7. WEIGH-IN-MOTION ACCURACY AND QUALITY ASSURANCE RELATED TO PROBLEMS OCCURRING AT THE WIM SITE

Although weigh-in-motion (WIM) systems can provide massive amounts of valuable data in a relatively efficient manner, the data must be checked for accuracy. This accuracy check is a WIM user’s quality assurance (QA) program. A QA program adds confidence to the validity of the WIM data and alerts the data analyst to problems occurring at the WIM site. The purpose of a QA procedure is to help WIM users check data for accuracy and precision. A QA procedure conducted regularly will point out problems at the WIM site and help maintain the system throughout the site design life. The need for quality assurance prompted the development of software programs that could be used to validate data and point to problems occurring at the WIM site. These programs include the Long Term Pavement Performance (LTPP) QA software, the Vehicle TRavel Information System (VTRIS) and individual state software.

7.1 LONG TERM PAVEMENT PERFORMANCE PROCEDURE

This section is a brief description of the LTPP QA program. State agencies can use these same tests to help identify potential errors in any WIM data, whether or not it is intended for submission to the LTPP program, as long as those data are in a record format the LTPP QA Software can read (7). The LTPP QA Software automates these checks through a series of Statistical Analysis Software (SAS) programs. The SAS programs produce a number of output reports and graphs that require interpretation. Essentially, the LTPP software summarizes a data set in a series of simple graphs that can be used to identify “unusual occurrences” in the submitted traffic data. These “unusual occurrences” are examined to determine whether they are actually invalid data or rather the result of unusual traffic patterns or site malfunctions.

All graphs produced by the LTPP software are lane- and direction-specific. The software creates graphs for all lanes and directions for which data are submitted. The software automatically performs the following analyses and comparisons:

1. Gross Vehicle Weight Analysis
2. 7-Card Versus 4-Card Volume Comparison
3. 4- and 7-Card Vehicle Class Distribution Comparison
4. Cluster Analysis

7.2 VEHICLE TRAVEL INFORMATION SYSTEM SOFTWARE

The VTRIS software replaces the Truck Weight Software and uses the standards, formats, and methods specified by the Traffic Monitoring Guide (TMG), 1995 edition (15). VTRIS is a recommended, but not required, method to submit data to the Federal Highway Administration (FHWA) in a uniform format. The software validates, summarizes, and generates reports on vehicle travel characteristics by lane and by direction in the TMG format.
The VTRIS software develops and maintains a permanent database of the WIM data. The data are validated by VTRIS before inclusion into the VTRIS maintained database. The validation process can be adjusted for each station’s site characteristics and user defined parameters for axle spacings and axle weights. Errors detected by the software can be viewed to determine the type of error and whether or not to include the record in the database. The software also converts the WIM data to metric units, thus complying with the FHWA Metric Conversion Plan.

### 7.3 CALTRANS SUCCESSFUL PRACTICE: QUALITY ASSURANCE PROGRAM

While the LTPP and VTRIS quality assurance software are available to states upon request, individual states may prefer to develop their own QA program that better fits their specifications. These states can work either independently or with a vendor to produce a QA process and reports. The advantages of a state's personalized QA process lie in the ability of the state to meet its specific requirements.

The QA procedure developed by the California Department of Transportation (Caltrans) is discussed in the manual as a “successful practice” due in part to the 10-plus years experience they have using WIM data (16). During those learning years the state developed and used a QA procedure for validating data from the WIM systems they have installed. Although their procedure bears several similarities to the procedure used for the LTPP program, it is distinctly different in many respects. Therefore, it is a good example of an individual state's QA procedure formed separately from the LTPP program. Table 7.1 on the following page is a checklist of the quality assurance principles.

#### 7.1 Knowledge

“To properly diagnose, interpret, and validate data from a WIM System, the analyst must have knowledge of 1) the site’s physical characteristics, 2) traffic and truck behavior, and 3) the WIM System’s vehicle passage processing.” ... Caltrans.

The Caltrans QA process applies to bending plate systems and consists of four parts. Part 1 is called the “Knowledge of Site Characteristics” Review. Part 2 is called “Real Time” Review. Part 3 is called the First Level Data Review. Part 4 is called the Second Level Data Review.

