LONG TERM PAVEMENT PERFORMANCE PROGRAM
PROTOCOL FOR CALIBRATING
TRAFFIC DATA COLLECTION EQUIPMENT

For the Technical Direction of the LTPP Program

Program Area: **Traffic Monitoring**

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Subject: **Traffic Data Collection Equipment Calibration**

This document describes the procedures that the Long Term Pavement Performance (LTPP) program recommends for ensuring that traffic data collection equipment used for LTPP traffic monitoring efforts operates correctly and collects valid data.

Recommendations are made for the following subject areas:

- Steps for checking equipment calibration.
- Quality control steps to be taken in the field.
- Quality control steps to be taken in the office.

The LTPP program acknowledges that weigh-in-motion (WIM) and automatic vehicle classification (AVC) are not mature technologies. As such, participating agency and site-specific conditions may legitimately warrant the use of procedures other than those presented below. In addition, LTPP recognizes that participating agencies use a variety of types of traffic data collection equipment and have different levels of available labor. Consequently, different participating agencies may prefer to use different methods for checking calibration and performing quality assurance checks on their data.

As a result, while LTPP strongly recommends the use of the following procedures, agencies may request permission to substitute alternative, equivalent procedures. When a participating agency wants to use an alternative technique, it should discuss the recommended alternative with its LTPP regional office (its Regional Contractor's Office Coordinator) prior to collecting data for submission to LTPP. As long as the participating agency can achieve the desired levels of accuracy and data reliability, the Regional Contractor's Office Coordinator should allow use of those alternatives when:

- LTPP procedures are unreasonable, given the specific equipment or staffing available to a participating agency.
- Site conditions at a given LTPP test section dictate changes to these procedures.
- The participating agency can show that an alternative procedure will yield better, more accurate traffic monitoring estimates at a test site.

This flexibility is intended to take advantage of professional experience within the participating agencies and to further encourage the collection of accurate, reliable traffic data at a cost that is acceptable to the participating agencies.

STEPS FOR CHECKING EQUIPMENT CALIBRATION[1]

Weigh-in-Motion

Each time a WIM scale will be used to collect data for the LTPP program, its calibration should be checked and, if necessary, revised. In addition, permanent WIM scales should have their calibration settings field-validated (and updated as necessary) at least twice per year, and their data should be monitored on a monthly basis to ensure that the scales remain calibrated. This calibration check must include both the weight and vehicle classification data produced by the equipment. In addition, the participating agency should monitor the performance of the equipment to ensure that the equipment is operating properly throughout the data collection effort. Data from an improperly functioning WIM device should not be sent to LTPP.

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[1] Additional information on calibration techniques can be found in the following references.

ASTM Standard E1318-94, Highway Weigh-in-Motion (WIM) Systems With User Requirements and Test Method, *Annual Book of ASTM Standards*.

Peter Davies and Fraser Sommerville, "Calibration and Accuracy Testing of Weigh-in-Motion Systems," *Transportation Research Record 1123, Pavement Management and Weigh-In-Motion*, 1987, pp. 122-126.

Bahman Izadmehr and Clyde Lee, "On-Site Calibration of Weigh-in-Motion Systems," *Transportation Research Record 1123*, *Pavement Management and Weigh-In-Motion*, 1987, pp. 136-144.

Bill McCall and Walter Vodrazka Jr., *State's Successful Practices Weigh-in-Motion Handbook,* December 15, 1997.

"On-Site Evaluation and Calibration Procedures for Weigh-in-Motion Systems," *NCHRP Research Results Digest#214*, 1996.

LTPP specifies the use of one of two scale calibration confirmation methods. To be accepted by LTPP, any alternative method must:

- Have a proven track record (i.e., its use must be backed up by documented evidence that it works effectively).

- Be actively employed (i.e., it must be routinely used at non-LTPP WIM sites as well as at LTPP sites).

- Include site-specific characteristics for each LTPP test site (e.g., before an average front axle weight can be used as part of a calibration check, an independent check of the front axle weights of the subject trucks at that site must be undertaken).

