# WIM System Field Calibration and Validation Summary Report

Washington SPS-2
SHRP ID – 530200

Validation Date: March 29, 2011
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# 1 Executive Summary

A WIM validation was performed on March 29 and 30, 2011 at the Washington SPS-2 site located on route US-395 at milepost 93.0, 3.1 miles south of Interstate 90.

This site was installed on March, 1998. The in-road sensors are installed in the northbound lane. The site is equipped with quartz WIM sensors and IRD 1068 WIM controller. The LTPP lane is identified as lane 1 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on April 23, 2008 and this validation visit, it appears that changes to the speed compensation factors have occurred during this time.

The equipment is in working order. Electronic and electrical checks of the WIM components determined that the the equipment is operating within the manufacturer's tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, there were no pavement distresses were noted that may affect the accuracies of the WIM system. A visual observation of the trucks as they approach, traverse, and leave the sensor area did not indicate any adverse dynamics that would affect the accuracy of the WIM system. The trucks appear to track down the center of the lane. Further pavement condition discussion is provided in Section 4.

Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is providing research quality loading data. The summary results of the validation are provided in Table 1-1 below.

**Table 1-1 – Post-Validation Results – 30-Mar-11**

| Parameter | 95% Confidence Limit of Error | Site Values | Pass/Fail |
|---|---|---|---|
| Steering Axles | ±20 percent | -0.4 ± 14.2% | Pass |
| Tandem Axles | ±15 percent | 1.4 ± 9.5% | Pass |
| GVW | ±10 percent | 1.0 ± 7.6% | Pass |
| Vehicle Length | ±3.0 percent (2.0 ft) | 0.1 ± 1.1 ft | Pass |
| Axle Length | ± 0.5 ft [150mm] | 0.0 ± 0.2 ft | Pass |

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was -0.4 ± 2.6 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 1.2% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 8.0% from the 100 truck sample (Class 4 – 13) was due to the seven cross-classifications of Class 3, 4, 5, and 8 vehicles.

There were two test trucks used for the post-validation. They were configured and loaded as follows:

- The *Primary* truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with concrete blocks.

- The *Secondary* truck was a Class 9 vehicle with air suspension on the tractor tandem, air suspension on the trailer tandem, standard tandem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with concrete blocks.

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 7). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Axle spacings were measured from the center hub of the each axle to the center hub of the subsequent axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average post-validation test truck weights and measurements are provided in Table 1-2.

**Table 1-2 – Post-Validation Test Truck Measurements**

| Test Truck | Weights (kips) | | | | | | Spacings (feet) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GVW | Ax1 | Ax2 | Ax3 | Ax4 | Ax5 | 1-2 | 2-3 | 3-4 | 4-5 | AL | OL |
| 1 | 69.7 | 10.4 | 14.1 | 14.1 | 15.6 | 15.6 | 12.8 | 4.3 | 33.7 | 4.2 | 55.0 | 68.5 |
| 2 | 50.6 | 10.4 | 10.5 | 10.5 | 9.6 | 9.6 | 12.8 | 4.3 | 34.0 | 4.0 | 55.1 | 67.8 |

The posted speed limit at the site is 60 mph. During the testing, the speed of the test trucks ranged from to 47 to 60 mph, a variance of 13 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 54.2 to 65.3 degrees Fahrenheit, a range of 11.1 degrees Fahrenheit. The cloudy weather conditions prevented attaining the desired 30 degree range in pavement temperatures.

A review of the LTPP Standard Release Database 24 shows that there are 24 consecutive months of level "E" WIM data for this site. This site requires at least 3 additional years of data to meet the minimum of five years of research quality data.

# 2 WIM System Data Availability and Pre-Visit Data Analysis

To assess the quality of the current traffic data, a pre-visit analysis was conducted by comparing a two-week data sample from August 18, 2010 (Data) to the most recent Comparison Data Set (CDS) from May 01, 2008. The assessments performed prior to the site visits are used to develop reasonable expectations for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

## 2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 24 shows that there are two years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2006 to 2009.

**Table 2-1 – LTPP Data Availability**

| Year | Total Number of Days in Year | Number of Months |
|---|---|---|
| 2006 | 31 | 1 |
| 2007 | 365 | 12 |
| 2008 | 343 | 12 |
| 2009 | 149 | 5 |

As shown in the table, this site requires three additional years of data to meet the minimum of five years of research quality data. The 2006 and 2009 data does not meet the 210-day minimum requirement for a calendar year.

Table 2-2 provides a monthly breakdown of the available data for years 2006 through 2009.

**Table 2-2 – LTPP Data Availability by Month**

| YEAR | Month | | | | | | | | | | | | No. of Months |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| 2006 | | | | | | | | | | | | 31 | 1 |
| 2007 | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 12 |
| 2008 | 31 | 29 | 31 | 30 | 31 | 24 | 24 | 31 | 30 | 21 | 30 | 31 | 12 |
| 2009 | 31 | 28 | 30 | 29 | 31 | | | | | | | | 5 |

## 2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site. Figure 2-1 provides a comparison of the truck type distributions for the two datasets.

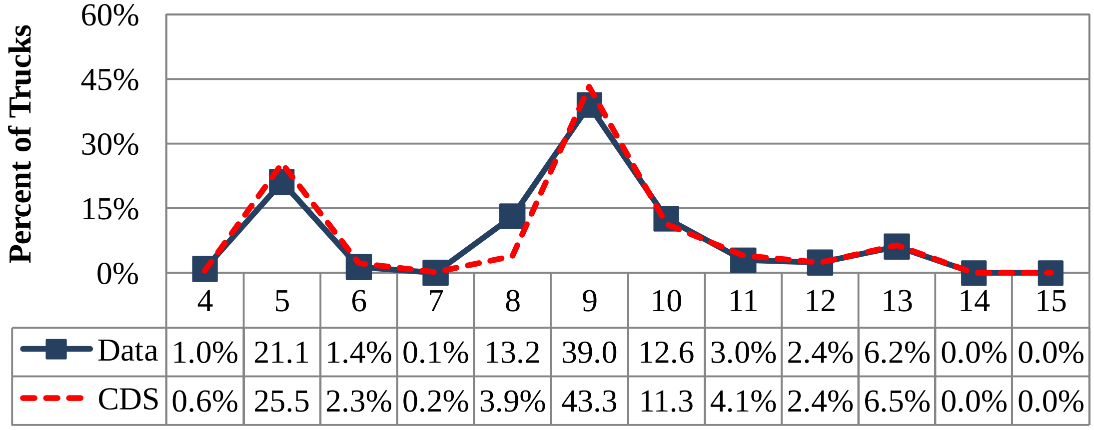



**Figure 2-1 – Comparison of Truck Distribution**

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the most frequent truck types crossing the WIM scale are Class 9 (39.0%) and Class 5 (21.1%). Table 2-3 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles. The table indicates that 0.0 percent of the vehicles at this site are unclassified.

**Table 2-3 – Truck Distribution from W-Card**

| Vehicle Classification | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 5/1/2008 | | 8/18/2010 | | |
| 4 | 176 | 0.6% | 324 | 1.0% | 0.4% |
| 5 | 7959 | 25.5% | 7150 | 21.1% | -4.3% |
| 6 | 708 | 2.3% | 484 | 1.4% | -0.8% |
| 7 | 53 | 0.2% | 35 | 0.1% | -0.1% |
| 8 | 1234 | 3.9% | 4454 | 13.2% | 9.2% |
| 9 | 13521 | 43.3% | 13181 | 39.0% | -4.3% |
| 10 | 3542 | 11.3% | 4263 | 12.6% | 1.3% |
| 11 | 1269 | 4.1% | 1013 | 3.0% | -1.1% |
| 12 | 764 | 2.4% | 817 | 2.4% | 0.0% |
| 13 | 2017 | 6.5% | 2086 | 6.2% | -0.3% |
| 14 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 15 | 0 | 0.0% | 0 | 0.0% | 0.0% |

From the table it can be seen that the number of Class 9 vehicles has decreased by 4.3 percent from May 2008 and August 2010. Changes in the number of heavier trucks may be attributed to seasonal variations in truck distributions. During the same time period, the number of Class 5 vehicles decreased by 4.3 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes. Class 8 vehicles increased by 9.2 %, and now represent 13.2 % of all commercial vehicles. This percentage of Class 8 vehicles is atypically high and may be influenced by the presence of misclassified vehicles.

## 2.3 Speed Data Analysis

The traffic data received from the Phase II Contractor was analyzed to determine the expected truck speed distributions. This will provide a basis for determining the speed of the test trucks during validation testing. The CDS distribution of speeds is shown in Figure 2-2.

