Development of an Integrated Statewide Traffic-Monitoring System

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ABSTRACT

Most states expend a significant amount of resources for collecting traffic volume, vehicle classification, and truck weight information. Most of this data collection reflects the continuation of past practices and does not result in either cost-effective data collection or the establishment of an integrated, statistically valid data base for use in design, maintenance, or planning applications. As a result of an FHWA study, it was determined that an integrated, cost-effective data collection program is feasible. The recommended program framework described in this paper provides traffic monitoring procedures for state DOTs that allow each state to establish a productive traffic monitoring process that meets state and federal needs, often reduces the total amount of data collected, and improves the quality of the data that are obtained. It must be emphasized that this framework does not specify the amount of traffic data a state must collect. Each state has different needs, budgets, equipment, and other resources. Each state must make individual decisions about the trade-offs between collecting more data (with the intent of obtaining higher quality data) and the need to limit the expenditure of funds for data collection.

With the increasing deterioration of major portions of the U.S. highway system, the need for better data on the volume and composition of highway traffic is growing. At the same time, many states are facing or have recently faced cutbacks in the resources available to collect and analyze traffic information. Compounding the problem is the fact that many of the data collection efforts performed by the states, particularly for vehicle classification and truck weight monitoring, are not related in any way. For example, vehicle classification data collected at truck weight-monitoring locations are often not included in the vehicle classification data bases. This causes unnecessary double counting at some traffic-monitoring locations and reduces the quality and effectiveness of the established data base.

Another area of concern is that the data collected in many states do not necessarily provide high-quality engineering data. Locations chosen for collecting traffic data often are not randomly chosen (for statistical purposes) or representative of existing travel. Instead, the data collected are often heavily biased for one reason or another, which in turn can lead to inappropriate engineering designs.

As an initial step toward strengthening the methods used by the states for collecting, estimating, and reporting traffic count data, and to help reduce the effort involved in providing the federal government with necessary traffic data, the Federal Highway Administration (FHWA) introduced the Highway Performance Monitoring System (HPMS) in 1978. This program provided a framework for developing statistically valid estimates of vehicle-miles of travel (VMT) for functionally classified roads in each state. A study, "Development of a Statewide Traffic Counting Program Based on the Highway Performance Monitoring System," completed in March 1984, expanded on this program to develop a framework for an integrated statewide traffic-monitoring program that could meet all state and federal data needs.

The recommended monitoring program uses statistically based traffic-monitoring techniques and integrated data collection (i.e., collecting volumes, classification, and weight data simultaneously) to produce valid traffic estimates for engineering purposes when valid site-specific data cannot be obtained. This approach has two significant advantages over most existing statewide traffic-monitoring practices:

- It provides statistically reliable data and
- It requires fewer resources to collect data of equivalent quality; integrated traffic monitoring usually causes a reduction in the overall quantity of data that needs to be collected.

Because the collected data are statistically valid, a design engineer can take into account the variability (distribution) and reliability (precision) of data used in the design effort. This allows for more informed decision making in the design process and should result in more cost-effective roadway and structural designs.

STUDY APPROACH

To determine the scope of the proposed data collection program, the study included a thorough review of the uses and users of traffic data collected by state DOTs. The review encompassed both federal and state data needs. Interviews were conducted with state DOT personnel from five participating states as well as FHWA employees. In addition, a literature search of existing traffic-counting studies and papers was performed. The review included such topics as

- Who uses state traffic data?
- What data do these users currently use, require, or wish to have available?

• What is the level of precision required for those data?

This information was then compared with existing data collection programs to determine which programs could meet multiple information needs. It was determined that the use of a limited number of data collection programs that met multiple needs could reduce the amount of data collection and, at the same time, improve the integration, quality, and usefulness of the data obtained.

In addition to the review of data needs, a review of available data collection equipment was undertaken (1,2). This review examined available reports and other documentation to ascertain whether new equipment currently being tested and marketed could reliably perform automatic vehicle classification, truck weight-monitoring, or electronic data transfer of all types of traffic information. The investigation determined that this new equipment is capable of providing most of these functions. Although this equipment is not as accurate or reliable as desired, the proposed program relies to a limited extent on its use and encourages its continued development because of the significant effects it can have on the quality, quantity, and cost of the data collected.