- Be performed multiple times per year, and always before the start of any short-duration data collection at a test site.

Where a weigh station is located upstream or downstream from the WIM site, the required LTPP calibration confirmation technique is as follows:

- Use the static scale[2] at the weigh station to measure trucks randomly selected from the traffic stream and then compare the various weights from those trucks with the WIM system measurements (a minimum of 150 trucks must be matched).

Where a weigh station is not located upstream or downstream from a test site, the following calibration confirmation mechanism is desired by LTPP:

- Use a minimum of two legally loaded[3] test trucks, one of which must be a 3S2[4] vehicle. The two vehicles must be either different configurations or at least different suspension types. The 3S2 vehicle must be loaded to between 72,000 lb and 80,000 lb (gross vehicle weight) and preferably have an air suspension system. A minimum of 40 passes must be made (20 for each vehicle—more runs are preferred). All test runs must be made at highway speeds. (If more loaded test vehicles are used, the number of passes each vehicle

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[2] These scales must meet the specifications that are found in *National Institute of Standards and Technology Handbook 44*, "Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices," U.S. Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD 20899.

[3] Prior to testing, determine the actual static axle weights of these vehicles, as loaded, on a scale that meets Handbook 44 standards. See footnote 2 for complete Handbook 44 citation.

[4] A 3S2 is a three-axle tractor pulling a conventional two-axle (tandem axle) semi-trailer.

makes can be reduced.) Three- or four-axle single-unit dump trucks should not be used for calibration checking.[5]

The participating agency must make sure the trucks' tires have a conventional highway tread pattern, not an off-road pattern, as the "knobby" tread can cause unusual sensor readings from some WIM systems.

WIM scales that will be used at LTPP test sites must be capable of estimating static weights within the tolerances listed in table 1.

These values can be computed by calculating the percentage difference in the static and dynamic weights of the vehicles used for the calibration check (either test trucks or trucks weighed at a nearby scale that meets law enforcement standards) and converting that error into percentage form. The standard deviation of that error can then be used to determine the 95 percent confidence limits.

Table 1.
WIM system calibration tolerances.[6]

SPS-1 and SPS-2 Sites	**95 Percent Confidence Limit**[7]
Loaded single axles	±20 percent
Loaded tandem axles	±15 percent
Gross vehicle weights	±10 percent
All Other Test Sites	
Loaded single axles	±30 percent
Loaded tandem axles	±20 percent
Gross vehicle weights	±15 percent

Note that some WIM systems require separate calibration factors for different vehicle speed ranges, temperatures, and/or gross vehicle weights. For systems that require multiple calibration constants, the calibration check must be repeated for each calibration step. The scale will not be

5 Conventional dump trucks tend to have unusual suspension characteristics. These characteristics result in inappropriate calibration settings. Therefore, they should not be used for most calibration efforts. Where these trucks make up the vast majority of heavy vehicles on a given roadway, it may be appropriate to use such a vehicle as one of the calibration trucks (along with the 3S2). If this is the case, consult with the RCOC before selecting vehicles to be used in the calibration check.

6 These tolerances are taken from ASTM Standard E1318-94.

7 If two vehicles with similar suspension characteristics are used for the calibration check, a properly operating scale should produce static weight estimates well within these limits. Using 150 trucks from the traffic stream on a roadway with a pavement surface in poor condition, it will be very difficult to meet these tolerances, because of the different dynamic motions of various trucks. For more on this subject, please see Clyde Lee, "Factors That Affect the Accuracy of WIM Systems," *Proceedings From the Third National Conference on Weigh-in-Motion*, 1988.

accepted by FHWA-LTPP until it is capable of operating correctly during all times of the year and under all environmental and traffic conditions that can reasonably be expected to occur during data collection operations. In addition, note that these calibration confirmation steps are minimums, which must be exceeded whenever a manufacturer's calibration instructions require additional effort.

