Section 4

Vehicle Classification Monitoring

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VEHICLE CLASSIFICATION MONITORING

CHAPTER 1
INTRODUCTION

This section addresses the collection, manipulation, and reporting of vehicle classification data to meet the needs for vehicle classification information. It includes examples of how to apply the general data collection principles discussed in Section 2 to the subject of vehicle classification counting.

This chapter summarizes the material presented in Section 2, with specific emphasis on vehicle classification counting. Chapter 2 discusses the basic user requirements that the vehicle classification program needs to meet. Chapter 3 presents the recommended process for selecting the size, frequency, and duration of vehicle classification counts to meet those needs. Chapter 4 discusses the computation of annual summary information and provides ideas on how to present that information effectively. Finally, Chapter 5 discusses the data collection equipment that is currently available and the need for both acceptance testing and field validation tests after the equipment has been installed.

VARIABILITY

Traffic volumes vary over time on all roads. Traffic volumes also vary dramatically from one road to another. These variations in traffic volume are even more apparent when volumes for specific vehicle types (classification) are analyzed. Consequently, the vehicle classification data collection program must gather sufficient data on traffic patterns of important vehicle types to accurately quantify the truck traffic stream to meet the needs of users.

The same sources of variation that are present in traditional traffic volumes apply to vehicle classification estimates. These include:

- time of day
- day of week
- time of year
- direction
- geography.

Complicating the monitoring of these traffic patterns is the fact that not much data has been collected by classification and not much analytical work performed. Thus, many of these patterns are not well understood at the State and individual roadway levels. Further complicating matters is the fact that travel patterns for trucks are usually quite different than those for cars, and the data collection plans currently used tend to be structured around understanding the movements of cars not trucks.

Thus, the structure of the recommended traffic data collection plan has been expanded to understand and account for the movement of trucks.

DATA COLLECTION TO ACCOUNT FOR TRUCK MOVEMENTS

The recommended structure of a good classification counting program parallels that traditionally followed for volume counting. The classification counting program should include both extensive, geographically distributed, short duration counts and a smaller set of permanent, continuous counters.

A fairly large number of short duration classification counts should be performed to monitor and capture truck movements taking place on individual roads. These counts should be collected by equipment capable of providing hourly volume summaries. They should normally include data for all lanes and directions for a given location, since truck traffic varies considerably from lane to lane and often by direction. This data collection effort yields the basic truck traffic statistics needed on any given road including the geographic variability of truck movements, and the time-of-day distribution at a variety of locations.

These data serve as the starting point for other statistics needed including truck VDT (or VMT), freight flows (tonnage) carried by trucks on specific roadways and along specific corridors, and traffic load design statistics (ESAL and axle load distributions).

However, without adjustment, short duration classification counts yield biased estimates. Thus, as with traditional traffic volume counting, classification coverage counts must be supplemented by the use of permanent, continuously operating, vehicle classification counters (CVC). The permanent counters provide an understanding of how truck travel varies by day of the week and season of the year.

As with traditional volume counting, the permanent classifiers should be used to compute adjustment factors that can be applied to short duration classification count data to convert a daily count into an estimate of annual average daily volume for that roadway. The difference between the recommended counting program for vehicle classification information and the traditional volume counting program is that the factor groups used for volume counts do not usually create accurate factors for adjusting vehicle classification data.

Truck volumes patterns are heavily affected by local economic activity. They are also heavily influenced by the presence or absence of large through-freight movements. For example, a high percentage of through trucks on a road tends to result in higher weekend truck traffic and higher nighttime truck traffic than would otherwise be expected. Similarly, the lower the volume of through-traffic, the lower the volume of trucks in the evening, and the more heavily oriented truck travel is to weekdays. Because typical volume factor groups do not differentiate among these types of roads, total volume-based adjustment factors do not accurately account for these factors.

Finally, traditional volume factoring groups are oriented toward functional classification of roadway, which may or may not correlate well with truck travel patterns. Consequently, to better estimate the annual average travel by trucks on the roads, most States will need to develop a classification factoring process specifically to factor short duration classification (truck) counts.

INTEGRATION OF CLASSIFICATION COUNTING PROGRAMS

The vehicle classification counts required should not be considered separate from the volume counts traditionally performed. Instead, they should be integrated with the traditional volume counts. Because classification counts provide both classification and total volume information, they can replace traditional volume counts reducing duplication and error. This is true for both short duration counts and permanent traffic recorders.

Traffic surveillance equipment used as part of advanced traffic management systems (ATMS) or advanced traveler information systems (ATIS) can be used to supply both total volume and vehicle classification information. Intelligent transportation system (ITS) technology and its resulting data are often present at high profile locations as part of safety enhancement systems.[1] These systems can supply useful, continuous traffic monitoring data, while also accomplishing their primary ITS safety/operations objective. Other agencies and even multiple divisions within a State DOT collect classification information that can be routinely incorporated into the statewide traffic counting database. Coordinating these traffic monitoring activities can lead to significant improvements in the amount of data available to users, while at the same time reducing the cost of data collection.

Excellent sources of classification data can often be found at locations associated with freeway operation surveillance systems, long-term pavement performance monitoring, vehicle weight enforcement, and toll facility revenue collection points. Finding these sources and developing the procedures to obtain and make the data available to others, can be significant tasks. However, the benefits of cooperation in the data collection process are substantial and long lasting. The benefits from the effort are well worth the cost.

REQUIRED OUTPUTS FROM THE VEHICLE CLASSIFICATION DATA COLLECTION PROGRAM

It is difficult to describe all of the outputs that can result from the vehicle classification data collection effort. In general, a State DOT should be able to provide users with an estimate of the amount of truck traffic by type of truck by road segment. Truck volume and percentage estimates should be made available for the date when data

1 For example, Colorado DOT operates truck rollover and truck speed/braking warning systems that can provide truck use data.

were collected and as annual average estimates corrected for seasonal and day-of-week variation. States should always provide annual average daily truck volumes by truck type, but other average statistics, such as average peak hour truck volume, may also be appropriate.

CLASSIFICATION SCHEMES

Highway agencies use a large number of vehicle classification schemes. For many analyses, simple vehicle classification schemes (passenger vehicles, single unit trucks, combination trucks) are more than sufficient. In other cases, more sophisticated vehicle classification categories are needed. For example, in the early 1990's Canada investigated the creation of a classification scheme that would have included the type of hitch used between tractors and trailers. This would have allowed much more reliable research on the crash history, and consequently the safety benefits, of alternative hitch types. Unfortunately, the available data collection technology could not accurately classify vehicles by hitch type.

As was found in Canada, the classification schemes that can be used are a function of the data collection equipment available. The three types of sensors most frequently used for collecting truck volume information (visual, axle, and presence sensors) each provide a different mechanism for classifying vehicles. Within each of these three broad categories are an array of sensors with different capabilities, levels of accuracy, performance capabilities within different operating environments,[2] and output characteristics. Each type of sensor works well under some conditions and poorly in others.

Further complicating matters is the fact that different manufacturers attach different types of electronics to those sensors and analyze, store, and report sensor outputs differently. Some data collection equipment is capable of maintaining large amounts of data that provide very descriptive classification information. For example, some systems store individual vehicle images (either video images or axle weights and spacing information) and differentiate among a wide variety of vehicle types. Other, less powerful systems can differentiate only a few general classes, based largely on measures of overall vehicle length, and store and report the data only as summary totals for specified time intervals.

The result is an array of options for classifying vehicles, and an even wider array of ways in which the resulting vehicle counts are stored and reported from the field. Many States use a variety of equipment for different conditions and therefore are confronted with the task of dealing with different vehicle classification schemes at different points in the network. This is not necessarily a bad situation. **The key is to understand how the different classification schemes relate to one another**. That is, if

[2] That is, some work well at high vehicle speeds but not under congested traffic conditions. Some work well in all weather conditions, but only when vehicles remain in their lanes, whereas others are not affected by poor lane discipline but can be affected by weather conditions such as snow or fog.

the State normally uses axle classification schemes (such as the FHWA 13 categories) but relies on inductance loop classifiers on urban freeways, it must determine the appropriate length-based classification boundaries that allow accurate comparison between these two schemes. This can be accomplished by comparing estimates of overall vehicle length stored on individual vehicle weight records obtained from a WIM scale that uses inductance loops for detecting vehicle presence with the FHWA 13-category classification scheme associated with each vehicle. **States should maintain and be able to report the classification algorithm used to define each vehicle category they collect.**

The FHWA 13-Category Classification System

In the 1980's, the FHWA developed the 13-category scheme used for most federal vehicle classification count reporting (Appendix 4-C). The scheme was a compromise among several factors: the manual (vision based) classification schemes used before that time, the need to create a nationally consistent classification scheme, the automated counters being developed at that time, and the need to provide basic information on different truck types as input to a variety of policy issues.

All States currently use this classification scheme or some variation of it for classifying vehicles, although few use it exclusively. Many States separate one or more of the FHWA categories into two or more additional classifications to track vehicles of specific interest to them. They then aggregate the categories back together when reporting to the FHWA. This allows each State to meet both its own needs and the FHWA's needs. In addition, many States use other classification schemes in places where axle sensors do not work effectively (e.g., congested urban conditions) or where non-intrusive sensors are needed.

Since the earliest work done by Maine DOT (Wyman, Braley and Stevens 1985) on classification algorithms[3], it has been apparent that different States have trucking fleets with slightly different axle spacing characteristics. Thus, even when States use the same FHWA classification scheme, the algorithm they use to convert axle-sensor information into vehicle counts by category differs. In most cases, the vehicle classification algorithm provided by each manufacturer needs to be "fine tuned" to accurately convert that State's truck fleet axle spacing characteristics into an accurate measure of truck volumes for the FHWA categories.

Fine-tuning the classification algorithm is needed because the visual basis of the FHWA 13 categories does not translate to an exact set of axle spacings. For example, classes 2 and 3 (passenger car and other two-axle, four-tire, single-unit vehicles) are easily identified visually. However these classes are often inter-mixed by axle-sensor-based classification counters. This is because larger cars often have wheelbases equal to or longer than those of small trucks. Consequently, it is not possible to create an

[3] The Maine DOT work, led by John Wyman, created the algorithm commonly referred to as "Scheme F," which serves as the basis for most current axle-sensor based classification counter algorithms.

algorithm that uses only axle spacing information to differentiate between these two classes of vehicles.

These types of problems exist in a variety of vehicle classes. Recreational vehicles are particularly hard to classify with axle sensors. In many cases, States can do little about these problems (such as the class 2 and 3 problem mentioned above). Difficult choices are made to fine-tune the classification algorithms to limit the effects these errors have on the data they collect. This usually means ensuring that the algorithms correctly classify “important” truck categories and only have problems classifying types of trucks that are rare and of less importance to the highway community. Highway agencies must educate their users on the limitations in the data collected.

Calibration and Testing of Classifiers

Each State must periodically calibrate, test, and validate the performance of its classification equipment to ensure that the equipment is operating as intended. This includes testing each new shipment of classifiers received from the manufacturer, and a short field test whenever a classifier is placed in traffic to ensure that the counter is working correctly. The quality of the data collected is highly dependent on the quality of the calibration/testing operation.

Alternative Classification Schemes

When the FHWA 13 categories cannot be used (because the data collection equipment can not collect them), or the FHWA classes do not meet State needs, it is recommended that the classes be either a subset of the FHWA classes or a clean disaggregation of the FHWA classes. That is, the State should strive to create classes that consist of either several FHWA classes added together (e.g., a “single-unit truck” category that consists of FHWA classes 5, 6, and 7), or FHWA categories split into two or more classes (e.g., dividing FHWA Class 13 into the two classes, “triple-trailer trucks” and “other seven or more axle multi-trailer vehicles”).

The aggregation of the FHWA 13 classes into three or four classes is specifically recommended for the seasonal factoring of truck volumes.

Highway agencies are also encouraged to collect and analyze detailed vehicle characteristic data (i.e., actual axle weight and spacing information) every few years from several WIM locations to examine changes in fleet characteristics over time. Examination of detailed axle spacing information will allow currently emerging vehicle characteristics such as split tandems and changing axle spacing relationships to be tracked. Such changes can result in the need to update vehicle classification algorithms.

The detailed data needed for this type of analysis (number of axles, axle spacings, total vehicle length, and trailer configuration information) can be obtained from individual vehicle records collected by WIM equipment. For some analyses, these data need to be supplemented by a video record with a visible time recording to allow the video record to be matched against the WIM vehicle record.

CHAPTER 2
USER NEEDS

User needs drive the data collection process. **A key to making the data collection process valuable to agency's decision makers (a requirement for adequate funding) is the ability of the traffic monitoring program to supply users with the data they need.** This can be a difficult problem because in many cases data users and collectors do not communicate well with each other.

Data collectors and data users are frustrated by the lack of communication. Data collectors often know little about how the data will be used but are asked to provide data and summary statistics. Many of these statistics require the application of professional judgment, and that judgment is hard to apply when the impact of different assumptions on analytical outcomes are not fully known. Data users often receive data with no explanation. The precision of the estimates is rarely provided. In many cases users settle for the data or summary information provided. Generally, better data and information will result if communication between the data and user groups are improved.

This chapter discusses briefly some of the uses of traffic classification 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 actively investigate the data needs of their agency and then work creatively to meet those needs.

USES FOR CLASSIFICATION DATA

Vehicle classification data are of considerable use to agencies involved in almost all aspects of transportation planning and engineering. The need for information on truck volumes and freight movements is growing with the recognition of the role that freight mobility plays in the economy, and as highway engineers realize the importance of truck volume and operating characteristics on the geometric and structural design of roadways and bridges. Common uses of truck volume information include the following:

- pavement design
- pavement management
- scheduling the resurfacing, reconditioning, and reconstruction of highways based on projected remaining pavement life
- prediction and planning for commodity flows and freight movements
- provision of design inputs relative to the current and predicted capacity of highways
- development of weight enforcement strategies
- vehicle crash record analysis
- environmental impact analysis, including air quality studies
- analysis of alternative highway regulatory and investment policies.

In short, vehicle classification data are extremely important and will become even more important as transportation agencies and legislatures grapple with increasingly older, more congested roadways that need long lasting repair and rehabilitation in order to ensure statewide economic vitality.

SUMMARY VEHICLE CLASSIFICATION STATISTICS

The many uses for classification data require the production of a wide variety of summary statistics. For example, a State wishes to develop the annual average daily traffic by class for each roadway. To comply, several actions are required which the program must be capable of producing. A sufficient base of short duration classification counts must be taken. The short-duration classification counts must be adjusted to account for changing traffic volumes on different days of the week and different months of the year. The adjustment process must be developed and applied, which assumes the availability of continuous classification counter data. The resulting statistics are then capable of meeting defined user needs.

The average classification estimates can also be combined with load data to produce annual average loading conditions useful for monitoring the growth of trucks over time, for determining the loads being placed on pavement and bridges, and for tracking freight movements on the road system.

In addition to annual average conditions, users may want to be able to describe truck traffic by time of day during the average weekday. These estimates can be useful for scheduling road closures and in examining the effects of new development. Weekdays are also a normal design consideration from a traffic operations perspective, and understanding the mix of traffic is an important input to the design of an operational control strategy. Special procedures based on the available data can be developed to produce the desired information

Many statistics can be extracted from the vehicle classification data available from a comprehensive program. Several current revenue distribution formulas require vehicle distance traveled (VDT) information, and given the sensitivity of pavement design procedures to truck volume and load, it is quite possible that at some point, truck VDT could also be used in this fashion. Other common uses of VDT statistics by vehicle class include:

- air quality emission calculations
- crash statistics by type of vehicle
- general trend monitoring.