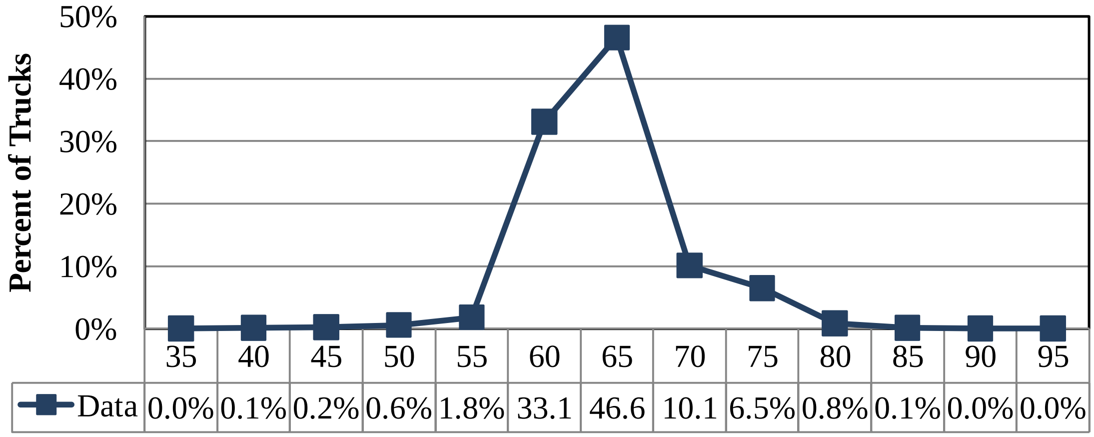



**Figure 2-2 – Truck Speed Distribution – 01-Jan-11**

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 60 and 70 mph. The posted speed limit at this site is 60 and the 85th percentile speed for trucks at this site is 66 mph. The range of truck speeds for the validation will be 50 to 60 mph.

## 2.4 GVW Data Analysis

The traffic CDS data received from the Regional Support Contractor was analyzed to determine the expected Class 9 GVW distributions. Figure 2-3 shows a comparison between GVW plots generated using a two-week W-card sample from August 2010 and the Comparison Data Set from May 2008.

As shown in Figure 2-3, there is a downward and right shift for the loaded peaks between the May 2008 Comparison Data Set (CDS) and the August 2010 two-week sample W-card dataset (Data).

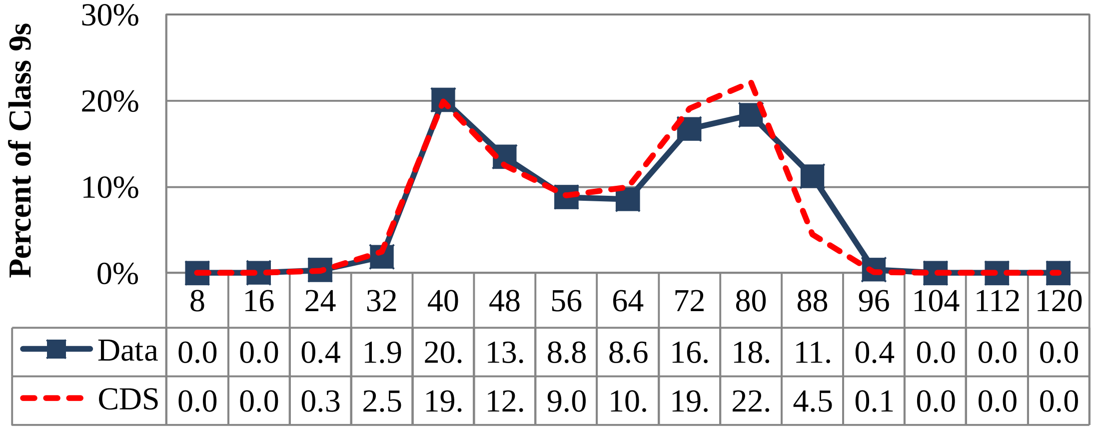



**Figure 2-3 – Comparison of Class 9 GVW Distribution**

Table 2-4 is provided to show the statistical comparison for Class 9 GVW between the Comparison Data Set and the current dataset.

**Table 2-4 – Class 9 GVW Distribution from W-Card**

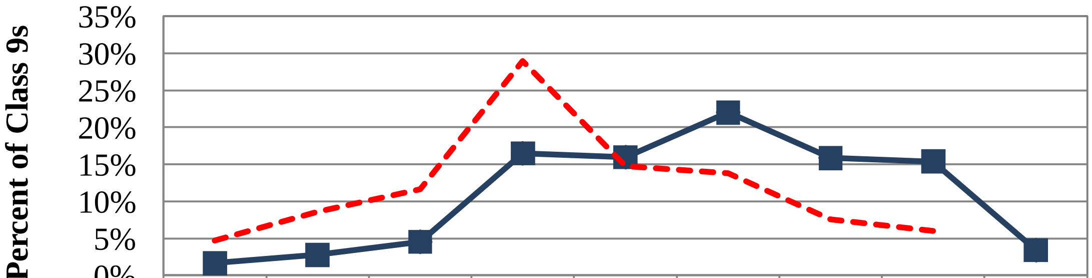
| GVW weight bins (kips) | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 5/1/2008 | | 8/18/2010 | | |
| 8 | 0 | 0.0% | 1 | 0.0% | 0.0% |
| 16 | 1 | 0.0% | 4 | 0.0% | 0.0% |
| 24 | 37 | 0.3% | 47 | 0.4% | 0.1% |
| 32 | 332 | 2.5% | 244 | 1.9% | -0.6% |
| 40 | 2697 | 19.9% | 2619 | 20.1% | 0.2% |
| 48 | 1694 | 12.5% | 1756 | 13.5% | 1.0% |
| 56 | 1215 | 9.0% | 1148 | 8.8% | -0.2% |
| 64 | 1350 | 10.0% | 1116 | 8.6% | -1.4% |
| 72 | 2586 | 19.1% | 2177 | 16.7% | -2.4% |
| 80 | 2990 | 22.1% | 2390 | 18.4% | -3.8% |
| 88 | 605 | 4.5% | 1464 | 11.2% | 6.8% |
| 96 | 13 | 0.1% | 52 | 0.4% | 0.3% |
| 104 | 1 | 0.0% | 1 | 0.0% | 0.0% |
| 112 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| Average = | 57.9 kips | | 58.8 kips | | 0.9 kips |

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range increased by 0.2 percent while the number of loaded class 9 trucks in the 72 to 80 kips range decreased by 3.8 percent. During this time period the number of overweight trucks increased by 7.1 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 0.9 kips, or 1.6 percent, from 57.9 to 58.8 kips.

## 2.5 Class 9 Front Axle Weight Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average front axle weight. This will provide a basis for the evaluation of the quality of the data by comparing the average front axle weight from the current data sample set with the expected average front axle weight average from the Data Comparison Set.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from August 2010 and the Comparison Data Set from May 2008.




| | 9.0 | 9.5 | 10.0 | 10.5 | 11.0 | 11.5 | 12.0 | 12.5 | 13.0 |
|---|---|---|---|---|---|---|---|---|---|
| Data | 1.7% | 2.8% | 4.5% | 16.5% | 16.0% | 22.0% | 15.8% | 15.4% | 3.4% |
| CDS | 4.7% | 8.6% | 11.6% | 29.0% | 14.7% | 13.8% | 7.6% | 6.0% | |

**Figure 2-4 – Distribution of Class 9 Front Axle Weights**

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 10.5 and 12.5 kips. The percentage of trucks in this range has increased between the May 2008 Comparison Data Set (CDS) and the August 2010 dataset (Data). The front axle weights for the data sample indicate higher than typical steering axle weights for Class 9 vehicles. The higher than expected front axle weights indicate that the WIM system may be overestimating steering axle weights.

Table 2-5 provides the Class 9 front axle weight distribution data for the May 2008 Comparison Data Set (CDS) and the August 2010 dataset (Data).

**Table 2-5 – Class 9 Front Axle Weight Distribution from W-Card**

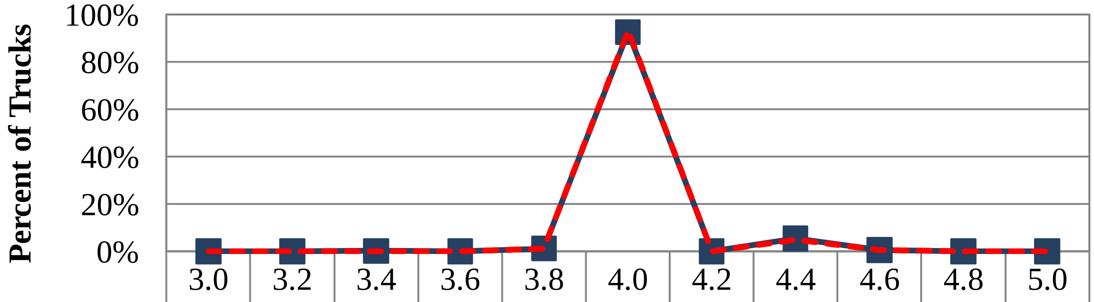
| F/A weight bins (kips) | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 5/1/2008 | | 8/18/2010 | | |
| 9.0 | 418 | 3.1% | 240 | 1.9% | -1.2% |
| 9.5 | 631 | 4.7% | 210 | 1.7% | -3.0% |
| 10.0 | 1152 | 8.6% | 354 | 2.8% | -5.8% |
| 10.5 | 1559 | 11.6% | 577 | 4.5% | -7.1% |
| 11.0 | 3888 | 29.0% | 2093 | 16.5% | -12.5% |
| 11.5 | 1978 | 14.7% | 2027 | 16.0% | 1.2% |
| 12.0 | 1849 | 13.8% | 2793 | 22.0% | 8.2% |
| 12.5 | 1014 | 7.6% | 2012 | 15.8% | 8.3% |
| 13.0 | 807 | 6.0% | 1954 | 15.4% | 9.4% |
| 13.5 | 128 | 1.0% | 436 | 3.4% | 2.5% |
| Average = | 11.0 kips | | 11.6 kips | | 0.7 kips |

The table shows that the average front axle weight for Class 9 trucks has increased by 0.7 kips, or 6.4 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.6 kips.