When the system calibration has been confirmed, the data collected during the time that the scale is certain to be within calibration tolerances will be used to create an “expected loading pattern” for five-axle tractor semi-trailer gross vehicle weights (i.e., GVWs for 3S2 vehicles) at that site. At least 100 3S2s are needed to determine this pattern, which can be calculated with the LTPP quality control software.

Changes in this pattern, specifically movement in the location of the loaded or unloaded peaks in the GVW distribution, are a sign that scale calibration may have shifted. (See figure 1.) These observed changes are a preliminary indicator that the calibration at that site may be improper and that the site calibration factor requires confirmation or changing. A scale’s calibration must be validated (and potentially changed) whenever one of the following happens:

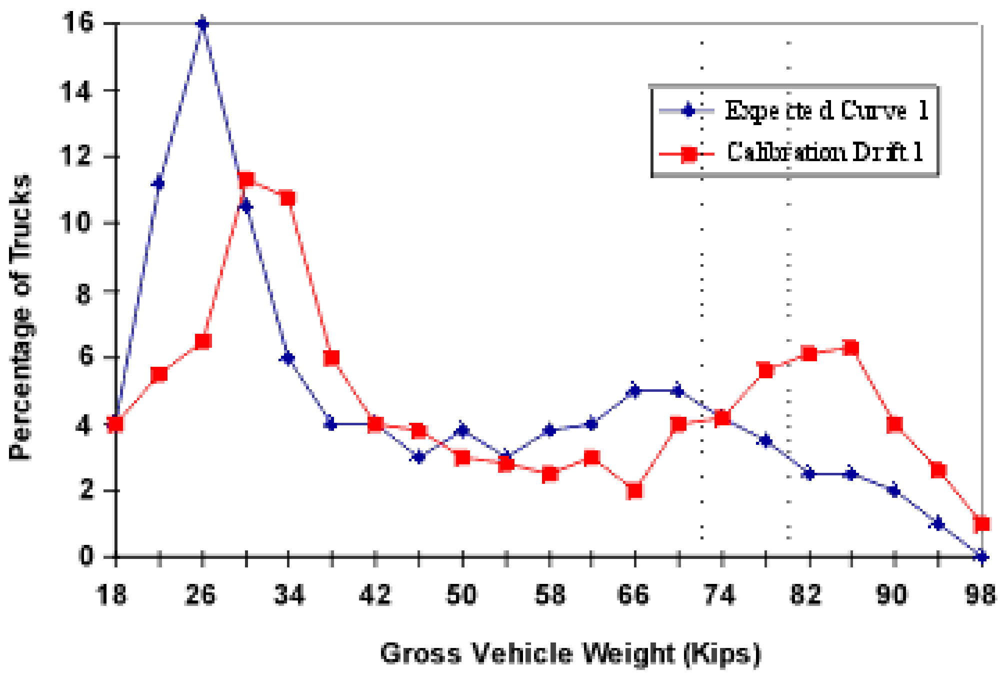

Figure 1. Calibration drift using GVW for five-axle tractor semi-trailer trucks.

- The unloaded peak in the quality control graph of the 3S2 GVW distribution shifts more than 4000 lb.

- The location of the loaded peak shifts 8000 lb or more.

- The location of the loaded peak exceeds the legal weight limit for 3S2 vehicles (unless previous calibration review efforts have shown that at this site, this result legitimately occurs).

If the field review of the current scale calibration setting shows that the scale is performing correctly (i.e., the GVW pattern for 3S2 trucks has, in fact, changed), then this new pattern can also be used in conjunction with the original GVW pattern to describe legitimate truck weight patterns that exist at the test site. If the participating agency has firm evidence (i.e., data collected immediately after successful calibration efforts have been completed) that a measured pattern is expected and is the result of normal traffic conditions at that site (e.g., the pattern represents an expected seasonal pattern), the scale does not have to be recalibrated, even when that pattern is different than the pattern most recently observed at the site.

