



# Standard Practice for Highway-Traffic Monitoring<sup>1</sup>

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## 1. Scope

1.1 This practice describes highway-traffic monitoring, which is the activity of collecting, summarizing, and reporting traffic volume, vehicle classification, and vehicle weight data. This practice is foundational and is not intended to be all-inclusive. Users of this practice are allowed, indeed encouraged, to exceed the practice.

1.2 Traffic monitoring results in traffic-volume, classification, and weight-summary statistics which are used in highway geometric and pavement design, alternative highway route selection, roadway demand and service assessment, and accident-exposure estimation.

1.3 Traffic-monitoring practices are based on the principle of truth-in-data. This principle involves providing the supplementary information required for appropriate use of traffic data and summary statistics.

1.4 To measure traffic for summary-statistic calculation, traffic-monitoring practices are also based on the principle of unedited base-data integrity. Missing or inaccurate unedited base data shall not be completed, filled-in, or replaced for any type of traffic measurement.

1.5 A limitation of this practice is traffic-data summarization. Traffic-data summarization procedures are hypotheses, particularly in the use of adjustment factors. These hypotheses shall be consistently calculated, but may also be expected to be challenged and to change across time. These changes will be important in improving the precision of traffic-summary statistics.

1.6 The inherent limitation of traffic-monitoring practice results in strict adherence to the principle of unedited base-data retention. Only with adequate historical unedited base data can alternative hypotheses be tested, the impact of the alternative hypotheses assessed, and standard practice refined.

1.7 The values stated in inch-pound units are to be regarded as standard.

1.8 The following safety hazards caveat applies only to the traffic data collection portion, Section 6, of this practice. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health*

*practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

E 1318 Specification for Highway Weigh-in-Motion (WIM) Systems with User Requirements and Test Method<sup>2</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *adjustment factors, n*—traffic summary statistic corrections for multiple-axle vehicles, weekday-traffic variation, seasonal-traffic variation, and regional-traffic characteristics; and, the estimate of annual growth or decline for traffic-summary statistics on road segments not recounted during a year.

3.1.2 *annual average daily traffic (AADT), n*—the estimate of typical traffic on a road segment for all days of the week, Sunday through Saturday, over the period of one year and calculated from permanent-counter data as the sum of Monthly Average Daily Traffic (MADTs) divided by the number of MADTs, and for short-term counts by using adjustment factors.

3.1.3 *annual average days of the week, (AADW), n*—a traffic volume mean statistic for each day of the week, over the period of one year, and calculated from included permanent-counter data as the sum of Monthly Average Days of the Week (MADWs) for a year divided by the number of MADWs.

3.1.4 *annual average weekday traffic, (AAWDT), n*—the estimate of typical traffic over the period of one year, for the days Monday through Thursday, calculated from permanent counter data as the sum of Monthly Average Weekday Traffic (MAWDTs) divided by the number of MAWDTs.

3.1.4.1 *Discussion*—Friday traffic may be included in AAWDT calculation at a permanent-counter site or for summary statistics from permanent counters by functional and operational classification if the inclusion of these data does not increase the AAWDT coefficient of variation.

3.1.5 *annual average weekend traffic, (AAWET), n*—the estimate of typical traffic over the period of one year, for the days Saturday through Sunday, calculated from included permanent-counter data as the sum of Monthly Average Weekend Traffic (MAWETs) divided by the number of MAWETs.

3.1.5.1 *Discussion*—Friday traffic may be included in

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.03.

AAWDT calculation at a permanent-counter site or for summary statistics from permanent counters by functional or operational classification if the inclusion of these data does not increase the AAWET coefficient of variation.

3.1.6 *annual summary statistics, n*—yearly estimates of the central tendency of traffic volume, vehicle classification, and Equivalent Single Axle Load (ESALs, see 3.1.17) by vehicle classification, based on traffic measurements during the week-day combinations of Sunday through Saturday, Monday through Thursday, and Friday through Sunday.

3.1.6.1 *Discussion*—Calendar year is the most common and recommended basis for the count year.

3.1.7 *annual vehicle miles traveled (AVMT), n*—average annual traffic on a road segment, expressed as AADT multiplied by the number of days in the year, multiplied by the length of the road segment.

3.1.8 *approach, n*—a set of lanes accommodating all left-turn, through, and right-turn movements arriving at an intersection from a given direction.

3.1.9 *axle correction factor, n*—an adjustment of vehicle axle sensor summarized base data for incidence of multiple axle vehicles.

3.1.9.1 *Discussion*—The purpose of the axle correction factor is to account for the incidence of multiple-axle vehicles in the traffic stream.

3.1.10 *base data, n*—the unedited and unadjusted measurements of traffic volume, vehicle classification, and vehicle or axle weight.

3.1.11 *count, n*—the activity of measuring and recording traffic characteristics such as vehicle volume, classification, speed, weight, or a combination of these characteristics.

3.1.12 *count period, n*—the beginning and ending time of traffic characteristic measurement.

3.1.13 *count type, n*—the traffic characteristic being measured, the measurement device, and period.

3.1.14 *daily vehicle miles traveled, (DVMT), n*—average daily traffic on a road segment, expressed as AADT, multiplied by the length of the road segment.

3.1.15 *edit-accepted, adj*—having the unadjusted base data compliant with standards of practice.

3.1.15.1 *Discussion*—The standards of practice are those described in this document combined with edit routines related to specific types and models of traffic-measurement devices and data-retrieval procedures.

3.1.16 *edit-rejected, adj*—having the unedited base data non-compliant with standards of practice.

3.1.16.1 *Discussion*—The standards of practice are those described in this document combined with edit routines related to specific types and models of traffic-measurement devices and data-retrieval procedures.

3.1.17 *equivalent single axle load, (ESAL), n*—a numerical factor that expresses the relationship of a given axle load to another axle load in terms of their effect on the serviceability of a pavement structure.

3.1.17.1 *Discussion*—In common usage, all axle loads are equated in terms of the equivalent number of repetitions of an 18 000 lb single axle.

3.1.18 *excluded counters, n*—permanent traffic counters for

which monthly traffic adjustment factors may not be calculated for a given year.