## 2.6 Class 9 Tractor Tandem Spacing Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average tractor tandem spacing. This will provide a basis for the evaluation of the accuracy of the equipment distance and speed measurements by comparing the observed average tractor tandem spacing from the sample data (Data) with the expected average tractor tandem spacing from the comparison data set (CDS).

The class 9 tractor tandem spacing plot in Figure 2-5 is provided to indicate possible shifts in WIM system distance and speed measurement accuracies.




| | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 | 4.2 | 4.4 | 4.6 | 4.8 | 5.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Data | 0.0% | 0.1% | 0.2% | 0.0% | 1.2% | 92.6% | 0.0% | 5.4% | 0.5% | 0.0% | 0.0% |
| CDS | 0.0% | 0.0% | 0.1% | 0.0% | 1.1% | 93.3% | 0.0% | 4.9% | 0.5% | 0.0% | 0.0% |

**Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing**

As seen in the figure, the Class 9 tractor tandem spacings for the May 2008 Comparison Data Set and the August 2010 Data are nearly identical.

Table 2-6 shows the Class 9 axle spacings between the second and third axles. .

**Table 2-6 – Class 9 Axle 2 to 3 Spacing from W-Card**

| Tandem 1 spacing bins (feet) | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 5/1/2008 | | 8/18/2010 | | |
| 3.0 | 0 | 0.0% | 1 | 0.0% | 0.0% |
| 3.2 | 1 | 0.0% | 8 | 0.1% | 0.1% |
| 3.4 | 20 | 0.1% | 22 | 0.2% | 0.0% |
| 3.6 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 3.8 | 143 | 1.1% | 156 | 1.2% | 0.1% |
| 4.0 | 12610 | 93.3% | 12060 | 92.6% | -0.6% |
| 4.2 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 4.4 | 669 | 4.9% | 702 | 5.4% | 0.4% |
| 4.6 | 74 | 0.5% | 67 | 0.5% | 0.0% |
| 4.8 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 5.0 | 4 | 0.0% | 3 | 0.0% | 0.0% |
| Average = | 4.0 feet | | 4.0 feet | | 0.0 feet |

From the table it can be seen that the drive tandem spacing of Class 9 trucks at this site is between 3.8 and 4.6 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.0, which is identical to the expected average of 4.0 from the CDS per vehicle records. Further axle spacing analyses are performed during the validation and post-validation analysis.

## 2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (May 2008) based on the last calibration with the most recent two-week WIM data sample from the site (August 2010). Comparison of vehicle class distribution data indicates a 4.3 percent decrease in the number of Class 9 vehicles, and an atypically large percentage of Class 8 vehicles (13.2%). Analysis of Class 9 weight data indicates that front axle weights have increased by 6.4 percent and average Class 9 GVW has increased by 1.6 percent for the August 2010 data. The increase in front axle weights suggests that the WIM system may be overestimating axle weights. The data indicates an average truck tandem spacing of 4.0 feet, which is identical the expected average of 4.0 feet.

# 3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on April 23, 2008 and this validation visit, it appears that changes to the speed compensation factors have occurred during this time.

## 3.1 Description

This site was installed on March, 1998 by the Washington DOT. It is instrumented with quartz weighing sensors and an IRD 1060 Series WIM Controller. The agency also performs routine equipment maintenance and data quality checks of the WIM data.

## 3.2 Physical Inspection

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented after Section 7.

## 3.3 Electronic and Electrical Testing

Electronic and electrical checks of all system components were conducted prior to the pre-validation test truck runs. Dynamic and static electronic checks of the in-road sensors were performed. All values for the WIM sensors and inductive loops were within tolerances. Electronic tests of the power and communication devices indicated that they were operating normally.

## 3.4 Equipment Troubleshooting and Diagnostics

The WIM system appeared to collect, analyze and report vehicle measurements normally. No troubleshooting actions were taken.

## 3.5 Recommended Equipment Maintenance

No unscheduled equipment maintenance actions are recommended.

# 4 Pavement Discussion

## 4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, no areas of pavement distress that may affect the accuracy of the WIM sensors were noted.

## 4.2 Profile and Vehicle Interaction

Profile data was collected on July 29, 2010 by the Western Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, 900 feet prior to WIM scales and 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 10 profile passes were made, 4 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 400 foot approach section was 139 in/mi and is located approximately 63 feet prior to the WIM scale. This area of pavement was closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed that would influence truck dynamics in the WIM scale area. Additionally, a visual observation of the trucks as they approach, traverse and leave the sensor area did not indicate any visible motion of the trucks that would affect the performance of the WIM scales. Trucks appear to track down the center of the lane.

## 4.3 LTPP Pavement Profile Data Analysis

The IRI data files are processed using the WIM Smoothness Index software. The indices produced by the software provide an indication of whether or not the pavement roughness may affect the operation of the WIM equipment. The recommended thresholds for WIM Site pavement smoothness are provided in Table 4-1.

**Table 4-1 – Recommended WIM Smoothness Index Thresholds**

| Index | Lower Threshold (m/km) | Upper Threshold (m/km) |
|---|---|---|
| Long Range Index (LRI) | 0.50 | 2.1 |
| Short Range Index (SRI) | 0.50 | 2.1 |
| Peak LRI | 0.50 | 2.1 |
| Peak SRI | 0.75 | 2.9 |

When all values are less than the lower threshold shown in Table 4-1, it is unlikely that pavement conditions will significantly influence sensor output. Values between the threshold values may or may not influence the accuracy of the sensor output and values above the upper threshold would lead to sensor output that would preclude achieving the research quality loading data.

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the 3 left, 3 right and 4 center profiler runs are presented in Table 4-2.

**Table 4-2 – WIM Index Values**

| **Profiler Passes** | | | **Pass 1** | **Pass 2** | **Pass 3** | **Pass 4** | **Pass5** | **Avg** |
|---|---|---|---|---|---|---|---|---|
| Left | LWP | LRI (m/km) | 0.973 | 0.877 | 1.099 | | | 0.983 |
| | | SRI (m/km) | *0.473* | *0.274* | *0.481* | | | *0.409* |
| | | Peak LRI (m/km) | 1.004 | 1.035 | 1.126 | | | 1.055 |
| | | Peak SRI (m/km) | 0.891 | 0.857 | 0.882 | | | 0.877 |
| | RWP | LRI (m/km) | 0.854 | 0.956 | 1.001 | | | 0.937 |
| | | SRI (m/km) | 0.562 | 0.614 | 0.511 | | | 0.562 |
| | | Peak LRI (m/km) | 0.951 | 1.049 | 1.051 | | | 1.017 |
| | | Peak SRI (m/km) | *0.633* | *0.669* | 0.942 | | | *0.748* |
| Center | LWP | LRI (m/km) | 1.153 | 1.231 | 1.126 | 1.072 | | 1.146 |
| | | SRI (m/km) | 0.985 | 1.408 | 0.796 | 0.629 | | 0.955 |
| | | Peak LRI (m/km) | 1.153 | 1.277 | 1.133 | 1.146 | | 1.177 |
| | | Peak SRI (m/km) | 1.106 | 1.538 | 0.935 | *0.681* | | 1.065 |
| | RWP | LRI (m/km) | 0.884 | 0.959 | 0.920 | 0.903 | | 0.917 |
| | | SRI (m/km) | *0.252* | *0.401* | 0.659 | 0.557 | | *0.467* |
| | | Peak LRI (m/km) | 0.937 | 0.998 | 0.924 | 0.914 | | 0.943 |
| | | Peak SRI (m/km) | *0.508* | *0.582* | 0.764 | *0.670* | | *0.631* |
| Right | LWP | LRI (m/km) | 0.881 | 0.926 | 0.929 | | | 0.912 |
| | | SRI (m/km) | *0.491* | 0.611 | *0.470* | | | 0.524 |
| | | Peak LRI (m/km) | 0.948 | 0.911 | 0.941 | | | 0.933 |
| | | Peak SRI (m/km) | *0.513* | *0.637* | *0.573* | | | *0.574* |
| | RWP | LRI (m/km) | 1.250 | 1.053 | 1.079 | | | 1.127 |
| | | SRI (m/km) | 0.744 | 1.019 | 0.733 | | | 0.832 |
| | | **Peak LRI (m/km)** | **1.253** | **1.246** | **1.256** | | | **1.252** |
| | | Peak SRI (m/km) | 0.925 | 1.061 | 0.843 | | | 0.943 |

From Table 4-2 it can be seen that most of the indices computed from the profiles are between the upper and lower threshold values, with the remaining values under the lower threshold. The highest values, on average, are the Peak LRI values in the right wheel path (shown in bold).