The second part of the calibration review process is the examination of the effectiveness of the vehicle classification algorithm used by the WIM equipment. The procedures for this effort are the same as those described below for examination of the operation of automatic vehicle classification equipment. Each WIM system's classification algorithm only needs to be field-checked once. This calibration review involves extensive testing of the algorithm. However, the algorithm of each new shipment of WIM systems must be tested, since even minor changes in classification algorithms from one model of a manufacturer's WIM scale to another have been known to cause significantly different classification results. In addition, it is important to test the classification results of the WIM system against those produced by the State's automatic vehicle classification equipment to ensure that the results from these alternative devices are comparable.

Finally, for each LTPP WIM installation, the quality control checks described later in this document must be completed. These will confirm that the various algorithm parameters and sensor measurements are set correctly for each installation of equipment (i.e., the Automatic Vehicle Classification (AVC) algorithm can be calibrated once for each type of WIM equipment, but the calibration must be validated at <u>each site</u> through the quality control process described later in this document).

Automatic Vehicle Classification

WIM and AVC equipment use a series of inputs (usually including some combination of vehicle presence, number of axles, spacings between axles, and weight of those axles) to categorize vehicles into vehicle classes. The calibration review process does tests to ensure that the algorithm using these inputs correctly classifies the vehicles. Adjustments are then made to the algorithm until the output (vehicle volumes by classification) meets the acceptance criteria.

As with WIM equipment, each new set of automatic classification equipment <u>must</u> be field-tested (i.e., at least one device from each order, not each device) to ensure that the algorithm accurately classifies the State's vehicles, since different devices use different classification algorithms. In addition, several cases have been documented in which manufacturers accidentally shipped equipment with the wrong classification algorithm to a State.

Calibration checking involves collecting samples of classified vehicle counts and comparing them with independent measurements of the same classified vehicle counts. In most cases, the independent counts are performed either by hand or by collecting videotape and converting that tape to vehicle classification information. However, one calibrated, correctly functioning classification counter can be used to calibrate a second type or model of classifier. In fact, one very useful calibration test is to compare the output of AVC and WIM equipment with each other.

Two basic types of checks need to be performed to test a classifier's functioning — a review of the equipment's ability to classify specific types of vehicles and a comparison of aggregated classification device output with known control totals. The first of these checks allows the State to test whether the device correctly handles vehicles that have traditionally caused problems for classifiers. The second test reveals errors that are apparent only over a longer term data collection effort.

Many AVC counters have problems correctly differentiating specific vehicle types because the axle-spacing characteristics of these vehicle types are similar. Therefore, the calibration effort needs to review how well specific types of vehicles are classified. These vehicles include the following:

- Recreational vehicles.
- Passenger vehicles (and pick-ups) pulling light trailers.
- Long tractor semi-trailer combinations.

Other vehicle classifications can also be tested, given a State's experience with AVC equipment. These tests are accomplished by placing the counter on a roadway and observing the results of the classification process for individual vehicles crossing the test sensors. The location for this test must be selected carefully to ensure that all vehicle types are present and that the counter's ability to correctly classify those vehicles can be observed.

The second portion of this calibration test involves comparing a minimum of 24 hours of vehicle classification output from the device with records known to correctly measure those same 24 hours. (These records are normally collected from a series of manual counts, but they can also be obtained through other means.) Two analyses are then performed with the output of the classifier.

The first comparison examines the number of "unclassified" vehicles produced by the device. If this percentage is greater than 5 percent of the traffic stream, there is a strong possibility that either the time-out or vehicle-length threshold is set inappropriately. If either of these values is too large, it will allow multiple vehicles to be included in the same vehicle record, creating an axle pattern for that "vehicle" that falls outside of established parameters.

The second comparison examines the individual volume estimates for different vehicle classes for a given time period from the test equipment with the known “true” value. (Note that the clocks for the two devices must be set precisely for this comparison to be valid.) Significant differences in these two measurements mean that the classification algorithm parameters need to be adjusted and the equipment retested.

Areas that should be investigated include the following:

- The presence of a large number of motorcycles (Class 1) when few motorcycles were present.
- Overly large numbers of Class 8 (four-axle tractor semi-trailer or 2S2) vehicles.
- Significant differences in other vehicle classes.