VDT by classification is a critical input to vehicle safety studies (crash rate and exposure calculations), cost responsibility studies, and vehicle size and weight studies. Many States track the use of specific types of vehicles. For example, Oregon tracks the use of triple-trailer combination trucks. Computing statewide or systemwide VDT by classification allows the State to compare not just total travel trends, but differences between trends for the subject vehicle class and for other similar classes. Oregon can not only measure the growth of triple-trailer truck travel (and changes to the crash exposure of these vehicles) but can also compare the growth of travel in that category of trucks to the increased travel of vehicles in other large truck classifications.

Developing data collection programs and aggregation methodologies that allow the computation of average facility statistics from average daily traffic estimates allows users to target these types of analyses to much lower levels (for example, how much is heavy truck travel growing on Interstate highways?). These statistics in turn facilitate improved geometric design work, more accurate safety analyses, and improvements to other critical engineering tasks.

The user may not always be interested in producing results using all 13 of the FHWA vehicle classes. In many cases three or four simple categories may suffice to meet user needs. Four traditional categories often used are:

- passenger vehicles (cars and light pick-ups)
- single unit trucks
- single combination trucks (tractor- trailer)
- multi-trailer trucks

Each of these categories is an aggregation of existing FHWA classes. Reporting and use of these simpler categories has the advantages of requiring less work (by the data collectors and the user) and of providing more statistically reliable truck volume counts for many analyses. Several of the FHWA categories contain so few vehicles that it is not possible to count and accurately report them. Using a smaller number of vehicle classes increases the confidence in the volume estimates reported.

Where practical, a State highway agency should collect data in the 13 FHWA vehicle classes but perform the majority of its data reporting with a more aggregated classification system, such as the four categories described above. This has the advantage of providing most users with as much information as they can use, while allowing those users who require more detailed information to obtain it. Such an approach is successful as long as users understand that more detailed data are available at some locations but that the quality of the details may be lower.

Axle correction factors are derived from classification data. Conventional volume counting performed with road tubes or other single axle sensors provides axle counts that must be converted into vehicle volume estimates. If all vehicles were passenger cars, dividing the number of axle hits by two would provide a good estimate of the total traffic volume. However, the more multi-axle vehicles that are present, the less accurate an adjustment factor of 2.0 becomes.

Where classification counts exist (particularly those that use the 13 FHWA classes), a much more accurate axle correction factor can be computed by assigning an average number of axles to each of the 13 classes and then calculating the average number of axles per vehicle for each vehicle on that road. This number can then be used to factor conventional axle counts taken on that road near the classification count. Table 4-2-1 provides a sample conversion chart that can help compute axle correction factors from classification counts that use the FHWA 13 vehicle classes.

Table 4-2-1
Conversion Chart

Vehicle Class	Average Number of Axles Per Vehicle
1	2
2	2
3	2
4	2.2
5	2
6	3
7	4
8	4
9	5
10	6
11	5
12	6
13	7

Axle correction factors should be taken from classification counts performed on the same days of the week as the volume count (or at least weekday counts need weekday classification counts) because the difference in vehicle mix from weekday to weekend at many sites can create significant error.

Axle correction factors from multiple counts within a group of roads can also be averaged to provide an estimate of an "expected" axle correction factor for roads within that group. This procedure is useful for computing axle correction factors for roads on which no recent classification count has been computed.

States should look to expand on the classification data they provide to users. Several States publish "truck volume" maps and/or "freight flow" maps. These maps, analogous to traditional traffic flow maps, show truck volumes (or truck freight tonnage) in a graphic form by roadway. They allow visual inspection and comparison of the magnitude of freight movement carried by alternative routes. The information can be used to prioritize alternative road improvement projects, provide public information needed to reach consensus on required transportation alternatives, and provide a resource for engineers and planners who are trying to balance funding constraints with the need to support freight movement.

Lastly, States have traditionally reported a basic "truck percentage" statistic for most roadways. This statistic can be easily computed and reported on the basis of the annual average vehicle classification estimates. Time of day and day of week biases can affect the calculation of truck percentages and can also affect the use of this statistic. For example, the truck percentage calculated from a 24-hour classification count taken on a Wednesday, while being accurate for the period where the data were collected, probably overstates the true annual truck percentage. This percentage is also probably incorrect if it is used to estimate peak period truck traffic. Peak hour and peak period truck percentage statistics should be produced and reported specifically to meet those data needs.

CLASSIFICATION DATA NEEDS FOR PAVEMENT DESIGN

The new pavement design guide currently being developed by the NCHRP[4] requires considerably more traffic data than traditional pavement design procedures. Location-specific truck volume estimates are crucial to the accurate estimation of pavement loads. The annual average daily truck traffic statistics discussed above meet the primary need for current truck volume estimates necessary to compute pavement loadings.

However, the new pavement design guide also requests knowledge about seasonal variation in truck volumes and time of day distributions in those volumes. Seasonal variation will be input to the guide as monthly factors. Seasonality is important to pavement design, because the structural response of most pavements changes with environmental conditions. Thus, the timing of loads is important to the accurate prediction of pavement life.

Time-of-day distributions are used in the draft NCHRP design guide to predict the day and night temperature differentials on the curling and warping of PCC pavements.

[4] The new pavement design guide, currently in draft form, will be reviewed by AASHTO.

CHAPTER 3
VEHICLE CLASSIFICATION DATA COLLECTION DESIGN

As with traditional traffic volume counts, a vehicle classification counting program should consist of both short duration and continuous counts. The short duration counts provide geographic coverage and the continuous counts provide the information needed to account for day-of-week and seasonal variations when the short duration counts are converted into annual estimates.

Data on volumes by vehicle classification come from a variety of sources. The majority of the spatial data will come from short duration counts. Other sources include WIM sites, urban traffic management centers, toll facilities, and other agencies that collect truck volume information. Obtaining data from these external sources greatly increases the data available for agency use, often at a far lower cost to the highway agency than if it had collected the data directly.

The key to a successful classification data collection program is not the source of the data, but the ability to routinely obtain it, verify its validity, summarize it into useable formats, report it in a manner that is useful to data users, and manage the process efficiently. Major portions of the management function involve understanding the need for both short duration and continuous vehicle classification counts and creating a program that collects the appropriate amount of data within both categories.

SHORT DURATION COUNTS

Short duration vehicle classification counts serve as the primary mechanism for collecting information on truck volumes. They provide the geographic distribution necessary to meet the general agency needs and the needs of its customers, as well as the site-specific knowledge needed for the more detailed technical analyses of users.

Large numbers of transportation analyses are starting to require more and better truck volume information. Truck volume information has become particularly important for pavement design, freight mobility, planning, safety, and project programming decisions.

Earlier versions of the TMG recommended the collection of 300 vehicle classification counts during a three-year data collection cycle. This recommendation stemmed from research performed in the early 1980s, when automated vehicle classifiers were just beginning to be adopted by highway agencies. However, 100 vehicle classification counts per year is not adequate to meet the current truck volume data needs of most State highway agencies, and many currently collect far more classification data than this.

A more comprehensive approach is needed to provide the classification data. The recommendation is based on the following objectives:

- increasing the accuracy and availability of truck volume data
- improving the truck volume data for national studies
- improving the truck volume data used for site-specific studies
- decreasing the cost of collecting the truck volume data by making it a primary focus of the traffic data collection program.

Short duration counts by themselves, however, are only part of the data collection process. Research has shown that truck volumes vary dramatically during the day, often differ significantly between weekdays and weekends, and can change as well from one season to the next season. If adjustments are not made for day-of-week and seasonal variation, the result is likely to be erroneous analytical conclusions. For example, safety research that uses truck crash rates computed only from weekday counts will significantly under-estimate the truck crash rate for most locations because unadjusted weekday volumes tend to over-estimate annual average daily volumes. A base of continuous classification counters is used to support the temporal factoring process.

Classification Coverage Counts

The classification coverage count program should be designed to operate like a traditional volume coverage program to provide a minimum level of truck traffic data on all system roads. The basic coverage program would be supplemented by special counts as needed to meet site-specific data needs.

To develop a classification coverage program, the highway system should be divided into vehicle classification (truck) segments akin to what is currently done for volume and described in Section 3. Vehicle classification segments should, in theory, carry a homogeneous volume of trucks, where trucks are defined as the aggregation of FHWA classes 4 to 13. In practice, development of these section definitions is a judgment call since the definition is usually based on the available classification data combined with specific knowledge of the system. The more classification data and the better knowledge of trucks available, the easier and better the definition will be. The availability of truck or commercial vehicle flow maps during the road segmentation process is very useful.

Most vehicle classification segments are expected to span several traffic volume segments because truck traffic can remain fairly constant despite changes in total traffic volume (that is, changes in car volumes do not necessarily result in changes in truck volume). With time, as more data and information become available, the definition of segments will improve.

As with traffic volume, the classification segments will change over time as roadway and traffic characteristics change and as more classification data helps to better define the segments. Periodic reassessments will be necessary to maintain the classification segment inventory current.

Many caveats apply to the development of the classification coverage count program. Each agency will have to develop a classification inventory system to cover its roads that meets its needs. In some cases, the truck traffic may not change over large expanses of road and a small number of classification segments will cover the road. In the Interstate system, for example, classification segments may extend over several interchanges and be very long. The character of the highway and the traffic it carries will play a major role in the definition of these segments and in the number of classification counts needed. Roads that service truck traffic generating activities will necessitate more classification segments, more classification counts, and more frequent revision than roads through regions that experience little trucking activity.

Lower functional systems, where truck traffic may be sporadic, may require long segments in some areas and shorter segments in others, particularly, where truck traffic generators are found. Judgment will play a large role in the roadway segmentation and the classification count planning in these areas. Additional classification counting may be needed to better identify where significant changes occur and how these affect the definition of segments.

The structure of the road system is superimposed by a system of traffic volume segments that allow the traffic counting program to cover it. Likewise, the traffic volume segments will be covered with a smaller subset of vehicle classification segments that allow the establishment of a vehicle classification program that covers the system and provides comprehensive truck data.

The vehicle classification segment inventory will allow a determination of how much classification counting is needed and how many of the volume counts should be classified. **A general rule of thumb is that 25 to 30 percent of the coverage volume counts should be classified.** This, of course, depends on the actual volume coverage program in operation, the character of the road system covered, and many other considerations. The general rule of thumb applies to the traffic volume program recommendation using a coverage program over a 6-year cycle.

Common sense and judgment are greatly needed to determine how to integrate classification and volume counting. Different agencies will make different decisions depending on many considerations. In some cases, the availability of low cost classification equipment can almost justify the conversion of all counting to classification. The gain in information on trucks combined with the elimination of the error introduced by axle correction may justify the extra cost. Many of the newer counters perform classification and many agencies that have acquired the new equipment classify rather than count.

On the other hand, changes in program direction, the acquisition of newer equipment, and the implementation of program changes do not occur overnight. Many organizations depend on available counters, have long-term data collection contracts, or do not have established classification programs.

Many lower volume roads do not have the volume of classified vehicles (trucks) to justify the full conversion of volume counting to classification. These are the roads where the installation of classifiers based on road tubes is easier and where equipment limitations are not a problem. However, once a classified count is taken, additional repetitive counts may not improve the truck volume estimates. In these cases, a decision to save a little time, effort, and funding could be appropriate.

On higher road systems, repetitive classification may greatly enhance the understanding of truck volume variability and result in better truck volume estimates. However, on these roads the collection of classification data is much more problematic. In the higher volume systems, portable equipment installation may not be safe or effective and the installation of more expensive equipment the only solution.

Such constraints may dictate a slower conversion from the current data collection program to the recommended program that emphasizes classification counting. Still, all highway agencies need to understand the use of their roadways by trucks, and thus counting of trucks is an important task. To help achieve that objective, **another useful rule of thumb is that a minimum of one vehicle classification count should be taken on each road each year** to insure a minimum of data available annually to represent each road. Where practical, these counts should be taken at existing HPMS volume sample sections to insure the quality of classification data reported to the HPMS.

Many caveats apply to this rule of thumb as well. For long roads (such as roads that extend across an entire State), far more than one count must be taken. For roads that change character (e.g., a route may be primarily a farm to market road in one place but become a major freight hauling road in another) several classification counts may be appropriate.

Roads that experience significant changes in truck traffic due to changes in industrial activity and/or junctions that lead to truck generators may need classification counts on either side of the junctions where truck activity levels change. For minor routes, a single classification count may be all that is needed. Finally, some agencies may decide to take additional vehicle classification counts whenever resources permit simply because truck volume data play a major role in defining coverage program segments and to insure quality data are available to meet user needs.

The implementation of a comprehensive classification coverage program requires direct integration into the standard volume counting program activities. The manner of scheduling, equipment, staff, and resources must be adequately considered.

It may not be necessary to perform vehicle classification counts at the same location every year. Any placement within the defined segment should provide adequate representation and any additional counts taken help to verify the annual estimate provided. Likewise, classification counts need not be taken at the same time each year because the conversion to annual estimates accounts for the temporal variability. In fact, counts taken at different times of the year provide independent estimates that will help to verify and/or improve the segment estimate. Careful scheduling of the data collection effort may also be necessary to measure important, seasonal truck movements such as those due to harvesting or other highly seasonal events.

The recommended length of monitoring for vehicle classification data remains 48 hours. The recommended cycle of monitoring for the classification program is also 6 years. The schedule of counts should be developed to insure that coverage of each classification segment occurs at least once within a 6-year cycle.

Whenever possible, vehicle classification counts should be taken within the HPMS volume sample sections. This results in direct estimates for each sample section, thereby allowing the expansion of the truck percent variables in the HPMS to valid system estimates of truck travel.

Other Special Needs Counts

As with traditional volume counting, the vehicle classification count program requires special counts in addition to those collected for coverage to meet needs that the coverage program does not cover. Traditionally, these counts have been primarily project related.

Project Counts

In many States, the majority of classification counts are project related. Most commonly these counts are taken to determine the truck traffic on a road segment that requires a traffic load estimate as an input for a pavement rehabilitation design. Collection of the data specifically for the road segment being rehabilitated ensures that the count data reflect current conditions and that the data used in the geometric and structural design procedures are accurate enough to ensure adequate performance of the new pavement over the design life of the project. Common reasons for project counts include pavement design, operational design (e.g., signal timing or testing the need for truck climbing and/or passing lanes), geometric design, and corridor studies. Each project count can have different requirements for duration, spatial frequency, and types of summary measures that must be produced.

The establishment of a classification coverage program will allow a more complete understanding of truck traffic on the highway systems and hopefully limit the need for additional counting to special cases.

Urban Classification Count Programs

The need for classification data in urban areas is pressing. Unfortunately, these are some of the most difficult places for current data collection equipment to operate. Existing counter technologies have significant difficulty classifying vehicles in conditions where vehicles do not operate at constant speed, where vehicles follow very closely, or where stop and go traffic occurs. This is particularly true for equipment that relies on inductance loops and axle detectors.

However, this does not mean that vehicle classification counts cannot be taken in urban areas. Agencies must simply take special care in selecting both the technologies they use and the locations where they place the equipment to ensure that the data collected are valid. Research efforts to investigate new technologies should continue. Several new technologies, particularly video and various laser-based technologies, can classify accurately in urban conditions when they are correctly placed and calibrated.