3.1.19 *functional classification, n*—the grouping of streets and highways into classes, or systems, according to the character of service they are intended to provide.

3.1.19.1 *Discussion*—Basic to functional classification is the recognition that individual roads do not serve travel independently in any major way. Most travel involves movement through a network of roads. It is helpful and necessary to determine how travel can be channelized within the road network in a logical and efficient manner. Functional classification is a way of describing how travel is channelized and the part that a particular road or street plays in serving the flow of trips through the road network.<sup>3</sup>

3.1.20 *included counters, n*—permanent-traffic counters for which monthly traffic adjustment factors may be calculated for a given year, based on the quantity of edit-accepted data.

3.1.21 *isolated ramps, n*—an interstate interchange ramp at which the traffic flow is not influenced by upstream or downstream ramps.

3.1.22 *MADT*—see *monthly average daily traffic*.

3.1.23 *manual count, n*—measurement of traffic characteristics based on human observation, which may or may not be electronically recorded.

3.1.24 *mechanical count, n*—measurement of traffic characteristics by sensors and electronic recording of the measurements, independent of human observations.

3.1.25 *monthly average daily traffic, (MADT), n*—the mean traffic volume for a month, calculated by the sum of Monthly Average Days of the Week (MADWs) divided by seven; or, in the absence of a MADW for each day of the week, divided by the number of MADWs during the month.

3.1.26 *monthly average days of the week, (MADWs), n*—a traffic volume mean statistic for each day of the week, over the period of one month, calculated from included permanent counter data as the sum of all traffic for each day of the week (Sunday, Monday, and so forth through the week), during a month, divided by the occurrences of that day during the month.

3.1.27 *monthly average weekday traffic, (MAWDT), n*—the four-day average of traffic for the period Monday through Thursday in each month, calculated as the sum of MADWs for Monday through Thursday, divided by four.

3.1.27.1 *Discussion*—Friday traffic may be included in MAWDT calculation if the inclusion of these data does not increase the coefficient of variation. If Friday traffic is included, MAWDT is the five-day average of traffic for the period Monday through Friday in each month, calculated as the sum of MADWs for Monday through Friday, divided by five.

3.1.28 *monthly average weekend traffic, (MAWET), n*—the two-day average of traffic for the period Saturday through Sunday in each month, calculated by the sum of MADWs for Saturday through Sunday divided by the number of MADWs for Saturday through Sunday during the month.

3.1.28.1 *Discussion*—Friday traffic may be included in

<sup>3</sup> *Highway Functional Classification Concepts, Criteria and Procedures*, March 1989, U.S. Department of Transportation, Federal Highway Administration, Washington, DC 20590.

MAWET calculation if the inclusion of these data does not increase the coefficient of variation. If Friday traffic is included, MAWET is the three-day average of traffic for the period Friday through Sunday in each month, calculated as the sum of MADWs for Friday through Sunday, divided by three.

3.1.29 *monthly classification ratio*, (MCR), *n*—the monthly average volume by vehicle classification divided by the annual average volume by vehicle classification, calculated for vehicle classification annual summary statistics.

3.1.30 *monthly traffic ratio*, (MTR), *n*—the monthly average traffic volume divided by the annual average traffic volume, calculated for traffic volume annual summary statistics.

3.1.31 *monthly weight ratio*, (MWR), *n*—the monthly average ESALs by vehicle classification divided by the annual average ESALs by vehicle classification, calculated for the vehicle weight annual summary statistics.

3.1.32 *operational classification*, *n*—the grouping of permanent-counter sites, and roadways, on the basis of observed variation in traffic measurements, rather than designed purpose of the roadways.

3.1.33 *permanent counter*, *n*—a device intended to continuously measure and periodically record traffic volume, vehicle classification, or weight, or combination thereof.

3.1.34 *polling*, *n*—automated transfer of traffic measurements from permanent counters to a computer for editing and summarization.

3.1.35 *portable counter*, *n*—a device which may be moved to various locations and periodically measures and records traffic volume, vehicle classification, or weight, or combination thereof.

3.1.36 *rural area*, *n*—individual agencies may have a political boundary definition of rural, which would be the definition for traffic-monitoring purposes; in the absence of such an individual agency definition, a rural area is defined as an area outside of a community with a population of 5000 persons or more.

3.1.36.1 *Discussion*—If an agency’s political definition differs from this definition of rural, the exception must be documented.

3.1.37 *seasonal factor*, *n*—a summarized short-term count adjustment for variability by period of year, which can be based on monthly, weekly or daily factors when estimating typical annual traffic characteristics.

3.1.37.1 *Discussion*—An alternative to defining seasonal factors as months or weeks is to use edit-accepted data variability during the year. This alternative may result in separate seasons for traffic volume, vehicle classification, and weight.

3.1.38 *thirtieth highest hour*, *n*—for all edit-accepted hours of data during a one-year period, the thirtieth highest hourly traffic volume; this volume is commonly used as a representative hour of traffic volume in roadway design.

3.1.39 *traffic volume*, *n*—the number of motorized highway vehicles with two or more axles passing a point on a roadway in a unit of time.

3.1.40 *urban area*, *n*—individual agencies may have a political boundary definition of urban, which would be the

definition for traffic-monitoring purposes; in the absence of such an individual agency definition, an urban area is defined as a community with a population of 5000 persons or more.

3.1.41 *validation count*, *n*—measurement of traffic characteristics for acceptance testing of a separate traffic measurement on the same road segment.

3.1.42 *vehicle classification*, *n*—the identification, summarization and reporting of traffic volume by vehicle configuration.

3.1.43 *vehicle miles traveled*, (VMT), *n*—average Sunday through Saturday vehicle movement on a specific road segment multiplied by the length of the road segment, reported in the form of daily and annual VMT; this statistic is also referred to as “vehicle miles of travel.”

3.1.44 *weekday traffic factor*, *n*—the relationship of MAWDT to MADT and MAWET, from permanent counters, used to adjust short-term weekday counts to MADT and MAWET.

3.1.44.1 *Discussion*—In operational classification this short-term count adjustment factor may be based on the relationship of periods of time other than day, week, and month.