## 4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

# 5 Statistical Reliability of the WIM Equipment

The following section provides summaries of data collected during the pre-validation, the calibration, and the post-validation test truck runs, as well as information resulting from the classification and speed studies. All analyses of test truck data and information on necessary equipment adjustments are provided.

## 5.1 Pre-Validation

The first set of test runs provides a general overview of system performance prior to any calibration adjustments for the given environmental, vehicle speed and other conditions.

The 40 pre-validation test truck runs were conducted on March 29, 2011, beginning at approximately 8:51 AM and continuing until 3:30 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

The test trucks were weighed prior to the pre-validation and were re-weighed at the conclusion of the pre-validation. The average test truck weights and measurements are provided in Table 5-1.

**Table 5-1 - Pre-Validation Test Truck Weights and Measurements**

| Test Truck | Weights (kips) | | | | | | Spacings (feet) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GVW | Ax1 | Ax2 | Ax3 | Ax4 | Ax5 | 1-2 | 2-3 | 3-4 | 4-5 | AL | OL |
| 1 | 70.7 | 10.9 | 14.2 | 14.2 | 15.7 | 15.7 | 12.8 | 4.3 | 33.7 | 4.2 | 55.0 | 68.5 |
| 2 | 50.3 | 10.2 | 10.4 | 10.4 | 9.6 | 9.6 | 12.8 | 4.3 | 34.0 | 4.0 | 55.1 | 67.8 |

Test truck speeds varied by 13 mph, from 47 to 60 mph. The measured pre-validation pavement temperatures varied 22.4 degrees Fahrenheit, from 39.5 to 61.9. The partly sunny weather conditions prevented attaining the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

**Table 5-2 – Pre-Validation Overall Results – 29-Mar-11**

| Parameter | 95% Confidence Limit of Error | Site Values | Pass/Fail |
|---|---|---|---|
| Steering Axles | ±20 percent | 4.8 ± 14.4% | Pass |
| Tandem Axles | ±15 percent | 5.3 ± 10.9% | FAIL |
| GVW | ±10 percent | 5.3 ± 7.9% | FAIL |
| Vehicle Length | ±3.0 percent (2.0 ft) | -0.1 ± 1.3 ft | Pass |
| Axle Length | ± 0.5 ft [150mm] | 0.0 ± 0.1 ft | Pass |

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was 0.6 ± 5.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

### *5.1.1 Statistical Speed Analysis*

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 60 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3.

**Table 5-3 – Pre-Validation Results by Speed – 29-Mar-11**

| Parameter | 95% Confidence Limit of Error | Low | Medium | High |
|---|---|---|---|---|
| | | 47.0 to 51.3 mph | 51.4 to 55.8 mph | 55.9 to 60.0 mph |
| Steering Axles | ±20 percent | 7.3 ± 18.8% | 5.5 ± 12.7% | 2.3 ± 14.9% |
| Tandem Axles | ±15 percent | 3.1 ± 15.3% | 6.4 ± 10.1% | 5.9 ± 9.7% |
| GVW | ±10 percent | 3.9 ± 11.5% | 6.2 ± 7.5% | 5.3 ± 6.9% |
| Vehicle Length | ±3.0 percent (2.0 ft) | -0.1 ± 1.7 ft | 0.0 ± 1.3 ft | -0.2 ± 1.4 ft |
| Vehicle Speed | ± 1.0 mph | -1.2 ± 5.6 mph | 1.7 ± 4.6 mph | 0.8 ± 5.7 mph |
| Axle Length | ± 0.5 ft [150mm] | 0.0 ± 0.2 ft | 0.0 ± 0.1 ft | 0.0 ± 0.1 ft |

From the table, it can be seen that, on average, the WIM equipment overestimates all weights at all speeds and the variance of errors generally decreases as speed increases. There does appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following sections.

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment generally overestimated GVW at all speeds. The range in GVW errors is greater at the lower speeds when compared with the medium and high speeds.

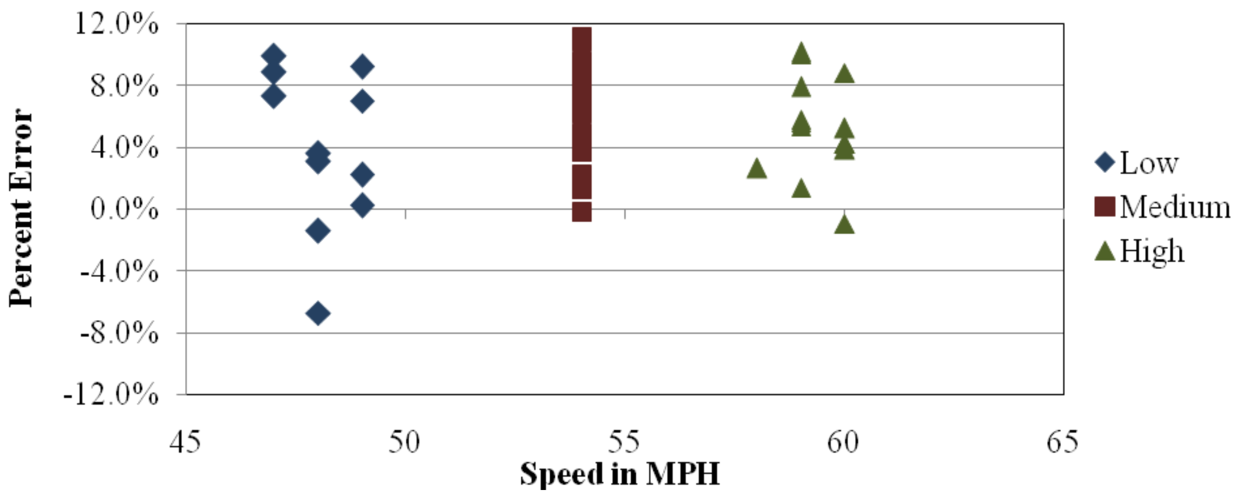



**Figure 5-1 – Pre-Validation GVW Error by Speed – 29-Mar-11**

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment generally overestimates steering axle weights at all speeds. The range in error appears to be greater at the low and high speeds.

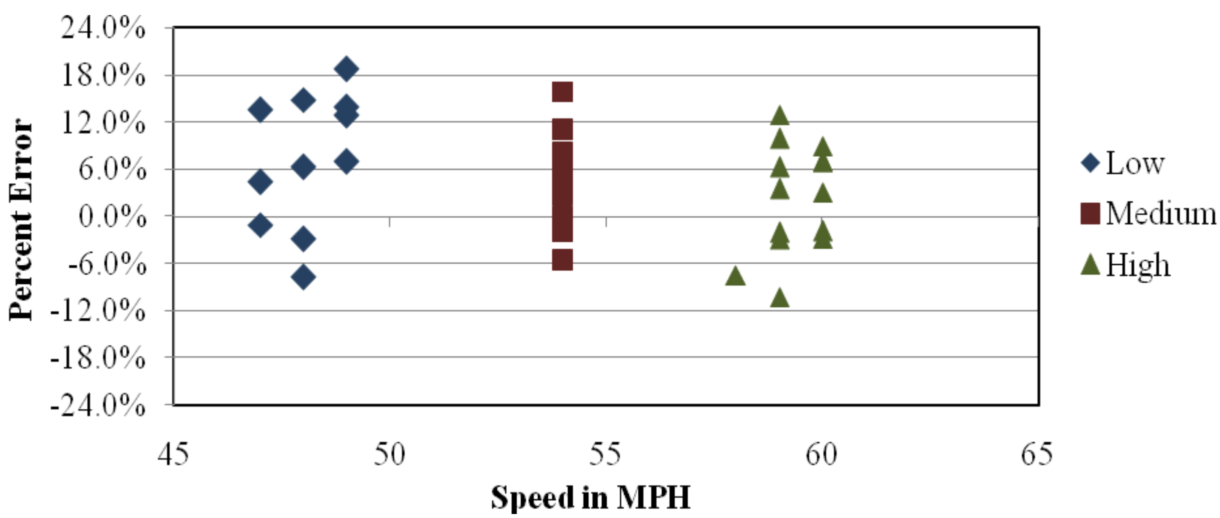



**Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 29-Mar-11**

#### 5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, on average, the equipment overestimates tandem axle weights at all speeds. The range in error appears to be greater at the lower speeds.

