

# **Section 3**

## Traffic Volume Monitoring

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## **SECTION 3 TRAFFIC VOLUME MONITORING**

### **CHAPTER 1 INTRODUCTION**

The measurement of traffic volumes is one of the most basic functions of highway planning and management. Traffic volume counts provide the most commonly employed measure of roadway usage and are needed for the majority of traffic engineering analyses. While a number of traffic volume statistics are used in traffic engineering analyses, two are of primary interest for the design of a statewide traffic monitoring program: annual average daily traffic (AADT) and average daily vehicle distance traveled (DVDT).

AADT describes the number of vehicles that traverse a road at a specific point on the road system. DVDT describes the travel usage of an entire segment of roadway. DVDT is computed by multiplying the length of a roadway segment by its AADT. AADT is the primary traffic input to most traffic engineering analyses. DVDT is the primary measure for describing roadway usage for an entire system or network of roads.

The primary objective of this section is to describe how to structure statewide traffic monitoring programs to compute AADT and DVDT estimates.

#### **TRAFFIC VOLUME DATA COLLECTION**

For many years, the traditional approach to the development of annual average daily traffic (AADT) had consisted of three different but complementary types of traffic counts: continuous, control, and coverage (Federal Highway Administration 1970).

Continuous counts are taken 365 days a year at a small number of locations. These counts provide a variety of useful information. Because these counts are most consistent and are maintained at permanent locations, the FHWA summarizes the information in a monthly Travel Volume Trends (TVT) report.

Control or seasonal counts are much more difficult to characterize because different State planning organizations perform these counts differently. These counts are usually taken from two to twelve times a year, for periods of time ranging from 24 hours to two weeks. The main purpose of control counts was to help identify traffic patterns on specific roads in order to help place those roads into seasonal adjustment factor groups. Control counts can also be used to compute highly accurate measures of annual average daily traffic at specific locations, and are very effective in high growth or recreational areas. The 1985 version of the TMG did not utilize control counts for the development of grouping procedures or for AADT estimation.

Coverage counts are short duration counts, ranging from six hours to seven days, distributed throughout the system to provide point-specific information and area-wide coverage. Coverage count programs also vary considerably, as the diverse requirements and constraints faced by State highway agencies have translated into divergent programs. Many States have implemented coverage programs that feature relatively long (2 to 7 days) traffic counts, but where only a part of the State is counted every year. Other States have emphasized complete coverage of the highway systems each year, resulting in a large number of short duration (usually 24 or 48-hour) counts.

### **OBJECTIVES OF THE TRAFFIC VOLUME MONITORING PROGRAM**

The traffic monitoring program described in this section was designed to meet the following objectives:

- collect data needed by users as efficiently as possible (including both point estimates and summary variables derived from those point estimates)
- provide a mechanism for collecting data needed on “short notice” (that is, data that cannot be collected as part of a program planned six months or more in advance) as efficiently as possible, and ensure that these data are still made available to all users
- ensure that all reliable traffic data collected within the State highway agency are made available to users.

### **ORGANIZATION OF THIS SECTION**

The section consists of four chapters. Chapter 2 discusses the needs of users and the steps highway agencies should undertake in order to meet those needs. Chapter 3 presents a framework for collecting the traffic volume data needed to meet user requirements. It also discusses the data processing steps necessary to translate data into information. Chapter 4 presents a ramp counting technique that can be used to estimate traffic volumes on high volume freeway sections where portable traffic counters cannot be placed. Finally, an appendix answers frequently asked question about the design of traffic counting programs and/or the handling of traffic volume data.

## CHAPTER 2 USER NEEDS

The measurement of traffic volumes is one of the most basic functions of highway planning and management. Traffic volume counts are the most common measure of roadway usage, and they are needed as an input to the majority of traffic engineering analyses. A key to making the traffic monitoring process valuable to the highway agency's decision makers (a requirement for adequate funding for traffic monitoring) is the ability of the traffic monitoring program to supply users with the data they need. The ease of access to and the quality of the data provided directly affect the level of support users provide to the data collection activity. At the same time, the adage "you get what you pay for" is often true of traffic monitoring information. However, even with limited data collection budgets, good communication between data users and data collectors can result in data summaries that meet the needs, if not always the desires, of the data users.

This chapter discusses very briefly some of the uses that State agency personnel have for traffic data. It is intended to start the communication process by helping data collectors begin to understand how data may be used and, thus, what summary statistics are needed. Data collection personnel are encouraged to expand on this beginning by actively investigating the data needs of their agency and then working creatively to meet those needs.

### USES FOR TRAFFIC VOLUME DATA

A number of traffic volume statistics are used in traffic engineering analyses. The statewide traffic monitoring program concentrates on the estimation of annual average daily traffic (AADT) and then the computation of average daily vehicle distance traveled (DVDT) from that AADT value. In addition to VDT calculations, AADT is used in a wide variety of analyses such as calculating:

- exposure rates as part of safety analyses,
- vehicle loadings as part of pavement design,
- vehicle use as part of revenue forecasts
- statistics used by the private sector for placement of businesses and services.

AADT is not the only useful traffic volume statistic. Users commonly request a wide variety of other traffic volume statistics, and a good traffic monitoring program should collect, store, and report those additional statistics in order to meet those needs. In particular, whenever possible, **traffic monitoring programs should collect (at a minimum) hourly volumes by direction (and lane)** since these statistics are commonly used by analysts who must look at operational characteristics of the roadway at different times of the day. Examples of the uses of these lower aggregation volume statistics include:

- traffic signal timing
- air quality analysis
- noise analysis
- planning studies
- planning of the timing of maintenance activities.

To meet user needs, the highway agency should report, at a minimum, the following statistics:

- AADT,
- AAWDT, annual average weekday daily traffic (for roads where weekday traffic is more important than weekend traffic)
- peak hour volumes
- peak period volumes (where the highway agency must also define the duration and timing of the peak period)
- truck volumes and/or percentages (see Section 4)

Data users should also be able to easily obtain adjustment factors that apply to traffic counts taken at each location. These include:

- day-of-week factors
- seasonal adjustment factors
- axle correction factors, and
- growth factors.

All of these statistics can be measured or estimated using the data collection framework discussed in this section.

### **MEETING USER NEEDS**

Collection of data is only useful if those data are processed and the resulting summary statistics are made readily available to users. Users require access to these traffic data in a variety of forms, including both the summary statistics discussed above and the raw data collected from the field. Meeting user needs is further complicated by the fact that many data users are not familiar with the available data resources. Developing a mechanism that users can access to learn what data are available, and how those data can be obtained, is a key component for getting users to take advantage of data already collected by the highway agency.

These “data discovery” mechanisms are becoming more “user friendly” as computer technology and power continues to increase. Each State highway agency should use a fully computerized system to maintain its traffic monitoring data. This system should download data from the field, perform the necessary quality assurance checks to ensure that the data are valid, allow the data to be edited as necessary to remove

invalid data, summarize the raw data as appropriate, store the data, report the summary statistics, and allow retrieval of both summary and raw data as needed.

Many highway agencies link their traffic databases to other agency databases through geographic information systems (GIS) and other relational tools. GIS systems are particularly effective means for helping users identify and obtain available traffic information. New Internet technologies that allow remote access to GIS based traffic databases offer even wider distribution of collected traffic data, and can significantly increase the use and utility of traffic data collected by the highway agency. These tools allow users to determine the availability of traffic statistics and then access those data via simple interfaces. In addition, some States have developed CD-ROM based data distribution systems (Florida DOT) that allow users to obtain traffic statistics without having to have web access.

Routine reporting systems (and reports) should be part of this computerized process. Three key reporting capabilities are needed to meet FHWA traffic data requirements. These include the annual reporting of HPMS traffic statistics, the monthly transmittal of hourly ATR records (used to produce the monthly Traffic Volume Trends report), and the annual reporting of WIM data. The standard formats used to perform the ATR and WIM data transmittals are shown in Section 6. The HPMS Field Manual presents information on how to submit HPMS data.

Transmission of the HPMS sample data is particularly important since it is used for a variety of important national and State level analyses. HPMS is unique in that:

- all States collect the HPMS data,
- the HPMS sample design process is the same for all States maintaining national consistency,
- the HPMS database is reasonably comprehensive, and
- there are a number of significant analytical tools available for using the HPMS data.

The HPMS mileage and travel estimates are used in the apportionment of Federal-Aid funds. However, the HPMS data are also used in a number of key analytical tools. These include the HPMS analytical package, the Highway Economic Requirements System (HERS), and the ITS Deployment Analysis System (IDAS), as well as a host of State-specific planning and performance modeling systems.

Finally, all highway agencies require flexible output reporting capabilities in order to meet the wide variety of project level data needs. Traffic data are required to meet the specific analytical tasks associated with all manner of transportation engineering functions (planning, design, operations, maintenance.) In many cases, these analyses require only general statistics (AADT) collected as part of the general data collection program. However, other projects require access to the summary statistics described above, as well as raw data from the field, or special statistics designed to meet specialized project needs.



### CHAPTER 3

#### TRAFFIC VOLUME DATA COLLECTION DESIGN

Previous sections have presented general discussions of the need for a systematic approach to traffic counting in order to reliably account for traffic variability. This systematic approach also improves the statistical reliability of traffic estimates, and it allows integration of multiple traffic counting efforts into a more efficient system. The traffic volume data collection program presented in this section consists of three major elements:

1. a limited continuous count element,
2. an extensive coverage count element, and
3. a flexible special needs element.

This basic framework provides a flexible but comprehensive approach to traffic data collection that allows each highway agency to account for its individual needs and limitations, while providing a very robust data set to meet data user needs.

The procedures presented below are intended to help highway agencies refine their traffic volume data collection efforts to obtain both the system and point estimates they need as efficiently as possible. Although the proposed program does not make use of control or seasonal count programs, these counts can be included in an agency's special needs element, if those counts provide a cost effective means of meeting an agency objective.

In addition, highway agencies are encouraged to look for ways to obtain traffic volume information from a variety of sources to supplement data collected as part of the statewide monitoring program. In many highway agencies, more than one division of the agency collects traffic volume data. In many cases, not all of these data are stored in the central traffic database available to all data users. This often results in duplication of data collection efforts, as one division must collect data at a location where data have already been collected by another division. In many States, agencies other than the State highway agency collect traffic volume information. These groups may include toll authorities, other State regulatory or operating authorities (such as U.S. Customs), as well as local jurisdictions.

Obtaining traffic data already collected by these groups eliminates the cost of having to count those locations, helps foster a stronger working relationship between these diverse groups, and improves a State highway agency's knowledge of the use of its roadway system. As a result, the integration of the data collection efforts performed by different agencies and agency divisions is highly recommended.

## **SHORT DURATION VOLUME COUNTS**

Short duration traffic volume counts are traditionally the primary focus of most statewide traffic monitoring efforts. They provide the majority of the geographic diversity needed to provide traffic volume information on the State roadway system.

**The recommended short duration volume counting program is divided into two primary subsets, coverage counts and Special Needs counts.** The coverage count subset covers the roadway system on a periodic basis to meet both point-specific and area needs, including the HPMS reporting requirements. The Special Needs subset comprises additional counts necessary to meet the needs of other users. This second category of counts can be further subdivided into counts taken to meet State-specific statistical monitoring goals, to provide increased geographic coverage of the roadway system, and to meet the needs of specific project or data collection efforts.

This chapter also discusses the adjustment factors that must be applied to all short duration counts to develop unbiased estimates of annual average conditions. These adjustments include day-of-week, month, axle correction, and growth (to develop annual estimates for those road segments that are not counted during the current year).

### **Coverage Count Programs**

Coverage counts are needed to ensure that adequate geographic coverage exists for all roads under the jurisdiction of the highway authority. In simple terms, “coverage counts” are data collection efforts that are undertaken to ensure that “at least some” data exist for all roads maintained by the agency. How much data should be collected to provide “adequate geographic coverage” is a function of each agency’s policy perspective. Some State highway agencies consider “adequate” a week-long count every seven years with data recorded for every hour of each day. Others consider “adequate” a 24-hour count every year, with no hourly records. Obviously, significant utility can be gained from having at least hourly volume estimates at coverage counts, since that data can be used to obtain a much more accurate understanding of traffic volume peaks during the day.

The spacing between coverage counts in a roadway is also subject to agency discretion. The primary objective is to count enough locations on a roadway so that the traffic volume estimate available for a given highway segment accurately portrays the traffic volume on that segment. Generally, roadway “segments” are treated as homogenous traffic sections (that is, traffic volumes are the same for the entire segment.) For a limited access highway, this is true between interchanges. However, it is also true for all practical engineering purposes for a rural road where access and egress along a ten-mile segment is limited to a few driveways and low volume, local access roads. **Highway agencies are encourage to examine existing traffic volume information to determine how best to segment their roadway systems in order to optimize the number and spacing of coverage counts.** A rule of thumb that has been used in the past to define these traffic count segments is that traffic volume in each roadway segment be

plus or minus 10 percent. Breaking the system into very large segments reduces the number of counts needed but also the reliability of the resulting traffic estimates for any given section of that large roadway segment. Use of small segments increases the reliability of a specific count but also the number of traffic counts needed.