3.1.45 *weigh in-motion*, (WIM), *n*—the process of estimating a moving vehicle’s gross weight and the portion of that weight that is carried by each wheel, axle, or axle group, or combination thereof, by measurement and analysis of dynamic vehicle tire forces. (See Specification E 1318.)

## 4. Summary of Practices

4.1 Traffic-monitoring practice constitutes the collection, summarization, and reporting of traffic volume, vehicle classification, and vehicle weight.

## 5. Significance and Use

5.1 This practice addresses both short-term and long-term measurement of traffic characteristics, using either portable or permanent measurement and recording devices. Where mechanical or electronic devices cannot be used for traffic volume and classification, manual procedures are described. It provides a reference for improving traffic-monitoring practice by governmental agencies and private firms.

5.2 Traffic monitoring is important in the safe and efficient movement of people and goods. The purpose of this standard is to help ensure that traffic-monitoring procedures produce traffic data and summary statistics which are adequate to satisfy diverse and critical traffic needs.

## 6. Measurement and Summarization Procedures

6.1 General measurement and summarization procedures in traffic monitoring are related to traffic volume, vehicle classification, and weight.

6.1.1 *Traffic volume*—Traffic monitoring includes measuring and recording traffic volume.

6.1.1.1 Traffic volume is in part monitored by permanent traffic recording devices operated on a continuous basis.

6.1.1.2 Traffic volume is also in part monitored by portable counters operated on a short-term basis on a given road segment. Traffic counts are for all traffic on a road segment and may include traffic direction and lane use. Short-term mechanical volume measurement on non-interstate rural roads will

have a planned duration of 48 consecutive hours of data reported from each short-term count site. Short-term mechanical volume measurement on non-interstate urban roads will have a planned duration of 24 consecutive hours of data reported from each short-term count site. On both rural and urban roads, if portable equipment fails with less than 24 complete and edit-accepted hours of data collection, retake the count. This count duration includes screenline or cordon counts, and project or research site specific applications. The date associated with the traffic count is the first calendar day during which there are 24 hourly edit-accepted traffic measurements; or, in the absence of 24 hourly traffic measurements during one calendar day, the calendar day with the most consecutive edit-accepted hours of data. If there are 48 consecutive hours of data, divide the sum of hourly measurements by two to provide the unadjusted 24-h volume. If there is a minimum of 24 consecutive hours of data, but less than 48 h, use the first 24 consecutive hours of edited-accepted data as the unadjusted 24-h volume.

6.1.1.3 Count traffic volume on urban and rural interstate roads and interchange ramps for a minimum of 48 consecutive hours. Interchange ramps which are considered as influenced by upstream or downstream ramps, as opposed to isolated ramps, should be counted in the same 48 h period, and minimally shall be counted within the same seasonal adjustment period. Interstate interchange traffic volume monitoring may include analysis of traffic on the contiguous upstream and downstream interstate road segments. If traffic counts were taken on the contiguous interstate segments in the same or prior year, no additional measurement activity is required. If no traffic counts were taken on the contiguous upstream and downstream interstate segments, it is recommended that interchange traffic monitoring include counts on the interstate road segments. If traffic volume counts are taken on the interstate road segments, the counts shall be a minimum of 48 h, with notation of days of week counted, conducted in the same seasonal adjustment period as the interchange ramp monitoring.

6.1.2 *Vehicle Classification* is another type of traffic monitoring. Vehicle classification mechanical measurement shall be based on, or capable of direct translation to, the Federal Highway Administration thirteen vehicle classifications.<sup>4</sup>

6.1.2.1 Measure continuous vehicle classification by permanent counters which collect vehicle classification data at a specific point on a road segment. The devices record the number of axles per vehicle, and store individual records or records aggregated by classification within a discrete time period. Maintain all records by lane. Permanent traffic recorder installations may combine periodic measurement of total volume, with periodic measurement of vehicle classification. This reduces the quantity of data collected by primary measurement of traffic volume, while sampling the classification of vehicles comprising the traffic stream. The period of classification sampling should be based on an estimate of seasonality of vehicle composition in the traffic stream. In the absence of

site-specific measurement of seasonality, it is recommended that a minimum of one week of vehicle classification data be collected during each quarter over the period of one year.

6.1.2.2 Short-term mechanical classification measurement on non-interstate rural roads shall have a planned duration of 48 consecutive hours of data reported from each short-term monitoring site. Short-term mechanical classification measurement on non-interstate urban roads shall have a planned duration of 24 consecutive hours of data reported from each short-term count site. In both rural and urban areas, if portable equipment fails with less than 24 complete, consecutive hours of data collection, retake the count. This standard includes screenline or cordon counts, and project or research site specific applications.

6.1.2.3 Count vehicle classification on urban and rural interstate roads and interchange ramps for a minimum of 48 consecutive hours. If interchange ramps are considered influenced by upstream or downstream ramps, as opposed to isolated ramps, the ramps should be counted in the same 48 h period, and minimally shall be counted within the same seasonal adjustment period. Interstate interchange vehicle classification traffic monitoring may include analysis of traffic on the contiguous upstream and downstream interstate road segments. If traffic counts were taken on the contiguous interstate segments in the same or prior year, no additional measurement activity is required. If no traffic counts were taken on the contiguous upstream and downstream interstate segments, it is recommended that interchange traffic monitoring include counts on the interstate road segments. If vehicle classification counts are taken on the interstate road segments, the counts shall be a minimum of 48 h, weekday counts, conducted in the same seasonal adjustment period as the interchange ramp monitoring.

