TRAFFIC MONITORING GUIDE

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U.S. Department of Transportation
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TRAFFIC MONITORING GUIDE

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Preface to the Third Edition

This edition of the Traffic Monitoring Guide incorporates the metric system of measurement for the first time. In accordance with the 1988 Omnibus Trade and Competitiveness Act which required the Federal government to convert to the metric system, the Federal Highway Administration (FHWA) produced the Metric Conversion Plan in 1991. This plan specifies that data for 1995 and thereafter shall be in metric units.

New traffic monitoring data formats were necessitated because of the need to change the weight and length measurements to metric units. This was also an opportunity to make other changes at the same time. Accordingly, TRB Committee A2B08 on Traffic Monitoring was asked to query State traffic monitoring contacts for their ideas on what should be changed. Based on the results, a draft of new data formats was sent to the States for comment. The draft was revised, and a memorandum was distributed in February, 1994, with the new data formats. Those formats are incorporated in this edition of the Traffic Monitoring Guide in a new Section 6 which pulls together the traffic data formats into one place.

Changes include expanding the Station Identification field from three to a six characters to conform to that used by the #1 and #3 Records for ATR data. This allows a State to identify all traffic monitoring stations in a common format. The #1 and #2 ("2-card") records were combined into a new Station Description record which may be used for all traffic volume, vehicle classification, and truck weight stations. However, the #1 record may still be used for ATR stations.

Some terminology changes were also necessitated because the terms included units of measure. These were replaced by generic terms which don't specify the units. For example, "vehicle miles traveled" was replaced by "vehicle distance traveled" and "mileage" as a measure of the length of highways was replaced by "roadway extent." Unless specified otherwise, these quantities would be in kilometers.

Acronyms

Acronym	Meaning
3S2	3 axle tractor with a 2 axle semi-trailer
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
ATR	Automatic Traffic Recorder
AVC	Automatic Vehicle Classification
BMS	Bridge Management System
CAAA	Clean Air Act Amendments (1990)
CMS	Congestion Management System
EAL	Equivalent Axle Load
EPA	Environmental Protection Agency
ESAL	Equivalent Single Axle Load
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	Geographic Information System
HPMS	Highway Performance Monitoring System
IRI	International Roughness Index
ISTEA	Intermodal Surface Transportation Efficiency Act (1991)
ITFSMS	Intermodal Transportation Facilities and Systems Management System
LTPP	Long Term Pavement Performance
MADT	Monthly Average Daily Traffic
MPO	Metropolitan Planning Organization
NHI	National Highway Institute
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
OFE	Other Freeways and Expressways
OPA	Other Principal Arterial
PMS	Pavement Management System
PSR	Present Serviceability Rating
PTFEMS	Public Transportation Facilities and Equipment Management System
PTR	Permanent Traffic Recorder
SHRP	Strategic Highway Research Program
SMS	Safety Management System
TMG	Traffic Monitoring Guide
TMS/H	Traffic Monitoring System for Highways
TQM	Total Quality Management
TWS	Truck Weight Study
VDT	Vehicle Distance Traveled
WIM	Weigh-in-Motion

SECTION 1

Overview

SECTION 1

OVERVIEW

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OVERVIEW OF THIS GUIDE

The following discussion provides a synopsis of the material covered in the following sections.

In Section 2 of this Guide, the reader will find a discussion of the structure of traffic characteristics monitoring; how traffic counting, vehicle classification, and truck weighing relate to the overall monitoring effort; and how this effort is structured through the sample design.

In Section 3, traffic counting is discussed. This chapter focuses on the development of the statistical scheme. The sample is critical to both the reliability of information on traffic volumes and to the later development of samples for vehicle classification and vehicle weighing.

Section 4 covers vehicle classification. This section includes aspects of sample development pertinent to obtaining vehicle classification information along with a description of the Federal Highway Administration (FHWA) vehicle categories.

Section 5 covers truck weighing and contains information on collection and summarizing of data obtained at truck weigh sites. Also included are discussions of methods of weighing vehicles and the specification of the sample design for truck weight data.

Section 6 presents the coordinated record formats for station identification, traffic volume, vehicle classification, and truck weight data.

This Guide is intended to be a statement of good practice. It is not to be considered a Federal standard. Data collection agencies are encouraged to consider the methods presented here in their administration of a data collection program and to compare the cost-effectiveness of this methodology to procedures they presently use.

GUIDE OBJECTIVES

Beginning with the statewide highway planning surveys of the 1930's, the collection of information on traffic volumes, vehicle types, and truck weights have formed a set of activities that are a significant portion of a highway planning program in terms of both cost and personnel. Manuals and guides have been issued describing data collection procedures for each type of activity. During most of the preceding period, each traffic data collection activity was approached as a unique endeavor. Decisions as to the degree to which each activity should be pursued, i.e., number of monitoring sites, duration of monitoring, time or season of year for data collection, were generally determined by available funding, perceived need for the data and the size of previous data gathering efforts rather than by a statistical analysis of the monitoring needed.

The FHWA has a history of providing improved methodologies for monitoring the use of America's highways. In keeping with that history, this Guide provides direction for improved traffic counting, vehicle classification, and truck weighing. Beyond simply providing ideas for updating these activities, this Guide also provides statistical procedures that allow the manager to determine how much monitoring is needed to achieve a desired precision level.

This Guide has two major objectives. First, to relate the intensity of the monitoring effort to the quality of the data gathered. This situation comes about through the development of a sample design procedure. Using the procedure, it is possible to assess the reliability of the gathered data. The second objective of this guide is to change our perception of traffic counting, vehicle classification, and truck weighing as being separate activities to the recognition of these activities as part of a related set of traffic characteristic monitoring functions.

The concept of the direct relationship of the volume counts, vehicle classification counts, and truck weight measurements is a unifying element of this Guide.

More than being an advocate of a unified approach for the gathering of traffic characteristic data, this Guide provides specific recommendations on the number, extent, and duration of such monitoring. Further, the design of the data monitoring is set up in an interrelated and hierarchical fashion. Truck weighing sessions are selected as a subset of vehicle classification sessions. Vehicle classification sessions, in turn, are a subset of volume counting sessions. This ì nestingî of sessions leads to economies of operation. For example, truck weighing locations will serve to gather a portion of the vehicle class and volume count data called for by the sample design. Similarly, vehicle classification sessions will provide needed volume count data.

DATA USES

This Guide provides direction on the monitoring of traffic characteristics. Traffic characteristics are those data obtained through a coordinated program of traffic counting, vehicle classifica tion, and truck weighing. This Guide provides direction for persons interested in conducting a statistically based monitoring of traffic characteristics. Information on traffic characteristics is used in all phases of highway transportation. Figure 1-3-1 shows examples of how the traffic characteristic data derived from traffic counting, vehicle classification, and truck weighing can be applied in highway engineering, economic studies, finance, legislation, planning, research, safety, and statistics and by the private sector. Figure 1-3-1 is not intended as a comprehensive listing of data uses but rather to portray the extensive utility of the data.

FIGURE 1-3-1

Examples of Studies Using Traffic Characteristics Data

Highway Management Phase	Traffic Counting	Vehicle Classification	Truck Weighing
Engineering	Highway Geometry	Pavement Design	Structural Design
Engineering Economy	Benefit of Highway Improvements	Cost of Vehicle Operation	Benefit of Truck Climbing Lane
Finance	Estimates of Road Revenue	Highway Cost Allocation	Weight Distance Taxes
Legislation	Selection of State Highway Routes	Speed Limits and Oversize Vehicle Policy	Permit Policy for Overweight Vehicles
Planning	Location and Design of Highway Systems	Forecasts of Travel by Vehicle Type	Resurfacing Forecasts
Safety	Design of Traffic Control Systems and Accident Rates	Safety Conflicts Due to Vehicle Mix and Accident Rates	Posting of Bridges for Load Limits
Statistics	Average Daily Traffic	Travel by Vehicle Type	Weight Distance Travelled
Private Sector	Location of Service Areas	Marketing Keyed to Particular Vehicle Types	Trends in Freight Movement

SECTION 2

An Integrated Sample Design For Traffic Monitoring

SECTION 2

AN INTEGRATED SAMPLE DESIGN FOR TRAFFIC MONITORING

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References

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3. Federal Highway Administration, "Highway Performance Monitoring System -Vehicle Classification Case Study", U.S. DOT, August 1982.

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INTRODUCTION

This chapter outlines procedures for the development of a statistical sampling program for the estimation of traffic volume, annual vehicle distance traveled (AVDT), annual average daily traffic (AADT), vehicle classification, and truck weight with known levels of reliability. The procedures emphasize the use of statistical sampling tied to the Highway Performance Monitoring System (HPMS) standard sample and the complete integration of the estimation and data collection processes at every level to produce reliable, directly-linked estimates which minimize data collection and eliminate duplication. The proposed program does not ignore the reality of practical considerations and the procedures allow flexibility beyond the theoretical constraints. The integration of the sampling program favors the development of the samples in a sequential or top-down format, i.e., volume samples are taken from the existing HPMS standard sample, vehicle classification samples are taken from the volume samples, and truck weight samples are taken from the classification samples.

The philosophical approach to the program development follows the system analysis concepts of holism and parsimony. Holism is a system analysis term expressing the idea that the whole is much more than the sum of the parts, that is, program integration is far superior to program separation. However, it also implies that deficiencies in any part of the system will affect the whole system.

Parsimony in a systems sense is defined as the belief that the simplest, most economical, valid solution is the best. Complex solutions, difficult to comprehend and apply, fall apart during implementation. The reduction in complexity resulting from a simple solution is many times worth the relatively small losses of efficiency or information.

The use of statistical sampling results in estimates with known reliability levels, which are directly estimable from the data.

By using the HPMS standard sample, which is already available and well understood, the need to redesign and implement a new sampling design is eliminated. Furthermore, the tie-in to the HPMS results in directly coordinated programs to address State as well as Federal information needs while eliminating the redundancy of separate programs.

One of the major disadvantages of a sampling program is the fact that sampling produces estimates for an aggregation of elements rather than estimates for specific elements. In context, this translates to the production of system estimates rather than of specific points in the system. Therefore, sampling leaves a gap which must be addressed in a separate manner. This aspect is discussed in Section 3. The use of sampling, on the other hand, allows very precise estimates of the reliability of estimates and of the relationship between reliability and number of samples or cost of the program.

Decision-makers are then able to judge the cost of programs versus the reliability of the estimates provided. Since the relationship between reliability and sample size is exponential, the implications of very precise estimates can be directly translated to the costs of the needed programs. In cases where existing programs are pseudo-randomized (approximate or assume randomness) it becomes possible to approximate the reliability of estimates derived from those programs.

The development of a sampling program has clearly defined steps:

1. Definition of desired objectives.
2. Establishment of cost limits or precision requirements.
3. Definition of the universe to be sampled.
4. Definition of sampling element.
5. Determination of reporting stratification desired.
6. Estimation of sampling element variability.
7. Development of sample design.
8. Implementation of sample design.
9. Development of estimation procedures.

However, this task can, in reality, be enormously complex. The definition of desired objectives is usually difficult. Sample size estimation procedures are only applicable to a single data item, while most data collection programs must address a wide variety of needs and purposes. The need to provide estimates for subsets of the data (reporting strata) create constraints which may greatly reduce the overall efficiency of the sample. Sampling element definition can be subject to numerous constraints and require great skill. Finally, as previously mentioned, sampling is concerned with the whole rather than the parts. The development of a real-life probability sample design is an art as much as a science. Even though great efforts are expended to maintain the theoretical constraints, the point is usually reached where practical considerations outweigh theory.

The structure of the traffic monitoring sample design proposed in this Guide consists of three major elements as shown below:

Traffic Monitoring Sample Design

1. Continuous (ATR) element
2. HPMS (coverage) element
    a. HPMS sample subelement
    b. Traffic volume subelement
    c. Vehicle classification subelement
    d. Truck weight subelement
3. Special Needs Element

THE HIGHWAY PERFORMANCE MONITORING SYSTEM (HPMS)

A basic understanding of the HPMS standard sampling base must precede a generalized discussion of the procedures in this Guide. The HPMS universe consists of all public highways or roads within a State. The reporting strata for the HPMS standard sample include type of area (rural, small urban, and individual or collective urbanized areas) and functional class (in rural areas these are Interstate, Other Principal Arterial, Minor Arterial, and Major Collector). In urban areas these are Interstate, Other Freeways or Expressways, Other Principal Arterial, Minor Arterial, and Collector; the Local and Rural Minor Collector systems are not sampled). A third level of stratification based on volume was added as a statistical device to reduce sample size and ensure the inclusion of higher volume sections in the standard sample. For a complete definition of the stratification levels refer to Appendix F of the HPMS Field Manual, August, 1993, or later versions.

The HPMS standard sample design is a stratified simple random sample (for statistical definitions, refer to any of the sampling texts listed as references). The HPMS standard sample size estimation process is tied to AADT, although about 80 data items are collected. The decision for using AADT was partly based on the fact that AADT is the most variable data item in the HPMS. Therefore, the reliability of most other characteristics would be expected to exceed that of AADT.

The spatial sampling element in the HPMS could have been defined as a point or a section of road. The use of a point approach would have resulted in more samples (there are an infinite number of points in the universe, but a finite number of sections), and would have required a definition of what constitutes a point, which in the end would have required a conversion to short sections. The use of sections or links acts to reduce sample size, to increase the precision of estimates, and to allow the use of existing State highway agency inventories.

Traditionally, roads have been thought of in terms of sections and the use of this concept as the sampling element allows a simple translation to road construction and traffic engineering terminology. However, the use of road sections introduces additional constraints which include the assumption that traffic volume and other characteristics or data elements remain constant within the defined section. The fact that some characteristics other than volume may not meet the assumption outright, and that other characteristics may change drastically over time within the section, requires the subdivision of sample sections.

The HPMS sampling element was defined on the basis of road sections which include both directions of travel and all travel lanes within the section. Direction of travel further complicates the definition because characteristics can change drastically depending on the direction of travel. The same problems exist in the case of multilane facilities where characteristics change by lane of travel. In the interest of simplicity, direction of travel and travel lane were excluded from the sample design with the consequential loss of information.

The AADT variability was estimated based on data from the 1976 National Highway Inventory and Performance Study (NHIPS). The standard sample was originally selected as a simple random sample within strata according to predetermined levels of precision presented in the HPMS Field Manual. The HPMS expansion factors are computed as the ratio of universe roadway extent to standard sample roadway extent within strata, thereby ensuring that roadway extent estimates at design stratification categories match the reported universe roadway extent.

The HPMS standard sample panel has now been implemented in every State, the District of Columbia, and Puerto Rico. It provides a statistically valid, reliable, and consistent data base for analysis within States, between States, and for any aggregation of States up to the national level.

Since the HPMS standard sample provides the basic framework for the traffic monitoring sample, it would be very appropriate for a State to reanalyze its HPMS standard sample prior to developing the traffic monitoring samples to insure an adequate, up-to-date base. Procedures to reevaluate the HPMS standard sample are provided in Appendices E through H of the HPMS Field Manual.

DEVELOPMENT OF A VOLUME ESTIMATION SAMPLE BASED ON THE HPMS

A statistically valid sample design could be developed independently of the HPMS, but the availability of the clearly defined and implemented HPMS standard sample design results in an enormous reduction of effort. This fact, combined with the gigantic analysis capability offered by the direct linkage of traffic estimates to the data items collected by the HPMS, makes it unrealistic to consider an alternative design.

The conversion, staging, or incorporation of the volume sample into the HPMS framework presents several difficulties. Temporal variation and equipment error were ignored in the HPMS design by examining only sampling error using AADT figures which were assumed to be exact numbers. If the assumption is correct, no adjustments are needed. However, this assumption must now be compared to the reality of the situation. AADT numbers are based on factored short counts subject to error, be it due to equipment or to estimation procedures. These errors must be considered in an overall reliability assessment which goes beyond sampling error.

Traffic volume estimation can be subdivided into two basic categories: annual vehicle distance traveled (AVDT) estimation, and annual average daily traffic (AADT) estimation. AVDT estimation presents a much simpler approach than AADT estimation because AVDT is basically a system measure while AADT is a point-specific measure.

Annual Vehicle Distance Traveled Estimation Based on the HPMS

The existing AVDT estimation procedure used to expand the HPMS standard sample involves multiplying each section's AADT, section length, and expansion factor and summing the product for all sample sections of interest to yield any desired aggregation level. Estimation of sampling reliability based on this procedure ignores the fact that the AADT values reported are not exact, and this may introduce significant error.

Given that the spatial sample is already defined by the HPMS, only the temporal aspects remain to be incorporated into the plan. Many possible definitions of the universe and sample elements can be considered to address temporal variation. The recommended definition is that of link-days, which combine the spatial (HPMS section or link) and temporal components.

Within each HPMS stratum, the number of link-days equals the number of sections in the universe times 365. For 48-hour periods, the universe of link-days equals the number of sections times 365 divided by 2. Definitions for other time periods would be similarly derived. The variability of link-day volume can be roughly estimated and sample size specifications derived.

Theoretically, the resulting sample would require a fairly complex randomized schedule which may result in multiple counts for a section.

A simpler procedure is to arbitrarily assume that daily (24-hour) VDT is the characteristic of interest and to distribute the measurement of sections systematically throughout the year (equivalent to a systematic sample). This procedure would result in a single volume measurement for each section during the year, and the measurements would be equally distributed throughout the months or seasons of the year. The daily estimates resulting from this approach would be multiplied by 365 to convert to AVDT. Available data indicate that application of this process to the full Interstate HPMS standard sample would result in AVDT estimates of approximately $\pm$ 2 percent precision with 95 percent confidence for Interstate statewide estimates. The same process taking one-third of the HPMS standard sample for the remaining functional classes (excluding Interstate) would result in statewide AVDT estimates with an approximate $\pm$ 5 percent precision with 95 percent confidence. The actual reliability achieved by each State could be directly estimated after the program has been in operation a full year, and a new assessment of sample vs. precision made using the latest data. The proposed program would cover the full HPMS standard sample every three years through a rotating schedule.

Traditionally, traffic volume counts under the coverage program have been tied to short periods of time with 24 hours being the predominant period. The usage of a 24-hour period in the previous discussion was arbitrary. Longer periods (say 48 hours) can provide more accurate information but tie-up equipment twice as long and double the data collection. As will be discussed later, AADT requirements may necessitate the use of a 48-hour period of monitoring, but the point that 24-hour periods would be sufficient for AVDT estimation is clearly made. This Guide emphasizes the need to discuss alternatives and to provide minimum guidelines. States wishing to expand on the minimum procedures are encouraged to do so and the procedures can be easily modified to incorporate changes.

The procedures for AVDT estimation discussed in detail in Section 3 will recommend the development of an AADT estimate for each HPMS standard sample section. This section AADT estimate will consist of a short volume count (48 hours) adjusted as needed for seasonality, axle correction, day-of-week or growth. The summation of the section AADT estimates multiplied by the section lengths and the HPMS expansion factors will then provide the total AVDT estimate.

A basic assumption made in the development of these procedures is that automatic equipment can collect accurate 48-hour volumes. Equipment error introduces bias which is not affected by sample size. For example, if counters undercount by 10 percent, then system estimates will be 10 percent low whether 300 or 3,000 sections are sampled. Since we assume that equipment bias is normally distributed with a zero mean, then no adjustment is required. If on the other hand, the equipment consistently undercounts or overcounts, then an adjustment should be made. The magnitude of this adjustment could be estimated based on an experimental comparison between the equipment counters and manual counts or between different types of equipment.

Annual Average Daily Traffic (AADT) Estimation Based on the HPMS

The estimation of AADT based on short counts presents a very complex problem. Statistical approaches are designed to estimate system rather than section characteristics, yet AADT estimates may be desired for each individual section. The only statistical way to estimate AADT for each section is to actually take measurements on every section of road. While this would be an expensive process, States may desire this type of program for their day-to-day management and administrative responsibility for these roads.

Present procedures for estimation of AADT are based on the application of the appropriate adjustment factors to the actual short term counts. The temporal or seasonal factors are usually estimated based on small samples of continuous traffic recorders (ATR's). Day-of-week and axle correction factors should also be incorporated into this process as needed.

The central problem with the existing factorization procedure is that it ignores random day-to-day variability which in many cases is larger than the combined factors applied to the short count. The following example illustrates the situation:

> Example 2-3-1
>
> Let's assume that a 24-hour count was taken on Monday and a volume of 2,000 axles recorded. The AADT would be estimated by multiplying the count by a seasonal factor (say 1.06), a day-of-week factor (say 1.1), and an axle correction factor (say 0.45). This would result in AADT estimate of 1,050. Now let's assume that a 24-hour count was taken on Tuesday and a volume of 2,400 axles recorded. By the same procedure, 2400 times a seasonal factor (1.06), a day-of-week factor (1.08), and an axle correction factor (0.45) results in an AADT estimate of 1,237. The difference of 20 percent in the initial volume measurements remains basically unchanged by the factors.

This example explains the reason why a statistical approach to estimate AADT requires several measurements at the specific point of interest. The factors account only for what they are intended to measure, i.e., seasonal, day-of-week, and axle correction variability; but they do not address random variation in volume at the specific points. Atypical variation caused by holidays or related days must be avoided, if possible.

Analysis of ATR data have shown the coefficient of variation of daily volume to be in the 10 to 15 percent range. This translates to a variation of $\pm$ 20 to 30 percent within the 95 percent confidence band. With this knowledge, daily variations of 20 percent would be expected to be the rule rather than the exception. One method of addressing the problem of random variation is to take several measurements at each point and take an average. After all, AADT stands for annual average daily traffic. However, such a procedure would be very costly. Many alternatives can be considered to account for or reduce random variation, such as measuring over longer periods such as 48 hours, 72 hours, 7 days, or taking several randomly selected 24-hour period counts each season or month. The cost implications of these alternatives should be explored as well as the need for the higher accuracy achieved.

The FHWA guidelines for the development of a traffic volume estimation program consist of three major parts or elements:

1. Continuous (ATR) element
2. HPMS (coverage) element and
3. Special Needs element.

The procedures in this Guide revolve around using the previous volume monitoring counts needed for VDT estimation to provide a minimum, basic systemwide AADT coverage framework which could be expanded and supplemented by the individual States depending on their philosophical approach or needs. The VDT sample based on the HPMS provides a basic framework, randomly selected, consistent, and well distributed throughout the State. In some cases, one year's data would be sufficient to develop a rough, annual flow map. For others, 2 or 3 years may be needed. For some States, particularly heavily populated urbanized States, significantly more counting may be required which can be handled as part of the Special Needs element, justified and supported by the specific State needs. The Special Needs element is an integral part of the program.

The continuous (ATR) element (Chapter 2 of Section 3) discusses the procedures for establishing statistical (pseudo-randomized) interpretations of the reliability of seasonal factorization and groupings. The term pseudo-randomized means that randomization is assumed although the ATR locations were not randomly selected. Based on these procedures, the number of ATRs needed to achieve desired reliability levels will be determined and fixed. Seasonal factors and estimation of precision levels require a reassessment of the ATR programs. The result is a clear evaluation of the number of seasonal groups needed by a State, of the composition of those groups, and of the number of locations needed to achieve desired levels of precision within these groups.

The HPMS element provides a minimum coverage framework of Statewide short counts for AVDT and AADT estimation. The guidelines on the HPMS (coverage) element recommend the use of 48-hour counts on the full sample of HPMS sections over a 3-year cycle. This proposal reduces the effect of the random variation, although it does not eliminate the problem. The procedures streamline the development of factors to compensate for seasonal (monthly) variation, day-of-week variation, axle correction, and growth factors.

Day-of-week factors will compensate for day-of-week travel differences identifiable from data collected by the continuous counters. Axle correction factors are used to compensate for equipment counting axles rather than vehicles, i.e., to account for vehicles with more than two axles. The direct tie-in to the vehicle classification element in Section 4 will provide estimates for axle correction. Growth factors are used to convert the 3-year cycle counts to annual estimates, i.e., sections not counted during the year are estimated by multiplying earlier counts by growth factors. All of these procedures will be discussed in detail in Section 3.

It is recognized that the proposed HPMS element of the traffic monitoring program cannot possibly address all data needs. The Special Needs element allows each State to devise traffic procedures or strategies to supplement the recommended framework to compensate for special requirements.

VEHICLE CLASSIFICATION
BASED ON THE HPMS VOLUME SAMPLE

The proposed vehicle classification sample is selected as a subset of the volume estimation sample using simple random selection procedures within the defined strata. This approach eliminates duplication and directly ties the volume and vehicle classification estimation procedures. Duplication is eliminated because classification equipment also collects total volume. Therefore, the sections in the classification subsample are excluded from counting in the HPMS volume element. Direct linking of classification and volume eliminates the need for axle correction factors at the sampled section, and provides a direct procedure for the development of axle correction factors for the remaining sections in the volume sample. The standard vehicle classification categories are provided in Section 4. The estimation procedures will combine the classification estimates from the classification sample with the AVDT or AADT estimates from the volume sample to produce system AVDT estimates by classification categories. The HPMS standard sample and the volume sample are stratified by type of area, functional class, and volume group. The full HPMS stratification approach is inefficient for vehicle classification. It would result in an unnecessarily large sample because samples would be needed in each strata. Also, most of the HPMS standard sample is concentrated in lower volume sections while the interest and priority of higher volume sections is paramount. Therefore, a procedure that insures an adequate presence or distribution of high volume sections in the classification sample was developed.

The proposed stratification for vehicle classification consists of type of area (rural and urban) and functional class (HPMS categories). As an option, States willing to apply larger samples than this Guide recommends may wish to apply the full HPMS area stratification (rural, small urban, and individual urbanized areas). The vehicle classification sample is allocated to HPMS strata proportional to AVDT or DVDT. For example, if the rural Interstate system of a State carries 30 percent of the AVDT, then 30 percent of the classification sample will be allocated to that system. Other possible candidates for the sample distribution were examined including roadway extent, truck AVDT, or truck volume. Total AVDT or DVDT provides the best result since it accounts for both roadway extent and travel, and can be easily estimated from the HPMS standard sample data.

The estimation of vehicle classification variability needed to determine sample size versus precision is difficult due to the present lack of data. The following stratification groups are defined:

1. Rural Interstate
2. Rural Other Principal Arterial
3. Rural Minor Arterial
4. Rural Collector
5. Urban Interstate
6. Urban Other Freeways and Expressways

7. Urban Other Principal Arterial
8. Urban Minor Arterial
9. Urban Collector

These categories represent reporting strata. When following a direct sampling approach, each category requires basically the same number of samples, and total sample size is approximated as the number of samples in a stratum times the number of strata. It is quite easy to see that sample size is directly proportional to the number of strata. Therefore, the best way to minimize the sample is to reduce the number of reporting strata or not to specify target precision levels for reporting strata.

The recommended sample selection procedures (proportional to AVDT) will insure that some sample sections fall in every strata, but the subdomain reporting precision requirements will not be maintained. The procedures used to estimate sample size are based on standard statistical sampling theory. Estimates of variability from the HPMS Vehicle Classification Case Study are used. Figure 2-4-1 presents an example (using Interstate Rural data) of the relationship between sample size and precision at the 95 percent confidence level. The graph shows that an accurate estimate of the percentage of standard automobiles in the system requires a small number of sites. However, the percentage of vehicles in truck categories require much larger samples.

The equation used to estimate the sample size needed to achieve a specified reliability (precision) for a simple random sample is:

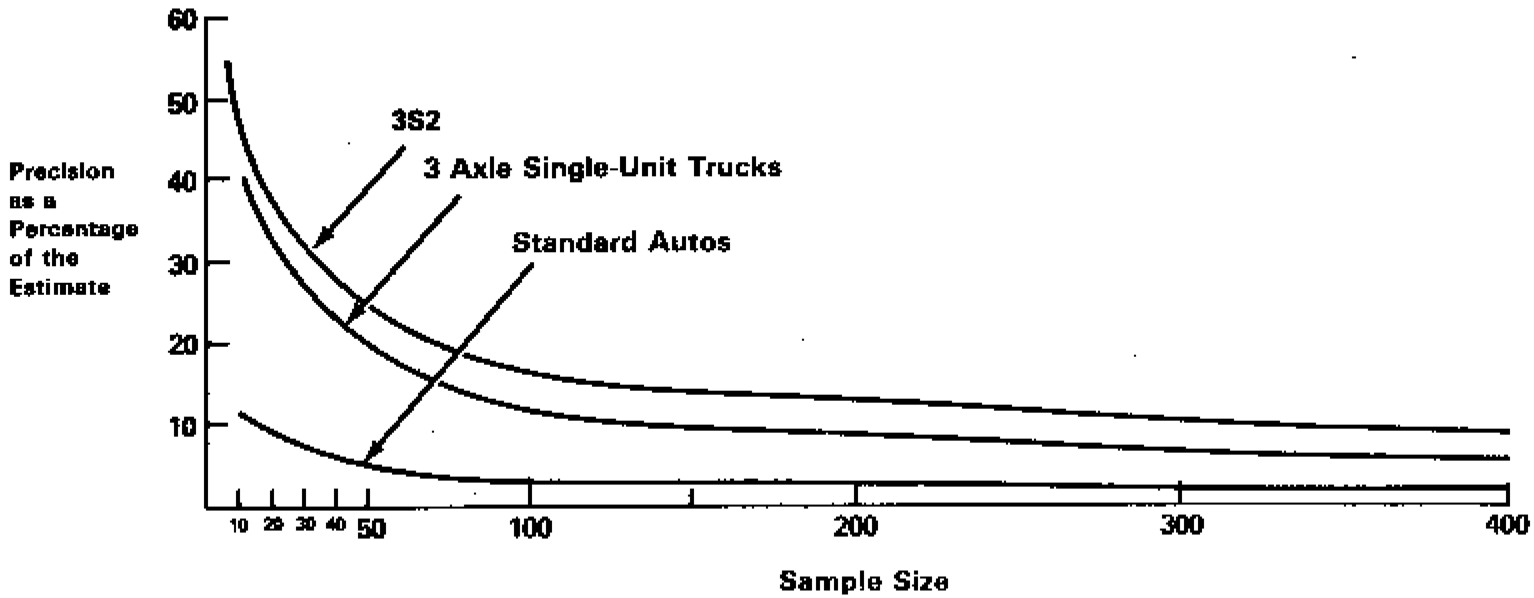
$$n = \frac{(Z_{d/2})^2 \; C^2}{D^2} \qquad 1$$

where

n = sample size,
$Z_{d/2}$ = value of the two-sided normal distribution for d level of significance (value equals 1.96 for 95% confidence),
C = coefficient of variation, and
D = desired accuracy as a proportion of the estimate.

The coefficient of variation estimates used in Figure 2-4-1 were taken from page A.2, Reference 1 and are shown below.

FIGURE 2-4-1
Rural Interstate Sample Size vs. Precision
Vehicle Classification Percentages at the 95% Confidence Level



Vehicle Category	Vehicle Percentage	Standard Deviation (% of Estimate)	Coefficient of Variation (%)
Standard Auto	41.5	7.4	18%
3-Axle Single	.6	.4	67%
3S2	14.9	12.6	85%

These data present generalized information and will not be applicable to each State. States that have vehicle classification data bases available are encouraged to develop their own specific estimates.

The following table examines the precision vs. sample size relationships:

Vehicle Category	Sample Size	Precision Achieved With 95% Confidence
Standard Auto	10	11
	20	8
	30	6
	100	4
	300	2
3-Axle Single	10	42
	20	29
	30	24
	100	13
	300	8
3S2	10	53
	20	37
	30	30
	100	17
	300	10

Several interpretations can be made based on this table. First, statistical precision is tied only to the variability of the characteristic under consideration. Basically, 10 samples would be expected to approximate a 10 percent of the estimate precision for standard autos, but 53 percent for 3S2's.

Second, in the table precision is presented as a percentage of the estimate. For example, the percentage of 3S2 vehicles in the Rural Interstate is 14.9 and the 95 percent confidence precision is 14.9 $\pm$ 1.5 or between 13.4 and 16.4 of the traffic stream. Third, the analysis examines only the Rural Interstate, which means that to achieve the 3S2 target precision would necessitate 300 measurements.

The estimates of variability based on the generalized data can be expected to differ considerably from State to State. Small States with less variability may achieve the target precision with a much smaller sample. On the other hand, States with large roadway networks, heavy industry, or trucking concentrations may show more variability. To reduce the overall burden and because precise truck information is not needed on an annual basis, the sample has been spread out over a 3-year cycle.

Based on the analysis conducted, 300 measurements taken over a 3-year cycle and proportionately distributed by functional class will result in statewide estimates of percentage of 3S2's in the traffic stream with an approximate precision of $\pm$10 percent of the estimate with 95 percent confidence. Estimates for each of the vehicle classification categories will be possible, but estimates for rare vehicle categories (i.e., six-axle multitrailer trucks) will be much less reliable. Actual reliability estimates can be computed for any desired vehicle class category after the sample is in place. Adjustments (increases or decreases) to the sample to meet desired reliability levels can then be made based on a valid sample design and using the latest available data.

As a result of the foregoing discussion, this Guide recommends a minimum of 300 vehicle classification measurements over a 3-year cycle. This represents 100 measurements each year. Under the recommended program, the reliability of system percentages of 3S2 vehicles would be expected to approximate a precision of 95-17 on an annual basis and 95-10 after a 3-year cycle. A halving of the recommended program to 150 measurements would result in an annual target precision (3S2 percentages) of 95-24 and 3-year cycle precision of 95-14. Since the sample is subdivided by functional class VDT, functional class estimates would deteriorate enormously. Under the recommended program and assuming 20 percent VDT, the Interstate sample size would be 60 measurements resulting in target precision of 95-20 for the 3-year cycle and 95-38 annually. The one-half reduction would result in target precision of 95-30 for the 3-year cycle and 95-53 annually. The inferences that could be made from the core program for site specific concerns would be significantly reduced by the sparser sample. The linking of truck weight, vehicle classification, and volume estimates would be significantly affected since the magnitude of collective error would be larger. The size of the Special Needs part of the program may necessitate substantial increases.

In summary, the graph in Figure 2-4-1 presents a deceptively simple picture. Traffic monitoring is a very complex issue which requires adequate consideration of many interrelated concerns. Decisions on the appropriate level of effort vs. cost should not be based on simplistic assessments.

The value of incorrect decisions made on the basis of incorrect information and the need for or planned use of the information collected merit adequate review.

Once selected, the classification sample would become a permanent panel or fixed sample, as in the case for the HPMS standard sample or the volume sample. This is intended to introduce stability and to allow the installation of permanent equipment at any desired sites. The rotating sample would be monitored completely every 3 years. Although proposed as a panel (fixed) sample, changes or modifications must be expected to occur for one reason or another. The recommended approach is to establish a fixed sample where modifications would be made only when sufficient justification exists to require such modification.

Because of the lack of specific State information (results are based on the HPMS Vehicle Classification Case Study data) and the cost of data collection, an implementation schedule in stages is recommended. A small number of measurements would be scheduled during one year and analysis of the data conducted prior to adding locations. The process would be continued until the specified reliability or the recommended sample is reached. This type of implementa tion would allow feedback to insure a State-specific answer to the precision vs. cost question. Small States with limited roadway extent and variability may be able to achieve the desired precision levels with sample sizes substantially below those in the recommended program.

The period of monitoring also requires trade-offs. Longer periods increase the accuracy of the data by reducing random variation, but increase data collection cost. A 48-hour period was selected as the recommended monitoring period. Analysis of the available data have shown that the number of vehicles for several vehicle types vary widely with daily coefficients of variation of about 100 percent (by comparison ATR total daily volume coefficients of variation are in the range of 10 to 15 percent). The use of a 48-hour period would help to stabilize this variation, would not extend beyond the capability of portable classification equipment, and would tie directly to the period recommended for the volume sample.

The distribution of traffic by direction of travel and travel lane for multilane facilities also demands consideration. This Guide recommends retaining classification by travel lane. Direction of travel could be handled in a number of alternative ways. This Guide recommends monitoring both directions of travel and maintaining separate figures for each direction. Other possible alternatives include 24 hours in each direction or selecting the direction of monitoring by the flip of a fair coin. All alternatives present trade-offs. The objectives of the data collection should guide the decision.

As discussed previously for the volume sample, the process is designed to provide system estimates of a specified reliability. Direct section estimates are only provided for sections in the vehicle classification sample. For others, stratum inferences are made. As before, only guidelines are specified. States wishing to expand the recommended samples or to measure specific sections or points under the Special Needs element are encouraged to do so.

Temporal variation of vehicle classification is the last item to be discussed. Classification volume is affected by seasonal effects. The vehicle classification monitoring must be equally distributed throughout the year, otherwise the system estimates will be biased and seasonal adjustment procedures will be necessary.

Count distribution alternatives include random selection of periods or a consistent systematic schedule throughout the year. This Guide recommends a systematic schedule throughout the year.

The HPMS estimation procedures vary depending on whether sections are in or out of the sample. Sections in the classification sample have direct (section specific) estimates. Sections not in the sample are estimated by assigning the stratum averages from their specific stratum. Stratum estimates of classification AVDT are simply derived by multiplying the stratum average classified category percentage by the total stratum AVDT from the volume sample. Aggregation of classification AVDT strata to any level can be accomplished by summation of classification AVDT over strata. Aggregated percentages of classification are computed by dividing the aggregated classification category AVDT by the total AVDT. Specific procedures, formulas, and examples are provided in Section 4.

TRUCK WEIGHT SAMPLE
BASED ON VEHICLE CLASSIFICATION SAMPLE

The proposed truck weight sample is selected as a subset of the vehicle classification sample. This eliminates duplication and directly ties the estimates on weight, classification, and volume. Since automatic vehicle weighing equipment classifies and counts, and the recommended period of measurement is the same (48 hours); sample sections in the weight sample do not require a separate classification or volume count. This combination further reduces the level of effort required by the recommended program.