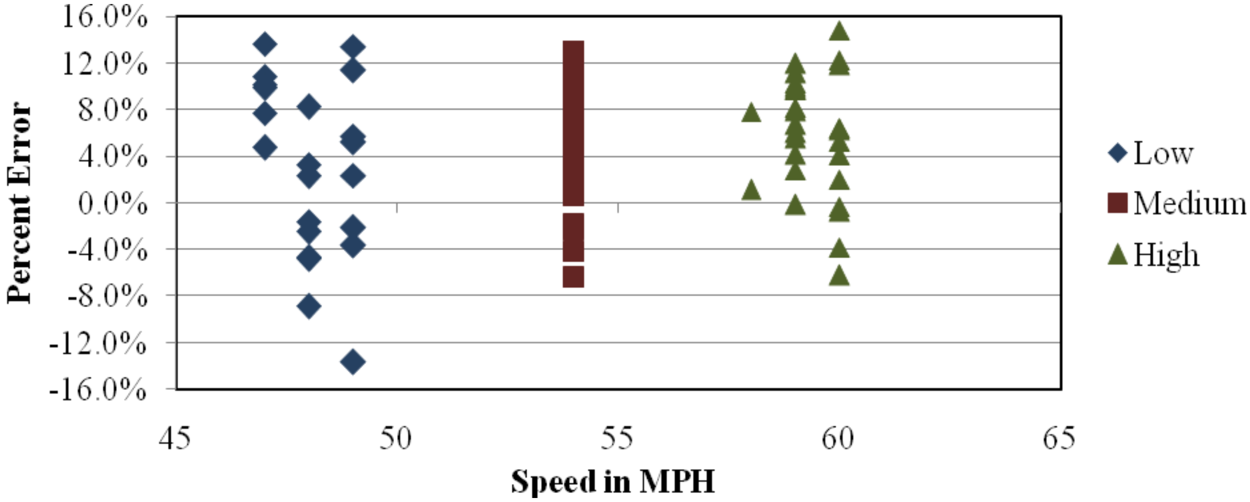



**Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 29-Mar-11**

#### 5.1.1.4 GVW Errors by Speed and Truck Type

When the GVW error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. Distribution of errors is shown graphically in Figure 5-4.

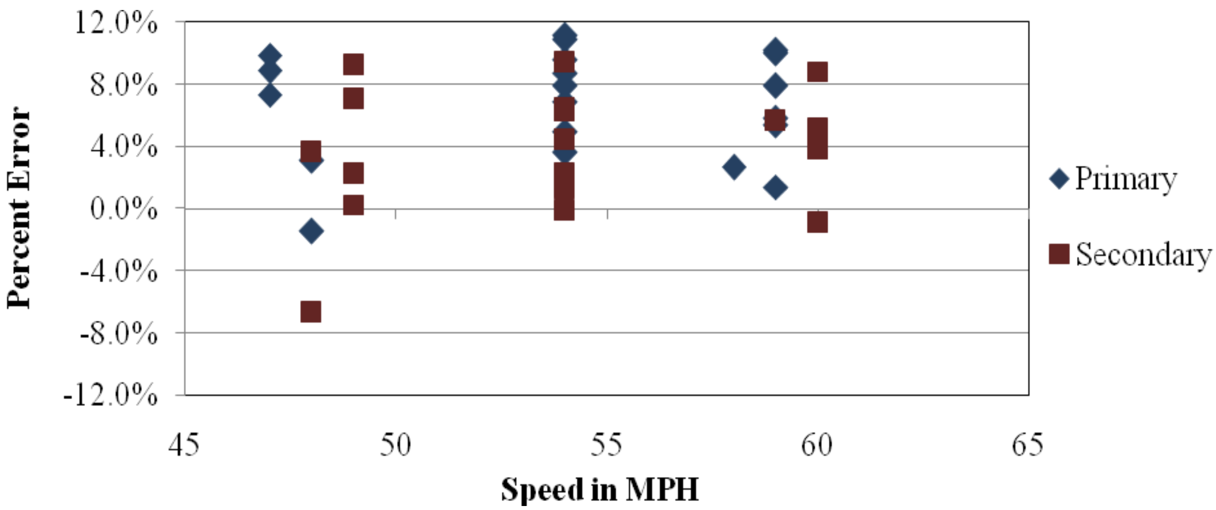



**Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 29-Mar-11**

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from -0.1 feet to 0.3 feet. Distribution of errors is shown graphically in Figure 5-5.

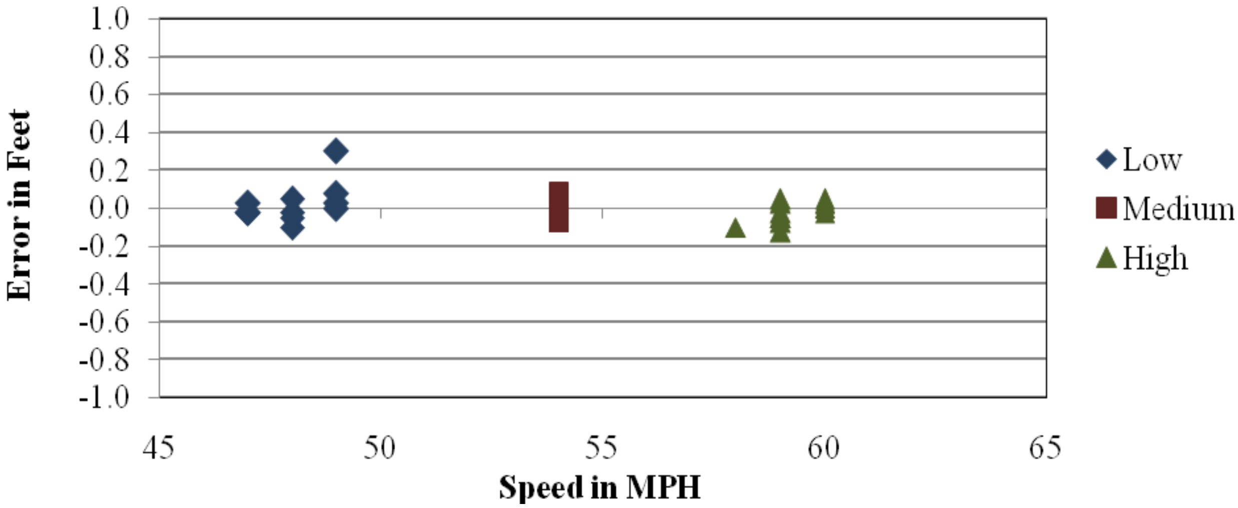



**Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 29-Mar-11**

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measured overall vehicle length consistently over the entire range of speeds, with an error range of -1.8 to 0.5 feet. Distribution of errors is shown graphically in Figure 5-6.

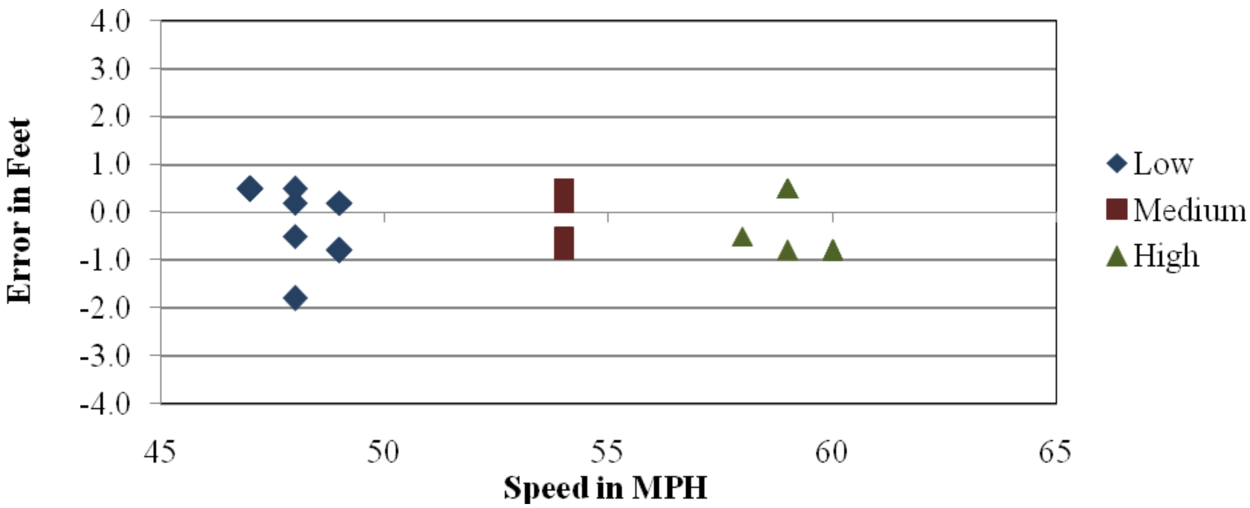



**Figure 5-6 – Pre-Validation Overall Length Error by Speed – 29-Mar-11**

### *5.1.2 Statistical Temperature Analysis*

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 22.4 degrees, from 39.5 to 61.9 degrees Fahrenheit. The pre-validation test runs are being reported under two temperature groups – low and high temperatures, as shown in Table 5-4.

**Table 5-4 – Pre-Validation Results by Temperature – 29-Mar-11**

| **Parameter** | **95% Confidence Limit of Error** | **Low** | **High** |
|---|---|---|---|
| | | **39.5 to 50.7 degF** | **50.8 to 61.9 degF** |
| Steering Axles | ±20 percent | 8.5 ± 16.8% | 2.6 ± 11.9% |
| Tandem Axles | ±15 percent | 5.0 ± 12.7% | 5.5 ± 10.6% |
| GVW | ±10 percent | 5.7 ± 9.9% | 5.0 ± 7.3% |
| Vehicle Length | ±3.0 percent (2.0 ft) | -0.3 ± 1.5 ft | 0.0 ± 1.2 ft |
| Vehicle Speed | ± 1.0 mph | -0.1 ± 3.5 mph | 1.0 ± 6.3 mph |
| Axle Length | ± 0.5 ft [150mm] | 0.0 ± 0.2 ft | 0.0 ± 0.1 ft |

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle, and axle group weights.

