6056	536056	G	6S	2	2	Q	I	F	1998	300	4.62	73,920
WA	7322	537322	G	6A	2	2	Q	I	F	1998	240	4.59	26,290
WA	7409	537409	G	3	1	2	A	I	R	1998	1,530	4.89	461,410
WV	1640	541640	G	6B	2	3	N	R	F	1998	350	6.00	–
WV	4003	544003	G	4	2	3	N	R	R	1998	450	4.98	–
WV	4004	544004	G	7B	1	2	A	R	R	1998	3,490	-8.82	3,848,320
WV	5007	545007	G	7B	2	2	A	R	R	1998	530	2.76	186,720
WV	7008	547008	G	7A	11	2	A	R	R	1998	2,810	1.85	1,426,860
WI	0100	550100	S	1	14	5	N	I	–	–	–	–	–
WI	0200	550200	S	2	14	5	N	I	–	–	–	–	–
WI	0800	550800	S	8	14	5	N	I	–	–	–	–	–
WI	0900	550900	S	9	–	5	N	I	–	–	–	–	–
WI	3008	553008	G	3	1	2	Q	I	R	1998	2,680	5.21	1,321,470
WI	3009	553009	G	3	2	2	Q	I	R	1998	480	0.00	214,100
WI	3010	553010	G	3	2	2	Q	I	R	1998	470	6.93	139,350
WI	3012	553012	G	3	6	3	N	I	R	1998	90	0.00	–
WI	3014	553014	G	3	1	2	A	I	R	1998	1,480	4.23	530,510

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
WI	3015	553015	G	3	2	2	A	I	R	1998	660	1.68	337,870
WI	3016	553016	G	3	2	2	A	I	R	1998	600	1.65	236,130
WI	3019	553019	G	3	2	2	Q	I	R	1998	100	0.00	20,040
WI	5037	555037	G	5	2	2	Q	I	R	1998	290	0.00	78,970
WI	5040	555040	G	5	1	2	Q	I	R	1998	2,150	5.34	1,257,940
WI	6351	556351	G	3	2	2	Q	I	R	1998	620	0.00	325,840
WI	6352	556352	G	3	2	2	Q	I	R	1998	620	0.00	322,110
WI	6353	556353	G	3	2	2	Q	I	R	1998	620	0.00	328,560
WI	6354	556354	G	3	2	2	Q	I	R	1998	620	0.00	325,520
WI	6355	556355	G	3	2	2	Q	I	R	1998	620	0.00	307,680
WI	A900	55A900	S	9	–	5	N	I	–	–	–	–	–
WI	B900	55B900	S	9	–	5	N	I	–	–	–	–	–
WI	C900	55C900	S	9	14	5	N	I	–	–	–	–	–
WY	1007	561007	G	1	6	2	Q	I	F	1998	80	0.88	10,360
WY	2015	562015	G	2	1	2	A	I	F	1998	440	0.83	152,260
WY	2017	562017	G	2	6	2	Q	I	F	1998	100	-3.94	38,950
WY	2018	562018	G	2	2	3	N	I	F	1994	200	0.00	–
WY	2019	562019	G	2	6	2	Q	I	F	1998	210	0.00	56,700
WY	2020	562020	G	2	1	2	Q	I	F	1998	460	4.22	138,820
WY	2037	562037	G	2	6	2	Q	I	F	1998	100	0.00	32,160
WY	3027	563027	G	3	11	2	A	I	R	1998	2,300	4.21	1,529,380
WY	6029	566029	G	6A	2	2	Q	I	F	1998	50	-3.59	8,340
WY	6031	566031	G	6A	2	5	N	I	–	–	–	–	–
WY	6032	566032	G	6A	7	2	Q	I	F	1998	150	6.00	18,620
WY	7772	567772	G	2	6	2	Q	I	F	1998	60	2.00	10,220
WY	7773	567773	G	2	6	2	Q	I	F	1998	30	0.00	6,250
WY	7775	567775	G	1	7	2	Q	I	F	1998	100	1.59	48,740
PR	1003	721003	G	2	2	4	N	I	–	1997	1,340	3.00	–
PR	3008	723008	G	3	2	4	N	I	–	1998	4,070	6.00	–
PR	4121	724121	G	3	2	4	N	I	–	1998	990	5.70	–
PR	4122	724122	G	2	2	4	N	I	–	1998	990	5.70	–
Canadian Provinces													
AB	0500	810500	S	5	2	4	N	R	–	1998	650	9.00	–
AB	1803	811803	G	1	1	4	N	R	–	1998	410	3.41	–
AB	1804	811804	G	6B	2	4	N	R	–	1998	520	8.20	–