A large number of invalid motorcycle counts usually mean that the time-out and/or the vehicle-length thresholds are set too low. This causes the last set of tandem axles on a semi-trailer to be treated as a separate vehicle. The short spacing between the tandem axles viewed by themselves tend to be classified as motorcycles. (Note that this error should also result in an under-counting of tractor semi-trailer trucks and an over-counting of single-unit trucks.)

An overly large value for Class 8 trucks usually means one of three things:

- Pairs of cars following closely are being recorded as trucks.
- Passenger vehicles pulling trailers are being classified as tractors pulling trailers.
- The axle sensors are routinely not recording one of the tandem axles on conventional five-axle tractor semi-trailer trucks.

Significant differences in other classes usually mean that either the axle sensors are not set as described in the classification algorithm’s parameter file, or that the algorithm itself is not accurately tuned to the axle characteristics of the State’s vehicle fleet. Remeasuring the sensor spacings and checking the parameter file will allow the user to determine whether the problems are due to equipment set-up or whether a different processing algorithm is needed.

Not all classification errors are significant. Differences in Class 2 (cars) and Class 3 (light-duty trucks) counts are not significant for LTPP purposes. (These differences may be important for other State analyses.) To be acceptable to LTPP, the differences between the manual (“true”) counts and equipment counts for vehicle categories 8, 9, and any other heavy-truck category that exceeds 20 percent of the total truck volume at the site, should not exceed 10 percent for any of those truck categories. In addition, during the calibration tests, the counter should not list more than 5 percent unclassified vehicles.

QUALITY CONTROL STEPS TO BE TAKEN IN THE FIELD

Quality control checks are similar to, but should not be confused with, calibration tests. Both require the comparison of a set of system outputs with independent measurements of "truth." Both are intended to allow a user to set, check, or refine parameters that allow a data collection device to operate correctly. Calibration efforts are comprehensive. Quality control checks are intended to allow the application of simple rules of thumb to quickly confirm that a data collection device is working as expected. Quality control is only meant to ensure that a properly calibrated piece of equipment is working as intended in a given field installation. Therefore, the quality control steps described below should be followed for all LTPP traffic data collection.

AVC Equipment and Data

The field quality control check should be performed at least twice for each portable data collection effort: once when the counter is set out and once when the counter is picked up. In addition, for longer "short-duration" counts (e.g., a week or longer), it is recommended that these steps be undertaken at least once during the middle of the count.

Using a laptop computer:

- Set the counter to record vehicle by vehicle or in raw mode, and observe the category assigned and the number of axles on each vehicle.

- Check the axle spacing on class 9 vehicles (three-axle tractor pulling a two-axle semi-trailer). The drive axles should be greater than 4.1 ft and less than 4.9 ft, and the trailer tandem axle's spacing should be greater than 3.8 ft and less than 4.9 ft unless the trailer tandem is a spread tandem. In this case, the tandem spacing could be up to approximately 8 ft apart (depending on State laws). If the spacing is consistently larger or smaller than the above, remeasure the road-tube spacing, then check the road-tube spacing setting in the recorder.

Manually checking the AVC unit:

- If the AVC counter can collect data on an individual truck's characteristics, perform the following checks. Observe the passing vehicles and how they are recorded by the AVC unit. Look for the unit's ability to correctly count the number of axles and measure the axle spacing of the vehicle. If the number of axles is correct and the axle spacing looks reasonable (e.g., a small car's axle spacing is near 9 feet; a 3S2's front axle spacing can vary from 9.9 ft to 13.0 ft, depending on the cab), then the equipment can be considered to be functioning correctly.

- Record any unusual events and describe how the counter handles them. Examples of unusual events include: unusual truck configurations, no motorcycles in the traffic stream, or a large number of light passenger vehicles pulling trailers being classified as heavy trucks.