6.1.2.4 Manual vehicle classification may be taken at intersections where manual classification is not practical. In manual counts of turning movements at urban intersections, Federal Highway Administration classifications are preferred, but the measurement may be aggregated by passenger cars and trucks, in which trucks are commercial vehicles with Gross Vehicle Weights typically 1.5 tons and heavier. Monitor interstate interchange ramp/street junctions by the same traffic-monitoring procedures identified for intersections. Short-term manual measurements at intersections shall include turning movements. Conduct the counts within a given day, or between two consecutive weekdays, Monday through Thursday. The minimum fixed measurement periods will be from 0700 to 1000 and 1500 to 1800. This provides two traffic monitoring periods during the day, each of a 3-h duration, for a total of 6 h of data collection. A flexible intersection count period may be defined based on observed peak traffic observations. The typical morning and evening peak hours may each be defined, using 15-min intervals rather than the clock hour. One hour before and one hour after the anticipated peak hour may be defined. This results in two traffic-monitoring periods during the day, each of a 3-h duration, for a total of 6 h of data collection. At urban intersections an additional third peak period around the noon hour may be monitored. The third fixed time period shall be from 1100 to 1400; and if selected, the

<sup>4</sup> *Traffic Monitoring Guide*, June 1985, U.S. Department of Transportation, Federal Highway Administration, Office of Highway Planning, Washington, DC 20590.

flexible monitoring period shall include 1 h before and after the observed noon peak. If the flexible 6- or 9-h period is selected, take a 48 h mechanical classification count during the same hours as the intersection count.

6.1.2.5 Short-term manual classification measurements may be made on urban street segments when mechanical measurements cannot be accurately taken. Typically the restriction relates to vehicle queues across lanes of travel. The urban road segment manual count activity shall follow one of two count periods, designed to collect classification data manually when vehicle speed is most restricted. The two manual count periods shall be the same as identified for intersection turning movement counts as described in 6.1.2.4. This results in either two or three traffic-monitoring periods during the day, each of a 3-h duration, for a total of 6 or 9 h of data collection.

6.1.3 *Vehicle Weighing* is a type of traffic monitoring based on the measurement of axle loads.

6.1.3.1 Permanent highway weigh-in-motion (WIM) systems shall record axle load, axle group load, and gross vehicle weight. These devices shall report the data either as individual records, or as records aggregated by hour or portion of an hour. Counters should be selected which record weight data by lane.

6.1.3.2 Short-term vehicle weighing shall have a minimum duration of 48 consecutive hours.

6.2 *Traffic Monitoring Data Summarization Procedures* will be consistently applied to all unedited-base data.

6.2.1 Unedited-base data (see 3.1.10) that are missing or edit-rejected shall not be completed, filled-in, or replaced for any type of traffic measurement, at any location. Calculate traffic-summary statistics from edit-accepted base datasets. The computational method selected should be based upon edit-accepted measurements.

6.2.2 It is recommended that the calendar year be used as the traffic monitoring yearly cycle, and therefore as the basis of all reported annual traffic summary statistics. Annual traffic summary statistic computation may be based on other periods, such as federal and state fiscal year. Clearly state the basis for the annual statistic in all summary-statistic reports.

6.2.3 All traffic measurements taken in an urban area must have a maximum data summarization period of 15 min. For some applications the urban traffic measurements may be summarized and reported by hour. All measurements taken in a rural area must have a maximum data summarization period of 1 h.

6.2.4 Devices at permanent-count sites should be polled on a 24 h basis to ensure data collection and device maintenance.

6.2.5 Measure traffic data at locations within road segments which facilitate accurate measurement.

6.2.5.1 When monitoring on road segments for which there is not full access control, measurements shall be located to measure traffic at a specific point projected across all lanes of travel. On road segments for which there is full access control, measurements may be made for a given direction, at any point within the unique road segment, but shall include all lanes of travel.

6.2.5.2 Locate short-term, portable counts at the site for which the count has been requested and for which the base data will be summarized and reported. Base location at the site of

short-term counts in rural areas on equipment tie-down for security. For counts on urban road segments near intersections, the location should be sufficiently distant from the intersection to diminish queuing of vehicles at the measurement site.

6.2.5.3 Randomly select road segments for short-term traffic counts system-level analyses.

6.2.6 The same traffic-summary statistics should be relatively consistent within a road segment. If two values of the same traffic summary statistic within a road segment have a difference which exceeds their combined confidence interval, an average segment summary statistic should not be reported. If a combined summary statistic is not appropriate for reporting, separate summary statistics should be reported for the different traffic monitoring locations within the road segment.

6.3 The following method should be used to calculate site specific traffic summary statistics from permanent counter data.

6.3.1 Calculate traffic monthly average days of the week (MADW) as the sum of all edit-accepted daily volumes of each day, Sunday through Saturday, in a month divided by the number of days of edit-accepted data of that day in the month. This produces an average traffic volume for each day of the week for that month. Next, calculate annual average days of the week (AADW) as the mean of MADWs for a year. This produces an annual traffic volume average for each day of the week. Next, calculate annual average daily traffic (AADT) in two steps: MADT is the sum of MADWs divided by the number of MADWs; and AADT is the sum of MADTs divided by the number of MADTs. Calculate annual average weekday traffic (AAWDT) in two steps: MAWDT is the sum of MADWs for Monday through Thursday divided by the number of MADWs for Monday through Thursday; and AAWDT is the sum of MAWDTs divided by the number of MAWDTs. Calculate annual average weekend traffic (AAWET) in two steps: MAWET is the sum of MADWs for Friday through Sunday divided by the number of MADWs for Friday through Sunday; and AAWET is the sum of MAWETs divided by the number of MAWETs.

6.3.1.1 Friday traffic data may be included in AAWDT or AAWET calculations based on the variability of the data. Based on the variability of traffic, Friday data may be grouped with weekday rather than weekend traffic for permanent traffic devices which are grouped by functional, operational, or other roadway classification. If included in weekday calculations, this alternative inclusion of Friday data will be reported to data users with the mean statistics.

6.3.2 Permanent traffic recorder data may be included in computing mean statistics by same functionally, operationally, or other classified roads. The minimum requirement for an included counter is one day of edit-accepted measurements for each day of the week, for all twelve months in the reporting year.

6.3.3 If a permanent counter is excluded from the computation of mean traffic characteristics by functional or operational classification of roadway, site-specific summary statistics should include the quantity of edit-accepted base data (see 3.1.10) from which the summary statistics were calculated.

6.4 For short-term traffic measurements in which 48 consecutive hour counts were successfully taken, the total 48 h

traffic volume divided by 2 equals the 24 h base count statistic. For short-term traffic measurements in which between 24 and 47 h of edit-accepted data were collected, average the same, or duplicate hours during the second 24-h period and do not adjust the hours not duplicated. This results in a 24-h base count statistic. When reporting summary statistics from less than 48 consecutive hours of traffic monitoring, state the number of hours of edit-accepted data.