The stratification categories will remain the same as those in the classification element. However, the reporting categories are simplified by collapsing categories to insure that sample sizes reduce to realistic numbers. As in the classification element, the distribution of the sample within the combined strata will remain proportional to AVDT. The minimum recommended reporting strata are:

1. Interstate
2. All other roads

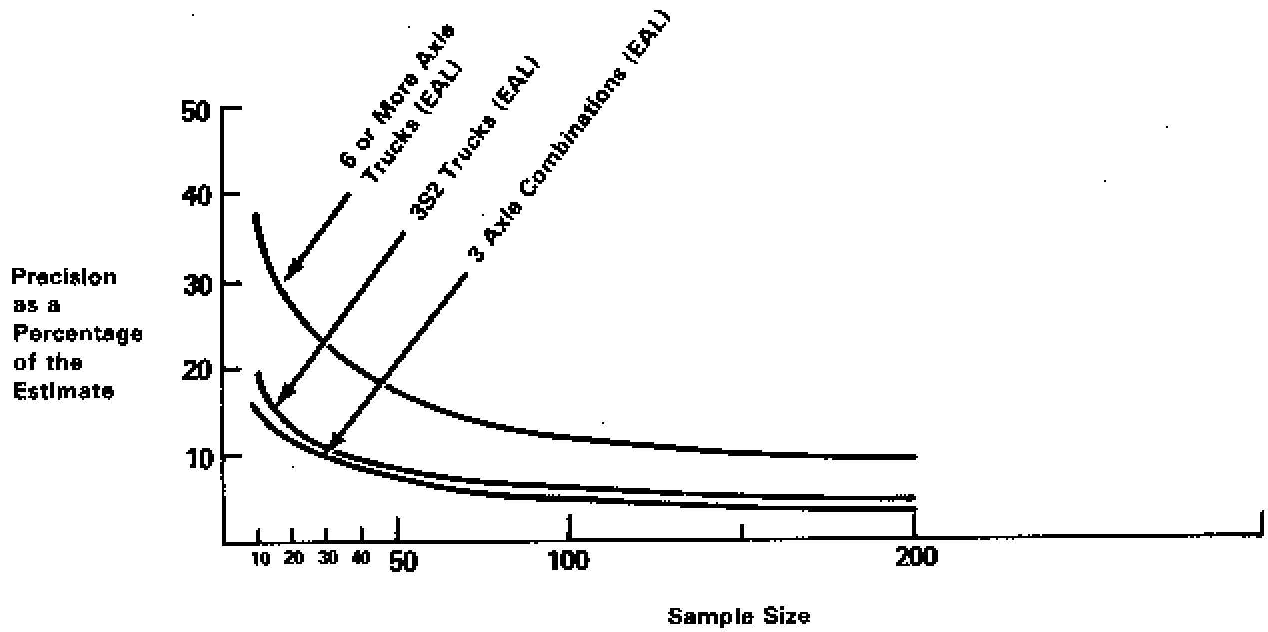
The estimation of sample size for the truck weight sample was based on the characteristic Equivalent Single Axle Loadings or Loads (ESAL). The variability of ESAL's was estimated from the HPMS Vehicle Classification and Truck Weight Case Studies. Since 3S2 trucks carry a high proportion of the loadings, this vehicle type was selected as the one to guide the sample estimation process. It should be noted that the ESAL variability of 3S2's is significantly less than for most other vehicle types, therefore, the decision also reduced the number of samples needed. Research work conducted for the FHWA (Reference 1) provided estimates of the ESAL's and their variability by vehicle type and functional class of highway. Figure 2 -5-1 illustrates the sample size and precision relationships at the 95 percent confidence level for the total Interstate system.

The procedure is the same as used in Chapter 4, where equation 1 is used to estimate the sample size. The following table presents the estimated ESAL coefficients of variation:

ESAL COEFFICIENTS OF VARIATION (% OF ESTIMATE)

Vehicle Category	Urban (%)	Rural (%)	Average (%)
3-Axle Combination	26	24	25
3S2	35	25	30
6 or more axles	68	54	61

FIGURE 2-5-1
Interstate Sample Size vs. Precision
Equivalent Single Axle Loads at the 95% Confidence Level



The figure shows that a target precision of 3S2 ESAL estimates on the Interstate system of ±10 percent of the estimate (95-10) necessitates 30 measurements. The remaining functional classes show more variability than the Interstate, and the combination of all other roads (excluding local) is necessary to bring the sample size to realistic levels.

A halving of the sample size to 15 would reduce total 3S2 Interstate estimates to 95 -15, which is not a large reduction for the corresponding halving of the cost. However, lower subdivisions of the Interstate category would degrade much quicker. Assuming a one-half sample of 8 measurements (corresponding to a 50% break in VDT between urban and rural) on the Interstate Rural system, the target precision of 3S2 ESAL would approximate 95-26 over a 3-year cycle and 95-45 for annual data. Regardless of precision figures, statistical samples this small can be inadequate. Small samples are also more likely to miss changes occurring in the system and to greatly reflect the effects of atypical occurrences, equipment problems, or other biases. Development of the sample in stages and followed by analysis as described in Chapter 4 would serve to provide State-specific data to better guide the precision vs. cost decision process.

The analysis conducted shows that about 30 measurements (over a 3-year cycle) are needed to estimate equivalent axle loadings (ESAL) on the Interstate system for 3S2 trucks (18-wheelers) with a precision of ± 10 percent with 95 percent confidence. The 3-year cycle acts to further reduce the sample needed annually. If the reporting strata were Interstate Rural and Interstate Urban, and the same precision levels were desired in each; then a sample of 60 locations, 30 in the rural and 30 in the urban, would be needed.

Using the single Interstate reporting stratum would necessitate 30 measurements, and these would be distributed to urban and rural as well as to HPMS volume subgroups proportional to AVDT (or truck AVDT) as estimated from the HPMS for the vehicle classification sample and considering existing installations (Section 4). In this manner, sufficient urban and rural measurements would be available to produce estimates for these subgroups, although, reliability levels for non-reporting subdomains would be much wider. This procedure will also allow future expansion or reduction of the program to other desired reliability levels.

The same sampling procedure would be applied to the second highway category "all other roads." However, since the variability of the data is much greater (as is the distance traveled), a sample of 60 measurements (over a 3-year cycle) would be needed to estimate 3S2 truck EAL's with approximately ± 10 to 20 percent precision with 95 percent confidence. As before, these samples would be distributed based on AVDT from the HPMS and selected by a simple random sample procedure.

The recommended program consists of 90 measurements over a 3-year cycle (30 per year) and results in statewide 3-year ESAL estimates of 3S2 trucks with approximately ±10 percent precision with 95 percent confidence. Although, so far only ESAL's have been discussed, it will also be possible to estimate the reliability of any estimate derived from the sample, including the number of overweight trucks or overweight AVDT in the system. The procedures for making such estimates will be discussed in Section 5. The recommendation is, of course, presented as a minimum guideline. Options to expand the system based on States' desires are encouraged and can be easily accommodated on a case by case basis.

The recommended period of monitoring is 48 hours. This is the established goal. The data analyses have shown so much variability, particularly for the less common vehicle categories, that anything less would make the reliability of estimates extremely questionable. All the temporal problems present and discussed in the volume estimation section are compounded in the vehicle classification and truck weight samples.

The distribution of the sample to cover temporal aspects requires judgment. Obviously, a purely statistical procedure would specify a random sample. However, the fixing of sample size on 3S2 EAL variability has ignored the difference in size (roadway extent and travel) between the systems of different States. This is particularly a problem for the Interstate system sample. Since the differences between spatial (distribution over locations) and temporal (distribution over time) variation have not been clearly identified, both must be incorporated into the sample. Here is where judgment must play a part. For example, a State with very limited Interstate roadway extent could propose to take the 30 weight measurements over a 3-year cycle or 10 per year, at a small number of locations. Rather than single 48-hour measurements during the 3-year cycle at 30 separate locations, multiple measurements would be taken at a small sample of locations. That is, due to the limited system extent, the distribution of the sample of measurements would be made over time (temporal) rather than location (spatial). At the opposite extreme, very large States would be better served by establishing 30 separate locations of monitoring over a 3-year cycle. A combination of approaches between the two extremes should also be considered. As with previous parts of the program, once selected the sites would become permanent (fixed sample) until events produced sufficient justification to require change.

The previous discussion makes it clear that equipment portability is a critical need. Collecting five 48-hour periods of data at a single point is far less efficient statistically than collecting 48 hours at five different points in the system. In terms of information gain, very little is accrued after data have been collected at a point for periods longer than 7 days (except for specific objectives that require it, such as seasonality, 30th highest hourly volume, etc.). If seasonal differences are present in vehicle classification and truck weight data, the rudimentary temporal distribution over the year would compensate for it when making system estimates. In States where truck weight seasonality is expected to be high, special strategies could be devised. If continuous truck weight data are available, 7-day samples taken quarterly are sufficient for most purposes.

Finally, complete truck weight information is difficult to capture given the enormous cost constraints presented. Although the average weight of loaded trucks may not have changed much over time; the bimodal distribution of weights due to loaded and empty trucks combined with the changing vehicle fleets and the difficulties involved in truck weighing operations, make the assessment of actual loads an arduous task. The spatial differences caused by concentration of certain kinds of vehicles on certain routes and the effect of measurement on truck travel behavior further complicate the situation. The program proposed in this Guide presents a sensible solution to the information needs faced by most agencies. It will not, however, provide an answer to every question that will be asked. Special studies or supplementary information will always be needed.

SUMMARY OF RECOMMENDATIONS

The proposed traffic monitoring program described in this section integrates traffic volume, vehicle classification, and truck weight. The traffic volume part of the program consists of three major elements:

1. Continuous (ATR) element
2. HPMS (coverage) element
3. Special Needs element

The sampling guidelines which are the main topic of this section are applicable to the HPMS (coverage) element. The basic sampling framework for traffic volume, vehicle classification, and truck weight data is then expanded and supplemented by the Special Needs element.

The nested sample design incorporated into the HPMS element consists of four major samples:

1. HPMS sample
2. Traffic volume sample
3. Vehicle classification sample
4. Truck weight sample

The HPMS sample is already defined and implemented in each State. The volume sample corresponds to the HPMS sample at the completion of each 3-year cycle. The vehicle classification sample consists of a subsample of the volume sample. The truck weight sample consists of a subsample of the vehicle classification sample. A diagram of the sample structure is presented in Figure 2-6-1, and a brief description of the sample design is presented in Figure 2-6-2.

The traffic volume sample consists of 48-hour measurements systematically distributed throughout the year and the State, annually covering a randomly selected one-third of the HPMS sample sections. The vehicle classification sample consists of 300 48-hour measurements over a 3-year cycle. These measurements are systematically distributed throughout the year and the State, and are taken at randomly selected volume sample sections which have been distributed based on HPMS AVDT to provide a fully balanced sample. The recommended truck weight sample consists of 90 48-hour measurements over a 3-year cycle with 30 of the samples on the Interstate system. The locations are randomly selected from the vehicle classification sample and are allocated to strata based on AVDT. The measurements are distributed systematically throughout the year and the State.

The guidelines are presented as minimum specifications which can be expanded and supplemented to any degree desired by the States. The Special Needs element allows each State flexibility to address additional concerns.

Although the emphasis is on volume, the Special Needs element also concerns vehicle classification and truck weight. Great emphasis has been placed on the use of portable automatic equipment as the most effective and cost-efficient means of achieving statistical validity. The following sections provide more detailed discussions of the traffic volume, vehicle classification, and truck weight procedures.

FIGURE 2-6-1
Traffic Monitoring Sample Structure

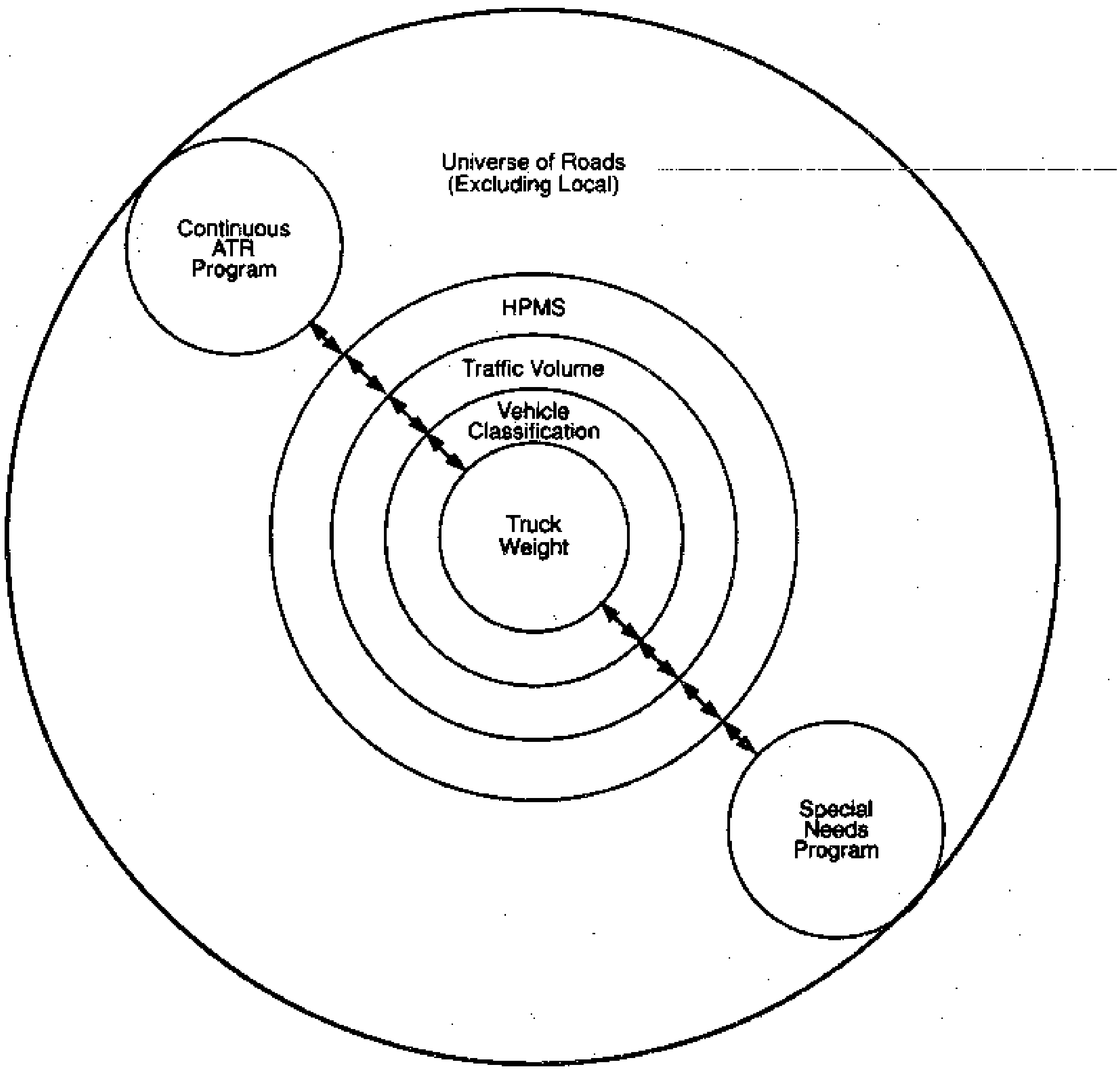


FIGURE 2-6-2
Recommended Traffic Monitoring Sample Design

Program Element	Sample Subelement	Minimum Period	Number of Sessions	Products	Design (Target) Precision
1. Continuous	—	365 Days	40 to 60 (Average State)	Seasonality Growth Temporal Distribution	Annual Seasonal Factors 95-10
2. HPMS	HPMS Sample	—	HPMS Sample	System Estimates by Functional Class	Stratum AADT (See HPMS Field Manual)
	Traffic Volume	48 Hours	Annual - 1/3 of HPMS Sample 3-Year Cycle - Full HPMS Sample	System AVDT by Functional Class AADT at Sample Points	Annual AVDT 95-5 (Excluding Local)
	Vehicle Classification	48 Hours	Annual - 100 Sessions 3-Year Cycle - 300 Sessions	Classified AVDT Axle Correction Factor Percentage Distribu- tion of Vehicles	Statewide Percentage of 3S2s 95-10 (3-year)
	Truck Weight	48 Hours Maximum: 1 Week per Quarter	Annual - 30 Sessions: 10 Interstate 20 Others 3-Year Cycle - 90 Sessions: 30 Interstate 60 Other	Weight & Equivalent Axle Loads by Classification Category	Interstate EAL for 3S2: 95-10 (3-year) Other Roads EAL for 3S2: 95-20 (3-year)
3. Special Needs (State Needs and Others)	—	—	At State Discretion	Site-Specific Info. Project Information Truck Routes Pick-up/Auto Split Local Roads Any Others	—

SECTION 3

TRAFFIC VOLUME MONITORING

SECTION 3

TRAFFIC VOLUME MONITORING

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INTRODUCTION AND GENERAL SUMMARY

The measurement of traffic volumes is one of the most basic functions of highway planning and management. For many years, the traditional approach to the development of annual average daily traffic (AADT) has consisted of three different but complementary types of traffic counts: continuous, control, and coverage (Reference 1).

Continuous counts are taken 365 days a year at a small number of locations. These counts provide the most useful information and, usually, imply the use of the most sophisticated permanent counting equipment available to the planning organizations. Because these counts are most consistent from State to State and are maintained at permanent locations, the FHWA summarizes the information on a monthly basis for the development of national travel trends. Continuous counts are the backbone of contemporary State traffic counting programs.

Control or seasonal counts are much more difficult to characterize because of the many alternatives in use by the State planning organizations. These counts are usually taken from 2 to 12 times a year, for periods of time ranging from 24 hours to two weeks. The main purpose of control counts is to provide a seasonal assignment linkage for factoring short counts to AADT.

Coverage counts are short duration counts, ranging from 6 hours to 7 days, distributed throughout the system to provide point-specific information. Coverage count programs vary considerably from State to State. Several States have implemented coverage programs as system tools with limited numbers of counts, lengthy count cycles, and efficient computerized analysis capability. Other States have emphasized complete and detailed coverage of the highway systems resulting in a very large number of counts taken on short cycles and stored in manual form. Obviously the diverse requirements and constraints faced by State planning organizations have translated into very divergent programs.

Previous sections of this Guide have presented general discussions of the need for a more rigorous statistical procedure, the tie in to the Highway Performance Monitoring System (HPMS), the emphasis on program integration, and the dependence on technological advances in monitoring equipment.

The program as presented in this section consists of 3 major elements:

1. A limited Continuous Count element,
2. A more extensive HPMS framework as the traffic volume sample, and
3. A very flexible Special Needs element.

The procedures are intended to combine system and point estimation in an efficient manner. The proposed program does not make use of control or seasonal count programs.

Chapter 2 presents the recommended approach for the restructuring of continuous ATR programs. The objectives of the recommended programs are to develop adequate and reliable seasonal factors based on a cost-efficient approach; to provide limited statistical rigor; to integrate the continuous program with the overall traffic monitoring program; to minimize modifications to existing continuous programs; to emphasize the development of a consistent approach for national analysis; to establish minimum precision levels for seasonal factors; and to make available a powerful, flexible, analytical tool through the use of computer technology.

Chapter 2 begins with a general introduction, followed by seven subsections. The following is a brief summary of the seven subsections:

- Seasonality Analysis of Existing Continuous ATR Data

  The need to analyze available data to guide the development of the procedures is discussed. A cluster analysis procedure to gain insight into existing patterns of seasonality is described.

- Seasonality Procedures Based on Functional Class

  One of the major recommendations of the Guide is the establishment of seasonal patterns based on functional class to allow a simple and direct identification and assignment of short count locations to pattern groups.

- Establishing the Seasonal Pattern Groups

  The procedures for the establishment of seasonal pattern groups are presented. The methodology is guided by the analysis of each State's data and the knowledge of specific travel characteristics. The procedures are designed to be tailored for each State.

  The minimum seasonal groups recommended are:

  1. Interstate Rural
  2. Other Rural
  3. Interstate Urban
  4. Other Urban
  5. Recreational

Additional groups for regional or other particular concerns are optional. The determination of recreational patterns is based on substantial judgement and is treated as an exception.

- Determining the Appropriate Number of Continuous ATR Locations

  Statistical procedures to tie precision to number of locations in each seasonal group are presented. In general, 5 to 8 locations per seasonal group are sufficient to achieve the desired target precision ($\pm$ 10 percent with 95 percent confidence) of average monthly seasonal factors.

- Modifications to the Existing Continuous ATR Program

  A discussion of how to modify present programs, if necessary, to bring them in line within the recommended procedures is presented.

- Computation of Monthly Factors

  The methodology for the development of the monthly factors for the appropriate seasonal groups is presented. The application of the factors to expand short counts and the assignment of location to groups are discussed.

- Hardware and Software for Data Management and Analyses

  A brief discussion of computer technology and its application to traffic data is presented. The emphasis is on the development of fully computerized data processing and analytical tools.

Chapter 3 discusses the HPMS element of the Traffic Monitoring Program.
It begins with a general introduction followed by eleven subsections which completely describe the recommended approach.

The following summarizes the Chapter subsections:

- Monitoring Period Specification

  A 48-hour period of monitoring is recommended to provide reliable estimates of AADT at the specific locations.

- Monitoring Cycle Specification

  A 3-year cycle of monitoring is recommended as the most appropriate alternative for the HPMS standard sample.

- Selection of the Core Interstate Sample

  The procedures for defining and selecting the Interstate samples are described. The annual sample consists of a rotating one-third of the HPMS standard sample.

- Selection of the Core Sample for the Remaining HPMS Functional Classes

The procedures for defining and selecting the core non-Interstate sample are described. The annual sample consists of a rotating one-third of the HPMS standard sample.

- Spatial and Temporal Distribution of Core Counts

  The distribution of counts over the system (spatial) and the year (temporal) are discussed. The spatial considerations are covered by the HPMS distribution. A temporal distribution over the complete year or the appropriate months of the year is recommended.

- AADT Estimation for HPMS Core Sample Sections

  AADT is used as the basic starting point for the estimation process. The procedures for AADT estimation are presented.

- AVDT Estimation

  The procedures for expanding the AADT estimates to system AVDT are presented.

- Computation of Growth Factors

  Procedures for the development of growth factors are presented, including a discussion of several alternative methodologies.

- Estimation of Day-of-Week Factors

  A discussion of procedures for the development of day-of-week factors is presented.

- Estimation of Axle Correction Factors

  The recommended procedures for estimation of axle correction factors are presented. Estimates by functional class from the vehicle classification sample are used to adjust coverage counts taken by axle counting equipment.

- Data Collection and Processing Considerations

  Several concerns including the use of hourly breakdowns, missed counts, imputation, computer processes, and the use of unique section identification numbers (HPMS) are mentioned.

The different topics discussed have a common basis, which results in similar procedural development. This makes the process easy to understand and very effective in terms of learning or training.

Chapter 4 discusses the Special Needs element of the program. The main focus is on defining additional needs beyond those addressed in earlier chapters. Since the focus of the earlier two elements is system information which can be addressed with a limited amount of coverage, the focus of this chapter is on point-specific information beyond the capabilities of the earlier parts of the program. Because of the great differences existing between States, the presentation is intended to allow maximum flexibility to address any issues of concern to the States. The chapter consists of an introduction followed by limited discussions of system needs beyond the continuous and HPMS core elements, of point-specific needs, of related programs, and of data processing cons iderations.

Chapter 5 describes the use of ramp counts in freeway/expressway situations where mainline counting is not possible due to equipment or safety limitations. Ramp counting allows the determination of mainline estimates of AADT by successive addition or subtraction of ramp volumes from instrumented mainline locations (anchor points). Ramp counting is a special case process and differs substantially from the statistical procedures described in previous chapters.

Appendix A presents an example of the continuous ATR seasonal grouping procedures and a table of the Student's T distribution.

THE CONTINUOUS COUNT ELEMENT

Background and Introduction

The continuous count programs are the most common and consistent traffic data collection programs existing today. These programs have strong historical ties and have become the most basic planning data collection tools in most states. In terms of statistical rigor, most continuous programs lack a firm statistical base. Their design can best be characterized as evolutionary and incremental. These programs, however, have provided the data to guide the development of most of the highway programs in existence today. By providing a permanent, data-intensive method of operation, continuous Automated Traffic Recorders (ATR) have made available a large periodic data base with enormous utility potential to the trained analyst.

One of the purposes of this Guide is to emphasize the need to establish a strong, integrated, and effective analysis capability through the use of analytical computer tools.

Because of the enormous expenditures made to implement existing continuous programs and their present utility in terms of the data base provided, the intent of this chapter is more towards modifying than redoing. By using as much as possible of the existing framework, cost-effectiveness is improved and modifications to existing programs minimized. On the other hand, utilizing existing locations causes statistical rigor to suffer because of the lack of a strict probability sampling approach.

The objectives of continuous ATR programs are many and varied. These objectives should translate directly to the number and location of the counters, the type of equipment used, the analysis procedures, etc. In recent years, the improvements in equipment and the introduction of new programs have resulted in increases in the permanent counter base. Programs such as the Strategic Highway Research Program (SHRP) and the Clean Air Act have emphasized the need for additional traffic data. It is of the utmost importance for each organization responsible for the implementation of the continuous ATR program to establish, document, and analyze the objectives of the program. Only by thoroughly defining the objectives and designing the program to meet those objectives will it be possible to develop an effective and cost-efficient program.

The development of seasonal factors to expand short-term counts to annual average daily traffic (AADT) is a primary objective of the continuous ATR program and the one that should guide the establishment of sample size.

This assessment does not in any way imply that it is the only objective, and sufficient flexibility is built-in to address other objectives as needed. Nevertheless, the first objective of the continuous program recommended in this Guide is then to provide a cost-effective approach for the development of statewide seasonal factors. The second objective is to allow a direct tie-in or grounding of the continuous program to the integrated traffic monitoring program based on the HPMS, thereby providing a strong statistical framework and estimation linkage. The third objective, as mentioned earlier, is to minimize modifications to existing continuous ATR programs, thereby emphasizing incremental rather than revolutionary change. Since the second and third objectives are not independent or exhaustive, compromises must be made.

It must be recognized that the objectives of the permanent counter programs are statewide in nature. In general, the number of permanent counters is insufficient to provide very accurate estimates for smaller subdivisions within the State. In particular, the development of very accurate VDT estimates for the urbanized areas of a State is not addressed in this document and may not be supportable given the existing permanent counter base.

The development of the procedures in the following chapters and sections is the result of compromises between many competing factors. The major emphases are on: 1) the development of data driven procedures, that is, allowing information extracted from available data to guide the formation of the program; 2) the complete integration of related traffic programs; 3) the continuing dependence on technological advances in automated monitoring equipment; and 4) the development of programs that provide an effective and efficient analysis tool.

The continuous ATR data are reported to the FHWA monthly. These data form the basis of the Traffic Volume Trends report published each month by the FHWA. The standard data formats used for the reporting of hourly counts are shown in Section 6.

Seasonality Analysis of Continuous ATR Data

The first step is to define, analyze, and document the present continuous ATR program. A clear understanding of the present program will increase the confidence placed on later decisions to modify the program. The review should explore the historical design, procedures, equipment, personnel, and uses of the information. In most cases, the traffic data is available in computerized form resulting in easy access for statistical data analyses. Many types of analyses are possible and encouraged depending on the desired objectives.

Establishing the quality of the traffic data used in the analysis should be a prerequisite. Permanent traffic data are subject to discontinuities due to equipment malfunctions and errors. Subjective editing procedures to impute missing data have been the norm in most States. The effect of such data adjustments to the analytical procedures is unknown.

The implementation of truth-in-data concepts as recommended by AASHTO will greatly enhance the analytical results and help in establishing objective data patterns.

The cluster analysis carried out is intended to assess the degree of seasonal (monthly) variation existing in each State as detected from the existing ATR program, and to corroborate or examine the validity of the existing grouping procedures used by the States. The analysis consists of examining the monthly variation (attributed to seasonality) of traffic volume at the existing ATR locations, followed by an attempt to group these locations into clusters or patterns of variation. An understanding of the monthly variation of traffic at the different points (ATR's) within the State and of the similarities of this variation as shown by the pattern groupings will help to ascertain the assignment of the ATR locations according to the recommended procedures.

The analysis begins by computing the monthly average daily traffic (MADT) and the monthly factors (described later in the chapter) at each ATR location. The monthly factors are then used as input to a computerized cluster analysis procedure (a variety of statistical packages are available to perform this work). The seasonal analysis is carried out on a monthly basis because other studies have shown that patterns based on weekly or daily variation reduce the veracity of the resulting seasonal factors (Reference 2). The results of the clustering program are then used to roughly identify seasonal patterns detectable from the existing data. If the planning organization responsible for the counting program has developed seasonal patterns based on manual or computer procedures, a direct comparison is then possible.

Application of these procedures to a number of State programs has produced very reasonable results. In most cases, the patterns of variation that stand out are those of rural, urban and recreational areas. However, there are exceptions where clear patterns have failed to emerge. Plotting the resulting groups on a map is sometimes helpful to discern the reasons for patterns which are obviously influenced by the ATR locations. The advantage of this type of analysis is that it provides early evidence of the existence of and the validity of established seasonal traffic patterns.

The cluster procedure is illustrated by an example using actual data in Appendix A, where the monthly factors (ratio of AADT to MADT) at the ATR stations are used as the basic input to the statistical procedures.

An understanding of the computer programs used or of statistical clustering procedures is helpful but not required to make an adequate interpretation of the program results. The major weakness of clustering procedures is the lack of theoretical guidelines for establishing the optimal number of groups. Therefore, a subjective assessment is needed to establish what is appropriate. However, the objective of this analysis is to identify patterns based on available ATR data rather than to provide an optimal solution. In general, 3 to 6 groups are usually sufficient to address the traffic patterns in a State. If a State Agency uses a fixed number of groups in its existing seasonal grouping methodology, then it is appropriate to compare those groups with those resulting from the analytical procedure described in this Guide.

Seasonality Procedures Based on Functional Class

The previous FHWA procedures (Reference 1) for establishing seasonal patterns were based on random variation, that is, locations showing similar patterns of variation are grouped into a pattern.

The weakness of that process is that no clear, definable characteristics exist to guide the development of these seasonal patterns.

The statistical process recommended in this Guide defines seasonal patterns based on functional class or a combination of functional classes according to the actual variability as shown in the existing data. Exceptions to the rule do exist and provision is made to address regional differences or recreational patterns. The decision on the appropriate number of groups is based on the actual data analysis results and the analyst's knowledge of specific, relevant conditions.

The definition of these seasonal patterns based on functional class provides a consistent national framework for comparisons between States and, more important, provides a simple procedure for allocating coverage counts to the factor groups for estimation of annual average daily traffic (AADT).

The statistical procedure emphasizes the use of composite (mean) factors for each seasonal group rather than the subjective allocation of specific counts based on nearness to continuous ATR's. The use of mean factors allows the incorporation of statistical theory to tie factor precision levels to sample size (number of locations). The resulting factors are generalized system factors. Maintaining an awareness of the individual factors at each ATR location will allow a judicious determination of the effects of using system factors for point-specific concerns. In cases where the ATR sample provides insufficient information, additional special counts may be desirable.

Establishing the Seasonal Pattern Groups

The previously described clustering analysis can be used to extract traffic pattern information from ATR data. The following descriptive analysis presents a more direct approach to examine existing data from continuous ATR's or alternatively, from control or seasonal programs. The combined result of both analyses provides the information needed to establish the groups.

The descriptive analysis is carried out by sorting the ATR locations by functional class, computing the percent coefficient of variation of monthly average daily traffic (MADT) at each location, and interpreting the results. The SAS (Statistical Analysis System) software system is used in this Guide. Other statistical software systems also have similar capabilities. An example of the descriptive analysis of the continuous ATR data is presented in Appendix A.

The interpretation of the descriptive analysis is fairly straightforward. The seasonality peaks can be identified by examining the MADT's. The typical pattern shows an increase of travel during the summer months with a peak during July or August. The actual variability is shown by the standard deviation (MSD) and the percent coefficient of variation (MCV). The percent coefficient of variation, the ratio of the standard deviation to the mean times 100, is a standardized measure that allows direct comparison between locations.

In general, the descriptive analysis accounts for the variation of monthly values during the year, but it does not necessarily account for variation patterns. This is to say that locations with completely different monthly patterns may show the same variability as measured by the standard deviation or the coefficient of variation. However, descriptive analysis combined with the clustering of volumes or factors, an examination of monthly factors at the ATR's, and the knowledge of State characteristics provide adequate information to establish the appropriate seasonal groups by functional class.

It is important to realize that hardly any two points in a road system show the same pattern of variation. The aggregation of points (ATR location) into seasonal groups is solidified into a functional class assignment process, which will always remain tempered by judgment. Locations showing very distinct patterns are easily grouped, but many borderline cases exist where assignment is difficult. The saving point is that correct identification or assignment is much more important for the distinct pattern locations than for the borderline cases.

Typical monthly variation patterns for urban areas have a percent coefficient of variation under 10%, while those of rural areas range between 10 and 25%. Values higher than 25% are indicative of highly variable travel patterns, which this Guide terms "recreational" patterns but which may be due to other reasons. The existence of a recreational pattern should be verified by knowledge of the specific locations and the presence of a recreational travel generator. The typical patterns identifiable in most States are then urban, rural, and recreational. An examination of the descriptive and cluster analysis should be sufficient to identify the recreational locations and the general variation patterns as detected from the data. An example is provided in Appendix A.

Because of the importance assigned to the Interstate system, it is recommended that separate groups be maintained for the Interstate categories. The Interstate system because of its national emphasis will always be subject to higher data constraints. The determination to separate the Interstate groups is, however, an administrative recommendation justified by the importance of the system, not because the data show that separate groups are needed. An exception to the specification of separate Interstate groups may apply for States with very limited roadway extent in either the Interstate rural or urban categories where the level of effort necessary to establish reliable groups factors would not be justifiable.

This Guide recommends the following groups as a minimum:

Recommended Group	HPMS Functional Code
Interstate Rural	1
Other Rural	2, 6, 7, 8
Interstate Urban	11
Other Urban	12, 14, 16, 17
Recreational	Any

The first 4 groups are self-defining. The recreational group requires the use of subjective judgement and knowledge of the travel characteristics of the State. Usually, the recreational pattern is identifiable from an examination of the continuous ATR data. The minimum group specification can be expanded, as desired by each State, to account for regional variation or other concerns. However, data support should be one of the prerequisites for establishing additional groups, since more groups translate to the need for more ATR stations with the corresponding increase in program cost and complexity.

Determining the Appropriate Number of Continuous ATR Locations

Having analyzed the data, extracted the relevant interpretations, established the appropriate seasonal groups, and allocated the existing locations to those groups; the next step is to determine the number of locations needed to achieve the desired precision level of the composite group factors. To carry out the task, a grounding on statistical sampling procedures is needed. Since the continuous ATR locations in existing programs have not been randomly selected, assumptions must be made. The basic assumption made in the procedure is that the existing locations are equivalent to a simple random sample selection (pseudo-random assumption). Once this assumption is made, the normal distribution theory provides the appropriate methodology. The standard equation for estimating the confidence intervals for a simple random sample is:

$$B = \bar{X} \pm T_{1-d/2,n-1} \frac{s}{\sqrt{n}} \qquad (1)$$

where

B = upper and lower boundaries of the confidence interval,

$\bar{X}$ = mean factor,

T = value of Student's T distribution with 1-d/2 level of confidence and n-1 degrees of freedom,

n = number of locations,

d = significance level, and

s = standard deviation of the factors.

The precision interval is:

$$D = T_{1-d/2,n-1} \frac{S}{\sqrt{n}} \qquad 2$$

where

D = absolute precision interval,
S = standard deviation of the factors.

Since the coefficient of variation is the ratio of the standard deviation to the mean, the equation can be simplified to express the interval as a proportion or a percentage of the estimate. The equation becomes:

$$D = T_{1-d/2,n-1} \frac{C}{\sqrt{n}} \qquad 3$$

where

D = precision interval as a proportion or percentage of the mean, and
C = coefficient of variation of the factors.

Note that a percentage is equal to a proportion times 100, i.e., 10 percent is equivalent to a proportion of 1/10.

Using this last formula it is now possible to estimate the sample size needed to achieve any desired precision intervals or confidence levels. Specifying the level of precision desired can be a very difficult undertaking. Very tight precision requires large sample sizes which translates to expensive programs. Very loose precision reduces the usefulness of the data for decision-making purposes. Traditionally, traffic estimates of this nature have been thought of as having a precision of $\pm$ 10 percent. A precision of 10 percent can be established with a high confidence level or a low confidence level. The higher the confidence level desired the higher the sample size required. Further, the precision requirement could be applied individually to each seasonal group or to an aggregate statewide estimate based on more complex stratified random sampling procedures.

The reliability levels recommended in this Guide are 10 percent precision with 95 percent confidence, 95-10, for each individual seasonal group excluding recreational groups where no precision requirement is specified.

The procedure begins by examining the monthly average seasonal factors for each group using the existing ATR's, establishing the desired groups, using the equations to establish the number of stations, and determining the modifications needed in the existing program. An example is presented in Appendix A. When applying this procedure, the number of locations needed is usually 5 to 8 per seasonal group, although cases where more locations are needed have surfaced. The only exception is the recreational group where a subjective assignment is recommended.