The actual Data Validation process itself is preceded by two separate, non-validation processes, the “Knowledge of Site Characteristics” Review and the “Real Time” Review, which supplement the data validation procedure. The “Knowledge of Site Characteristics” Review generates a “site database” based on the physical and traffic characteristics of the site. The “site database” is used and updated throughout the QA procedure to help explain any data anomalies that may occur. The “Real Time” Review performs a spot check of the site’s performance. Four flowcharts, including descriptions of the main process events, are provided to aid in the discussion of the QA process developed and used by Caltrans.
### Table 7.1
#### Quality Assurance Principles Checklist

<table>
<thead>
<tr>
<th>Quality Assurance Principles</th>
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<tbody>
<tr>
<td>7.3</td>
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</tr>
<tr>
<td>7.3.5.2</td>
</tr>
<tr>
<td>7.3.5.3</td>
</tr>
</tbody>
</table>
The Caltrans Data Validation process consists of two levels of review. The First Level Data Review is intended to identify:

1. The extent of loop or loop processing problems
2. Any erratic weighpad behavior causing “ghost axles” or missed axles
3. Missing data from a particular lane(s) and the suspected causes

The First Level Data Review includes two steps. Step 1 consists of reviewing the First Level Data Review - Summary Report presenting daily classification and speed summary data. Step 2 consists of reviewing the First Level Data Review - Individual Truck Report presenting individual truck records. The contents and general formats of the reports provided by the vendor’s application software are as required by Caltrans’ specifications.

The Second Level Data Review is intended to identify and correct any site calibration problems, including:

1. Wheel weights
2. Axle Spacings (affected by speed)
3. Vehicle overall lengths

The Second Level Data Review consists of reviewing reports generated by Caltrans’ WIM system analysis program utilizing known relationships of Class 9 and Class 11 trucks and comparing the report data with the known truck operating characteristics for each WIM site.

One of the modifications Caltrans implemented in the FHWA vehicle classification system is the addition of two vehicle classifications. This change brings the total number of vehicle classifications to 15 instead of the 13 classifications recognized by FHWA. The changes to the vehicle classifications are described as follows:

1. Class 9 is a five-axle tractor-semi trailer
2. Class 14 is a five-axle truck trailer
3. Class 15 is for vehicles not meeting the axle configurations and/or weights set for classifications 1 through 14 and vehicles unclassified due to system error

The California 15 Class Scheme is converted to the FHWA 13 Class Scheme when the data are submitted to FHWA. The California classification scheme for Classes 3 through 15 only is shown in Table 7.2 for english units and Table 7.2 (a) for metric units. Class 1, motorcycles, and Class 2, passenger cars, are not included in the table since these classes are not relevant to the manual.

The Caltrans QA procedure discussed in this section is for WIM data in general. Slight modifications may need to be made to the QA procedure depending on the type of system installed and the reports generated by each vendor.
<table>
<thead>
<tr>
<th>Class</th>
<th>Vehicle Description</th>
<th>No. Axles</th>
<th>Axle Space Between Axle Numbers (feet)</th>
<th>Weight (kips)</th>
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<tr>
<td>3</td>
<td>Other (Limo, Van, RV)</td>
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<td>10-14.5</td>
<td>1.00 - 7.99</td>
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<tr>
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<td>Other w/ 1 axle trailer</td>
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<td>10-14.5 6.0-25</td>
<td>1.00 - 11.99</td>
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<td>Other w/ 2 AT</td>
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<td>10-14.5 6.0-25 1-11.99</td>
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<td>6.10-23 3.5-6.0</td>
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<tr>
<td>7</td>
<td>4 axle</td>
<td>4</td>
<td>6.10-23 3.5-6.0 3.5-13.0</td>
<td>&gt;</td>
</tr>
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<td>8</td>
<td>2S1, 2L</td>
<td>3</td>
<td>6.10-23 11-40</td>
<td>&gt;</td>
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<td>6.10-23 3.5-6.0 6.1-44.0</td>
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<tr>
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<td>6.10-23 11-44 3.5-11.99</td>
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</tr>
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<td>5</td>
<td>6.10-26 3.5-6.0 6.1-46.0 3.5-10</td>
<td>&gt;</td>
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<tr>
<td>10</td>
<td>3S3, 33</td>
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<tr>
<td>Class</td>
<td>Vehicle Description</td>
<td>No. Axles</td>
<td>Axle Space Between Axle Numbers (meters)</td>
<td>Weight (kg)</td>
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<td>3-4: 1.8-7.6</td>
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</tr>
<tr>
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<td>5450 - &gt;</td>
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<td>3</td>
<td>7-8: 1.1-1.8</td>
<td>5450 - &gt;</td>
</tr>
<tr>
<td>7</td>
<td>4 axle</td>
<td>4</td>
<td>8-9: 1.1-4.0</td>
<td>5450 - &gt;</td>
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<tr>
<td>8</td>
<td>2S1, 2L</td>
<td>3</td>
<td>1-2: 1.9-7.0</td>
<td>5450 - &gt;</td>
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<td>8</td>
<td>3S1, 3L</td>
<td>4</td>
<td>2-3: 3.4-12.2</td>
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<td>4</td>
<td>3-4: 1.9-7.0</td>
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<td>4-5: 1.9-14.0</td>
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<td>5-6: 0.03-3.4</td>
<td>5450 - &gt;</td>
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</tr>
<tr>
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<td>8</td>
<td>1-2: 1.9-13.7</td>
<td>5450 - &gt;</td>
</tr>
<tr>
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<td>Permit</td>
<td>9</td>
<td>2-3: 1.9-13.7</td>
<td>5450 - &gt;</td>
</tr>
<tr>
<td>14</td>
<td>32</td>
<td>5</td>
<td>3-4: 1.9-7.0</td>
<td>5450 - &gt;</td>
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<td>15</td>
<td>Unclassified and Errors - Vehicles not meeting axle configurations set for Classifications 1 thru 14 and &quot;error&quot; vehicles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.3.1 **“Knowledge of Site Characteristics” Review**