A third element included in the design of the traffic-monitoring program was the investigation of the variation inherent in traffic data. This examination included estimating the variation in

• Traffic volumes across days and seasons,
• Percentage of travel by vehicle class, and
• Average weight (or equivalent axle load) of each vehicle type.

The results of this analysis were used to provide estimates of the statistical reliability of various traffic estimates. The analysis was performed using previously compiled FHWA data bases, including

• HPMS traffic volume data base,
• Annual traffic recorder data,
• HPMS vehicle classification case study data base, and
• HPMS truck weight case study data base.

It is acknowledged that these sources have serious limitations in terms of statistical rigor and are not always appropriate for a specific state's applications. They are, however, the best national data bases available at this time, and they do provide a reasonable estimate of traffic variability.

The data derived in this analysis were used to develop an initial statewide traffic-monitoring program. This initial program was then examined in relation to the traffic-counting needs and procedures currently practiced in the five states participating in the study: Georgia, Kansas, Maine, Ohio, and Oregon. The case studies were used to convert the initial program into a framework that could be applied by any state. Each state could then take advantage of the recommended program's integration and cost saving capabilities while maintaining sufficient flexibility to address its own specific needs and issues. Among the issues that differed among the case study states were

• Data needs,
• Organizational structures,
• Labor utilization,
• Data manipulation procedures, and
• Capabilities of the equipment being used.

DATA NEEDS

Although specific data needs varied from state to state, it was possible to aggregate the various needs into three basic functions:

• Roadway system management and maintenance (day-to-day operations management and limited repair functions);
• Future systems improvements (major project planning, engineering, and investment analyses); and
• Reporting and research needs (system usage monitoring, federal reporting requirements, and data for public policy analyses).

Specific activities were defined within each of these three categories, and the specific data needs of those activities were detailed (Table 1).

TABLE 1 Traffic Data Requirements

Data Needs	Volume	Vehicle Classification	Truck Weights
Roadway system management and maintenance			
Maintenance	SS, AADT	Avg VC by FC	(None)
Capacity analysis	SS, AADT, and turns	SS or avg VC by FC	(None)
Safety analysis	SS, AADT, and turns	SS, VC	(None)
Taxation	N/A	N/A	N/A
EIS	SS, AADT	SS (avg by FC)	(None)
Future system improvements			
Trend analysis	VMT by FC (by region)	Avg VC by FC (by region) by year	Avg weight by VC by FC
Project identification and selection	(SS, AADT)	(SS, VC)	(None)
Project design	SS, AADT	SS, VC, or avg VC by FC	Avg weight by VC by FC
Highway investment analysis	SS, AADT	Avg VC by FC (by region)	(None)
EIS	VMT by FC	Avg VC by FC (by region)	(None)
Reporting and research			
System usage monitoring			
Fund allocation	VMT by FC by region	Avg VC by FC (by region)	Avg weight by VC by FC
Trend analysis	VMT by FC by region	Avg VC by FC (by region)	Avg weight by VC by FC
Public policy and legislation	VMT by FC by region	Avg VC by FC (by region)	Avg weight by VC by FC
Taxation	VMT by FC	(VC by FC)	(None)
Research	VMT by FC	VC by FC	Weight by VC by FC

Note: SS = site specific, AADT = average annual daily traffic, FC = functional classification, VC = vehicle classification, VMT = vehicle-miles of travel, ( ) = optional value, Avg = average, and EIS = environmental impact statement.

In almost all cases involving engineering design work, the users of the data preferred current site-specific data on volumes, vehicle classifications, and truck weights. In practice, because these data were often not available (particularly for vehicle classification and truck weights), most users relied extensively on old traffic counts factored to represent current traffic levels and "average" values for vehicle classifications and weights included in engineering manuals. For systemwide analyses, the predominant need expressed was for statistically valid systemwide estimates.

From this information it became apparent that statistically valid data could fulfill the needs of many users and reduce the resources necessary to collect much of the necessary information. The savings made by using statistics could then be used either to collect important site-specific data or could be diverted to other important functions within the DOT.