Distinct recreational patterns can not be defined simply on the basis of functional class or area boundaries. Recreational patterns are very obvious for some locations but non -existent for other, almost adjacent, locations. The boundaries of these recreational groups must be defined based on subjective knowledge. Due to the high variability of the factors, blind application of the statistical procedure presented would result in too many locations and not be cost -efficient. The existence of different patterns, summer vs. winter, further complicates the situation. Therefore, the recommendation is to use a strategic approach, that is, subjectively determine the routes or general areas where the pattern is clearly identifiable, establish a set of locations, and subjectively allocate factors to short counts based on the judgement and knowledge of the analyst. While this may appear to be a capitulation to ad hoc procedures, it is actually a realistic assessment that statistical procedures are not directly applicable in all cases. However, recreational areas or patterns are usually confined to limited areas of the State and, in terms of total VDT, are very small in most cases. The direct statistical approach will suffice for the large majority of cases.

The procedure for recreational areas is then to define the areas or routes based on available data (as shown by the analysis of continuous and control data) and knowledge of the highway systems and to subjectively determine which short counts will be factored by which continuous ATR (recreational) location. The remaining short counts would be assigned on the basis of the functional class groups as defined in this Guide. The number of stations assigned to the recreational groups depends on the importance assigned by the planning agency to the monitoring of recreational travel, the importance of recreational travel in the State, and the different recreational patterns identified.

Modifications to the Existing Continuous ATR Program

Once the number of groups and locations per group are established, the existing program must be modified. The first step is to distribute the existing locations according to the defined groups. In general from 5 to 8 locations are needed in each of the 5 groups, usually resulting in a total of 30 to 40 locations in the State. Exceptions to this rule of thumb are expected; but since the procedures are directly driven by the analysis of each State's data, the results will be justifiable and directly applicable to each State.

If the distribution of existing locations results in a surplus of locations for a group, then redundant locations are candidates for discontinuation. If the surplus is large, reduction should be planned in stages and after adequate analysis to insure that the cuts do not affect reliability in unexpected ways. For example if 12 locations are available and six are needed then the reduction may be carried out by discontinuing 2 locations annually over a period of 3 years. The sample size analysis would be recomputed each of the 3 years prior to the annual discontinuation to insure that the desired precision was maintained.

Location reductions should be carefully thought out. Maintaining a few additional surplus locations, would help to supplement the groups and to compensate for equipment downtime or missing data problems. If the distribution of present locations results in a shortage of locations, then additional locations should be selected and added to the group. Since the number of additional locations is expected to be small, the recommendation is to select and include them as soon as possible.

Because of the small number of locations under consideration, extensive criteria for discontinua tion or selection of additional sites will not be presented. Several important considerations are:

1. Other uses of existing information or importance assigned to sites -- As mentioned before, seasonality is not the only objective or use of continuous ATR data. Each state should insure that these other criteria are met before discontinuation. It should also be clear that additional locations increase the reliability of the data.
2. Quality of the traffic data -- Permanent counter data is subject to many discontinuities due to equipment downtime resulting in missing data and to the vagaries of data editing and imputation.
3. Existing locations -- Available locations from control or other programs may be candidates for upgrading to continuous status.
4. Location on or near HPMS sites -- Because of the direct linkage to the randomly selected HPMS standard sample sections, these locations should be given priority.
5. Tie-in to the classification, speed, or weight programs as mentioned in other sections of this Guide -- Coordination with other programs is essential.
6. Distribution over geographical areas of the State
7. Distribution by functional class system
8. Random selection to reduce bias -- New locations should be randomly selected, if possible, from HPMS standard sample sections.
9. Quality of ATR equipment of sites -- Older or malfunctioning equipment sh ould be given higher priority for discontinuation.

Computation of Monthly Factors

The procedures for the development and use of monthly factors to adjust short volume counts to produce AADT estimates follow directly from the structure of the program. The individual monthly factors for each ATR station are the ratio of the AADT to MADT.

Group monthly factors are derived for each of the seasonal groups (with the exception of recreational or other optional groups) as the average of the factors of all the locations within the group. In the development of data processing or storage specifications, provision should be made for producing a table of factors to be used in the computerized expansion of short counts.

The individual annual factors for each specific ATR location are exact, that is, there is no sampling variability (assuming that all 365 days were actually counted). The reliability also depends on bias such as equipment error or missing data due to equipment malfunction, etc. The precision of annual group factors has been estimated by using equation 3 with the procedure described earlier for estimating the number of locations per group.

The recommended statistical approach defines seasonality based on functional class or a combination of functional classes according to the variability shown in each state's continuous ATR data. For system estimation, the average monthly factors for each group are then used to expand all short counts within the established boundaries of the group. For example, if a short count is taken on the Interstate Rural system during the month of March, then the March factor from the Interstate Rural group is used in the expansion of the short count to AADT. The only exception is for clearly different patterns, such as recreational, which have been defined during the data analysis stage. In these cases, a subjective allocation based on knowledge of conditions must be made.

The individual factors are best for each continuous location, but the application of these individual factors to short counts subjectively based on knowledge of conditions ignores the myriad of unidentifiable dynamic characteristics (weather, random variation, growth, economic conditions, traffic discontinuities, etc.) affecting the patterns. The use of statistical average factors will not produce exact results (there are no exact figures in traffic counting), but on the average will compensate and balance out the many sources of variation.

The statistical approach is not without disadvantages. Knowledge of very different conditions may in some circumstances result in better estimates. Recreational areas are a case in point, but other exceptions are always possible.

The recommended procedure breaks down to the application of the average group monthly factors as the default value for generalized (system) AADT estimates for all functional class groups, with the exception of other identifiable patterns outside of the norm (recreational for example) where subjective knowledge would indicate the use of either the generalized group value or the specific value of an appropriate continuous ATR location.

The specific ATR factors for each location should also be computerized. When developing site-specific information, the default values can be compared with the specific factors of nearby ATR locations to provide a sensitivity type of analysis. If the information available is judged insufficient for the desired objective, then special counts can be scheduled.

To estimate AVDT the use of annual factors would be preferable because direct representation of the year in question is provided (assuming no problems with equipment, construction, etc.). On the other hand, random occurrences such as a cold winter, a rainy summer, construction, or missing data can substantially distort the annual factors at a specific ATR (the group factors are less affected because of the averaging procedure). In most cases, however, historical factors computed over a number of years provide a better indication of seasonality over time. The procedures previously described can be applied either on an annual basis or over a number of years. Each State should determine which procedures to apply depending on specific analysis of available data.

Hardware and Software for Data Management and Analysis

The management and analysis of continuous ATR data require the use of computers. The basic data management functions including input, editing, manipulation, and report generation could be performed using mainframes or microcomputers. Analysis functions could also be carried out on both types of computers, but the use of complex statistical analysis packages and extensive data bases may be beyond the capacity of existing microcomputers.

The advantages of larger machines are high speed, capacity, and package availability. The disadvantages of mainframes are the expense involved and the lack of user control. With the advent of very powerful mini and microcomputers with high processing speeds and large memories, the cost-effectiveness of these machines has greatly increased. Because of the large expenditures on computer processing related to the management of the several interrelated databases of the traffic monitoring programs, it has become cost-efficient to explore the acquisition of dedicated microcomputers with the capability to handle the desired functions.

Software for data management and analysis for the micro machines is available from a number of sources. Careful assessment of the capabilities of both hardware and software is of the utmost importance before final acquisition. Software needs beyond the available packages can be developed through the use of language compilers, or through contracts with appropriate sources. In general, because of the costs, required skills, and problems in developing software; it is usually more efficient to find third-party software that can perform the desired functions.

Finally, the ability to communicate directly and transfer files between micro and mainframe would allow the transfer of existing mainframe files to the micro. This transferability allows the analysis or data processing to be performed on the most cost-effective computer system be it mainframe or micro. The development of the Traffic Monitoring Guide procedures are intended to spur the use of efficient computer capabilities emphasizing storage and analysis on a cost-effective basis. A fully computerized operation would allow early preparation of reports and reduce the existing information lag.

THE HPMS TRAFFIC VOLUME SAMPLE

Introduction

The major purpose of the HPMS element as defined in this chapter is to provide a limited core framework or structure of randomly selected HPMS standard sample sections throughout the state. This core is, first, a systems tool that will completely satisfy the needs for statewide information such as system vehicle distance traveled (VDT). Second, it will provide a well balanced, geographically distributed, and statistically sound sample of HPMS sections. Third, it will provide an adequate statistical base for the development of adjustment factors for expanding short coverage counts to AADT. Fourth, the framework serves as the base for the selection of the vehicle classification and truck weight samples.

A clear understanding of the HPMS sample approach must precede the application of the procedures in this chapter. The HPMS has a direct, statistical link between the sample and the universe of roads in each State. Through this link, estimation procedures tying any of the HPMS collected variables to volume estimates (later to vehicle classification, and truck weight information) can be developed. Because of this connection, it will be possible to make reliability statements for any estimates derived by following the appropriate estimation procedures. Maps showing the location of existing HPMS standard samples would be sufficient to realize the degree of coverage provided by the sample in each specific state. Maps will also help to pinpoint voids which may require filling by the Special Needs element described in Chapter 4.

Monitoring Period Specification

This guide recommends a 48-hour monitoring period for volume, classification, and truck weight monitoring.

The selection of a time period for monitoring requires many trade-offs. This selection is a complex decision affected by many other considerations such as cycle of monitoring, cost, specific State characteristics, volume differentials, equipment, specific location characteristics, growth, and data collection constraints. The recommendations made in this guide are based on research conducted for the FHWA (Reference 2), work done by FHWA staff, reviews of existing State programs, and the redefinition of specific objectives to produce an integrated program. The recommendations in this Guide are intended for automatic monitoring equipment.

The recommendation of a 48-hour monitoring period is a compromise given various alternatives and designed to maximize data validity subject to cost and equipment limitation constraints. As discussed in Chapter 3 of Section 2, the use of a 48-hour period is related to the reliability of AADT estimates. VDT system estimation is less influenced by the length of monitoring periods. The research conducted (Reference 2) clearly showed that the magnitude of daily traffic variation is much larger than the long term growth trend at most sites. This assessment supports the emphasis on longer monitoring periods taken on longer cycles rather than shorter monitoring periods taken on shorter cycles.

Figure 3-3-1, from Reference 2, compares cost versus precision for several alternatives ranging from 24 hour annual counts to 72 hours on a 5 year cycle. The implicit assumptions of this exhibit are discussed in the reference. A 48-hour monitoring period taken on a 3-year cycle was recommended as the most cost-effective alternative.

The use of longer periods of time reduces the cost-effectiveness of the program by reducing the number of counts per machine. However, the objectives and validity of the counts should take precedence. There is a direct trade-off between the collection of a smaller number of more reliable counts versus a larger number of less reliable counts. This Guide emphasizes the former, thereby, preferring quality over quantity.

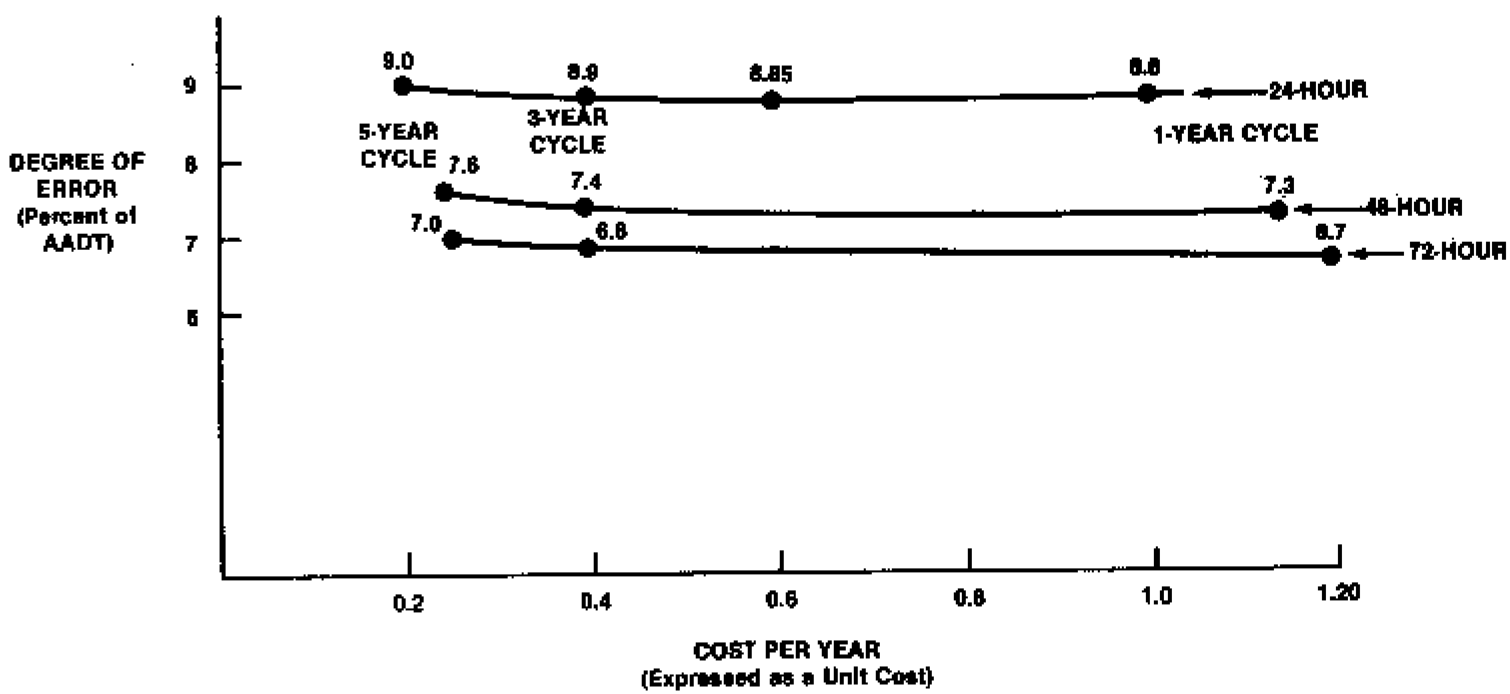
State characteristics such as the organization and structure of the traffic data program, objectives and emphasis areas, specific State or local jurisdiction requirements, resources, and staffing have a direct effect on the selection of an appropriate period of monitoring.

Location characteristics can greatly influence the length of monitoring periods as well as the cycle, the counting equipment, and other data collection concerns. Urban areas because of lower variability may be better served by shorter periods. Recreational areas because of much higher variability would benefit by longer counts. Analysis of ATR locations shows standard deviations of 24-hour monitoring periods in the 10 to 25 percent range, indicating that periods longer than 24 hours are needed if estimates with lower than 10 percent precision are desired. The analysis indicates that the gains produced by increasing the length of monitoring periods quickly diminish; the well-known economic principle of diminishing returns is applicable in this context.

Equipment plays an important role. Obviously, equipment based on loops is not affected by the determination of monitoring period, but equipment based on pneumatic tubes is directly affected. The assessment made is that a 48-hour monitoring period approaches the maximum limit to the use of pneumatic tubes for collecting volume or classification information.

The coordination or integration of the complete program introduces restrictions. Analysis of vehicle classification information from the HPMS Vehicle Classification Case study (Reference 6) showed the standard deviations of daily volume for most truck classification categories to be in the vicinity of 100 percent. Although the data on which the assessment is based is tenuous at best, it clearly indicates that the numbers of vehicles in a number of classification categories can halve or double from day to day. Given this variability, the collection of reliable classification information requires the use of monitoring periods of longer than 24-hour duration. Analysis of truck weight operations have indicated that substantial bias is introduced due to

FIGURE 3-3-1
Relative Cost and Accuracy of Count Duration and Frequency



station bypassing, waiting out, or the shifting of the travel patterns of heavier trucks to periods when the monitoring has stopped. The need for longer monitoring periods to reduce these effects and produce valid estimates is apparent. The longer periods help to provide an adequate sample of certain type of vehicles which although important for many highway issues are rare in the traffic stream.

Since the framework established consists of a limited number of annual counts, the advantages of a 48-hour period are believed to surpass the disadvantages. The recommendation of a 48 -hour period for volume, classification, and truck weight monitoring apply only to the HPMS framework or core element of the program. The Special Needs element, since it is guided by each State's own specific objectives, has no such requirement although the results presented here are directly applicable and worthy of consideration. It is clear that although the program's foundation is based on automation, situations will always arise where automation may not be possible. Exceptions to the arguments made in defense of the 48-hour monitoring period would not be difficult to fin d given the enormous differences in travel characteristics, highway systems, and methods of operation in the 50 states. There may be clear circumstances where the use of shorter or longer periods of monitoring may be more effective. It is important, however, to adequately explore, assess, and document alternative options to insure that all avenues have been considered and that the final decision is, indeed, responsive to the specific situation.

Finally, the basic foundation of State programs and of the procedures recommended in this chapter is to collect reliable and unbiased information. Alternatives and constraints can be analyzed and modifications made where applicable, however, it is important to maintain perspective to insure retaining the basic premise of reliable data.

Monitoring Cycle Specification

This guide recommends a 3-year cycle for traffic volume, vehicle classification and truck weight monitoring. As discussed earlier, the analytical work (Reference 2) indicated that, generally, growth is less influential than daily variation. It was determined that on the average a 48 -hour count taken every three years would be more cost-effective and reliable than an annual 24-hour count in estimating AADT. The reason is that the daily variability of volume is in the 10 to 25 percent range while annual growth would be in the range of 1 to 4 percent. On the average this is quite correct. However, traffic characteristics at specific locations can change quite rapidly by causes such as the opening of a new traffic generator such (shopping center) or a maintenance project. Growth areas can easily surpass the 2 to 3 percent annual statewide growth rates.

Another concern pulling in the opposite direction is how far to extend the cycle. If a 3 -year cycle is better than a one-year cycle, would a 5-year cycle be better than a 3-year cycle? Solely on a cost basis, a 10-year cycle is more cost-effective than a 5-year cycle. The law of diminishing returns applies here. Three-year-cycles produce, on the average, slightly less reliable information than annual cycles when using the same monitoring period length, but at substantial cost savings. Five year cycles would further reduce the cost at an additional reliability penalty. However, the growth area factor mentioned earlier works heavily against these gains. At 5 -year cycles, the compounded 2 to 3 percent average growth rate approaches and confounds the daily volume variability of 10 to

25 percent.

The use of 3-year cycles can also be used to reduce the sample size needed annually to achieve the desired target precision of a sampling program. For example, establishing the precision levels on a 3-year cycle for a rotating sample of HPMS sections results in one-third of the sample needed each year, thereby, reducing the annual effort by a factor of 3. The selection of a cycle could be combined with the length of the monitoring period to produce a two-dimension optimization problem. Evaluation of all possibilities considering the different characteristics, personnel, equipment, and cost constraints of different States is beyond the scope of this Guide. The emphasis then becomes the selection of a consistent approach which will meet adequate reliability needs in a reasonable cost-effective manner. The decision is to recommend the use of 48-hour counts on a 3-year cycle for traffic volume, vehicle classification and truck weight monitoring. There may be clear circumstances where the use of different cycles may be appropriate. In those cases, it is important to adequately consider the objectives and constraints, and to document in detail the reasoning process behind the decision.

Selection of the Core Interstate Sample

The Interstate System has top priority from a national or State perspective. On a national basis, it consists of 1 percent of the roadway extent, yet it carries an estimated 20 percent of the travel. The enormous investment and the magnitude of the programs to maintain that investment will always require a higher level of information. The HPMS sampling rate is far higher for the Interstate than for any other highway system. Similarly, the development of the Traffic Monitoring Guide places the Interstate System in a category second to none.

A brief description of the HPMS was provided in Chapter 2 of Section 2. The HPMS ratio of sample roadway extent to universe roadway extent for the Interstate varies by State from 11 to 100 percent with a national average of 50 percent. There are approximately 9,000 Interstate sample sections or a ratio of 1 sample per 6 kilometers of road. Although sample sections may represent up to several kilometers of road, it is quite apparent that for most States the large sample is sufficient to provide very adequate spatial coverage of the system. Given the controlled access and egress built into the system, a count between interchanges would provide 100 percent coverage of the spatial requirements. In many cases, the existing HPMS standard sample provides sufficient coverage to interpolate estimates of points located between samples. However, points where such interpretation would be judged inadequate would be monitored as a part of the Special Needs element. Because of the large HPMS Interstate sample framework, the need for special counts should be minimal.

In summary, the framework of spatial coverage provided by the HPMS standard sample for the Interstate system is sufficient to provide very reliable system estimates and most point-specific needs. Any remaining needs for information can be addressed through the Special Needs element described in the next chapter.

The HPMS standard sample is then the starting point for the selection of the volume core sample. The Interstate HPMS sample is substratified into urban, rural, and urbanized areas and by volume group within these areas. The HPMS Field Manual (Reference 8) provides a complete description of the stratification of the sample. The selection of the annual Interstate subsample of volume sections is carried out by randomly assigning 1/3 of the sections in each HPMS Interstate stratum. The procedure is described in more detail in the next section.

Since the HPMS standard sample was selected as a simple random sample within strata, the equations in Chapter 2 may be used to estimate the reliability of the HPMS standard sample. VDT estimates require more work because the estimation procedures involve the use of section lengths.

Sample section DVDT is computed by multiplying section AADT by section length. Stratum DVDT estimates are derived by summing section DVDT and multiplying by the HPMS stratum expansion factor. Aggregate DVDT estimates are derived by summing the appropriate HPMS strata DVDT estimates. For example, to obtain estimates of Interstate Rural DVDT, sum the expanded DVDT estimates for each volume group strata within the Interstate Rural system. Annual Vehicle Distance Traveled (AVDT) is simply estimated by multiplying DVDT times 365.

The HPMS standard sample sizes were defined in terms of AADT within strata (refer to the HPMS Field Manual, Reference 8, for a complete description). To estimate the precision of DVDT estimates, a complex procedure is needed to account for the variation in AADT and also for the variation in section length. The equation to estimate the sampling variability of aggregate DVDT estimates is given on page 164 of Reference 5. Studies conducted by the FHWA have shown the precision of statewide estimates of Interstate DVDT to approximate plus or minus 2 to 3 percent with 95 percent confidence. These results, however, consider only sampling variability and ignore other sources of error introduced by equipment or the factoring process used to estimate section AADT.

The recommended procedure covers the HPMS standard sample over a 3 -year cycle, therefore 1/3 of the sample is to be counted annually. This, however does not necessarily translate to an actual count at every HPMS standard sample section. Judgment is necessary when determining the exact number of counts. Subdivided sample sections in the HPMS sense (see discussion of item 29 on page IV-18 of reference 8) may not need separate counts. Adjacent sample sections, without separation by interchanges or access/egress points, do not need separate counts. HPMS standard sample sections on or adjacent to continuous ATR locations or other related monitoring (speed, vehicle classification, truck weight, etc.) do not need separate counts. Considerations of this nature will, obviously, be more pronounced for States having higher sampling rates.

The development of an annual Interstate traffic counting plan requires an examination of the locations of the HPMS standard sample, the availability of resources for traffic counting, and the location of traffic monitoring devices for other related programs. A determination would then be made as to whether a separate count is needed. After this examination, some locations will be judged to have the available information without taking a separate count. However, we assume that the majority of the HPMS Interstate sample locations will still need a separate count.

States with low HPMS sample rates in the Interstate system may need to take additional counts under the Special Needs program element to allow the preparation of detailed flow maps or to address other concerns. The determination would be made based on the need for the additional information after the establishment of the desired objectives.

Selection of the Core Sample for the Remaining HPMS Functional Classes

The HPMS standard sample design specifications lower the precision requirements of AADT estimates for lower functional class systems (refer to Appendix F of the HPMS Field Manual, Reference 8). This, of course, translates to smaller sample sizes and lower sampling rates. The level of coverage by functional class provided by the HPMS standard sample ranges, on a national average, from about 50 percent of total roadway extent for the Interstate System to 3 percent for rural major collectors. This indicates that for the lower systems the core structure or HPMS -based coverage framework may be very sparse. For overall system information this presents no problem at all. However, for point-specific needs the voids or gaps in the HPMS-based framework will be larger for the lower systems necessitating more extensive coverage or potential coverage in the Special Needs element.

Procedures to estimate the precision of aggregate DVDT estimates from the HPMS have been alluded to earlier in this chapter. Analysis conducted by FHWA has shown the precision of statewide DVDT estimates (excluding local functional class) to approximate 5 percent with 95 percent confidence. The analysis assumed that AADT values reported for the HPMS standard sample sections were exact (obviously an incorrect assumption). Because of the assumptions made, it would be realistic to target the achievable precision towards the 5 to 10 percent range. The spatial target precision levels in this Guide have been specified in terms of the HPMS statewide DVDT estimates as plus or minus 5 percent with 95 percent confidence. Computation of annual DVDT estimates using the complete HPMS standard sample by expanding the AADT from each HPMS standard sample would be expected to approximate the stated precision.

The procedures used to develop the AADT estimates at each sample section use factors developed from other locations. The research work (Reference 2) provided statistical procedures to incorporate or aggregate some of the known or tractable errors that affect AADT and consequently DVDT estimates. This study indicated the use of a 48-hour period tied to a 3-year cycle as the most realistic procedure considering all alternatives. The recommended procedure uses a 48 -hour count taken on a 3-year cycle. This recommendation reduces the level of effort to 1/3 of the HPMS standard sample annually. The procedures can be carried out by the use of strict simple random sample procedures using a table of random numbers to divide the sample in each stratum into three random subsets. One of the three subsets would be counted annually on a rotating basis. Following the described procedures insures the complete counting of the HPMS standard sample every three years. HPMS standard sample sections not counted during the current year are expanded by growth factors described later in this chapter.

Tables of random numbers to be used in the random selection are available from a variety of sources as are computerized random number generators. Since the stratum sample sizes are not all divisible by 3, the 3 subsets need not be exactly equal. For example, a stratum with 8 sample sections may be subdivided as 3, 3, and 2. Other strata may have less than 3 sample sections, but the same procedures apply. For example, a stratum with 1 sample section could be subdivided alternatively as 1,0,0 or 0,1,0 or 0,0,1. A certain degree of reconcilement will be necessary after the subsetting to insure that the annual subsamples are approximately equal. Organizing the full sample as shown in the following table would help to make the determina tion:

HPMS SAMPLE

Area Type	Functional Class	Volume Group	Full Sample	Annual Subsets 1	2	3
Rural	Minor Arterial	1	125	42	42	41
Rural	Minor Arterial	2	73	24	24	25
Rural	Minor Arterial	3	15	5	5	5
		Total	213	71	71	71

After the sample is subdivided, a determination as to the actual number of counts needed would be made. As mentioned before, some of the locations may be coordinated with other programs (ATR, vehicle classification, speed monitoring, Stragegic Highway Research Program (SHRP), or others) and have actual counts available for use. The sample sections remaining would then be scheduled for counting.

Spatial and Temporal Distribution of Core Counts

Theoretically, the selection and distribution of the sample must be conducted randomly to maintain statistical validity. Statistical validity requires random spatial (geographical) and temporal (calendar year) distribution. The HPMS standard sample by virtue of its extensive stratification and random selection already provides a balanced spatial distribution. However, bias can be easily introduced by improper temporal selection or scheduling procedures. On the other hand, scheduling operations are very dependent on effective use of personnel and equipment. Compromises will be necessary to insure that all important considerations are adequately addressed.

Because of the emphasis on statistical validity, the recommendation is to provide an adequate distribution over the two dimensions (spatial and temporal) even if this implies a loss of scheduling efficiency. This recommendation applies only to core counts. By coordinating the core and special counts, it may be possible to minimize or reduce the scheduling problems. The manner of operation and organizational structure of different States may turn the scheduling question into a major problem for some States and no problem at all for others. Because of these constraints, latitude is given while emphasizing the recommendation. However, scheduling considerations are secondary to the objectives of the traffic program and should not be allowed to completely dictate or dominate the counting process.

The procedures for distribution of counts are to subdivide the annual subsample by the HPMS stratification categories and as many months of the year as possible in a random manner. That is, the counts should not be concentrated in one area of the State during a certain time of the year. Although the seasonal factoring procedure based on continuous ATR's will provide monthly factors to adjust counts, events specific to an area of the State or time of the year could easily bias the estimates. Valid statistical inference procedures require an appropriate distribution.

A random procedure to incorporate both dimensions can be designed by assigning a unique sequential number to each of the annual sample sections up to 365 (the number of days in the year) and selecting a random number between 1 and 365 which would indicate the HPMS standard sample section and the day the 48-hour monitoring period would begin. If the annual sample is greater than 365 then the process would be continued with the next 365 sections or until the sample were exhausted. Many other similar procedures could be developed based on the specific circumstances. For example, in cases where counting must be restricted to several months of the year the applicable number of days would replace 365; or in cases where counting operations are organized by districts, the process could be applied independently to each district. Alternative procedures developed by highway agencies to satisfy specific requirements are encouraged.

Once the schedule or complete counting plan is developed, the recommendation is to maintain the same schedule for use in the next cycle three years in the future. Although minor modifications are to be expected for one reason or another, maintaining the schedule would provide stability and begin to provide time-series data at the specific sample sections.

AADT Estimation for HPMS Core Sample Sections

The development of AADT estimates from the sample structure described in this Guide follows a straightforward procedure. The 48-hour count taken at the sample sections during the current year may require adjustment by monthly (seasonal), day-of-week, and axle correction factors. For sections not counted during the current year, growth factors are also required. A description of the procedures to develop the factors and/or the need to use them is presented later in this chapter. The recommended method for expansion of 48-hour counts is to convert each of the two separate 24-hour periods to AADT and then average.

The equation used to estimate AADT at the sample sections is:

$$AADT_{hi} = \frac{1}{2} \Sigma \left(Vol_{hi} \text{ x } M_h \text{ x } D_h \text{ x } A_h \text{ x } G_h\right) \tag{1}$$

where

- $AADT_{hi}$ = the annual average daily travel at location i of functional class h,
- VOl_{hi} = the 24-hour axle volume at location i of functional class h,
- M_h = the applicable monthly factor for functional class h,
- D_h = the applicable day-of-week factor for functional class h (if needed),
- A_h = the applicable axle-correction factor for functional class h (if needed), and
- G_h = the applicable growth factor for functional class h (if needed).

NOTE: For equipment units that automatically divide by two to produce a "vehicle" count, the number of axles can be estimated by multiplying by 2 or by modifying the software to report axles.

In some cases (as discussed in the appropriate section), the application of some of the factors may be unnecessary. For example, automatic equipment which counts vehicles does not require axle correction. In these cases, the inappropriate factors would be assigned a value of one or dropped from the equation.

An estimate of precision of the AADT estimates cannot be directly developed since the application of system (group) factors to a site-specific short count is an inference rather than the traditional expansion from a sampling process. Precision estimates apply to sampling processes which use probability theory to relate the size of the sample to the precision of the estimate developed from the sample.

An approximate estimate of the relative variance coefficient as a percentage of the AADT is given by the following equation (the relative variance coefficient is defined as the standard error divided by the estimate):

$$C = \sqrt{CV^2 + CM^2 + CD^2 + CA^2 + CG^2} \quad (2)$$

where

C = relative variance coefficient as a percentage of the AADT,
CV = relative variance coefficient of the 48-hour volume,
CM = relative variance coefficient of the monthly factor,
CD = relative variance coefficient of the day-of-week factor,
CA = relative variance coefficient of the axle correction factor, and
CG = relative variance coefficient of the growth factor.

The equation shows the precision gained by increasing the number of sites used to develop the factors. The equation cannot be used to estimate the precision of a site-specific estimate. The equation indicates that the more factors used the larger the error, incorrectly implying that the error can be minimized by not using factors. It is obvious that a short uncorrected count is less reliable than a count that has been adjusted by seasonality, axle correction, or growth.

A method to estimate the precision of AADT estimates derived from short counts and adjusted by system factors would require approximations derived by simulation at continuous ATR locations. This involves estimating the AADT using random 48-hour periods (or all such periods during the year), adjusting the counts using the system factors, computing the differences from the actual AADT at the ATR site, computing the coefficient of variation (CV) of the error from all the 48-hour periods, and then averaging the CV's from all ATR locations within the functional class or seasonal group used.

Annual Vehicle Distance Traveled (AVDT) Estimation

The procedures for developing daily vehicle distance traveled (DVDT) use the standard HPMS procedures for sample expansion. The first step is to compute an AADT estimate for each HPMS standard sample section. Next, the section AADT is multiplied by the section length and by the HPMS stratum expansion factor. The expanded stratum DVDT estimate is the sum of the expanded section DVDT estimates of all the sample sections within the stratum. Aggregate estimates at any level (volume group, functional class, area type, statewide, or other combinations of these) can now be derived by summing the DVDT of the appropriate strata. Annual vehicle distance traveled (AVDT) are computed by multiplying any resulting DVDT estimates by 365. Estimates of DVDT or AVDT for specific vehicle classes or categories are derived by multiplying total DVDT strata figures by the appropriate percentages derived from the vehicle classification or weight sample subsets.

An estimate of the standard error of a stratum DVDT estimate is given by the following equation:

$$s_h = \sqrt{\frac{n_h (N_h - n_h)}{n_h (n_h - 1)} \left[\Sigma D_{hi}^2 + \left(\frac{\Sigma D_{hi}}{\Sigma L_{hi}} \right)^2 (\Sigma L_{hi}^2) - 2 \left(\frac{\Sigma D_{hi}}{\Sigma L_{hi}} \right) \Sigma D_{hi} L_{hi} \right]} \quad (3)$$

where

s_h = standard error of DVDT estimate in stratum h,
N_h = number of universe sections in stratum h,
n_h = number of sample sections in stratum h,
D_{hi} = DVDT of section i in stratum h, and
L_{hi} = length of section i in stratum h.

This equation is presented in page 155 of Reference 5. A complete discussion of ratio estimation procedures is included in the reference.

The process is dependent on AADT because this is what is reported to the HPMS. The estimates produced by this process are conservative since the errors introduced by the use of factors to develop AADT estimates have been ignored. The assumption made is that these errors are normally distributed and therefore will cancel out when aggregated. VDT estimates could be derived independently of AADT, i.e., by directly expanding the 48-hour short counts adjusted only for axle correction or growth, but this requires maintaining the short count base.
Estimates of the standard error of aggregate VDT estimates for HPMS strata are derived by summing the squared standard errors of the appropriate strata and taking the square root of the total. Coefficients of variation and confidence intervals can be derived by standard statistical procedures.

Computation of Growth Factors

The development of growth factors again highlights the difference between point and system estimation. Growth factors at a point can be best estimated based on the presence of a continuous ATR, assuming that the ATR data is reliable and that the differences found from year to year can be attributed to growth. Since it is well known that many extraneous effects contribute to these differences, the assumption may not be realistic in many cases. It should be clear that even with continuous ATR's the site-specific growth factor may be questionable. System growth estimates can be developed from all the continuous ATR's and the averaging effect compensates to a limited extent for the extraneous effects. However, the number of continuous ATR counters is very limited and may be insufficient to develop accurate system figures, since growth may not occur at the places where the ATR stations are located. The location of the ATR stations becomes very important in this context since growth is very location specific. Estimating growth in urban areas using small number of stations or stations located in rural areas or other urban areas is not recommended.

Growth factors can also be developed from the coverage program if structured in the manner recommended in this guide. Since AADT estimates will be developed annually at each HPMS standard sample, the AADT ratios from year to year should provide point -specific growth ratios. If the continuous ATR factors were considered questionable, then site-specific estimates based on coverage counts would be expected to be less reliable by an order of magnitude. However, since the number of counts is large, system growth estimates developed from the many current counts would benefit by the averaging effect which would be expected to reduce the variability considerably. Also, since the three rotating panels are independent of each other and randomly selected, independent verification of the growth estimates would be available annually.

The point of this discussion is to emphasize that there is not a best procedure that would be applicable in all cases. Instead of concentrating on a specific procedure, a better approach is to use all the tools available to examine the growth issue from several perspectives. Rather than develop a single estimate, the different programs may be used to provide a number of alternatives from which appropriate growth estimates can be derived.

The procedure recommended in this Guide is based on the coverage program because it is believed that the large spatial sample size in the coverage program is superior to the large temporal sample size in the continuous ATR program. However, both procedures will be presented because of the importance for adequate verification and examination of alternatives.

The estimation of annual growth factors based on continuous ATR's requires a minimum of two continuous years of data. Estimates can be developed by specific location, aggregation of specific locations, seasonal factor groups, functional class, or other aggregation of groups. Individual location estimates are simply the ratio of AADT for the current year to AADT for the previous year. Other aggregations require the averaging of all appropriate locations within the group.

Perhaps, aggregation by the established seasonal groups defined using the procedures in Chapter 2 would be the most appropriate. To provide proportional representation, statewide estimates should be weighed by the VDT carried by each of the defined groups.

The equations used for the development of growth factors based on continuous ATR's or current coverage counts are as follows:

Annual growth factor at a single location:

$$G_n = \frac{AADT_t}{AADT_{t-1}} \qquad (4)$$

where

G_n = growth factor of location n,
$AADT_t$ = annual average daily traffic (AADT) for year t, and
$AADT_{t-1}$ = AADT for year t-1.

Annual growth factor for a seasonal group:

$$G_h = \sum \frac{G_n}{n_h} \tag{5}$$

where

G_h = growth factor for seasonal group h,
G_n = growth factor of station n within group h, and
n_h = number of stations in seasonal group h.

Standard error of annual growth factor for a seasonal group:

$$s_h = \sqrt{\frac{1}{n_h} \sum \frac{(G_n - G_h)^2}{(n_h - 1)}} \tag{6}$$

where

s_h = standard error.

Annual statewide growth factor:

$$G = \frac{1}{V} \sum V_h \times G_h \tag{7}$$

where

G = statewide growth factor,
V_h = VDT or DVDT for the seasonal group h, and
V = statewide VDT or DVDT (excluding local functional class).

A rough estimate of the variability (standard error) of the statewide growth factor is obtained by adding the square of the standard errors of the seasonal groups used in the computation of the statewide growth factor and taking the square root of the total. More complex formulas which account for VDT error could be developed, but the many uncertainties and assumptions in the estimation process would hardly justify the additional effort.