For each WIM site, there is an initial stage of preparation that begins at the time of installation, referred to as the Knowledge of Site Characteristics, described by the flowchart in Figure 7.1. The physical and truck traffic characteristics of the WIM site are observed and recorded by the Caltrans site review person during installation, on-site calibration, and acceptance testing of the WIM equipment. This information is placed in a “site database” to be used during the validation and analysis of downloaded data to help explain any data abnormalities. The “site database” is updated as additional information is identified.

7.3.1.1 **Purpose**

The Knowledge of Site Characteristics is used to develop a “site database” which is used during the validation and analysis of downloaded data to help explain any data abnormalities.

7.3.1.2 **Process 1**

The success of the Caltrans QA technique is strongly founded upon a base of knowledge about the WIM site's characteristics. The physical and truck traffic characteristics noted during this review include the following:

1. Physical characteristics of a site
   a. Pavement condition and profile
   b. Grade
   c. Traffic flow restrictions
   d. Weather, including wind
2. Truck traffic characteristics of a site
   a. Empty vs. loaded trends
   b. Seasonal variations
   c. Enforcement effects
   d. Unique vehicles
   e. Traffic operating characteristics

7.3.1.3 **Process 2**

These characteristics are placed in a “site database” to be used during the data validation and analysis process. The “site database” helps in the development of a “site profile” which the reviewer can use to explain data abnormalities. While there are no pre-printed forms for the “site database,” it exists as a file of notes, log sheets and pictures to aid the reviewer.

7.3.1.4 **Process 3**

Throughout the life of a site the “site database” should be reviewed, updated, and expanded whenever atypical traffic or physical site characteristics become apparent.
Figure 7.1 “Knowledge of Site Characteristics” Review Flowchart
7.3.2 “Real Time” Review

In addition to the two levels of data validation, Caltrans also accesses each site by modem and performs a quick spot check of each site's operation at least twice per month. This process is referred to as a “Real Time” Review and is shown in Figure 7.2. This “Real Time” Review is not actually a validation of data, but it can give an early indication of system problems and identify unusable data.

7.3.2.1 Purpose

The WIM system is monitored in “real time” via telemetry to get a “snapshot” of the site’s performance condition indicators, at that time. This method is also used to review the status of data files accumulated since the last file download.

7.3.2.2 Step 1

The files stored at the site are checked first for proper time, date, and sizes; “real time” traffic is then monitored for proper axle spacing. An example of the data displayed in the “Real Time” review is shown in Figure 7.3. This figure was taken directly from one of Caltrans’ WIM sites and therefore was not converted to metric. The file sizes vary greatly by site dependent upon traffic characteristics and the number of lanes.