RECOMMENDED PROGRAM

The recommended program structure was designed to meet all of the previously mentioned needs. It also takes into account the need to develop factors for applying seasonal and other corrections to individual traffic counts and provides a rational method for applying these factors to raw data. Finally, the program structure was designed to encourage the implementation of new cost-saving technologies and the gradual refinement of the data base and data collection process based on the statistically valid data collected as a result of the initial program design.

To meet the wide variety of data needs described, the recommended program was structured in three separate but integrated elements:

- A series of automatic traffic recorders (ATRs) to provide seasonal factors;
- Statistically valid volume, vehicle classification, and truck weight-monitoring sessions, based on the existing HPMS program and data base; and
- A special count element, which allows states to collect data necessary for the state but not included in either of the other two programs.

Integration of these three program elements is based on the functional classification system used in the HPMS sampling procedure. All factoring of raw traffic volume data (seasonal, axle correction, growth, etc.) is based on the functional classification of a road. In states in which significant variations in traffic characteristics occur, functional classifications may be supplemented by regional stratifications. Functional classification was chosen as the method for integration because it is the basis for the HPMS sample and because it offers a high degree of continuity of roadway designations among states.

One significant difference between the recommended factoring process and the HPMS sample is that individual urban areas are not treated separately for factoring and sample selection purposes. All urban areas are included in the urban functionally classed categories (e.g., urban Interstates, urban principal arterials) regardless of their size.

In the following subsection, in which continuous ATRs are discussed, the steps that should be performed to determine the appropriate number of factor groups and the need for regional stratifications are described.

Continuous Count Element

The primary purposes of the continuous count element are to provide seasonal adjustment factors and to collect short- and long-term trend data. These are consistent with the current uses of ATR data. Although some existing ATR stations are capable of providing combinations of vehicle classification, vehicle weight, and vehicle speed data, depending on the equipment available at the site and the type of sensing device used, these "enhanced" ATR locations are not required by the recommended program. However, their use is encouraged because of the considerable amount of valuable data they can provide.

Recommended Element

The program recommends a structured continuous count element that combines ATRs by functional class to provide seasonal and day-of-week adjustment factors. The intent of the structured process is to provide adjustment factors that allow for

- Ease in applying the factoring process, including the use of automation;
- Calculation of the statistical precision of the applied factors; and
- Application of the factors to roads with similar seasonal traffic patterns.

Applying seasonal factors by functional classification was determined to be the best alternative for meeting these three objectives.

Available data show that roads of the same functional class tend to exhibit the same basic seasonal pattern within a state (or within a region of a state). However, as mentioned previously, there may be more than one pattern per functional class within a state because of regional differences in topography or demography (mountainous industrial areas versus oceanfront recreational areas). In addition, different functional classifications may exhibit similar seasonal patterns. A prime example of this is urban Interstates and other urban freeways and expressways. These two road classifications usually exhibit similar seasonal patterns, vehicle classification percentages, and other characteristics.

To provide each state with the maximum amount of flexibility in applying the program, each state has the option of combining the data collection for different functional classes and of creating regional stratifications if they are necessary to develop reasonable factor groups. As a result, a state may split functional classes of roads into different regions to account for different travel patterns and at the same time combine several functional classes within each region because they exhibit strong similarities. Finally, a state may need to allow some exceptions to the factoring process because some roads consistently exhibit abnormal traffic patterns (e.g., a road leading into a major ski resort may have a seasonal pattern unlike other roads in the state). An example of a possible seasonal factor grouping is shown in Figure 1.

Creating Factor Groups

The creation of the new factor groups is a complicated process to describe, although not difficult to perform. It is diagrammed in Figure 2 and briefly outlined. A review of existing ATR data and some knowledge of a state and its traffic patterns are all that is necessary to develop the new groups for applying seasonal factors.