The procedures for the estimation of growth factors based on the HPMS core framework are recommended in this Guide, as stated earlier, because of the belief that the large spatial sample size of the coverage program is superior to the temporal sample size of the limited continuous program. Several different procedures could be used to estimate growth rates and the procedure presented here is just one of many possible. The annual counts could be used directly, converted to AADT, or converted to system VDT through the HPMS procedures before proceeding to estimate growth rates. Because of the emphasis on point-specific estimation and to provide a firm starting base, the recommended procedure is to convert to AADT all current year counts before developing the growth factors. This will allow the development of point-specific, system, and statewide estimates starting from the basic building block in traffic counting, the AADT.

The computation of growth factors from coverage counts would be more effective after the program has been in operation for a complete 3-year cycle to insure adequate AADT development at the sample sections. However, even with one year's data very rough estimates could be derived based on historical or earlier AADT estimates at the corresponding sample sections.

The first step of the procedure is then to compute the AADT at each of the coverage count sections monitored during the current year. A direct point-specific growth estimate can be derived based on the ratio of the current year AADT to the previous year AADT. Because of the HPMS sample design, aggregations by HPMS strata or combination of strata could be developed as needed. The recommendation is to develop factors at the functional class level for use in the expansion of sections not counted during the current year to AADT. The reason for the recommended procedure is that extraneous effects will be averaged out resulting in a better estimate of system growth.

It is appropriate to mention that computation of point-specific growth estimates from the coverage counts would indicate whether the point values differ significantly from the system estimate and whether the system value may be inappropriate for point-specific or area concerns. This is where the ATR approach breaks down because of the very limited number of stations.
Plotting the coverage count growth information on a map would be invaluable in estimating pockets or patterns of growth and in the detection of errors. This step is very important because growth tends to occur in some parts of the system and not in others. The use of functional class system factors may not be appropriate, particularly, when dealing with large urban or suburban areas where growth patterns are concentrated in some areas and absent in others. State agencies may prefer to develop growth factors in a far more disaggregate manner that reflect area patterns. The coverage count approach can support such alternatives.

Estimation of Day-of-Week Factors

The statistical procedures described in this Guide recommend the use of day-of-week factors only if such use is shown to be necessary. The use of these factors may serve to improve both AADT and VDT estimates depending on the manner by which the counting procedures are structured and implemented.

Statistical sampling procedures require that each element in the universe or sampling frame have a positive chance of selection. Therefore, excluding weekends from the temporal sampling frame would act to bias the procedures in unmeasurable ways. This is the reason for recommending full inclusion of the 7 days of the week. On the other hand, it is well known that in many cases traffic flows during the work-week days are more consistent than on weekends. Many State programs prefer the use of work-week days which eliminate the higher variability found during weekends. The additional cost of using personnel outside of normal working schedules has also restricted the use of weekend counts in the past. The development of automatic equipment which can be placed and retrieved during normal working schedules may eliminate or reduce the restriction in future programs.

The dichotomy is caused by the fact that the HPMS is a probabilistic sample while the expansion of short counts to AADT by factors is not. A sampling approach requires statistical rigor to remain valid, yet counts taken during weekdays can be quite accurately expanded to AADT without the need for statistical rigor. To reconcile this dichotomy a compromise that considers both positions is needed.

Data from the continuous ATR program must be used to develop the day -of-week factors. Because of the potential differences between functional classes, the analysis would be carried out using the established seasonal groups as described earlier in Chapter 2 of this section. If no significant or large differences are detected between the groups, then statewide aggregation would be appropriate.

Since the use of monthly factors has already accounted for month to month variation, the development of day-of-week factors would be carried out for each month. It is likely that monthly differences may be insignificant, in which case aggregation of several months or the use of the combined factors for the full year would be appropriate. However, traffic effects can change in unpredictable ways and the use of the full day-of-week factoring approach will cover any changes that may occur.

The factors may be computed on an individual basis (7 daily factors) or a combined weekday (Monday, Tuesday, Wednesday, and Thursday) and weekend (Friday, Saturday and Sunday) factors. The decision depends on the data analysis and the State's perspective. If the computation of daily factors results in very similar figures then the simpler combined approach would be preferable.

So far, the discussion has considered an extensive number of possible actions including the determination of individual or combined day -of-week factors, by seasonal group, and by month. It is highly unlikely that all of these effects will be judged significant; indeed, since the procedures recommend the use of 48-hour periods which dilute the daily differences, daily factors may not be needed at all. Another consideration is introduced by the fact that examining all the possibilities mentioned will dilute the available ATR data, thereby introducing small sample discrepancies. In the final analysis, the judgment of the analyst guided by the knowledge of State conditions and supported by the interpretations derived from the data must be the deciding factor. Adequate documentation should be maintained to support the decisions made and to allow future reexamination.

Due to the unpredictability of traffic change, this guide recommends the use of 7 day-of-week factors for each month of the year, which will cover all possibilities and provide a consistent mechanism unaffected by future changes.

The daily factors for a single continuous ATR location by month and seasonal group are computed as the ratio of MADT to monthly average day-of-week volume. For example, the Monday factor in January is the January MADT divided by the average volume of the Mondays in January. The seasonal daily factor for a seasonal group would be the average of all the continuous locations within the seasonal factor group. For example, the Monday factors in January for the Interstate Rural seasonal group is the average of the Monday factors of the Interstate Rural continuous ATR locations in January. The standard error and relative variance coefficient are estimated using standard procedures assuming a simple random sample (the same procedures used in the monthly factor discussion in Chapter 2 of this section).

Estimation of Axle Correction Factors

The application of axle correction factors is dependent on the type of equipment in use. Obviously, vehicle detectors do not require axle adjustment. However, the preponderance of equipment dependent on pneumatic tube detectors in counting operations makes the development of these factors a virtual necessity. To represent vehicles, counts taken by axle counting equipment require adjustment by axle correction factors. The magnitude of the problem will obviously depend on the traffic characteristics at the point or system. For the system purposes of this Guide, axle correction factors by functional class are considered sufficient. For point-specific concerns, the judgment of the analyst and knowledge of specific conditions are of primary importance. If the system factor is not considered appropriate, then a special classification count may be required. This condition is likely to surface for specific situations such as truck routes or truck traffic generators.

The structure of the Traffic Monitoring Guide provides a simple process for estimating these factors for the specific points in the classification sample and for the system in general. The adjustment factor at a point is simply the ratio of vehicles to axles as determined from a classification count (if a classification count has been taken then that count is used). Since most classification equipment provides both a vehicle and axle count directly, very specific procedures are unnecessary. If the AADT is estimated based on axles and the axle correction factor is multiplicative (the recommended procedure), then the ratio of vehicles to axles (axle correction factor) must be positive and generally ranges between the values of 0.2 and 0.5. A functional class factor is derived as the average of the individual factors of all the classification locations within the specific functional class. Standard errors and relative variance coefficients are estimated based on standard procedures assuming a simple random sample (the same procedure used in Chapter 2 of this section).

The application of the factors is a straightforward procedure. Sample sections where classification counts are taken or where vehicle detecting equipment is used require no adjustment since the number of vehicles are known. Sample sections where axle counts are taken are assigned the factors on the basis of functional class and these are applied in the computation of section AADT.

Data Collection and Processing Considerations

Many concerns must be addressed when establishing a traffic monitoring program. Only some of the most salient considerations are addressed here. So far, no mention has been made of actual detail of data to be collected. Obviously much depends on equipment capability and the objectives of the program. In general, hourly breakdowns are recommended for the traffic volume, vehicle classification and truck weight sample sections. This would allow examination of other concerns such as peak-hour volume and design-hour factors. For special analysis, urban location data may be desired by 15 minute intervals. Rural volume locations not tied to classification or weight may need only daily volumes for the monitoring period. Although the Guide recommends the use of 48-hour periods, a break or subtotal for each 24-hour period is recommended for all locations. The daily (24-hour) break is very useful for analysis of daily variation and is required for the factoring procedures. Furthermore, it may be very desirable to structure the full HPMS coverage element on an hourly basis (equipment permitting). This would allow addressing other related concerns such as peak-hour periods or examination of traffic conditions during specific hours, and provide sufficient records to detect equipment malfunctions or to help edit missing periods due to equipment malfunction.

Missed counts due to equipment failures, bad weather, or other reasons should be made up during the year. Partial counts should be retaken. Abnormal situations such as major construction, etc., should be handled based on the judgment of the responsible official. The typical procedures in use by each State should be consistently applied and fully documented.

Data processing procedures should be designed to allow efficient utilization of computerized data. All procedures for data editing, the calculation of AADT estimates, and the development of factors should be fully computerized. Documentation on the processes including tables of the factors used should be maintained for historical purposes and to allow future evaluation. Computerized data management and analysis procedures should allow the use of both mainframes and microcomputers and provide a connection to other relevant data bases. Since the HPMS requires reporting of

AADT information, the use of unique HPMS standard sample section identification numbers in the data base would allow a direct connection between all the related programs (HPMS, volume, classification, weight, and, any other). These numbers would also allow a tie-in to future developments such as computerized mapping tools.

THE SPECIAL NEEDS ELEMENT

Introduction

The development of a sampling approach for volume estimation can be predicated on two related but different concepts: Vehicle Distance Traveled (VDT) and Annual Average Daily Traffic (AADT). VDT estimates are more relevant to the highway systems and usually referred to as system estimates. AADT refers to specific locations and is termed point-estimation. The procedures for developing these estimates are dependent on multidimensional effects which include temporal variation, spatial variation, equipment error, and adjustment factors.

The two major concerns in VDT estimation, excluding equipment, are the temporal and spatial dimensions. AADT estimation presents a somewhat different problem since spatial considerations become immaterial. AADT estimation is concerned with temporal variation at the specific point in question. The only way to obtain an exact AADT (ignoring equipment error) is to install a continuous ATR at the desired point and count 365 days a year. Lacking an ATR, a number of short counts distributed throughout the year and averaged would provide an estimate. Sampling theory could then be used to define the length of counts and the number needed to achieve a desired precision. If the temporal periods of measurement were strictly defined and randomly selected, the reliability of the AADT estimate could be directly estimated.

A less costly and less reliable approach is to take a short count and use a variety of adjustment factors to develop the AADT estimate (less reliable because extraneous factors are imputed to the specific location). Since this latter approach is, by far, the most common today; it is clear that cost considerations take precedence over reliability. The reliability of AADT estimates does not appear to be an overriding concern judging from the majority of existing State programs. It is apparent that the major need is to roughly quantify the average traffic at specific points rather than using rigorous statistical sampling methods. The concerns are then to detect changes of a large nature rather that one of detecting minute differences. This definition, as presented, allows a simple tie-in of AADT to VDT since system VDT estimates do not require accuracy at the point level.

It should be clear from this discussion that it is AADT (point-specific) estimation that complicates traffic counting programs. VDT estimation, by itself, would require small samples of short duration randomly distributed over the geographical (spatial) system and the calendar year (temporal). The adjustment factor approach would be unnecessary. In fact, for generalized VDT estimation, the continuous ATR or Special Needs elements would not be needed. The combination of AADT and VDT requirements into a statistical program has been described in the previous two chapters, and it is accomplished by establishing a sample framework (HPMS core) and adding the factoring procedures to insure reliable AADT estimation at the sample points. What remains to be done is to tie points not included in the HPMS core sample into the program to provide estimates of AADT to support other objectives of the traffic monitoring program.

In the case of the Interstate system, the higher precision HPMS reliability requirements for VDT result in a large HPMS core sample which should easily address most needs for AADT or VDT. The lower functional classes, due to lower VDT reliability requirements and far greater system extent, have a smaller, sparse HPMS core sample framework. These non-Interstate samples are sufficient for VDT estimation and for AADT estimation at the sample locations. However, the wide dispersion of the non-Interstate sample leaves enormous gaps which can be filled to the degree desired by each State by the Special Needs element of the program.

Chapters 2 and 3 have described the Continuous ATR element needed to adjust short counts to AADT estimates; and the HPMS standard sample framework to produce VDT estimates, AADT at the specific sample points, and the statistical tie to vehicle classification and truck weight. This chapter describes the Special Needs element of the program. This is the last element of the three-tiered volume counting program. The Special Needs element is designed to complement and complete the program by providing sufficient flexibility to address any additional needs.

There is no question that after the first two elements are in place additional traffic data needs remain. However, these remaining needs vary substantially from State to State. A comprehensive discussion of all needs presents a difficult task. The needs and the circumstances requiring additional data are diverse and change periodically. The programs, philosophies, and constraints faced by each of the 50 States are too different for complete coverage in one report and must be dealt with individually. Therefore, these special needs are described in general terms. The philosophy of the Special Needs element is then to provide wide flexibility, to encompass the diversity of situations, and to allow each State to design its program in accordance with its self-defined needs and priorities. The Special Needs program can range from minimal, limited coverage to a full, 100 percent inventory of the system depending on the desires and needs of each State. In general, judging by the size of existing programs, needs, and data requirements; the Special Needs element is expected to become the largest of the three elements of the program in most States.

The discussion of the Special Needs program in this chapter concentrates on volume considerations. Although the initial direction and immediate needs may be more concerned with volume aspects, other parts of the overall program also have special needs. The vehicle classification and truck weight samples are very limited by comparison to the volume sample. The development of special vehicle classification and weight programs will be needed to address the very specific objectives in those areas. The Special Needs element should then be inclusive to incorporate needs in all related programs such as the Strategic Highway Research Program (SHRP), speed monitoring, etc. The integration of these separate needs will require more emphasis on initial planning and coordination but will result in a more efficient and effective program. Special needs can be generally subdivided into 2 major categories: system needs and point needs. System needs reflect those concerns that affect the overall highway system, while point needs refer to specific concerns needed for a decision at a single point in the system.

System Needs

System needs are the result of national programs or State programs. Highway managers need data to address pavement, congestion, safety, bridge, and air quality related issues in a consistent and reliable manner. Addressing these issues is very dependent on the availability of reliable traffic data. Others system needs include the use of VDT for apportionment of funds, the development of volume flow maps on a periodic basis, the determination of volume group strata for the HPMS and the development of subunit VDT estimates.

Traffic flow maps have been traditionally developed by most highway agencies to serve a variety of purposes. FHWA programs that make use of traffic flow map information include the HPMS, the National Bridge Inspection Program, and the National Railroad-Highway Crossing Program. Obviously, the first considerations are the level of detail desired by each State in terms of geography and highway system, and the tolerances desired in terms of accuracy of AADT. For the Interstate system, the HPMS standard sample should in most cases be sufficient to develop adequate and accurate flow maps. Plotting of the HPMS standard sample sections on maps will allow a decision as to how many additional counts are needed to satisfy the State's desires. In general, because of the controlled access on the Interstate, only changes in traffic volume of a large magnitude such as major interchanges not already covered require counting. Concerns at a much finer level of detail such as interchange or ramp volumes are beyond the capability of the defined procedures and would require special coverage. Concerns of this nature may be more applicable to point than to system estimation.

For systems other than the Interstate, the HPMS standard sample is very sparse and may be insufficient in many States for adequate flow maps even those of a general nature. Plots of the existing HPMS standard sample locations will allow a determination of the number of additional counts needed to satisfy the State's needs.

The determination of volume group strata for the HPMS is of key importance in insuring that the HPMS standard sample reflects changes in the highway systems. With the passage of time, the traffic volumes on the HPMS universe and standard sample sections change. These changes must be monitored and the sample updated on a periodic basis to insure that representation is indeed maintained over time. Since the changes in the system are not, in general, of a drastic nature and the HPMS by virtue of its statistical design provides a self-correcting mechanism for minor deviations; the tolerance of needed estimates is fairly wide. Minor departures from volume group strata specifications have little or no effect. Therefore, results from a wide tolerance, up-to-date flow map are quite adequate for the purpose of establishing and updating HPMS volume group strata, and no additional requirements beyond the development of rough flow maps are needed.

The development of subunit VDT estimates is a very important concern to a number of States; since apportionment of highway funds to lower jurisdictions such as counties, urban areas, or towns may be based on travel estimates. If only VDT estimates by subunit are desired, simplified procedures based on the existing framework can be developed. First, short monitoring periods are adequate for VDT estimation. Second, the HPMS provides a complete universe definition of the State's road systems with the exception of the local functional class which is excluded from the HPMS and would require separate development.

For all functional classes except local, the HPMS sampling procedures as described in the HPMS Field Manual can be used to develop the necessary sample sizes for the desired reliability levels of subunit VDT estimates. All available samples, whether from the HPMS core or other special purposes would be used in the scheme. Any additional samples would be randomly selected from the remaining universe sections within the subunits. Adjustment procedures to convert short counts to AADT could be used before expansion to VDT or, alternatively, direct expansion (requiring a random spatial and temporal distribution of the count schedule) of the short counts to VDT requiring no adjustment could be carried out. It should be intuitively obvious that if high reliability estimates for a large number of subunits within a State are desired, the sample sizes will be enormous.

Point-Specific Needs

One of the most basic concerns for traffic information is the need for highway project information.

This is perhaps the most important concern from the point of view of State management of highway programs. It is unlikely that available information from the continuous or HPMS coverage elements will be sufficient to address this need, however, available information should be exhausted before additional data is collected. The manner by which this need has been met in the past differs markedly by State. In some States the information provided by the planning department through its regular count program is judged adequate and no special counts are taken. In others, the planning information is disregarded no matter how current and a special count is made whenever requested.

It should be clear that taking a special count by no means insures an accurate estimate at the point in question. The reliability of a special count, particularly a very short one, may be no better than plus or minus 50 percent. Yet, this may be quite sufficient to support the intended decision. Project counts depend on the importance of the project and of the decisions that will be made based on the count and should be justifiable on that basis. Many projects may be adequately supported based on existing information, while an important project in a major urban area may require taking hundreds of special volume and classification counts.

The recommended procedure is to examine the available information from the continuous, HPMS core, classification, and any other special need programs to determine whether sufficient information is available. Even if the specific location is not directly available, extrapolation from or interpolation between existing points may be sufficient to address the need and may be even more reliable than a special count. If in the judgment of the analyst, the available information is sufficient, then special counts should not be scheduled. The adjustment procedures previously described could be used to estimate AADT or other appropriate procedures substituted. Since the number of projects considered during an annual program is not very large, the described methodology would seem far more efficient than a blanket coverage of the complete State system which may still necessitate supplementary special counts and the maintenance of an enormous data base. The decision on what is required is, obviously, best made close to the source, thus complete flexibility is emphasized for this level of the traffic monitoring program.

Other Related Programs

Other concerns can also be at least partially addressed by the defined structure. Studies of a special nature, urbanized area transportation studies, intersection studies, turning movements, traffic signalization, etc., can make use of any available information. Otherwise, special counts can be taken justified by the importance assigned to the study. If all or most of the specific needs can be defined at an early stage, it may be possible to coordinate the data collection to address as many concerns as possible. It is, however, unlikely that one program will be able to address all needs. Some redundancy and duplication will always exist and may actually be beneficial.

Growth areas and other areas where traffic variability is large, such as recreational areas, should receive a high level of priority in the planning of a Special Needs program. This is a basic consideration because fixed samples (continuous ATR and HPMS core elements) tend to be impervious to changes that occur away from the sample points. This is particularly important for the continuous ATR element which consists of a very limited sample. Growth areas are identifiable based on knowledge of the highway systems and by monitoring available information on travel generators, construction projects, highway construction, highway maintenance, zoning laws, building permits, population growth, etc. Maintaining a higher level of attention in these areas should also serve to indicate when seasonal patterns or use of growth factors developed as a part of the general program require revision or modification. Obviously, a periodic review of the procedures will be needed to keep them up-to-date.

Future programs and studies can present a challenge to the organization of any program. The maintenance of a clearly defined yet limited structure (the continuous ATR and the HPMS Coverage core) combined with a very flexible Special Needs program should provide adequate leeway for the use of existing information as well as the future implementation of any needed modifications.

Data Processing Considerations

The effectiveness of a data base depends on the ability to extract information quickly. This in turn depends on the computer systems where the data is stored and the skills of the analysts. The integrated traffic monitoring program requires an effective data base management function that permits easy access to the data base for information, update, and control purposes. Capacity and processing speeds must be carefully considered before a hardware determination is made. The emphasis of the Traffic Monitoring Guide is on the use of microcomputers, although larger machines may be necessary in some cases. The sizes of the continuous and HPMS core elements are well suited for small computer processing. However, the Special Needs element, since it depends on State definition, requires careful analysis.

Software must include a capable data base management package with report or quick inquiry functions. A distributed data base operation, where different purpose data bases are stored separately but can be easily linked through common identifiers, may allow independent operation of the different sub-programs without sacrificing overall program integration. The intricacies of a fully computerized program must be explored early in the planning stage. The development of an integrated traffic program is totally dependent on the efficiency of a computerized operation.

FREEWAY-EXPRESSWAY RAMP COUNTING PROCEDURES

Introduction

This chapter describes the use of ramp counting to estimate freeway-Expressway mainline traffic volume (AADT). Although these procedures are applicable to any controlled access facility, they are specially applicable to the Interstate system.

The installation and use of portable traffic counting equipment on high volume freeways in urban areas present great difficulties. Insuring the safety of the traffic counting crews and the motoring public is costly and requires extensive traffic control. Installation in high volume, multilane facilities often exceeds the limitations of existing portable axle detectors.

Many State Highway Agencies have searched for alternative solutions. These include the installation of permanent loops covering the complete system, the counting of entrance/exit ramps, or the development of new equipment and detector technology. The installation of permanent loops is the most effective long-term solution. However, due to the large number of installations needed, it is costly and would require extensive start-up effort. Ramp counting has become a common alternative because it can be implemented rather quickly using existing technology and staff and reduces the number of permanent installations needed.

New technology, particularly the development of more effective axle or vehicle detectors or the use of traffic surveillance or video devices, has great future potential. New initiatives to monitor congestion and research into Intelligent Vehicle/Highway Systems have given technological development a boost. However, these efforts have not yet reached a practical implementation stage.

The Ramp Counting Process

The importance of the Interstate system necessitates the estimation of AADT for all sections based on actual traffic counts. Taking mainline counts can be very difficult or impossible due to the reasons discussed above.

Ramp counting is defined as the process of counting all entrance/exit ramps between two established mainline counters, such as permanent ATR's or other installations, and then reconciling the count data to estimate mainline AADT.

The two boundary ATR's or mainline instrumented locations used to control the counting and adjustment process are referred to as anchor points.

The ramp counting process is very similar to a traffic flow problem where mainline volumes are known at two points and all input/outputs are measured in between. As with any estimates involving traffic, the process is much more involved and complex than it appears at first.

The process is designed to estimate mainline AADT. Annual mainline estimates of AADT are a reporting requirement of the HPMS system. Note that the HPMS definition of Interstate mainline AADT excludes volume from frontage roads, collector-distributor roadway extent within interchanges, or any ramps.

The following sections will describe the methodology for developing a ramp counting program and reconciling the counts to mainline estimates of AADT. A very simple example, consisting of one figure and three tables, is used to illustrate the process. Figure 3-5-1 presents a diagram of the study section. Table 3-5-1 shows the estimation of adjusted daily volumes at the mainlines. Table 3-5-2 shows the estimation of AADT at the mainlines. Table 3-5-3 shows the reconcilement of mainline AADT between ramps into AADT for HPMS reporting.

One of the requirements of the ramp counting process is the availability of detailed maps or computerized inventories showing the locations and distances between anchor points and the ramps for each direction of travel. The distances will be needed to develop AADT estimates that correspond to HPMS universe and standard sample sections. Therefore, the HPMS universe sections need also be defined on the maps or inventory systems used.

One of the limitations of the ramp counting approach is that travel-lane volumes cannot be estimated since traffic entering the road cannot be allocated to lanes. This limitation does not affect the data collection specifications of the HPMS, but may effect other programs which depend on lane information.

Establishing the Anchor Points

The first step is to select the two anchor points (continuous counters or other loop installations) which will be used to control the estimation process. The use of permanent counters as anchor points provides the highest accuracy and is the preferred approach. However, the number of existing permanent ATR's available for this purpose will not be sufficient and the cost of a large number of continuous counter installations may not be feasible, therefore, using any available instrumented sites where mainline volumes can be obtained will be necessary. Installation of additional permanent detectors as anchor points (either counting continuously or on a periodic basis) is also a very likely possibility.

When determining the number of anchor points, there is a trade-off between accuracy and cost.

Generally, the closer the anchor points the more reliable the estimates. On the other hand, the farther away the anchor points the lower the number of anchor points needed to estimate the complete system. The number of anchor points depends on the specific situation and traffic characteristics under consideration. Each State will have to make its own determination regarding the appropriate number of anchor points. As a rule-of-thumb, the maximum number of interchanges between anchor points is five.

In making a decision regarding the placement of anchor points, the importance of interchanges and, of course, major route connections (junctions) play a major role. The location of existing ATR's, control counters, permanent loops, toll booths, traffic control points, or other instrumented sites also figure prominently in the selection of appropriate anchor points.

Taking Counts Between Two Anchor Points

Since the volumes at the anchor points can be "assumed" to be exact (that is, no missing data imputation or equipment error problems), a short count at each ramp may appear sufficient to provide a reasonable estimate. However, complications due to commuter patterns, weather, traffic fluctuation, peak-hour effects, truck volume changes, incidents, equipment error, etc., necessitate the use of longer monitoring periods. The minimum period of monitoring recommended for ramp counting is 24 hours.

Under this approach, a section between two anchor points would be counted once every three years (this is a minimum recommendation). The 3-year counting schedule could be applied in alternative ways, and one method is to count one third of the system each year on a rotating basis. To provide annual AADT estimates during non-counting years in the cycle, annual conversion or current-year factors based on the two anchor points or nearby permanent ATR sites will be used.

In theory, all ramp counts between two anchor points should be taken during the same 24-hour period which would eliminate the need to adjust the counts prior to reconcilement. Recognizing that some of the ramp counts will be missed due to equipment problems or errors, recounts should be taken as soon as possible during the same days of the week as the original count and, preferably, during the same month. In cases where the counts cannot be taken during comparable periods, it becomes necessary to adjust the ramp counts to AADT before reconciling (this is not recommended because the use of system factors or factors from other locations may introduce substantial error).

Counts between two anchor points are adjusted based on those two anchor points and the discussion here assumes that the two anchor points are permanent ATR's. If the anchor points are not permanent ATR's or lack adequate data, then the adjustment is based on other ATR's located on the same route in close proximity. As a last resort, system adjustment factors can be based on the average of the ATR's within the functional class group. The use of any alternatives to the two boundary ATR's is likely to result in additional differences in the sequential AADT estimates.

The ramp counting process is not statistical sampling and, therefore, it does not require the strict temporal and spatial control needed in the sampling parts of the program described in other chapters. Due to the anchor point-to-point reconciling, the ramp counting program only requires temporal control between the set of two anchor points (that is the same counting period for all ramp counts in between the two anchor points). No control is needed over other sets of anchor points, routes, or systems. This allows great flexibility in scheduling counting operations.

The schedule of counts could be organized systematically over the counting season to minimize the staff needed and allow recounting as needed. It is recommended that sets of ramp counts between anchor points be scheduled sequentially by route starting from a defined starting point and continuing to the end of the route. For example, for a North to South route the starting point could be the Northern or Southern boundary. Many States already have defined starting and ending route boundary points for milepost markers, and these established definitions should be followed. Count scheduling is the responsibility of the State counting organizations, and other scheduling alternatives better suited to decentralized counting operations are also quite feasible.

It is recommended that ramp count data be collected and maintained in 15-minute intervals. Use of 15-minute counters will simplify the detection/correction of errors and allow a better identification of traffic patterns at the ramps. Since ramp counts prevail in urban areas, these counts would greatly expand the value of the information collected. Recent interest in the use of traffic data to address urban congestion have resulted in calls for the collection of data in 15-minute periods to better address the duration and extent of peak periods.

So far this discussion has assumed that all ramps can be counted using portable detectors such as road tubes, mats, switches, or portable loops. However, there may be ramps that will be impossible to count using these methods. In those situations, the use of shorter visual or video counts may become necessary and an appropriate adjustment process will have to be developed to expand these short counts to 24-hours. For example, the process defined in this chapter for 24-hour counts could be modified to fit 8-hour counts and used for this exceptional situation. The modified process would be used to estimate only the visual count sections and is not a substitute for the 24-hour process (although, the results of the shorter count could provide a comparison with the 24-hour count estimates).

Mainline Daily Volume Estimation Based on Ramp Counts

The reconciling of ramp counts to anchor points begins by establishing the daily volume at the two anchor points for the 24-hour period during which the ramps were counted.

The next step is to select one of the two anchor points as the starting point. Since the access/egress points will vary by direction of travel, it is recommended that the reconciling be carried out independently by direction of travel and that the computation proceed in the direction of the traffic flow. This will provide AADT estimates for each direction of travel. The aggregation of the two directions of travel to provide total volume or AADT will be carried out in later steps. The computation by direction of travel responds to the high volume levels and difficulties encountered in larger urban areas. Alternatively, many States have indicated that in cases of parallel interchanges with minor volume differences combining both directions of travel produces almost the exact results but reduces the effort required.

The directional volume between the starting anchor point and the first ramp is the directional volume at the starting anchor point. The directional volume between the first ramp and the second ramp is the directional volume at the starting anchor point plus the entering volume if the ramp is an entrance ramp or minus the exiting volume if the ramp is an exit ramp. The process of addition or subtraction is carried out until a daily directional volume has been developed for each mainline section between each ramp break between the two anchor points. Many States with parallel interchanges basically estimate the interchange volume and then use it to determine the mainline volume between interchanges. This process is quite effective for some applications. However, recognizing that interchanges in major urban areas may present problems with the simpler approach, the more detailed computation using exact roadway extent differences between ramps and the weighted section approach are recommended.

In theory, assuming no equipment error and exact vehicle counts at each ramp, the addition/subtraction process should provide exact results. That is, the volume computed for the last mainline section before the ending anchor point should exactly match the mainline volume at the ending anchor point. In practice, due to equipment error or the conversion of axle counts to vehicles, a difference will always exist at the end of the process. The difference should not be large since a large difference is a clear indication of problems. It is recommended that this difference be proportionally allocated to each section between the two anchor points, but only if the difference is greater than 1 percent and less than 5 percent ($1 < d < 5$) of the directional volume at the ending anchor point. In most cases, differences under 1 percent should be considered negligible and ignored (if the process is computerized then the adjustment should be carried out to insure an exact volume match). In most cases, differences greater than 5 percent may require, at a minimum, a check and verification of the ramp counts and anchor point data. At worst, it may necessitate a complete recount of all the ramps between the anchor points. Differences of this magnitude need to be accounted for because of the potential for major changes to the ramp volumes.

The allocation of the volume difference to the ramps is carried out by proportionally distributing the volume difference remaining at the ending control point to each of the ramps. The adjustment to each ramp is computed as the ratio of the difference in volume (remaining at the end of the reconciling) to the sum of the ramp volumes. The process is described in the example.

Actions that can be taken to minimize the error include accuracy checks on the counters, proper installation of equipment, adequate control over time periods of monitoring, and the use of vehicle counters rather than axle counters. Ramp counting can be a difficult operation and staff workloads should be designed to emphasize quality rather than quantity. Regardless of the actions taken, a small reconciling difference should always be expected.

Figure 3-5-1 will be used to explain the recommended ramp counting process. The figure illustrates an Interstate segment of six kilometers bounded by ATR anchor locations. The Eastbound direction of travel (used in the example) consists of 4 segments separated by 3 ramps. The segments are identified by capital letters (A, B, C, and D). Ramps 1 and 3 are entrance ramps and ramp 2 is an exit ramp. The length between the ramp-separated segments is included.

Notice that in the analysis, a very meticulous determination of distance between ramps is used. Entrance ramps are, by definition, measured from the point where the ramp connects to the Interstate. Likewise, exit ramps are measured from the point where the ramp ends. The distance measurements play an important part later in the conversion of ramp break AADT's to HPMS section AADT. Several States have indicated that simpler procedures may provide accurate mainline volume estimates. The point is well taken. The example computations as presented cover all possibilities. Simpler and less detailed applications could be used if appropriate.

FIGURE 3-5-1
Ramp Counting Example

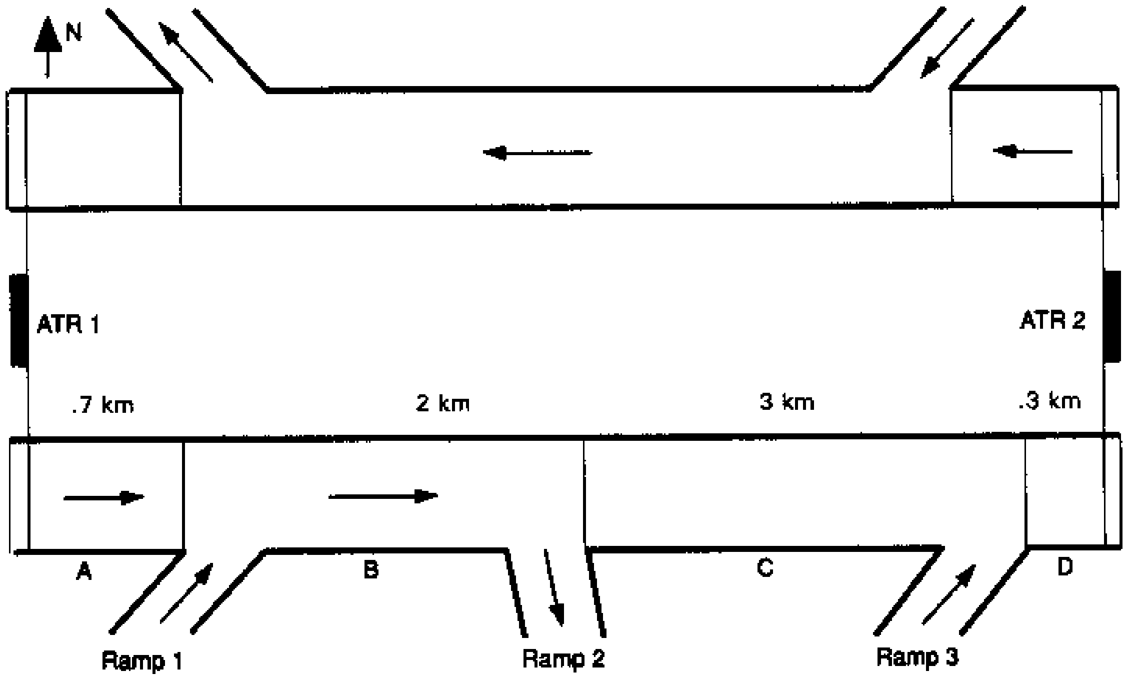


Table 3-5-1 presents the computation of the adjusted mainline volumes for a 24-hour period in one direction of travel.

TABLE 3-5-1
Computation of Adjusted Mainline Volumes

Ramp count date:	May 17
Length of analysis section:	6 kilometers
Direction of travel analyzed:	Eastbound

Ramp Counts

	Ramp 1	Ramp 2	Ramp 3	Total
Ramp count volumes	923	1,053	786	2,762

Mainline Segments

	ATR 1	A	B	C	D	ATR 2	Remaining Difference
Initial Volumes	11,995	11,995	12,918	11,865	12,651	13,053	402 (-3%)

Adjusted Ramp Volumes

	Ramp 1	Ramp 2	Ramp 3	Total
Ramp adjustment	+134	-153	+115	402
Balanced ramp volumes	1,057	900	901	

Mainline Volume Estimates

	ATR 1	A	B	C	D	ATR 2	Remaining Difference
Balanced Volumes	11,995	11,995	13,052	12,152	13,053	13,053	0

The volumes in the table are computed starting with the volume at ATR # 1 and adding or subtracting ramp volumes until reaching ATR # 2. In the example, a difference of -3% resulted at the end. The adjusted ramp figures were computed by proportional allocation of the difference based on ramp volumes [dividing the difference (402) by the total ramp volume (2762) to compute the allocation proportion (.145) and multiplying this factor by the counted ramp volumes].

Allocations, whether done by this method or any others, can result in substantial changes to some of the ramp volumes. The adjustment may result in major changes to the ramp counts. It is important to recognize the effects of the process on the ramps volumes. An equipment error in any of the initial ramp counts may have caused the problem with the ending difference, and the error is then further aggravated by the adjustments. When carrying out a ramp counting adjustment process, large differences should be suspect and thoroughly examined by checking the ramp counts and the ATR figures. In general, the effects will be minimal for mainline volumes, but can be very substantial for the ramp volumes.

In examining the validity of ramp counts, the use of historical data, if available, is of great help. Likewise, knowledge of the equipment, the area, and of any special events that may have affected the counts may help to explain discrepancies and assist the correction and verification process.

Axle Correction for Ramp Counts

As previously shown, ramp counting necessitates accurate volume measurements to reduce the adjustments needed to reconcile the estimates. It is expected that daily volumes at anchor points will directly represent vehicles rather than axles converted to vehicles, therefore, no axle correction will be needed for anchor points. However, in some very rare situations mainline counts may be based on axle detectors requiring conversion to vehicles.

Axle correction for ramp counts is a difficult issue because the ramp counts must represent precise figures which are reconciled to known volumes from ATR's. For this reason, it is recommended that counts using vehicle detectors (loops) be taken at the ramps to eliminate the need for ramp axle correction.

Lacking portable loop counters, the use of automated vehicle classification (AVC) equipment using switch or tube detectors is recommended, if possible, to eliminate the need for axle correction. The use of axle counts should be the last resort, just as the use of manual or visual counts is the last resort for counting. Any ramp axle counts must be converted to vehicle counts prior to reconciling.

Other sections of this guide have discussed the development of statistical axle correction factors for system application. However, the ramp counting process is unique. It is not a sampling process but rather a very precise site-specific analysis. The use of system axle correction factors will introduce additional error into the process.