Studies can be undertaken to identify the classification segments where classification data needs exist. The first step may be identifying current installations where classification data may already be collected by ITS installations, State permanent counters, tolls, bridges, traffic signals, etc. Retrieving that data reduces the need for the use of portable data collection equipment at many sites. Second, identify the remaining locations where the portable data collection program can collect data using current technology. Subtracting these sites from the set of all needed locations should result in a set of locations where data cannot be collected using current means. The use of visual counts is often a last resort in cases where data cannot be collected by other means. Finally, a determination can be made of the counting/classification program needed to provide system coverage and meet special count needs.

Classification data also offers the additional advantage of providing speed data that are often used in air quality analysis and other urban studies. Likewise, speed studies provide classification data. Thereby offering an opportunity for coordination and reduced data collection.

Integration of the Coverage Count Program with Other Programs

At first glance, the coverage program recommended for classification counts can seem large. It is true that the recommended program is an expansion over previous recommendations. The expansion is due to the maturation of vehicle classification technology and an explosion of the need for truck data. However, many States that already actively collect substantial amounts of classification data to meet their own data needs may find that the current recommendations do not significantly increase the size of the program.

The first level of integration is that classification counts should replace traditional volume counts on road sections where classification counts are taken. Thus, for every classification count taken, one less volume count is needed.[5] Use of classification counters to provide total daily volume estimates also has the advantage of providing direct measurement of daily volume since the need for axle correction is eliminated.

The coverage count program should also be integrated as much as possible with the project count program. Existing project counting activities can eliminate the need for coverage counts. Similarly, existing coverage counts can often supply project information, if the existing coverage count meets the informational needs of the project.

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[5] In most cases, this still requires an increase in data collection resources because it takes more staff time as well as more physical data collection equipment to set classification counters than it does to set traditional volume counters for the same number of lanes of data collection.

Finally, the classification count program should be integrated with other traffic surveillance systems, particularly those involving regulation of the trucking industry (such as mainline sorting scale operations upstream of weight enforcement stations), as well as surveillance systems installed as part of traffic management, safety, and traveler information systems.

Duration of Short Counts

The period of monitoring recommended for vehicle classification counts is 48 consecutive hours. Other count durations can produce reasonable results in some cases, but are not recommended for general use. Equipment that can collect data in hourly traffic "bins" should be used for the general program. In urban areas or for special studies, the use of shorter intervals, such as 15 minutes, may be appropriate. The use of 48-hour periods is recommended because:

- the accuracy of the annual load estimates of 48-hour counts is better than that of 24-hour counts
- significant improvement in quality control capabilities become possible with the comparison of one day's hourly traffic counts against the second day's counts
- axle sensors will normally stay in place for 48 hours if correctly installed.

Counts for less than 24 hours are not recommended unless they are intended to provide project specific information (such as turning movement counts for signal timing plans). This is because truck travel changes significantly during the day, and some sites can experience relatively large truck volumes at times when other traffic volumes are light. Counting throughout the day is important to determine accurate daily truck volumes, particularly in roads that carry substantial numbers of trucks.

Counts of less than 24 hours are usually taken as a last resort when other data collection alternatives are not available. These counts need to be adjusted to daily totals using a daily adjustment factor to convert the shorter period to a 24-hour estimate. This adjustment factor should be obtained from more extensive classification counts on similar roads because the time-of-day distribution of truck volume is not the same as that for total volume. The daily volume must also be converted to an annual estimate by using the appropriate day-of-week and monthly factors.

Vehicle classification counts of longer than 48 hours are useful, particularly when those counts extend over the weekend, since they provide better day-of-week volume information. However, in many locations it is difficult to keep portable axle sensors in place for periods that significantly exceed 48 hours. Many highway agencies have also experienced difficulty in developing cost-effective staff and equipment utilization plans when using 72-hour or longer count durations. Whether a highway agency can conduct longer counts is a function of coverage area size, staff utilization, and other factors.

While a strong case can be made for a number of other count durations, the benefits of 48-hour counts are supported by recent research findings. In particular, a study of truck volume variability and the effect of factoring classification counts showed that an improvement of between 3 and 5 percent in estimation of annual average volumes could be achieved by increasing the duration of the classification count from 24 to 48 hours (Hallenbeck and Kim 1993). A study of total traffic volume counts by Cambridge Systematics found that lower volume roads tend to have much greater day-to-day volume fluctuations (in percentage terms) than higher volume roads. These roads showed the greatest improvement when traffic counts were extended from 24 to 48 hours (Cambridge Systematics et al 1994).

PERMANENT/CONTINUOUS CLASSIFIERS

Research has shown that truck travel does not follow the same time-of-day, day-of-week, and seasonal patterns as total volume (Hallenbeck and Kim 1993, Weinblatt 1996, Hallenbeck et al 1997). Analysis of continuously collected data sets also seems to indicate that truck volumes on many roads (even high volume Interstate) can change dramatically as a result of changes in the national and local economy. Continuously operating classification counters are needed to monitor truck flows so that these patterns can be detected and accounted for in engineering and planning analyses. **Each State highway agency needs to operate a set of continuous classification counters to measure truck travel patterns and provide the factors to convert short classification counts to annual averages.**

All State highway agencies have been operating permanently installed, continuous traffic counters (commonly referred to as ATRs) for many years. It has only been since the mid-1980s that technology allowed the installation and operation of similar counters to collect continuous classification data. A significant increase in the number of these counters has taken place since 1990, as a result of the start of traffic data collection for the Strategic Highway Research Program's (SHRP) Long Term Pavement Performance (LTPP) project. Many States have also converted ATR installations to classification as the old equipment wore out and was replaced.

Data from these continuous classification devices have shown that truck volumes have time-of-day, day-of-week, and seasonal variations that are very different from those of cars. In addition, sources of continuous classification data may be obtained from installations from regulatory, safety, and traffic management systems installed to operate and manage the infrastructure. To obtain these existing data, highway agencies often must create close working relationships with other public agencies. The effort may result in considerable improvement to the available classification data.

Introduction to Continuous Classification Counts and Factors

The objective of seasonal factor procedures is to remove the temporal bias in current estimates of truck volume. There are four primary reasons for installing and operating permanent, continuously operating vehicle classifiers for traffic monitoring purposes. These include the ability to:

- provide a highly accurate measure of truck volumes at a limited number of specific sites around the state
- track the changes in those volumes over time with a high degree of accuracy
- determine the travel patterns of different truck types on different roadways across the State
- create adjustment factors and factor groups that allow application of the factors for converting short duration classification counts into annual average estimates of vehicle volume by vehicle type.

This section discusses ways to establish a continuous vehicle classification count program, and presents two alternative methods for the development of factor groups for classification. The continuous vehicle classification data collection program is related to, but can be distinct from, the traditional ATR program. In addition, factoring of vehicle classification counts (i.e., truck volume counts) may be performed independently from the process used to compute AADT from short duration volume counts.

There is still a significant lack of data in most States concerning the travel patterns of trucks. Much work needs to be done to gain the knowledge needed to refine the vehicle classification factor groups and factor procedures. The first step has been taken to recommend a process that will improve the quality of truck volume data and information. To become effective the process will have to be implemented and given time to mature and fully develop as knowledge is gained and improvements made.

Vehicle Classes Used for Factoring

Regardless of the approach taken for the computation and application of factors, **it is recommended that adjustment factors be computed only for three or four "generalized" vehicle classes.** The groups recommended are:

- passenger vehicles (motorcycles, cars, and light trucks)
- single-unit trucks (including buses)
- single-unit combination trucks (tractor-trailers), and
- multi-trailer combination trucks.

In States with few multi-trailer trucks (often the case East of the Mississippi River), three vehicle classes may be sufficient. In these cases, single-trailer and multi-trailer combination trucks should be combined. Highway agencies may adjust these categories to best reflect their vehicle fleets and travel patterns, as well as the capabilities of the classification equipment in their programs.

Several reasons support the recommendations. The factoring process does not work well with very low traffic volumes. With low volumes, even small changes result in high percentage changes that make the computed factors highly unstable and unreliable. Even on moderately busy roads, many of the 13-category vehicle classes will have mathematically unstable vehicle flows simply because their volumes are low. Aggregating the vehicle classes provides for more stable and reliable factors.

A second reason is that computing factors for 13 vehicle classes, in what is clearly recognized as the pioneering development of classification factoring processes, may introduce too much complexity and may create a computational and application nightmare. There is no gain in separately annualizing extremely variable and rare vehicle classification categories at this relatively primitive stage of the process.

A third reason is that many issues relating to the quality of the classification data available from continuous and portable counters remain unanswered. Adequate editing procedures, resolution of the assignment of vehicles to classification categories, inability of equipment to collect a standard set of vehicle classes in all conditions, and tremendous disparity in equipment already present major challenges to the factor development and application process. Unnecessary complications at this stage of development should be avoided.

Alternative Factor Procedures

Two alternative truck volume factor procedures are presented. Both have advantages and disadvantages. Both are very complementary and can be combined as appropriate. Unlike procedures for total traffic volume that have benefited from many years of trial and error by 50 State highway agencies, the procedures discussed here are in their infancy. Recognizing that fact, flexibility is offered to apply these or any other alternatives that effectively remove temporal bias.

The first procedure involves the use of roadway-specific factors. The second is an extension of the traditional traffic volume factoring process involving the creation of groups and the development of average factors for each of the groups.

Either applying factors to a road or fitting road segments into groups involves making decisions to resolve difficulties. A factor process may result in one set of factors for cars, another set of factors for trucks, and the combination of both to arrive at a total volume. A factor process may also require more than one set of factors for trucks when different truck types are factored separately. Some roads could conceivably fit in one factor group for cars, a second factor group for single unit trucks, and a third factor group for combination trucks. Resolutions have to be made by each State between the need for accuracy, and reductions in unnecessary complexity in the approach to removing temporal bias. The current state-of-the-art has not progressed to the point where detailed guidance can be given on the precise number of factor groups that need to be created or on the resolution of the many issues that will arise.

There are two basic parts to the factoring process, the computation of the factors that will be applied to the short counts, and the development of a process that assigns these factors to specific counts taken on specific roadways. The roadway-specific and the traditional procedures approach these two aspects of the factoring process differently. The result is two very different mechanisms for creating and applying factors, each with its own strengths and weaknesses.

Roadway-Specific Factors

This process was developed by the Virginia Department of Transportation (VDOT) in the late 1990's. The VDOT operates continuous counters on all major roads and the counters are used to develop road-specific factors. A short classification count taken on a specific road is adjusted using factors taken from the nearest continuous classification counter on that road. A factor computed for a specific road is not applicable to any other road.

As a result, a continuous classification counter must be placed on every road for which an adjustment factor is needed. This requires a large number of continuous vehicle classification counters and substantial resources. However, it ensures that a road can be directly identified with an appropriate factor and provides considerable insight into the movement of freight and goods within the State. The rule for assigning factors to short counts is simple and objective.

Identifying a specific road with a specific factor removes a major source of error in the computation of annual traffic volumes by removing the “location” error associated with applying an average factor. Further, it produces factors that are applicable to all trucks using that road. The fact that different truck classes (single-unit versus combination trucks) exhibit different travel patterns is irrelevant, since all patterns are computed for that road.

Having road-specific continuous counters also greatly reduces the number of short duration counts that are needed, since the continuous counters provide classification data for road sections near the count locations. The quality of data from continuous counters is usually superior to that of short counts.

Finally, this approach has the advantage of simplifying the calculation of adjustment factors, the application of those factors, and the maintenance of the program. For example, there is no need to develop groups and the application is done one road at a time. Problems with continuous counters only apply to the affected roads and prioritization of counter problem correction can be based on road priority.

There are also disadvantages with this approach. The most important is cost. It is expensive to install, operate, and maintain large numbers of continuous traffic counters.

The larger the system that must be covered the larger the cost. Even for smaller States, the cost to install a large counter base may be prohibitive. However, this approach may apply effectively to the Interstate, where sufficient continuous counters may be available. It can also be applied to roads where current counters are installed.

A second disadvantage is that many roads are quite long and the character of truck traffic over their length can change drastically. This is why short count coverage programs are needed at all. An adjustment factor taken on a road segment may not be applicable to another segment a few miles down the road, particularly if large truck generation activities take place along that stretch of roadway. Truck patterns change because of economic activity, traffic generators, or road junctions. Not only does this further increase the number of continuous counters required, it also creates difficulty in selecting between the two permanent counters when a short count falls in between.

The next problem is maintenance. Because of the large number of counters required, some counters will always be down. The inability to quickly repair failed continuous counters results in a lack factors for those roads.

One solution may be to develop and use the "traditional" method described below as a "back-up" for places where a specific road factor is not available. That is, specific road factors may be used for the most important truck roads and the traditional factor groups for routes without continuous counters. When continuous counters fail, traditional factoring techniques can then be used to provide adjustment factors on those roads. This combination of the traditional and "roadway specific" factors may be an effective compromise between these two techniques

One final problem with the "roadway specific" technique is that there is no mathematical mechanism that allows computation of the accuracy/precision of the factors as they are applied to a given roadway section. When these factors are applied to count locations that are close to the continuous counter, they can be assumed to be quite accurate. However, as the distance between the short count and the permanent counter grows, and particularly as more opportunity exists for trucking patterns to change, the potential for error in the factor being applied grows, and at an unknown (but potentially substantial) rate.

The Traditional Factor Approach

The traditional factor process involves categorizing roads that have similar truck traffic patterns. A sample of data collection locations is then selected from within each group of roads, and factors are computed and averaged for each of the data collection sites within a group. A definition for each group describes characteristics that "explain" the observed pattern and which is used to allow the objective assignment of short counts to the groups.

For traffic volume, the traditional "characteristics" for grouping roads have been the functional class of the road (including urban or rural designation) and geographic location within the State. These groups are then supplemented with an occasional "recreational" designation for roads that are affected by large recreational traffic generators.

This same technique can be applied to truck traffic patterns. However, the characteristics that need to be accounted for can be very different. Functional class of roadway has been shown to have a very inconsistent relationship to truck travel patterns (Hallenbeck et al 1997). Instead, truck travel patterns appear to be governed by the amount of long distance "through" truck traffic versus the amount of locally oriented truck traffic, the existence of large truck traffic generators along a road, such as agricultural or major industrial activity, and the presence or absence of large populations that require the delivery of freight and goods. Understanding how these and other factors affect truck traffic is the first step toward developing truck volume factors.

Create Initial Factor Groups

States must depend on available classification data and knowledge to begin the development of basic truck traffic patterns. Truck traffic patterns are governed by a combination of local freight movements and through-truck movements. Extensive through-truck movements are likely to result in higher nighttime truck travel and higher weekend truck travel. Through-traffic can "flatten" the seasonal fluctuations present on some roads, while creating seasonal peaks on other roads that have nothing to do with economic activity associated with the land abutting that roadway section. Similarly, a road that primarily serves local freight movements will be highly affected by the timing of those local freight movements. For example, if the factory located along a given road[6] does not operate at night, there will likely be little freight movement on that road at night.

Functional road classification can be used to a limited extent to help differentiate between roads with heavy through-traffic and those with only local traffic. Interstates and principal arterials tend to have higher through-truck traffic volumes than lower functional classes. However, there are Interstates and Principal Arterial highways with little or no through-truck traffic, just as some roads with lower functional classifications can carry considerable through-truck volumes. Thus, functional classification of a road by itself has been shown to be a poor identifier of truck usage patterns. To identify road usage characteristics, additional information must be obtained from either truck volume data collection efforts or the knowledge of staff familiar with the trucking usage of specific roads.