#### 5.1.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment generally overestimates GVW across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

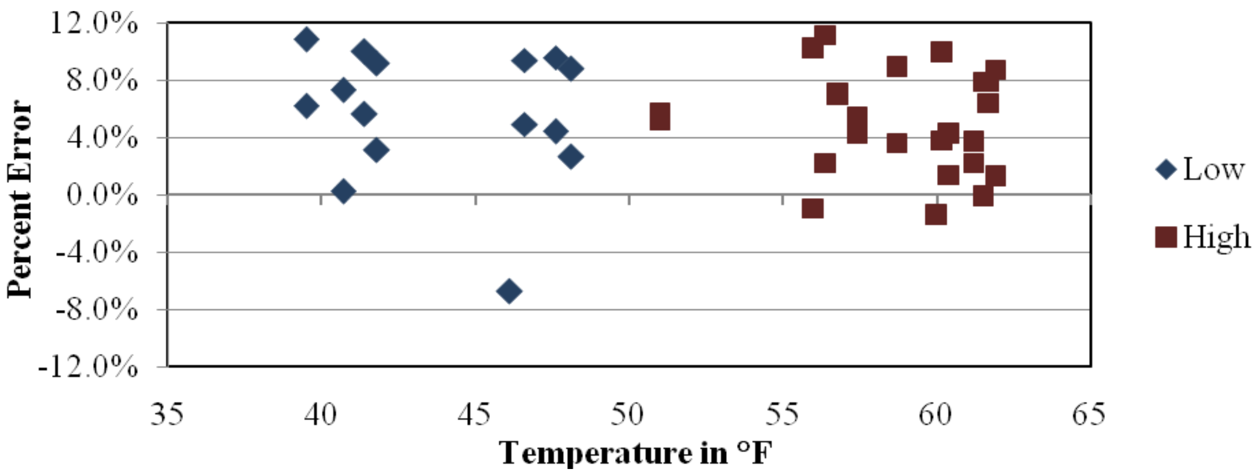



**Figure 5-7 – Pre-Validation GVW Errors by Temperature – 29-Mar-11**

#### 5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 illustrates that the WIM equipment generally overestimates steering axle weights at the lower temperatures. The range in error is similar for the two temperature groups.

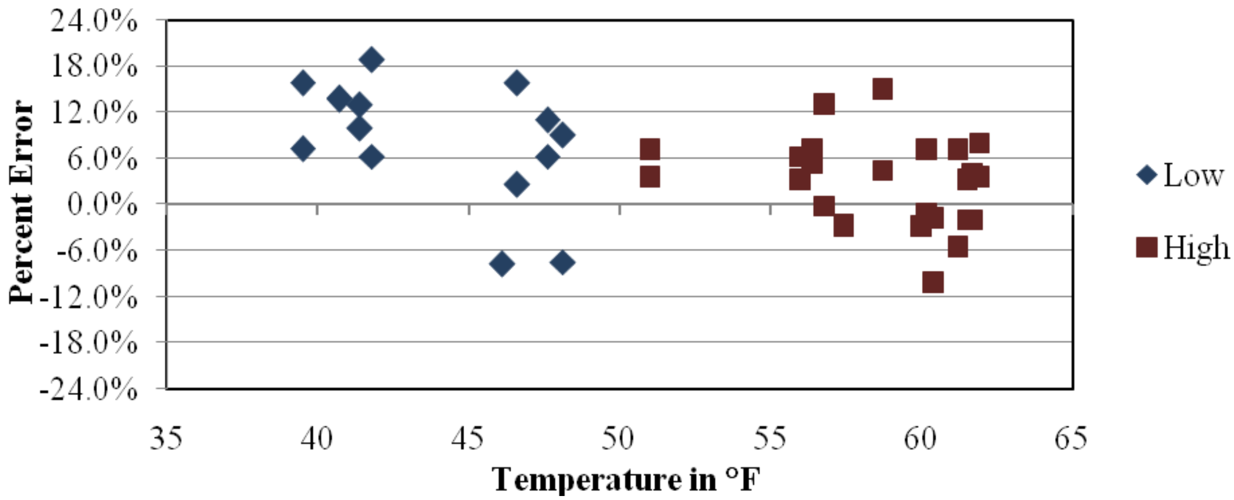



**Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 29-Mar-11**

#### 5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment appears to overestimate tandem axle weights by a greater degree at the higher temperatures when compared with the lower temperatures. The range in tandem axle errors is similar for the two temperature groups.

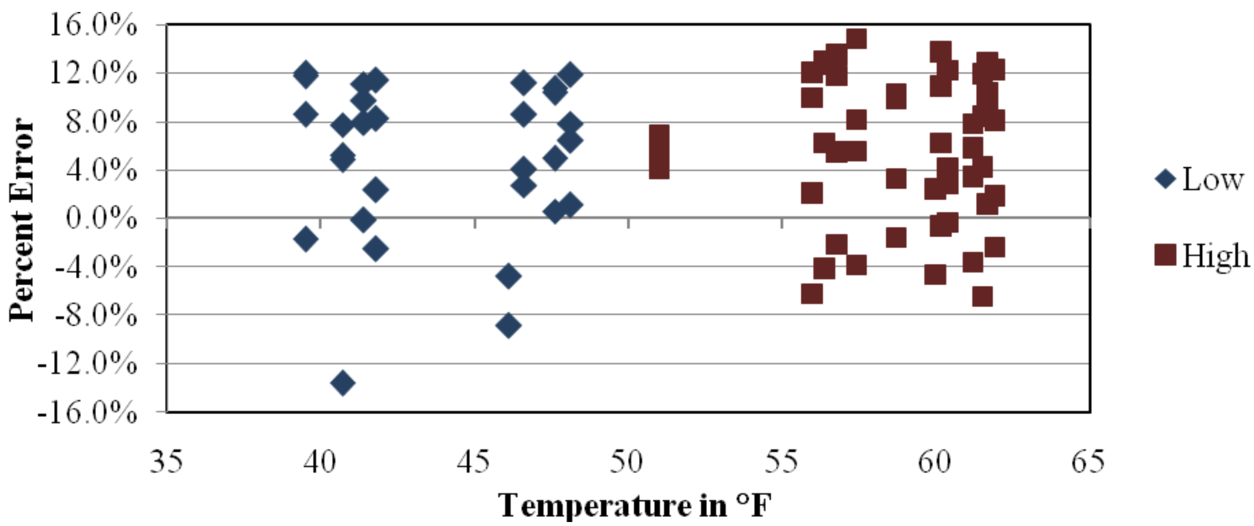



**Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 29-Mar-11**

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, WIM equipment overestimated GVW for both the partially loaded (Secondary) truck and the heavily loaded (Primary) truck. For both trucks, the range of errors and bias are similar over the range of temperatures. Distribution of errors is shown graphically in Figure 5-10.

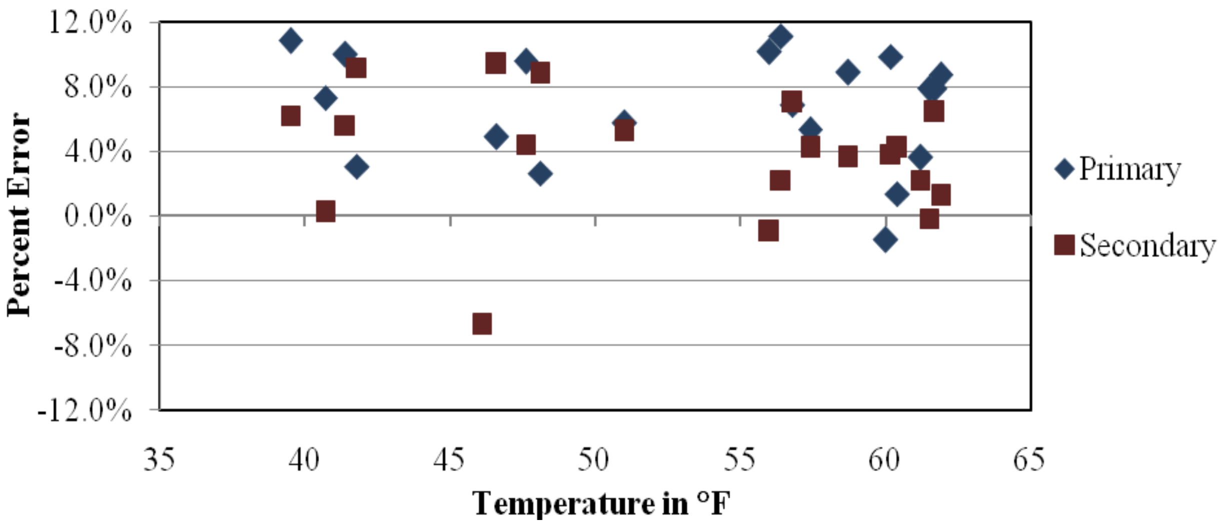



**Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 29-Mar-11**

### *5.1.3 Classification and Speed Evaluation*

The pre-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment.