Because of the cost involved in the construction of new ATR locations, it was decided that existing ATR stations would be used in the recommended program whenever possible. Although this compromises

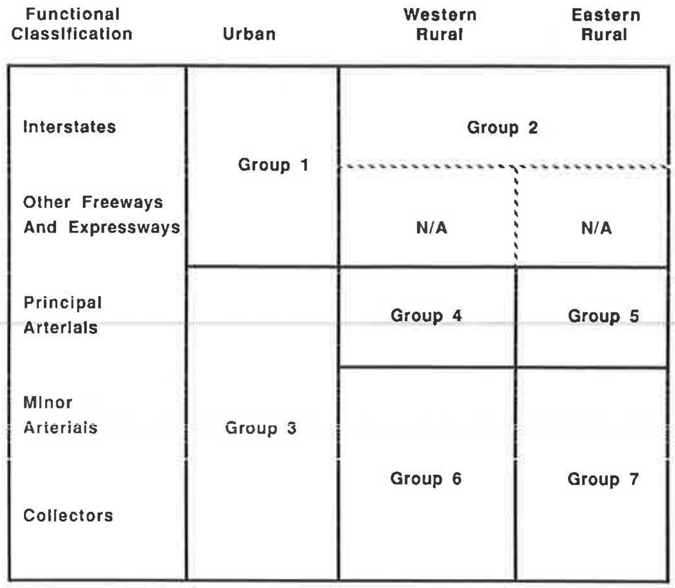

FIGURE 1 Example seasonal factor groupings.

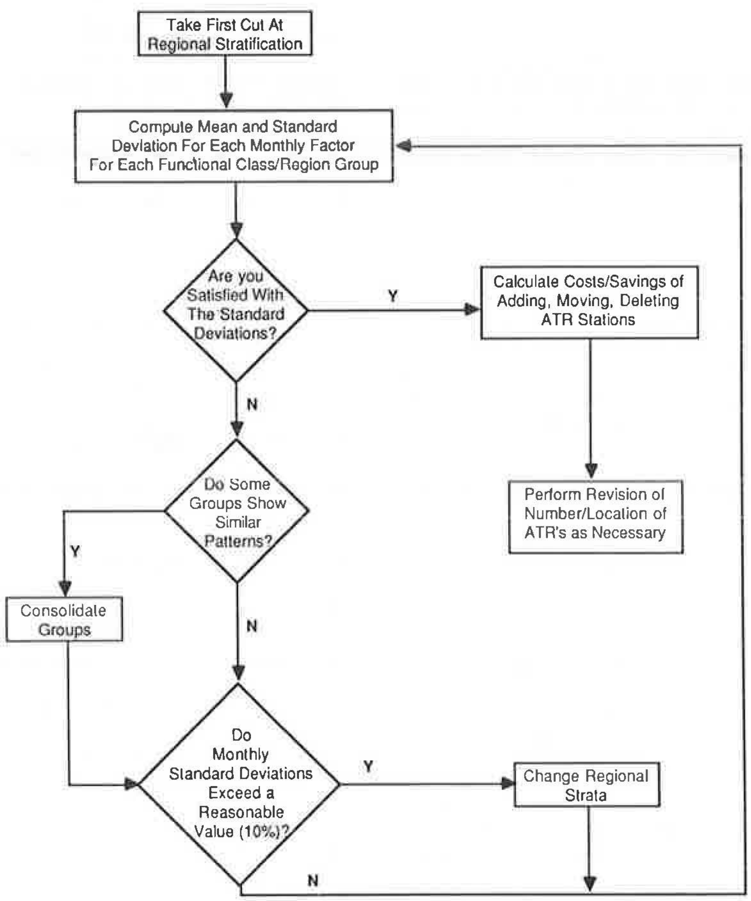

FIGURE 2 Process for determining seasonal factor groupings.

some of the statistical rigor of the program, the practical realities of trying to relocate ATRs outweighed the benefits that could be gained from maintaining statistical rigor. Because of this relaxation of the sampling process, a state could review its existing ATRs to ensure that counters included in the factoring process were not placed to capture data on "unusual" or "abnormal" traffic movements that might adversely bias the calculated factors.