The character of the road systems and the volumes carried have a major impact in the definition of segments. For roads where access is controlled (such as the Interstate system), a simple definition of segments between interchanges is appropriate. For lower systems, clear traffic volume breaks are not always apparent and other rules of thumb (such as major intersections) must be applied. Rural and urban characteristics also require different handling. For the lowest volume roads, the 10 percent rule of thumb may be too narrow and a wider definition sought. Careful definition of roadway segments can significantly reduce the number of counts needed to cover all highways within an agency's jurisdiction, while still providing the accurate volume data required for planning and engineering purposes.

Once roadway segments are finalized, **the FHWA recommends, as a general rule, that each roadway segment be counted at least once every six years.** This ensures that reasonable traffic volume data are available for State needs, and that all roadway segments are correctly classified within the proper HPMS volume groups when State highway agencies compute statewide VDT as part of their required federal reporting.

Not all count locations should be counted on a six-year basis. Some count locations need to be counted more often. Other roads can be counted less frequently without loss of volume estimate accuracy. In general, roadway sections that experience high rates of growth require more frequent data collection than those that do not experience growth. Therefore, roads near growing urban centers and expanding recreational sites tend to need to be counted more frequently than roads in areas where activity levels have hardly changed for many years. Counting roads more frequently in volatile areas also allows the highway agency to respond with confidence to questions from the public about road use (a common concern in high growth areas), and ensures that up-to-date statistics are available for the roadway design, maintenance, and repair work that is common in high growth areas.

The coverage count data collection program itself can be structured in many ways. One simplistic approach is to randomly separate all of the roadway segments into unique sets and count one of these sets each year. However, this approach does not always lend itself to efficient use of data collection staff and equipment. Grouping counts geographically leads to more efficient data collection activity, but results in the need to account for the geographic bias in the data collected when computing annual average traffic statistics or looking at trends in traffic growth around the State.

In addition, most highway agencies collect data at some sites on a cycle shorter than six years. For example, more frequent counts (3-year cycle) are requested at HPMS sections, and most States count higher system roads more frequently as well. Still,

considerable flexibility is allowed in the structure of each agency's coverage count program.

### **The HPMS Volume Element**

The HPMS sample and universe sections are located within the traffic volume segments defined in the coverage count program. Traffic counts taken to meet the HPMS requirements are taken the same way as other short duration traffic volume counts. The main difference is that the HPMS has specified nationally standardized criteria for the collection and duration of the counts. The coverage count program meets the traffic data needs of the HPMS, but the HPMS has specified a 3-year cycle for the traffic count data. Whenever possible, coverage counts taken within a defined traffic count roadway section should be taken within an HPMS section.

**One third of the HPMS universe (NHS/PAS) and sample sections should be included in each current year coverage sample to ensure that at a minimum each of these HPMS universe/sample sections are counted once every three years.**

The HPMS traffic data collection system was designed as a statistical sample of locations to meet the HPMS volume stratification criteria to support the estimation of vehicle distance traveled. The HPMS data collection requirement has evolved into a combination of a universal count program for the National Highway System and the Principal Arterial system (that is, a count program in which every segment of the roadway is counted) and a statistical sample. In addition, traffic data is needed on all roadway sections not included in the HPMS data collection sample so that those sections can be accurately assigned to HPMS volume strata. This is necessary to develop expansion factors to expand HPMS sample counts into accurate estimates of statewide VDT, and to meet the many additional identified needs for AADT and VDT. Notice that the HPMS covers all roads in the State regardless of jurisdiction.

The above discussion does not imply that State highway agencies need physically count each HPMS sample location. There may be several HPMS sections within a State traffic count roadway segment. In many cases, State highway agencies rely on local jurisdictions to collect and report these data. In other cases, procedures such as "ramp balancing" can be used to estimate traffic volumes on roads where safety or equipment limitations do not allow portable counting. Permanent counters, classifiers, WIM sites, or ITS installations may also provide the traffic data.

The HPMS locations at which data should be collected have already been selected by each State. The latest Highway Performance Monitoring System Field Manual includes a complete description on how the HPMS sample sections were selected and how to periodically update those sample sections to maintain valid representation as the roadway systems change over time.

The primary HPMS strata are the functional classes of roadway<sup>1</sup> (Table 3-3-1), plus the further designation of rural, small urban, and urbanized areas. In addition, the functional classification strata are further subdivided by traffic volume group.

**Table 3-3-1**  
**Functional Classifications of Roadway**

<b>Functional Class</b>	<b>Reporting Code</b>
Rural Interstate	1
Rural Other Principal Arterial	2
Rural Minor Arterial	6
Rural Major Collector	7
Urban Interstate	11
Urban Other Freeways and Expressways	12
Urban Other Principal Arterials	14
Urban Minor Arterials	16
Urban Collector	17

**Duration of Short Count HPMS Traffic Monitoring Efforts**

While short duration traffic counts can be taken for anywhere from just a few hours to more than a week, this Guide **recommends a 48-hour monitoring period for traffic volume and vehicle classification.** The most common data collection time periods for traffic volume counts taken with conventional traffic counting equipment are 24 and 48-hour counts. The 48-hour counts are particularly important for the HPMS because common data collection periods from all States ensure similar levels of accuracy and precision for all volume data in the HPMS database.

In general, the longer the duration of the count, the more accurate the resulting estimate of AADT from the count. At the same time, the longer the count, the higher the cost. This is because fewer counts can be taken with a given number of automatic counters and because the staffing resources needed to place and retrieve counters cannot usually be used as efficiently. Consequently, the selection of a time period for monitoring requires trade-offs. This is a complex decision affected by many other considerations such as quality control procedures for the counts, the cycle (frequency with which counts are taken at the same location) for monitoring, cost of data collection, State characteristics such as size and the percentage of roads controlled by the State highway agency, the volume of roads being monitored, the availability and characteristics of traffic counting equipment, the characteristics of the locations being counted, the rate of traffic growth, and a variety of other data collection constraints.

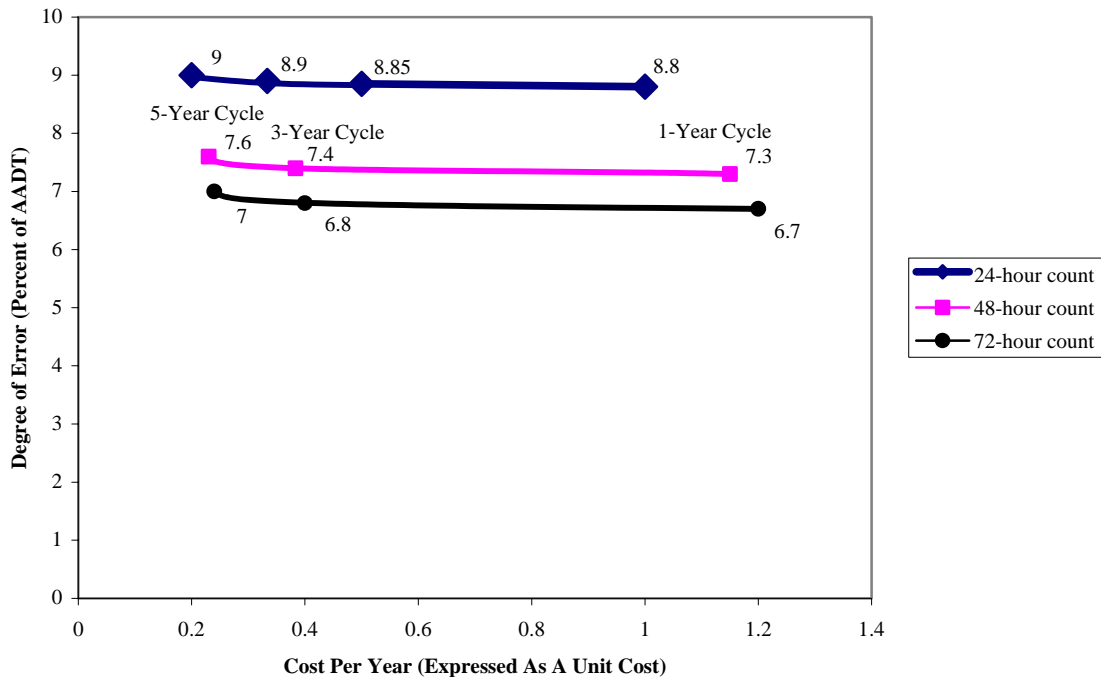
The recommendations offered are based on research conducted for the FHWA (Hallenbeck and Bowman 1984; Cambridge Systematics and Science Applications International 1994), work done by FHWA staff, reviews of existing State programs, and

<sup>1</sup> The HPMS sample does not include the lowest functional classes of roadway, rural minor collectors (reporting code 8), and functional system local roads (rural code 9 and urban code 19).

recent work that highlights the importance of quality control in the traffic data collection process. The recommendations assume that automatic monitoring equipment will be used to collect the volume data. In addition, **the use of equipment that record and report hourly volumes is recommended.** The hourly recording allows editing and quality control checks.

The recommendation of a 48-hour monitoring period is a compromise, given various alternatives, and is designed to maximize data validity subject to cost and equipment limitation constraints. Research has clearly shown that the magnitude of daily traffic variation is much larger than the long-term growth trend at most sites (Hallenbeck and Bowman 1984). Figure 3-3-1, from that report, compares cost versus precision for several alternatives ranging from 24-hour annual counts to 72-hour counts on a 5-year cycle. The implicit assumptions of this exhibit are discussed in the reference.

Not all research agrees with these conclusions. More recent work (Cambridge Systematics and Science Applications International 1994) shows that traffic variation at higher volume sites is much lower than estimated earlier. This supports the argument for shorter count duration in urban areas. However, higher levels of daily volume variation have been found in vehicle classification counts, where a combination of more variable traffic generation and the low volume of vehicles within vehicle categories make daily classification volumes much more variable.



**Figure 3-3-1: Relative Cost and Accuracy of Different Count Durations**

Location also plays a major role in the level of variability. Urban roads tend to have a much lower level of daily traffic variability than rural roads. Recreational areas have much higher levels of variability than non-recreational areas. Analysis of ATR locations shows standard deviations of 24-hour monitoring periods in the 2 to 25 percent range, depending on the location, volume, and time of year. For sites with higher levels of variability, if estimates of annual average daily traffic volumes are desired with better than 10 percent precision, a minimum of 48 hours must be counted. For sites with little traffic variability, a 24-hour count may be sufficient.

The use of longer periods of time reduces the cost-effectiveness of the program by reducing the number of counts per machine. The equipment being used is also important in that some sensors will not work reliably over long periods of time. For example, pneumatic tubes for collecting volume or classification information may not last longer than 48 hours without being reset on the pavement. Other equipment, such as inductance loop detectors buried in the pavement, to which data collection equipment are attached when desired, are not subject to these constraints.

One last consideration is the fact that longer duration counts allow the comparison of more than one data days. This is particularly valuable when hourly volume measurements for one day can be directly compared to hourly volume measurements for the next day. Comparison of consecutive days of traffic volume considerably improves the quality assurance process because it gives data collection staff confidence that the data collection equipment worked correctly throughout the data collection period. It also allows the identification of “unusual circumstances,” such as volume changes caused by accidents or special events that were not anticipated at the time the count was scheduled.

All of these arguments are offered in support of the 48-hour monitoring period recommendation. While this count duration may be slightly more than needed for some locations, it provides reliable data at most locations, regardless of how much is known about a given location’s current level of traffic variability. The basic objective of traffic monitoring programs and of the procedures recommended in this chapter is to collect reliable and unbiased information.

Individual State highway agencies may conclude that other traffic counting durations fit their needs more appropriately than the 48-hour recommendation. These agencies are encouraged to collect 48-hour counts for the HPMS sample whenever feasible but may select the count duration that best fits their own constraints for their coverage or special need counts. There may be clear circumstances where the use of shorter or longer periods of monitoring may be more effective. It is important to adequately explore, assess, and document these alternative options to ensure that all avenues have been considered and that the final decision is, indeed, responsive to the specific situation.

#### **Monitoring Cycle Specification**

**As discussed earlier, the TMG recommends a 3-year cycle for monitoring traffic volume for the HPMS submittal and a 6-year cycle for the coverage program.**

Analytical work performed for the FHWA indicated that, in the vast majority of locations, growth is far less of a factor than is daily variation in the measurement and accurate estimation of annual traffic volumes (Hallenbeck and Bowman 1984). The research determined that for many locations, a 48-hour count taken every three years would be a more cost-effective and reliable means of estimating AADT than an annual 24-hour count. The reason is that the daily variability of volume is in the 2 to 25 percent range while annual growth tends to be in the range of 1 to 4 percent.