Any axle correction factors applied to ramps should be based on the most reliable information available and should be appropriate for the traffic mix using the ramp. Comparability should be based on temporal and spatial concerns. Temporal comparability means that the classification counts used to develop the axle correction factors for the specific ramps should be taken the same day-of-week and month as the ramp counts. For example, ramps counted on Wednesdays in May should use axle corrections factors developed based on classification counts taken on Wednesdays in May. At a minimum, counts taken on weekdays should be adjusted based on classification counts taken during weekdays.

Spatial comparability means that axle correction factors applied to ramps should be developed based on classification counts representative of the route connecting the ramp to the Interstate. At a minimum, the axle correction should be based on the functional classification of the connecting route.

Estimation of Mainline AADT

Once the daily volumes for each mainline section between the anchor points and each ramp for each direction of travel have been developed (as shown in Table 3-5-1), then conversion to AADT is carried out.

For the sampling program described in other sections of this Guide, daily and monthly system factors were used to expand the 48-hour counts to AADT. System factors apply to a system sampling process rather than to the detailed, controlled, non-sampling ramp process. The ramp process described in this chapter is completely controlled by the two anchor ATR's. The use of system factors for the estimation of mainlines in a ramp process would result in large differences between the AADT estimates and the anchor ATR's requiring another round of adjusting. For that reason, the use of system factors is not recommended and should be used only in exceptional cases.

It is recommended that directional section-specific AADT expansion factors be based on the two anchor ATR's and applied only to those estimates developed between the anchor points excluding the sections where the permanent ATR counters are located where the ATR AADT would be used. Each directional factor would be computed for each ATR as the ratio of directional ATR AADT to the directional daily volume of the ramp count date. For example, if the ramp counts were taken May 17, then the starting ATR factor is the ratio of AADT to the May 17 daily volume.

The factors would be computed independently for each direction of travel for each ATR. Since there are two ATR anchor points in each direction of travel, the directional factors at the starting and ending ATR's would be averaged resulting in the final daily AADT conversion factor. The sections where the ATR's are located require no adjustment since the ATR's already provide a direct estimate of AADT.

The directional mainline daily volume estimates would be multiplied by the conversion factor resulting in a mainline directional AADT estimate.

Table 3-5-2 describes the process used to develop the mainline AADT estimates and continues the example introduced in Table 3-5-1.

TABLE 3-5-2
Estimation of Mainline AADT

ATR	Volume (May 17)	AADT	AADT Conversion Factor
1	11,995	14,011	1.17
2	13,053	14,574	1.12

		Average	1.15

Section	Daily Volume (5/17)	AADT Factor	AADT Estimate
A	11,995	--	14,011
B	13,052	1.15	15,010
C	12,152	1.15	13,975
D	13,053	--	14,574

The AADT conversion factors are computed as the ratio of AADT to the day of the ramp counts. For example, at ATR #1 the factor is 1.17, the ratio of 14,011 to 11,995. The factor used is the average of the two ATR's. Notice that the AADT estimates at sections where the ATR's are located correspond to the ATR figures and require no adjustment.

The reconciling process is designed to estimate mainlines and may not necessarily provide very accurate estimates of the ramp volumes (notice that no estimates of ramp AADT are presented, although these could be estimated from the section AADT estimates). As described in other sections of this guide, the accuracy of unfactored counts is unknown and the ramp counting process is not inherently designed to provide ramp AADT, although as shown it can be a byproduct.

Adjustment of AADT Estimates to Current Year

AADT estimates based on counts taken during the current year need no current-year adjustment. AADT estimates based on counts taken in previous years need updating to provide current year estimates.

Due to the completely controlled ramp approach, these current year factors are developed based on the anchor ATR's. The factor for each ATR is the ratio of current year AADT to previous year AADT. For example, a one year factor is the ratio of current-year ATR AADT to the previous year's ATR AADT, while a two-year factor is the ratio of current-year ATR AADT to ATR AADT from two years earlier.

The current year factor for all the mainline estimates between two anchor points is the average of the factors at the two anchor points. The sections where the ATR's are located use the ATR AADT values directly and require no adjustment.

The process becomes more complex in cases where continuous ATR's are not the anchor points. In these cases, the factors must be based on other continuous counters in the same functional system. The list of possibilities includes ATR locations in close proximity within the same route, the same urban area, or the system factors for the appropriate functional class. Additionally, single locations or averages could be used. Because of the many different situations, each State will have to examine and develop an appropriate procedure.

Conversion of Mainline Estimates to HPMS Section Estimates

The ramp counting/reconcilement process results in directional AADT estimates between every ramp or between anchor points and ramps. The already defined HPMS standard sample or universe sections may extend over several ramp breaks due to the very detailed definition of lengths between ramps. If the HPMS section exactly coincides with a ramp break in both directions of travel, then no conversion is necessary. Otherwise, the conversion of ramp estimates to produce the HPMS section AADT is accomplished by weighing the ramp AADT estimates by the length of the ramp section.

Each directional ramp break AADT is multiplied by its length. The results are summed until the HPMS section is covered and the sum is divided by the HPMS section length resulting in the HPMS section AADT. This process is equivalent to computing the DVDT of each ramp section and averaging all ramp sections within the HPMS section by using the HPMS section length.

After the AADT is estimated for each direction of travel, both directions are summed to produce the HPMS section AADT.

Table 3-5-3 continues the example under the assumption that the HPMS section begins at the first ATR and ends at the second ATR (from Figure 3-5-1).

TABLE 3-5-3
Estimation of Eastbound HPMS Section AADT

Segment	AADT	Length (km)	AADT × Length (km)
A	14,011	0.7	9,807.7
B	15,010	2.0	30,020.0
C	13,975	3.0	41,925.0
D	14,574	0.3	4,372.2
		--------	-----------
	Sum	6.0	86,124.9

HPMS Section Eastbound AADT = 14,355
HPMS Section Westbound AADT = 13,256 (assumed)
HPMS Section AADT = 27,611 or 28,000 (rounded to thousands).

The table computes the directional weighted average sum of each segment and divides by the total section length. Both directions of travel are then added to estimate total AADT. This simple example is intended as an illustration of the principles of the ramp reconcilement process. As mentioned earlier, collector-distributor interchange, frontage road, or ramp volumes are excluded from the Interstate mainline volume.

HPMS sections on the Interstate or Other Freeway/Expressways must not extend beyond the next interchange (with limited exceptions in low volume States where interchange volumes are under 100). Any discrepancies of this nature found during the analysis should be corrected by redefining the HPMS sections.

System Application of Ramp Counting

At the completion of the ramp reconcilement process, all mainline sections between ramp breaks in the area defined should have very accurate estimates of AADT. Likewise, all HPMS universe (and sample) sections will have been estimated. Estimates will also be available for each entrance and exit ramp, although these ramp estimates may represent only daily estimates. If annualized estimates are desired at each ramp, then the appropriate adjustment factors must be applied to the ramp count.

The ramp counting and reconciling process can be applied as needed by the highway agencies. Agencies may decide to apply the process only to those areas where mainline counting is not possible, only to urban areas, or to the complete Interstate system. Due to the simplicity of counting ramps in rural areas, many States apply the process statewide to insure a consistent methodology is applied and to provide complete coverage of the Interstate system. Other States use ramp counting because of a need for ramp counts and as a check for mainline counts.

The intense geographical detail needed to apply the ramp reconcilement process coupled with the data collection, data manipulation, and data dissemination functions; make it a very likely candidate for using a microcomputer database, spreadsheet, or geographical information system (GIS). Such an application would greatly simplify entering, storing, computing, maintaining, and reviewing the Interstate traffic figures.

Seasonal Group Development Example

The computer printout tables included in this appendix were produced by the SAS (Statistical Analysis System) package on a microcomputer. For a description of SAS procedures refer to the SAS User's Guides (References 3 and 4). The SAS statistical procedures are also available for minicomputers or mainframes. Other statistical packages can also be used to conduct the analysis.

Cluster Analysis Example

Table 3-A-1 describes the continuous ATR data used in the example. The first column presents the observation number (OBS), followed by station number (STNUM), the monthly average daily traffic from January thorough December (Ml to M12), the functional class (FUNC),
the AADT, and the coefficient of variation of the monthly factors as a percentage of the estimate (MCV). In the figure, the monthly traffic peaks are underlined.

Table 3-A-2 presents the monthly factors (computed as the ratio of MADT to AADT) in the same format as Table 3-A-1. The cluster analysis is carried out using the monthly factors, otherwise the volume differences will affect cluster formation. As can be seen by examining the variation coefficients from the two tables, the numbers have changed somewhat (due to the data transformation) but the variation picture has not really changed.

Table 3-A-3 describes statistical information used to evaluate the cluster formation. An understanding of this page is helpful but not necessary to interpret the results of the clustering. A complete explanation of the statistical terminology and procedures is provided in the SAS User's Guide (Reference 4).

Table 3-A-4 presents a dendogram or graph of the cluster formation. An understanding of this graph is necessary to select the clusters. The station location numbers (STNUM) are presented at the top. The semipartial r-squared values gained during cluster formation are shown along the x-axis. The blank columns in the graph indicate the cluster breaks. The first two clusters (separated by the highest blank column) consist of the first 14 and last 6 stations. The third cluster break separated station 14. The fourth separated stations 20 and 15 from the previous group. The process continues the until the semi-partial r-square gains are negligible.

Cluster analysis is used to determine the natural groupings in the data. These groupings are based on the variation in the data. Some of the differences between groups and stations within groups can be very large and others hardly detectable. However, the programs compute the differences in groups or group membership using fixed mathematical algorithms. The cluster programs will

TABLE 3-A-1. Cluster Analysis - Monthly ADT

CLUSTER ANALYSIS

Continuous ATR Data

Monthly ADT

OBS	STNUM	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	FUNC	AADT	MCV
1	6	15333	17594	16111	16131	17668	18311	20981	21460	20809	<u>22114</u>	17929	16867	1	18442	12.6
2	9	32804	34095	36175	41362	47371	49410	<u>50445</u>	50431	42124	41530	44345	38398	1	42374	14.7
3	18	25424	26269	28001	30186	33693	37683	45575	<u>46661</u>	38521	36077	31847	30643	1	34215	20.3
4	20	11372	11627	13529	15827	18847	22660	<u>28528</u>	19564	15411	13354	11978	14471	2	16431	31.4
5	15	16480	19060	20797	24846	28779	37099	<u>48206</u>	45510	37253	28074	20789	20824	2	28976	36.8
6	5	3785	3188	4206	3147	4671	<u>4872</u>	4572	4781	4835	4768	4445	3772	6	4254	14.9
7	2	2820	2902	2953	3359	4054	4566	<u>5990</u>	5910	4398	4033	3450	3059	6	3958	27.8
8	14	1570	1778	1013	1070	2650	2668	<u>2768</u>	2742	2590	2545	2180	1975	7	2129	30.2
9	26	43544	45043	45822	46704	47865	49329	<u>51554</u>	45851	47108	43581	46240	49501	11	46845	5.1
10	22	63980	66140	71135	75364	77367	<u>77706</u>	75087	77275	76569	76368	73924	68590	11	73292	6.4
11	60	34276	33817	37513	40193	43226	45610	46000	<u>46528</u>	46499	42912	40973	39138	11	41390	11.0
12	7	13230	13076	14694	16721	18969	21338	24895	<u>26296</u>	22159	19101	17303	16024	11	18651	23.2
13	8	49576	49554	54095	54992	56945	59423	57404	<u>60159</u>	57560	58489	56035	55045	12	55773	6.1
14	19	37879	37977	40989	41970	41753	45023	43756	45391	44822	<u>46168</u>	43325	41780	12	42569	6.4
15	16	20370	19204	21015	21657	22618	24109	24797	<u>25618</u>	25341	23777	22923	22024	12	22788	8.9
16	1	8067	8259	8846	9165	<u>10183</u>	10155	9466	10026	9851	9745	9413	9374	14	9379	7.4
17	13	7244	7305	7848	8183	8589	8765	8570	8885	<u>9039</u>	8895	7724	8090	14	8261	7.6
18	3	6574	6497	7175	7624	7629	7936	7600	<u>8670</u>	7909	7686	7561	7418	14	7523	7.8
19	4	4494	5390	5531	6061	7021	6157	7739	7728	7653	<u>7995</u>	6619	5528	14	6493	17.6
20	12	5416	5379	6220	6574	6804	<u>7265</u>	6572	6709	7054	6803	6219	6070	16	6424	9.2

TABLE 3-A-2. Cluster Analysis - Monthly Factors

CLUSTER ANALYSIS

Continuous ATR Data

Monthly Factors

OBS	STNUM	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	FUNC	MFAC	CV
1	6	1.20	1.05	1.14	1.14	1.04	1.01	0.88	0.86	0.89	0.83	1.03	1.09	1	1.01	12.2
2	9	1.29	1.24	1.17	1.02	0.89	0.86	0.84	0.84	1.01	1.02	0.96	1.10	1	1.02	15.2
3	18	1.35	1.30	1.22	1.13	1.02	0.91	0.75	0.73	0.89	0.95	1.07	1.12	1	1.04	19.3
4	20	1.44	1.41	1.21	1.04	0.87	0.73	0.58	0.84	1.07	1.23	1.37	1.14	2	1.08	25.9
5	15	1.76	1.52	1.39	1.17	1.01	0.78	0.60	0.64	0.78	1.03	1.39	1.39	2	1.12	33.5
6	5	1.12	1.33	1.01	1.35	0.91	0.87	0.93	0.89	0.88	0.89	0.96	1.13	6	1.02	16.9
7	2	1.40	1.36	1.34	1.18	0.98	0.87	0.66	0.67	0.90	0.98	1.15	1.29	6	1.07	24.6
8	14	1.36	1.20	2.10	1.99	0.80	0.80	0.77	0.78	0.82	0.84	0.98	1.08	7	1.13	41.7
9	26	1.08	1.04	1.02	1.00	0.98	0.95	0.91	1.02	0.99	1.07	1.01	0.95	11	1.00	5.06
10	22	1.15	1.11	1.03	0.97	0.95	0.94	0.98	0.95	0.96	0.96	0.99	1.07	11	1.00	6.84
11	60	1.21	1.22	1.10	1.03	0.96	0.91	0.90	0.89	0.89	0.96	1.01	1.06	11	1.01	11.6
12	7	1.41	1.43	1.27	1.12	0.98	0.87	0.75	0.71	0.84	0.98	1.08	1.16	11	1.05	22.8
13	8	1.13	1.13	1.03	1.01	0.98	0.94	0.97	0.93	0.97	0.95	1.00	1.01	12	1.00	6.44
14	19	1.12	1.12	1.04	1.01	1.02	0.95	0.97	0.94	0.95	0.92	0.98	1.02	12	1.00	6.63
15	16	1.12	1.19	1.08	1.05	1.01	0.95	0.92	0.89	0.90	0.96	0.99	1.03	12	1.01	9.13
16	1	1.16	1.14	1.06	1.02	0.92	0.92	0.99	0.94	0.95	0.96	1.00	1.00	14	1.01	7.86
17	13	1.14	1.13	1.05	1.01	0.96	0.94	0.96	0.93	0.91	0.93	1.07	1.02	14	1.01	7.83
18	3	1.14	1.16	1.05	0.99	0.99	0.95	0.99	0.87	0.95	0.98	1.00	1.01	14	1.01	8.02
19	4	1.44	1.20	1.17	1.07	0.92	1.05	0.84	0.84	0.85	0.81	0.98	1.17	14	1.03	18.8
20	12	1.19	1.19	1.03	0.98	0.94	0.88	0.98	0.96	0.91	0.94	1.03	1.06	16	1.01	9.81

TABLE 3-A-3. Ward's Minimum Variance Cluster Analysis

Ward's Minimum Variance Cluster Analysis

Eigenvalues of the Covariance Matrix

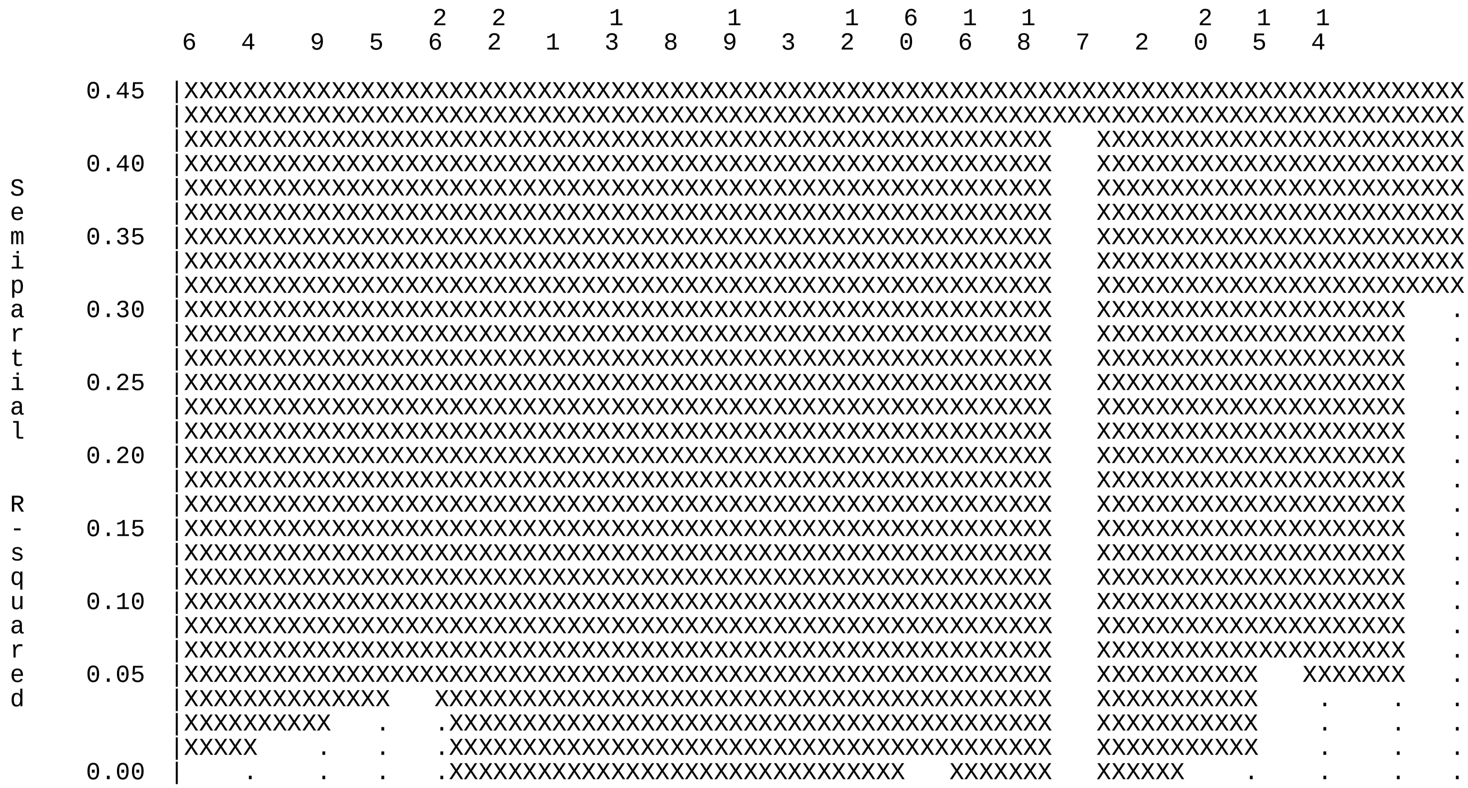
	Eigenvalue	Difference	Proportion	Cumulative
1	0.136135	0.072741	0.586741	0.58674
2	0.063393	0.048811	0.273226	0.85997
3	0.014582	0.007335	0.062848	0.92281
4	0.007247	0.003818	0.031234	0.95405
5	0.003429	0.000509	0.014777	0.96883
6	0.002920	0.000804	0.012585	0.98141
7	0.002116	0.001131	0.009119	0.99053
8	0.000985	0.000503	0.004243	0.99477
9	0.000481	0.000078	0.002074	0.99685
10	0.000403	0.000159	0.001736	0.99858
11	0.000244	0.000160	0.001053	0.99964
12	0.000084		0.000364	1.00000

Root-Mean-Square Total-Sample Standard Deviation = 0.13905
Root-Mean-Square Distance Between Observations = 0.681202

Number of Clusters	Clusters Joined		Frequency of New Cluster	Semipartial R-Squared	R-Squared Tie
19	8	19	2	0.000387	0.999613
18	22	1	2	0.001211	0.998402
17	CL19	3	3	0.001369	0.997033
16	CL18	13	3	0.001578	0.995455
15	60	16	2	0.001741	0.993715
14	CL16	CL17	6	0.001778	0.991936
13	CL14	12	7	0.003005	0.988931
12	18	7	2	0.003399	0.985532
11	CL13	CL15	9	0.006515	0.979017
10	CL12	2	3	0.008241	0.970776
9	26	CL11	10	0.012101	0.958676
8	6	4	2	0.013411	0.945265
7	CL8	9	3	0.018388	0.926877
6	CL7	5	4	0.031209	0.895668
5	20	15	2	0.046489	0.849178
4	CL6	CL9	14	0.049053	0.800125
3	CL10	CL5	5	0.057443	0.742682
2	CL3	14	6	0.307726	0.434956
1	CL4	CL2	20	0.434956	0.000000

TABLE 3-A-4. Cluster Analysis - Dendogram

CLUSTER ANALYSIS
Continuous ATR Data
Ward's Minimum Variance Cluster Analysis
STNUM



always create groups and assign all the stations to groups. Some of the differences between clusters may be very slight. Likewise, stations may be assigned to a group based on minute differences because the program must make an assignment. It is importantto recognize that statistical programs are tools which a trained analyst uses to understand data. Caution and judgment are necessary to interpret the results.

The basic intent of the cluster analysis is to identify variation patterns to allow the analyst to develop a grouping criteria to expand short counts to AADT. Since the cluster analysis program groups only on variation, it provides no definable characteristic or criteria upon which to form groups. The establishment of the groups requires the determination of relevant criteria (functional class, geography, topography, etc) and the use of analytical judgment.

Table 3-A-5 presents the four cluster breaks as extracted from Table 3-A-4.

TABLE 3-A-5
Cluster Analysis Example

Cluster	ATR Number	Functional Class
Cluster 1	6, 9	1
	5	6
	4	14
Cluster 2	22, 26, 60	11
	8, 16, 19	12
	1, 3, 13	14
	12	16
Cluster 3	18	1
	2	6
	7	11
Cluster 4	15, 20	2
Cluster 5	14	7

Examining the location of the stations and groups on a map is very helpful in identifying or distinguishing the characteristics of the patterns. In general, clustering procedures are adequate to identify patterns but are usually insufficient for a complete determination of what groups are appropriate. In this example, the cluster program has identified the patterns and singled out the extreme variation stations, but no criteria for assignment of short counts to the groups has been defined. This is where the descriptive analysis and the tie in to functional class, geography, or topography is needed to provide adequate criteria for group formation.

Descriptive Analysis of ATR Data

The descriptive analysis is carried out by examining the coefficients of variation of the MADT values for each station. These coefficients are presented in Table 3-A-1. In general, urban stations show less variability than rural stations, and recreational stations show the highest variability. The established rule-of-thumb is urban stations with coefficients of variation (MCV in Table 3-A-1) of less than 10%, rural stations with MCV's between 10 and 20%, and recreational stations higher than 25%.

This general pattern is reflected in the data. Only two (stations 4 and 7) of the twelve urban stations do not follow the general rule. These two stations could vary due to borderline urban location, recreational travel, data problems, or other special effects. Previous years data could be examined to determine if the higher variation was present in earlier years. Expert judgment will be needed to determine if the stations should be included in the urban group.

Several of the rural stations (20, 15, and 14) show a high variation pattern which may indicate a recreational pattern. These differences were also identified by the cluster program.

Seasonal Group Formation

The establishment of the groups is made based on the results of both the cluster and descriptive analysis. Once the recreational patterns are identified, either by specific areas or as individual locations, a subjective determination is made regarding the allocation of continuous counters to the recreational groups. The remaining locations are assigned to the appropriate groups solely on the basis of the appropriate criteria defined (functional class, region, etc.). Based on the analysis conducted the continuous ATR locations have been allocated to the seasonal groups as shown in Table 3-A-6.

Analytical judgment was used to determine the factor groups based on functional class. The cluster analysis placed Interstate stations 6 and 9 in one group and 18 in another. Yet, examination of the descriptive pattern and the factors indicates that the differences are not that substantial. Therefore, all the Interstate rural stations have been combined into a single group to facilitate assignment.

With the exception of station 5, all Other Rural stations exhibit very pronounced variability, which usually connotes a recreational pattern. Station 5 needs to be examined to determine the reason for the lower variability. It may be due to proximity to an urban area in which case it should be excluded from the group. In the example, all other rural stations with the exception of 14 were combined into a single group. These stations show great similarities with the exception of station 5.

TABLE 3-A-6
ATR Seasonal Groups

GROUP	STATION NUMBER	FUNCTIONAL CLASS
INTERSTATE RURAL	6, 9, 18	1
OTHER RURAL	2, 5, 14, 20	2, 6, 7
INTERSTATE URBAN	7, 22, 26, 60	11
OTHER URBAN	8, 16, 19	12
	1, 3, 4, 13	14
	12	16
RECREATIONAL	15	2

The Interstate Urban group includes all the stations. Station 7 shows a rural character and the reason needs to be explored to determine whether it really belongs in this group. Exceptions of this nature are usually due to errors in functional class code or borderline location. In this example, it was included in the group. In a real case, the reason for the difference must be established prior to assignment to the group or exclusion from the group.

In the Other Urban group only station 4 appears questionable since it shows a rural pattern. An explanation for this variation must be established or the station excluded from the group.
Station 15 has been placed in the Recreational group since it shows the most extreme variation. Stations 14 and 20 could also fit as recreational depending on their location. However, they seem to fit better in the Other Urban group. The Recreational group should include all cases where a distinct recreational or extreme pattern does not fit the established patterns.

Table 3-A-7 presents the precision analysis for the Interstate Rural Group. The precision of the monthly factor is determined by the use of equation 3 in Chapter 2 of this section. Values of the T distribution are shown on the last figure of this Appendix. For the January factor the 95% two-sided precision is given by 4.303 (the T value) times 5.64 (CV) divided by the square root of 3 which equals 14.

As the last column in the figure shows, the precision varies for each monthly estimate. The design precision criteria could be tied to individual monthly factor estimates or to the annual average of the twelve monthly factors. The recommendation is to use the average of the twelve monthly values. Under these criteria, the average precision achieved by the use of the existing 3 locations is approximately 95-15. To estimate the number of locations needed to reduce the precision to the desired 95-10, an iterative process using equation 3 is used. The process involves using the average coefficient of variation and substituting values of T and n in the equation.

TABLE 3-A-7
Precision Analysis
Interstate Rural Group

MONTH	N	MEAN FACTOR	CV (%)	PRECISION (%)
JAN	3	1.28	5.64	95 ± 14
FEB	3	1.20	11.1	95 ± 28
MAR	3	1.18	3.33	95 ± 8
APR	3	1.10	5.99	95 ± 15
MAY	3	.99	8.05	95 ± 20
JUN	3	.92	8.23	95 ± 20
JUL	3	.82	7.99	95 ± 20
AUG	3	.81	8.38	95 ± 20
SEP	3	.93	7.40	95 ± 18
OCT	3	.94	10.06	95 ± 25
NOV	3	1.02	5.88	95 ± 15
DEC	3	1.11	1.05	95 ± 3
AVERAGE	-	1.03	6.09	95 ± 15

Table 3-A-8 presents the sample size analysis for the Interstate Rural Group. Under the assumptions made, 5 locations would be sufficient to achieve the target 95 -10 criteria in this example. This same procedure is applied to all the defined groups with the exception of recreational groups where the use of system factors is not recommended.

TABLE 3-A-8
Sample Size Analysis
Interstate Rural Group

NUMBER of ATR'S	T value	CV	ESTIMATED PRECISION
3	4.303	6.09	95 ± 15
4	3.182	6.09	95 ± 10
5	2.776	6.09	95 ± 8
6	2.571	6.09	95 ± 6
7	2.447	6.09	95 ± 6
8	2.365	6.09	95 ± 5

Table of Student's T Distribution

Table 3-A-9 presents a two-sided (also referred to two-tailed in statistical texts) table of the T distribution. In the table, n represents the degrees of freedom (which is equivalent to the sample size minus one). For example, the two-sided T value with 95 percent confidence and a sample size of 4 (3 degrees of freedom) is 3.182 ($T_{.95,3} = 3.182$).

TABLE 3-A-9
Two-Sided Student's T Distribution

Confidence Level

n	.50	.80	.90	.95	.975	.99	.995
1	1.000	3.078	6.314	12.706	31.821	63.657	636.619
2	.816	1.886	2.920	4.303	6.965	9.925	31.598
3	.765	1.638	2.353	3.182	4.541	5.841	12.941
4	.741	1.533	2.132	2.776	3.747	4.604	8.610
5	.727	1.476	2.015	2.571	3.365	4.032	6.859
6	.718	1.440	1.943	2.447	3.143	3.707	5.959
7	.711	1.415	1.895	2.365	2.998	3.499	5.405
8	.706	1.397	1.860	2.306	2.896	3.355	5.041
9	.703	1.383	1.833	2.262	2.821	3.250	4.781
10	.700	1.372	1.812	2.228	2.764	3.169	4.587
11	.697	1.363	1.796	2.201	2.718	3.106	4.437
12	.695	1.356	1.782	2.179	2.681	3.055	4.318
13	.694	1,350	1.771	2.160	2.650	3.012	4.221
14	.692	1.345	1.761	2.145	2.624	2.977	4.140
15	.691	1.341	1.753	2.131	2.602	2.947	4.073
16	.690	1.337	1.746	2.120	2.583	2.921	4.015
17	.689	1.333	1.740	2.110	2.567	2.898	3.965
18	.688	1.330	1.734	2.101	2.552	2.878	3.922
19	.688	1.328	1.729	2.093	2.539	2.861	3.883
20	.687	1.325	1.725	2.086	2.528	2.845	3.850
21	.686	1.323	1.721	2.080	2.518	2.831	3.819
22	.686	1.321	1.717	2.074	2.508	2.819	3.792
23	.685	1.319	1.714	2.069	2.500	2.807	3.767
24	.685	1.318	1.711	2.064	2.492	2.797	3.745
25	.684	1.316	1.708	2.060	2.485	2.787	3.725
26	.684	1.315	1.706	2.056	2.479	2.779	3.707
27	.684	1.314	1.703	2.052	2.473	2.771	3.690
28	.683	1.313	1.701	2.048	2.467	2.763	3.674
29	.683	1.311	1.699	2.045	2.462	2.756	3.659
30	.683	1.310	1.697	2.042	2.457	2.750	3.646
40	.681	1.303	1.684	2.021	2.423	2.704	3.551
60	.679	1.296	1.671	2.000	2.390	2.660	3.460
120	.677	1.289	1.668	1.960	2.358	2.617	3.373
>120	.674	1.282	1.645	1.960	2.326	2.576	3.291

n = degrees of freedom

SECTION 4

VEHICLE CLASSIFICATION MONITORING

SECTION 4

VEHICLE CLASSIFICATION MONITORING

Table of Contents

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INTRODUCTION

Vehicle classification is the observation of highway vehicles and the subsequent sorting of the resulting data into a fixed set of categories.

As with any classification scheme, the one for highway vehicles attempts to provide structure to the reporting of the multitude of vehicles observed while providing a scheme of logical relationships between categories.

Vehicle classification data are of considerable use to agencies involved in almost any aspect of transportation planning and engineering. Some examples include the following:

- pavement design and pavement management;
- scheduling resurfacing, reconditioning, and reconstructing of highways based on projected pavement life remaining;
- predicting commodity flows and freight movements;
- providing design input relative to current and predicted capacity of highways;
- developing weight enforcement strategies;
- accident record analysis;
- environmental impact analysis, including air quality studies; and
- analysis of alternative highway regulatory and investment policies.

In short, vehicle classification data are extremely important as transportation agencies and State legislatures grapple with the need to determine and allocate the costs associated with maintaining the highway system and in selecting the improvements that will be programmed.

The presentation of vehicle classification data collection in this section is intended to address system concerns. Vehicle classification volumes are subject to wide variability due to seasonal patterns, day-of-week, etc. Trucks and other commercial vehicles serve different purposes and may have travel patterns which differ from those of automobiles. The collection of short monitoring periods using the sample design specified in this section allows the development of unbiased system estimates of truck percentages, which when multiplied by total VDT result in classified VDT estimates.

However, a short monitoring period at a site represents only the classified volumes during the specific period of monitoring at the specific site (assuming no equipment error). In order to provide annual average estimates of percentages of vehicles, it becomes necessary to develop and apply factors, as was done in Section 3 to estimate AADT.

Many difficulties are apparent. The first is that to develop these temporal and spatial factors, it is necessary to have an established and geographically distributed base of continuous classifiers. Many States have continuous volume counters and some of these are capable of classifying by length, but the collection and processing of these data have not been a high priority. These continuous classification counters, if available, provide the starting point for the exploration of classification variability. In addition, as a result of the SHRP program, many States have instrumented permanent classifiers capable of classifying in the 13 standard categories. Therefore, data bases needed to pursue classification factors may be available.

Second, research is necessary to develop an appropriate process for the development of factors. In terms of AADT, the process is based on day-of-week, monthly variation, and established seasonal group patterns. This is the recommended approach for vehicle classification at this time. However, due to the different purposes of truck travel, alternative processes have to be explored. In addition, the development of appropriate spatial patterns for classification categories will be difficult. Research is underway at this time and it remains to be seen if alternative processes are more effective.

Third, it is unclear whether factors are needed for each classification category or whether a global approach applies to all truck traffic. For example, due to different travel purposes and uses in industry, single-unit trailer-combination trucks may have different travel patterns than twin-trailer combination trucks. The temporal and spatial variability of different classes of vehicles will have to be analyzed before an answer can be provided.

Fourth, the capability of equipment will need detailed analysis. Volume counters are, in general, highly accurate. To achieve acceptable accuracies for classified data collection, agencies should assess the appropriateness of the algorithm used in the classification process. The algorithm should be specific to the traffic composition in each State. Some States have opted to retain individual vehicle information (number of axles and distance between axles) rather than only recording the FHWA vehicle type. Individual vehicle records are then sorted into the appropriate FHWA classes while retaining the ability to do more detailed analysis of the data, if needed. Whether using vehicle specific or aggregated data, the magnitude of classification error must be quantified for incorporation into the classification adjustment process.

Fifth, the great difficulties in obtaining accurate vehicle classification counts in high-volume roads may create a data gap in urban areas. Hopefully, future technological developments will help to narrow this gap.

PROCEDURES FOR THE VEHICLE CLASSIFICATION SAMPLE

The purpose of this chapter is to provide guidelines on practical procedures the States may use to develop the vehicle classification sample. Similar procedures are also applicable to the truck weight sample and can be used for that purpose.

The FHWA recognizes that States have a considerable investment in equipment, expertise, and historical data trends at fixed locations in each State. Historic data from these locations may include volume, speed, classification, and weight; States generally return to the same sites annually for the latter three items. Many of these sites have instrumented equipment in place. From a cost and an efficiency viewpoint, it would be wise wherever possible to incorporate these existing sites into an expanded sample of sites based upon the HPMS structure. The financial investment in these sites is substantial and this incorporation would allow continuation of long-term trend series at these locations. This chapter provides guidelines on incorporating existing sites into the broader design, thus achieving the joint objectives of maintaining continuity while limiting additional capital cost investments, as well as achieving the representativeness necessary for estimation of State-level totals.

States have already identified the HPMS sections to represent the highway network. In addition to the HPMS standard sample, States also have in place a varying number of automatic traffic recorders (ATR's), speed, weight, and classification sites at which they had been obtaining data historically. These sites may or may not conform to the HPMS standard samples; generally, some sites will conform exactly, others will be quite close to existing HPMS sites, and the rest will not match. The objective is to describe the procedures needed to augment the existing sites by an additional number of sites, such that, when taken together, the group is representative of the HPMS sites and of the State system as a whole. Because of the importance of instrumented sites, attempts to incorporate as many of these sites as possible into the sample plan should be made.

The methodology is as follows:

Stage 1. Identify the distribution and number of desired sites by HPMS functional class and volume group.

Stage 2. Determine the distribution of existing sites by HPMS functional class and volume group.

Stage 3. Determine the distribution of additional needed sites by HPMS functional class and volume group.

Stage 4. Identify the specific locations of the additional needed sites.

Stage 5. Check the combined distribution of existing and additional sites overall distribution of HPMS samples to insure an adequate distribution of samples.

STAGE 1: Identify the Desired Distribution of Sites

As described in Section 2 (Sample Design), this Guide recommends that the HPMS standard samples be used as the sampling frame from which the smaller groups of volume, classification, and weight sites should be drawn.

The distribution of sites should conform to the distribution of HPMS annual VDT (an alternative is to use truck VDT if reliable figures are available) by area type and functional class. The steps necessary to achieve this are as follows:

Step 1A: Summarize HPMS Statistics by Area, Functional Class, and Volume Group

The first step is to prepare basic summaries of expanded traffic, system extent, the number of HPMS standard samples, and existing fixed sites by area, functional class, and volume group. Table 4-2-1 shows such a summary based on the HPMS submittal for a State.

Step 1B: Estimate the Total Sample Size Required

Procedures for estimating the total sample size are given in Chapter 4 of Section 2.

Based on the analysis shown, a sample size of 300 classification sites, to be sampled for 48 hours over a 3-year period, would be sufficient to achieve a 95-10 reliability for key parameters such as the proportion of 3S2's in the statewide population. Smaller sample sizes will, of course, have greater error. For purposes of the following example, we will assume a sample size of 300 spread over a 3-year period, or 100 annually.

Step 1C: Determine the Desired Distribution of the Sample by Area, Functional Class, and Volume Group

This step is a straightforward allocation of the total sample size to each of the cells of the HPMS area/functional class/volume group matrix. If additional samples are ultimately to be drawn within a volume group in simple random sample fashion, then this allocation must be made to each of the volume groups within each of the cells shown in Table 4-2-1.