Determine if the time, date, or file sizes are incorrect.

7.3.2.3 Step 2

Check the data files’ time and date stamps and sizes so to locate the day and time the site failed.

7.3.2.4 Step 3

If necessary, correct the system’s time and date.

Determine if the axle weights and spacings are correct.

7.3.2.5 Step 4

If the “real time” axle weights or spacings are found to be questionable, the system components (i.e.: loop signals, weigh pad signals, etc.) are checked. Problems with the system components may lead to actual physical repairs.
Determine if the system components are functioning properly.

7.3.2.6 Step 5

If the system components are not functioning properly, identify the equipment problem(s) and initiate corrective maintenance.

7.3.2.7 Step 6

If the “real time” axle weights or spacings are found to be questionable, the calibration parameters are also checked. A problem with calibration may lead to adjustments of the calibration parameters within the system software. These calibration parameters can be for axle weights, axle spacings, and vehicle overall length.

Determine if the calibration parameters are properly set.

7.3.2.8 Step 7

If the calibration parameters are not properly set, make the necessary adjustments.

7.3.2.9 Step 8

If any problem is found throughout the “Real Time” Review, the questionable data are identified for future analysis and appropriateness of use.
Figure 7.2 “Real Time” Review Flowchart
Figure 7.3 “Real Time” Review Example

Note: The axles are read from the right to the left, units are shown as they are in the field.
7.3.3 First Level Data Review - Summary Report

The procedure for the First Level Data Review - Summary is shown as a flowchart in Figure 7.4. In general, the first level is intended to identify any system equipment malfunctions, missing data, atypical traffic patterns, and atypical truck operating characteristics, by examining the reports shown in Figures 7.5 - 7.9. Included in the figures are examples of the results obtained from analyzing each report. The figures were obtained from Caltrans and were not converted to metric units. The information established for each site in the “site database” provides a foundation for this review.

Caltrans’ First Level Data Review - Summary is accomplished by examining reports that are generated using the WIM vendor's application software. The contents and general format of these reports are in accordance with the Caltrans’ specifications.

About 14 days of WIM data per month per site are downloaded to a host PC by modem. This is usually enough data to support planning and pavement design analysis, unless a special study or situation arises. The QA procedure is performed on at least seven days of data per month.

7.3.3.1 Purpose

The first process is to review information on the distribution of vehicle classifications by hour of day and the distribution of speeds by vehicle classification. This process is intended to identify:

1. The extent of loop or loop processing problems
2. Any erratic weighpad behavior causing “ghost axles” or missed axles

The second process is to review daily vehicle counts by hour of day by lane to identify any time periods in which the WIM system is not reporting data. This process also identifies the suspected causes of the lack of data. Both processes are done during this data review.

7.3.3.2 Process 1

Figure 7.5 is an example of the classification summary report. Specific counts that should be examined on this report are:

1. Class 1. Abnormally high Class 1 (motorcycle) counts are generally the result of erroneous low speeds and shortened axle spacings caused by loop errors.
2. Class 13. An obvious increase in Class 13 vehicles usually shows a problem of ghost axles being read by the weighpad.
3. Class 15. Unclassified vehicle counts greater than 0.5 percent are generally caused by loop errors.
Another explanation for an abnormally high Class 1 count would be if the loop drops out between the truck and the trailer, which might happen for logging trucks. This would cause the truck to be classified as a Class 5, three-axle truck and the trailer to be classified as a Class 1, motorcycle. One of the counts that should be examined that is not included in this example is the Class 8 counts. Class 8 counts may be abnormally high by missing or dropping one of the drive or trailer tandem axles. This can occur if the axle sensors do not stabilize in sufficient time to receive the second axle of a tandem.

Determine if the counts for Class 1, Class 13, or Class 15 are too high.

7.3.3.2.1  Step 1

If any of the classification counts are questionable, they then should be checked on a lane-by-lane basis. An example of this report is shown in Figure 7.6. Studying this report may quickly associate any problems with a specific lane.

7.3.3.2.2  Step 2

The speed distribution report, shown in Figure 7.7, should be reviewed when the Class 1 or Class 15 counts are too high. High and low speed errors are usually caused by loop malfunctions, which can affect the axle spacing used to classify vehicles.

Determine if the high counts occur all day or sporadically.