After 20 to 30 vehicles have been checked and there is certainty that the number of axles and the axle spacings being recorded are accurate, then the device can be considered to be working properly. Reset the counter to record vehicles according to the 13 categories in 1-hour intervals.

Regardless of whether the counter can collect detailed data on specific trucks, perform the following:

Obtain either a 3-hour manual count or record 100 trucks (whichever comes later if the device will operate for more than 72 hours, or whichever comes first if a portable device is being used for a count of 72 hours or less). Under no circumstances should the count be for less than 1 full hour. Record vehicle volumes in hourly intervals. **It is critical that the watch is synchronized with the counter. It is very important that the manual count is started on the hour**. Starting the count early or late will produce bias in the comparisons.

For short-duration counts, a similar check of 1 hour's duration should be conducted at the end of the survey period to ensure that the counter is still operating correctly. In addition, whenever staff is sent to the site to check on the status and performance of the axle sensors, at least some minimal check of classifier performance is recommended. This manual count effort will provide the analysts with several observation points against which to verify the accuracy of the data recorded. Send the manual count with the field sheet and the collected data to the office.

While observing the operation of the counter, check to see whether class 1 (motorcycles) is significantly greater than the number of motorcycles actually observed. If motorcycles are being over-counted, check the time-out and/or the vehicle-length threshold value in the electronics. If this value is set too small, trailer tandems can be separated from the trucks and tractors pulling those trailers. Independent trailer tandems are usually assumed to be motorcycles by automatic classifiers with poorly adjusted vehicle-length thresholds. This will usually occur with tractors pulling long, two-axle semi-trailers. The trailer tandem will be recorded in category 1, and the truck or tractor pulling the trailer will be recorded in categories 2, 3, or 6, depending on its length and the number of axles present. Check the manufacturer's installation or set-up manual to determine how (and to what extent) to change the threshold value.

It is also important to examine (where possible) how well the device differentiates between vehicles from Classes 3, 5, and 6, as well as how it classifies passenger vehicles towing trailers. A poor selection of vehicle-length and axle-spacing criteria can lead to a significant interchange of vehicles between the various two-axle single-unit truck categories and the various passenger-vehicle categories. In addition, recreational vehicles can cause significant classification difficulties. If these types of vehicles are present, it is important to note whether they are being classified correctly, misclassified consistently, or are not being classified at all (i.e., reported as “unclassified” vehicles). Note that in some cases, it is not possible to accurately classify some vehicle types, given only axle count and axle spacing information. A careful calibration test will illustrate these classification program shortcomings. Where possible, States can then either adjust their classification algorithm or, if necessary, handle these problems within their normal analytical procedures.

Next, check the number of vehicles being included in the device’s “unclassified” category. If this percentage is greater than 5 percent of the traffic stream, there is a strong possibility that the time-out or vehicle-length threshold is set inappropriately. If this value is too large, it will allow multiple vehicles to be included in the same vehicle record, often creating an axle pattern for the “vehicle” that falls outside of established parameters.

For both of the previous types of errors, the following steps are recommended to ensure that these are correctly recorded in the equipment:

- Recheck the loop setting in the data collection equipment.
- Confirm the measurement of the distance between the loops and axle sensors.

If the loop distance from leading edge to leading edge or the distance between the axle sensors is wrong, then the axle spacings and speed estimated by the equipment will be wrong. This can cause vehicles to be either misclassified or placed in the “unclassified” category.

If more than 5 percent of the vehicles are unclassified, it is also possible that the road-tubes may not be tight, a hole may have developed in a road-tube, or the road surface may be too rutted. If one of the road-tubes crosses a shallow rut or hole, bouncing of the sensor may produce the appearance of an extra axle for that one tube. If this occurs, it may be necessary to place the counter in either a different location or use different axle sensors.

Should the error (the difference between the hourly manual counts and the AVC data) be greater than ± 5 percent for each of the primary vehicle categories, the road sensors and counter should be reset. In addition, the equipment should be checked for weak batteries, bad air switches, road tubes with holes in them, road tubes that are not matched in length, and other sensor failures.