6.4.1 The entire 48-h count should fall in either the weekday period (0000 Monday to 2400 Thursday) or the weekend period (0000 Saturday to 2400 Sunday). For specific applications alternative short-term count periods may be adopted for inclusion of Monday morning in the weekend count period, or Friday morning in the weekday count period, or both. These alternative data collection periods shall not be applied for permanent counters. Permanent counter data, however, should be used to analyze the impact of either or both alternatives on traffic-summary statistics.

6.4.1.1 The inclusion of Monday morning in the weekend count period must be on the basis of site-specific determination that the traffic characteristic being measured varies with weekend rather than weekday traffic. Because the analysis is specific to road segments, the Monday morning hours included in the weekend period may vary from site-to-site. The alternative, site-specific period of weekend data collection must be documented with the summary statistics for each site.

6.4.1.2 The inclusion of Friday morning in the weekday count period may be based on efficiency of short-term count activities, and may be implemented for either a specific site or a road system. This alternative period of weekday data collection is weekday defined as the period from 0000 Monday to 1300 Friday, and weekend defined as 1301 Friday to 2400 Sunday. The time period must be documented with the summary statistics.

6.4.2 Short-term measurement activities designed to monitor weekend traffic for purposes related to estimating recreational-traffic characteristics should have data collection for the entire weekend period (0000 Saturday to 2400 Sunday).

6.4.3 Summarize all short-term counts used to estimate traffic summary statistics into base 24-h traffic volume, and then adjust for axle correction, weekday, season, and region. The adjustment shall not affect unedited base data integrity and retention.

6.4.3.1 Apply short-term count adjustment by axle correction factor to measurements from counters which measure only axle impulses. If a site-specific vehicle classification count was taken in the current or previous year, at the same site at which axle impulses are measured, use the classification count to calculate the axle correction factor to adjust axle impulses to vehicles. Derive axle correction factors for road segment measurements where vehicle classification counts were not taken in the current or previous year, as follows: (1) On rural roads with a minimum number of permanent counters on the same functional classification or roadways with similar traffic characteristics, use the mean axle correction factor from permanent vehicle classification and weighing counters. The accepted minimum is five permanent classification and weighing counters in the same functional classification or on road-

ways with similar traffic characteristics. (2) On rural roads with an inadequate sample of grouped permanent classification and weighing counters, the axle correction factor shall be the mean short-term vehicle classification counts during the preceding year on the same functionally classified roads, or on roadways with similar traffic characteristics. (3) On urban roads with an inadequate sample of grouped permanent classification and weighing counters, the axle correction factor shall be the mean of combined short-term manual and mechanical vehicle classification counts in the preceding year, from the same functional classification or roadways with similar traffic characteristics. Duplicate or validation counts are not included in the manual and mechanical short-term counts from which axle correction factors are calculated.

6.4.3.2 Weekday traffic factors may be used to adjust summary statistics from a traffic count which was taken during the period Monday through Thursday (or an alternative weekday data collection period) to represent traffic for all days of the week, the weekend, or both. Short-term counts taken during the period Monday through Thursday provide an estimate of MAWDT. For each short-term count the weekday factors are adjustment of the MAWDT to both MADT and MAWET. Weekday traffic factors may be calculated from permanent counter data from same functionally classified roads or roadways with similar traffic characteristics. The factors may be expected to vary by season. Short-term count MAWDT, MADT, and MAWET summary statistics may next be adjusted by seasonal factor to estimate annual traffic summary statistics. Prior to applying mean daily, weekly, monthly or seasonal adjustment factors the variability of the mean adjustment factor should be carefully examined.

6.4.3.3 Short-term counts used to estimate traffic-summary statistics may be adjusted for seasonality of the traffic characteristic being measured. The seasonal adjustment factors should be calculated as the mean monthly traffic ratio among same roadways with the same functional classification, among roadways with similar traffic characteristics, or from mean-traffic ratios grouped on the basis of operational classification of permanent-counter sites. If operational classification is used to calculate seasonal adjustment factors, provide the methodology to the data user along with the adjustment factors. Seasonal adjustment factors, whether from functional or operational classification, or other grouping, may be based on other than mean summary statistics. If other than the mean statistic is used, label the statistic and the methodology reported to the data user.

6.4.3.4 Regional correction factors may be developed using cluster analysis or other procedures to group traffic measurements. If developed, report the computational method and regional correction factor to the data user with the summary statistics.

6.4.3.5 Annual growth factors should be used to adjust a previous year's standard compliant count summary statistics, for those road segments not recounted after a one-year period. Road segments for which summary statistics are based on non-standard counts introduce problems related to data obsolescence, and these sites should be counted under standard practice rather than adjusted by annual growth factor. Annual

growth factors should be used only for three consecutive years, but may be used for a maximum of five consecutive years before the site is recounted. Summary statistics based on annual growth factors must be labeled and reported with the year of the last site specific standard count, and the method of annual growth factor calculation. Calculate an annual growth factor as the mean permanent counter annual traffic volume growth rate by functional classification or by roadways with similar traffic characteristics; or, the mean permanent counter annual traffic volume growth rate by operational classification.

6.5 For computation of thirtieth-highest hour and related highway demand design hours, compile a list of the highest hourly volumes from edit-accepted days of traffic volume measurements at permanent counters.

6.6 Summarize permanent vehicle classification measurements on the same basis as permanent counter traffic volume data. Summarize short-term vehicle classification measurements on the same basis as short-term traffic volume measurement.

6.6.1 Identify unclassified vehicles from mechanical vehicle classification counts as unclassified in vehicle classification reports.

6.6.2 Calculate monthly classification ratios, (MCRs). Calculate the MCR at each permanent classification site. Calculate MCR by vehicle classification and by functional classification of road or roads with similar traffic characteristics. MCRs may be used for seasonal adjustment of short-term vehicle classification counts. The alternative computations for MTRs may be made for MCRs, and shall be documented for the data user.