A further review of the classification report for specific lanes can give insight to the source of problems that might cause bad data. If the errors are present sporadically, the problem is probably a poor splice or terminal connection that is affected by moisture or temperature. If the errors are present continuously throughout the day, the problem is probably a malfunctioning loop board or bad connection. In both instances the equipment needs to be visually inspected and repaired. Figure 7.8 is an example of sporadic error readings.

7.3.3.2.3  Step 3

If there appears to be a high Class 13 count, the WIM system may be reporting “ghost” axles. A weighpad diagnostic needs to be performed to determine if the weighpad is functioning properly.

7.3.3.3  Process 2

After the classification and speed summary reports are examined for unusual counts of specific classes, a review of the vehicle counts by lane, shown in Figure 7.9, is done. The vehicle
counts report is used to reveal time periods in which the WIM system is not reporting data for a particular lane.

3 Determine if there are any times of the day when data are not recorded.

4 Determine if the data are missing from all lanes or from a single lane.

If the data are missing from all lanes it is probably due to a system failure such as a power outage. If the missing data are from a single lane it could be due to a lane closure for maintenance or a loop malfunction.

5 Determine if the vehicle counts in the adjacent lanes are higher than normal.

By looking at the lane distributions in the report, it can usually be determined if the lack of traffic data is simply due to traffic being shifted to an adjacent lane, as opposed to a system failure. If the vehicle counts in the adjacent lanes are higher than normal then the data are probably missing due to a lane closure for maintenance or construction. If the vehicle counts in the adjacent lanes are not higher, the missing data are probably due to a loop malfunction.
Figure 7.4 First Level Data Review - Summary Report Flowchart
Example Data Review:

- The percentage of Class 15 vehicles (10 percent) is too high (> 0.5%) for this site and indicates that one or more lanes are experiencing minor loop problems.

- The class 13 count is acceptable and indicates that there are no "ghost axle" problems.

- The Class 1 count is acceptable and indicates that loop problems are not "shortening" axle spacings.

- The Class 15 hourly distribution indicates that the "error" vehicles are distributed throughout the day and, as such, are probably not due to changes in temperature or moisture.

**Figure 7.5**
Distribution of Vehicle Classification by Hour of Day
Example Data Review:

- The circled numbers indicate that almost half of the Class 15 "errors" are in lane 1, whereas almost all of the speed "errors" are in lanes 2 and 3.

**Figure 7.6**
Distribution of Classification and Speed Counts by Lane
Example Data Review:
- The table represents all lanes.
- The speed distribution pattern in this report makes it apparent that most of the vehicles exceeding 95 MPH are "error" vehicles. Less than half of these errors, however, have resulted in axle spacings such that the vehicles are "unclassified."

Figure 7.7
Distribution of Speed by Vehicle Classification

Circled vehicles are, for the most part, "error" vehicles.
Example Data Review:

- This report is the same as the report in Figure 7.5, but only for lane 1.

- By reviewing report, it is apparent that between the hours 1500 and 1700 either a loop or the processing of loop inputs was malfunctioning. Since counts for all the classifications are erroneous for this time period, the data for this lane would be usable only for vehicle counts purposes.

Figure 7.8
Distribution of Vehicle Classifications
By Hour of Day
Example Data Review:

- Data is missing from Lane 4: all other lanes appear to have normal data.

- In reviewing the Lane 3 and Lane 4 distributions it is apparent that the "0" counts in Lane 4 are not due to traffic shifts to Lane 3. Therefore, the lack of data could be due to a loop malfunction.

**Figure 7.9**

Distribution of Vehicle Counts by Hour of Day by Lane
7.3.4 First Level Data Review - Individual Truck Report

The procedure for the First Level Data Review - Individual Truck Report is shown in Figure 7.10. In general, this procedure is intended to identify any system equipment malfunctions, missing data, atypical traffic patterns, or atypical truck operating characteristics by examining the reports shown in Figure 7.11 and 7.12. Included in the figures are examples of the results obtained from analyzing each report. The information established for each site in the “site database” provides a foundation for this review.

7.3.4.1 Purpose

The next data review is conducted on the distribution of weight violations and invalid measurements report, displayed in Figure 7.11. This report covers truck information for all lanes. The truck record data should also be checked on a lane-by-lane basis, as displayed in Figure 7.12. The review of these reports is intended to identify:

1. Any classification problems due to a loop or loop processing malfunction
2. A bad weighpad
3. Any obvious calibration problem
4. Truck operation patterns

Any vehicle with a steering axle exceeding 3500 pounds (Classes 4-15) is included in these individual vehicle records.