Should the error be greater than ± 5 percent for each of the primary vehicle categories, the count should be retaken.

WIM Equipment and Data

Perform the field checks described in the previous section for AVC. Once it is determined that the WIM equipment can correctly count axles and classify vehicles, the following checks should be performed. (Note that some of these checks can be performed at the same time as the AVC checks.)

Observe the front axle and the drive tandem weights of class 9 trucks (3S2). The front axle should be in the range of 10,000 lb ± 2000 lb, regardless of whether the truck is loaded or empty (although the front axle of a loaded 3S2 is normally heavier than that of an unloaded 3S2). The drive tandems of a fully loaded truck and trailer should be around 33,000 lb ± 3000 lb. If the front axles are routinely less than 7000 lb, then check the calibration value of the WIM scale. It may be set wrong for the WIM system.

QUALITY CONTROL STEPS TO BE TAKEN IN THE OFFICE

AVC Data

Check the field sheet for comments concerning the traffic stream and special road conditions, as well as counter problems that occurred in the field.

Tabulate the manual counts, compare them with the AVC data for the same time and date, and calculate the absolute difference and percentage difference between the manual count and AVC data for each vehicle type.

Check class 1 (motorcycles) to see if it is greater than 5 percent of the total traffic. (While the field person checked the counter and observed the traffic stream, did he or she observe any motorcycles traveling on the roadway?) Large numbers of motorcycles (unless their presence is noted) usually means that trailers are being separated from tractors because the threshold for identifying a new vehicle is set too low. When the time or length between axle hits is greater than this preset threshold, the device sees the last axle hits as part of a following vehicle. The last tandem or the truck is then recorded as a motorcycle because of its short spacing.

If the data recorder reports “unclassified” vehicles, no more than 5 percent of the vehicles recorded should be in the “unclassified” categories. Unclassified vehicles are vehicles that do not fit any of the formulas used in determining the vehicle type. They may also be caused by errors in the axle sensing that have prevented the data collection equipment from measuring all of the appropriate axle pulses.

If more than 5 percent of the vehicles are unclassified, the road-tubes may not have been tight, a hole may have developed in the road-tube, or the road surface may have been rutted. If one of the road-tubes crosses a shallow rut or hole, the tube may bounce, producing the appearance of extra axles for that one tube. Piezo cable (and other sensor) devices can also generate extra “ghost signal” for a variety of reasons, including when the sensor is not securely held within the pavement, when extraneous pavement stresses are occurring (e.g., a piezo cable may pick up vibrations from the rocking of a neighboring concrete panel), and when the system electronics are providing feedback that registers as additional axle pulses. These ghost axles lead to a variety of classification and weighing errors.

Should the errors (the difference between the hourly manual counts and the AVC data) be greater than ± 5 percent for each of the primary vehicle categories, the count should be retaken. In addition, the equipment should be checked for weak batteries, bad air switches, road-tubes with holes in them, road-tubes that are not matched in length, and other sensor failures. These items should be checked and verified at the beginning of a survey.

Finally, if historical values are available, compare current truck percentages (by class) to historical percentages (by class) to determine whether unexpected changes in vehicle mix have occurred. In particular, look for interchange of vehicles that commonly occur as equipment begins to fail (e.g., transfer of Class 9 vehicles into Class 8 as axle sensors begin to have problems).

A summary comparing the manual counts and the AVC data should be prepared and sent to the regional LTPP offices.

WIM Data

This section describes the basic office procedure that LTPP recommends for performing a quick check to determine whether the calibration of a WIM scale is changing. It requires that the participating agency be able to produce a GVW histogram plot of Class 9 trucks (mostly 3S2 tractor semi-trailers). LTPP normally uses a 4000-lb increment for creating the histogram plot, but the participating agency may use any weight increment that meets its own needs.