Local truck traffic can be generated by a single facility such as a factory, or by a wider activity such as agriculture or commercial and industrial centers. These "point" or "area" truck trip generators create specific seasonal and day-of-week patterns much like recreational activity creates specific passenger car patterns. Truck trips produced by these generators can be highly seasonal (such as from many agricultural areas) or fairly constant (such as flow patterns produced by many types of major industrial plants). Where these trips predominate on a road, that road has truck travel patterns that match the

[6] Not subject to significant amounts of through traffic

activity of the geographic point or area that produces those trips. In addition, note that changes in the output of these facilities can have dramatic changes in the level of trucking activity. For example, a labor problem at one West Coast container port may produce dramatic shifts in container truck traffic to other ports. This results in significant changes in truck traffic on major routes serving those ports. Expansion or contraction of factory production at a major automobile plant in the Midwest can cause similar dramatic changes on roads that serve those facilities.

Truck trip generators can also affect the types of trucks found on a road. Specific commodities tend to be carried by specific types of trucks. However, State-specific truck size and weight laws can mean that trucks typical in one State may not be common in others. For example, multi-trailer trucks are common in most western States, while they make up a much smaller percentage of the trucking fleet in many eastern States. Understanding the types of trucks used in a State to carry specific commodities (e.g., coal trucks in Kentucky and Pennsylvania) is critical to understand the trucking patterns that should be expected on a road and how those patterns are likely to change.

There are many other patterns that affect truck travel. For example, construction trucks operate in an area's roads until the construction project is completed and then they move somewhere else. This type of truck movement is difficult to quantify. Roads near truck travel generators, such as quarries or trash dumps, carry consistent truck traffic and the type of truck is well known.

Summarizing the different patterns in a way that allows creation of accurate factor groups is difficult. Obviously, the more knowledge that exists about truck traffic on a road, the easier it is to characterize that roadway.

Geographic stratification and functional classification can be used to create truck volume factor groups that capture the temporal patterns and are reasonably easy to apply. An initial set of factor groups might look something like that shown in Table 4-3-1. Roads might then be moved between these initial starting groups as needed.

Definitions like those presented above group roads with as homogenous truck travel patterns as possible, and also provide easy identification of the groups for application purposes. They present a starting point to begin the identification process necessary to form adequate groups.

Performing a cluster analysis using truck volumes (as done in Section 3 for total volume) will help to identify the natural patterns of variation and to place the continuous counters in variation groups. This will help in identifying which groups may be appropriate and in the determination of how many groups are needed. One of strengths of the cluster analysis is that it identifies groups but only by variation. The weakness is that it does not describe the characteristics of the group that allow application of the resulting factors to other short counts.

The example definition in Table 4-3-1 does exactly the opposite. It clearly establishes group characteristics but cannot indicate whether the temporal variation is worth creating separate groups or not. As is the case for AADT group procedures, a combination of statistical methods and knowledge must be used to establish the appropriate groups.

Table 4-3-1
Example Truck Factor Groups

Rural	Urban
Interstate and arterial major through-truck routes	Interstate and arterial major truck routes
Other roads (e.g., regional agricultural roads) with little through traffic	Interstate and other freeways serving primarily local truck traffic
Other non-restricted truck routes	Other non-restricted truck routes
Other rural roads (e.g., mining areas)	Other roads (non-truck routes)
Special cases (e.g., recreational, ports)	

Determine the Variability of Group Patterns

All roads within the defined factor groups should have similar truck volume patterns. To verify that, the continuous counter data available within the groups must be examined. For each continuous classification counter in a group, compute the temporal adjustment factors of interest (day-of-week, month, or combined) for each of the vehicle types desired and then compute the mean and standard deviation for the group as a whole. Plots of the volumes and the factors over time can also help to determine whether the travel patterns at the continuous sites are reasonably similar.

In most cases only a few roads within each group will have data (continuous counters) needed to estimate travel patterns. The assumptions this analysis makes are similar to those made for AADT factors. The implication is that the continuous counters typify the existing temporal variation. Then the continuous counter variation reflects the variation existing at locations where there are no continuous counters. A combined monthly and weekday factor can be computed as follows[7]:

$$\text{Adjustment Factor}_{C,\ June} = AADTT_C / MAWDTT_{C,\ June} \qquad (4\text{-}1)$$

where

Adjustment Factor $_{C,\ June}$	=	a multiplicative factor for a specific vehicle type used to convert a 24-hour count taken on any weekday in June to an estimate of annual average daily traffic.
$AADTT_C$	=	annual average daily (truck) traffic volume for a specific vehicle type
$MAWDTT_{C,\ June}$	=	monthly average weekday (truck) traffic volume for the month of June for a specific vehicle type.

Computing the mean (or average) for the June factor for all sites within the factor group yields the group factor for application to all short counts (weekdays in June) taken on road segments within the group. The standard deviation of the factors within the group describes the variability of the group factor. The variability can be used to determine whether a given factor group should be divided into two or more factor groups, to compute the precision of the group factor, and to estimate the number of continuous counter locations needed to compute the group factor within a given level of precision.

The variability of each statistic computed for the factor group will have a different level of precision. For example, the June factor will have different precision than the July factor. The precision will also vary for each of the vehicle types analyzed.

<u>Test the Quality of the Selected Groups</u>

The information on variability must be reviewed to determine whether the roads grouped together actually have similar truck travel patterns. A number of methods can be used to determine whether various sites "belong" together. A statistically rigorous approach to testing the precision of the selected groups requires the use of fairly complex statistics, an examination of all the truck classes used, the comparison of statistical reliability for all the different types of statistics produced with the reliability users need for those statistics.

This is a complex and difficult analysis. The analysis can be simplified by concentrating on the most important vehicle classes and statistics produced. However, even with the simplifications suggested, trade-offs are necessary. No designed group will be optimal for all purposes or apply perfectly to all sites.

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[7] This formulation assumes a multiplicative application, that is, AADTT is equal to the average 24-hour count times the adjustment factor. Many states use the inverse of formula 4-1 and apply the resulting factor by dividing the average 24-hour volume obtained from their short count by the adjustment factor.

For example, in one group of roads, the single tractor-trailer volumes on roads within each group may have similar travel characteristics, but the single-unit truck volume patterns are very different from each other. By changing the road groups, it may be possible to classify roads so that all roads have similar travel patterns for single-unit trucks, but then the single tractor-trailer patterns become highly variable.

At some point, the analyst will need to determine the proper balance between the precision of the group factors developed for these two classes of trucks, or they will have to accept the fact that different factor groups are needed for different vehicle classes. Then each road may end up in multiple factor groups depending on what vehicle classification volume is being factored. Use of multiple groups may result in a more accurate factor process but will certainly result in a more complicated and confusing procedure.

The trade-offs between alternative factor groups can only be compared by understanding the value of the precision of each statistic to the data user. In most cases this is simply a function of determining the relative importance of different statistics. For example, if 95 percent of all trucks are single tractor-trailer trucks, then having road groups that accurately describe tractor-trailer vehicle patterns is more important than having road groups that accurately describe single-unit truck patterns. Similarly, if single-unit trucks carry the predominate amount of freight (this occurs in mineral extraction areas), then the emphasis should be on forming road groups that accurately measure single-unit truck volume patterns.

The quality of a given factor group can be examined in two ways. The first is to graphically examine the traffic patterns present at each site in the group. Figure 4-3-1 gives an example of a set of monthly truck volume patterns for a group of sites in the State of Washington that could be considered a single factor group. Graphs like these give an excellent visual description of whether different data collection sites have similar travel patterns.

The second method is to compute the mean and standard deviation for various factors that the factor group is designed to provide. If these factors have small amounts of deviation, the roads can be considered to have similar characteristics. If the standard deviations are large, the road groupings may need to be revised.

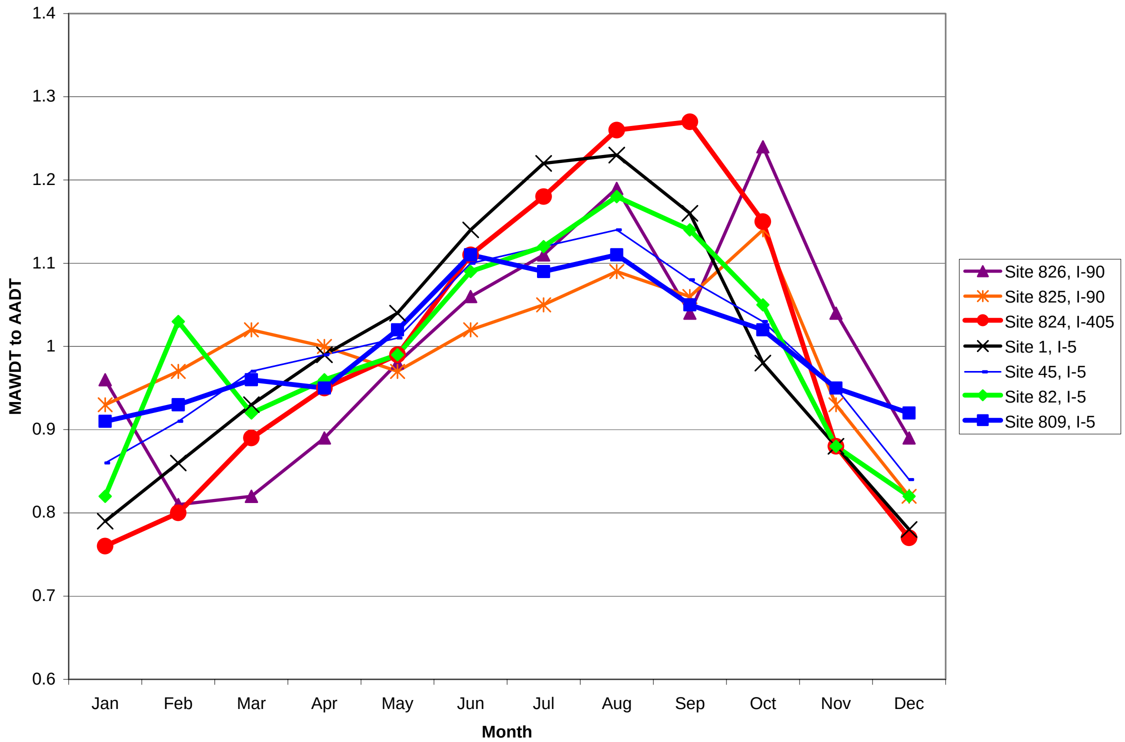

Figure 4-3-1: Ratio of Average Weekday Traffic per Month to Average Annual Daily Traffic for Combination Trucks (FHWA Classes 8 - 10) at Interstate Sites

Determine the Precision of Factors

An estimate of the precision of the group factor can be derived from the standard deviation. For example, the precision of the June adjustment factor computed above can be estimated using the standard deviation of that estimate. The precision of the group factor can be estimated with 95 percent confidence as approximately[8] plus or minus 1.96 times the standard deviation divided by the square root of the number of sites in the group.

Increasing the number of continuous counter locations within a group will improve the precision of the group factor. However, increasing the number of continuous counter locations only marginally improves the precision of the group factor application at specific roadway sections. That is, increasing the sample size makes the group factor itself a better measure of the mean for the group, but the mean value may or may not be a

[8] This is a relatively crude approximation because it assumes that the standard deviation calculated from the seven sample sites is equal to the actual standard deviation of the population of the group of roads. The value 1.96 should be used only for sample sizes of 30 sites or more. A more statistically correct estimate would use the Student's *t* distribution, which for six degrees of freedom (seven classification sites) is 2.45. The calculation also assumes that the factors are normally distributed, and that sites are randomly selected.

good estimate of the pattern at any given roadway section within that group. The standard deviation of the group factor measures the diversity of the site factors within the group.

There can be cases where the factors will not improve the annual volume estimates, particularly in high variability situations. An alternative is to take multiple site-specific classification counts at different times during the year to directly measure seasonal change. This can be an effective way to accurately estimate annual truck traffic for high profile projects that can afford this additional data collection effort. This alternative can also be used to test the accuracy of the annual estimates derived from the group factors.

Refine the Factor Groups

If the factor groups selected have reasonably homogenous travel patterns (i.e., the variability of the factors is low), then the groups can be used for factor development and application. If the factors for the group are too variable, then the groups may need to be modified.

These modifications can include the creation of new groups (by removing the roads represented by some continuous counters from one group and placing them in a new group), and the realignment of counters within existing groups (by shifting some counters and the roads they represent from one existing factor group to another). This process continues until a judgment is made that the groups are adequate.

Be aware, as noted earlier, that if very precise adjustment factors are desired, it is possible that the factor process will require different factor groups for each vehicle class. That is, traffic patterns for combination trucks may be significantly different (and affected by different factors) than the traffic patterns found for smaller, short-haul trucks. These patterns may in turn be sufficiently different than passenger vehicle patterns that three different factor groupings may need to be developed. In such a case, passenger car volumes may need to be adjusted using the state's existing factor process (since total volume tends to be determined by passenger car volumes in most locations); while single unit trucks are factored with data obtained from different groups of counters and combination trucks are factored with counts obtained from those same counters but aggregated in a different fashion. Then the three independent volume estimates need to be added to produce the total AADT estimate.

Determine the Number of Locations to Monitor

Once groups have been established and the variability of the group factors computed, it is possible to determine the number of count locations needed to create and apply factors for a given level of precision. Note that because each statistic computed for a group has a different level of variability, each statistic computed will have a different level of precision.

The first step in determining the number of sites needed per group is to determine which statistics will guide the decision. In general the key statistics are those that define the objective of the formation of groups, that is, the correction for temporal bias in truck volumes. The combined day-of-week and monthly factor, computed for the truck-trailer combination vehicles during the months when short duration counts are taken, may well be the most appropriate statistic to guide the group size, at least for the Interstate/arterial groups. For other groups, the single-unit truck may be more appropriate.

If counts are routinely taken over a nine-month period, the one month with the most variable monthly adjustment factor (among those nine months) should be used to determine the variability of the adjustment factors and should thus be used to determine the total sample size desired. In that way, factors computed for any other month have higher precision.

For most factor groups, at least six continuous counters should be included within each factor group. This is an initial estimation based on AADT factor groups. If it is assumed that some counters will fail each year because of equipment, communications, or other problems, a margin of safety may be achieved by adding additional counters.

Collect Additional Data and Refine the Established Process

Much needs to be learned about vehicle classification. **States are encouraged to convert as many of their ATR continuous counters to classification as possible and to analyze the available data to better understand truck travel patterns and variation.**

A substantial continuous vehicle classification program allows States to refine the classification count factoring process as needed. The addition of new continuous count locations allows the comparison of newly measured truck travel patterns with previously known patterns. This is true even for the road-specific factoring procedure, since traffic patterns along a road can change dramatically from one section to another. One way of adding new count locations is to move counter locations when equipment or sensors fail and need replacement at an existing continuous site.

If a new data collection site fits well within the expected group pattern, that site can be incorporated into the factor group. However, if a new site shows a truck travel pattern that does not fit within the expected group pattern, a reassessment of the truck volume factoring procedures may be appropriate. Modifications include moving specific roads or road sections from one factor group to another, creating new factor groups, and even revising the entire classification factoring process.

The factoring process should be reviewed periodically to ensure that it is performing as intended. For the first few years after initial development or until the process has matured, these evaluations should be conducted every year. After that, the classification process should be reviewed periodically every 3 years or the same review cycle used for the AADT group factor process.