7.3.4.2 Process

The First Level Data Review - Individual Truck Reports is completed by reviewing the distribution of weight violations and invalid measurements report (Figure 7.11) and the distribution of truck data by lane report (Figure 7.12). In general, these “truck” reports should be studied for a high number of unclassified (Class 15) counts, invalid measurement counts, and percent of overweight vehicles.

Determine if a high number of Class 15 counts are recorded.

For most California WIM sites, an unclassified count not exceeding four percent is acceptable. It is important to note that the unclassified count will generally increase on weekends when many of the more “typical” trucks, conforming to the Vehicle Classification Table in Table 7.2, are not running and a higher number of recreational vehicles (“Heavy” Class 3) are on the road.
Determine if there is a high number of invalid measurements.

When the difference between the left and right wheel weights of an axle exceed 40 percent, the measurement for that vehicle is classified as invalid. An imbalance that large may be caused by the following:

1. A truck changing lanes or not driving in the middle of the lane
2. Bouncing, usually by empty trailers
3. Empty van trailers in heavy cross winds
4. An extremely bad weighpad calibration factor
5. A malfunctioning weighpad

Determine if the truck traffic characteristics from the “site database” explains the high number of invalid counts.

Caltrans has performed extensive data analyses to determine at which WIM sites bouncing and cross winds cause a high percentage of invalid measurements and to what extent the two factors affect the invalid measurements. Once again the “site database” is useful in determining the cause for the invalid measurements. Caltrans also requires that the WIM on-site software be programmable from the host PC to modify the algorithm that determines invalid measurements. If the extent of invalid measurements is still suspicious after reviewing the site characteristics, a check should be made on the weighpad calibration parameters and, if necessary, the weighpads.

Determine if there is a high percentage of overweight vehicles.

The percent of overweight vehicles may be used as a check of system calibration. However, the percentage of overweights can vary greatly, depending upon the WIM site, the time of year, and the truck traffic characteristics. If the “site database” does not explain the high percentage of overweight trucks a check should be made of the weighpad calibration parameters. Also, the actual percentage of overweight trucks, if the trucks were weighed statically, may be approximately half the WIM-reported overweights. Some reasons for this are as follows:

1. Many trucks travel very close to their maximum legal weight; the slightest overage read of the static weight by the WIM system will result in a violation count.
2. Although a well-calibrated WIM system may produce good average gross weights, plus or minus three percent of the actual average gross weight, a violation count due to a slightly high reading will be recorded.
3. There is generally some weight transfer from the steer axle to the drive axle for most of the heavier trucks, particularly if there is any uphill grade, which could be recorded as a violation due to heavier drive axles.

4. The weight violation look-up tables do not account for certain exceptions, particularly for the steering axle.

It is important to review the total counts and distributions by class shown in the weight violations and invalid measurements report (Figure 7.11). Doing so will provide additional information about the site characteristics, specifically seasonal variations in truck traffic due to agricultural and industrial shipping.

As the analyses of the reports covered under the First Level Data Review - Summary Report (Figures 7.5 - 7.9) and - Individual Truck Report (Figures 7.11 - 7.12) are performed, certain key elements are entered into log sheets along with any annotations deemed necessary. Figure 7.13 is an example of a log sheet prepared during the analysis of the classification and speed summary reports (Figure 7.6). These log sheets serve three basic purposes:

1. They show what data are available and what data have been validated.
2. They show any exceptions to otherwise "valid" data and show any warnings, if appropriate, as to the use of the data for general or specific use.
3. They track trends of site characteristics which may be added to the “site database.” Therefore, the trends may be checked quickly by the reviewer for comparison reasons in future data analysis.