Highway agencies may decide to collect traffic data more frequently at locations where traffic characteristics are rapidly changing, such as those affected by the opening of a new traffic generator (e.g., a shopping center) or completion of a new road project. Roads in growth areas can easily surpass the normally expected annual growth rates. Short duration counts adjusted to AADT are not very reliable in these situations. More frequent counts, longer periods, or control counting procedures are more effective in high growth or recreational areas.

Another concern is how far to extend the coverage cycle. If a 3-year cycle is better than a 1-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. However, the law of diminishing returns applies to the collection of traffic volume data. Three-year cycles produce a substantial cost savings, but on average, slightly less reliable estimates than those produced from annual cycles, all else being the same. Five-year cycles would further reduce the cost at an additional reliability penalty. However, errors due to growth tend to expand over time. For a 5-year cycle, the potential error from a compounded 2 to 3 percent average growth rate approach and exceed that from the daily volume variability.

An advantage of using a 3-year cycle instead of an annual cycle for the HPMS is that it reduces the annual counts. For example, establishing the precision levels on a 3-year cycle for the HPMS sections means that only one-third of the universe or sample sections need counting each year, thereby, reducing the annual effort by a factor of 3.

The issue is the selection of a consistent approach that will meet adequate reliability requirements in a reasonable, cost-effective manner. The conclusion reached was to recommend the use of a 48-hour period on a 3-year cycle for traffic volume and vehicle classification for the HPMS. There may be clear circumstances in which 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.

The TMG recommends that one third of all HPMS volume counts be taken each year of the 3-year cycle. Over the course of the 3-year cycle, all HPMS volume locations should be counted at least once. HPMS standard sample sections not counted during the current year must be reported as part of the HPMS submittal, and their AADT values should be expanded by using the growth factors described later in this chapter. In a perfect world, States should randomly select one third of the HPMS counts each year of



the 3-year cycle. Table 3-3-2 provides an example of how the counts required for strata containing three volume groups might be distributed.

The fact that specific count locations are allocated to a given year in the 3-year cycle does not restrict counting during the interim years at those locations. More frequent counting may have been done at any site for specific purposes such as monitoring volumes in a high growth area, for special events, or for projects. The AADT value derived from a current year count may be submitted to the HPMS in place of an earlier year count factored for growth. It should be clear that once a reliable count is taken at the HPMS section within the 3-year cycle, then a second count is not needed (as long as the initial count meets the requirements of the HPMS), but if a more recent count is available then it can be used. The process of integrating the various count programs is intended to identify and as much as possible eliminate duplication and to make use of the best available data for all purposes. Table 3-3-2 presents an example showing how HPMS sections can be subdivided into 3-year counting cycles.

**Table 3-3-2**  
**Distribution of HPMS Sample over 3-Year Cycle**

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
		<b>Total</b>	213	71	71	71

For the coverage program, the recommendation is to carry it out over a 6-year cycle. The main consideration is to provide a basic count for each section on a periodic basis to cover data needs. State programs vary in their application of system coverage from complete annual coverage each year to several years in between. It is also likely that the coverage cycle will vary depending on the functional system covered and that the longer cycles will be used for the lower systems.

Coverage counts ensure that “at least some” data exist for all roads. The amount of data needed to provide “adequate geographic coverage” is a function of each agency’s policy perspective. Some State highway agencies consider “adequate” to be a 7-day count every seven years, with data recorded for every hour of each day. Others consider “adequate” to be a 24-hour count every year, with no hourly records. Each agency must determine adequate coverage itself, given available funding for data collection, the extent of the highway system, and the uses for which the data are intended.

For the higher systems, a shorter cycle of 3 years, or even an annual cycle may be more appropriate given the data needs. Since these systems are covered fully by the

HPMS universe, the 3-year cycle described earlier for the HPMS applies. Likewise, in cases where ITS systems provide the data or where continuous counts and short ramp counts are used, annual cycles are common.

For the lower functional systems, longer cycles may be applicable, particularly in areas that change very little over time. However, areas do change and very old counts are always questionable resulting in more frequent recounting. The general 6-year cycle recommendation is designed to maintain a reliable data and information source throughout the system. States have to consider their highway systems, the traffic characteristics, the traffic data programs, the resources available, and the needs before making an appropriate judgment. The decision should also include a consideration of the special needs program since more reliable and frequent coverage counting will reduce the need for special counts.

### **Timing of the HPMS Counts**

If HPMS counts were only used to estimate annual average daily vehicle distance traveled, it would be possible to randomly schedule each year's HPMS data collection effort and eliminate the day-of-week, month, and growth adjustments discussed later in this chapter. Unfortunately, two constraints prevent the use of a true temporal random sample approach to HPMS count scheduling.

The first constraint is that HPMS data are used for a wide variety of analyses in addition to statewide VDT estimation. AADT is the basic traffic characteristic required by the HPMS. For many analyses, it is vital that each HPMS section include an unbiased estimate of annual traffic volume.

The second concern is that a truly random sample of data collection times and locations results in a very inefficient use of data collection personnel. In many cases, it is not possible to collect short duration counts simply because of weather and many other conditions.

While a random sample of data collection times for each of the HPMS counts has merit, it is not recommended. Instead, **this Guide recommends that the HPMS short duration counts be fully integrated with the agency's coverage count program.** This means using the same personnel, procedure, equipment, and counting schedule used for coverage and other traffic counts.

This recommendation is likely to cause the data collection effort to be skewed both temporally and geographically. In order to use staff and equipment efficiently, most highway agencies collect data by region, county, or area. For example, all counts that need to be taken in the Southwestern part of the State may be collected in May. In addition, most highway agencies do not collect short count data on weekends except for special studies. Concentrating counts geographically and temporally reduces the travel time and distance between counts, resulting in more efficient use of staff and equipment. Counting only on weekdays results in a better working environment for data collection staff.

Unfortunately, the problem with concentrating counts in this manner is that geographic and temporal biases are easily inserted into the data set. That is, if all counts in the southwestern part of a State are taken in May and bad weather occurs in May (reducing traffic levels there, but not in other places), then the traffic volume statistics will be biased downward. Similarly, if counts are never taken on weekends, the differences between weekend and weekday travel are never accounted for by the short counts.

As a result, the temporal/geographic biases that are created by concentrating the counts must be completely counteracted by the adjustment factors. Theoretically, the statewide adjustment process accounts for both seasonal and temporal biases, but it is not likely to cover smaller regional or temporal effects. Highway agencies should be aware of the potential for geographic and temporal bias when scheduling counts, and counteract it by devising strategies to distribute counts as much as feasible.

### **Special Needs Counts**

The HPMS standard sample meets the need for computation of a statistically reliable measure of statewide travel. The data collected also cover many highway agency needs. However, there remain traffic data needs that cannot be met by the coverage count program. This is where an effective coverage program supplemented by special counts can substantially fill the gap.

Non-HPMS data needs vary dramatically from State to State and from agency to agency. Some State highway agencies are responsible for almost all road mileage in their State. Other State highway agencies control, operate, and maintain only the largest, most inter-regional facilities. Some States must meet strict reporting requirements (by jurisdiction) adopted by their legislatures. Others have relatively few mandatory reporting requirements and, instead, focus on collecting data that meet particular, changing agency priorities. In some extreme cases, agencies are prohibited by law from expending resources outside of their areas of responsibility.

A consequence of this variety of traffic data needs is that no single traffic monitoring program design fits all cases. Therefore, **the philosophy of the Special Needs element is to provide highway agencies wide flexibility to design this portion of their monitoring program in accordance with their own self-defined needs and priorities.** The guidance in this report is intended to provide highway agencies with a framework within which they can ensure that they collect the data they need.

The Special Needs portion of a data collection program can be divided into two basic portions:

- statistical samples for developing system wide summary measures, and
- point-specific estimates intended to meet project requirements and other studies defined by the highway agency.

### **Statistical Samples in the Special Needs Program**

Statistical samples such as the HPMS are the most efficient ways to estimate population means and totals. Most statistical samples involve the collection of data at randomly selected locations to compute unbiased estimates of population means and totals. Random sampling is a very efficient mechanism for computing these totals.

A variety of texts are available on the design of samples. “Sampling Techniques” (Cochran 1977) is one such standard text. The HPMS Field Manual provides a description of how the HPMS sample was developed and implemented. These documents are useful in helping design a sampling program to meet objective needs. The keys to successfully designing a statistical sampling plan are defining the objectives, understanding the variability of the data being sampled, having a clear understanding of what statistics should be computed, and establishing the accuracy and precision of the estimates. Any statistical samples developed should, as much as possible, make use of the available data from the coverage element to minimize the duplication of effort. One possible use of statistical samples is to estimate VDT for the local functional systems, where extensive mileage makes the collection of traffic data very costly.

### **Point Specific Estimates in the Special Needs Program**

Unfortunately, the random selection of count locations required by most statistical samples is an inefficient mechanism for meeting many site-specific traffic data needs. For example, an “uncounted” roadway section is not a major concern for HPMS because the sample expansion process represents all road sections in the statewide VDT estimation. However, if pavement needs to be designed for that section of roadway, a statewide average or total is not a substitute for one or many traffic counts specific to that road section.

Consequently, data needs require agencies to collect data at locations that are not part of the coverage program. However, by maximizing the use of available data, it is possible to keep the number of these “special” counts to a minimum and to save resources for other data collection and analysis tasks. No additional data should be collected if existing data meet the desired need.

Special counts are generally required for specific project needs. Project counts are undertaken to meet the needs of a given study (for example, a pavement rehabilitation design or a specific research project). They cover a range of data collection subjects and are usually paid for by project funds. Project counts are traditionally taken on relatively short notice, and they often collect data at a greater level of detail than for the coverage or the HPMS parts of the program. Often, the need is not realized until after a project has been selected for construction, and insufficient time exists by that date to schedule the project counts within the regular counting program. However, where it is possible to include project counts within the regular count program’s schedule, significant improvements in staff utilization and decreases in overall costs can be achieved.

There are many different types of counts that can fall within the special needs element. Counts are taken by many public and private organizations for many purposes

including intersection studies, signal warrants, turning movements, safety analysis, and environmental studies. As much as possible, these activities should be coordinated within the program umbrella.

In general, roadway sections that experience high rates of growth and recreational areas require more frequent counting than those that do not experience growth. Counting roads frequently in volatile areas allows the highway agency to respond with confidence to questions from the public about road use (a common concern in high growth areas), while also ensuring that up-to-date statistics are available for the roadway design, maintenance, and repair work that is common in high growth areas. Many agencies prefer the use of several counts a year to better understand the traffic variability inherent in high growth. Likewise, recreational roads usually experience major traffic peaking at specific times necessitating frequent information.

High growth areas (if not necessarily roads with high volume growth) can usually be selected on the basis of knowledge of the highway system and available information on the construction of new travel generators, highway construction projects, requirements for highway maintenance, applications for building permits, and changes in population. Recreational areas are also well known to experienced transportation professionals.

### **Coordinating the Coverage and Special Needs Counts**

Cost efficiency in the traffic monitoring program is best achieved by carefully coordinating the different aspects within the program. This includes both permanent and short duration counts. It also includes the coverage, HPMS, and special needs counts.

In theory, the highway agency would start each year with a clear understanding of all of the counts that need to be performed. The list could then be examined to determine whether one count could be used for more than one purpose. For example, a classification count at one Interstate milepost might easily provide the data required for both that count and a volume count required at the next milepost, since no major interchanges exist between those mileposts. By careful analysis of traffic count segments, location, and data requirements; it is often possible to significantly reduce the total number of counts required to meet user needs.

The next step is to compare the reduced list of count locations with locations covered by permanent counters (volume, classification, weight, and ITS). Permanent counter locations can be removed from this list, and the remaining sites are the locations that require short duration counts. These locations should then be scheduled to make best use of available staffing and resources.

To make this scenario work, it is necessary to understand not just where data must be collected, but the kinds of data that need to be collected. This can be difficult to do because some requirements, such as those for project counts, are not identified until after the count schedule has been developed. Many project count locations and project count needs can be anticipated by examining the highway agency's priority project list and from knowledge of previous requests for data. Project lists detail and prioritize road

projects that need to be funded in the near future, normally including road sections with poor pavement that require repair or rehabilitation, locations with high accident rates, sections that experience heavy congestion, and roadways with other significant deficiencies. While priority lists are rarely equivalent to the final project selection list, high priority projects are commonly selected, analyzed, and otherwise examined. Making sure that up-to-date, accurate traffic data are available for these analyses helps make the traffic database useful and relevant to the data users and increases the support for maintenance and improvements to that database.