For the pre-validation classification study at this site, a manual sample of 103 vehicles including 103 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Table 5-5 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study. Misclassified vehicles are defined as those vehicles that are manually classified by observation as one class of vehicle but identified by the WIM equipment as another class of vehicle. As shown in Table 5-6, one Class 5 vehicle was identified as a Class 4 vehicle (bus) by the equipment. Additionally, two Class 5 vehicles were identified as Class 8 trucks by the equipment. This resulted in an overcount of one Class 4 and two Class 8s, and an undercount of three Class 5 vehicles by the equipment, as shown in Table 5-5.

**Table 5-5 – Pre-Validation Classification Study Results – 29-Mar-11**

| Class | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed Count | 0 | 1 | 8 | 3 | 0 | 1 | 61 | 18 | 1 | 1 | 9 |
| WIM Count | 0 | 2 | 5 | 3 | 0 | 3 | 61 | 18 | 1 | 1 | 9 |
| Observed Percent | 0.0 | 1.0 | 7.8 | 2.9 | 0.0 | 1.0 | 59.2 | 17.5 | 1.0 | 1.0 | 8.7 |
| WIM Percent | 0.0 | 1.9 | 4.9 | 2.9 | 0.0 | 2.9 | 59.2 | 17.5 | 1.0 | 1.0 | 8.7 |
| Misclassified Count | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Misclassified Percent | 0.0 | 0.0 | 37.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Unclassified Count | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unclassified Percent | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample. The misclassifications by pair are provided in Table 5-6.

**Table 5-6 – Pre-Validation Misclassifications by Pair – 29-Mar-11**

| Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs |
|---|---|---|---|---|---|
| 3/8 | 0 | 6/4 | 0 | 9/5 | 0 |
| 4/5 | 0 | 6/7 | 0 | 9/8 | 0 |
| 4/6 | 0 | 6/8 | 0 | 9/10 | 0 |
| 5/3 | 0 | 6/9 | 0 | 10/9 | 0 |
| 5/4 | 1 | 6/10 | 0 | 10/13 | 0 |
| 5/6 | 0 | 7/6 | 0 | 11/12 | 0 |
| 5/7 | 0 | 8/3 | 0 | 12/11 | 0 |
| 5/8 | 2 | 8/5 | 0 | 13/10 | 0 |
| 5/9 | 0 | 8/9 | 0 | 13/11 | 0 |

As shown in the table, a total of three vehicles, including zero heavy trucks (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the pre-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 2.9%.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-7.

**Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 29-Mar-11**

| Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs |
|---|---|---|---|---|---|
| 3/15 | 0 | 7/15 | 0 | 11/15 | 0 |
| 4/15 | 0 | 8/15 | 0 | 12/15 | 0 |
| 5/15 | 0 | 9/15 | 0 | 13/15 | 0 |
| 6/15 | 0 | 10/15 | | | |

Based on the manually collected sample of the 103 trucks, 0.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was -0.8 mph; the range of errors was 1.5 mph.

## 5.2 Calibration

The WIM equipment required two calibration iterations between the pre- and post-validations. Information regarding the basis for changing equipment compensation factors, supporting data for the changes, and the resulting WIM accuracies from the calibrations are provided in this section.

The operating system weight compensation parameters that were in place prior to the pre-validation are shown in Table 5-8.

**Table 5-8 – Initial System Parameters – 30-Mar-11**

| Speed Point | MPH | Left | Right |
|---|---|---|---|
| | | 1 | 2 |
| 80 | 50 | 6.891273 | 6.891273 |
| 100 | 62 | 6.891273 | 6.891273 |
| 120 | 75 | 6.891273 | 6.891273 |
| **Axle Distance (cm)** | | 119 | |
| **Dynamic Comp (%)** | | 101 | |
| **Loop Width (cm)** | | 102 | |

### *5.2.1 Calibration Iteration 1*

#### 5.2.1.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of 5.3% and errors of 3.9%, 6.2%, and 5.3% at the 50, 56 and 62 mph speed points respectively. The error for the 62 speed point was extrapolated to derive a new compensation factors for the 75 mph speed point. To compensate for these errors, the changes in Table 5-9 were made to the compensation factors.

**Table 5-9 – Calibration 1 Equipment Factor Changes – 30-Mar-11**

| Speed Points | Old Factors | | Error | New Factors | |
|---|---|---|---|---|---|
| | Left | Right | | Left | Right |
| | 1 | 2 | | 1 | 2 |
| 80 | 6.891273 | 6.891273 | 3.76% | 6.641266 | 6.641266 |
| 100 | 6.891273 | 6.891273 | 4.05% | 6.623147 | 6.623147 |
| 120 | 6.891273 | 6.891273 | 4.05% | 6.623147 | 6.623147 |
| **Axle Distance (cm)** | 119 | | -0.17% | 119 | |
| **Dynamic Comp (%)** | 101 | | 4.85% | 101 | |
| **Loop Width (cm)** | 102 | | -0.1 ft | 98 | |

5.2.1.2 Calibration 1 Results

The results of the 12 calibration verification runs are provided in Table 5-10 and Figure 5-11. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the first calibration iteration.

**Table 5-10 – Calibration 1 Results – 30-Mar-11**

| Parameter | 95% Confidence Limit of Error | Site Values | Pass/Fail |
|---|---|---|---|
| Steering Axles | ±20 percent | -5.9 ± 13.0% | Pass |
| Tandem Axles | ±15 percent | 4.8 ± 13.3% | FAIL |
| GVW | ±10 percent | 2.6 ± 9.4% | FAIL |
| Vehicle Length | ±3.0 percent (2.0 ft) | 0.1 ± 1.1 ft | Pass |
| Axle Length | ± 0.5 ft [150mm] | 0.0 ± 0.2 ft | Pass |

Figure 5-11 shows that the WIM equipment is generally overestimating GVW at the medium and high speeds.

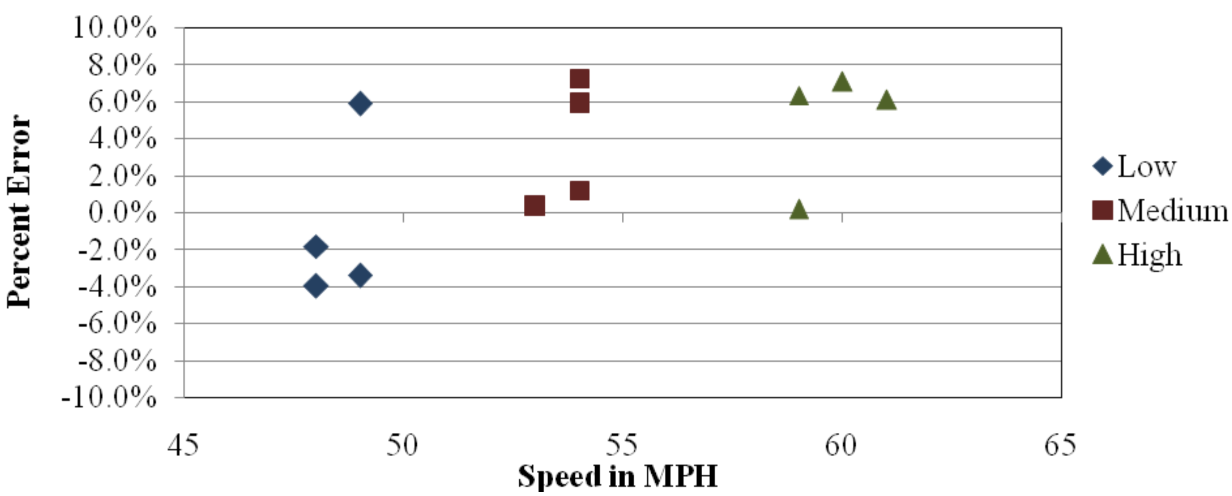



**Figure 5-11 – Calibration 1 GVW Error by Speed – 30-Mar-11**

Based on the results of the first calibration, where weight estimate bias decreased to 2.6 percent, but the equipment did not measure GVW or tandem axle weights within specified tolerances, a second calibration was considered to be necessary.

### *5.2.2 Calibration Iteration 2*

#### 5.2.2.1 Equipment Adjustments

The first calibration test truck runs produced an overall error of 2.6% and errors of -0.8%, 3.7%, and 4.9% at the 50, 56 and 62 mph speed points, respectively. The error for the 62 mph speed point was extrapolated to derive new compensation factors for the 75 mph speed point. To compensate for these errors, the following changes to the compensation factors were made:

**Table 5-11 – Calibration 2 Equipment Factor Changes – 30-Mar-11**

| Speed Points | Old Factors | | Error | New Factors | |
|---|---|---|---|---|---|
| | Left | Right | | Left | Right |
| | 1 | 2 | | 1 | 2 |
| 80 | 6.641266 | 6.641266 | 0.47% | 6.641266 | 6.641266 |
| 100 | 6.623147 | 6.623147 | 7.83% | 6.368410 | 6.368410 |
| 120 | 6.623147 | 6.623147 | 7.83% | 6.368410 | 6.368410 |
| **Axle Distance (cm)** | 119 | | | 119 | |
| **Dynamic Comp (%)** | 101 | | | 105 | |
| **Loop Width (cm)** | 98 | | | 98 | |

#### 5.2.2.2 Calibration 2 Results

The results of the 14 second calibration verification runs are provided in Table 5-12 and Figure 5-12. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the second calibration iteration.