The logic underlying this quality assurance process is based on the expectation of finding consistent peaks in the GVW distribution at each site. Most sites have two peaks in the GVW distribution. One represents unloaded tractor semi-trailers and should occur between 28,000 lb and 36,000 lb. This weight range has been determined from data collected from static scales around the country and appears to be reasonable for most locations. (Most, but not all, unloaded peaks fall between 28,000 lb and 32,000 lb.) The second peak in the GVW distribution represents the most common loaded vehicle condition at that site, and varies somewhat with the type of commodity commonly being carried on a given road and the weight limits for five-axle trucks. Generally, the loaded peak falls somewhere between 72,000 lb and 80,000 lb.

For most sites, the location of these peaks within the GVW histogram remains fairly constant, although the height of the two peaks changes somewhat over time as a result of changing volumes and/or percentages of loaded and unloaded vehicles (depending on whether the participating agency is plotting volume or percentage on the vertical axis, either will work). The reviewer must examine this distribution and decide whether the vehicle weights illustrated represent valid data, or whether the scale is either not correctly calibrated or is malfunctioning. This is easily done when the current graph can be compared with graphs produced from data collected <u>at that site</u> when the scale was known to have been operating correctly.

Both Peaks Shifted

If a plot shows both peaks have shifted from their expected location in the same direction (i.e., both peaks are lighter than expected or heavier than expected), the scale is probably out of calibration. The participating agency should then recalibrate that scale at that site and collect a new sample of data.

One Peak Shifted

If a plot shows one peak correctly located, but another peak has shifted from its expected location, the site should be reviewed for other potential scale problems (such as a high number of classified, but not weighed, vehicles or scale failure during the data collection session). Additional information on that site may also need to be obtained to determine whether the scale is operating correctly. Information that can be very useful in this investigation includes the types of commodities carried by Class 9 trucks using that road and the load distribution obtained from that scale when it was last calibrated. (For example, it might be discovered that a cement plant is just down the road from the WIM scale, and the loaded, five-axle cement trucks are routinely exceeding the 80,000-lb legal weight limit. This might result in acceptance of a loaded peak at that site that exceeds the normal 80,000-lb upper limit for the loaded peak.)

If additional information indicates the presence of scale problems, the data from the malfunctioning scale should not be submitted to LTPP. If there is no evidence of scale problems and State personnel believe that the data accurately reflect truck weights at that site, LTPP will accept the submitted data for use within the LTPP data base. The State should submit an explanation of why the data are valid, despite their appearance, so that LTPP researchers can be aware of the unusual truck characteristics at that site.

Number of Vehicles Heavier Than 80 kips

A second check performed with the Class 9 GVW graphic is an examination of the number (and/or percentage) of vehicles that are heavier than 80,000 lb. It is particularly important to look at the number and percentage of Class 9 vehicles that weigh more than 100 kips. If the percentage of overweight vehicles (particularly vehicles over 100,000 lb) is high, the scale calibration is questionable, although some States routinely allow these weights and thus would not question these results. (Note that this check must be done with knowledge of a specific State's weight and permitting laws, as well as knowledge of the types of commodities carried by trucks operating on that road.)

This check is performed partly because when many piezo-electric scales begin to fail, they generate an almost flat GVW distribution. This results in an extremely large (and inaccurate) equivalent single-axle load computation for a given number of trucks. It is also highly unusual for FHWA Class 9 trucks to carry such heavy loads. In most cases, trucks legally carrying these heavy weights are required to use additional axles, and they are thus classified as FHWA Class 10 (or higher) and do not appear in the Class 9 GVW graph. While illegally loaded five-axle trucks may be operating at the site in question, most illegally loaded trucks do not exceed the legal weight limit by more than several thousand pounds, and the number (or percentage) of these extremely high weights is usually fairly low. Thus, it is assumed that high percentages of extremely heavy Class 9 trucks are a sign of scale calibration or operational problems. (Again, if a participating agency routinely permits much higher loads to be carried on five-axle trucks, this check may not be useful.)

In either case (scale problems or extreme numbers of overloaded trucks), State personnel should investigate the situation. If the data are valid, they should be submitted to the LTPP data base along with an explanation of the investigation findings. Otherwise, the data should not be used by LTPP.

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