### **Adjustments to Short Duration Volume Counts**

Short duration volume counts usually require a number of adjustments in order to convert a daily traffic volume "raw" count into an estimate of AADT. The specific set of adjustments needed is a function of the equipment used to collect the count and the duration of the count itself. **Almost all short duration counts require adjustments to reduce the effects of temporal bias, if those short duration counts will be used to estimate AADT.** In general, a 24-hour, axle count, is converted to AADT with the following formula:

$$AADT_{hi} = VOL_{hi} * M_h * D_h * A_i * G_h \quad (3-1)$$

where

- $AADT_{hi}$  = the annual average daily travel at location  $i$  of factor group  $h$
- $VOL_{hi}$  = the 24-hour axle volume at location  $i$  of factor group  $h$
- $M_h$  = the applicable seasonal (monthly) factor for factor group  $h$
- $D_h$  = the applicable day-of-week factor for factor group  $h$  (if needed)
- $A_i$  = the applicable axle-correction factor for location  $i$  (if needed)
- $G_h$  = the applicable growth factor for factor group  $h$  (if needed).

This formula is then modified as necessary to account for the traffic count's specific characteristics. For example, if the short duration count is taken with an inductance loop detector instead of a conventional pneumatic axle sensor, the axle correction factor ( $A_h$ ) is removed from the formula. Similarly, if the count is taken for seven consecutive days, the seven daily volumes can be averaged, substituted for the term  $VOL_{hi}$ , and the day-of-week factor ( $D_h$ ) removed from the equation. Lastly, growth factors are only needed if the count was taken in a year other than the year for which AADT is being estimated.

### **Seasonal (Monthly) Factors**

Monthly factors are used to correct for seasonal bias in short duration counts. Directions on how to create and apply monthly factors are provided in the previous chapter on Continuous Counts, and in the general discussion of factoring in Chapter 4 of Section 2. Those procedures are recommended for the HPMS reporting. States may choose to select alternative seasonal adjustment procedures if they have performed the analytical work necessary to document the applicability of their chosen procedure.

### **Day-of-Week Factors**

Day-of-week factors are needed to estimate AADT if the period of monitoring for a short duration count does not account for the differences in travel by day of week. These factors can be computed and applied independently from the seasonal adjustment factors, or they can be combined into the seasonal adjustment factors (Wright and Hu 1994).

In either case, data from the continuous ATR program must be used to develop the day-of-week factors. These factors should be developed for the same factor groups used for seasonal analysis, but each State should examine its own data to determine whether these groups are homogeneous with respect to day-of-week travel. If day-of-week factors are integral to the seasonal adjustment, this examination will be carried out as part of the factor group creation process. If significant differences are detected, either new seasonal factor groups should be developed, or a separate “grouping process” will be needed specifically for the application of day-of-week adjustments.

Considerable flexibility is given in the creation of day-of-week factors. The report by Cambridge Systematics and Science Applications International (1994) showed that any one of several common approaches to day-of-week factoring yields roughly equivalent results in terms of the expected accuracy of the AADT estimate. Factors may be computed on an individual basis (seven daily factors) or as combined weekday (Monday, Tuesday, Wednesday, and Thursday) and weekend (Friday, Saturday and Sunday) factors. These factors can be combined with the monthly seasonal adjustment, or treated as separate adjustments. Finally, separate day-of-week adjustments can be computed for each month (i.e., 84 factors computed for the year), or a single set of factors can be applied throughout the year.

State highway agencies should select among these varied alternatives on the basis of how these procedures best fit their specific roadway usage conditions. (For example, a mid-western State with Interstate highways heavily influenced by through-traffic might choose to adopt seven day-of-week factors for each month. This is because through-traffic is unlikely to follow the traditional weekday/weekend pattern of an urban area, and that pattern might change as economic conditions change elsewhere in the country. A northeastern State that is primarily urban/suburban might choose to incorporate the day-of-week adjustment into its seasonal factor and treat it as a simple weekday/weekend adjustment. This is because its traffic is heavily dominated by urban/suburban traffic patterns, which tend to be consistent from weekday to weekday.)

Adequate documentation should be maintained to support the decisions made and to allow future reexamination of those decisions as experience is gained with the factoring process.

### **Axle Correction Factors**

The application of axle correction factors is dependent on the type of equipment in use. Equipment that detects vehicles directly (such as inductance loops or vehicle classification counters), do not require axle adjustment. However, the preponderance of

data collection equipment dependent on pneumatic tubes actually counts axles rather than vehicles. To represent vehicles, counts taken by axle counting equipment require adjustment by axle correction factors. In general, the higher the percentage of multi-axle vehicles on a road, the more significant the need for axle correction factors.

Axle correction factors can be applied at either the point or system level. That is, axle correction factors can be developed either from specific vehicle classification counts at specific locations, or from a combination of vehicle classification counts averaged together to represent an entire system of roads.

Because truck percentages (and consequently axle correction factors) change dramatically from road to road, even within functional classes and HPMS strata, **this Guide recommends that axle correction factors be developed for specific roads, from vehicle classification counts taken on that road whenever possible.** Where possible, the axle correction factor applied to an axle count should come from a classification count performed nearby, on that same road, and from a vehicle classification count that was taken during the same approximate period as the volume count. For roads where these adjustment factors are not available, a “system wide” factor is recommended. The “system wide” factor should be computed by averaging all of the axle correction factors computed in the vehicle classification count sample within a functional classification of roads. Where State highway agencies have developed a “truck route” classification system, this classification system may be substituted for the functional class strata.

A methodology for computing axle correction factors is given in Chapter 4 of Section 4.

### **Growth Factors**

Available research does not reach a definitive conclusion about the “best” mechanism for computing growth factors for application to AADT estimates from previous years (Cambridge Systematics, Volume I, 1994).

Growth factors at a particular point can be best estimated when a continuous ATR is available, assuming that the ATR data is reliable and that the differences found from year to year can be attributed to growth. However, it is well known that volumes at a single point can be affected by a variety of extraneous factors, and thus growth factors computed from the limited number of ATRs operated by a State highway agency can be easily biased.

Growth factors can also be developed from the short duration counts. The individual estimates of AADT at these locations are not nearly as accurate as those available at an ATR. However, because of the large number of volume counts, and the wide geographic distribution of those counts, the potential for bias from the use of ATRs is significantly reduced. In addition, if the same count locations are used continually over time to compute growth, errors at any one given location due to the inaccuracy of the AADT estimate are self-correcting. That is, if this year’s AADT count is too high,



making this year's growth estimate too high, next year's "correct" AADT value will cause a much lower growth estimate to be computed, resulting in a more reliable growth estimate over time.

The use of the AADT at HPMS sample locations also allows the computation of region-specific growth factors. Many States have VDT growth rates that differ dramatically from one region to another. The large number of HPMS sample locations means that in most cases, a large sample of data sites will exist within each region. Thus, region-specific growth factors can be developed.

The point of the above discussion is to emphasize that there is not a best procedure that is 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.

### **Annual Vehicle Distance Traveled (AVDT) Estimation**

The HPMS procedures for developing daily vehicle distance traveled (DVDT) rely on the standard HPMS sample expansion. The first step is to compute an AADT estimate for each HPMS section. Next, the section AADT is multiplied by the section length to compute section-specific DVDT. These are then summed for an entire stratum and multiplied by the HPMS stratum expansion factor to compute DVDT. Aggregate estimates at any stratification level (volume group, functional class, area type, statewide, or other combinations of these) can be derived by summing the DVDT of the appropriate strata. 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 computed by multiplying any resulting DVDT estimate by 365. Estimates of DVDT or AVDT for specific HPMS vehicle classes can be derived by multiplying DVDT strata figures by the appropriate percentages derived from the vehicle classification counts and aggregating to the strata totals as done for volume.

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

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

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  $h$   
 $L_{hi}$  = length of section  $i$  in stratum  $h$ .

This equation is presented on page 155 of “Sampling Techniques” (Cochran 1977). A complete discussion of ratio estimation procedures is included in the reference. The estimates produced by this process are conservative since the errors introduced by using the factors to develop AADT estimates have been ignored. The assumption is that these errors are normally distributed and therefore will cancel out when aggregated. The equation shows that 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.

As a rule of thumb, the precision of statewide DVDT estimates (excluding local functional class) are expected to approximate  $\pm 5$  percent with 95 percent confidence, although the analysis assumed that the AADT values reported were exact. Because of this assumption, precision estimates are conservative. Computation of annual DVDT estimates with the complete HPMS standard sample by expanding the AADT from each HPMS standard sample would be expected to approximate the stated precision.

The HPMS standard sample sizes were defined in terms of AADT within strata (described in the HPMS Field Manual). 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 “Sampling Techniques” (Cochran 1977). In an early HPMS study, the precision of statewide estimates of Interstate DVDT to approximated  $\pm 2$  to 3 percent with 95 percent confidence, but these results considered only sampling variability and ignored error introduced by equipment or the factoring process used to estimate sample section AADT.

### **Other Data Collection and Processing Considerations**

Many concerns must be addressed when a traffic monitoring program is established. Only some of the most salient considerations are addressed here. So far, no mention has been made of the 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 traffic volume and vehicle classification data collection.** This allows examination of other concerns such as peak-hour volume and design-hour factors. **For special analysis, urban location data may be desired in 15-minute intervals.** Although the TMG recommends the use of 48-hour periods for short counts, 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 standardize the coverage program on an hourly basis (equipment permitting). This allows other related concerns to be addressed, such as peak-hour periods or traffic conditions during specific hours, and provides sufficient records to detect equipment malfunctions or to help edit periods that are missing because of equipment malfunction.

Counts missed because of equipment failures, bad weather, or other reasons should be made up during the year. Partial counts of less than 24 hours should, as a general rule, be retaken. Abnormal situations such as major construction, etc., should be handled according to the judgment of the responsible staff. 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 of 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 databases.

### **THE CONTINUOUS COUNT ELEMENT**

All State highway agencies (and many local highway agencies) operate continuous count programs. These programs tend to have strong historical ties and usually supply much of the basic planning data used by those agencies. Continuous traffic volume counters are so widespread that many States now operate several different continuous count programs, sometimes without realizing it. Not all of these programs currently supply data that are actively used as part of the traffic monitoring program, although many of the data could be used for these purposes.

These ATR counters are most commonly operated by, or in conjunction with, the agency planning office. They are used to collect data that provide the seasonal, day-of-week, and time-of-day adjustments needed to convert short duration traffic volume counts into estimates of AADT. They are also used to accurately monitor traffic trends at a small number of locations in each State.

In addition, State highway agencies need to realize that a number of other permanent, continuously operating data collection devices may also exist that can collect continuous traffic count data and provide these same statistics. These devices are being installed and operated by different groups for entirely different purposes. For example, modern traffic control and management systems require continuous monitoring of traffic volumes and speeds. Automated weight enforcement sites also tend to involve monitoring of traffic volumes continuously throughout the year. These systems are not primarily intended to serve as ATRs, but they collect all of the data required from ATRs and can be used to supplement the existing ATR program.

Because all States already operate ATR programs, and because the existing continuous count equipment is expensive to move and/or significantly expand, the emphasis is to review existing continuous count programs in order to refine their performance for more accurate and cost effective operation.

Refining the continuous count program consists of the following tasks:

- defining the objectives of the continuous count program
- reviewing the existing continuous count program
- developing an inventory of the available continuous count locations and equipment
- determining the traffic patterns that need to be monitored by examining the seasonality in the State's traffic
- establishing seasonal pattern groups
- determining the appropriate number of count locations in each group, and
- selecting specific count locations.

Also discussed below are how to compute seasonal adjustment factors and the need to develop analytical procedures that meet the needs of the agency's data users.

### **Objectives of the Continuous Count Program**

The objectives of continuous ATR programs are many and vary from State to State. ATRs can be used to develop adjustment factors. They can be used to track traffic volume trends on important roadway segments. They can be used to provide inputs to traffic management and traveler information systems.

The number and location of the counters, the type of equipment used, and the analysis procedures used to manipulate data supplied by these counters are functions of these objectives. As a result, it is of the utmost importance for each organization responsible for the implementation of the continuous ATR program to establish, refine, and document 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 TMG assumes that **the development of seasonal factors to expand short-term counts to annual average daily traffic (AADT) is the primary objective of the continuous ATR program, and this is the objective that should carry the most weight in establishing the number and location of ATR sites operated by the state highway agency.** Secondary objectives include the following:

- ATRs provide peak hour, 30<sup>th</sup> highest hour, and directional distribution data used by traffic forecasters and roadway designers.
- ATRs track volume trends on specific roadway sections on the State highway system.
- ATRs are dispersed geographically to understand geographic differences in travel trends.

- ATRs are directly integrated with the HPMS volume sample.
- ATRs collect data on roadway sections where it is not possible, or is prohibitively expensive, to collect data with portable counters.
- The number of ATRs installed and operated by the highway agency is minimized to the extent possible in order to contain the cost of the ATR program.