The process of converting an existing group of ATRs into a group usable for the recommended process includes the following steps:

- Use professional knowledge of the state's traffic patterns and analysis of available state ATR data to determine any obvious regional stratification that should be included in the factors.
- Use existing ATR data to compute mean seasonal factors and their standard deviation for each functional class of road within the state or region.
- Plot the mean ATR data and examine the standard errors.
- Consolidate the functional classes or regions where possible or create new regions if necessary.
- Determine the number of ATRs currently located in each of the new factor groups.
- Determine the costs or savings of moving, adding, and eliminating ATRs.
- Compare these costs with the changes in the estimated sample variance that result from possible changes to determine the advisability of adding, deleting, or moving ATRs.
- Select new ATR sites and eliminate or relocate extraneous old ATR stations.

As a general guide, the project team attempted to keep the standard deviation of each monthly factor below 10 percent. Factor groups with months having larger deviations were normally investigated with the intent of further stratifying that functional class of roads by region.

The study determined that the optimum number of ATR stations per factor group was between three and eight depending on the variability of the data, the size of the state counting budget, and the number of existing ATR stations in each factor group. Additional ATR stations were usually not added to factor groups containing six or more counters. Similarly, if more than eight stations were in the factor group, the number of stations was rarely decreased below eight unless cost savings were of major importance to the state.

Comparison of New and Old Seasonal Factor Methods

The recommended factor process differs from the way most states currently calculate and apply seasonal correction factors to raw traffic counts. Many states currently develop seasonal factors by grouping data from ATRs with similar seasonal patterns without regard for ATR location or functional classification. These factors are then applied to individual roads across the state on the basis of which of the factor group patterns is thought to be applicable to that particular road. The result is a seasonal factor that has little variation (because the ATRs are specifically grouped to keep the variation low) but a large degree of uncertainty concerning its application because there is no assurance that the road in question exhibits that particular seasonal pattern.

The recommended process has the advantage that the factors are calculated specifically for functional classes and thus all groups by definition. ATR data are grouped because the ATRs are from the same functional class not because their seasonal patterns most closely resemble each other. This means that when the factor is applied to roads in the state, no unknown error is added to the traffic estimate. Thus the error in the seasonal factor process can be estimated as a function of the variability of the ATR data used to calculate the factor. This provides the design engineer with a better understanding of the quality of his data, which, in turn, allows him to exercise informed professional judgment in the design process.

The case studies performed for this project showed that, with the judicious use of regions within a state, the seasonal factors developed using this method contain variation equal to or only slightly greater than the factors they replace. Because there is no additional error (of unknown magnitude) in applying these new factors to individual roads, they are most likely as accurate as if not better than the factors currently used.

One final advantage of the recommended process is that it allows the simple automation of the factor process. Unlike many of the existing procedures, which require an engineer to select the appropriate factor for a count based on his past experience with that road or geographic area, the factoring of data with the new system can be accomplished by machine. This is possible because the assignment is made systematically without the need for professional judgment. The machine simply keys on one or two fields (functional class and possibly a county code) and applies a factor assigned to that combination. The recommended process can therefore be easily adapted to computerized applications.

Statistically Valid HPMS Element

The primary purpose of this program element is to provide statistically representative estimates of volume, vehicle classification, and truck weight data. These statistically valid data can then be used in other areas of the complete traffic count program. It is acknowledged that some compromise in the statistical rigor of data collection is necessary for the implementation of the program because of the realities of traffic counter placement and manpower utilization. The program therefore uses statistical procedures as the sampling basis and encourages the state implementing the program to avoid choosing "exceptional" monitoring locations (e.g., weigh stations next to cement plants) when performing adjustments to the statistical sampling process.

The program element is structured as a series of subsamples of the existing HPMS data base. That is, vehicle classification and truck weight-monitoring locations are selected from the existing HPMS volume count locations. The purpose of this is to provide a direct correlation among the volume, vehicle classification, and truck weight-monitoring data collection efforts and to take advantage of the sampling effort already performed for the existing HPMS process.

To make use of this opportunity for integration, a volume and vehicle classification count is taken every time a truck weight-monitoring session occurs. In this manner three separate "counts" are taken that directly correlate with each other. Vehicle classification counts are also taken without a corresponding truck weight session, but a 24-hr volume (machine) count should accompany each classification count. In each of these cases a member of the vehicle classification team should be responsible for setting up a traffic recorder to collect traffic volume data. This eliminates the need for separate DOT personnel to place a counter at that location and reduces the manpower necessary to collect the volume count data.