Table 4-2-1 presents an example of the simple random sample procedure to the full stratification of the HPMS. In the table, it is assumed that the Interstate Rural System carries 6 percent of the VDT according to the HPMS. Therefore, 6 percent of the proposed 300 sample sections corresponds to 18 samples or six per year. The sections are then distributed to the volume groups based on the

TABLE 4-2-1. Example of Distribution of HPMS samples.

RURAL FUNCTIONAL CLASS

HPMS Volume Group	Data Type	Interstate	Other Principal Arterial	Major Arterials	Major Collectors	Minor Collectors
1	A	48	173	93	82	135
	B	2,186	3,010	3,464	5,929	2,866
	C	338	1,076	2,350	4,924	6,884
	D	0	0	2	0	0
2	A	26	35	36	21	37
	B	6,423	3,470	4,749	3,793	4,507
	C	444	435	1,484	1,175	3,100
	D	4	2	5	2	0
3	A	4	7	19	11	4
	B	1,807	1,424	4,873	1,944	1,408
	C	70	128	719	282	611
	D	0	3	4	4	0
4	A	6	5	10	--	8
	B	722	827	1,564	--	1,404
	C	20	52	127	--	378
	D	2	1	3	--	0
5	A	1	14	1	--	1
	B	40	557	77	--	225
	C	1	23	3	--	31
	D	0	1	0	--	0
6	A	--	1	--	--	--
	B	--	94	--	--	--
	C	--	3	--	--	--
	D	--	0	--	--	--

LEGEND
A - Number of HPMS Sections
B - DVDT (Expanded) in Thousands
C - Roadway Extent (Expanded)
D - Fixed Existing Sites

percentage of VDT. To insure a positive chance of selection for every section in the HPMS standard sample, one section has been moved from group 2 to group 5. This type of minor adjustment will occur often. An alternative may be to combine groups 4 and 5.

Several advantages of the simple random procedures are:

1. It allocates equal probability of selection to sample sections within each strata. Combined with the distribution of strata proportional to VDT, this results in a self-weighing sample, i.e., an average can be derived directly by summing the sample characteristics and dividing by the sample size.

2. It provides a well-balanced sample insuring a full distribution on the basis of volume.

3. It insures that higher volume sections are included in the classification sample in proportion to their representation in the universe.

One disadvantage is that minor adjustments will be needed because of the large number of strata in the HPMS standard sample.

The allocation of the sample proportional to VDT or DVDT was made to distribute the sample in proportion to travel, not system extent. An additional advantage is that systems (strata) with a limited proportion of travel do not receive an inordinate number of samples. This type of application, while quite appropriate for statewide estimation, may not account fully for the perceived importance of portions of the statewide highway system. For instance, in the example presented, the Interstate Rural System carried 6 percent of HPMS VDT (which excludes local functional class VDT), resulting in an annual classification sample of 6 sections. Although the statewide sampling on all functional classifications will approximate the target reliability, the 6 samples attributable to the Rural Interstate strata are insufficient to provide very reliable estimates of classified VDT on the Rural Interstate System. Therefore, in order to provide adequate system coverage and obtain more reliable estimates; the States may desire to specify individual target reliability levels on the Interstate strata. Two alternatives are provided to address this situation: (1) increase the sample sizes in the affected strata (Interstate) to establish individual target reliabilities (resulting in an increase in the overall sample); or (2) arbitrarily assign a percentage of the sample to the Interstate. This second alternative is used in the truck weight sample (Section 5). For example, assigning one-third of the classification sample to the Interstate would result in an annual sample of 33 sections in the Interstate and these would be distributed to urban and rural areas based on VDT. Note that the latter method decreases the sample and precision on the other functional systems.

Because of the importance of the Interstate system, either of these alternatives are recommend ed for

States with extensive Interstate system extent, regardless of system travel.

STAGE 2: Determine the Distribution of Existing Sites

The purpose of this exercise is to maximize the opportunities for using existing sites as part of the recommended distribution. The reason for this focus is FHWA's recognition that the States have invested considerable funds and effort and have obtained considerable historic knowledge from these existing locations; therefore, to the extent possible, this investment should not be lost. The methodology described below allows for maximum integration of the existing sites into the revised sampling plan. Examples of the application are continued on Table 4 -2-2.

The procedures to allow the use of existing sites in the sampling approach may change the structure of the program. The use of fixed sites may allow the collection of classification data on a continuous basis. The structure of the proposed program is then changed from a sample of short (48-hour) classification counts to a combination of continuous (ATR) and short classification counts. This gain can result in much better estimates of seasonality of classification data and allow the future development of seasonal factors in a manner similar to that used in the volume counting program.

Step 2A: Locate the Existing Sites

The next step is to describe each of the existing sites by area, functional class, and HPMS volume group. These are the locations which have installed equipment (ATR's) or locations at which speed, classification, or weight data have been collected in the past. The distribution of these sites by area, functional class, and volume group should be developed. Table 4 -2-2, column 7, shows an example of such a distribution of six fixed sites. These six fixed sites were chosen for this example because they each contain physical equipment which can be modified for classification purposes and form the basic fixed investment which is possibly usable. In each State, of course, the analyst may wish to include ATR sites, weight, classification, speed, or other instrumented sites.

Step 2B: Assess Usefulness of each Site for Inclusion in the Sampling Distribution

In this step, the analyst determines the degree to which each site identified can possibly be used as a portion of the desired sampling distribution. The basic criteria on which the assessment should be made is whether or not the site matches exactly, is close to, or does not match an existing HPMS standard sample. This determination requires knowledge of the location of the HPMS standard sample sections and of the fixed sites. In Table 4-2-2, our example shows that the existing sites in column 7 are subdivided into those that "match HPMS sections" (column 4), are "close to HPMS section" (column 5), or "do not match" (column 6).

TABLE 4-2-2
Stratification Example

Example of Full Stratification Simple Random Sample Procedure for the Interstate Rural System Described in Table 4 -2-1

Volume Group	Stage 1 Desired Distribution			Stage 2 Existing Sites				Stage 3 Remaining Sites			Stage 4 Sampling Frame	
	1 DVDT (000)	2 Percent	3 Desired Sample Sections	4 HPMS Match	5 Close Match	6 No Match	7 Total	8 Usable Existing Sites	9 Additional Sites Needed	10 Existing Samples	11 Sample Sites	12 Samples Available
1	2,186	20	4	0	0	0	0	0	4	48	0	48
2	6,423	57	(10) 9*	2	1	1	4	3	6	26	3	23
3	1,807	16	3	0	0	0	0	0	3	4	0	4
4	722	6	1	0	1	1	2	1	0	6	1	5
5	40	1	(0) 1*	0	0	0	0	0	1	1	0	1
Total	11,178	100	18	2	2	2	6	4	14	85	4	81

* One section from Group 2 has been added to Group 5.

Obviously, some judgment is necessary to determine whether a site is "close to" or "does not match" an HPMS section. Generally, if the existing site is so close to the section that either the total volume or the classification of traffic by type and weight is judged to not be substantially different between the site and the HPMS section close to it, then the site can be considered, for practical purposes, to be at the HPMS section. Only in the case where no match occurs would a site be considered for relocation. However, there may be many other reasons for retaining such sites for other purposes or as part of the Special Needs element.

The procedures recommended in Section 3 (Volume) of this Guide which are used to streamline the seasonal factor program and the number of ATR's needed by seasonal group should also be addressed when considering the use of existing fixed sites.

The HPMS standard samples constitute, overall, about 5 percent of highway extent, but this proportion can vary substantially for higher volume facilities where the proportion may be as high as 100 percent. Thus, on arterial facilities, many sites will in fact coincide with HPMS standard samples, while on (major) collector facilities the match will be much smaller and most sites will not correspond to HPMS standard sample sections. One may, therefore, expect that additional investments may be necessary on the lower level facilities.

STAGE 3: Determine the Distribution of Additional Needed Sites

The purpose of this stage is to determine whether additional sites are necessary to bring the existing distribution of sites in line with the desired distribution. To achieve this the following steps are used. (The example is continued on Table 4-2-2).

Step 3A: Determine the Distribution of Existing Usable Sites

The existing usable sites are defined as those which presently exactly match the HPMS sections and those which have been determined to be sufficiently close to HPMS sections to be considered to match.

In the example in Table 4-2-2, column 8 is the sum of the sites in columns 4 and 5. The example shows that four of the six existing sites were deemed to be usable as a portion of the desired distribution.

Step 3B: Determine the Distribution of Additional Needed Sites

This distribution is obtained by subtraction of the existing usable sites from the desired distribution. This is shown in column 9. The proposed program recommends only portable, short classification counts (48 hours). Therefore, after the selection of the additional sites, a determination would have to be made regarding how many of the sites could be monitored with portable equipment versus installation of fixed equipment.

Application of the recommended procedure may, of course, leave a number of existing sites for which no match with the HPMS standard sample is achievable. A number of alternatives are possible to handle these remaining sites:

1. The sites may already be justified by another purpose, i.e., speed monitoring or truck weight enforcement site, SHRP site, in which case the locations would be retained.

2. The State may wish to maintain the location to continue historical trends at these locations and to augment the information obtained from the HPMS-based program.

3. The State may wish to eliminate these sites if no reason exists to maintain them.

4. The State may wish to relocate these locations over a period of time to conform with the desired distribution and improve the sampling and estimation processes.

5. The oversampling implied by these sites can be incorporated into the desired distribution by the use of weighting factors although the surplus sites will always lack a direct tie-in to the HPMS.

The decision of which, if any, of these "no match" sites to retain must be made on a case-by-case basis. Careful comparison of the characteristics of these sites with respect to such factors as need for data, ease of administration, stability of trends in the data, accuracy of equipment, local concerns for a continuous effort, degree to which the site can be integrated into future plans, and prospects for upcoming construction which may destroy the location, etc., should all be considered for each location.

STAGE 4: Identify Specific Locations for Additional Needed Sites

This stage consists of the actual sampling effort necessary to identify the HPMS sections which will be added to the existing locations to form the desired sampling distribution. The steps necessary are as follows:

Step 4A: Establish the Sampling Frame

The sampling frame consists of the HPMS standard samples minus any samples already used as existing fixed sites. An example is presented in Table 4-2-2, where column 10 contains the number of samples in the HPMS standard sample, column 11 contains the number of existing sites which are matched to HPMS sites, and column 12 contains the remaining samples available for further sampling.

Step 4B: Draw the Vehicle Classification Subsample

In this step, the sites needed for addition to the sample are selected from the available HPMS standard samples. The method used is simple random sampling from each HPMS strata.

Table 4-2-3 presents an example using data from tables 4-2-1 and 4-2-2. The table presents the percentage VDT, the HPMS standard samples remaining after accounting for the fixed sites, the additional samples needed, and the final sample including the fixed sites. The selection is made by assigning a unique sequential number to each section within a single stratum and randomly (by a table of random numbers or computer-generated random numbers) selecting the desired sample.

For example, in volume group 1 of Table 4-2-3, assign to each of the 48 available HPMS standard samples a unique number ranging from 1 to 48. Randomly select four unique numbers from 1 to 48 from a table of random numbers (disregard any duplicate numbers during the selection process). These would become the sample.

TABLE 4-2-3. Simple Random Selection for Rural Interstate

		1	2	3	4
Functional Class	Volume Group	Percent VDT	HPMS Samples Available	Additional Samples Needed	Final Sample
Interstate Rural	1	20	48	4	4
	2	57	23	6	9
	3	16	4	3	3
	4	6	5	0	1
	5	1	1	1	1
	Total	100%	81	14	18

Step 4C: Evaluate the Feasibility of New Sites

Once the particular locations of new sites have been identified, they must be carefully assessed with respect to other features which include:

1. Location characteristics - site geometry, physical safety for crews and equipment installation constraints, suitability of equipment types, etc.

2. Administrative concerns - difficulty in outfitting site, type of equipment to be used, availability of land, etc.

3. System concerns - proximity to other sites (geographically, functionally or otherwise), overall coverage patterns, etc.

It is possible that some of the new randomly selected sites will not meet the test of practicality. These selections should be discarded and additional sites randomly selected by the previously described procedures. However, these modifications should be undertaken with great care, since sites which may be satisfactory on all the practical factors may be unique in other respects and reduce the representativeness of the resulting distribution. In general, new sites selected initially for inclusion should not be discarded unless sufficient reasons exist for doing so. It is of the utmost importance to maintain the statistical validity and representativeness of the sample.

STAGE 5: Check to Insure Representativeness

Once the final samples have been identified, the final step is to review the total distribution to insure that the sample as a whole is, indeed, representative of the HPMS standard sample and HPMS universe. The check should proceed by comparing the percentage distribution of the final sample against the percent distribution of the HPMS standard sample and/or universe over several dimensions. These may include:

1. The DVDT or VDT by area, functional class, or volume group. Because of its design, the sample should match these characteristics.

2. Federal-Aid class.

3. Area type (urban, suburban, rural).

4. Pavement type.

5. Region of the State.

The distribution will not match exactly and due to the small sample and design constraints, minor differences can be ignored. In case major differences are detected, special procedures that modify the selection procedures can be considered. Additionally, as data is collected and begins to flow in, the data itself should be checked for reasonableness and representativeness against other data that may be available.

DATA COLLECTION EQUIPMENT AND DATA REPORTING

To obtain classification data many States use visual observation and recording techniques, while some States use automated vehicle classification devices as a method of overcoming the high cost of visual procedures and as a means to gather more comprehensive vehicle classification data. In order to support the number and duration of classification sessions called for in this Guide, automation should be given serious consideration.

Automatic vehicle classification is a rapidly improving technology. An FHWA-sponsored evaluation of various automated vehicle classification systems was published in 1985. The evaluation found equipment to be 90 to 95 percent accurate. This compares well with visually obtained information which has been found to have a ten percent error on total vehicle flows with errors above 30 percent for certain specific vehicle types.

In general, each automated vehicle classification system has a common set of components:

1. the sensing device (sensor) which provides the system with the raw data of presence or passage of the vehicle to be classified;

2. the detector which receives the signals from the sensors, and amplifies and/or interprets them and passes them on to a recorder;

3. the recorder which performs the basic calculation of vehicle length, number of axles, or whatever data is being produced; and

4. the information processor which manipulates the basic data into the presentation format.

Typically, the last three components are not separable or interchangeable among systems from different manufacturers.

The typical installation of an automated vehicle classification system consists of sensing devices on the road connected to a roadside unit which contains the detector(s) and recording device. In some instances the roadside unit is self-contained (i.e., all data are recorded and/or displayed there), while in others it is only a temporary repository for the raw data which is transferred to another unit for ultimate processing, hard copies, etc.

While the sensing devices used for data acquisition vary from manufacturer to manufacturer, current equipment generally records both axle count and vehicle speed. The method of calculating vehicle speed uses a pair of presence or axle detectors. If loop detectors are used, the speed calculation involves dividing the distances from the leading edge of the first loop to the leading edge of the second loop by the time it takes the vehicle to travel the known distance. A similar calculation is made if pneumatic tubes are used instead of loops. Since the tubes are narrow, they can also be used to simultaneously count the number of axles passing over them.

Loop systems alone are not able to distinguish individual axles and must be augmented by an axle sensing device. Such devices may be simple tubes or more elaborate devices such as capacitance pads whose resonant circuit frequency changes under pressure or magnetic sensors enclosed in a steel frame and permanently installed in the roadway.

Automatic vehicle classifiers need an algorithm to interpret the axle spacings as a vehicle of a particular class. The algorithm used is often based on the "Scheme F" developed in Maine. FHWA does not endorse "Scheme F" or any other classification algorithm. No single algorithm is the best for all geographic regions and time spans. The algorithm used by a unit of equipment should be checked and, if possible, modified to conform to the traffic at the site. Many units of equipment place unclassified vehicles in an "other" category. This "other" category is not reported in the FHWA 13 classification scheme. It is important that vehicles placed in the "other" category be examined and placed into one of the 13 classes. States should identify and document the classification scheme being used to collect the data and the procedures used to classify "unclassified" vehicles assigned to the "other" category into the standard 13 class reporting format.

Reporting

In the past, site specific vehicle classification information was reported to the FHWA only for those vehicle classification operations carried on in conjunction with truck weight surveys. At present, the FHWA is requesting States to submit all site-specific vehicle classification data as a part of the HPMS annual data submittal including both the station description and the vehicle data records. Section 6 (Truck Weight) discusses coding and editing of vehicle classification data for submission to FHWA and contains the vehicle classification reporting formats.

The HPMS areawide vehicle classification form reports VDT data for the functional highway classes differentiated by various vehicle types. Application of the sampling scheme recommended in this manual provides data compatible with the HPMS form reporting format.

Finally, FHWA Headquarters (HPM-30) is interested in receiving a copy of all vehicle classification reports developed by the States whether or not they are based on the procedures recommended in this Guide.

FHWA VEHICLE TYPES

The vehicle types of interest to FHWA are described below. The classification scheme is separated into categories depending on whether the vehicle carries passengers or commodities. Non-passenger vehicles are further subdivided by number of axles and number of units including both power and trailer units. Note that the addition of a light trailer to a vehicle doesn't change the classification of the vehicle.

FHWA Vehicle Classes with Definitions

Type Name and Description

1. Motorcycles (Optional) -- All two-or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.

2. Passenger Cars -- All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

3. Other Two-Axle, Four-Tire Single Unit Vehicles -- All two-axle, four tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification. Because automatic vehicle classifiers have difficulty distinguishing class 3 from class 2, these two classes may be combined into class 2.

4. Buses -- All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and be appropriately classified.

   NOTE: In reporting information on trucks the following criteria should be used:

   a. Truck tractor units traveling without a trailer will be considered single unit trucks.

b. A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered as one single unit truck and will be defined only by the axles on the pulling unit.

c. Vehicles shall be defined by the number of axles in contact with the roadway. Therefore, "floating" axles are counted only when in the down position.

d. The term "trailer" includes both semi- and full trailers.

5. Two-Axle, Six-Tire, Single Unit Trucks -- All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.

6. Three-Axle Single Unit Trucks -- All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.

7. Four or More Axle Single Unit Trucks -- All trucks on a single frame with four or more axles.

8. Four or Less Axle Single Trailer Trucks -- All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.

9. Five-Axle Single Trailer Trucks -- All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

10. Six or More Axle Single Trailer Trucks -- All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

11. Five or Less Axle Multi-Trailer Trucks -- All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.

12. Six-Axle Multi-Trailer Trucks -- All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

13. Seven or More Axle Multi-Trailer Trucks -- All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

SECTION 5

TRUCK
WEIGHT
MONITORING

SECTION 5

TRUCK WEIGHT MONITORING

Table of Contents

INTRODUCTION

Purpose of Truck Weight Data Collection

Information about the distribution and weight of the various vehicle types in the traffic stream is essential to the administration of the highway program at both the State and national levels.

Decisions concerning such matters as pavement design, pavement maintenance, equitable tax structures, revenue projections, safety, enforcement, and research require knowledge of the volumes of traffic using highway facilities, the proportion of vehicles of each type, and the weights of such vehicles. For adequate assessment of pavement life, pavement quality, and the investment levels needed to improve or maintain the systems, it is fundamental to know the range and frequencies of the loads imposed upon the facilities.

Vehicle classification counts and truck weight data form the bases for estimating frequencies of each type of truck and year-to-year changes in axle and gross weights and for comparison of the characteristics of actual usage with administrative policies. The results are used at the State and national levels in the consideration of transportation policy, the allocation of highway costs and revenue, truck size and weight regulation, the establishment of geometric design criteria related to the size and weight of vehicles, pavement design criteria and selection, and a variety of special administrative, planning, design and research studies. At the State level, truck weight data are used in calculating pavement loadings in single axle equivalents or other comparable procedures, and in bridge loading analyses. Planning, program budgeting, and evaluations, and other administrative studies require statistically reliable axle, vehicle, and total loadings which can be related to operational characteristics, taxation rates, cost responsibility, and enforcement effectiveness.

Objectives of the Truck Weight Section

This section describes procedures that may be used to establish a statistical sample design for the collection of weight data. It has been developed to accomplish the following four objectives:

1. To provide guidance in the selection of truck weigh sites based on a statistically-based sampling scheme to insure statistical representation.

2. To provide information on techniques for gathering truck weight data.

3. To document the instructions for coding, editing and submitting the truck weight and associated vehicle classification information to the FHWA Office of Highway Information Management (OHIM).

4. To give examples of the types of useful analysis and summaries that can be produced from the truck weight and vehicle classification information.

The objectives are covered in subsequent chapters of this section as follows:

Chapter 2 presents the recommended statistical sampling method for monitoring truck weights based on locating weigh sites on HPMS standard sample sections.

Chapter 3 gives some general guidelines for setting up and operating a truck weighing site and describes various types of equipment available for weighing trucks.

Chapter 4 describes and gives examples of each of the FHWA W-Tables that are used to summarize the truck weight and related vehicle classification data by the FHWA and the States.

Appendix A contains a glossary of terms.

Appendix B gives the bridge weight formula.

PROCEDURES FOR THE TRUCK WEIGHT SAMPLE

Introduction

The development of an integrated sample framework based on the HPMS for monitoring truck weights to estimate pavement loads is the last link in the chain of the HPMS element of the recommended traffic monitoring program. The basic framework of the HPMS element is the HPMS standard sample followed by the volume sample, the vehicle classification sample, and the truck weight sample. This chapter describes the procedures to be used in selecting the truck weight monitoring sample, and discusses the implications of such an approach.

Statistical validity is a very desirable and well-understood quality, however, there is a price to be paid in achieving it. One of the results of the work undertaken to develop this Guide has been a much clearer understanding of the need for reliable truck weight information on which to base policy decisions. Since the loads which the highway systems support are a major factor in the determination of pavement life, then it is important to develop reliable estimates of these loads. It is our belief that the application of the guidelines will translate into better, more informed decisions; more effective and efficient construction and maintenance programs; and, in the end, better highway service.

The truck weight sampling procedures developed in this Guide are intended to provide system estimates. As was discussed in the introduction to the vehicle classification section, short data collection periods (in this case truck weight data) represent only the specific periods of monitoring. The development of average estimates for a section require compensation for temporal variability, necessitating the use of adjustment factors. Truck loads are heavily influenced by the type of operation or industry. The effect of weather on construction, farming, and commodity movements makes the development of factors a difficult process. Research is underway to explore the development of a site-specific factoring process using continuous truck weight data.

Recommended Traffic Monitoring Program

Section 2 describes the objectives and the development of the sample design for an integrated traffic monitoring program based on the HPMS. The program consists of three major elements:

1. Continuous Count element,
2. HPMS element, and
3. Special Needs element.

The HPMS element consists of four sample subsets:

1. HPMS standard sample,
2. Traffic Volume sample,
3. Vehicle Classification sample, and
4. Truck Weight sample.

The recommended development of the HPMS element framework should be conducted in the sequential order presented. To maintain consistency a complete plan of the four sample subsets should be prepared prior to implementation of any of the specific parts of the program. However, the actual implementation need not follow any specific order, although the integrated estimation process requires all elements to be effective.

The HPMS standard sample requires limited effort since the sample is already defined and implemented. It is essential to reevaluate the HPMS standard sample to ensure that the reliability requirements in the HPMS Field Manual are being met, that all Census-designated urbanized areas are included, and that the sample is as efficient as possible.

The traffic volume sample has also been clearly defined. On an annual basis, it consists of a rotating one-third of the HPMS standard sample.

The vehicle classification sample was selected as a subset of the volume (HPMS) sample sections. In an average State it consists of 100 measurements annually.

The truck weight and vehicle classification sample selections processes are very similar. The information needed to develop the vehicle classification sample will also be needed to develop the truck weight sample. The truck weight sample consists of 90 measurements taken over a 3-year cycle with 1/3 of the sample concentrated on the Interstate system. A number of options are discussed to allow application to very different State systems.

The guidelines are presented as suggested minimums. Large States may logically opt to expand on the minimum level of effort. The overall efforts required may also be beyond existing expenditures. Hopefully, the savings incurred in the reduction or streamlining of the excesses will compensate for the added cost of any increase.

The statistical process allows direct estimation of the reliabilities involved. Therefore, after the program has been fully implemented for 3 years, it will be possible to reevaluate the State's sampling plans using the data collected by each individual State. Options on cost versus reliability can then be more clearly assessed. Finally, it would be naive to assume that changes and alterations will not be made in the future. We live in a dynamic world and circumstances, which are unpredictable or beyond our control, will conspire to force change tomorrow. Future changes can be dealt with on a case by case basis as needed.

Selection of the Truck Weight Sample

The sample consists of 90 measurements taken over a 3-year cycle, or 30 each year. An arbitrary decision to allocate 1/3 of the 3-year sample to the Interstate system was made to ensure higher precision estimates and focus the program on this system. The Interstate sample should result, after 3 years of data collection, in EAL estimates for combination trucks with a three axle tractor and a two axle trailer (3S2) with an approximate precision of 10 percent with 95 percent confidence. In layman's terms this means that if 100 independent samples were taken, the estimates derived from 95 of the 100 samples will be ± 10 percent of the population value.

The remaining 60 measurements are distributed over the remaining road systems (with the exception of roads functionally classified as local which are excluded from the HPMS, or unpaved roads). The precision of 3S2 EAL estimates is expected to approach ± 10 to 20 percent with 95 percent confidence. The following table describes the truck weight sample:

TABLE 5-2-1
Truck Weight Sample

Strata	Number of Measurements (3-year)	Annual Measurements	Expected Precision of 3S2 System Estimates Statewide (3-year cycle)
Interstate System	30	10	95-10
Other Non-local Systems	60	20	95-10 to 20

Only two reporting stratification levels are used:

1. Interstate
2. Other Roads (excluding local functional class or unpaved)

The reduced stratification is necessary due to the limited size of the sample. More extensive stratification requires increases in sample size. Large States may opt to expand the stratification to increase reliability or provide more information. For example, separating the Interstate into rural and urban portions would require 60 measurements, 30 in the rural and 30 in the urban strata, to approximately achieve the precision levels in both strata. Approximate curves relating precision levels to sample size are presented in Section 2.

The distribution and selection of the sample section within strata could be carried out in a variety of ways. The most theoretically correct would be a procedure which accounts for the probability of selection of HPMS sections, the traffic volume sample sections, and the vehicle classification sample sections. The simplest would be a simple random sample of vehicle classification sample sections. The first procedure is enormously complex. The second procedure would not allow control over the selected sections. For example, since there are many more low volume sections in the road universe and HPMS standard sample, chances are that very few high volume sections would be included in the subsample. Also, the geometric or pavement characteristics of some sections may not allow weighing operations. The recommended procedure allocates the sample to type of area, functional class, and volume groups based on the proportion of AVDT those systems carry (HPMS AVDT) relative to other systems. The procedure will be explained by an application using actual 1982 HPMS data for one State. The results can be clearly applied to any State.

The following example consisting of several tables illustrates the procedure given the need to have 10 Interstate truck weight samples in a year.
Example 5-2-1

TABLE 5-2-2
Interstate System Data

Type of Area	HPMS Expanded Roadway Extent	HPMS Expanded DVDT (millions)	DVDT (percent)	Unadjusted Truck Weight Sample	Adjusted Truck Weight Sample
Rural	642	6.9	57.0	6	5
Small Urban	37	0.3	2.5	0	1
Urbanized	143	4.9	40.5	4	4
State Total	822	12.1	100.0	10	10

The unadjusted sample is derived by multiplying the area DVDT percentage times the total number of samples. Due to the low VDT in small urban areas, no sample is allocated. To insure at east one sample in each area type, one sample is taken from the largest group, i.e., Rural, and assigned to the small urban.

For a State with this much Interstate roadway extent, the recommendation would be to select

30 different locations (3-year cycle), or ten different locations each year. Once selected, the locations would become fixed and sampled each 3-year cycle. Since the travel distribution is not expected to change much over 3 years, the DVDT distribution shown above would be used for 3 years. Alternatively, the computation could be carried out annually. Since 10 locations are needed annually, the area distribution would be five rural, one small urban, and four urbanized locations.

The assignment of samples to the Rural Interstate volume groups would be carried out using the same procedure as shown in the following table.

TABLE 5-2-3
Rural Interstate Data (continued)

Volume Group	HPMS Expanded DVDT (millions)	DVDT (percent)	Annual Truck Weight Sample
1	2.2	31.9	2
2	4.2	60.9	3
3	0.5	7.2	0
Total	6.9	100.0	5

Since the truck weight sample in this example is much too small for the extensive HPMS stratification and to ensure that every vehicle classification sample has a positive selection probability, the sections in volume group 3 have been combined with those of volume group 2. Two of the sections would be randomly selected from the first volume group and three from the second and third groups.

The selection of the sample should follow simple random sampling procedures using a table of random numbers. Existing fixed sites would be incorporated into the sample by the same procedure used in the vehicle classification sample (see Chapter 4-2). Application of these procedures to urbanized areas will present problems because of the large number of strata. Judgment will be required when applying the procedure.

Table 5-2-4 continues the example. Assume that there are three Rural Interstate volume groups, from which 15 vehicle classification samples were selected. Five truck weight samples are desired.

TABLE 5-2-4
Rural Interstate Data (continued)

Volume Group	Number of Classification Samples	Number of Weight Samples	Existing Fixed Sites	Remaining Selection Sites
1	6	2	1	1
2	8	3	1	2
3	1	0	0	0

The fixed sites would be subtracted from the number of samples needed. The remaining samples are to be randomly selected. In volume group 1, the five vehicle classification sections (5 sections remain after the preselection of the fixed site) would be assigned a unique sequential number from 1 to 5. Using a table of random numbers, a number from 1 to 5 would be selected, and the selected vehicle classification sample section would become a truck weight sample section.

The same procedure would be applied to volume groups 2 and 3 combined. In this case, the eight remaining sections could be assigned unique numbers and two of the sections randomly selected. The combination of volume groups 2 and 3 is needed to insure a positive probability of selection for each section sampling universe (otherwise the single section in volume group 3 would be excluded).

As discussed extensively in the vehicle classification section, practical considerations also play a role. If the randomly selected sections are not amenable to weighing operations due to equipment capabilities, safety of crews, or other reasons; then another random location from the vehicle classification sample should be examined. If none of the sections in the vehicle classification sample are suitable for weight monitoring, then it will be necessary to randomly substitute sections in the vehicle classification sample, or alternatively to add additional sections to the vehicle classification sample to include vehicle class sample sections which can be used for weighing operations. This is another reason for emphasizing that the integration of the procedures requires very close coordination, and that a problem in one part of the program may require changes in other parts of the program as well.

For States with very limited roadway extent, the 30 measurements could be taken at fewer than 30 locations. For example, if a State has 100 kilometers of Interstate, it would be ridiculous to sample at 30 different points in the 3-year cycle. Alternatives would be to annually take two measurements scheduled at different times of the year at five different locations or five annual measurements at two different locations. Under the first alternative, the 5 monitoring sites would be fixed during the 3-year cycle resulting in 30 measurements at five sites. Under the second alternative, 2 different locations would be sampled each year of the 3-year cycle resulting in 30 measurements at six sites. Data analysis would be carried out to determine if a smaller sample was statistically justified given the special circumstances.

It should be clear from the discussion that judgment is needed. The truck weight sample has been designed to provide maximum flexibility to ensure adequate application given varied circumstances. It is appropriate, however, to caution that flexibility may well result in the introduction of bias and error. Care should be exercised when applying these procedures to ensure that statistical objectives are maintained. In situations where compromises with the guidelines have been necessary, the data collection sites and schedule should be reassessed every 3 years to determine if the guidelines can be more closely followed.

The recommended period of monitoring has been set at 48 hours to reduce the effects of random variation and for direct combination with the volume and classification samples. As discussed in Section 2, research has shown that the coefficients of variation of ESAL's can be as high as 100 percent. Longer periods reduce the variation. The use of a 48-hour period was selected as the best compromise among all possible alternatives given present data. This recommendation implies the use of accurate automatic classification and weight monitoring equipment. The emphasis on automatic equipment is unavoidable.

Estimation Procedures

The procedures described in this section are used to develop statistical estimates. To estimate system averages, the sample section data is averaged by functional system (since the sample was selected proportional to VDT) or expanded using the HPMS expansion process.

Site-specific information cannot be prepared without the development of an adjustment process as done for AADT. In the truck weight sample sections where truck weight data are collected, the estimates are direct. However, the short counts still require adjustment before presenting as annual estimates. For other road sections not included in the sample (HPMS, volume, or vehicle classification sections) or universe sections in general, statistical inferences based on stratum data or judgment inferences based on proximity must be used to generate estimates.
For the development of site-specific estimates three alternatives are presented:

1) the development of a statistical inference approach;

2) the collection of additional information under the Special Needs element; and

3) the application of judgment procedures based on expert knowledge or subjective inference based on other characteristics.

The first alternative could involve the development of a process similar to the estimation of AADT from short counts. The second alternative involves collecting all the data necessary at the site and could involve extensive data collection. The third alternative represents the use of common sense and traditional traffic engineering procedures.

The recommended sample will provide a very balanced sample, well-distributed over the areas, functional classes, and traffic volumes. Obviously, if correctly selected, a very representative sample should be available. Since the samples are HPMS sections, a wealth of information is available on the characteristics of those sections. Site-specific information or estimates could be derived by selecting sample sections with characteristics similar or equivalent to those of the section for which the point-specific inferences are desired. For example, if inferences on ESAL's are desired for a four-lane Interstate section with high truck percentages and high volume in an urbanized area, the sample can be easily screened to find sample locations in close proximity to the desired location or with similar characteristics. Inferences would then be based on the results of the search.

For truck weight sample sections, the percentage of vehicles in any vehicle class is simply the number of vehicles in that class divided by the total volume for all vehicle types at that location. The equation is:

$$P_{ijh} = \frac{v_{ijh}}{v_{jh}} \times 100 \qquad (1)$$

where

P_{ijh} = percentage of vehicles in vehicle class i at location j in stratum h,
v_{ijh} = volume for vehicle class i, and
v_{jh} = total volume for all vehicles types.

Notice that the sum of all the P_{ijh}'s for the 13 vehicle categories must equal 100 percent.

The sample section AVDT is estimated by multiplying the section AADT by the section length (from the HPMS). The classification AVDT at each section is estimated by multiplying the total AVDT by the P_i's. Truck weight information is similarly derived. Assuming that axle weights have been collected; total axle load, average axle load, equivalent axle load, average truck weight, total truck weight, number of overloaded axles, number of overloaded trucks, weight overload, etc., could be directly computed for each vehicle classification category and any derived aggregation. The statewide AVDT estimates for any of the vehicle classification categories are derived by simply multiplying the percentage estimate by the AVDT in each strata and then summing.

Standard error estimates for any of these point estimates could be derived using cluster sampling procedures, since the 48-hour session constitutes a 48-hour cluster of vehicles randomly selected from a universe of 365/2 such periods; or, alternatively, by simple random sampling procedures assuming that the trucks constitute a simple random sample of the truck population at that point.

It should be obvious that this analysis has ignored seasonality. If the sample has been temporally distributed, system estimates are accounted for. However, site-specific estimates must examine seasonality.

The estimation methodology is applied in the following example.

Example 5-2-2

Assume the following data were collected from a single 48-hour measurement on the Rural Interstate system:

48-hour volume	: 48,000 vehicles
Number of 3S2's (18 wheeler)	: 4,800 vehicles
Average weight of 3S2's	: 25,000 kilograms

The following estimates are derived:

Percentage of 3S2's in 48-hour measurement is $100 \times 4{,}800 / 48{,}000 = 10\%$.

Assuming a seasonal factor of 1.1 (lacking a seasonal factor for 3S2, the seasonal factor for total travel has been used and this highlights the need to explore the development of vehicle classification seasonal factors):

Estimated AADT = seasonal factor $\times$ 48,000 / 2 = $1.1 \times 48{,}000 / 2 = 26{,}400$.

Estimated annual average daily number of 3S2's in traffic stream = $26{,}400 \times 10\% = 2{,}640$. [Note that the estimate of 3S2 volume is based on total volume adjustment factors, which assume that the seasonal variation of the 3S2 vehicle type is the same as total volume. Lacking any supporting evidence, this is a heroic assumption to make.]

Estimated DVDT = AADT $\times$ length of section

$$= 26{,}400 \times 1.0 = 26{,}400 \text{ (assuming a one kilometer section).}$$

The estimated section AVDT for 3S2's

$= \text{DVDT} \times \text{percentage of 3S2's } (P_{ijh}) \times 365$
$= 26{,}400 \times 10\% \times 365 = 963{,}600.$

The section estimated annual gross metric ton-kilometers (tkm) for 3S2's

$= \text{3S2 AVDT} \times \text{average 3S2 weight} / 2{,}000$

$= 963{,}600 \times 25{,}000 / 2{,}000 = 12{,}045{,}000.$

The estimated daily average 3S2 load on the sample section for the 48-hour measurement period (disregarding seasonality)

$= \text{average weight of 3S2's} \times \text{average number of 3S2's}$

$= 25{,}000 \times 4{,}800 / 2 = 60{,}000{,}000.$

The estimated annual daily average 3S2 load on the sample se ction (after seasonality)

$= \text{average weight of 3S2} \times \text{annual estimate of 3S2's}$

$= 25{,}000 \times 2{,}640 = 66{,}000{,}000.$

To develop estimates for stratum characteristics, inferences from the sample are made. In the truck weight sample, only two strata are defined. However, since the sample was allocated proportionally to the HPMS strata, estimates for lower strata can be derived by applying the procedures using only the points (sample sections) within the desired lower strata.