These additional objectives can be met by refining the preliminary ATR locations. It is obvious that some objectives are better served by increasing the number and diversity of ATR locations. Other objectives are better served by minimizing the number of ATR locations. This conflict between primary objectives requires careful analysis within each State highway agency. Each agency will need to develop its own balance between having larger numbers of ATRs (increasing the accuracy and reliability of the analyses that depend on the data supplied by those counters) and reducing the expenditures required to operate and maintain those counters. The TMG recommendations provide highway agencies sufficient flexibility for each agency to find the appropriate compromise between objectives.

When determining the balance point, the primary objectives of the permanent counter programs should be statewide in nature, and the initial focus of the ATR program should reflect this statewide perspective<sup>2</sup>. As a result, the initial ATR program should be developed to meet the minimum requirements of the State highway agency for factor development. Sub-area and road specific data collection needs should be secondary considerations in the design of the ATR program as desired by the appropriate agency.

Consequently, the TMG recommends that the State highway agency division responsible for factor development operate, at least, the minimum number of ATR locations needed to meet the accuracy and reliability requirements of the factoring program. Expansion of the data available through the ATR program should come from other available count programs. That is, data available through continuous count programs such as advanced traffic management systems and WIM programs, where the funding for the installation and operation of the counters comes from other sources, should be used to supplement and expand the ATR database. This will allow expansion of the database provided by the ATR program while minimizing the cost of the total data collection process.

Note, however, that while the cost of equipment installation and operation of these supplemental ATR programs is the responsibility of those other programs, the statewide monitoring division should be responsible for making these data available to users. Determining how best to obtain, summarize and report these data is an issue that can only be addressed at the State level.

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<sup>2</sup> Local agencies are not affected by this same constraint, although local agencies can substitute “area” for “State” the primary goal of their ATR program is to develop region specific adjustment factors.

### **Review the Existing Continuous Count Program**

The first step in refining the ATR system is to define, analyze, and document the present continuous ATR program. A clear understanding of the present program will increase confidence in later decisions to modify the program. The review should explore the historical design, procedures, equipment, personnel, objectives, and uses of the information.

This review should start with an inventory of the available, continuously operating traffic data collection equipment in the State. It should then progress to determining how the data are being used, who is using it, and how it would be used if tools for using it in new ways were available.

Next, the data should be reviewed to determine what traffic patterns exist in the State and whether previous patterns have changed to establish whether the monitoring process should change.

The next step is to review how the data are being manipulated, and whether those data manipulation steps can be improved or otherwise made more efficient. Of considerable interest in this review is how the quality of the data being collected and reported is maintained. Establishing the quality of the traffic data reported by the ATR system and the outputs of the ATR analysis process is a prerequisite for future improvements. Permanent traffic data are subject to discontinuities due to equipment malfunctions and errors. The way a State identifies and handles errors in the data stream is a key component of the ATR program. Subjective editing procedures for identifying and imputing missing or invalid data are discouraged, since the effects of such data adjustments are unknown and frequently bias the resulting estimates.

Each State highway agency should have formal rules and procedures for these important quality control efforts (ASTM 1991). **The implementation of truth-in-data concepts as recommended by the AASHTO Guidelines for Traffic Data Programs will greatly enhance the analytical results and help in establishing objective data patterns.**

Truth-in-data implies that agencies maintain a record of how data are manipulated, and that each manipulation has a strong basis in statistically rigorous analysis. Data should not be discarded or replaced simply because “they didn’t look right.” Instead, each State should establish systematic procedures that provide the checks and balances needed to identify invalid data, control how those invalid data are handled in the analysis process, and identify when those quality control steps have been performed. Finally, the State highway agency should periodically review whether these procedures themselves are performed as intended or need to be revised. For states that currently do not have formal quality control procedures, the documentation being developed by the Minnesota pooled fund study to examine automated data collection procedures provides an excellent starting place (Intelligent Decision Technologies 1997). In addition, the AASHTO has also provided guidance on how to develop and implement

a quality control process for traffic data collection (Guidelines for Traffic Data Programs 1992).

The last portion of the review process should entail the steps for creating summary statistics from the raw data collected by ATRs. These procedures must be consistent and must accurately account for the limitations that are often present in continuous count data. For example, AASHTO has adopted a recommended procedure for computing AADT for data collected at continuous count locations. The procedure computes average day-of-week values by month, and then averages those summary values to create annual average day-of-week volumes, and finally averages those seven values to compute AADT. This procedure allows consistent computation of AADT even when significant portions of a month of data are missing, without losing the effects of seasonal or day-of-week effects.

### **Develop an Inventory of the Available Continuous Count Locations and Equipment**

Correctly manipulating continuous count data after the data have been collected is vital. The inventory of existing (and planned) ATR sites ensures that the State's traffic monitoring effort obtains all of the continuous count data that are available. As noted earlier, the key to the inventory process is for the agency to identify not just the traditional ATR sites but also other data collection devices that can supply continuous volume data. These secondary sites include, but are not limited to:

- continuous classification counters
- continuous weigh-in-motion sites
- traffic management systems
- regulatory monitoring sites (such as international border crossings and toll plazas).

Data collection devices operated by the same group that operates the ATRs are the easiest to obtain volume data from, but a surprising number of State highway agencies do not make use of these data as part of their ATR process.

Posing more challenge are devices operated by other divisions within the State highway agency. Obtaining these data can be more difficult, particularly where internal cooperation within the agency is limited. However, the current emphasis on improved cost-efficiency in government means that in most States there is strong upper management support for "making the most use" of data resources, wherever they exist. The key to taking advantage of this support is to make the transfer of the data as automated as possible, so that little or no staff time has to be expended outside of the ATR data collection group to obtain the data.

Lastly, the State highway agency should look for data outside of its own agency. While it may not be possible to obtain these data at the level provided by standard ATR devices (i.e., hourly records by lane for all days of the year), it is often possible to obtain useful summary statistics such as AADT and seasonal volume patterns from these

locations. These summary data can, at a minimum, be used to supplement the State's data at those locations and geographic areas. The availability of data from supplemental locations reduces the cost of collecting and increases access to useful data.

To obtain these data, the State highway agency may have to pay for the development of software that automatically collects and reports these data. The intent, once again, is to reduce the operating agency's staff time needed to collect and transmit the data. The easier this task is for the agency collecting the data, the more likely it is that these data can be obtained by the highway agency.

A second part is to inventory data uses and users. This step involves determining how the ATR data are currently being used, who the customers are for those data, and which data products (raw data? summary statistics? factors?) are being produced.

Many organizations seem to collect data for the sake of collecting data, that is, data is not being used as it should be. Data need to be collected for a purpose, and the users and uses of those data should be given priority in the data collection process. By themselves, data have no value. Data only have value in that they answer important questions. Thus, by understanding who uses the data and how those data are being used, it is possible to develop a clear understanding of what value the data collection effort has to the organization. Understanding this value, and being able to describe it, is crucial to defending the data collection budget when budget decisions are made.

At the same time, this inventory process may uncover the fact that some data and/or summary statistics are not being used. If that is the case, then these data and statistics can often be eliminated in favor of the collection of data or production of statistics that will be used. This results in better use of available resources, makes the data collection system more focused on products actively desired by agency users, and results in more support for the data collection program from others in the agency.

### **Determine the Traffic Patterns to Be Monitored**

One of the tasks central to the existence of the continuous counter program is the monitoring of traffic volume trends. Foremost among these trends are the monitoring of AADT at specific highway locations over time, and the tracking of seasonal and day-of-week patterns around the state. The inventory process should document how the ATR program is being used to create and apply adjustment factors to short duration traffic counts in order to estimate AADT, as well as which highway locations require continuous counters simply because of the importance of tracking volume with a high degree of confidence.

Monitoring AADT with continuous traffic counters is not a primary issue that significantly determines the design of the ATR program. Instead it is a secondary consideration normally dealt with when siting the ATRs. The collection of continuous data to determine AADT should only be necessary at a limited number of locations.



Monitoring seasonal and day-of-week patterns is of much greater concern in the refinement of the continuous count program, since the effectiveness of the seasonal factoring process (and consequently the accuracy of most AADT counts) is a function of the seasonal patterns observed around the State. Understanding what patterns exist, how those patterns are distributed, and how they can be cost-effectively monitored is a major portion of the factor review process.

The review of seasonal patterns can be undertaken with a number of analytical tools. Two of the most useful are cluster analysis, which can be performed using any one of several major statistical software packages such as SAS or SPSS, and the graphic examination of seasonal pattern data from individual sites.

The intent of the seasonal pattern review is to assess the degree of seasonal (monthly) variation that exists in the State as measured by the existing ATR data. Also, to examine the validity of the existing factor grouping procedures that produce the seasonal factors. The review consists of examining the monthly variation (attributed to seasonality) in traffic volume at the existing ATR locations, followed by a review of how roads are grouped into common patterns of variation. The goal of this review is to determine whether the State's procedures successfully group roads with similar seasonal patterns, and whether individual road segments can be correctly assigned to those groups.

The review process begins by computing the monthly average daily traffic (MADT) and the monthly factors at each ATR location. The monthly factors are then used as input to a computerized cluster analysis procedure. The patterns for individual sites can also be plotted on paper or electronically, so that patterns from different sites can be overlaid to visually test for similarities and/or differences.

If the groups of roads reported by the cluster analysis are very similar to the groups of roads already in use, or if the visual patterns of all ATRs in each factor group are similar, then it can be concluded that the factor groups are reasonably homogeneous; that is, that the ATRs that make up the factor group all have the same basic seasonal pattern.

It is not necessary for the factor groups to be identical to the cluster analysis output. This is for two reasons. For any given year, the cluster output is likely to be slightly different, as minor variations in traffic patterns are likely to be reflected in minor changes in the cluster analysis output. In addition, the cluster analysis output will require adjustment in order to create identifiable groups of roads.

The remaining review step is to make sure that the groups are defined by an easily identifiable characteristic that allows easy assignment of short counts to the group. The definition of each group must be complete enough to allow analysts to correctly select the appropriate factor for every applicable roadway section.

### **Establish the Seasonal Pattern Groups**

If the factor groups are not reasonably homogeneous, the definition of the groups is not clear, or new traffic patterns are emerging; it may be necessary to re-form the seasonal factor groups. The TMG recommends that the seasonal analysis be carried out monthly because studies have shown that patterns based on weekly or daily variation reduce the reliability of the resulting seasonal factors (Hallenbeck and Bowman 1984).<sup>3</sup>

The basic statistic used to create factor groups can be either the ratio of AADT to MADT, or the ratio of AADT to MAWDT. A general description of alternative methods for creating factor groups is presented in Section 2.

In most cases, the patterns of variation that stand out from the grouping process are those of rural roads, urban roads, and recreational areas. However, in some States there are significant geographic differences in travel that need to be accounted for in the seasonal factoring process. For example, rural roads in the northern half of the State may have very different travel patterns than rural roads in the southern half of the State. In addition, in some States clear patterns have failed to emerge.

The cluster procedure is illustrated by an example in Appendix A of Section 2, 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 adequately interpret the program results.

The cluster analysis procedures have two major weaknesses. One is the lack of theoretical guidelines for establishing the optimal number of groups. It is often difficult to determine how many “groups” should be formed. The cluster analysis process starts with all ATRs in a single group, and proceeds until each ATR is in an individual group. The difficult task is to determine at what point to stop this sequential clustering process. Unfortunately, the “optimal” number of groups cannot be described mathematically.

The second weakness in the cluster analysis approach is that the groups that are formed often cannot be adequately defined, since the cluster procedure considers only variability at the ATRs not applicability to the short counts. Plotting on a map the sites that fall within a specific cluster group is sometimes helpful when attempting to define a given group output by the cluster process, but in some cases, the purely mathematical nature of the cluster process simply does not lend itself to easily identifiable groups.

Two advantages of cluster analysis are that it allows for independent determination of “similarity” between groups, thus making the groups less subject to bias, and that it can identify travel patterns that may not be intuitively obvious to the analyst.

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<sup>3</sup> Some States prefer to use weekly factors, since there is no direct correlation between traffic patterns and months, while there is a strong relationship between specific weeks and traffic patterns. For example, the week containing the Fourth of July always has a different traffic pattern than the remaining weeks of July. However, weekly factors are less stable than monthly factors and have accuracy drawbacks. Monthly factors are recommended, but States have the option of choosing the factoring process that best meets their traffic patterns and needs.

Thus, it helps agency staff investigate road groupings they might not otherwise examine, which in turn can lead to more efficient and accurate factor groups, as well as providing new insights into the State's travel patterns.

The more subjective traditional approach to grouping roads and identifying like patterns is based on a general knowledge of the road system combined with visual interpretation of the monthly graphs. An example of the traditional approach to creating vehicle classification factor groups is presented in Appendix 4-B.