The number of vehicle classification counts and truck weight-monitoring sessions needed to produce estimates of vehicle characteristics within desired levels of precision can be computed from statistical equations and the variability of the data being estimated [i.e., the variation in the average weight or equivalent axle load (EAL) of each type of vehicle or the percentage of certain types of vehicles in the traffic stream]. For example, the number of counts needed to estimate the percentage of 3-S2 trucks in the traffic stream can be calculated from

$$n = (z \cdot COV3\text{-}S2)^2/d^2$$

where

- n = number of counts,
- z = normal variate for the specified level of confidence,
- d = desired accuracy of the estimate expressed as a fraction, and
- COV3-S2 = coefficient of variation for the percentage of 3-S2s in the traffic stream.

For a given level of variability, the relationship between precision and sample size can be expressed in a graphic format. Figure 3 shows one such sample size-versus-precision relationship using data contained in the FHWA HPMS vehicle classification data base to approximate the variability in the percentage of trucks on rural Interstates.

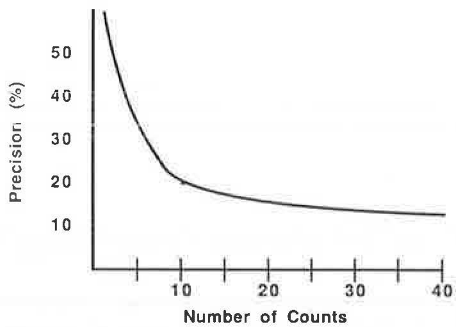

FIGURE 3 Vehicle classification precision.

Sampling Approach

The objective of the sampling approach for this program element is to collect a data set that can be used to acceptably represent the characteristics of existing vehicle traffic. It is acknowledged that other factors, such as the avoidance of weighing scales by heavy trucks, will prevent any data collection effort from being truly free from bias. The intent of the sampling approach is to limit this inherent bias as much as possible while dealing directly with the practical realities of data collection. It is hoped that further reductions in this bias can be made through the increased usage of unobtrusive weigh-in-motion (WIM) equipment.

To reduce the effort involved in selecting the traffic-monitoring locations it was decided to start the selection process using the existing HPMS traffic count locations. Although this collection of monitoring locations may not be perfect, it does provide the basis for an unbiased starting point for collecting data. From these points, the vehicle classification locations are chosen, and from the vehicle classification locations, truck weight locations are chosen.

It is suggested that a random sample approach, mixed with some professional judgment, be used to select vehicle classification and truck weight-monitoring locations. Ideally, the random sample should be taken for count days as well as locations. This ensures that the data represent traffic throughout the year and not just during the summer months. Because random sampling of count days can produce schedules that severely limit manpower and equipment utilization, it is acknowledged that the systematic selection of count days may be more realistic for a state DOT. However, this systematic selection should include data collected throughout the year.

A second reason for the use of professional judgment in the selection of count days and locations is that the equipment available to any one state (e.g., bridge WIM systems) often creates significant limitations on where some of these counts can be taken. Therefore any random sampling procedure for selecting vehicle classification and truck weight locations must be tempered with professional judgment about whether a location is usable for vehicle classification or truck weight monitoring.

Sites selected in the original sample that are not suitable for vehicle classification and truck weight data collection must be replaced with additional locations to complete the sampling needs. Some states will want to substitute sites where they have already located in-ground WIM equipment. Although this has some ill effects on the statistical rigor of the data collection, it is a reasonable practice given the cost of installing much of this equipment. The only drawback to this approach is that any site chosen in a nonrandom manner should not be included if it was selected because of particular traffic occurrences. For example, if a number of sites are selected because of the presence of overweight trucks, the mean EAL calculated from these raw data will be biased toward heavy trucks and will thus overestimate the actual weights of trucks on the state's roads.

One way of combining these various issues in an acceptable systematic sampling procedure is to take multiple counts at fewer locations in place of taking one count at many locations. For example, instead of taking a separate count at 12 locations, three counts could be taken at four locations. These three counts would be spread evenly throughout the year, thus decreasing the chance of seasonal bias in the data. This method also reduces the number of truck weight-monitoring locations needed, which will significantly reduce the number of suitable locations that must be found as well as the cost of using in-ground equipment.