CHAPTER 4
COMPUTATION AND REPORTING OF ANNUAL, SUMMARY, VEHICLE CLASSIFICATION STATISTICS

This chapter presents basic procedures for computing statistics or estimates derived from the vehicle classification program. Statistics discussed include:

- AADTT (annual average daily truck traffic)
- axle correction factors
- factors for converting daily truck traffic counts into estimates of AADTT (by class)
- factors that allow conversion of AADTT estimates (by class) into average day of week estimates for use in the draft NCHRP 1-37A Pavement Design Guide.

COMPUTATION OF AADTT

Computation of AADTT (by vehicle class) from a short duration count requires the application of one or more factors that account for differences in time-of-day, day-of-week, and seasonal truck traffic patterns. These adjustments are the same as those applied to traditional volume counts, except that they must be applied by individual vehicle classification when working with classification count data.

Estimating Daily Volumes from Less-than-Daily Counts

Classification counts should be taken for 48 consecutive hours. When it is not possible to collect at least 24 hours of data, time-of-day adjustments are needed to expand the short counts to daily estimates. Most classification counts are taken in hourly increments. When these hourly volumes add up to less than 24 hours (usually with visual counts), it is necessary to expand them to 24-hour estimates.

This should be accomplished using adjustments from data collected by permanent vehicle classification counters. Adjustment tables should be created for specific types of roadways (using the factor groups discussed in the previous chapter of this section if a better system is not available) and specific hours of the day. In this manner, the factor applied to adjust a very short count to an estimate of daily traffic volume (by class) will depend not just on how many hours were counted but on which hours were counted, as well as on which class of vehicles is being adjusted. For example, the adjustment for a 6-hour count taken from 8 AM to 2 PM may be very different than the adjustment that should be applied to a 6-hour count taken from 2 PM to 8 PM.

These adjustment tables can be created by simply computing the percentage of daily traffic that occurs during any one hour of the day for each vehicle class for each type of day of the week. These percentages can then be added together as needed to create an adjustment percentage for any series of hours of data collection.

Table 4-4-1
Calculation of Average Travel by Time of Day for Combination Trucks at an Example Continuous Counter Site

Hour	Average Weekday Volumes By Hour	Percentage of Traffic
Midnight - 1 AM	20	1.9%
1 AM - 2 AM	30	2.8%
2 AM - 3 AM	10	0.9%
3 AM - 4 AM	10	0.9%
4 AM - 5 AM	20	1.9%
5 AM - 6 AM	40	3.7%
6 AM - 7 AM	80	7.4%
7 AM - 8 AM	100	9.3%
8 AM - 9 AM	60	5.6%
9 AM - 10 AM	80	7.4%
10 AM - 11 AM	70	6.5%
11 AM - Noon	80	7.4%
Noon - 1 PM	50	4.6%
1 PM - 2 PM	60	5.6%
2 PM - 3 PM	90	8.3%
3 PM - 4 PM	80	7.4%
4 PM - 5 PM	50	4.6%
5 PM - 6 PM	40	3.7%
6 PM - 7 PM	30	2.8%
7 PM - 8 PM	20	1.9%
8 PM - 9 PM	10	0.9%
9 PM - 10 PM	20	1.9%
10 PM - 11 PM	10	0.9%
11 PM - Midnight	20	1.9%
	1080	100%

To compute the daily total traffic volume estimated by the short count, the simple formula below is used:

$$\text{Daily Traffic Volume} = \frac{\text{Short count volume} * 100}{\text{percent of travel during time period counted}} \qquad (4\text{-}2)$$

Thus, if a 6-hour count was taken from 6 AM to noon on a weekday, and 260 combination trucks were counted, then using Table 4-4-1, the total daily combination truck volume would be estimated as 600 trucks (260 * 100 / 43.6 = 596 ≈ 600).

Estimating Annual Average Daily Traffic Volume from a 24-Hour Classification Count

This calculation is equivalent to converting ADT to AADT. It requires the application of two adjustments, a day-of-week adjustment and a seasonal adjustment. These two factors can be applied as one combined factor (usually a ratio of AADT / MAWDT, or annual average daily traffic to average weekday traffic for a given month), or as two separate factors, a seasonal adjustment (usually AADT to monthly average) and a day-of-week adjustment.

Both of these techniques work with roughly the same accuracy, if the factor groups that are used to compute and apply those factors are correctly formed.

Estimating Annual Average Daily Traffic Volumes from More Than 24-Hour Counts

If the data collected cover more than 24 hours, the data should be summarized to represent a single daily count. This can be done in two ways, depending on how the factoring process is performed.

If individual day-of-week factors are used (e.g., a different factor for Tuesdays than for Wednesdays), then each 24-hour count can be converted into an estimate of annual average daily traffic, and the different daily values averaged into a single estimate of AADTT.

If a general day-of-week adjustment (e.g., a single weekday to average day-of-week adjustment), the individual hourly volumes[9] can be averaged. These averages are then totaled to produce a single daily volume, which can then be adjusted for seasonality and day of week.

COMPUTATION OF AXLE CORRECTION FACTORS

Emphasis on the collection of classification data should minimize the need for axle correction. Whenever possible, axle correction factors needed to convert axle counts to vehicles should be developed from vehicle classification counts taken on the specific road. In addition, the classification count should be taken from the same general vicinity and on the same day of week (a weekday classification count is usually sufficient for a weekday volume count) as the axle count it will be used to adjust. Where a classification count has not been taken on the road in question, an “average” axle correction factors can be estimated from the WIM and continuous classification sites.

[9] Only data for complete hours should be used. Partial hours should be discarded.

The computation is the same whether the data come from a single short duration count or from a continuous WIM scale. Table 4-4-2 illustrates the process.

In the table, vehicle volume is computed by dividing the total number of axles counted by the average number of axles per vehicle. Thus, an axle count of 4,520 axles would be equal to a vehicle volume of 1,949 (4,520 / 2.32 = 1,949).

Multiplicative axle correction factors can be derived as the inverse of the average number of axles per vehicle. In the above example, the factor would be 0.43 (the inverse of 2.32. The number of vehicles (1,949) would then be estimated by multiplying the number of axles (4520) times the factor (.43).

Table 4-4-2[10]
Number of Axles per Vehicle

FHWA Vehicle Class	Daily Vehicle Volume	Average Number of Axles Per Vehicle	Total Number of Axles
1	100	2	200
2	1,400	2	2,800
3	45	2	90
4	15	2	30
5	20	2	40
6	40	3	120
7	5	4	20
8	15	4	60
9	120	5	600
10	5	6	30
11	15	5	75
12	5	6	30
13	10	7	70
Total Volume	1,795	Total Number of Axles	4,165
		Average Number of Axles Per Vehicle	2.32

FACTORS FOR CONVERTING DAILY CLASSIFICATION COUNTS TO AADTT BY CLASS

The calculation of factors for converting average daily traffic (by class) to annual average conditions begins by computing average day-of-week, average-day-of-month,

[10] This table provides a conservative estimate of the number of axles per vehicle for the 13 FHWA vehicle classes. Appropriate numbers must be computed at each site.

and annual average daily traffic statistics at each continuous count location. The ratios from each continuous count location are then averaged within the factor groups to produce the average factor for the group.

The first step in computing day-of-week adjustment factors is to compute an average day of week for each month. For example, the average Monday is computed by adding the Monday traffic volumes in the month, and then dividing by the number of Mondays in the month.

An average-day-of-month can be computed by simply averaging the seven daily values within each month. This is preferable to calculating a simple average for all days of the month, because then average monthly statistics can be compared from one year to the next without worry that in one year there were more weekend days than in another year.

Annual average daily traffic for each day of the week for each vehicle class can then be computed as the average of the 12 months. The best computational procedure is recommended in the AASHTO Guidelines for Traffic Data Programs and can be shown mathematically as follows:

$$AADTT_c = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} ADTT_{ijkc}\right)\right] \qquad (4\text{-}3)$$

where: $ADTT_c$ = daily truck traffic for class c, 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 calendar and the number of missing days).

CHAPTER 5
VEHICLE CLASSIFICATION DATA COLLECTION EQUIPMENT

A variety of equipment can be used to classify the traffic stream. Available technology allows use of axle, vehicle length, and machine vision classifiers. New technologies are rapidly evolving. As a last resort, human observation is used.

For each of the technology solutions (axle, length, or vision) there are generally a number of different sensor technologies. Each sensor has its own advantages and disadvantages regarding cost, reliability, accuracy, life span, ease of set up, and type of information provided.

Each of the basic classification and sensing technologies has strengths and weaknesses that allow some classification techniques to work better than others under specific environmental and traffic conditions. No technology has proven to be the best under all conditions.

The different sensor technologies also require a variety of different vehicle classification schemes because the vehicle characteristic information provided by each sensor differs. The ideal vehicle classifier would be able to measure a wide variety of vehicle characteristics to differentiate trucks on the basis of several different factors and to meet the needs of different users. Unfortunately, such a sensor does not currently exist at an affordable price. Consequently, agencies must select the technologies that provide the data they most need to provide the classification information they require, at the locations where those data are needed, at prices they can afford.

For most engineering tasks the primary issue is separating "heavy" vehicles from "light" vehicles, because heavy vehicles cause more pavement damage and tend to have poorer acceleration and braking characteristics. However, weight is not the only issue, since total vehicle size (length, width, height) has a major impact on the geometric design needed for safe roadway operation. Other desired vehicle classification attributes include the type of connection used on multi-unit vehicles (the connection has major safety implications) and the type of engine that provides the power (since the type of engine affects the amount and type of pollutants emitted). Unfortunately, these last two vehicle characteristics are extremely difficult to obtain from conventional classification equipment, and as a result, these vehicle characteristics are normally collected as part of special studies, not as part of the traffic monitoring effort.

The FHWA 13-category classification system is a direct result of the compromises forced on highway agencies by the limitations in affordable vehicle sensors. The FHWA 13-category classification scheme is a compromise between a classification scheme based on standard axle sensing technology, and a classification scheme based on observation of the traffic stream by human observers. Like all compromises, the FHWA 13-category scheme is not perfect. However, its strengths and weaknesses are viewed differently by different groups, each of which needs a different type of data to perform a particular important analysis. **The FHWA 13-category scheme does provide an**

excellent mechanism for classifying vehicles, given available technology. Its use is recommended as the basic classification scheme for highway agencies. However, agencies may choose to expand on the FHWA scheme to meet their own needs, and they may use other classification systems in locations where non-axle based vehicle sensors are in operation.

The remainder of this chapter introduces the available vehicle sensor technology. However, because this field is changing rapidly, the reader is encouraged to access current research results when exploring vehicle sensors. Good starting points for further research in this field are the Vehicle Detector Clearinghouse operated by the New Mexico State University and the North American Travel Monitoring Exhibition and Conference, held every two years.

The basic strengths and weaknesses of the commonly available technologies are presented below.

MANUAL COUNTS

Historically, truck counts (classification counts) could only be done by visually counting the traffic stream. Visual counts are traditionally called manual counts. Manual classification of the traffic stream has several advantages. Visual identification can classify trucks on the basis of a vehicle’s body style (tank trucks versus dump trucks versus flat bed trucks versus delivery trucks). Looking at trucks can also increase the accuracy with which an individual truck is classified into being either “potentially heavy” or “not likely to be heavy”. That is, a human observer can easily determine the difference between a car pulling a light trailer and a tractor pulling a semi-trailer, when these two vehicles have the same number of axles and possibly even similar axle spacing characteristics. Thus, “classification errors” from human observers are usually small when the data collector is highly motivated. Visual short counts can potentially be taken in all conditions.

Unfortunately, manual classification counts are expensive and prone to error. It is very difficult for a person to count accurately for more than about three consecutive hours. After three hours, the concentration of most observers tends to wander, causing the number of errors to increase. Counting traffic can be a very boring job for a person. Substantial supervision is needed to ensure the quality of the data reported. In addition, most human observers cannot count accurately under high volume, multi-lane conditions (additional observers are needed, further increasing the cost of data collection).

AXLE SENSOR BASED COUNTERS

Automated classification was developed to help resolve the limitations of manual counting. Automated classifiers became common in the 1980's with the advent of microchip equipment that relied on two carefully spaced axle sensors (usually road tubes). These counters measure the number of axles associated with each passing vehicle and the spacing between axles. The axle spacing is computed from the speed of the vehicle and the time between axle pulses on each sensor. Vehicle speed is commonly computed by measuring the time it takes for the front axle to travel from the first axle sensor to the second (a known distance). The number and spacing of axles is then fed into an algorithm that associates a given number and spacing of axles with a particular class of vehicles.

The accuracy of axle sensor based counters is a function of several factors, including (but not limited to) the following:

- the accuracy of the distance measurement between the two axle sensors
- the need for constant vehicle speed over the two sensors (changing vehicle speeds cause errors in the axle spacing computation)
- the need for a vehicle to stay in a single lane until it has passed completely over both sensors
- the speed with which the axle sensor can respond to axles crossing the sensor,
- the accuracy of the axle sensors themselves (that is how often they either report non-existent axles (ghost axles) and/or miss axles that pass over them)
- the presence of different types of vehicles with similar axle spacing
- the care with which the classification algorithm was developed that converts the number and spacing of axles into vehicle.

Some of these factors are a function of the type of axle sensor used. Others are a function of the roadway geometry at the site where the sensors are placed. Others are a function of the quality of the equipment installation and/or the pavement on which the sensors are placed. Others are simply a function of the types of vehicles that actually operate on the road site.

Most classifiers report not only the number of vehicles in each class but also the number of vehicles that crossed the sensors but could not be classified. These "unclassified" vehicles normally fall into two categories, "errors" and "unclassified." Errors are normally vehicle measurements in which the two axle sensors reported different numbers of axles (usually because the vehicle changed lanes as it crossed the sensors); significant changes in vehicle speed occurred over the sensor, making it impossible to accurately measure axle spacing; or extraneous noise in the sensors made the system unable to determine the type of vehicle passing. Unclassified vehicles are normally vehicles for which the system measurements are complete but that do not fit within any of the proscribed vehicle categories.

Each agency should carefully examine the types of vehicles that are not being successfully classified so that it can both improve its classification algorithm over time and allocate the reported "unclassified" vehicles to the appropriate vehicle classes. This is necessary, or the reported volumes by class will underestimate the true number of vehicles. **Agencies should identify and document the classification scheme being**

used to collect classification data and the procedures used to assign "unclassified" vehicles to the standard 13 categories.

In general, axle sensors either are designed for portable operation (they are taped or nailed to the pavement on a temporary basis) or are permanently imbedded in the pavement by cutting a slot in the roadbed and using an adhesive to fix the sensor in that slot.

Portable sensors have the advantage of being usable at many locations. However, they are usually difficult to place on lanes that are not next to the shoulder of a road, thus making it difficult to use these classifiers on multi-lane, undivided arterials. It is also easy to make a mistake when placing portable sensors so that the distance between the sensors is incorrectly reported and/or is not consistent from the right hand edge of the lane to the left. Finally, portable sensors can come loose during data collection yielding invalid results after the sensor pulls loose but before the sensor has become completely detached from the roadway.

Permanent sensors are often used for both long-term data collection sessions and for collecting data on multi-lane highways, where portable axle-sensors cannot be placed. The primary drawbacks to permanent sensors are:

- higher cost to acquire than portable sensors
- more expensive to install
- require lane closure for installation
- can only be used in one location.