When data are requested, the logs may be used as “guides” for determining whether or not available data are suitable for the intended use. Since data from a particular lane may be questionable or invalid, the log sheets are used to quickly determine what data can be used from that WIM site. Since a portion of the questionable or invalid records may still be used in research, Caltrans rarely discards WIM data.
Figure 7.10 First Level Data Review - Individual Truck Report Flowchart
Example Data Review:
- This review is for all lanes.
- Considering that this is "truck" only data, the 2.3 percent unclassified is below the allowable 4.0 percent and indicates that there is no major problem with classification.
- The eight data errors for speed (out of range errors) is below the allowable 0.1 percent and indicates that there are no major loop problems.
- The 4.0 percent of "invalid measurement" trucks is acceptable for an overall review (4.0 percent is the maximum).
- This report shows almost 3000 Class 11's, which is twice the average for this site. These additional trucks are seasonal tomato haulers.
- By understanding the way overweight vehicles are recorded, the percent vehicles overweight in this report is considered high and the calibration parameters should be reviewed.
- Since the operating characteristics of the seasonal tomato haulers are well known, these trucks are used to check the WIM systems calibration.

**Figure 7.11**
Distribution of Weight Violations and Invalid Measurements for Vehicle Classes 4-15
Example Data Review:

- In that only a small percentage of trucks use the inside ("fast") lanes at this site (Lanes 2 and 3 on this report), the malfunctioning loop or weighpad from one of these lanes might not be evident in reviewing the "combined lanes" report shown in the Figure 7.11.

- It is noted that the invalid percentages for Lanes 2 and 3 are quite high, but these higher percentages are common for the "fast" lanes due to trucks crossing the lane lines to pass.

Figure 7.12
Distribution of Truck Record Data by Lane
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<th>Date</th>
<th>Day</th>
<th>Hourly Periods</th>
<th>No. Vehicles</th>
<th>No. Cl. 2</th>
<th>Speed Check</th>
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Figure 7.13 Sample Log Sheet
7.3.5 Second Level Data Review

Typically, the Second Level Data Review, shown in Figure 7.14, is performed on one day’s accumulation of individual vehicle records data per month per WIM system. If such review causes calibration parameter changes, an immediate follow-up review is normally performed to verify the results of such changes.

The Second Level Data Review reports, shown in Figures 7.15 - 7.18, are generated using the Caltrans WIM System Analysis program. The figures were obtained from Caltrans and were not converted to metric units. This program, written in the C++ programming language, was developed after several years of importing vehicle record data into a database program. This information was then analyzed to determine the relationships between Class 9 and Class 11 trucks as well as the relationships between speed and weight based upon observation at the WIM sites. The program can also provide statistical information on California's Class 14 vehicles.

7.3.5.1 Purpose

The Second Level Data Review is conducted to determine if adjustments are needed in the calibration parameters for the weighpads or the loops. This review may also disclose or lead to the disclosure of equipment idiosyncrasies or malfunctions not noted in the First Level Data Review.

7.3.5.2 Process 1

The review of the distribution of gross weight by lane report, shown in Figures 7.15 and 7.16, allows the analyst to evaluate gross weight relationships. Although the WIM vendor's application software is required to generate gross weight distribution reports, the Caltrans program displays the distributions for each lane in a single report and displays additional statistical data.

The usefulness of this report in analyzing whether or not a WIM system is properly calibrated for weight is dependent upon several site and truck characteristic factors, including:

1. How well the empty and loaded truck weight groups are distributed
2. How consistently the system reports accurate static weight predictions for different types of vehicles
3. The proportionality of the WIM weight accuracies in the lower and higher weight ranges

Determine if the empty and loaded truck weights are properly distributed.
If not, determine if the truck traffic characteristics explain the atypical data.

If the truck traffic characteristics do not explain the atypical data there is probably a problem with a calibration parameter.

### 7.3.5.3 Process 2

The weight and axle spacings by speed report, Figure 7.17 and 7.18, provides various data and relationships for weight, speed, axle spacings, and vehicle lengths for each lane.

Determine if the Class 9 average tractor tandem axle spacings and the Class 11 average vehicle lengths are accurate.

Checking the accuracy of axle spacings and overall vehicle lengths gives an indication of problems with the calibration parameters for speed and spacing. Caltrans has determined that the Class 9 tractor tandem axle space should average 1.3 meters (4.3 feet) and the average length for a Class 11 vehicle should be approximately 1.5 meters (5 feet) longer than the average wheelbase.

Determine if the left and right average steer axles weights balance for Class 9 and 11 vehicles.

When the report shows different values for the weights reported by the left and right weighpads of each lane, it is an indication of a malfunctioning weighpad or the need to adjust the calibration factor for one or both of the weighpads. The average left and right steer axle weights should be the same.