An estimate of average percentages of vehicles within strata for a vehicle classification category is derived by the equation:

$$P_{ih} = \frac{1}{n_h} \sum_{j\_1}^{n_h} P_{ijh} \qquad (2)$$

where
P_{ih} = average percentage of vehicles in vehicle classification category i stratum h,
P_{ijh} = percentage of vehicles in vehicle class i at location j of stratum h,
n_h = number of measurements within stratum h.

An estimate of the standard error is derived by the equation:

$$S_{ih} = \sqrt{\frac{1}{n_h (n_h - 1)} \sum_{j\_1}^{n_h} (P_{ijh} - P_{ih})^2} \qquad (3)$$

where

S_{ih} = standard error of the percentage of vehicles in vehicle classification category i in stratum h.

The coefficient of variation is the ratio of the standard error to the mean:

$$C_{ih} = \frac{S_{ih}}{P_{ih}} \tag{4}$$

A two-sided 95 percent confidence interval for the percentage of vehicles in vehicle classification category i in stratum h is given by:

$$P_{ih} \pm 1.96\ S_{ih} \tag{5}$$

and the two-sided precision interval in percentages is 1.96 C_{ih}.

Stratum estimates for any desired truck weight characteristics are derived by substituting the desired characteristic into the equations. For example, to estimate average truck weight in vehicle classification category i, compute the average weight for that classification at each measurement location and begin the process in equation 2. The following example illustrates the estimation process.

Example 5-2-3

Data from two Interstate Rural measurements at different sites is used to develop estimates for the Interstate system.

48-hour volume at location 1	: 48,000 vehicles
48-hour volume at location 2	: 20,000 vehicles
Number of 3S2's at location 1 (48-hour)	: 4,800 trucks
Number of 3S2's at location 2 (48-hour)	: 5,000 trucks
Average weight of 3S2's at location 1 (48-hour)	: 25,000 kilograms
Average weight of 3S2's at location 2 (48-hour)	: 22,500 kilograms

Percentage of 3S2's at location 1 during 48-hour (P_1): 10% (from example 5-2-2)
Percentage of 3S2's at location 2 during 48-hour (P_2): 25%

Estimated Interstate Rural percentage of 3S2's (equation 2)

P_{ih} = (10 + 25) / 2 = 17.5% where i = 3S2 and h = Interstate Rural.

Estimated standard error of percentage of 3S2's (equation 3)

$$S_{ih} = \sqrt{\frac{1}{2\,(2-1)} \left((10 - 17.5)^2 + (25 - 17.5)^2 \right)} = 7.5\%$$

Estimated coefficient of variation (equation 4)

$$C_{ih} = \frac{7.5}{17.5} = .43$$

A 95 percent confidence interval is 17.5 $\pm$ 1.96 $\times$ 7.5 = 17.5 $\pm$ 14.7 (equation 5). The precision interval is 84 percent (1.96 $\times$ .43) which shows the 95 percent confidence to be $\pm$ 84 percent. The precision in short form is 95-84 based on these data. A simple interpretation of the results is that based on the information provided the true percentage is between 2.8 and 32.2 with 95 percent confidence. Obviously, the estimate is very poor as would be expected from such a limited sample.

Estimates of average weights by system are computed using the same procedure.

The estimated Interstate Rural average 3S2 weight is (25,000 + 22,500) / 2 = 23,750.

Its standard error is

$$\sqrt{\frac{(25{,}000 - 23{,}750)^2 + (22{,}500 - 23{,}750)^2}{2}} = 1250$$

The coefficient of variation is 1,250 / 23,750 = .05.

A 95 percent confidence interval is given by 23,750 $\pm$ 1.96 $\times$ 1,250 and the precision interval is 10 percent (1.96 $\times$ .05).

Therefore, the precision of the system average weight based on these data is 95-10. The interpretation is that based on the information provided the true average 3S2 Interstate weight is between 21,300 and 26,200 with 95 percent confidence.

[Note that this is a simplification. Due to the small sample size (n = 2) the statistical procedures to estimate precision would require modification and the value of the normal distribution (1.96) in the confidence interval calculation would have to be replaced by the Student's distribution value. Even then, results based on very small samples are open to question. No implied judgment of the reliability of the sampling approach should be attempted based on any of these examples. We fully expect the recommended sample to achieve or approximate the sample design criteria, although differences from State to State are anticipated. Once data are available on the recommended program from any State, then full assessment of the procedures for that State will be possible.]

The above example is presented to show the computational procedure only. The procedure presented to estimate the average weight is the simplest and not the most efficient. Cluster procedures which consider the weight of every truck and take into account the volumes of trucks at each location would be more efficient but much more complex. Alternative estimation procedures are possible, and the sample design allows future use of improved estimation procedures.

Estimates of stratum AVDT for any of the estimates by vehicle class are derived by multiplying the vehicle class estimate by the stratum AVDT. In the case of the Interstate system, the AVDT of vehicle class i is computed by multiplying the HPMS AVDT estimate for the Interstate times the average stratum classification (P_{ih}). A percentage estimate of the two-sided precision interval of this estimate is given by 1.96 times the square root of the sum of the squared coefficients of variation of stratum AVDT and average stratum classification category. The equation is:

$$1.96\sqrt{C^2_{AVDT} + C^2_{ih}} \qquad (6)$$

where

C_{AVDT} = coefficient of variation of stratum AVDT estimate, and
C_{ih} = coefficient of variation of vehicle class i in stratum h (equation 4).

The computations are illustrated by example.

Example 5-2-4

Based on the previous example, the estimated percentages of 3S2's on the Interstate Rural system is 17.5 percent with a coefficient of variation of 0.43. For the purposes of this example, assume that the Interstate Rural DVDT estimated from the HPMS is 6.6 million with a coefficient of variation of 0.10. The estimate of 3S2 DVDT on the Interstate Rural system is 1.16 million (.175 × 6.6 million) and the coefficient of variation of this estimate is:

$$.44 = \sqrt{.43^2 + .1^2}$$

The precision interval is 86 percent (1.96 ¥ .44) and in short form is expressed as 95-86. Based on these data, the Interstate Rural estimate of 3S2 AVDT is 423 million (1.16 x 365) with a 95 percent precision of ± 86 percent. Obviously, this is an estimate of minimal value because of its lack of precision, but is just what would be expected based on a sample of two measurements.

Aggregation of estimates by strata up to statewide estimates is done by weighing the estimates by AVDT or DVDT. Therefore, an estimate of statewide percentage of vehicles in class i is given by:

$$P_i = \frac{1}{PAVDT} \sum_{h\_1}^{2} (PAVDT_h \times P_{ih}) \tag{7}$$

where

P_i = average statewide percent of vehicles in vehicle classification category i,
PAVDT = statewide AVDT,
$PAVDT_h$ = AVDT in stratum h for all vehicles,
P_{ih} = average percentage of vehicles in vehicle class i and stratum h.

The process is illustrated by example.

Example 5-2-5

Compute the average percentage of 3S2 vehicles in the Interstate stratum given the following data:

System	DVDT (000,000)	Percentage of 3S2's
Interstate Rural	6.6	17.5
Interstate Urban	2.0	7.3

The percentage is estimated using equation 7.

$$P_i = (1 / 8.6) \times (6.6 \times 17.5 + 2.0 \times 7.3) = 15.1.$$

Obviously, these are contrived examples. Given the obvious differences between the two systems, it would be more appropriate to maintain separate numbers for each system than to provide an average system number. Aggregation of estimates should be carried out only when it makes sense to do so or when it serves a desired objective. The purpose of statistical analysis should always be to extract useful information from a database, not to produce numbers or demonstrate mathematical prowess.

Estimates of statewide AVDT for any weight or vehicle class are aggregated by summing strata. Precision intervals are estimated by summing the squares of the coefficient of variation of the appropriate estimates and taking the square root. The process is shown in equation 6.

METHODS OF WEIGHING

Two different methods exist for weighing trucks. One involves stopping a vehicle and weighing it statically, and the other allows a vehicle to be weighed while in motion, or dynamically.

Static Weighing

The advantage of static weighing is the ability to acquire axle weights and spacings within tolerance acceptable to various weight and measure standards. It also allows sufficient time to determine the vehicle's characteristics such as the body type, whether or not the vehicle is loaded, and other related information that can only be ascertained by observation or driver interview.

There are several disadvantages associated with weighing trucks statically. The conventional weigh station is located at a fixed off-road site on a major highway and, therefore, occupies valuable real estate. Safety can be a problem if a queue of trucks forms on the highway. The stopping of trucks causes delays and motivates some truckers to bypass the station or wait until it closes. Enforcement of legal weight or driving statutes or truck inspections is usually carried out at these sites, thereby creating the oportunity for overloaded trucks or drivers aware of other violations to seek alternative routes or wait until the station is closed. Hence static weighing operations may represent atypical truck traffic.

Weigh-in-Motion (WIM)

WIM scales are dynamic weighing systems which determine weights while vehicles are in motion. They enable vehicles to be weighed with little or no interruption of their travel. WIM scales have been designed to sense the weights of the axles passing over the instrument through the use of piezo sensors, strain gauges or hydraulic or pneumatic pressure transducers. The readings are transmitted to a receiving unit where they are converted to actual weights.

The advantages of using WIM are many. It offers a method of recording and processing weight data automatically without disrupting the truck driver and overt enforcement. It offers a degree of concealment and anonymity which enhances data credibility since vehicles in violation, that normally may have deliberately bypassed a known weighing operation, are recorded at WIM sites. This provides highway planners, researchers, and enforcement officials with more representative statistical data. Also, since WIM does not interrupt the traffic flow, it is capable of weighing high volumes of traffic, such as in urban areas where it is difficult to obtain weight data using static weighing equipment. For these reasons, only WIM data are to be reported to the FHWA Truck Weight Study. The only exception would be in locations where there are no bypass routes.

However, WIM presents no panacea. It needs to be understood that static and dynamic weights reflect different conditions and will rarely match exactly. The dynamic forces on a moving vehicle will always influence WIM measurements. This does not mean that WIM measurements are incorrect. Even if WIM equipment were 100% accurate, dynamic forces resulting from site-specific characteristics such as pavement roughness, vehicle characteristics such as suspension system or tire pressure, or atmospheric conditions such as wind velocity can make the WIM reading differ from the static weight. Moreover, WIM equipment calibration must be checked regularly.

In converting to metric units a decision had to be made whether to use units of mass (kilograms) or force (kilonewtons). Because a WIM system is a type of scale which is calibrated to static weights, it was decided to use kilograms. By applying the local force of gravity, kilograms may be interpreted as kilograms of force and converted to kilonewtons. To convert kilograms to kilonewtons multiply the kilograms by 9.80665.

TRUCK WEIGHT DATA SUMMARIES
(FHWA W-TABLES)

Introduction

In order for the results of the truck weight surveys to be of value, summaries of the data must be made available in an appropriate form. The W-Tables were designed to provide a standard format for presenting the outcome of the vehicle weighing and classification efforts at truck weigh sites. The data that appears in the tables comes from the summary files that are generated by the Vehicle Travel Information System (VTRIS) which ultimately comes from the raw data. What follows is a brief description of each of the W-tables.

W-1 Table: Weigh Station Characteristics

This table displays the characteristics of each weigh station based on the information contained in the station description records. The characteristics include a brief description of the location of the station along with information about the type of station and the equipment used. The reported county code that appears is the three-digit FIPS county code.

W-2 Table: Comparison of Weighed vs. Counted

This table includes a summary of the vehicles counted and the vehicles weighed for each individual station, by vehicle classification. The vehicle classification data is averaged for each hour and the 24 hourly averages are added for the average daily count. The functional classes that appear in the table are the functional classes for the stations as defined in section 6.

The table breaks the data down by the thirteen vehicle type categories as defined in section 6. Notice that data for vehicle codes 1 through 4 is not as complete as for 5 through 13. This is because the W-2 Table only considers weight information for vehicle codes 5 through 13. The bottom row of the table summarizes truck traffic, trucks weighed, and average daily traffic.

Several additional figures are provided in the table and are calculated in the following manner:

"Percent Distribution
Total Vehicles" = 100 × Number Counted of a specific vehicle type ÷ Total Traffic

"Percent Distribution
Trucks & Comb." = 100 × Number Counted of a specific vehicle type ÷ Total Trucks

"Percent Dist. of Number Weighed" = 100 × Number Weighed of a specific vehicle type ÷ Total Weighed

"Weighed as Percent of Counted" = 100 × Number Weighed of a specific vehicle type ÷ Number Counted of that specific vehicle type

W-3 Table: Average Empty, Loaded and Cargo Weights

This table provides information on the average weights of empty, loaded and all trucks and their estimated average carried loads. This information is broken down by vehicle classifications 5 through 13 for each station location. The functional classes indicated on the table are the functional classes for the stations reported and are defined as mentioned above. The "Number Weighed" column contains the identical numbers as the W-2 Table under "Number Weighed." The numbers in the Breakpoint column are user-defined numbers for each vehicle classification defining the breakpoint between empty and loaded trucks. The "Estimated No. Loaded" column is the number of trucks that are above the breakpoint value and conversely, the "Estimated No. Empty" column is the number of trucks that are below the breakpoint value. These two numbers should sum to the number weighed for a given vehicle type.

The various figures in the table are calculated in the following manner:

"Average Gross Weight" = Total weight of all trucks of a specific type ÷ Number of trucks weighed of that specific type

"Percent Loaded" = 100 × Number of Trucks of a specific type heavier than Breakpoint ÷ Number of trucks weighed of that specific type

"Average Load Weight" = Total weight of all trucks of a specific type heavier than Breakpoint ÷ Number of trucks of that specific type heavier than Breakpoint

"Percent Empty" = 100 × Number of trucks of a specific type lighter than Breakpoint ÷ Number of trucks weighed of that specific type

"Average Empty Weight" = Total weight of all trucks of a specific type lighter than Breakpoint ÷ Number of trucks of that specific type lighter than Breakpoint

"Carried Load Wt. Avg." = "Average Load Weight" minus "Average Empty Weight"

W-4 Table: Equivalency Factors

This table is most commonly used in pavement design since it contains information on truck axle loadings and their effect on flexible and rigid pavements based on equivalent single axle loads. It also provides the number of single, tandem, and tridem axles weighed that fall into particular weight ranges and gives the resulting equivalent single axle loads on the two types of pavement. All of the information is produced by truck types 3 through 13 and can be shown for each station location and/or functional classification of highway. The user defines the ranges of axle load to be used in the calculations. (Tandems and tridems are omitted from the example.)

The bottom three rows on the first three pages of the table summarize vehicle information. The "Single Axles Weighed" row is the sum of the columns by vehicle type. The "Average Daily Count" row is the sum of vehicles counted according to their type, in this case types 3 through 13. These numbers match those indicated in the W-2 Table for those same vehicle types. The "Vehicles Weighed" row is the sum of vehicles weighed for that type, again in this case types 3 through 13. Likewise, these numbers should be the same as those indicated in the W-2 Table with the exception of types 3 and 4 which do not appear in the W-2 Table. Of the bottom three rows in the table, the last two will be identical for pages 1, 2, and 3 of the table and the first row will vary according to single, tandem, or tridem axles respectively.

The formula used in the calculation of the equivalent single axle loads is that developed by the American Association of State Highway and Transportation Officials. Three user-selected entry values are required:

1. Serviceability index: "P" values range from 0.0 to 5.0 with 0.0 representing the worst possible pavement condition and 5.0 representing the best possible pavement condition.

2. Depth of rigid pavement: The thickness of the rigid pavement in inches.

3. Structural number of flexible pavement: The structural number is calculated from the depth and layer coefficient of the subbase, base, and surface courses. The fourth page of the W-4 Table summarizes the data from the three previous pages on single-axles, tandems, and tridems, developing ESAL value per vehicle and percent distribution by vehicle type for rigid and flexible pavements. In addition, the total number of vehicles counted and vehicles weighed is shown.

Based upon the W-4 Table data, 20 YEAR ESAL ESTIMATES are shown, and depending upon the user's prediction of traffic growth and truck growth, a value can be developed for ESALs per 1000 vehicles of the average daily traffic (ADT). A compound growth factor is assumed for the ESAL's.

W-5 Table: Gross Vehicle Weights

This table shows the number of trucks weighed in various gross weight ranges. These figures are produced for truck types 3 through 13 and can be shown for each station and/or functional classification of highway. The user defines the ranges of gross operating weight. The bottom two rows of the table summarize total vehicles weighed and total vehicles counted for truck types 3 through 13.

W-6 Table: Overweight Vehicle Report

This table gives the number and percent of vehicles by type exceeding a user-specified axle, tandem, and gross weight limit and violations of the bridge formula as referenced in Appendix B. The information can be shown by station and/or functional classification of highway and is broken down by vehicle codes 3 through 13. As a cautionary note, it should be mentioned that vehicles can show up in more than one category such as "Bridge Formula" and "Gross Load Limit" in this table. A vehicle may have multiple violations of the set criteria.

W-7 Table: Distribution of Overweight Vehicles

The number and percent of vehicles above and below a selected gross weight value are summarized in this table. These can be shown for each station and/or functional classification of highway broken down by vehicle types 5 through 13. The numbers that appear under the "No. Weighed/Percent of Counted" column are identical to those found in the W-2 Table and are calculated in the same manner. The bottom row of the table displays the sum of the columns with its percentage. This percentage is the total number of trucks weighed as shown in this bottom row divided by "Total Trucks" counted as shown in the W-2 Table. The numbers shown under the "All in Excess" column are the vehicles that are classified as overweight in their respective axle groupings. The percentage of overweight vehicles within each axle grouping is also given. Numbers under the "Not in Excess" column plus the "All in Excess" column should add to the "No. Weighed/Percent of Counted". The columns under the title "Excess by Percent or More" are a frequency distribution of the most severe gross weight excesses.

In the frequency distribution, the same vehicle could exist in several of the excess categories. For example, a truck exceeding the specified gross weight by 11 percent would be shown in both the first and second categories, while a truck that exceeds the specified gross weight by 50 percent would be shown in all of the categories. If a vehicle does not exceed the specified gross weight by at least 5 percent, it will not be shown in the distribution.

GLOSSARY OF TERMS

AXLE	A shaft on which or with which two or more wheels on a vehicle revolve.
AXLE GROUP	Two or more consecutive axles considered together in determining their combined load effect on a bridge or pavement structure.
AXLE LOAD	The weight carried by one axle of a vehicle.
AXLE SPACING	The distance between two consecutive axles of a truck or combination, usually measured from the point of ground contact of one tire to the same point on the other tire or from a point on an axle hub to the same point on the other axle hub.
AXLE WEIGHT	See SINGLE AXLE WEIGHT or TANDEM AXLE WEIGHT.
BOBTAIL	A tractor on the road without a semitrailer.
BRIDGE FORMULA	Refer to APPENDIX B.
COMBINATION	A truck or tractor coupled to one or more trailers (including semitrailers).
CURB WEIGHT	The weight of an empty vehicle without a load or a driver but including fuel, coolant, oil, and all items of standard equipment.
DYNAMIC WEIGHT	The weight of a vehicle or an individual axle as measured while the vehicle is in motion.
EQUIVALENT AXLE LOAD (EAL)	The damage per pass to a pavement caused by a specific axle load relative to the damage per pass of a standard 18,000 pound axle load moving on the same pavement.
FIFTH WHEEL	A coupling device located on a vehicle's rear frame used to connect the vehicle to a semitrailer. It can sometimes be moved forward or backward on the vehicle to obtain the desired distribution of weight between the trailer axles and the pulling vehicle.
FLEXIBLE PAVEMENT	Road construction of a bituminous material, generally asphalt, which has little tensile strength.
FULL TRAILER	A truck trailer with wheels on the front and rear (as opposed to a

	semitrailer in which the front rests on the rear of the tractor).
GROSS WEIGHT	The weight of a vehicle and/or vehicle combination together with the weight of its load.
OVERWEIGHT	Over the Federal or State legal restrictions for single axle weight, tandem axle weight or gross weight.
PORTABLE SCALE	A scale of such size and weight as to be readily transportable from station to station.
RIGID PAVEMENT	Road construction of Portland cement concrete.
SADDLE MOUNT	A vehicle configuration using a tractor to transport other tractors or trailers by mounting the front axle of the vehicles to be transported on the rear of the tractor or the preceding mounted vehicle. Only the rear axle of the mounted vehicles are on the ground.
SEMITRAILER	A vehicle designed for carrying persons or property and drawn by another vehicle on which part of its weight and load rests.
SINGLE AXLE	An axle on a vehicle that is separated from any previous or succeeding axle by more than 2.44 meters (96 inches).
SINGLE AXLE WEIGHT	The total weight transmitted by all wheels whose centers may be included between two parallel transverse vertical planes 1.02 meters (40 inches) apart, extending across the full width of the vehicle.
SPREAD TANDEM	Two axles that are articulated from a common attachment but are considered as two single axles rather than one tandem axle because they are separated by more than 2.44 meters (96 inches).
STATIC SCALE	A scale that requires that a vehicle be stopped to be weighed.
STEERING AXLE	The axle to which a vehicle's steering mechanism is affixed.
STRAIGHT TRUCK	A self-propelled vehicle designed and used for the transportation of property and not including tractors.
TANDEM AXLE	Two consecutive axles that are more than 1.02 meters (40 inches) but not more than 2.44 meters (96 inches) apart and are articulated

from a common attachment.

TANDEM AXLE WEIGHT — The total weight transmitted to the road by two or more consecutive axles whose centers may be included between parallel vertical planes spaced more than 1.02 meters (40 inches) and not more than 2.44 meters (96 inches) apart, extending across the full width of the vehicle.

TOWED VEHICLE — A vehicle drawn or towed by another vehicle supplying the motive power.

TRACTOR — A vehicle designed and used primarily as the power unit for drawing a semitrailer or trailer.

TRAILER — A vehicle without motive power designed to be drawn by another vehicle and so constructed that no part of its weight rests upon or is carried by the pulling unit.

TRUCK — A motor vehicle designed, used, or maintained primarily for the transportation of property.

VEHICLE — Any conveyance of any type operated on a highway, whether self-propelled or drawn by another vehicle.

WEIGH-IN-MOTION SCALE — A scale that allows vehicle weights to be electronically recorded as the vehicle passes over the scale without stopping.

WEIGH STATION — A location equipped with weigh scales at which the axle weights and gross weights of vehicles are determined.

WEIGHT VIOLATION — A single axle weight, axle group weight, or gross weight of a vehicle exceeding the maximum allowed weight for that vehicle.

WHEELBASE — The distance between the front and rear axles of a vehicle, or the center point of contact of the front and rear wheels with the ground.

BRIDGE FORMULA WEIGHTS

The Bridge Formula provides a standard to control the spacing of truck axles on vehicles that use highway bridges.

In 1974, when higher axle and gross weight limits were adopted for the Interstate System, the Bridge Formula was written into Section 127 of the United States Code, Title 23. The Bridge Formula assures that the allowable weight of heavy trucks is correlated with the spacing of axles to prevent overstressing of highway bridges. The overstressing can occur even when the gross weight and each individual axle weight of a truck are within lawful limits.

The axle spacings are equally as important in design of bridges as the axle weights. This is illustrated by what happens when people try to walk across ice that is hardly thick enough to support their weight; they are likely to fall through. If they stretched out prone on the same ice and scooted across, it is unlikely that they would break through. This is because the load, or weight, is spread over a larger area in the latter situation.

A similar comparison can be made between trucks crossing a bridge. An extremely long truck would have its load spread out like someone lying on ice. However, a short truck is similar to someone standing up on ice with their total load placed on a limited area.

Until 1982, Federal law set only upper limits (or ceilings) on Interstate System weight limits. A few States retained significantly lower weight limits which eventually became barriers to long-distance truck traffic. In 1982, Federal law was amended to make Interstate System weight limits, including the bridge formula limits, both the maximum and the minimum weights (i.e., floors and ceilings) that States must allow on the Interstate System.

On October 6, 1994, the FHWA published in the Federal Register a notice on the interpretation of truck size and weight limits in metric units. Although the term weight should be replaced in the metric system by mass, it was decided to retain the term weight because of its historic and widespread use. The following weight limits are based on that notice:

- Gross Weight Limit -- The Federal gross weight limit on the Interstate System is 36,290 kilograms (80,000 pounds).

- Single Axle Weight Limit -- The Federal single axle weight limit on the Interstate System is 9,070 kilograms (20,000 pounds).

- Tandem Axle Weight Limit -- The Federal tandem axle weight limit on the Interstate System is 15,420 kilograms (34,000 pounds).

- Bridge Formula Limit -- The Federal law states that any group of two or more consecutive axles may not exceed the weight as computed by the Bridge Formula even though the single axles, tandem axles, and gross weights are within legal requirements.

The Bridge Formula as enacted uses U.S. Customary ("English") units rounded to the nearest 500 pounds. Because of this, the FHWA decided on a soft conversion of the Bridge Formula as a table (see Table 5-B-1 below). This table is essentially equivalent to the following metric version of the Bridge Formula:

$$W = \left\lfloor 0.5 + 226.8 \left\lfloor \frac{L}{0.3048} \frac{N}{N-1} + 12N + 36.49 \right\rfloor \right\rfloor$$

where

W = the maximum weight in kilograms that can be carried on two or more consecutive axles,
L = the spacing in meters between the outer axles of any two or more consecutive axles,
N = the number of axles being considered, and
the brackets indicate the integer function, i.e., truncate any fraction.

A distinction is made at 2.44 meters (8 feet) in the Bridge Formula table due to the tandem axle weight definition causing a considerable difference in the axle load depending on whether the spacing of the axles is 2.44 meters and less or more than 2.44 meters. The axle weight limit for any spacing greater than 2.44 meters shall be in accordance with the Bridge Formula. The tandem axle weight definition is not applicable when the axle spacing exceeds 2.44 meters. For example, three axles with an extreme spacing of 2.45 meters (more than 2.44 meters) can carry a load of 19,051 kilograms (42,000 pounds).

There is one exception to use of the Bridge Formula--two consecutive sets of tandem axles may each carry a gross load of 15,420 kilograms (34,000 pounds) provided that the overall distance between the first and last axles of such consecutive sets of tandem axles is 10.97 meters (36 feet) or more.

TABLE 5-B-1. Bridge Formula

N: Number of axles

L: Axle Extremes

feet	meters	2 lb	2 kg	3 lb	3 kg	4 lb	4 kg	5 lb	5 kg
4	1.22	34,000	15,422						
5	1.52	34,000	15,422						
6	1.83	34,000	15,422						
7	2.13	34,000	15,422						
8	2.44	34,000	15,422	34,000	15,422				
8.01	2.44	38,000	17,237	42,000	19,051				
9	2.74	39,000	17,690	42,500	19,278				
10	3.05	40,000	18,144	43,500	19,732				
11	3.35			44,000	19,958				
12	3.66			45,000	20,412	50,000	22,680		
13	3.96			45,500	20,639	50,500	22,907		
14	4.27			46,500	21,092	51,500	23,360		
15	4.57			47,000	21,319	52,000	23,587		
16	4.88			48,000	21,773	52,500	23,814	58,000	26,309
17	5.18			48,500	22,000	53,500	24,268	58,500	26,536
18	5.49			49,500	22,453	54,000	24,494	59,000	26,762
19	5.79			50,000	22,680	54,500	24,721	60,000	27,216
20	6.10			51,000	23,134	55,500	25,175	60,500	27,443
21	6.40			51,500	23,360	56,000	25,402	61,000	27,670
22	6.71			52,500	23,814	56,500	25,628	61,500	27,896
23	7.01			53,000	24,041	57,500	26,082	62,500	28,350
24	7.32			54,000	24,494	58,000	26,309	63,000	28,577
25	7.62			54,500	24,721	58,500	26,536	63,500	28,804
26	7.92			55,500	25,175	59,500	26,989	64,000	29,030
27	8.23			56,000	25,402	60,000	27,216	65,000	29,484
28	8.53			57,000	25,855	60,500	27,443	65,500	29,711
29	8.84			57,500	26,082	61,500	27,896	66,000	29,938
30	9.14			58,500	26,536	62,000	28,123	66,500	30,164
31	9.45			59,000	26,762	62,500	28,350	67,500	30,618
32	9.75			60,000	27,216	63,500	28,804	68,000	30,845
33	10.06					64,000	29,030	68,500	31,072
34	10.36					64,500	29,257	69,000	31,298
35	10.67					65,500	29,711	70,000	31,752
36	10.97					66,000	29,938	70,500	31,979
37	11.28					66,500	30,164	71,000	32,206
38	11.58					67,500	30,618	71,500	32,432
39	11.89					68,000	30,845	72,500	32,886

TABLE 5-B-1. Bridge Formula - continued

L: Axle Extremes		N: Number of axles							
		2	2	3	3	4	4	5	5
feet	meters	lb	kg	lb	kg	lb	kg	lb	kg
40	12.19					68,500	31,072	73,000	33,113
41	12.50					69,500	31,525	73,500	33,340
42	12.80					70,000	31,752	74,000	33,566
43	13.11					70,500	31,979	75,000	34,020
44	13.41					71,500	32,432	75,500	34,247
45	13.72					72,000	32,659	76,000	34,474
46	14.02					72,500	32,886	76,500	34,700
47	14.33					73,500	33,340	77,500	35,154
48	14.63					74,000	33,566	78,000	35,381
49	14.94					74,500	33,793	78,500	35,608
50	15.24					75,500	34,247	79,000	35,834
51	15.54					76,000	34,474	80,000	36,288
52	15.85					76,500	34,700	80,500	36,515
53	16.15					77,500	35,154	81,000	36,742
54	16.46					78,000	35,381	81,500	36,968
55	16.76					78,500	35,608	82,500	37,422
56	17.07					79,500	36,061	83,000	37,649
57	17.37					80,000	36,288	83,500	37,876
58	17.68							84,000	38,102
59	17.98							85,000	38,556
60	18.29							85,500	38,783

TABLE 5-B-1. Bridge Formula - continued

N: Number of axles

L: Axle Extremes

feet	meters	5 lb	5 kg	6 lb	6 kg	7 lb	7 kg	8 lb	8 kg	9 lb	9 kg
61	18.59	86,000	39,010	90,500	41,051	95,500	43,319	101,000	45,814	106,500	48,308
62	18.90	86,500	39,236	91,000	41,278	96,000	43,546	101,500	46,040	107,000	48,535
63	19.20	87,500	39,690	92,000	41,731	96,500	43,772	102,000	46,267	107,500	48,762
64	19.51	88,000	39,917	92,500	41,958	97,500	44,226	102,500	46,494	108,000	48,989
65	19.81	88,500	40,144	93,000	42,185	98,000	44,453	103,000	46,721	108,500	49,216
66	20.12	89,000	40,370	93,500	42,412	98,500	44,680	103,500	46,948	109,000	49,442
67	20.42	90,000	40,824	94,000	42,638	99,000	44,906	104,500	47,401	109,500	49,669
68	20.73	90,500	41,051	95,000	43,092	99,500	45,133	105,000	47,628	110,000	49,896
69	21.03	91,000	41,278	95,500	43,319	100,000	45,360	105,500	47,855	111,000	50,350
70	21.34	91,500	41,504	96,000	43,546	101,000	45,814	106,000	48,082	111,500	50,576
71	21.64	92,500	41,958	96,500	43,772	101,500	46,040	106,500	48,308	112,000	50,803
72	21.95	93,000	42,185	97,000	43,999	102,000	46,267	107,000	48,535	112,500	51,030
73	22.25	93,500	42,412	98,000	44,453	102,500	46,494	107,500	48,762	113,000	51,257
74	22.56	94,000	42,638	98,500	44,680	103,000	46,721	108,500	49,216	113,500	51,484
75	22.86	95,000	43,092	99,000	44,906	103,500	46,948	109,000	49,442	114,000	51,710
76	23.16	95,500	43,319	99,500	45,133	104,500	47,401	109,500	49,669	114,500	51,937
77	23.47	96,000	43,546	100,000	45,360	105,000	47,628	110,000	49,896	115,500	52,391
78	23.77	96,500	43,772	101,000	45,814	105,500	47,855	110,500	50,123	116,000	52,618
79	24.08	97,500	44,226	101,500	46,040	106,000	48,082	111,000	50,350	116,500	52,844
80	24.38	98,000	44,453	102,000	46,267	106,500	48,308	111,500	50,576	117,000	53,071
81	24.69	98,500	44,680	102,500	46,494	107,000	48,535	112,500	51,030	117,500	53,298
82	24.99	99,000	44,906	103,000	46,721	108,000	48,989	113,000	51,257	118,000	53,525
83	25.30	100,000	45,360	104,000	47,174	108,500	49,216	113,500	51,484	118,500	53,752
84	25.60	100,500	45,587	104,500	47,401	109,000	49,442	114,000	51,710	119,000	53,978
85	25.91	101,000	45,814	105,000	47,628	109,500	49,669	114,500	51,937	120,000	54,432
86	26.21	101,500	46,040	105,500	47,855	110,000	49,896	115,000	52,164	120,500	54,659
87	26.52	102,500	46,494	106,000	48,082	110,500	50,123	115,500	52,391	121,000	54,886
88	26.82	103,000	46,721	107,000	48,535	111,500	50,576	116,500	52,844	121,500	55,112
89	27.13	103,500	46,948	107,500	48,762	112,000	50,803	117,000	53,071	122,000	55,339
90	27.43	104,000	47,174	108,000	48,989	112,500	51,030	117,500	53,298	122,500	55,566
91	27.74	105,000	47,628	108,500	49,216	113,000	51,257	118,000	53,525	123,000	55,793
92	28.04	105,500	47,855	109,000	49,442	113,500	51,484	118,500	53,752	123,500	56,020
93	28.35	106,000	48,082	110,000	49,896	114,000	51,710	119,000	53,978	124,500	56,473
94	28.65	106,500	48,308	110,500	50,123	115,000	52,164	119,500	54,205	125,000	56,700
95	28.96	107,500	48,762	111,000	50,350	115,500	52,391	120,500	54,659	125,500	56,927
96	29.26	108,000	48,989	111,500	50,576	116,000	52,618	121,000	54,886	126,000	57,154
97	29.57	108,500	49,216	112,000	50,803	116,500	52,844	121,500	55,112	126,500	57,380
98	29.87	109,000	49,442	113,000	51,257	117,000	53,071	122,000	55,339	127,000	57,607
99	30.18	110,000	49,896	113,500	51,484	117,500	53,298	122,500	55,566	127,500	57,834

TABLE 5-B-1. Bridge Formula - continued

N: Number of axles

L: Axle Extremes

feet	meters	5 lb	5 kg	6 lb	6 kg	7 lb	7 kg	8 lb	8 kg	9 lb	9 kg
100	30.48	110,500	50,123	114,000	51,710	118,500	53,752	123,000	55,793	128,000	58,061
101	30.78	111,000	50,350	114,500	51,937	119,000	53,978	123,500	56,020	129,000	58,514
102	31.09	111,500	50,576	115,000	52,164	119,500	54,205	124,500	56,473	129,500	58,741
103	31.39	112,500	51,030	116,000	52,618	120,000	54,432	125,000	56,700	130,000	58,968
104	31.70	113,000	51,257	116,500	52,844	120,500	54,659	125,500	56,927	130,500	59,195
105	32.00	113,500	51,484	117,000	53,071	121,000	54,886	126,000	57,154	131,000	59,422
106	32.31	114,000	51,710	117,500	53,298	122,000	55,339	126,500	57,380	131,500	59,648
107	32.61	115,000	52,164	118,000	53,525	122,500	55,566	127,000	57,607	132,000	59,875
108	32.92	115,500	52,391	119,000	53,978	123,000	55,793	127,500	57,834	132,500	60,102
109	33.22	116,000	52,618	119,500	54,205	123,500	56,020	128,500	58,288	133,500	60,556
110	33.53	116,500	52,844	120,000	54,432	124,000	56,246	129,000	58,514	134,000	60,782
111	33.83	117,500	53,298	120,500	54,659	124,500	56,473	129,500	58,741	134,500	61,009
112	34.14	118,000	53,525	121,000	54,886	125,500	56,927	130,000	58,968	135,000	61,236
113	34.44	118,500	53,752	122,000	55,339	126,000	57,154	130,500	59,195	135,500	61,463
114	34.75	119,000	53,978	122,500	55,566	126,500	57,380	131,000	59,422	136,000	61,690
115	35.05	120,000	54,432	123,000	55,793	127,000	57,607	131,500	59,648	136,500	61,916
116	35.36	120,500	54,659	123,500	56,020	127,500	57,834	132,500	60,102	137,000	62,143
117	35.66	121,000	54,886	124,000	56,246	128,000	58,061	133,000	60,329	138,000	62,597
118	35.97	121,500	55,112	125,000	56,700	129,000	58,514	133,500	60,556	138,500	62,824
119	36.27	122,500	55,566	125,500	56,927	129,500	58,741	134,000	60,782	139,000	63,050
120	36.58	123,000	55,793	126,000	57,154	130,000	58,968	134,500	61,009	139,500	63,277

SECTION 6

Traffic Monitoring Data Formats

SECTION 6

TRAFFIC MONITORING DATA FORMATS

Table of Contents

Figures

INTRODUCTION

This section contains instructions for coding data in the formats requested by FHWA. The record formats and coding instructions have been developed to provide input to national data bases maintained by FHWA. This includes the Traffic Volume Trends (TVT) system and the Vehicle Travel Information System (VTRIS). TVT is the data base management system for the monthly publication Traffic Volume Trends based on State-supplied ATR data.

VTRIS is a microcomputer data base management system which validates, summarizes, and maintains vehicle classification and truck weight study data. It contains many features and is continually being improved. The latest version of VTRIS is available on the FHWA Electronic Bulletin Board System (FEBBS). Also on FEBBS are a conversion program to convert data files in the 2, 4, and 7 card formats to the new formats described in this section.

There is a toll-free telephone number for FEBBS: 800-337-FHWA (3492). To access FEBBS dial this number using any communications software through a modem on your computer, 24 hours a day, 7 days a week. The communications parameters are: no parity, 8 data bits, 1 stop bit, and full duplex. All modems up to 14,400 baud are supported. If you have questions about FEBBS, call the FHWA Computer Help Desk at 202-366-1120.