In general, axle based classifiers work very well on smaller (two-lane) rural roads and divided four-lane rural roads where congestion is not a problem. This type of counter has difficulty counting accurately on roads where traffic speeds are highly variable. This includes roads that are frequently congested and roads where vehicles are constantly accelerating or decelerating, such as on urban arterials. They have difficulty differentiating between closely spaced vehicles (i.e., tailgating cars). Two closely spaced cars are often reported as a single four-axle combination truck. Lastly, unless these devices use axle sensors that actually detect axle weight, they are unable to reliably differentiate between cars pulling trailers and multi-axle trucks, because of similar axle configurations.

VEHICLE LENGTH BASED COUNTERS

One of the earliest alternatives to axle sensor based counters was the "dual loop" classifier. Inductance loops were selected because they allowed for reliable, long lasting installation of the vehicle detector. Thus, many of the earliest permanent, continuously operating vehicle classifiers were dual loop systems.

This style of counter uses two inductance loops to estimate the total length of vehicles crossing the loops. Vehicle length is computed by dividing the total time a vehicle is over the loop by the speed of that vehicle. Vehicle speed is determined by the difference in time taken for the vehicle to be detected by the first loop and the second loop. This simple equation is then calibrated to account for each loop's sensitivity and the fact that the "zone of detection" is not a "point" on the roadway, so that a vehicle is "detected" for slightly longer than it takes to pass over the loop. The length of this "detection field" is a function of a number of factors related to loop sensitivity and vehicle characteristics.

Dual loop sensors generally classify vehicles into fewer, more general, categories than the FHWA 13 vehicle classes. This is for several reasons, including the following:

- Most of the length classifiers are not accurate enough to measure small differences in vehicle length. Thus, broad vehicle length categories are used to reduce the amount of misclassification. (That is, by using only four categories, there are only three boundaries where a one-foot error in measurement will cause a vehicle to be misclassified. This leads to more accurate classification.)
- Most length classifiers can not differentiate between a single long vehicle unit and two smaller units hitched together because the length between hitched units is too small to detect.
- Length alone is a poor variable for differentiating among vehicle classes. For example, five-axle, tractor, semi-trailer trucks come in a variety of lengths. Yet these trucks are commonly classified together.

Still, four classes are sufficient for many analytical purposes. When this is combined with the inability of axle sensors in many conditions, the low cost of the basic loop inductance sensor and the general reliability of these systems; it is easy to see why basic length classifiers remain popular.

However, length classifiers have many of the same operational problems that axle classifiers have. That is, on roadways where vehicle speeds are not constant over the detectors because of congestion, signalization, street parking, or operational conditions (e.g., driveways), the computation of vehicle lengths is not accurate. This makes the classification inaccurate and results in significant data collection errors. Dual loops also have difficulty differentiating among closely spaced cars (tailgaters) and tend to report two closely spaced cars as one mid-sized truck. Thus, these detectors tend to work most accurately in locations where free-flow traffic is assured.

MACHINE VISION BASED EQUIPMENT

Machine vision systems, most of which are based on video image processing, were developed in response to the desire by many transportation agencies to use a vehicle detector that did not have to be placed on or in the roadway. Camera systems allow the detector to be placed above or beside the roadway, in a location that is more accessible to maintenance crews. This provides a significant advantage for locations where access to the roadway is extremely limited and expensive, such as high volume urban freeways.

Machine vision systems are a much newer technology than axle sensor and traditional dual loop counters. As a result, the classification systems used by vision systems are still being refined. The early vision systems mimicked dual loop counters. They create "virtual loops" from the camera images being collected, and then compute vehicle speed and length from those loops.

These systems have performance characteristics that are similar to traditional dual loop counters. They are subject to the same limitations in terms of vehicle speed measurement and problems in differentiating between closely following vehicles. Image sensing systems are also subject to inaccuracy caused by occlusion (the blocking of the line of site by a second vehicle).

The primary advantage these systems provide is that they do not require installation of sensors in the roadway, thus eliminating one major cause of equipment failure (freeze/thaw damage to loop wires) and making sensor maintenance easier and less disruptive. In some cases, cameras are also able to transmit traditional video images to system operators, allowing for dual use of the data collection equipment.

Considerable research is being done in the area of image processing. New approaches to image processing (e.g., edge detection algorithms) are being developed to improve on the performance of the existing image processing algorithms. Systems currently on the market still tend to classify vehicles on the basis of their overall size and are thus likely to use classification schemes similar to those supplied by current loop based systems.

Information on image-processing technology for traffic data collection is available from the New Mexico Vehicle Detector Clearinghouse and from equipment manufacturers. Research efforts are underway in several States.

OTHER TECHNOLOGIES

Development with new technologies is moving very quickly. Research and development of new sensors using infrared, microwave, and radar technologies is in progress. Several traffic monitoring systems using these technologies are on the market and are capable of providing vehicle volumes by at least length classification. Highway agencies are encouraged to investigate these devices to determine where and when these new technologies can provide more cost-effective solutions to the accurate collection of classification data.

REFERENCES

Cambridge Systematics, et al, "Use of Data from Continuous Monitoring Sites, Volume I: Recommendations," FHWA, August 1994.

Hallenbeck, Mark, and Kim, Soon-Gwam, "Final Technical Report for Task A: Truck Loads and Flows," FHWA, WSDOT Report WA-RD 320.3, November 1993.

Hallenbeck, Mark, Rice, Mian, Smith, Betty, Cornell-Martinze, Cindy, and Wilkinson, Joe, "Vehicle Volume Distributions By Classification," FHWA-PL-97-025, June 1997.

Weinblatt, Herb, "Factoring of Short-Duration Classification Counts," presented at the National Traffic Data Acquisition Conference, May 5-9, 1996.

Wyman, John, Braley, Gary, and Stevens, Robert, "Field Evaluation of FHWA Vehicle Classification Categories," for Maine Department of Transportation, Final Report for contract DTFH-71-80-54-ME-03 for U.S. Department of Transportation, FHWA, Office of Planning, January 1985.

APPENDIX 4-A
FREQUENTLY ASKED QUESTIONS

How many vehicle classifications should I collect data for?

There is no simple answer. In most cases, when using portable vehicle classification equipment, the 13 FHWA vehicle classifications have become the standard. However, it is certainly appropriate to further sub-divide these classifications to provide data on specific vehicles of interest. For example, Oregon DOT collects data on the use of triple trailer vehicles. This classification is a sub-set of class 13 (Multi-trailer vehicles). Thus for their own purposes, these vehicles are a specific class of trucks. When Oregon reports data to the FHWA, the "triple trailer" class vehicles are simply combined with the other multi-trailer vehicles measured, and the total is reported as the volume in FHWA Class 13. Permanent, axle classifiers and WIM scales should also collect the FHWA 13 vehicle classes.

On many roadways, it is not possible to place axle sensors so that they accurately collect the 13 FHWA vehicle categories. However, it is possible to use two inductance loops or magnetic units to differentiate vehicles by total length. Four vehicle classes are recommended when collecting data in this fashion. These classes should reflect cars (and pick-up trucks), single-unit trucks, single-trailer combination trucks, and multi-trailer trucks. In some states, the multi-trailer truck category may be unnecessary, and these trucks can be incorporated into the "combination" category because there are few multi-trailer trucks. As the truck fleets and truck size and weight laws change, States not collecting data on these vehicles may have to revise their data collection process to collect the data. While use of the simplified vehicle classes does not meet the desired level of reporting for many purposes, collecting data in the simplified categories is far better than collecting no vehicle classification data at all, and it allows monitoring the presence of trucks in urban traffic.

How many permanent, continuously operating vehicle classifiers should my State install and maintain?

A reasonable answer to this question cannot be given without first understanding how the State proposes to factor short duration vehicle classification counts. If a traditional factoring approach is selected (i.e., something similar to the ATR program operated by almost all states), then as many continuous classifiers as ATRs should be operated. If the State chooses a classification count factoring approach that measures and applies road-specific factors, the number of counters required will increase significantly.

How many portable classification counts should my State undertake?

They are many factors to consider in the answer. As a rule of thumb, 25 to 30 percent of volume counts should be classified. In general, each State should undertake a vehicle classification count at least once every counting cycle that can be applied to each road segment under its control. This does not mean that each road segment should be counted. Instead, "super segments" consisting of combined roadway volume segments should be counted. Each "super segment" should be "relatively" homogeneous for truck traffic along its length. Each "super segment" should be counted at the same interval used by the State for collecting volume counts. Annual truck travel estimates can be derived from the counts. The annualized truck percentages can then be converted to estimates of truck travel for the entire "super segment".

How can my State collect classification data in urban areas?

Traditional vehicle classifiers have difficulties operating accurately in urban areas because vehicle acceleration/deceleration makes speed and length calculations inaccurate, and because closely following vehicles result in misclassification of cars as trucks. On freeways, careful placement and calibration of either video or loop based classification equipment can produce accurate truck volume counts. To date, no inexpensive classifier is available that works accurately under stop-and-go arterial conditions.

For higher systems, permanent classifiers using loops or video may be the only alternative. On lower systems, there are locations where axle or magnetic (length) portable classifiers will work. In many cases, visual counts may be the last resort.

How do I define a "vehicle classification road segment?"

In simple terms, a traffic road segment is a section of roadway that has similar (or homogeneous) volume or classification characteristics. The difficulty comes from the fact that a "homogeneous segment" for traffic volume may not be a homogeneous segment for other purposes such as classification or pavement design purposes. For example, the road may change from asphalt concrete to Portland cement concrete even though the volumes being carried on that road do not change appreciably. When developing a count program for vehicle classification, it may be necessary to create classification roadway segments where truck volumes do not change significantly. A single classification count taken within a properly defined "super segment" provides the classification data for all segments within that super segment. The use of these "super segments" reduces the number of physical classification counts needed to provide adequate roadway coverage for truck volume information.

What vehicle lengths should I use for vehicle classification?

An analysis of available data examined this issue. It was determined that no single set of vehicle lengths worked "best" for all States, as truck characteristics vary from State to State. The vehicle length classification scheme that worked "the best" on combined data from all States is shown in the tables on the next page.

These criteria did an acceptable, but by no means perfect, job of classifying vehicles into the four general categories. Considerable "error" was found in how well the length bins (and the corresponding classification results) performed when estimating aggregations of the FHWA 13-category classification scheme. A classifier can accurately measure vehicle length (for example as 34 feet for a given small tractor-trailer combination), place that count in the correct length bin (in this example, the bin from 13 to 35 feet), but “incorrectly” classify that vehicle (in this case calling a small combination truck-trailer a single unit).

Table 4-A-1
Length Based Classification Boundaries

Primary Description of Vehicles Included in the Class	Lower Length Bound >	Upper Length Bound < or =
Passenger vehicles (PV)	0 m (0 ft)	3.96 m (13 ft)
Single unit trucks (SU)	3.96 m (13 ft)	10.67 m (35 ft)
Combination trucks (CU)	10.67 m (35 ft)	18.59 m (61 ft)
Multi-trailer trucks (MU)	18.59 m (61 ft)	36.58 m (120 ft)

Table 4-A-2 shows the errors associated with using vehicle lengths to estimate the four vehicle categories (cars, single unit trucks, combination trucks, multi-trailer trucks) shown in Table 4-A-1 when using the vehicle length boundaries shown in that table.

Table 4-A-2
Misclassification Errors Caused By Using Only Total Vehicle Length As The Classification Criteria

Classification Based on Total Vehicle Length					
Classification Based on Configuration and Number of Axles		PV	SU	CU	MU
	SU	17.7%	81.9%	0.4%	0%
	CU	0%	1.8%	84.2%	14.0%
	MU	0%	0.1%	20.8%	79.1%

Many States will be able to improve on these results by fine-tuning the length spacing boundaries to account for the characteristics of their trucking fleets. However, no amount of fine-tuning will lead to a perfect length classification scheme (where perfection is defined as the ability to use overall vehicle length to classify vehicles based on the number of units they include or the number of axles they use). This is because total vehicle length is not a consistent indicator of vehicle class as defined by these attributes. Consequently, highway agencies should be aware of the size and type of misclassification error that exists, and set their length boundaries to minimize error.

APPENDIX 4-B
EXAMPLE TRAFFIC FACTOR GROUP COMPUTATIONS USING THE "TRADITIONAL" METHOD

This appendix shows an example of how to use the traditional method of factor group development to create truck factor groups. It uses data taken from 11 sites on four Interstate highways in Washington State. The locations include facilities east/west, north/south, and on both the eastern and western sides of the Cascade mountain range. The initial assumption going into the factor group creation process was that the Interstate highways fit a single factor group. However, the economic development patterns on the eastern side of the Cascades are very different from those on the western side. In addition, there is a significant possibility that east/west Interstates will have different truck travel patterns than north/south Interstates, since the commodities moving east/west tend to be very different than those moving north/south. These different "professional judgment" assumptions will be tested as part of the factor group development process.

In the example, factors are computed for four vehicle types: passenger vehicles (primarily cars), single-unit trucks (including most of the recreational vehicle population), combination trucks, and multi-trailer trucks. The factor group computations are based on the conversion of monthly average weekday traffic (MAWDT) to annual average daily traffic (AADT) by vehicle classification. This conversion accounts for both day-of-week and seasonal (monthly) variation in a single factor. It converts any count value (by class) taken from a weekday count into an estimate of AADT (by class). Combining both weekday/weekend and monthly effects into a single factor does add to the variability of the seasonal adjustment factors being computed, but it eliminates the need to compute separate day-of-week and monthly factors, and thus removes the need to create separate factoring procedures for the two factors.

Figure 4-B-1 shows the means of the four monthly patterns computed for eleven sites. As expected, the four different vehicle classes have different seasonal patterns. Single-unit trucks have the greatest change in volume over the course of the year. The other three vehicle classes have more consistent volume patterns. Much of the seasonal variation in the single unit truck classification is caused by the presence of recreational vehicles (RVs) and the fact that RVs are both numerous and highly seasonal.

Multi-trailer trucks have the "flattest" seasonal pattern. These trucks travel more consistently throughout the year. Still, these vehicles exhibit a seasonal volume peak in late summer and early fall, and a reduction in these volumes during the primary winter months (December through February). Because so much of the truck travel takes place during the weekdays, the vast majority (9 of 12) of the monthly adjustments for multi-trailer trucks are greater than 1.0. This means that a weekday classification count taken on any "normal" weekday from March through November is likely to over-estimate annual average multi-trailer truck volumes for the year, unless those weekday counts are factored appropriately as shown in Figure 4-B-1.