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
AB	1805	811805	G	6B	2	4	N	R	–	1998	270	4.42	–
AB	2812	812812	G	2	2	4	N	R	–	1998	210	8.00	–
AB	8529	818529	G	2	1	4	N	R	–	1998	1,400	7.00	–
AB	A900	81A900	S	9	2	4	N	R	–	1998	320	1.30	–
BC	1005	821005	G	6S	2	4	N	I	–	1998	460	9.50	–
BC	6006	826006	G	6A	2	4	N	I	–	1998	1,180	3.00	–
BC	6007	826007	G	6S	1	4	N	I	–	1998	1,030	3.00	–
BC	9017	829017	G	2	2	4	N	I	–	1998	400	8.00	–
MB	1801	831801	G	1	1	2	Q	I	F	1998	330	2.65	280,670
MB	3802	833802	G	3	2	2	Q	I	R	1998	370	6.93	309,080
MB	6450	836450	G	6B	1	2	Q	I	F	1998	310	4.00	235,830
MB	6451	836451	G	6B	1	3	N	I	F	1998	310	4.00	–
MB	6452	836452	G	7B	2	2	Q	I	R	1998	380	9.86	173,400
MB	6454	836454	G	2	2	3	N	I	F	1998	700	10.03	–
NB	1684	841684	G	6S	2	2	Q	I	F	1998	270	1.62	68,200
NB	1802	841802	G	2	2	2	Q	I	F	1998	340	8.60	315,600
NB	3803	843803	G	3	2	3	N	I	R	1996	290	8.71	–
NB	6804	846804	G	6S	2	2	Q	I	F	1998	720	2.97	477,280
NF	1801	851801	G	1	2	3	N	I	F	1998	500	2.36	–
NF	1803	851803	G	1	2	3	N	I	F	1998	200	0.00	–
NF	1808	851808	G	1	2	3	N	I	F	1998	140	0.00	–
NS	6802	866802	G	6A	1	2	A	R	F	1998	1,250	4.18	430,550
ON	0900	870900	S	9	–	5	N	I	–	–	–	–	–
ON	1620	871620	G	6S	1	2	Q	I	F	1998	630	3.65	362,500
ON	1622	871622	G	6S	2	2	Q	I	F	1998	710	3.99	359,190
ON	1680	871680	G	6S	1	3	N	I	F	1998	1,430	8.59	–
ON	1806	871806	G	6S	1	3	N	I	F	1998	1,430	8.59	–
ON	2811	872811	G	7A	1	2	Q	I	F	1998	1,470	4.22	696,600
ON	2812	872812	G	7A	1	2	A	I	F	1998	1,750	5.49	859,880
PE	1645	881645	G	1	1	2	Q	R	F	1998	250	5.57	94,720
PE	1646	881646	G	2	1	2	Q	R	F	1998	220	7.63	72,270
PE	1647	881647	G	2	2	3	N	R	F	1998	160	0.86	–
PQ	0900	890900	S	9	–	5	N	R	–	–	–	–	–
PQ	1021	891021	G	6C	1	2	A	R	F	1998	900	3.50	342,820
PQ	1125	891125	G	6B	1	2	A	R	F	1998	1,020	4.01	283,880

Table 21. Summary of traffic projection results, continued.

Agency	SHRP ID	Traffic ID	GPS/ SPS	Exp. No.	Highway Functional Class	Projections			Pav. Type	Last Pr. Year	Traffic Characteristics		
						Cat.	Code	Status			Traffic Volume	Annual Growth Rate (%)	ESALs
PQ	1127	891127	G	6B	1	2	Q	R	F	1998	800	4.00	198,610
PQ	2011	892011	G	2	2	2	Q	R	F	1998	150	5.00	47,500
PQ	3001	893001	G	3	1	2	Q	R	R	1998	430	3.00	396,790
PQ	3002	893002	G	3	1	2	Q	R	R	1998	840	8.80	327,160
PQ	3015	893015	G	3	1	2	Q	R	R	1998	800	2.11	708,820
PQ	3016	893016	G	3	1	3	A	R	R	1998	910	1.00	549,100
PQ	9018	899018	G	9	2	4	N	R	–	1998	390	3.98	–
PQ	A900	89A900	S	9	–	5	N	R	–	–	–	–	–
SK	0900	900900	S	9	14	2	Q	I	F	1998	400	0.00	118,190
SK	1802	901802	G	1	2	5	N	I	–	–	–	–	–
SK	6400	906400	G	6A	2	3	N	I	F	1998	80	2.97	–
SK	6405	906405	G	1	2	2	Q	I	F	1998	170	3.00	128,840
SK	6410	906410	G	6B	2	2	Q	I	F	1998	430	2.05	191,430
SK	6412	906412	G	6B	2	2	Q	I	F	1998	430	2.05	188,960
SK	6420	906420	G	1	2	3	N	I	F	1998	40	1.60	–
SK	6801	906801	G	6A	2	3	N	I	F	1998	80	2.97	–