The advantage of the "traditional" approach is that it allows the creation of groups that are easier for agency staff to identify and explain to users. This happens because the grouping process starts by defining road groups that are expected to "act alike." The hypothesis is then tested by examining the variation of the seasonal patterns that occur within these "expected" groups.

The initial groups of roads that "act alike" could consist of roads of the same functional classification, or a combination of functional classifications. The groups should be further modified by the State highway agency to account for the specific characteristics of the State. Expected revisions include the creation of specific groups of roads that have travel patterns driven by large recreational activities, or that exhibit strong regional differences.

The decision on the appropriate number of factor groups should be based on the actual data analysis results and the analyst's knowledge of specific, relevant conditions. As a general guideline, a minimum of three to six groups is usually needed. More groups may be appropriate if a number of recreational patterns need to be monitored, or if significant regional differences exist.

Because of the importance and unique inter-regional nature of travel on the Interstate system, it is also recommended that States consider maintaining separate volume factor groups for the Interstate functional categories. The Interstate system, because of its national emphasis and high usage levels, will always be subject to higher data constraints. Most States maintain many ATRs on the Interstate system. As a result, it is usually easy to create separate Interstate groups.

The TMG recommends the following groups as a minimum:

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

The first four groups are self-defining. The recreational group or groups requires the use of subjective judgment and knowledge of the travel characteristics of the State. Usually, recreational patterns are identifiable from an examination of the continuous

ATR data. The existence of a recreational pattern should be verified by knowledge of the specific locations and the presence of a recreational travel generator.

Distinct recreational patterns cannot be defined simply on the basis of functional class or area boundaries. Recreational patterns are very obvious for roads at some locations but non-existent for other, almost adjacent, road locations. The boundaries of the recreational groups must be defined on the basis of subjective knowledge. The existence of different patterns, say summer vs. winter, further complicates the situation. Therefore, the recommendation is to use a strategic approach, that is, to subjectively determine the routes or general areas where a given recreational pattern is clearly identifiable, establish a set of locations, and subjectively allocate factors to short counts on the basis of the judgment and knowledge of the analyst. The road segments where these recreational patterns have been assigned must be carefully documented so that these recreational factors can be accurately applied and periodically reviewed.

While this may appear to be a capitulation to ad hoc procedures, it is actually a realistic admission 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 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 should be assigned on the basis of the groups defined by the State.

The minimum group specification can be expanded as desired by each State to account for regional variation or other concerns. However, more groups result in the need for more ATR stations, with the corresponding increase in program cost and complexity. Each State highway agency will have to carefully examine the trade-offs between the need for more factor groups and the cost of operating additional ATRs.

The above definition of these seasonal patterns based on functional class provides a consistent national framework for comparisons among States and, more important, provides a simple procedure for allocating coverage counts to the factor groups for estimating annual average daily traffic (AADT). It also provides a direct mechanism for computing the statistical precision of the factors being applied.

The precision of the seasonal factors can be computed by calculating the mean, standard deviation, and coefficient of variation of each adjustment factor for all ATR locations within a group. The mean value for the group is the adjustment factor that should be applied to any short count taken on a road section in the group. The standard deviation and coefficient of variation of the factor describe its reliability. The error boundaries can be expressed in percentage terms using the coefficient of variation, where the error boundaries for 95 percent of all locations are roughly twice the coefficient of variation.

Typical monthly variation patterns for urban areas have a coefficient of variation under 10 percent, while those of rural areas range between 10 and 25 percent. Values higher than 25 percent are indicative of highly variable travel patterns, which reflect "recreational" patterns but which may be due to reasons other than recreational travel.

### **Determine the Appropriate Number of Continuous ATR Locations**

Having analyzed the data, established the appropriate seasonal groups, and allocated the existing ATR locations to those groups, the next step is to determine the total number of ATR locations needed in each factor group to achieve the desired precision level for the composite group factors. To carry out this task, statistical sampling procedures are used. 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. 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:

$$B = \bar{X} \pm T_{1-d/2, n-1} \frac{s}{\sqrt{n}} \quad (3-3)$$

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

$s$  = standard deviation of the factors.

The precision interval is

$$D = T_{1-d/2, n-1} \frac{s}{\sqrt{n}} \quad (3-4)$$

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

$$D = T_{1 - d / 2, n - 1} \frac{C}{\sqrt{n}} \quad (3-5)$$

where

$D$  = precision interval as a proportion or percentage of the mean  
 $C$  = 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 difficult undertaking. Very tight precision requires large sample sizes, which translate 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. Furthermore 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 are 10 percent precision with 95 percent confidence, 95-10, for each individual seasonal group, excluding recreational groups where no precision requirement is specified.**

When these reliability levels are applied, the number of ATR locations needed is usually five to eight per seasonal group, although cases where more locations are needed exist. The actual number of locations needed is a function of the variability of traffic patterns within that group and the precision desired. Thus, the required sample size may change from group to group.

Recreational factor groups usually are monitored with a smaller number of ATRs, simply because recreational patterns tend to cover a small number of roads, and it is not economically justifiable to maintain five to eight ATRs to track a small number of roads. 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.

### **Select Specific Count Locations**

Once the number of groups and the number of ATRs needed for each group have been established, the existing ATR locations can be modified if revision is necessary. The first step is to examine how many ATRs are located within each of the defined groups. This number is then compared to the number of locations necessary for that group to meet the required levels of factor reliability.

If the examination reveals a shortage of current ATR locations, the agency will need to select new locations to place ATRs within that defined group. Since the number of additional locations will probably be small, the recommendation is to select and include them as soon as possible. Issues to be considered when selecting locations to expand the sample size are discussed below.

If there is a surplus of ATRs within a group, then redundant locations are candidates for discontinuation. If the surplus is large, the reduction should be planned in stages and after adequate analysis to ensure that the cuts do not affect reliability in unexpected ways. For example, if twelve locations are available and six are needed, then the reduction could be carried out by discontinuing two locations annually over a period of three years. The sample size analysis should be recomputed each of the three years before the annual discontinuation to ensure that the desired precision has been maintained. Location reductions should be carefully thought out. Maintaining a few additional surplus locations may help supplement the groups and compensate for equipment downtime or missing data problems.

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

1. **Other uses of existing information or other reasons the sites are important**— As mentioned before, seasonality is not the only objective for use of continuous ATR data. Each State should ensure 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 are subject to many discontinuities due to equipment downtime, which results 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 HPMS standard sample sections, these locations should be given priority.
5. **Tie-in to the classification, speed, or weight programs**— 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 should be given higher priority for discontinuation.

### Compute Monthly Factors

The procedures for developing and using 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.** Alternatively, the State can combine the day-of-week adjustment and monthly adjustment into a single factor, for example the ratio of annual average daily traffic to monthly average weekday traffic (AADT / MAWDT). This term, or a similar seasonal adjustment, can be substituted directly for the ratio of AADT / MADT in the factor grouping and application process if desired.

For an ATR site that operates 365 days per year without failure, the AADT can be computed by adding all of the daily volumes and dividing by 365. Similarly, the MADT can be computed by adding the daily volumes during any given month and dividing by the number of days in the month.

The problems with this approach are that few ATRs operate totally reliably during any given year. Most suffer at least small amounts of down time because of power failures, communications failures, and other equipment or data handling problems. These missing hours or days of data can cause biases and other errors in the calculations, particularly when moderate amounts of data are lost in a block. As a result, AASHTO adopted a modified formula for computing these types of statistics that directly accounts for missing data.

The AASHTO formulation for AADT is as follows:

$$AADT = \frac{1}{7} \sum_{i=1}^7 \left[ \frac{1}{12} \sum_{j=1}^{12} \left( \frac{1}{n} \sum_{k=1}^n VOL_{ijk} \right) \right] \quad (3-6)$$

where: VOL = daily traffic for day k, of day-of-week i, and month j



$i$  = day of the week

$j$  = month of the year

$k$  = 1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week.

$n$  = the number of days of that day of the week during that month (usually between 1 and 5, depending on the number of missing data).

This formula computes an average day of week for each month, and then computes an annual average value from those monthly averages, before finally computing a single annual average daily value. This process effectively removes most biases that result from missing days of data, especially when those missing days are unequally distributed across months or days of the week.

The AASHTO calculation of MADT is similar to that of AADT. An average day-of-week is first computed for a given month, and then these seven values are averaged. MAWDT is similarly computed. However each State can define the specific days present in the MAWDT calculation. For example, some States do not count Fridays for routine short duration traffic counts and, therefore, choose not to include Fridays in the computation of MAWDT.

Monthly factors for each ATR are computed by the ratio of AADT to MADT or AADT to MAWDT. Group monthly factors are computed as the average of the factors for all ATR locations within the group. Both the individual ATR and the group factors should be made available to users in tabular and computer accessible form.

Seasonal factors are most accurately developed and applied on a year by year basis. That is, a short count taken in 1999 should be adjusted with factors developed exclusively from ATR data collected in 1999. This allows the adjustment process to account for economic and environmental conditions that occurred in the same year the short count was taken.

This last recommendation creates problems for the timing of factor computation and application. That is, if a short count is taken in the summer of this year, the “true” adjustment factor for this year cannot be computed until January of next year at the earliest, which may not be timely enough for many users. The recommendation is to compute “temporary” adjustment factors for estimating AADT before the end of the year, and then to revise that preliminary estimate once the year’s “true” adjustment factors can be computed in January. “Temporary factors” can be developed in one of three ways:

- applying last year’s factors
- computing an average of the three previous year’s factors
- computing a monthly rolling average (for example, the temporary July 1999 factor would be computed as the factor for the 12 consecutive months from August 1998 through July 1999).

The first of these approaches is the easiest but also the least accurate, because the effects of this year’s and last year’s economic/environmental conditions are likely to be

different. The second approach reduces the biases that occur from using a single year's factors. The last approach produces the most accurate adjustment factor but also requires the most labor-intensive data handling and processing effort.

## **SUMMARY OF VOLUME DATA COLLECTION REQUIREMENTS**

The recommended traffic monitoring program consists of two basic components, a continuous count program and a short duration count program.

### **Continuous Count Program**

All highway agencies should have access to data collected from continuous counters. These data are needed to understand temporal (day-of-week, seasonal) changes in traffic volume. However, not all agencies need to operate these devices. Agencies should work together to ensure that enough data are collected to allow calculation of accurate day-of-week and seasonal adjustment factors needed to convert short duration traffic counts into estimates of AADT. Roughly six ATRs are needed<sup>4</sup> for each "factor group" in order to develop stable, representative factors.

### **Short Duration Counts**

The short count program is designed to provide roadway segment-specific traffic count information on all covered roads. To compute AADT, the data collected during the short counts must be adjusted to annual conditions. These adjustments include

- axle correction (for counts made with single axle sensors)
- day-of-week (for counts taken for less than one week)
- seasonal (to account for changes in volume that occur from one time of year to another)
- time-of-day (for counts taken for less than 24 hours).

In addition, since AADT is usually desired for the current year, growth factors may also be computed and applied to earlier year counts. Finally, it is recommended that traffic volume data be collected for 48-hour periods with counters that record data at hourly intervals. Periods longer than 24 hours eliminate the need for time-of-day adjustments, provide data on peak travel times and the percentage of traffic volume occurring in those periods. The recommended 48-hour period provides sufficient hourly data to verify the quality and reliability of the collected data.

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<sup>4</sup> The major exception to this rule of thumb is for recreational routes and other "unusual" roads which experience unique travel patterns. In these cases, a single ATR may be all that is necessary to monitor each unique pattern.

### **Short Count Program Design**

The short duration counting program can be most efficient if the data collection efforts of different groups are coordinated so that one count session meets multiple needs. To produce that efficiency, the TMG recommends the following program design:

- Establish a coverage count program that covers the complete system on a 6- year cycle.
- Determine the count locations required to meet HPMS reporting needs. The HPMS universe/sample sections should be counted once every 3 years.
- Determine the count locations and data collection needs of special projects (such as pavement design or traffic operation improvement studies) that will require data in the near future.
- Overlay these counts<sup>5</sup> on a map of the highway system, along with the location of functioning continuous counters.
- Determine how these counts can be combined to make best use of available counting resources
- Schedule the counts to most efficiently use the available data collection crews and equipment.

This program design is intended to reduce count duplication and increase the efficiency of the data collection staff.

### **HPMS Counts**

Of particular importance to all highway agencies is the collection of the HPMS data. Volume data on HPMS universe/sample sections are used to apportion Federal-Aid funds to the States. Significant portions of these funds are then allocated by each State highway agency to lower jurisdictions. Consequently, each highway agency has a direct financial interest in the validity of data submitted to FHWA under the HPMS.