6.7 Summarize permanent counter vehicle weighing on the same basis as permanent counter traffic volume and vehicle classification data. Summarize short-term vehicle weighing on the same basis as short-term traffic volume and vehicle classification data.

6.7.1 Use the data from automatic vehicle weighing to calculate monthly weight ratios (MWRs). The weight data should be reviewed to determine if weight data can be grouped among sites. The analysis may include vehicle classification axle load distribution and gross vehicle weight by functional classification or roads with similar traffic characteristics, seasonal variation, and region. Following analysis of grouped weight data, MWRs may be used for seasonal adjustment of short-term WIM counts.

6.7.2 Axle loads should be calculated on the basis of equivalent single axle loadings (ESALs), derived from the AASHO (now AASHTO) Road Test data, using Road Test design equations.<sup>5</sup> Report the ESALs computation with assumed pavement characteristics, such as pavement type and Structural Number or thickness. Alternative equivalent axle computations may be made, with labeling and documentation of the method and comparison of results with ESALs computations.

6.8 Calculate daily vehicle miles traveled (DVMT) for each road segment by multiplying the length of each unique road segment by annual average daily traffic. Calculate a report of

DVMT for a system of road segments based on the summed DVMT for all individual road segments in the road system. Calculate annual vehicle miles traveled (AVMT) for each road segment by multiplying the daily vehicle miles traveled (DVMT) by 365, or 366 in leap years. Calculate a report of AVMT for a system of road segments based on the summed AVMT for all individual road segments in the road system.

## 7. Traffic Monitoring Edit Procedure

7.1 Not all measurements are accurate. Therefore, the following edits shall be implemented by traffic-monitoring agencies to screen measurements for appropriate summary statistic computation. If the measurements are found to be unacceptable for summary-statistic computation, other measurements must be made and similarly tested. Depending on the quantity of traffic measurements to be edited, the agency may find it helpful to automate measurement edits.

7.2 Permanent counter measurement edits are appropriate for vehicle volume, classification and weight traffic monitoring.

7.2.1 The permanent counter polling software shall include verification of the microcomputer date and time. Verify the internal clock before time corrections. If the clock on the permanent counter exceeds  $\pm 10$  min of the verified counter clock, then exclude all data for that day from summarization and reporting. If the clock on the permanent counter is less than  $\pm 10$  min, but greater than  $\pm 5$  min of the verified computer clock, issue a warning and adjust the time on the field clock.

7.2.2 If data from a permanent counter cannot be collected because of transmission error, complete data fields with nulls (or blanks), not zeros, and display a message that no data transmission occurred.

7.2.3 Successive same-volume measurements at specific thresholds indicate error. When the same recorded traffic volume, other than zero, occurs at a permanent counter for four successive hours, display an error message, and do not include the day's data when computing site traffic summary statistics. When 8 h of recorded successive zeros occur at a permanent counter in a non-repeated pattern, display an error message and do not include the day's data when computing site traffic summary statistics. Identification of a repeated pattern should be based on pattern recognition by type of permanent counter and by site. It may be based on consecutive zeros for 6 of the same 8 h, in a different day during the same seasonal adjustment period in the prior year.

NOTE 1—This practice requires a minimum of one complete year of standard practice in permanent counter polling prior to definition and automated implementation of a non-repeated pattern.

7.2.4 Specific thresholds of directional distribution of traffic-volume measurements, over the period of one day, by site, indicate measurement error. If the daily directional total volume at a permanent counter is within the range of 60 to 80 % of the total traffic for that day, display a data and counter review message. If a daily directional total volume at a permanent counter exceeds 80 % of the total traffic for that day, store the data in a separate file and do not include when computing site traffic summary statistics.

7.2.5 Summed measurement comparisons can indicate

<sup>5</sup> AASHTO *Guide for Design of Pavement Structure*, 1986, American Association of State Highway and Transportation Officials, 444 N. Capitol St. N.W., Washington, DC, 20001.

equipment measurement error. In order to derive representative MADW volumes, when the daily traffic volume for a given day of the week in a month exceeds  $\pm 2$  standard deviations from the mean volume for that day in the month, it may be considered an outlier and the mean volume may be recalculated excluding the outlier. The variability may be assessed based on the current year MADW, the prior year MADW, the three-year average MADW, or by individual and successive steps, in combination thereof.

7.3 There are edits associated with short-term traffic measurement. Traffic volume edits include turning movement volumes at urban intersections. Turning movement volume, and percent heavy commercial traffic, manually collected for intersections and ramp/street junctures should be compared with validation counts. Manual counts should be accepted as standard data based on validation by comparison with mechanical counts taken during the same seasonal adjustment period. For validation of manual data there should be less than a 10 % difference in total axle sensing between the mechanical volume axle count and axles calculated from manual vehicle classification. It is recommended that the mechanical count be taken in the same hours as the manual count.

7.4 Vehicle classification measurements may not provide consistent interpretation of axle impulses for classification at specific speeds of vehicles. Delete data collected at speeds below or above equipment tolerances from computation of summary statistics. Vehicle classification manual counts should be accepted as standard data based on validation by mechanical volume count. For acceptance of manual data, at those sites where mechanical equipment can operate within required operating tolerances, there should be less than a 10 % difference in total axle sensing between the mechanical measurement and axles calculated from manual vehicle classification. To ensure effective quality control, the validation count should be during the same hours as the manual measurement.

7.5 Weigh-in-motion devices do not always provide consistent, accurate measurement of axle load, axle-group load, and gross-vehicle weight when the monitored vehicle's speed is above or below equipment speed tolerances. Do not include weight data for vehicles outside speed tolerances of WIM measuring devices when computing load distribution by vehicle classification. Weight and load data for vehicles outside the speed range of WIM measuring devices shall be rejected for summary-statistic calculation, but the measurements may be used in volume and vehicle classification summary-statistic computation if the speed range of the equipment allows for these measurements.

7.5.1 Weigh-in-motion systems may require that vehicles travel in specific wheelpaths or singly occupy weighing transducers. Reject weights obtained when these conditions are not met for summary-statistic calculation. The measurements may be used in volume and classification summary-statistic computation if requirements for count and classification are met.