REFERENCES

1. Hajek, J.J., and Selezneva, O. *Estimating Cumulative Traffic Loads, Final Report for Phase 1*, FHWA-RD-00-054, USDOT, Federal Highway Administration, Washington, DC, July 2000.

2. *LTPP: Year in Review 2000*, FHWA-RD-01-136, USDOT, Federal Highway Administration, Washington, DC, 2001.

3. *Long-Term Traffic Monitoring Protocol: Revised Data Collection Plan for LTPP Test Sites*, unnumbered document prepared by Mark Hallenbeck and signed by Monte Symons, USDOT, Federal Highway Administration, April 1998.

4. *Guide to LTPP Traffic Data Collection and Processing*, unnumbered document, USDOT, Federal Highway Administration, Washington, DC, March 12, 2001.

5. *Long-Term Pavement Performance Information Management System Data Users Reference Manual*, FHWA-RD-97-001, USDOT, Federal Highway Administration, Washington, DC, May 1997.

6. *Traffic Monitoring Guide*, Third Edition, FHWA-PL-95-031, USDOT, Federal Highway Administration, Washington, DC, February 1995.

7. *2002 Pavement Design Guide*, FHWA-RD-00-129, USDOT, Federal Highway Administration, Washington, DC, Final product not yet published.

8. Hallenback, M., et al. *Vehicle Volume Distributions by Classification*, FHWA-PL-97-025, USDOT, Federal Highway Administration, Washington, DC, July 1997.

9. Hallenback, M. *Results of the Empirical Analysis of Alternative Data Collection Sampling Plans for Estimating Annual Vehicle Loads at LTPP Test Sites*, A study referenced and described in FHWA-RD-98-124, USDOT, Federal Highway Administration, Washington, DC, July 1998.

10. Kim, J.R., Titus-Glover, L., Darter, M.I., and Kumapley, R.K. "Axle Load Distribution Characterization for Mechanistic Pavement Design," *Transportation Research Record*, No. 1629, Transportation Research Board, Washington, DC, pp. 13-23.

11. *Development of LTPP Traffic Backcasting Procedure*, LTPP DATS—Work Order No. 12, Task 1—Interim Report, USDOT, Federal Highway Administration, Washington, DC, March 1999.

12. *LTPP Traffic QC User's Guide*, May 15, 2000, provided with LTPP Directive TDP-17, USDOT, Federal Highway Administration, Washington, DC, May 24, 2000.

13. Federal Regulation 23 CFR 658, USDOT, Federal Highway Administration, 2004.

14. Rada, G.R., Wu, C.L., Elkins, G.E., Bhandari, R.K., and Bellinger, W.Y. "Update of LTPP Manual Distress Data Variability: Bias and Precision," *Transporation Research Record*, No. 1643, Transportation Research Board, Washington, DC, pp. 71-79, 1998.

15. Roth, R.D. *The Motor Carrier Industry in Transition,* Transportation Technical Services, Fredericksburg, VA, 1992.

16. Hajek, J.J., and Kazmierowski, T. "Use of Long-Term Pavement Performance Data for Calibration of Pavement Design Models," *Transportation Research Record*, No. 1778, Transportation Research Board, Washington, DC, 2001.

17. *Guide for Design of Pavement Structures*, ISBN 1560510552, American Association of State Highway and Transportation Officials, Washington, DC, 1993.

18. *DataPave Version 2.0*, USDOT, Federal Highway Administration, Washington, DC, software released October 1999.

FHWA-RD-03-094

Estimating Cumulative Traffic Loads, Volume II: Traffic Data Assessment and Axle Load Projection for the Sites with Acceptable Axle Weight Data, Final Report for Phase 2

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