Determine if the weights over different speeds are consistent.

In reviewing the distribution of average weights by speed, the average gross weights should be consistent for different speed ranges, provided there is a large number of samples and all trucks are able to operate at a “cruising” speed. Any significant differences in the average gross weight through different speed ranges would indicate that the calibration parameters may need adjustment for certain speed ranges. A review of the most recent test truck calibration documentation on speed versus weight might be helpful in analyzing the speed versus weight report.
Certain key elements and comments of the Second Level Data Review process are entered onto a log sheet. A log sheet is a valuable tool in several respects, including:

1. Identifying the effects of calibration parameter changes on the WIM data for weight, axle spacings, and vehicle length
2. Establishing weight trends over a long period of time, including seasonal variations; by collecting site-to-site comparisons the analyst can determine whether any seasonal variations are due to differences in truck operating characteristics (such as hauling heavy produce in the summer) or to the effect of temperature on the weighpads’ reporting weight
3. Determining whether or not WIM weights “drift” over a period of time
4. Monitoring any changes in axle spacings or vehicle lengths which may indicate problems with loops.

The log information is added to the “site database,” so that the information may be reviewed at a future time.
Figure 7.14 Second Level Data Review Flowchart
Example Data Review:
- A review of this report allows an analyst to evaluate empty and loaded gross weight relationships.
- This report has well-defined empty and loaded distributions for both Class 9 and Class 11 trucks in both truck lanes (1 and 4).
- Many of the Class 11's in this report are seasonal tomato trucks which travel empty (26,000 lbs. + or -) in Lanes 1 and 2 and fully loaded in Lanes 3 and 4. Being that there is a weigh station between the tomato fields and the WIM site, counts exceeding 80,000 lbs. should be minimal, as is reflected in this report.
- Figure 7.16 displays a report of the kind in this figure, but is more difficult to analyze.

Figure 7.15
Distribution of Gross Weight by Lane
Example Data Review:

- In Lane 1 of the Class 9 report, the empties distribution is poorly defined, and there are too many trucks exceeding 80,000 lbs.

- In Lane 1 of the Class 11 report, over half of the trucks are seasonally tomato trucks which travel empty in Lanes 1 and 2 and loaded in Lanes 3 and 4. Although the empties distribution may be a bit light, the loaded distribution appears to be too heavy.

- In Lane 4 of the Class 9 report, the empties distribution is better defined than in Lane 1, but there are still too many loaded trucks exceeding 80,000 lbs.

- In Lane 4 of the Class 11 report, there are too few empties to make judgement; the loaded tomato trucks are well defined in terms of distribution, but too many exceeding 80,000 lbs.

- What makes the analysis difficult is the high number of trucks exceeding 80,000 lbs. In that much of the truck traffic at this site is short haul and there is no weigh station nearby, it is possible that many or most of the reported trucks exceeding 80,000 lbs. are valid. Another factor to consider is this was one of California’s initial WIM systems and there was no pavement preparation at the site.

Figure 7.16
Distribution of Gross Weight by Lane
Example Data Review:

- This report specifically displays Lane 4 data for the same vehicles that were displayed in the Figure 7.15 report.

- The Class 9 tractor tandem axle space averages 4.3 ft., which indicates that the parameter for determining speed and axle spacings is correct at this site.

- The Class 11 average vehicle length of 66.1 ft. is roughly five feet longer than the average wheelbase: the parameter for determining overall vehicle length is good.

- The left and right average steer axle weights match each other for both Class 9 and 11 trucks and the standard deviations show that 68% of the steer axle weights will be close to the average weight.

- The average weights in the "Vehicle Groove" column are consistent for the different speed ranges for which there are large numbers of samples; the calibration seems to be fine.

- For comparison, note another report of this type in the Figure 7.18.

Figure 7.17
Distribution of Average Weights and Spacings by Speed
Example Data Review:

- Lane 4 of this WIM system is on a long uphill grade and the heavier trucks travel at lower speeds than the lighter trucks. This is an example of the reviewer needing to know the traffic and truck characteristics for each specific site in order to make the correct analysis.

- The spacing of the tractor tandem axles reads 4.2, but it should be 4.3. This shows that there may be a problem with the calibration parameters.

Figure 7.18
Distribution of Average Weights and Spacings by Speed

7-36