7.5.2 WIM data which have negative weights and axle spacings will be edit-rejected, and will not be included in vehicle weight summary statistics.

## 8. Data Retention Procedure

8.1 Retain traffic monitoring measurements and summary

statistics at a minimum for the periods defined. The unedited base data (see 3.1.10) retention period for traffic measurements is defined by measurement application and type of measurement. Both edit-accepted measurements and edit-rejected measurements should be retained for the period recommended. Use edit-accepted measurements for initial and subsequent computation of summary statistics. Edit-rejected measurements may be used for further traffic monitoring research and development.

8.2 Define data retention for site specific traffic measurements for those research projects which do not include the development of a traffic database, in relation to the term of the project. Retain traffic measurements related to these research projects for a minimum of five years beyond the term of the project. For research projects which include the development of a traffic database, permanently retain the data. Also permanently retain database structure information required for access to and use of the unedited base data.

8.2.1 The retention period for site specific traffic measurements for highway project design is based on the period from project data collection to the beginning of construction. A typical period is two years for all traffic measurements.

8.2.2 The retention period for site specific traffic measurements for other than project design or research applications is based on the current level of understanding of each traffic measurement, and the related likelihood of change in summary-statistic calculation. The retention period by type of measurement shall be: traffic volume measurement, two years; vehicle classification measurement, three years; and, axle weight measurement, five years.

8.3 System-level sample traffic measurements representing the history of random samples collected for the purpose of assessing traffic characteristics on a road network, should be permanently retained.

8.4 The calculated summary statistics from traffic measurements shall be permanently maintained by the agency calculating the summary statistic, and may also be retained by the responsible regulatory authority.

8.5 Validation counts shall be retained for the same period as the traffic count being validated.

8.6 In addition to the traffic-monitoring measurements and summary statistics, the agency or agencies retaining the measurements and summary statistics shall, for the same period, retain supplemental information which shall include, but not be limited to, the count period, count type, and the method used to calculate the summary statistic. If calculated, statements of confidence level and interval shall be retained with the summary statistics.

## 9. Report

9.1 Publish and make available methods for calculating summary statistics to recipients of traffic reports. Note tabular reports in compliance with standard practice at the beginning of the report. Reports with summary statistics not in compliance with standard practice should describe all methodological exceptions.

9.1.1 The minimum information provided with traffic volume and classification summary statistics shall be the label of the statistic, a description of the count activity underlying the



statistic, and the precision and bias associated with the count activity.

9.1.2 The minimum information provided with traffic ES-ALs information shall be the same as provided for volume and classification, as stated in 9.1.1, and shall include assumed pavement characteristics.

9.1.3 The minimum information provided with system or functional classification Daily or Annual Vehicle Miles Traveled shall be the label of the statistic and the percent of Daily or Annual Vehicle Miles Traveled based on standard and non-standard traffic volume counts.

9.2 Traffic monitoring shall employ common data formats in electronic databases to facilitate data exchange. The common data formats are detailed in Annex A1 of the Annex. Vehicle weight data shall be stored in the weigh-in-motion format.<sup>4</sup>

9.3 For short-term traffic measurements, follow the same data format as permanent counts, with the following exceptions. For volume and vehicle classification submit a record for each day included in the short-term count. For weight measurement submit a truck weight record for each vehicle. This may be minimally on an individual vehicle basis for those vehicles having a classification of bus, a two-axle, six-wheel truck or truck with a larger number of axles. In this minimum case, records of classification of passenger car, motorcycle, or other two-axle, four-wheel truck may be aggregated by discrete time period.

9.4 Traffic reporting by traffic flow maps, whether prepared manually or through a geographic information system, shall not employ smoothing or other summary statistic adjustment techniques other than those specified in these standards.

9.4.1 Traffic flow maps shall designate traffic volumes in two ways: (1) summary statistics, noting that the summary statistic reported is in compliance with standard practice; or,

(2) other designation, such as a number in brackets [], denoting the summary statistic reported is not based on standard practice.

9.4.2 Urban areas shall use annual average weekday traffic (AAWDT) as the traffic flow map summary statistic for all links on the map.

9.4.3 Rural areas shall use annual average daily traffic (AADT) as the traffic flow summary statistic for all links on the map.

## 10. Precision and Bias

10.1 In calculating precision of traffic summary statistics, the confidence level shall be 95 %. If multiple days of data exist for a site, the confidence interval should be calculated based on between-day variability. If multiple days data do not exist, the confidence interval may be estimated. The method of confidence interval calculation or estimate shall be reported with the confidence interval, and shall be retained with the confidence interval. The method for calculating the confidence interval shall be the method specified in the *Traffic Monitoring Guide*.<sup>4</sup>

10.2 Confidence intervals for permanent traffic counters shall be based on variability between complete days of edit-accepted data.

10.3 Confidence interval estimates may be made for short-term traffic characteristic measurements. The estimates should be based on characteristic distribution of short-term counts at permanent counters on roadways with the same functional or operational classification.

## 11. Keywords

11.1 traffic; traffic monitoring; traffic volume; vehicle classification; weigh-in-motion

## ANNEX

### (Mandatory Information)

#### A1. TRAFFIC MONITORING DATA FORMAT

A1.1 The traffic monitoring data format:

A1.1.1 The traffic monitoring data format for permanent and portable traffic measurement shall be capable of being transmitted as shown in Table A1.1.

A1.1.2 Vehicle classification data shall be capable of being transmitted in the following format (Table A1.2), based on the

13 classifications of vehicles, and with a classification for those vehicles which could not be grouped by vehicle classification.

A1.1.3 Vehicle weight data shall be capable of being transmitted as in Table A1.3 and Table A1.4.