Factoring the Raw Data

The data collected are intended to be aggregated by functional classification. That is, from the vehicle weight data collected annually, an average EAL for each category of vehicle (e.g., 3-S2 trucks) can be calculated for each functional classification of roadway. The statistical reliability of the process means that the average EAL value for 3-S2 trucks (or any other truck type) is known within certain error bounds and with a certain level of confidence. Similarly, it will be possible to calculate the average percentage of traffic due to 3-S2 trucks for each functional classification of road within specified error bounds and with a given level of confidence.

Data on the percentage of vehicles by vehicle type or category can also be used to estimate axle correction factors for each functional classification of roadway for road tube-style traffic counts. The HPMS vehicle classification data base showed that the appropriate axle correction factor for roads often varied considerably for different functional classes (Table 2). The accuracy of traffic volume estimates will therefore be improved by using statistically valid axle correction factors for each functional classification developed from the vehicle classification data. This in turn improves the accuracy of all future traffic estimates, such as AADT, volume by vehicle type, and total EAL estimates.

Use of Data

Each of the mean values (percentage of vehicles by vehicle type, mean EAL per vehicle type, etc.) is

TABLE 2 Axle Correction Factors by Functional Classification

Functional Classification	Axle Correction Factor
Rural Interstates	2.46
Rural primary arterials	2.21
Rural minor arterials	2.15
Rural collectors	2.11
Urban Interstates and other freeways and expressways	2.16
Urban primary arterials	2.10
Urban minor arterials	2.04
Urban collectors	2.03

known within a calculated level of precision as a result of the sampling and data collection efforts. These values can be used to develop other traffic estimates such as the total number of expected EALs on a road segment in a given day:

$$EAL = axles \cdot ACF \cdot SAF \cdot \sum(PVT_a \cdot EAL_a)$$

where

- EAL = total daily equivalent axle load,
- axles = raw axle count,
- ACF = axle correction factor,
- SAF = seasonal adjustment factor,
- PVT_a = mean percentage of vehicles that are type a, and
- EAL_a = mean EAL for vehicle type a.

Because each of the values to the right of the equal sign can be calculated with a known level of precision from the proposed program, the precision of the total EAL estimate can be estimated as well.

Statistics can be used to estimate the reliability of any traffic count, based on the variation inherent in the raw traffic data and the factors applied to that value (i.e., the precision of an EAL estimate for a given road section depends on the variability of the mean EAL for each vehicle type, the variability of the percentage of each vehicle type at that location, and the variability of the daily traffic volume at that location). For example, the precision of a daily EAL estimate at a location, based on a site-specific volume count and functional classification strata estimates of vehicle classification percentages and EAL estimates per vehicle, can be calculated from

$$SEAL_j^2 = \sum_i \{EAL_{ij}^2[(\overline{SEAL}_{ih}^2/\overline{EAL}_{ih}^2) + (SVOL_{ij}^2)/(VOL_{ij}^2)]\}$$

where

- $SEAL_j$ = standard deviation of the total EAL estimate for location j,
- EAL_{ij} = total EAL for vehicle type i at location j,
- $\overline{SEAL}_{ih}$ = standard deviation of the EAL estimate for vehicle type i on stratum h,
- VOL_{ij} = volume of vehicle type i at location j, and
- $SVOL_{ij}$ = standard deviation of the volume estimate for vehicle type i at location j.