Each State highway agency is responsible for reporting data for each HPMS section on the National Highway System (NHS) and other principal arterials (PAS). In addition, the State highway agency is required to report traffic volume information on a sample of other arterials and major collector roads in the State. To support this reporting requirement, each roadway section for which an HPMS volume count is required must be counted at least once every three years. In addition, each State must maintain periodic count data on all roadway sections not included in the HPMS sample so that those sections can be accurately assigned to HPMS volume strata. This is necessary to expand the HPMS sample counts into accurate estimates of statewide VDT. To accomplish this,

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<sup>5</sup> Included in this effort should be all vehicle classification and WIM counts, since these counts should also provide total volume data.

the HPMS recommends that all road segments in the coverage program be counted on a six-year cycle.<sup>6</sup>

State highway agencies may not physically count all HPMS sample locations. In many cases, State highway agencies will rely on local jurisdictions to collect and report these data. Many sites are instrumented with permanent volume, classification, WIM, or ITS equipment. In other cases, procedures such as “ramp balancing” can be used to estimate traffic volumes on roads where portable counts cannot be safely performed.

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<sup>6</sup> This is a general recommendation. Roads in high growth areas should be counted more frequently, whereas roads in low growth portions of a State could conceivably go much longer between counts without a discernable loss in accuracy.

## CHAPTER 4

### FREEWAY-EXPRESSWAY RAMP COUNTING PROCEDURES

The importance of the Interstate system necessitates that AADT based on actual traffic counts be estimated and reported to the HPMS for all Interstate highway sections. Unfortunately, the installation and use of portable traffic counting equipment on high volume freeways present great difficulties. Ensuring the safety of traffic counting crews and the motoring public is costly and requires extensive traffic control. In addition, the traffic volumes on multilane facilities are often higher than can be accurately counted by conventional, widely available, portable axle detectors. Therefore, in many cases, portable counters cannot be used to collect mainline counts on freeways and expressways.

This chapter describes the use of special study ramp counts to estimate freeway and expressway mainline traffic volumes. Although this technique can be used to estimate any basic volume statistic on these sections of roadway, the discussion emphasizes the ability to compute the AADT estimates needed for submittal as part of the HPMS process. These count procedures are applicable to any controlled access facility. They are especially applicable to the Interstate system.

There are two alternatives for collecting these data. The first involves the installation of permanent traffic sensors covering roadway sections. The second relies on counts taken at entrance and exit ramps between known mainline volume counts. The mainline counts are then adjusted for the changes in volume that occur at each ramp.

The installation of permanent sensors is the most effective way to meet the need for data on these facilities. Permanent sensors can be operated continuously, often as part of a traffic management system, or periodically, as part of a data collection/performance reporting system. Continuously operating sensors are more common on high volume urban roadways, where the collected data are often needed by traffic management systems. When sensors are operated periodically, the State highway agency connects portable sets of data collection electronics to permanently installed sensors to collect data when needed. This allows staff to collect data without having to physically place vehicle or axle detectors on the road. This practice is becoming more widely used on high volume, high speed roadways.

The installation of permanent sensors is expensive, particularly if all sections of an urban facility must be covered. Funding for extensive freeway data collection is normally beyond the budget of most data collection groups. These detectors are most commonly installed as part of area-wide advanced traffic management systems that require facility performance data to help optimize roadway usage. The increasing installation and operation of traffic management systems is expected to increase the availability of basic traffic volume data from these permanently operating sensors.

However, State highway agencies must be aware of the large efforts needed to make the data collected by these systems available to other data users.

Where continuous data are not available from traffic management systems, ramp counting is the mechanism most commonly used to estimate volumes on freeways and expressways. The ramp counting process can be performed quickly with existing technology and staff.

### **THE RAMP COUNTING PROCESS**

**Ramp counting is the process of counting traffic volumes on all entrance/exit ramps between two established mainline counters, such as permanent ATRs or other installations, and then reconciling the count data to estimate mainline AADT.**

The process is designed to estimate **mainline** AADT. Annual mainline estimates of AADT are a reporting requirement of the HPMS system. The HPMS definition of Interstate mainline AADT excludes volume from frontage roads, collector-distributor roadways within interchanges, and the ramps themselves.

The following sections describe the methodology for developing a ramp counting program and reconciling the counts to mainline estimates of AADT. An example, consisting of one figure and three tables, illustrates the process. Figure 3-4-1 presents a diagram of the example study section. Table 3-4-1 shows the estimation of adjusted daily volumes for mainline sections. Table 3-4-2 shows the estimation of AADT for those mainline sections. Table 3-4-3 shows the reconciliation of the mainline AADT between ramps into AADT for the HPMS reporting sections. (These figures are presented in the text as they are discussed in the paragraphs below.)

The ramp counting process is similar to a traffic flow problem in which mainline volumes are known at two points and all input/outputs are measured between those two points. The two boundary points are normally ATRs or other instrumented mainline locations that provide a highly accurate measurement of annual traffic volumes. These points are used to control the counting and adjustment process and are referred to as “anchor points.”

Another requirement of the ramp counting process is the availability of detailed maps or computerized inventories showing the locations of the anchor points and the ramps for each direction of travel. These inventories should also provide the detail needed to map the freeway segments to the HPMS sample sections. This is particularly important where an HPMS section includes more than one interchange, and thus more than one “computed volume section.” In this case, computation of HPMS section volumes must account for the travel on each of the “computed volume sections” that make up that HPMS section.

One of the limitations of the ramp counting approach to mainline volume estimation is that travel-lane volumes cannot be estimated because traffic entering the

road cannot be allocated to lanes. This limitation is not a problem for data collected to meet the specifications of the HPMS, but it may have implications for other programs that depend on lane-specific traffic volume information.

### **ESTABLISHING THE ANCHOR POINTS**

The first step in ramp counting is to select the two anchor points (continuous counters or other loop installations) that will be used to control the estimation process. The use of permanent counters as anchor points provides the highest accuracy and is preferable. However, the number of existing permanent ATRs available for this purpose is often not sufficient and the cost of a large number of continuous counter installations may make this option infeasible. Therefore, any available instrumented site may be used as an anchor point. However, they should only be sites where mainline volumes can be accurately obtained. The installation of additional permanent detectors (counting either continuously or periodically) to provide accurate anchor points is strongly recommended whenever sufficient budget exists for this activity.

When determining the number of anchor points to be used for any given facility, the State highway agency must trade off accuracy and cost. Generally, the closer together the anchor points (in terms of the number of ramp interchanges between them) the more reliable will be the estimates for roadway sections between those points. On the other hand, the farther apart the anchor points are placed, the lower the number of anchor points needed to estimate volumes on the complete facility. The “correct” number of anchor points depends on the specific location and traffic characteristics under consideration. The number and placement of anchor points is really a function of the available budget; the importance of interchanges and major route connections (junctions); and the availability and location of existing mainline count locations, including ATRs, control counters, permanent loops, toll booths, traffic control points, and other instrumented sites. **Each State will have to make its own determination regarding the appropriate number of anchor points. As a general rule-of-thumb, the recommended number of interchanges between anchor points is five.**

### **TAKING COUNTS BETWEEN TWO ANCHOR POINTS**

Many studies have shown that traffic patterns tend to vary considerably during the day. Therefore, **the minimum period recommended for collecting ramp volume data is 24 hours.** Ideally, **all ramps between two anchor points should be counted for the same 24-hour period.** Multi-day counts are preferable to 24-hour counts, especially where these counts can extend over both weekdays and weekend days, and assuming that the vehicle detectors will continue to function accurately for more than 24 hours. Traffic patterns change from day to day, especially from weekday to weekend day. Ramp volumes (and thus mainline section volumes) are often particularly affected by day-of-week volume changes, as some activity centers have dramatically different

weekday/weekend usage patterns. Directly accounting for these changes in the ramp count data will help improve the accuracy of the mainline volume estimation process.

Ramp counts collected with conventional axle counting devices must be converted to estimates of vehicle volume before use in this process. Selection of appropriate axle correction factors is discussed under Axle Correction for Ramp Counts, presented later in this chapter.

Collecting all ramp data between two anchor points on the same day(s) eliminates the need to adjust the counts before reconciliation<sup>7</sup>. When ramp counts cannot be taken during comparable periods, they may have to be adjusted to AADT before reconciliation. If all ramps can be counted on the same day, conversion to AADT should be done after reconciliation. If some ramp counts are missed because of equipment problems, errors, or staffing limitations, 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 to limit the potential for errors caused by variation in the traffic and by limitations in the adjustment process used to estimate annual conditions from short duration counts.

Where volumes on an entire Interstate freeway are estimated in this fashion, the schedule of counts can be organized systematically over the counting season to minimize the staff needed and to allow recounting as needed.

So far this discussion has assumed that all ramps can be counted with portable detectors such as road tubes, mats, switches, magnetic sensors or portable loops. However, some ramps will be impossible to count with these methods. In those situations, the use of shorter visual or video counts may become necessary. In these cases, an appropriate adjustment process will have to be developed to expand these short duration counts to estimates of 24-hour traffic. For example, an 8-hour count could be converted to a daily estimate with data from the anchor points. This estimate could then be treated as if it were a 24-hour count. However, such an adjustment will add considerably to the error associated with the ramp counting approach.

### **MAINLINE DAILY VOLUME ESTIMATION BASED ON RAMP COUNTS**

The reconciliation 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. Then one of the two anchor points is selected as the starting point. Because the access and egress points will vary by direction of travel, **it is recommended that the reconciliation be carried out independently by direction of travel and that the computation proceed in the direction of traffic flow.** This will provide AADT estimates for each direction of travel. The two directions are added to provide total AADT. The computation by direction of travel simplifies the identification of on and

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<sup>7</sup>Reconciliation is the process by which ramp counts and data from anchor points are converted into mainline AADT estimates.



off-ramps. It also simplifies the computation of AADT for facilities that incorporate reversible travel lanes. However, it does require twice as many computational steps as doing both directions simultaneously. Several States have indicated that in many cases combining both directions of travel produces almost the exact results but reduces the effort required. Where interchange design allows both directions of travel to be treated simultaneously, States may choose to use this option.

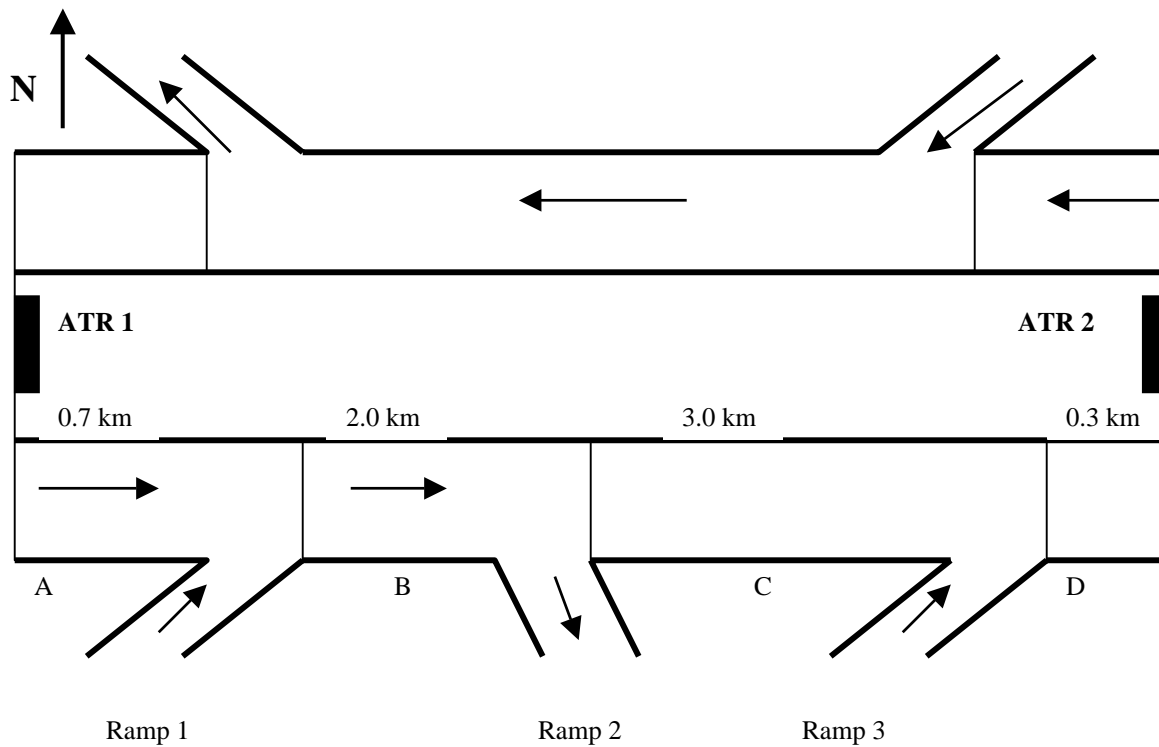
The process of addition or subtraction is carried out until a daily directional volume has been calculated for each mainline section between each ramp between the two anchor points. In theory, assuming no equipment error and exact vehicle counts at each ramp, the addition/subtraction process should produce a mainline volume estimate for the section ending at the end anchor point that is equivalent to the volume computed from data collected at that anchor point.