**TABLE A1.1 Permanent Counter Data Submittal Format**

Columns	Field Length	Alpha/Numeric	Description
1	1	N	Record identification: 3 = ATR data
2 to 3	2	N	FIPS State Code (TMG 5-6-2) <sup>4</sup>
4 to 5	2	N	Functional classification (TMG 5-6-3)
6 to 11	6	A	Station identification number
12	1	N	Direction of travel (TMG 5-6-3)
13	1	N	Mainline lane of travel <sup>4</sup>
14 to 15	2	N	Year of data (last two digits)
16 to 17	2	N	Month of data (1 to 12)
18 to 19	2	N	Day of month of data (01 to 31)
20	1	N	Day of week <sup>5</sup>
21 to 25	5	N	Traffic volume counted, 00:01 to 01:00
26 to 30	5	N	Traffic volume counted, 01:01 to 02:00
...	...	...	...
136 to 140	5	N	Traffic volume counted, 23:01 to 24:00
141	1	N	Restrictions <sup>6</sup>

<sup>4</sup>Lane of travel is defined by the following codes for reporting purposes:

- 0 combined lanes
- 1 outside (rightmost) lane
- 2 next to outside lane
- 3 to 9 inside lane

<sup>5</sup>Days of week are defined by the following codes:

- 1 Sunday
- 2 Monday
- 3 Tuesday
- 4 Wednesday
- 5 Thursday
- 6 Friday
- 7 Saturday

<sup>6</sup>Restrictions in appropriate use of the data are defined by the following codes:

- 0 no restrictions
- 1 construction or other activity affected traffic flow

**TABLE A1.3 Vehicle Weight Data Format (Face Card: Max 5 Axles)**

Columns	Field Description	Valid Values
1	Record type code	must be "7"
2 to 3	State code	use FIPS code
4 to 5	Functional class	01, 02, 06 to 09, 11, 12, 14, 16, 17, 19
6 to 8	Station ID number	numeric or alpha (no blanks)
9	Direction	0 to 9
10 to 11	Year	must agree columns 4 to 5 No. 4 card
12 to 13	Month	01 to 12, compatible columns 14 to 15
14 to 15	Date	01 to 31, compatible columns 12 to 13
16 to 17	Hour of day	00 to 23
18 to 23	Vehicle type code	numeric
24 to 41	Blank or optional	no edit check
35	Lane code designator (SHRP)	numeric or blank
42 to 45	Total weight	in hundreds of pounds
46 to 48	A-axle weight	in hundreds of pounds
49 to 51	B-axle weight	in hundreds of pounds
52 to 54	C-axle weight	in hundreds of pounds
55 to 57	D-axle weight	in hundreds of pounds
58 to 60	D-axle weight	in hundreds of pounds
61 to 63	A-B axle spacing	in feet and tenths
64 to 66	B-C axle spacing	in feet and tenths
67 to 69	C-D axle spacing	in feet and tenths
70 to 72	D-E axle spacing	in feet and tenths
73 to 76	Total wheel base	in feet and tenths
77 to 79	Record serial number	
80	Continuation card indicator	0 indicates no continuation record 1 indicates continuation record

**TABLE A1.2 Vehicle Classification Data Format**

Columns	Field Description	Valid Values
1	Record type code	Must be "4"
2 to 3	State code	Use FIPS code
4 to 5	Functional class	01, 02, 06 to 09, 11, 12, 14, 16, 17, 19
6 to 8	Station ID number	numeric or alpha (no blanks)
9	Direction	0 to 9
10 to 11	Year	last two digits of data year
12 to 13	Month	01 to 12, compatible columns 14 to 15
14 to 15	Date	01 to 31, compatible columns 12 to 13
16 to 17	Hour of day	00 to 23
18 to 19	Motorcycle count	numeric
20 to 23	Passenger car count	numeric
24 to 26	2 axle 4 tire single unit	numeric
27 to 28	Buses	numeric
29 to 31	2 axle 6 tire single unit	numeric
32 to 33	3 axle single unit	numeric
34 to 35	4 + axle single unit	numeric
36 to 37	4- axle single trailer	numeric
38 to 40	5 axle single trailer	numeric
41 to 42	6 + axle single trailer	numeric
43 to 44	5- axle multiple trailer	numeric
45 to 46	6 axle multiple trailer	numeric
47 to 48	7 + axle multiple trailer	numeric
49	Motorcycle report indicator	0 indicates motorcycles are not reported 1 indicates motorcycles are reported compatible columns 18 to 19
50	Vehicle class combination indicator	0 indicates passenger cars and 2-axle 4-tire are reported separately 1 indicates passenger cars and 2-axle 4-tire are reported together compatible columns 24 to 26
51	Lane code designator (SHRP)	numeric or blank
51 to 80	Blank or optional	no edit check

**TABLE A1.4 Vehicle Weight Data Format: Continuation Card**

Columns	Field Description	Valid Values
1	Record type code	must be "7"
2 to 3	State code	use FIPS code
4 to 5	Functional class	01, 02, 06 to 09, 11, 12, 14, 16, 17, 19
6 to 8	Station ID number	numeric or alpha (no blanks)
9	Direction	0 to 9
10 to 11	Year	must agree columns 4 to 5 No. 4 card
12 to 13	Month	01 to 12, compatible columns 14 to 15
14 to 15	Date	01 to 31, compatible columns 12 to 13
16 to 17	Hour of day	00 to 23
18 to 23	Vehicle type code	numeric
24 to 28	Blank or optional	no edit check
29 to 31	F-axle weight	in hundreds of pounds
32 to 34	G-axle weight	in hundreds of pounds
35 to 37	H-axle weight	in hundreds of pounds
38 to 40	I-axle weight	in hundreds of pounds
41 to 43	J-axle weight	in hundreds of pounds
44 to 46	K-axle weight	in hundreds of pounds
47 to 49	L-axle weight	in hundreds of pounds
50 to 52	M-axle weight	in hundreds of pounds
53 to 55	E-F axle spacing	in feet and tenths
56 to 58	F-G axle spacing	in feet and tenths
59 to 61	G-H axle spacing	in feet and tenths
62 to 64	H-I axle spacing	in feet and tenths
65 to 67	I-J axle spacing	in feet and tenths
68 to 70	J-K axle spacing	in feet and tenths
71 to 73	K-L axle spacing	in feet and tenths
74 to 76	L-M axle spacing	in feet and tenths
77 to 79	Record serial number	match with face card
80	Continuation card indicator	codes 2 to 9 indicate sequential records, 2 being the first and 9 the last

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