When you logon to FEBBS, you will be prompted for your first name, last name, city you are calling from, and a password. The password is case-sensitive; that is, small and capital letters are distinguished. Each new user will need to register with FEBBS. Until you register, you cannot access all of the menu options. After you register, call back the next day and all of the menu options should be available.

Each FHWA program area has its own Conference on FEBBS. The Conferences contain bulletins, messages (electronic mail), and files available for down loading (copying to your computer). There is also an FHWA Management Information Section and Questions and Answers on ISTEA (Intermodal Surface Transportation Efficiency Act).

For Conferences sponsored by the Office of Highway Information Management (under the Office of Policy), select C (Conferences) from the main menu and then select P (Policy) from the conference menu. The Travel Monitoring conference is option T. See Figure 6-1-1 for examples of FEBBS menus.

There are three options within the Travel Monitoring conference: Bulletins, Download, and Mail. The Bulletins are notes about recent and upcoming items of interest on traffic monitoring. Download refers to files that are available to be transferred to your computer. Mail is for messages such as questions that may be posted so that others may respond.

FIGURE 6-1-1. FEBBS Menus

```
 * MAIN MENU * FEBBS : Federal Highway Electronic Bulletin Board System *
=========================================================================
<G>oodbye   <U>ser Profile: password, terminal characteristics </> Chat

<F>            ... FHWA Management Information Section
<Q>            ... Questions and Answers on ISTEA

<C>onferences ... Special Topics organized by Program Area

<B>ulletins   ... General information  &  notices of new features
<I>nfo        ... System Information and Help Files

<M>ail        ... Person-to-Person Electronic Mail
<O>pen Forum  ... Public Messages & Discussions of FHWA Activities
<T>ech Talk   ... Public Discussions about Computers & Related Topics
<R>ead        ... Check all Conference Message Boards

<L>og ... Lists previous callers       <Y>ell ... Pages the SYSOP
```

```
       FHWA BBS :  CONFERENCE SELECTION MENU
=============================================================
<G>oodbye   <+> previous menu  <-> top menu  </>  Chat Online

 Conferences are organized into groups by program area.

< T >      [ FEDERAL TRANSIT ADMINISTRATION CONFERENCE ]
< C >      [ Office of CHIEF COUNSEL : 23 US Code, C.F.R. ]
< P >      [ POLICY ]
< R >      [ RESEARCH and DEVELOPMENT ]
< D >      [ PROGRAM DEVELOPMENT ]
< S >      [ SAFETY AND SYSTEM APPLICATIONS ]
< M >      [ MOTOR CARRIER SAFETY ]
< A >      [ ADMINISTRATION ]
< K >      [ CONTRACTS AND PROCUREMENT ]
< B >      [ STRATEGIC BUSINESS PLANNING ]
< F >      [ FHWA SECRETARIES ]
< O >      [ OTHER FHWA PROGRAM AREAS AND NEWSLETTERS ]
< E >      [ EDS - ELECTRONIC DATA SHARING ]
< L >      [ LAN - LOCAL AREA NETWORKS ]
< J >      [ PJ  - PROJECT TRACKING SYSTEMS ]
< H >      [ Hardware, Software, Communications, & Other Topics]
```

```
 FEBBS Conferences : sponsored by POLICY
 =======================================================================
 <G>oodbye    <+> previous menu     <-> top menu     </> Chat

 Enter Conference Number:

 <C>  STP Statistical Data Collection            HPM-10
 <D>  Highway Statistics Data Reporting          HPM-10
 <M>  Motor Fuel / Highway Trust Fund            HPM-10
 <S>  State Briefing Sheets on Highway Funds     HPM-10
 <H>  Highway System Performance                 HPM-20
 <T>  Travel Monitoring                          HPM-30

 <X>  HIGHWAY INFORMATION Message Board ...  Send messages/files
 .                                           to other Conference members
```

The data requested are divided into four types: station description data, traffic volume data, vehicle classification data, and truck weight data. Each type of data has its own individualized record format. Specific coding instructions and record layouts are discussed separately for each type of data in the next chapters.

All data files described herein are ASCII flat files. For character fields with missing or inapplicable data, code blanks. Numbers such as counts should be right-justified and filled with leading blanks or zeros unless noted otherwise. For numeric fields with missing or inapplicable data, code blanks or "-1" right-justified.

Certain data items are common to all three types of records. For example, all records contain a six-character station identification. This allows States to use a common identification system for all traffic monitoring stations.

Data Submittals to FHWA

Annually, each State should submit to FHWA the vehicle classification and truck weight data collected. The HPMS schedule should be followed: submit data by June 15 for the preceding calendar year. Quarterly submissions are also acceptable.

If continuous weigh-in-motion data are available, send up to one week of data per quarter (select any week without a holiday). Continuous vehicle classification data for the whole year may be sent if available. The data should be addressed as follows:

Federal Highway Administration
Travel Monitoring Division, HPM-30
400 7th Street, SW
Washington, D.C. 20590

Attention: Truck Weight Study

The data should be in the record formats described in this section and edited for reasonableness. It is preferable that a compression program such as PKZIP be used to condense the data files. Indicate a contact person and telephone number in case further clarification is necessary. For further information contact the Travel Monitoring Division at (202) 366-0175.

STATION DESCRIPTION DATA FORMATS

Station Description Record Format

The Station Description record format may be used for traffic volume, vehicle classification, and truck weight monitoring stations. However, the ATR Station Description (#1 record) may still be used for ATR stations. All of the information required for the ATR Station Description record is contained in the Station Description record. A program for creating or modifying Station Description records is available on FEBBS.

A Station Description file contains one record for each traffic monitoring station. All fields are considered to be character fields. Even codes which are numbers are treated as character fields. The optional file naming convention is "ssyy.STA" where ss is State postal abbreviation and yy is the last two digits of the year. Figure 6-2-1 summarizes the Station Description record.

Fields designated as Critical are required for entry into the VTRIS data base.

1. Record Type (Column 1) - Critical

   S = Station description record

2. FIPS State Codes (Columns 2-3) - Critical

State	Code	State	Code	State	Code
Alabama	01	Louisiana	22	Ohio	39
Alaska	02	Maine	23	Oklahoma	40
Arizona	04	Maryland	24	Oregon	41
Arkansas	05	Massachusetts	25	Pennsylvania	42
California	06	Michigan	26	Rhode Island	44
Colorado	08	Minnesota	27	South Carolina	45
Connecticut	09	Mississippi	28	South Dakota	46
Delaware	10	Missouri	29	Tennessee	47
D.C.	11	Montana	30	Texas	48
Florida	12	Nebraska	31	Utah	49
Georgia	13	Nevada	32	Vermont	50
Hawaii	15	New Hampshire	33	Virginia	51
Idaho	16	New Jersey	34	Washington	53
Illinois	17	New Mexico	35	West Virginia	54
Indiana	18	New York	36	Wisconsin	55
Iowa	19	North Carolina	37	Wyoming	56
Kansas	20	North Dakota	38	Puerto Rico	72
Kentucky	21				

FIGURE 6-2-1
Station Description Record

Columns	Width	Description	Page
1	1	Record Type	6-2-1
2-3	2	FIPS State Code	6-2-1
4-9	6	Station ID	6-2-3
10	1	Direction of Travel Code	6-2-3
11	1	Lane of Travel	6-2-3
12-13	2	Year of Data	6-2-3
14-15	2	Functional Classification Code	6-2-4
16	1	Number of Lanes in Direction Indicated	6-2-4
17	1	Sample Type for Traffic Volume	6-2-4
18	1	Number of Lanes Monitored for Traffic Volume	6-2-4
19	1	Method of Traffic Volume Counting	6-2-4
20	1	Sample Type for Vehicle Classification	6-2-5
21	1	Number of Lanes Monitored for Vehicle Classification	6-2-5
22	1	Method of Vehicle Classification	6-2-5
23	1	Algorithm for Vehicle Classification	6-2-5
24-25	2	Classification System for Vehicle Classification	6-2-5
26	1	Sample Type for Truck Weight	6-2-6
27	1	Number of Lanes Monitored for Truck Weight	6-2-6
28	1	Method of Truck Weighing	6-2-6
29	1	Calibration of Weighing System	6-2-7
30	1	Method of Data Retrieval	6-2-7
31	1	Type of Sensor	6-2-7
32	1	Second Type of Sensor	6-2-8
33-34	2	Equipment Make	6-2-8
35-49	15	Equipment Model	6-2-9
50-51	2	Second Equipment Make	6-2-9
52-66	15	Second Equipment Model	6-2-9
67-72	6	Current Directional AADT	6-2-10
73-78	6	Matching Station ID for Previous Data	6-2-10
79-80	2	Year Station Established	6-2-10
81-82	2	Year Station Discontinued	6-2-10
83-85	3	FIPS County Code	6-2-10
86	1	HPMS Sample Type	6-2-10
87-98	12	HPMS Sample Number or Kilometerpoints	6-2-10
99	1	HPMS Subdivision Number	6-2-10
100	1	Posted Route Signing	6-2-11
101-108	8	Posted Signed Route Number	6-2-11
109	1	Concurrent Route Signing	6-2-11
110-117	8	Concurrent Signed Route Number	6-2-11
118-167	50	Station Location	6-2-11

3. Station Identification (Columns 4-9) - Critical

This field should contain an alphanumeric designation for the station where the survey data are collected. Station identification field entries must be identical in all records for a given station. Differences in characters, including spaces, blanks, hyphens, etc., prevent proper match. Right justify the Station ID if it is less than 6 characters. There should be no embedded blanks.

4. Direction of Travel Code (Column 10) - Critical

Do not combine directions. There should be a separate record for each direction. Whether or not lanes are combined in each direction depends on the next field.

Code	Direction
1	North
2	Northeast
3	East
4	Southeast
5	South
6	Southwest
7	West
8	Northwest

5. Lane of Travel (Column 11) - Critical

Either each lane is considered as a separate station or all lanes in each direction are combined.

Code	Lane
0	Data with lanes combined
1	Outside (rightmost) lane
2-9	Other lanes

Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. There should be one Station Description record per Station Code. Stations can be either by lane or with lanes combined by direction, but not both.

6. Year of Data (Columns 12-13) - Critical

Code the last two digits of the year in which the data were collected.

7. Functional Classification Code (Columns 14-15) - Critical

RURAL

Code	Functional Classification
01	Principal Arterial - Interstate
02	Principal Arterial - Other
06	Minor Arterial
07	Major Collector
08	Minor Collector
09	Local System

URBAN

11	Principal Arterial - Interstate
12	Principal Arterial - Other Freeways or Expressways
14	Principal Arterial - Other
16	Minor Arterial
17	Collector
19	Local System

8. Number of Lanes in Direction Indicated (Column 16)

Code the number of lanes in one direction at the site. Use "9" if there are more than eight lanes.

9. Sample Type for Traffic Volume (Column 17)

T = Station used for Traffic Volume Trends
N = Station not used for Traffic Volume Trends

10. Number of Lanes Monitored for Traffic Volume (Column 18)

Code the number of lanes in one direction that are monitored at this site. Use "9" if there are more than eight lanes.

11. Method of Traffic Volume Counting (Column 19)

1 = Human observation (manual)
2 = Portable automatic volume counting
3 = Permanent automatic volume counting (ATR/PTR)

12. Sample Type for Vehicle Classification (Column 20)

H = Station used for HPMS areawide form
N = Station not used for HPMS areawide form

13. Number of Lanes Monitored for Vehicle Classification (Column 21)

Code the number of lanes in one direction that are monitored for vehicle classification at this site. Use "9" if there are more than eight lanes.

14. Method of Vehicle Classification (Column 22)

1 = Human observation (manual) vehicle classification
2 = Portable automatic vehicle classification
3 = Permanent automatic vehicle classification

15. Algorithm for Vehicle Classification (Column 23)

Code the type of input and processing used to classify vehicles:

A = Human observation on site (manual)
B = Human observation of vehicle image (e.g., video)
C = Automated interpretation of vehicle image or signature (e.g., video, microwave, sonic)
D = Vehicle length bins
E = Axle spacing with ASTM Standard E1572
F = Axle spacing with Scheme F
G = Axle spacing with Scheme F modified
H = Other axle spacing algorithm
K = Axle spacing and weight algorithm
L = Axle spacing and vehicle length algorithm
M = Axle spacing, weight, and vehicle length algorithm
N = Axle spacing and other input(s) not specified above
Z = Other means not specified above

16. Classification System for Vehicle Classification (Columns 24-25)

The record formats are designed to be used for different classification systems. For example, HPMS and the Traffic Monitoring System for Highways (TMS/H) indicate cases in which fewer than 13 vehicle classes may be used. The following codes indicate the number of classes in the classification system (the class numbers in parentheses are from the FHWA 13 class system):

1 = One class: total volume
2 = Two classes: non-commercial (classes 1-3) and commercial (classes 4-13) vehicles
3 = Three classes: non-commercial (classes 1-3), single-unit commercial (classes 4-7), combination commercial (classes 8-13) vehicles
4 = Four classes: non-commercial (classes 1-3), single-unit commercial (classes 4 -7), single-trailer commercial (classes 8-10), multi-trailer commercial (classes 11-13) vehicles
5 = Five classes as follows:
  1 of 5 = two-axle, two or four-tire vehicles (classes 1-3)
  2 of 5 = buses (class 4)
  3 of 5 = single-unit trucks (classes 5-7)
  4 of 5 = single-trailer combination trucks (classes 8 -10)
  5 of 5 = multiple-trailer combination trucks (classes 11 -13)
13 = FHWA's 13 class system
14 = FHWA's 13 class system plus a class 14
15 = FHWA's 13 class system plus classes 14 and 15
Other numbers = number of classes

17. Sample Type for Truck Weight (Column 26)

B = Station used for TMG sample and LTPP sample
L = Station used for LTPP sample (not TMG sample)
T = Station used for TMG sample (not LTPP sample)
N = Station not used for any of the above

18. Number of Lanes Monitored for Truck Weight (Column 27)

Code the number of lanes in one direction that are monitored for truck weight at this site. Use "9" if there are more than eight lanes.

19. Method of Truck Weighing (Column 28)

1 = Portable static scale
2 = Chassis-mounted, towed static scale
3 = Platform or pit static scale
4 = Portable weigh-in-motion system
5 = Permanent weigh-in-motion system

20. Calibration of Weighing System (Column 29)

Code the method used to calibrate the weighing system, e.g., comparing weight-in-motion and weights from static scales.

A = ASTM Standard E1318
B = Subset of ASTM Standard E1318
C = Combination of test trucks and trucks from the traffic stream (but not ASTM E1318)
D = Other sample of trucks from the traffic stream
M = Moving average of the steering axle of 3S2s
S = Static calibration
T = Test trucks only
U = Uncalibrated
Z = Other method

21. Method of Data Retrieval (Column 30)

1 = Not automated (manual)
2 = Automated (telemetry)

22. Type of Sensor (Column 31)

Code the type of sensor used for traffic detection.

A = Automatic vehicle identification (AVI)
B = Bending plate
C = Capacitance strip
D = Capacitance mat/pad
E = Hydraulic load cells
G = Strain gauge on bridge beam
H = Human observation (manual)
I = Infrared
K = Laser/lidar
L = Inductance loop
M = Magnetometer
P = Piezo film
Q = Piezo cable
R = Road tube
S = Sonic/acoustic
T = Tape switch
U = Ultrasonic
V = Video image

W = Microwave
X = Radio wave
Z = Other

23. Second Type of Sensor (Column 32)

If there are two types of sensors at the station, code the second using the same codes as Type of Sensor. Otherwise, code "N" for none.

24. Equipment Make (Columns 33-34)

Code the equipment make of the main piece of equipment.

00 = Not automated (manual)
01 = Computer Automation
02 = Digital Equipment Corp.
03 = Fischer-Porter
04 = Howe-Richardson (Streeter)
05 = GK Instruments
06 = Golden River
07 = K-Hill
08 = Leupold-Stevens
09 = Model 170 controller
10 = M.P.H. Industries
11 = Safetran
12 = Sarasota
13 = State built
14 = Traffic Data Systems
15 = PAT Equipment Corp.
16 = Diamond Traffic Products
17 = 3M
18 = International Road Dynamics (IRD)
21 = Telac
23 = Time Lapse
24 = Jamar
30 = AT&T
31 = Autochem
32 = Aviar
33 = Bridge Weighing Systems
34 = Computer Recognition Systems
35 = Condition Monitoring Systems
36 = Data Acuisition, Inc. (DAI)

37 = Detector Systems
38 = Docal Associates
39 = Econolite Control Products
40 = Electronic Integrated Systems (EIS)
41 = Electronique Control Mesure (ECM)
42 = Eltec
43 = Northrop Grumman
44 = IDC Data Acquisition
45 = Indicator Controls Corp.
46 = Insight Vision Systems
47 = Microwave Sensors
48 = Midian Electronics
49 = Mikros Systems
50 = Mitron Systems Corp.
51 = Nu-Metrics Instrumentation
52 = Peek Traffic
53 = Philips Electronic Instruments Co.
54 = Progressive Engineering Tech. Corp.
55 = Schwartz Electro-Optics
56 = Snowy Mountain Engineering Corp.
57 = Sumitomo Electric Industries
58 = Timemark
59 = TITAN Research & Technology
60 = Toledo Scale
61 = Traficon
62 = Traffic Control Technologies
63 = Whelen Engineering
99 = Other not specified above

25. Equipment Model (Columns 35-49)

State the model name and number of the main piece of equipment. Abbreviate if necessary. Left justify.

26. Second Equipment Make (Columns 50-51)

If there is a second manufacturer, code in same manner as Equipment Make.

27. Second Equipment Model (Columns 52-66)

State the model name and number of the second piece of equipment, if any. Abbreviate if necessary. Left justify.

28. Current Directional AADT (Columns 67-72)

Code the most current AADT for the roadway on which the station is located.

29. Matching Station ID for Previous Data (Columns 73-78)

If the station replaces another station, give the previous station ID.

30. Year Station Established (Columns 79-80)

Code the last two digits of the appropriate year if known.

31. Year Station Discontinued (Columns 81-82)

Code the last two digits of the appropriate year if known.

32. FIPS County Code (Columns 83-85)

Use the three-digit FIPS county code (see Federal Information Processing Standards Publication 6, "Counties of the States of the United States").

33. HPMS Sample Type (Column 86)

Y = On an HPMS standard sample section
N = Not on an HPMS standard sample section

34. HPMS Sample Number or Kilometerpoints (Columns 87-98)

If the station is on an HPMS standard sample section, code the HPMS Sample Number per the HPMS Field Manual. If the station is not on an HPMS standard sample section, code the beginning and ending kilometerpoints with implied decimals as XXX.XXX and XXX.XXX.

35. HPMS Subdivision Number (Column 99)

For those stations located on an HPMS sample section that is subdivided, enter the appropriate subdivision number from 0-9 as assigned to this portion of the section for the HPMS submission. For stations not on an HPMS sample section, leave this column blank.

36. Posted Route Signing (Column 100)

This is the same as Route Signing in HPMS Field Manual.

<u>Code</u>	<u>Category</u>
1	Interstate
2	U.S.
3	State
4	County
0	Other

37. Posted Signed Route Number (Columns 101-108)

Code the route number of the principal route on which the station is located. If the station is located on a city street, zero-fill this field. This is the same as Signed Route Number in HPMS Field Manual.

38. Concurrent Route Signing (Column 109)

Code same as Posted Route Signing for concurrent route if there is one.

39. Concurrent Signed Route Number (Columns 110-117)

Code same as Posted Signed Route Number for concurrent route if there is one.

40. Station Location (Columns 118-167)

For stations located on a numbered route, enter the distance and direction of the station from the nearest major intersecting route or State border or landmark on State road maps. If the station is located on a city street, enter the city and street name. Abbreviate if necessary. Left justify.

ATR Station Description Records

As stated above, the Station Description record format may be used for traffic volume monitoring stations. However, the ATR Station Description (#1 record) may still be used for ATR stations. All of the information required for the ATR Station Description record is contained in the Station Description record. See Figure 6-2-2 and the referenced pages for the ATR Station Description record format.

FIGURE 6-2-2
ATR Station Description Record Format (#1 Record)

Column	Field Length	Alpha/ Numeric	Description	Page
1	1	N	Record Type: 1 = ATR Station	
2-3	2	N	FIPS State Code	6-2-1
4-5	2	N	Functional Classification Code	6-2-4
6-11	6	A	Station Identification	6-2-3
12	1	N	Direction of Travel	6-2-3
13	1	N	Lane of Travel	6-2-3
14	1	N	Posted Route Signing	6-2-11
15-20	6	N	Posted Signed Route Number	6-2-11
21	1	N	Concurrent Route Signing	6-2-11
22-27	6	N	Concurrent Signed Route Number	6-2-11
28-30	3	N	FIPS County Code	6-2-10
31-42	12	N	HPMS Sample Number or Kilometerpoints	6-2-10
43	1	N	HPMS Subdivision Number	6-2-10
44-45	2	N	Year Station Established	6-2-10
46-47	2	N	Year Station Discontinued	6-2-10
48	1	N	Method of Data Retrieval	6-2-7
49-50	2	N	Equipment Make	6-2-8
51-100	50	A	Location of Station	6-2-11

NOTES
All numeric (N) fields should be right-justified and zero-filled.
The Station Identification Code should be right-justified and zero-filled.
For the Lane of Travel field, the code for combined lanes (0) is preferred.
The Station Location field should be left-justified.

TRAFFIC VOLUME DATA FORMATS
(#3 Record)

The Traffic Volume file contains one record for each day of traffic monitoring. All numeric fields should be right-justified and zero-filled. Figure 6-3-1 summarizes the Hourly Traffic Volume record. The fields are as follows:

1. Record Type (Column 1)

   3 = Traffic volume record

2. FIPS State Code (Columns 2-3) - See page 6-2-1.

3. Functional Classification Code (Columns 4-5) - See page 6-2-4.

4. Station Identification (Columns 6-11) - See page 6-2-3.

   This should be right-justified and zero-filled.

5. Direction of Travel Code (Column 12) - See page 6-2-3.

6. Lane of Travel (Column 13) - See page 6-2-3.

   The code for combined lanes (0) is preferred.

7. Year of Data (Columns 14-15) - See page 6-2-3.

8. Month of Data (Columns 16-17)

   01 = January
   02 = February
   03 = March
   04 = April
   05 = May
   06 = June
   07 = July
   08 = August
   09 = September
   10 = October
   11 = November
   12 = December

9. Day of Data (Columns 18-19)

   Code the day of the month of data, 01-31. Must correspond to the month of data.

10. Day of Week (Column 20)

1 = Sunday
2 = Monday
3 = Tuesday
4 = Wednesday
5 = Thursday
6 = Friday
7 = Saturday

11-34. Traffic Volume Counted Fields (Columns 21-25, …, 136-140)

Enter the traffic volume counted during the hour covered:

Field	Hour Covered
11	00:01 am to 01:00 am
12	01:01 am to 02:00 am
.	.
.	.
.	.
34	11:01 pm to 12:00 midnight

35. Footnotes (Column 141)

0 = no restrictions
1 = construction or other activity affected traffic flow

FIGURE 6-3-1
Hourly Traffic Volume Record (#3 Record)

Column	Field Length	Alpha/ Numeric	Description	Page
1	1	N	Record Type	6-3-1
2-3	2	N	FIPS State Code	6-2-1
4-5	2	N	Functional Classification	6-2-4
6-11	6	A	Station Identification	6-2-3
12	1	N	Direction of Travel	6-2-3
13	1	N	Lane of Travel	6-2-3
14-15	2	N	Year of Data	6-2-3
16-17	2	N	Month of Data	6-3-1
18-19	2	N	Day of Data	6-3-2
20	1	N	Day of Week	6-3-2
21-25	5	N	Traffic Volume Counted, 00:01 - 01:00	6-3-2
26-30	5	N	Traffic Volume Counted, 01:01 - 02:00	6-3-2
31-35	5	N	Traffic Volume Counted, 02:01 - 03:00	6-3-2
36-40	5	N	Traffic Volume Counted, 03:01 - 04:00	6-3-2
41-45	5	N	Traffic Volume Counted, 04:01 - 05:00	6-3-2
46-50	5	N	Traffic Volume Counted, 05:01 - 06:00	6-3-2
51-55	5	N	Traffic Volume Counted, 06:01 - 07:00	6-3-2
56-60	5	N	Traffic Volume Counted, 07:01 - 08:00	6-3-2
61-65	5	N	Traffic Volume Counted, 08:01 - 09:00	6-3-2
66-70	5	N	Traffic Volume Counted, 09:01 - 10:00	6-3-2
71-75	5	N	Traffic Volume Counted, 10:01 - 11:00	6-3-2
76-80	5	N	Traffic Volume Counted, 11:01 - 12:00	6-3-2
81-85	5	N	Traffic Volume Counted, 12:01 - 13:00	6-3-2
86-90	5	N	Traffic Volume Counted, 13:01 - 14:00	6-3-2
91-95	5	N	Traffic Volume Counted, 14:01 - 15:00	6-3-2
96-100	5	N	Traffic Volume Counted, 15:01 - 16:00	6-3-2
101-105	5	N	Traffic Volume Counted, 16:01 - 17:00	6-3-2
106-110	5	N	Traffic Volume Counted, 17:01 - 18:00	6-3-2
111-115	5	N	Traffic Volume Counted, 18:01 - 19:00	6-3-2
116-120	5	N	Traffic Volume Counted, 19:01 - 20:00	6-3-2
121-125	5	N	Traffic Volume Counted, 20:01 - 21:00	6-3-2
126-130	5	N	Traffic Volume Counted, 21:01 - 22:00	6-3-2
131-135	5	N	Traffic Volume Counted, 22:01 - 23:00	6-3-2
136-140	5	N	Traffic Volume Counted, 23:01 - 24:00	6-3-2
141	1	N	Footnotes	6-3-2

VEHICLE CLASSIFICATION DATA FORMATS

The Vehicle Classification file contains one record for each hour with the traffic volume by vehicle class. The optional file naming convention is "ssyy.CLA" where ss is State postal abbreviation and yy is the last two digits of the year. Figure 6-4-1 summarizes the Vehicle Classification record.

Fields designated as Critical are required for entry into the VTRIS data base.

1. Record Type (Column 1) - Critical

   C = Vehicle classification record

2. FIPS State Code (Columns 2-3) - Critical - See page 6-2-1.

3. Station Identification (Columns 4-9) - Critical - See page 6-2-3.

4. Direction of Travel Code (Column 10) - Critical - See page 6-2-3.

5. Lane of Travel (Column 11) - Critical - See page 6-2-3.

   Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. There should be one Station Description record per Station Code.

6. Year of Data (Columns 12-13) - Critical - See page 6-2-3.

7. Month of Data (Columns 14-15) - Critical - See page 6-3-1.

8. Day of Data (Columns 16-17) - Critical - See page 6-3-1.

9. Hour of Data (Columns 18-19) - Critical

   Code the beginning of the hour in which the count was taken:

   00 = 0:01 a.m. to 1:00 a.m.
   01 = 1:01 a.m. to 2:00 a.m.
   .
   .
   .
   22 = 10:01 p.m. to 11:00 p.m.
   23 = 11:01 p.m. to Midnight

FIGURE 6-4-1
Vehicle Classification Record

Columns	Width	Description	Page
1	1	Record Type	6-2-1
2-3	2	FIPS State Code	6-2-1
4-9	6	Station ID	6-2-3
10	1	Direction of Travel Code	6-2-3
11	1	Lane of Travel	6-2-3
12-13	2	Year of Data	6-2-3
14-15	2	Month of Data	6-3-1
16-17	2	Day of Data	6-4-1
18-19	2	Hour of Data	6-4-1
20-24	5	Total Volume	6-4-3
25-29	5	Class 1 Count	6-4-3
30-34	5	Class 2 Count	6-4-3
35-39	5	Class 3 Count	6-4-3
40-44	5	Class 4 Count	6-4-3
45-49	5	Class 5 Count	6-4-3
50-54	5	Class 6 Count	6-4-3
55-59	5	Class 7 Count	6-4-4
60-64	5	Class 8 Count	6-4-4
65-69	5	Class 9 Count	6-4-4
70-74	5	Class 10 Count	6-4-4
75-79	5	Class 11 Count	6-4-4
80-84	5	Class 12 Count	6-4-4
85-89	5	Class 13 Count	6-4-4
		The record may end here if the FHWA 13 class system is being used.	
90-94	5	Class 14 Count	6-4-4
95-99	5	Class 15 Count	6-4-4

10. Total Volume (Columns 20-24)

This numeric field is the total traffic volume for the hour. The reason for it is that some vehicles might not be classified so the sum of the class counts might not equal the total volume. If this field is omitted, a "-1" or blanks should be entered here.

The following class count fields are numeric fields with the traffic volume by vehicle class for the hour of data. The number of classes is determined by the "Classification System for Vehicle Classification" field in the Station Description record for the station. The default classification system is the FHWA 13 class system (see Appendix A of Section 4).

These counts should be checked for reasonableness. For example, Class 13 shouldn't be larger than 99. VTRIS allows users to set a limit for each class count.

11. Class 1 Count (Columns 25-29) - Optional

Class 1 is for Motorcycles which is an optional class. If motorcycles aren't counted, put "-1" or blanks in the Class 1 field.

12. Class 2 Count (Columns 30-34) - Critical

Class 2 is for Passenger Cars.

13. Class 3 Count (Columns 35-39) - Optional

Class 3 is for Other Two-Axle, Four-Tire, Single-Unit Vehicles. However, classes 2 and 3 may be combined, in which case the total for both classes should be put in the class 2 field and "-1" or blanks in the Class 3 field.

14. Class 4 Count (Columns 40-44) - Critical

Class 4 is for Buses.

15. Class 5 Count (Columns 45-49) - Critical

Class 5 is for Two-Axle, Six-Tire, Single-Unit Trucks.

16. Class 6 Count (Columns 50-54) - Critical

Class 6 is for Three-Axle, Single-Unit Trucks.

17. Class 7 Count (Columns 55-59) - Critical

    Class 7 is for Four-or-More Axle, Single-Unit Trucks.

18. Class 8 Count (Columns 60-64) - Critical

    Class 8 is for Four-or-Less Axle, Single-Trailer Trucks.

19. Class 9 Count (Columns 65-69) - Critical

    Class 9 is for Five-Axle, Single-Trailer Trucks.

20. Class 10 Count (Columns 70-74) - Critical

    Class 10 is for Six-or-More Axle, Single-Trailer Trucks.

21. Class 11 Count (Columns 75-79) - Critical

    Class 11 is for Five-or-Less Axle, Multi-Trailer Trucks.

22. Class 12 Count (Columns 80-84) - Critical

    Class 12 is for Six-Axle, Multi-Trailer Trucks.

23. Class 13 Count (Columns 85-89) - Critical

    Class 13 is for Seven-or-More Axle, Multi-Trailer Trucks.

    The Vehicle Classification record may be ended here if exactly 13 classes are used. However, some automatic vehicle classification systems have one or two more classes usually designating "Unclassified" or "Unclassifiable" vehicles. If Class 14 and/or Class 15 are included such that the total of all the classes equals the total volume, then the Total Volume field may be left blank.

24. Class 14 Count (Columns 90-94) - Optional

    If a Class 14 is used, enter the count for the hour here.

25. Class 15 Count (Columns 95-99) - Optional

    If a Class 15 is used, enter the count for the hour here.

TRUCK WEIGHT DATA FORMATS

The Truck Weight file contains one record for each truck with its axle weights and spacings. The optional file naming convention is "ssyy.WGT" where ss is the State postal abbreviation and yy is the last two digits of the year. Figure 6-5-1 summarizes the Truck Weight record.

Fields designated as Critical are required for entry into the VTRIS data base.

1. Record Type (Column 1) - Critical

   W = Truck weight record

2. FIPS State Code (Columns 2-3) - Critical - See page 6-2-1.

3. Station Identification (Columns 4-9) - Critical - See page 6-2-3.

4. Direction of Travel Code (Column 10) - Critical - See page 6-2-3.

5. Lane of Travel (Column 11) - Critical - See page 6-2-3.

   Note: The Station ID, Direction of Travel, and Lane of Travel make up the Station Code. There should be one Station Description record per Station Code.

6. Year of Data (Columns 12-13) - Critical - See page 6-2-3.

7. Month of Data (Columns 14-15) - Critical - See page 6-3-1.

8. Day of Data (Columns 16-17) - Critical - See page 6-3-1.

9. Hour of Data (Columns 18-19) - Critical

   Code the beginning of the hour in which the count was taken:

   00 = 0:01 a.m. to 1:00 a.m.
   01 = 1:01 a.m. to 2:00 a.m.
   .
   .
   .
   22 = 10:01 p.m. to 11:00 p.m.
   23 = 11:01 p.m. to Midnight

FIGURE 6-5-1
Truck Weight Record

Columns	Width	Description	Page
1	1	Record Type	6-2-1
2-3	2	FIPS State Code	6-2-1
4-9	6	Station ID	6-2-3
10	1	Direction of Travel Code	6-2-3
11	1	Lane of Travel	6-2-3
12-13	2	Year of Data	6-2-3
14-15	2	Month of Data	6-3-1
16-17	2	Day of Data	6-3-1
18-19	2	Hour of Data	6-3-1
20-21	2	Vehicle Class	6-5-3
22-24	3	Open	6-5-3
25-28	4	Total Weight of Vehicle	6-5-3
29-30	2	Number of Axles	6-5-3
31-33	3	A-axle Weight	6-5-3
34-36	3	A-B Axle Spacing	6-5-4
37-39	3	B-axle Weight	6-5-4
40-42	3	B-C Axle Spacing	6-5-4
43-45	3	C-axle Weight	6-5-4
46-48	3	C-D Axle Spacing	6-5-4
49-51	3	D-axle Weight	6-5-4
52-54	3	D-E Axle Spacing	6-5-4
55-57	3	E-axle Weight	6-5-4
58-60	3	E-F Axle Spacing	6-5-4
61-63	3	F-axle Weight	6-5-4
64-66	3	F-G Axle Spacing	6-5-4
67-69	3	G-axle Weight	6-5-4
70-72	3	G-H Axle Spacing	6-5-4
73-75	3	H-axle Weight	6-5-4
76-78	3	H-I Axle Spacing	6-5-4
79-81	3	I-axle Weight	6-5-4
82-84	3	I-J Axle Spacing	6-5-4
85-87	3	J-axle Weight	6-5-4
88-90	3	J-K Axle Spacing	6-5-4
91-93	3	K-axle Weight	6-5-4
94-96	3	K-L Axle Spacing	6-5-4
97-99	3	L-axle Weight	6-5-4
100-102	3	L-M Axle Spacing	6-5-4
103-105	3	M-axle Weight... Additional fields if needed	6-5-4

Note: The number of axles determines the number of axle weight and spacing fields expected.

10. Vehicle Class (Columns 20-21) - Critical

Enter the class of the vehicle from FHWA Vehicle Classes 1 to 13. Classes 1 - 3 are ordinarily omitted.

A dummy vehicle class of -1 indicates that weight data for this hour is missing. A dummy vehicle class of 0 indicates that weight data for this hour is not missing, and thus if there are no Truck Weight records for the hour, then there were no trucks during that hour. Otherwise, it may be uncertain whether no Truck Weight records for an hour means the WIM system wasn't working.

11. Open (Columns 22-24) - Optional

This field is for special studies or State use such as for vehicle length or vehicle speed. For vehicle length put the overall length of the vehicle including any trailers to the nearest tenth of a meter (100 millimeters) without the decimal point. For vehicle speed use kilometers per hour.

12. Total Weight of Vehicle (Columns 25-28)

Enter the gross vehicle weight to the nearest tenth of a metric ton (100 kilograms) without a decimal point. This should equal the sum of all the axle weights except for rounding.

13. Number of Axles (Columns 29-30)

Enter the total number of axles in use by the vehicle (including any trailers).

The Number of Axles determines how many Axle Weight and Spacing fields will be expected. Axle Weight and Spacing fields which are not needed may be omitted. If a fixed-length record is desired, pad the record with blanks to the desired length.

The rest of the record alternates between axle weights and axle spacings starting from the front of the vehicle. Axle weights are to the nearest tenth of a metric ton (100 kilograms) without a decimal point. Axle spacings are to the nearest tenth of a meter (100 millimeters) without a decimal point.

Reasonableness checks should be performed on the axle weights and spacings. The default limits in VTRIS are 200 to 20,000 kilograms for axle weights and 0.5 to 15 meters for axle spacings. These may be adjusted by the user.

14. A-axle Weight (Columns 31-33)

15. A-B Axle Spacing (Columns 34-36)

16. B-axle Weight (Columns 37-39)

17. B-C Axle Spacing (Columns 40-42)

18. C-axle Weight (Columns 43-45)

19. C-D Axle Spacing (Columns 46-48)

20. D-axle Weight (Columns 49-51)

21. D-E Axle Spacing (Columns 52-54)

22. E-axle Weight (Columns 55-57)

23. E-F Axle Spacing (Columns 58-60)

24. F-axle Weight (Columns 61-63)

25. F-G Axle Spacing (Columns 64-66)

26. G-axle Weight (Columns 67-69)

27. G-H Axle Spacing (Columns 70-72)

28. H-axle Weight (Columns 73-75)

29. H-I Axle Spacing (Columns 76-78)

30. I-axle Spacing (Columns 79-81)

31. I-J Axle Spacing (Columns 82-84)

32. J-axle Weight (Columns 85-87)

33. J-K Axle Spacing (Columns 88-90)

34. K-axle Weight (Columns 91-93)

35. K-L Axle Spacing (Columns 94-96)

36. L-axle Weight (Columns 97-99)

37. L-M Axle Spacing (Columns 100-102)

38. M-axle Weight (Columns 103-105)

Additional fields may be added in the same manner if needed.