In practice, because of equipment error and other factors, a difference will always exist at the end of the process. The difference should not be large. A large difference is an indication of problems, usually related to equipment accuracy. **It is recommended that the 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.** Differences under 1 percent can be considered negligible and ignored. If the process is computerized, then the adjustment should be carried out to ensure 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.

The allocation of the volume difference to the ramps (and subsequently to the mainline volume estimates) 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 reconciliation) to the sum of the ramp volumes. This process is described in the example.

Actions that can be taken to minimize error include accuracy checks on the counters, proper installation of equipment, adequate control over monitoring periods 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 reconciliation difference should always be expected.

Figure 3-4-1 illustrates the recommended ramp counting process. Table 3-4-1 presents the computation of the adjusted mainline volumes for a 24-hour period in one direction of travel. Figure 3-4-1 shows an Interstate segment of six kilometers bounded by ATR anchor locations. The eastbound direction of travel consists of four segments separated by three 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.



**Figure 3-4-1**  
**Ramp Counting Freeway Layout Example**

For computing section lengths, roadway sections that end with entrance ramps are, by definition, measured from the point where the ramp first connects to the mainline of the Interstate. Likewise, sections with exit ramps are measured from the last point where the ramp touches the mainline. The level of accuracy of these distance measurements should be governed by the State's existing roadway inventory database.

The volumes in Table 3-4-1 are computed starting with the volume at ATR # 1 and adding or subtracting ramp volumes until ATR # 2 is reached. In the example, a difference of -3 percent 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].

<b>Table 3-4-1</b>							
<b>Computation of Adjusted Mainline Volumes</b>							
Ramp count date:	May 17						
Length of analysis section:	6 kilometers						
Direction of travel analyzed:	Eastbound						
<b>Ramp Counts</b>							
	<u>Ramp 1</u>	<u>Ramp 2</u>	<u>Ramp 3</u>	<u>Total</u>			
Ramp count volume	923	1,053	786	2,762			
<b>Initial Mainline Volume Estimates</b>							
	<u>ATR 1</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>ATR 2</u>	<u>Remaining Difference</u>
Initial Volume	11,995	11,995	12,918	11,865	12,651	13,053	402 (-3%)
<b>Adjusted Ramp Volumes</b>							
	<u>Ramp 1</u>	<u>Ramp 2</u>	<u>Ramp 3</u>	<u>Total</u>			
Ramp adjustment	+134	-153	+115	402			
Balanced ramp volume	1,057	900	901				
<b>Adjusted Mainline Volume Estimates</b>							
	<u>ATR 1</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>ATR 2</u>	<u>Remaining Difference</u>
Balanced Volume	11,995	11,995	13,052	12,152	13,053	13,053	0

Allocations, whether accompanied by this method or others, can substantially change some of the ramp volumes. This is because differences in mainline volumes (usually caused by equipment error) at the two anchor points may be low in percentage terms (meaning reasonably small equipment error) but quite high in comparison to individual ramp volumes. Thus, whereas the percentage error in the mainline volume estimate may be small, that same absolute error can be a significant fraction of a given ramp volume.

As a result, it is important to recognize the effects of the adjustment process on ramp volumes. An equipment error in any of the initial counts may have caused the problem with the ending difference, and the error is then further aggravated by the adjustment. When calculating adjustments, large differences should be suspect and thoroughly examined by checking the ramp counts and the ATR figures. In general, the effects of these errors will be minimal (in percentage terms) for mainline volumes but can be substantial for 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 any special events that may have affected the counts may help explain discrepancies and assist in the verification and correction process.

### **AXLE CORRECTION FOR RAMP COUNTS**

As previously shown, ramp counting requires accurate volume measurements to reduce the size of adjustments needed to reconcile the estimates. Daily volumes at anchor points are expected to directly represent vehicles rather than axles converted to vehicles.

Axle correction for ramp counts is a difficult issue because the ramp counts must represent precise figures that are reconciled to known volumes from ATRs. For this reason, **ramp counts should be taken with vehicle counters to eliminate the need for ramp axle correction.**

Unfortunately, accurate vehicle classification may not be possible at many ramps because acceleration and deceleration over the axle/vehicle detectors and the close spacing of many cars on ramps significantly degrade the accuracy of this type of equipment. Vehicle classification equipment must be carefully placed and tested at each ramp location before being trusted. If an axle count must be made due to equipment, **the collected axle counts must be converted to vehicle estimates before reconciliation.**

The use of axle correction at ramps introduces much error and complexity and should be avoided as much as possible. Axle correction factors applied to ramps should be based on the most reliable estimates available and account for temporal and spatial concerns. Temporal comparability means that the classification counts used to develop the axle correction factors for specific ramps should be taken the same day of the week and same month as the ramp counts. At a minimum, counts taken on weekdays should be adjusted with classification counts taken during weekdays. Spatial comparability means that axle correction factors applied to ramps should be based on classification counts representative of the route connecting the ramp to the roadway. At an absolute minimum, the axle correction should be based on the functional classification of the connecting route.

Local knowledge of the ramp traffic is particularly important when estimating axle correction factors for ramps. The volumes and characteristics (numbers of axles per vehicle) of trucks using ramps, particularly in urban areas, can change dramatically from ramp to ramp. The emphasis the TMG places on collecting classification data can result in much more accurate vehicle data and help reduce the problems with axle correction. The development of statistically based axle correction factors for system wide application is covered in the vehicle classification section. However, system-wide factors are not appropriate for adjusting ramp counts and should be used only as a last resort.

### **ESTIMATION OF MAINLINE AADT**

Once the daily volumes for each mainline section between the anchor points and each ramp have been developed, then the volumes are converted to AADT. As with the axle correction factors, system factors are not appropriate for this adjustment process when better site-specific data are available. Consequently, **directional section-specific AADT expansion factors should be computed from the two anchor ATRs and applied to the estimates developed between the anchor points.** For the sections where the permanent ATR counters are located, the AADT from the ATRs should be used.

A directional factor should be computed for each ATR as the ratio of directional ATR AADT to the directional daily volume on the ramp at that date. For example, if a ramp count is taken on May 17, then the adjustment factor is the ratio of AADT at the ATR to the May 17 daily volume at that ATR. If more than 24 hours of data are collected for the ramp count, the daily volume for all days counted should be averaged at the ATR, and the ratio of AADT to that average used as the adjustment factor.

Because there are two ATR anchor points, the directional factors at the starting and ending ATRs are averaged to compute the final daily AADT conversion factor. The directional mainline daily volume estimates are multiplied by this conversion factor to obtain mainline directional AADT estimates.

The use of system-wide factors to adjust the ramp counts will add additional error to the mainline volume calculation process and should only be used in exceptional cases, such as when the anchor points are not ATRs, and no other AADT conversion information exists.

Table 3-4-2 illustrates the process used to develop the mainline AADT estimates and continues the example introduced in Table 3-4-1. The AADT conversion factors are computed for each specific day of ramp data collection. In the table, the factor at ATR #1 for May 17 is 1.16 (the ratio of 13,914 to 11,995). The factor applied is the average of the two ATRs.

<u>ATR</u>	<u>Volume (May 17)</u>	<u>AADT</u>	<u>AADT Conversion Factor</u>
1	11,995	13,914	1.16
2	13,053	14,574	1.14
		Average	----- 1.15

<u>Section</u>	<u>Daily Volume (5/17)</u>	<u>AADT Factor</u>	<u>AADT Estimate</u>
A	11,995	--	13,914
B	13,052	1.15	15,010
C	12,152	1.15	13,975
D	13,053	--	14,574

<u>Section</u>	<u>AADT Estimate</u>	<u>Final AADT<sup>8</sup></u>
A	13,914	14,000
B	15,010	15,000
C	13,975	14,000
D	14,574	14,600

### **ADJUSTMENT OF AADT ESTIMATES TO CURRENT YEAR**

AADT estimates based on counts taken during the current year need no current-year adjustment. If no new ramp volume data are collected in a given year, the AADT estimates from the last year data were collected should be adjusted to estimate current year traffic using anchor ATR factors.

The current year factors are developed on the basis of the anchor ATRs. The factor for each ATR is the ratio of current year AADT to previous year AADT. A one-year factor is the ratio of current-year AADT to the previous year's AADT, while a two-year factor is the ratio of current-year AADT to the 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 ATRs are located use the ATR AADT values directly and require no adjustment.

<sup>8</sup>Note that the accuracy of both the traffic counting equipment and the ramp count adjustment process does not warrant the use of more than three significant digits. Thus, after completion of the ramp counting mainline estimation procedure, mainline AADT volumes should be rounded to three significant digits.

The process becomes more complex where continuous ATRs are not the anchor points. In these cases, the factors must be based on other continuous counters. The list of possible ATRs from which to obtain these data includes locations near the sections in question and on the same route, locations within the same urban area, or system-wide growth factors for the appropriate functional class and/or geographic region. Because many conditions affect the selection of the appropriate base for making this adjustment, each State will have to examine and develop its own special case procedures.

### **CONVERSION OF MAINLINE ESTIMATES TO HPMS SECTION ESTIMATES**

The ramp counting/reconciliation 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 because of the more 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, ramp estimates are converted to produce the HPMS section AADT by weighing the ramp AADT estimates by the length of the ramp segments within the HPMS section.

Each directional ramp segment AADT is multiplied by its length. The results are summed until the HPMS section is covered. Then the sum is divided by the total HPMS section length. This yields the HPMS section AADT. This process is equivalent to computing the DVDT of each ramp section within the HPMS section, summing those values, and then dividing by the HPMS section length. After the AADT is estimated for each direction of travel, both directions are summed to produce the total HPMS section AADT.

Table 3-4-3 continues the example under the assumption that the HPMS section begins at the first ATR and ends at the second ATR. As mentioned earlier, collector-distributor interchange, frontage road, or ramp volumes are excluded from the HPMS Interstate mainline volume estimate.

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 very low. Any discrepancies of this nature found during the analysis should be corrected by redefining the HPMS sections.

**Table 3-4-3**  
**Estimation of Eastbound HPMS Section AADT**

<u>Segment</u>	<u>AADT</u>	<u>Length (km)</u>	<u>AADT × Length (km)<sup>9</sup></u>
A	13,914	0.7	9,740
B	15,010	2.0	30,020
C	13,975	3.0	41,925
D	14,574	0.3	4,372
		-----	-----
	Sum	6.0	86,057

HPMS Section Eastbound AADT = 14,300

HPMS Section Westbound AADT = 13,200 (assumed)

HPMS Section AADT = 27,500 (rounded to three significant digits.)

### **SYSTEM APPLICATION OF RAMP COUNTING**

The ramp reconciliation process should produce accurate estimates of AADT for all mainline sections between ramp breaks in the defined area. Likewise, all HPMS universe (and sample) sections should be 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 data collected.

The ramp counting and reconciliation process can be applied as needed by the highway agencies. Agencies may decide to apply the process only to areas where mainline counting is not possible, only to urban areas, or to the complete Interstate system. Because of the simplicity of counting ramps in rural areas, many States apply the process statewide to ensure consistency and to provide complete coverage of the Interstate system. Other States use ramp counting because of a need for ramp volume information and as a check on the accuracy of mainline counts.

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

<sup>9</sup> This example shows more significant digits than the count program warrants. It does so simply to make the math easier to follow. The user needs to remember to limit the number of significant digits when reporting the results.



### APPENDIX 3-A FREQUENTLY ASKED QUESTIONS

*Can ATRs be used to accurately track VDT?*

ATRs track traffic at a point. Depending on the site, this can be expanded to a section or route. It is rarely practical, to track areawide travel with ATRs. Few agencies have the large number of ATRs required to provide statistical reliability to the areawide travel estimates. In most cases, agencies use a limited number of ATR locations to provide traffic trends at a limited number of sites. Individual road volumes are dramatically affected by local changes in land use and economic activity. The use of a small number of ATR locations can result in highly biased VDT calculations. The FHWA uses the ATR data reported monthly to the Travel Volume Trends (TVT) system combined with the annual HPMS VDT estimates to track changes in monthly travel. A similar approach could be applied statewide for States with sufficient number of ATRs.

*How do I define a "Road Segment" for traffic counting?*

A road segment for traffic counting is a section of road with homogeneous volume (i.e., the traffic volume does not change throughout the segment). Many State traffic programs divide their systems into traffic segments and physically count each segment to provide complete system coverage. Traffic volume is constantly changing and a perfect segment definition is not possible. For access-controlled systems, a definition between interchanges is the simplest. For non-controlled systems, the TMG recommends keeping a single segment until volume changes of plus or minus 10 percent are identified, at which point a new segment should be created.

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