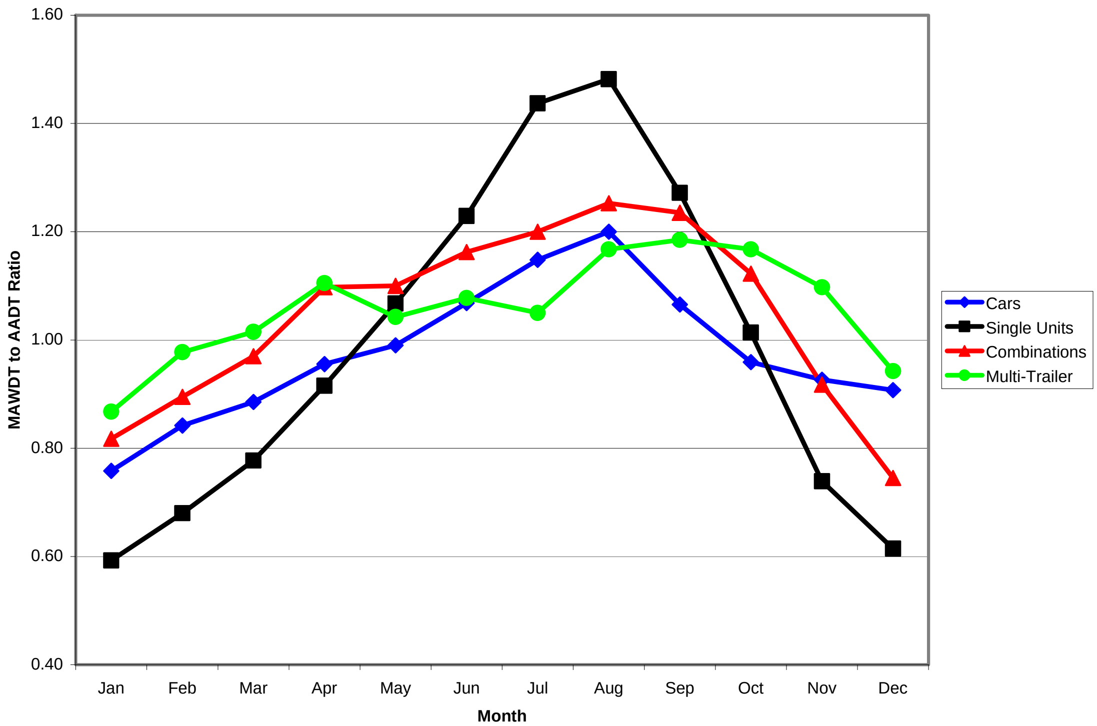

Figure 4-B-1: Seasonal Patterns by Vehicle Type on Interstates in Washington

The seasonal factors in Figure 4-B-1 are the mean values for the 11 locations. If all the Interstates in the State of Washington are treated as a single factor group, the mean value for each month is the factor that would be used to adjust any short count taken on the Interstate system. Thus, the question becomes, are these mean factors "good enough"? This can be answered by looking at the seasonal patterns for the individual sites and at the variation inherent in the computed monthly factors.

Figures 4-B-2 through 4-B-5 illustrate the variation in these seasonal patterns from site to site. Tables 4-B-1 through 4-B-4 show the individual seasonal adjustment factors used in these computations. These tables also show the mean and standard deviation for each adjustment factor for all sites combined. Not surprisingly, the count locations exhibit a wide range of traffic patterns, and the amount of variation present is dependent on the class of vehicles.

In general, there is a reasonably large amount of variation within these sites. Within any given month, the range between the highest and lowest of the individual adjustment factors is between 0.2 and 0.6 (or 20 to 60 percent of AADT). Another measure that describes the variability of these monthly factors is the standard deviation of the mean factor. This factor is the best of the available statistical measures for examining the effectiveness of the factoring process.

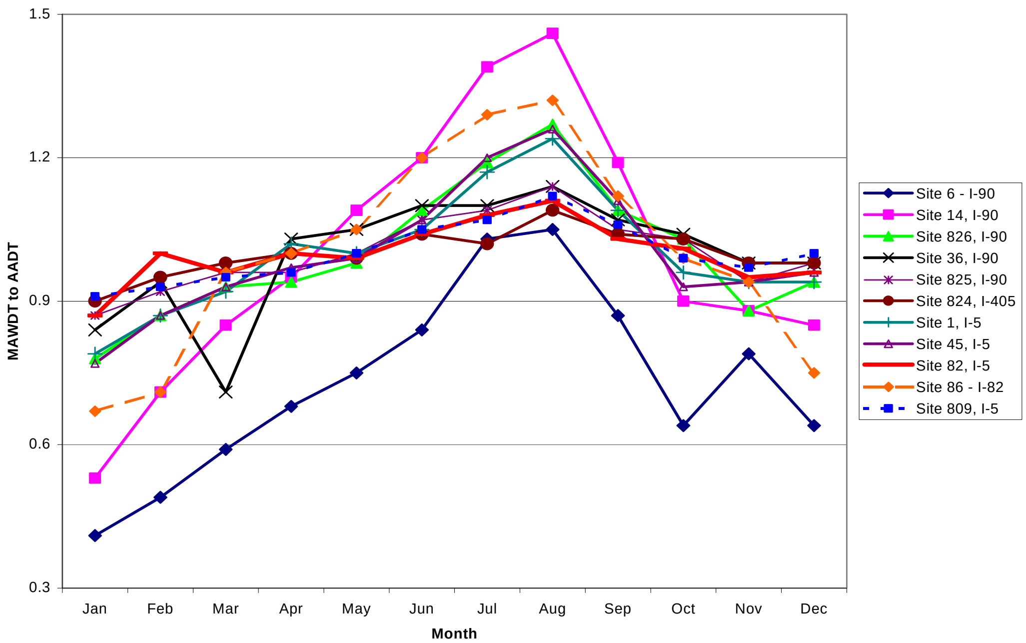

Figure 4-B-2: Ratio of Average Monthly Weekday Traffic to Average Annual Daily Traffic for Passenger Vehicles

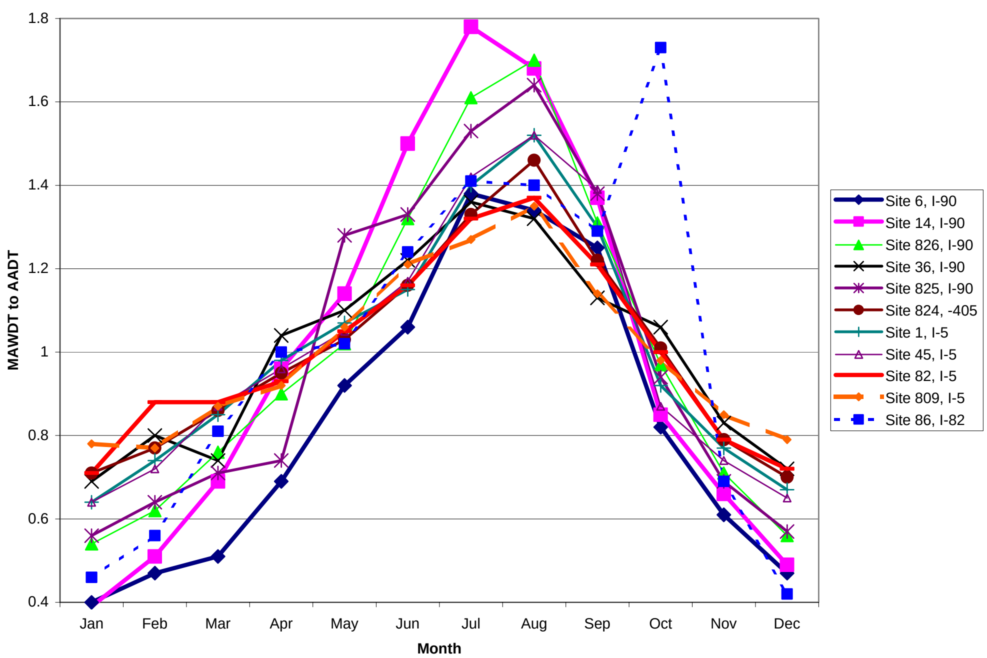

Figure 4-B-3: Ratio of Average Monthly Weekday Traffic to Average Annual Daily Traffic for Single-Unit Trucks

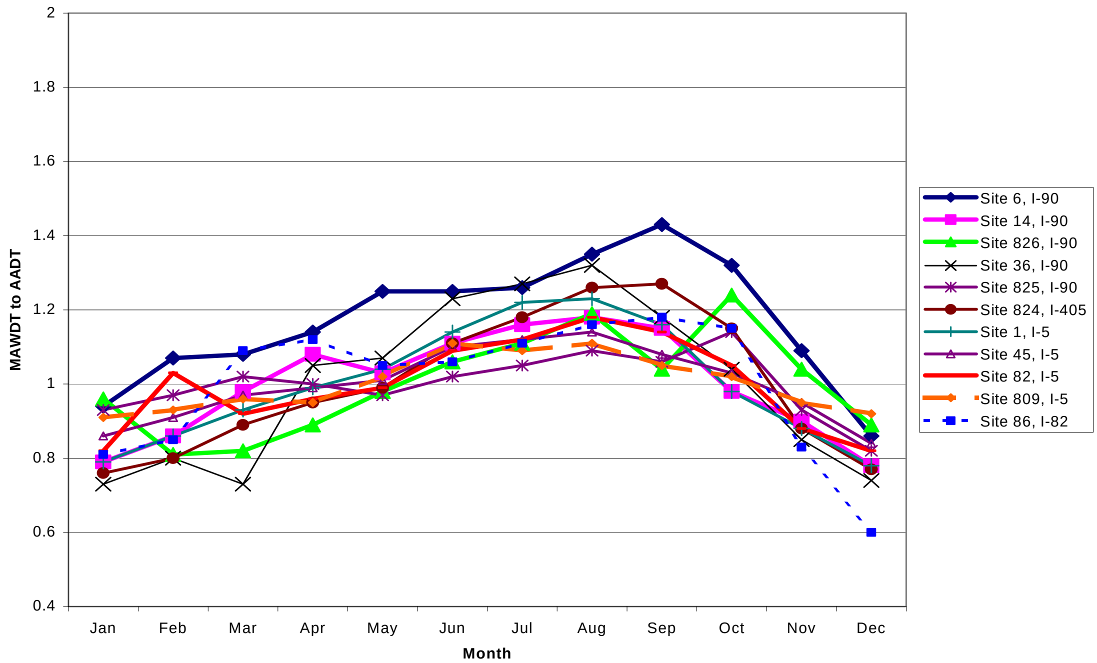

Figure 4-B-4: Ratio of Average Weekday Traffic per Month to Average Annual Daily Traffic for Combination Trucks

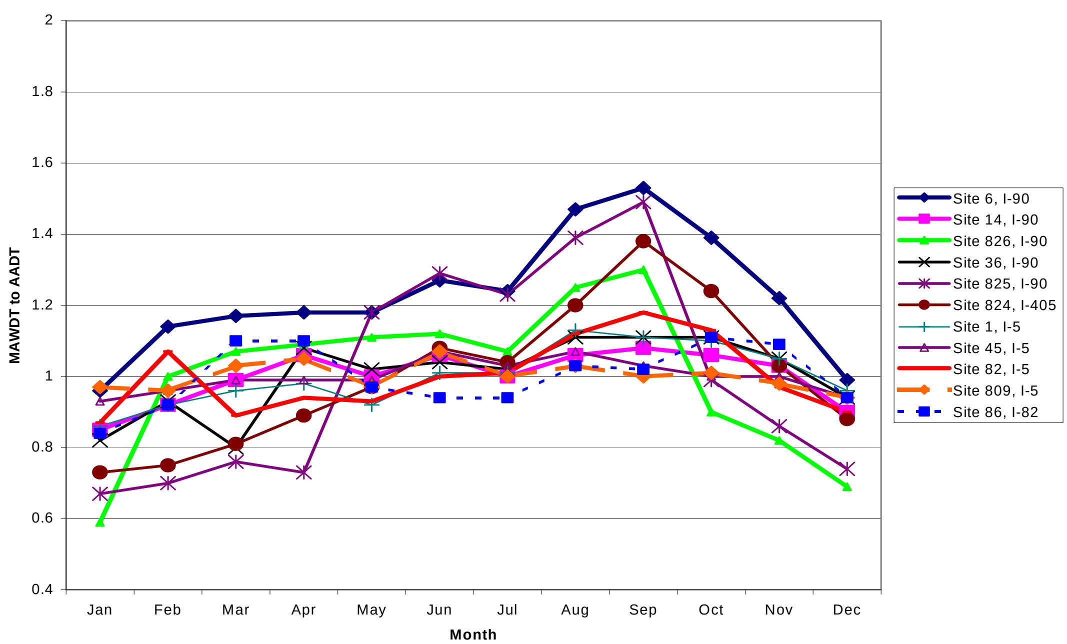

Figure 4-B-5: Ratio of Average Monthly Weekday Traffic to Average Annual Daily Traffic for Multi-Trailer Trucks

Table 4-B-1
Seasonal Adjustment Factors (MAWDTT/AADTT) for Cars

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Route	Rural / Urban
1	0.79	0.87	0.92	1.02	1	1.05	1.17	1.24	1.09	0.96	0.94	0.94	5	R
45	0.77	0.87	0.93	0.97	0.99	1.07	1.2	1.26	1.11	0.93	0.94	0.96	5	R
82	0.87	1	0.96	1	0.99	1.04	1.08	1.11	1.03	1.01	0.95	0.96	5	U
809	0.91	0.93	0.95	0.96	1	1.05	1.07	1.12	1.06	0.99	0.97	1	5	U
86	0.67	0.71	0.96	1	1.05	1.2	1.29	1.32	1.12	0.99	0.94	0.75	82	R
6	0.41	0.49	0.59	0.68	0.75	0.84	1.03	1.05	0.87	0.64	0.79	0.64	90	R
14	0.53	0.71	0.85	0.95	1.09	1.2	1.39	1.46	1.19	0.9	0.88	0.85	90	R
826	0.78	0.87	0.93	0.94	0.98	1.09	1.19	1.27	1.09	1.03	0.88	0.94	90	R
36	0.84	0.94	0.71	1.03	1.05	1.1	1.1	1.14	1.07	1.04	0.98	0.98	90	U
825	0.87	0.92	0.96	0.96	1	1.07	1.09	1.14	1.05	1.03	0.94	0.98	90	U
824	0.9	0.95	0.98	1	0.99	1.04	1.02	1.09	1.04	1.03	0.98	0.98	405	U
Mean for all Sites	0.76	0.84	0.89	0.96	0.99	1.07	1.15	1.20	1.07	0.96	0.93	0.91		
Stand. Dev. for all sites	0.16	0.15	0.12	0.10	0.09	0.10	0.11	0.12	0.08	0.12	0.06	0.11		

Table 4-B-2
Seasonal Adjustment Factors (MAWDTT/AADTT) for Single-Unit Trucks

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Route	Rural / Urban
1	0.64	0.74	0.85	0.98	1.07	1.15	1.4	1.52	1.3	0.92	0.77	0.67	5	R
45	0.64	0.72	0.87	0.96	1.05	1.17	1.42	1.52	1.39	0.87	0.74	0.65	5	R
82	0.71	0.88	0.88	0.93	1.05	1.16	1.32	1.37	1.21	1	0.79	0.72	5	U
809	0.78	0.77	0.87	0.92	1.06	1.21	1.27	1.35	1.14	0.98	0.85	0.79	5	U
86	0.46	0.56	0.81	1	1.02	1.24	1.41	1.4	1.29	1.73	0.69	0.42	82	R
6	0.4	0.47	0.51	0.69	0.92	1.06	1.38	1.34	1.25	0.82	0.61	0.47	90	R
14	0.39	0.51	0.69	0.96	1.14	1.5	1.78	1.68	1.37	0.85	0.66	0.49	90	R
826	0.54	0.62	0.76	0.9	1.02	1.32	1.61	1.7	1.31	0.97	0.71	0.56	90	R
36	0.69	0.8	0.74	1.04	1.1	1.22	1.36	1.32	1.13	1.06	0.83	0.72	90	U
825	0.56	0.64	0.71	0.74	1.28	1.33	1.53	1.64	1.38	0.94	0.69	0.57	90	U
824	0.71	0.77	0.86	0.95	1.03	1.16	1.33	1.46	1.22	1.01	0.79	0.7	405	U
Mean for all Sites	0.59	0.68	0.78	0.92	1.07	1.23	1.44	1.48	1.27	1.01	0.74	0.61		
Stand. Dev. for all sites	0.13	0.13	0.11	0.11	0.09	0.12	0.15	0.14	0.09	0.25	0.07	0.12		