$SVOL_{ij}$ is dependent on the variation in both volume and vehicle classifications and is calculated as follows:

$$SVOL_{ij}^2 = VOL_{ij}[(SVOL_j^2/VOL_j^2) + (\overline{SPVC}_{ih}^2/\overline{PVC}_{ih}^2)]$$

where

- $\overline{SPVC}_{ih}$ = standard deviation of the vehicle classification percentage for vehicle type i on stratum h;
- $\overline{PVC}_{ih}$ = percentage of vehicle type i on stratum h;
- VOL_j = volume estimate for location j; and
- $SVOL_j$ = standard deviation of the volume estimate as a result of the seasonal, axle correction, and other factors applied to the short volume count;

with

$$SVOL_j^2 = (SVOLD^2/nd) + \{SVOLS^2[1 + (1/ncc)]\} + \{SVOLA^2[1 + (1/nvc)]\}$$

where

- $SVOL_j$ = standard deviation of the volume count at location j,
- SVOLD = standard deviation of volume across days,
- SVOLS = standard deviation of volume across seasons,
- SVOLA = standard deviation of the average number of axles per vehicle per day,
- ncc = number of count locations used to calculate seasonal factors,
- nvc = number of vehicle classification counts taken to calculate the axle correction factor, and
- nd = length of the count in days.

These statistical equations are valid because all of the data used in them are collected in a statistically rigorous manner. Unfortunately, the number of different traffic data calculations (e.g., simple AADT estimates, EAL estimates, average vehicle classification estimates for HPMS strata) is too numerous to allow all of the appropriate equations to be reprinted in this paper. The interested reader is referred to Chapter IV of the final report for this study (3) as well as to the texts that served as the basis for these equations (4,5). The final report also provides default values for traffic characteristic variation derived from the FHWA data bases listed earlier for use in these equations.

The availability of precision estimates also gives some flexibility to the design engineer. For example, if an engineer is trying to design a road that is expected to carry higher than average numbers of heavy trucks, he can use an EAL value greater than the mean calculated for the applicable functional class (e.g., the mean plus one standard error). Alternative designs could be based on these two values and then compared to determine the optimal configuration in light of expected traffic.

Special Count Element

There are some traffic data that cannot be collected effectively with either an ATR program or a statistically based system. The special data collection element was designed to provide a means for collecting these data within the context of the total state program. This element is meant to be independent of the HPMS-based and continuous elements, although the mean values for each functional classification determined from those elements (seasonal factors, mean EAL per truck type, etc.) should be applied to the raw axle counts from this special count element.

A key to this element is that the state has complete control over what data are collected and the manner in which they are collected, analyzed, and distributed. Because the data primarily fulfill state needs, it is highly recommended that each state periodically (annually or biannually) review the data collected to ensure that they are still needed to fulfill changing state needs. Those programs that are no longer necessary or do not justify their costs can then be replaced by more important data collection needs. This will allow the states to maintain the cost-effectiveness of their traffic data collection programs.

The review process provides a means for each state to continually rank in priority order its remaining data needs and apportion its budget accordingly. Among the high-priority special data collection programs encountered during the five state reviews for this project were

- Railroad crossing counts,
- Truck counting on specially designated highways, and
- Specific counts mandated by state legislation.

Other potential uses of the special count program include

- Truck driver interview surveys;
- Traffic volume, vehicle classification, or truck weight-monitoring sessions at specific locations;
- Project-specific vehicle class and weight studies;
- Cordon line counts;
- Those parts of coverage count programs that cannot be eliminated by reliance on other data sources; and
- Local road VMT estimates.

With this final program element, each state can account for those needs that may not exist for other states, whereas the continuous and statistically based elements provide data needed by all states. In some cases the special data collection element will make up the majority of the data collection effort. No matter what its size, however, the special data collection element will still be integrated with the other data collection elements, and the statistical precision of these counts can still be estimated using the equations described. As a result, each state should be able to improve the quality of its data while continuing to collect all necessary data.

ACKNOWLEDGMENTS

This paper is a summary of the conclusions reached during a study that Peat, Marwick, Mitchell and Company performed for the Federal Highway Administration in 1983. The study was called "The Development of a Statewide Traffic Counting Program Based on the Highway Performance Monitoring System." A copy of the full report can be obtained from NTIS.

The author would like to thank those people involved with this project for their assistance, particularly Tony Esteve of the Federal Highway Administration who provided considerable help with the technical details of the study and provided insight into the needs of the FHWA; John DiRenzo and Ray Ellis of Peat Marwick for their continued support of both the original project and this paper; Robin Spring and Sharon Biederman for their editorial assistance; and the Peat Marwick word processing staff, without whom this paper would never have been completed.

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