Table 4-B-3
Seasonal Adjustment Factors (MAWDTT/AADTT) for Combination Trucks

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Route	Rural / Urban
1	0.79	0.86	0.93	0.99	1.04	1.14	1.22	1.23	1.16	0.98	0.88	0.78	5	R
45	0.86	0.91	0.97	0.99	1.01	1.1	1.12	1.14	1.08	1.03	0.95	0.84	5	R
82	0.82	1.03	0.92	0.96	0.99	1.09	1.12	1.18	1.14	1.05	0.88	0.82	5	U
809	0.91	0.93	0.96	0.95	1.02	1.11	1.09	1.11	1.05	1.02	0.95	0.92	5	U
86	0.81	0.85	1.09	1.12	1.05	1.06	1.11	1.16	1.18	1.15	0.83	0.6	82	R
6	0.94	1.07	1.08	1.14	1.25	1.25	1.26	1.35	1.43	1.32	1.09	0.86	90	R
14	0.79	0.86	0.98	1.08	1.03	1.11	1.16	1.18	1.15	0.98	0.9	0.78	90	R
826	0.96	0.81	0.82	0.89	0.98	1.06	1.11	1.19	1.04	1.24	1.04	0.89	90	R
36	0.73	0.8	0.73	1.05	1.07	1.23	1.27	1.32	1.18	1.04	0.85	0.74	90	U
825	0.93	0.97	1.02	1	0.97	1.02	1.05	1.09	1.06	1.14	0.93	0.82	90	U
824	0.76	0.8	0.89	0.95	0.99	1.11	1.18	1.26	1.27	1.15	0.88	0.77	405	U
Mean for all Sites	0.85	0.90	0.94	1.01	1.04	1.12	1.15	1.20	1.16	1.10	0.93	0.80		
Stand. Dev. for all sites	0.08	0.09	0.11	0.08	0.08	0.07	0.07	0.08	0.11	0.11	0.08	0.09		

Table 4-B-4
Seasonal Adjustment Factors (MAWDTT/AADTT) for Multi-Trailer Trucks

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Route	Rural / Urban
1	0.86	0.92	0.96	0.98	0.92	1.01	1.01	1.13	1.11	1.1	1.05	0.96	5	R
45	0.93	0.96	0.99	0.99	0.99	1.07	1.03	1.07	1.03	1	1	0.94	5	R
82	0.87	1.07	0.89	0.94	0.93	1	1.01	1.12	1.18	1.13	0.97	0.9	5	U
809	0.97	0.96	1.03	1.05	0.97	1.07	1	1.03	1	1.01	0.98	0.94	5	U
86	0.84	0.92	1.1	1.1	0.97	0.94	0.94	1.03	1.02	1.11	1.09	0.94	82	R
6	0.96	1.14	1.17	1.18	1.18	1.27	1.24	1.47	1.53	1.39	1.22	0.99	90	R
14	0.85	0.92	0.99	1.06	1	1.06	1	1.06	1.08	1.06	1.03	0.9	90	R
826	0.59	1	1.07	1.09	1.11	1.12	1.07	1.25	1.3	0.9	0.82	0.69	90	R
36	0.82	0.93	0.8	1.08	1.02	1.04	1.02	1.11	1.11	1.11	1.05	0.94	90	U
825	0.67	0.7	0.76	0.73	1.18	1.29	1.23	1.39	1.49	0.99	0.86	0.74	90	U
824	0.73	0.75	0.81	0.89	0.97	1.08	1.04	1.2	1.38	1.24	1.03	0.88	405	U
Mean for all Sites	0.83	0.93	0.96	1.01	1.02	1.09	1.05	1.17	1.20	1.09	1.01	0.89		
Stand. Dev. for all sites	0.12	0.12	0.13	0.12	0.09	0.11	0.10	0.15	0.19	0.13	0.11	0.09		

Table 4-B-5
Comparison of Seasonal Adjustment Factors for Different Interstate Groups

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Factors for Cars												
Std. Dev. for All Interstate Roads	0.16	0.15	0.12	0.10	0.09	0.10	0.11	0.12	0.08	0.12	0.06	0.11
Std. Dev. for Eastern Interstate Roads	0.19	0.18	0.16	0.16	0.16	0.17	0.17	0.18	0.14	0.18	0.08	0.14
Std. Dev. for Western Interstate Roads	0.06	0.05	0.02	0.03	0.01	0.02	0.07	0.08	0.03	0.04	0.03	0.02
Std. Dev. for Urban Interstate Roads	0.03	0.03	0.11	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01
St. Dev. for Rural East/West Interstate Roads	0.19	0.19	0.18	0.15	0.17	0.18	0.18	0.21	0.16	0.20	0.05	0.15
Std. Dev. for Rural North/South Interstate Roads	0.06	0.09	0.02	0.03	0.03	0.08	0.06	0.04	0.02	0.03	0.00	0.12
Factors for Single Unit Trucks												
Std. Dev. for All Interstate Roads	0.13	0.13	0.11	0.11	0.09	0.12	0.15	0.14	0.09	0.25	0.07	0.12
Std. Dev. for Eastern Interstate Roads	0.14	0.15	0.13	0.16	0.10	0.18	0.20	0.17	0.10	0.42	0.09	0.13
Std. Dev. for Western Interstate Roads	0.09	0.09	0.07	0.08	0.09	0.08	0.12	0.13	0.09	0.05	0.05	0.08
Std. Dev. for Urban Interstate Roads	0.08	0.09	0.08	0.11	0.10	0.07	0.10	0.13	0.10	0.04	0.06	0.08
St. Dev. for Rural East/West Interstate Roads	0.08	0.08	0.13	0.14	0.11	0.22	0.20	0.20	0.06	0.08	0.05	0.05
Std. Dev. for Rural North/South Interstate Roads	0.10	0.10	0.03	0.02	0.03	0.05	0.01	0.07	0.06	0.48	0.04	0.14

Table 4-B-5 (continued)

Factors for Combination Trucks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Std. Dev. for All Interstate Roads	0.08	0.09	0.11	0.08	0.08	0.07	0.07	0.08	0.11	0.11	0.08	0.09
Std. Dev. for Eastern Interstate Roads	0.09	0.12	0.17	0.04	0.10	0.09	0.08	0.10	0.13	0.15	0.12	0.11
Std. Dev. for Western Interstate Roads	0.08	0.08	0.06	0.04	0.02	0.04	0.06	0.06	0.08	0.09	0.06	0.05
Std. Dev. for Urban Interstate Roads	0.09	0.10	0.11	0.04	0.04	0.08	0.09	0.10	0.09	0.06	0.04	0.07
St. Dev. for Rural East/West Interstate Roads	0.09	0.14	0.13	0.13	0.14	0.10	0.08	0.10	0.20	0.18	0.10	0.06
Std. Dev. for Rural North/South Interstate Roads	0.04	0.03	0.08	0.08	0.02	0.04	0.06	0.05	0.05	0.09	0.06	0.12
Factors for Multi Trailer Trucks												
Std. Dev. for All Interstate Roads	0.12	0.12	0.13	0.12	0.09	0.11	0.10	0.15	0.19	0.13	0.11	0.09
Std. Dev. for Eastern Interstate Roads	0.06	0.11	0.16	0.05	0.09	0.14	0.13	0.20	0.23	0.15	0.09	0.04
Std. Dev. for Western Interstate Roads	0.14	0.13	0.11	0.12	0.10	0.10	0.08	0.12	0.18	0.11	0.09	0.11
Std. Dev. for Urban Interstate Roads	0.14	0.15	0.13	0.14	0.10	0.10	0.09	0.13	0.18	0.12	0.09	0.11
St. Dev. for Rural East/West Interstate Roads	0.08	0.16	0.13	0.08	0.13	0.15	0.17	0.29	0.32	0.23	0.13	0.06
Std. Dev. for Rural North/South Interstate Roads	0.05	0.02	0.07	0.07	0.04	0.07	0.05	0.05	0.05	0.06	0.05	0.01

It can be seen that for car volumes, two sites on I-90 (sites 6 and 14) have travel patterns that are rather distinct from the remaining nine sites. Both of these sites show a higher degree of seasonality than is present in the other sites. Both have much lower winter volumes than the remaining sites, and both exhibit a much greater increase in traffic during the summer months. It turns out that both of these sites are in eastern Washington. In addition, a third eastern site has a similarly high summer/low winter travel pattern (site 86) on I-82. These passenger car patterns suggest that keeping eastern Washington sites separate from western Washington sites might create better factor groups.

However, looking at the other vehicle classes does not lead to the same clear-cut decision. For both combination trucks and multi-trailer trucks, Site 14 has truck volume patterns that fall directly in the middle of the pattern exhibited by the various sites. Site 6, on the other hand, does show a traffic pattern for trucks that is slightly more extreme than for the other sites. Site 6 shows a pattern in which the weekday adjustment factor is almost always greater than 1, indicating very low weekend traffic in comparison to weekday traffic, whereas the other sites have winter volumes that fall below the average daily volumes.

This mixed result is common when one is trying to apply a single factor grouping process to multiple types of vehicles. Different classes of vehicles are affected by different land-use and travel patterns, and as a result factor groups will predict travel patterns more reliably for some vehicle classes than for others.

To determine the effectiveness of splitting these roads into two different factor groups, it is necessary to look at the statistics that would be generated by splitting these routes. Three different "simple" splits are possible, given the assumptions presented earlier. The three alternative groupings to be tested are given below. Each could be considered "intuitive" to an analyst familiar with the State. The testing process will show whether the "intuitive" process provides better analytical results. Each new group does allow easy assignment of short duration counts collected at specific road locations to an available factor group.

- All Interstates on the eastern side of the Cascades can be placed in one group, and all Interstates on the western side of the Cascades can be placed in the other.
- All east/west Interstates can be placed in one group, and all north/south Interstates in the other.
- All east/west rural Interstates can be placed in one group, all north/south rural Interstates can be placed in another, and all urban Interstates can be placed in a third.

Table 4-B-5 shows the effects of forming these groups and compares them with the variability found if all Interstates are treated as a single factor group. Not surprisingly, each of these three changes to the factor groups results in improvements in some factors (that is, the factors show a decrease in variability) and increased variation of other factors. For example, splitting the "All Interstates" factor group into eastern and

western factor groups results in significant improvement (a decrease in the standard deviation for almost all monthly factors) in the factors for the car, single-unit, and combination unit factors for the western Interstate factor groups. However, the multi-trailer truck factor group for western Interstates shows a minor increase in variability for all but the summer months. Conversely, the eastern factor group generally shows an increase in variability for all factor groups, except for multi-trailer trucks during the winter months. Thus, separating eastern and western roads only appears to improve the accuracy of annual traffic estimates west of the Cascade Mountains while reducing the accuracy of counts in the eastern portion of the state.

The second effort to improve factors is to split roads traveling primarily east/west from those traveling north/south. Table 4-B-5 shows that this has the effect of making the factors for north/south roads universally more accurate than factors for all Interstates combined. However, factors for the east/west Interstates are almost universally worse than the factors for all Interstates combined. This sets up the decision of choosing between a factoring process that more accurately adjusts short counts on some roads at the expense of poorly adjusting others. Before making this tough decision, it is important to look at the last idea for improving these basic factor groups.

The final effort is to remove the urban locations from the east/west and north/south factor groups. The intent behind this effort is again to separate roads assumed to have different seasonal and day-of-week patterns (i.e., urban versus rural). If these patterns are different, the factors for both east/west and north/south factor groups should have reduced seasonal variability. Given the results above, the primary improvement desired is in the area of east/west Interstates, since those roads have the highest variability between the two groups just tested.

Unfortunately, as shown in Table 4-B-5, removing the urban sites from the east/west factor group does not significantly improve the variability of the factor being produced. As with the original east/west factor group, the rural east/west factor group has monthly factors that are almost universally more variable than the original monthly factors. Thus, the original decision point remains, is it better to maintain the one single factor group that does all Interstate reasonably well, or split the Interstates into two groups, with one group having more reliable factors than the other?

It is very difficult to answer this question without including far more information than can be presented in this report. Issues that would be important in making this decision include the following:

- How many other factor groups are already used in the State?
- Are any of the roads of higher priority than the others?
- Would it be possible to use road specific factors to deal more effectively with the higher variation on the east/west roads?
- Are there specific reasons why the east/west roads are more variable for the year(s) for which data are being examined? (For example, could an unusual series of weather events have caused more variability than is normal for those roads?)

- Are either of the factoring groups easier to implement at either the user level or the database management level? (That is, can the average user understand which factor to apply for both factor groups? Will the existing traffic database management system support both types of factor groups?)

Without the answers to these questions, the decision can only be made on the basis of statistical reliability. Assuming that the short count program can be manipulated, it would therefore be in the interest of the State to select one of the more disaggregated factor groups. The last of these groups works slightly better than the first two. So it is selected. However, to allow the best possible computation of annual traffic estimates, it is recommended that counts in the eastern portion of the State be collected during the early winter if weather permits or early spring if reliable winter data collection is not possible, since these are the times of the year when the adjustment factors for most of the vehicle classes are most stable.

APPENDIX 4-C
FHWA VEHICLE TYPES

The classification scheme is separated into categories depending on whether the vehicle carries passengers or commodities. Non-passenger vehicles are further subdivided by number of axles and number of units, including both power and trailer units. Note that the addition of a light trailer to a vehicle does not change the classification of the vehicle.

Automatic vehicle classifiers need an algorithm to interpret axle spacing information to correctly classify vehicles into these categories. The algorithm most commonly used is based on the "Scheme F" developed by Maine DOT in the mid-1980s. **The FHWA does not endorse "Scheme F" or any other classification algorithm.** Axle spacing characteristics for specific vehicle types are known to change from State to State. As a result, no single algorithm is best for all cases. It is up to each agency to develop, test, and refine an algorithm that meets its own needs.

FHWA VEHICLE CLASSES WITH DEFINITIONS

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

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

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

4. ***Buses*** -- All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-

carrying vehicles. Modified buses should be considered to be a truck and should be appropriately classified.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX 4-D
RESOURCES ON TRAFFIC DATA COLLECTION

New Mexico Vehicle Detector Clearinghouse, http://www.nmsu.edu/~traffic/

"Traffic Detection Technologies for a Modern Transportation Infrastructure," by Klein, Kelley, and Mills, presented at SPIE Conference 2592, Collision Avoidance and Automated Traffic Management Sensors, October 25-26, 1995, Philadelphia.

"Detection Technology for IVHS – Task L: Final Report," FHWA Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C., 1996.

"Accuracy of Automatic Vehicle Classifiers," Kansas Department of Transportation, July 1989.

"Field Evaluation of FHWA Vehicle Classification Categories," by Wyman, Braley, and Stevens, Maine Department of Transportation, Final Report for Contract #DTFH-71-80-54-ME-03 for USDOT, 1985.

"Autoscope Evaluation at Trunk Highway 65 and 53rd Avenue North," Minnesota Department of Transportation, January 1996.

"Evaluation of Econolite Products Inc., Machine Vision Vehicle Detection System," Indiana Department of Transportation, 1996.

"Infrared Sensors for Counting, Classifying, and Weighing Vehicles," by Garner, Lee, and Huang, University of Texas, Report #FHWA/TX 91+1162-1F, December 1990.

"AASHTO Guidelines for Traffic Data Programs," by the Joint Task Force on Traffic Monitoring Standards, ISBN 1-56051-054-4, 1992.