**Table 5-12 – Calibration 2 Results – 30-Mar-11**

| Parameter | 95% Confidence Limit of Error | Site Values | Pass/Fail |
|---|---|---|---|
| Steering Axles | +20 percent | -0.5 ± 16.8% | Pass |
| Tandem Axles | +15 percent | 0.4 ± 9.5% | Pass |
| GVW | +10 percent | 0.2 ± 7.0% | Pass |
| Vehicle Length | ±3.0 percent (2.0 ft) | -0.1 ± 1.3 ft | Pass |
| Axle Length | + 0.5 ft [150mm] | 0.0 ± 0.2 ft | Pass |

Figure 5-12 shows that as a result of the second calibration, the WIM equipment is estimating GVW with reasonable accuracy at all speeds.

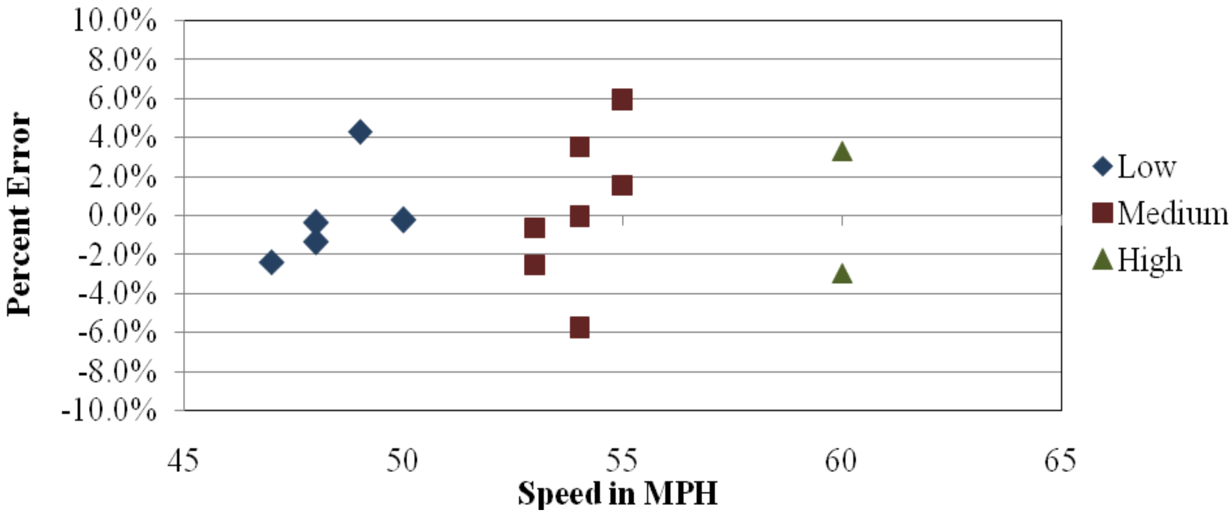



**Figure 5-12 – Calibration 2 GVW Error by Speed – 30-Mar-11**

Based on the results of the second calibration, where GVW estimate bias decreased to 0.2 percent, a third calibration was not considered to be necessary. The 14 calibration runs were combined with 26 additional post-validation runs to complete the WIM system validation.

## 5.3 Post-Validation

The 40 post-validation test truck runs were conducted on March 30, 2011, beginning at approximately 10:52 AM and continuing until 5:39 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

The test trucks were weighed prior to the post-validation and re-weighed at the conclusion of the post-validation. The average test truck weights and measurements are provided in Table 5-13.

**Table 5-13 - Post-Validation Test Truck Measurements**

| Test Truck | Weights (kips) | | | | | | Spacings (feet) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GVW | Ax1 | Ax2 | Ax3 | Ax4 | Ax5 | 1-2 | 2-3 | 3-4 | 4-5 | AL | OL |
| 1 | 69.7 | 10.4 | 14.1 | 14.1 | 15.6 | 15.6 | 12.8 | 4.3 | 33.7 | 4.2 | 55.0 | 68.5 |
| 2 | 50.6 | 10.4 | 10.5 | 10.5 | 9.6 | 9.6 | 12.8 | 4.3 | 34.0 | 4.0 | 55.1 | 67.8 |

Test truck speeds varied by 13 mph, from 47 to 60 mph. The measured post-validation pavement temperatures varied 11.1 degrees Fahrenheit, from 54.2 to 65.3. The cloudy weather conditions prevented attaining the desired 30 degree range in temperatures. Table 5-14 provides a summary of post validation results.

**Table 5-14 – Post-Validation Overall Results – 30-Mar-11**

| Parameter | 95% Confidence Limit of Error | Site Values | Pass/Fail |
|---|---|---|---|
| Steering Axles | ±20 percent | -0.4 ± 14.2% | Pass |
| Tandem Axles | ±15 percent | 1.4 ± 9.5% | Pass |
| GVW | ±10 percent | 1.0 ± 7.6% | Pass |
| Vehicle Length | ±3.0 percent (2.0 ft) | 0.1 ± 1.1 ft | Pass |
| Axle Length | ± 0.5 ft [150mm] | 0.0 ± 0.2 ft | Pass |

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average speed measurement error for all speeds was -0.4 ± 2.6 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.0, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

### *5.3.1 Statistical Speed Analysis*

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 60 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-15.

**Table 5-15 – Post-Validation Results by Speed – 30-Mar-11**

| Parameter | 95% Confidence Limit of Error | Low | Medium | High |
|---|---|---|---|---|
| | | 47.0 to 51.3 mph | 51.4 to 55.8 mph | 55.9 to 60.0 mph |
| Steering Axles | +20 percent | -0.7 ± 14.3% | 3.9 ± 12.7% | -5.4 ± 12.8% |
| Tandem Axles | +15 percent | 1.3 ± 9.0% | 1.2 ± 11.0% | 2.0 ± 11.6% |
| GVW | +10 percent | 0.8 ± 6.9% | 1.6 ± 8.6% | 0.5 ± 9.8% |
| Vehicle Length | ±3.0 percent (2.0 ft) | 0.2 ± 1.5 ft | 0.1 ± 1.0 ft | 0.1 ± 1.2 ft |
| Vehicle Speed | ± 1.0 mph | -0.9 ± 2.8 mph | 0.4 ± 2.6 mph | -0.9 ± 1.9 mph |
| Axle Length | + 0.5 ft [150mm] | 0.0 ± 0.3 ft | 0.0 ± 0.2 ft | 0.0 ± 0.3 ft |

From the table, it can be seen that the WIM equipment estimates all weights with similar accuracy and that the variance of errors is consistent at all speeds. There does not appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following paragraphs.

#### 5.3.1.1 GVW Errors by Speed

As shown in Figure 5-13, the equipment estimated GVW with similar accuracy at all speed groups. The range in error is also similar at all speed groups.

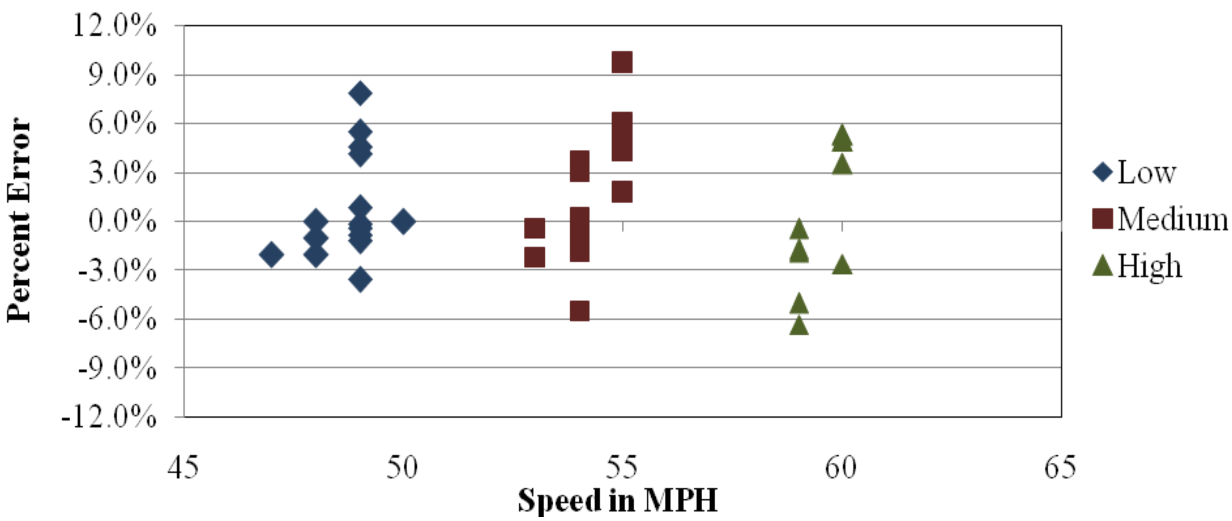



**Figure 5-13 – Post-Validation GVW Errors by Speed – 30-Mar-11**

#### 5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-14, the equipment estimated steering axle weights with similar accuracy at all speed groups. The range in error was greater at the low and medium speed groups than at the high speed group. There does not appear to be a correlation between speed and weight estimates at this site.

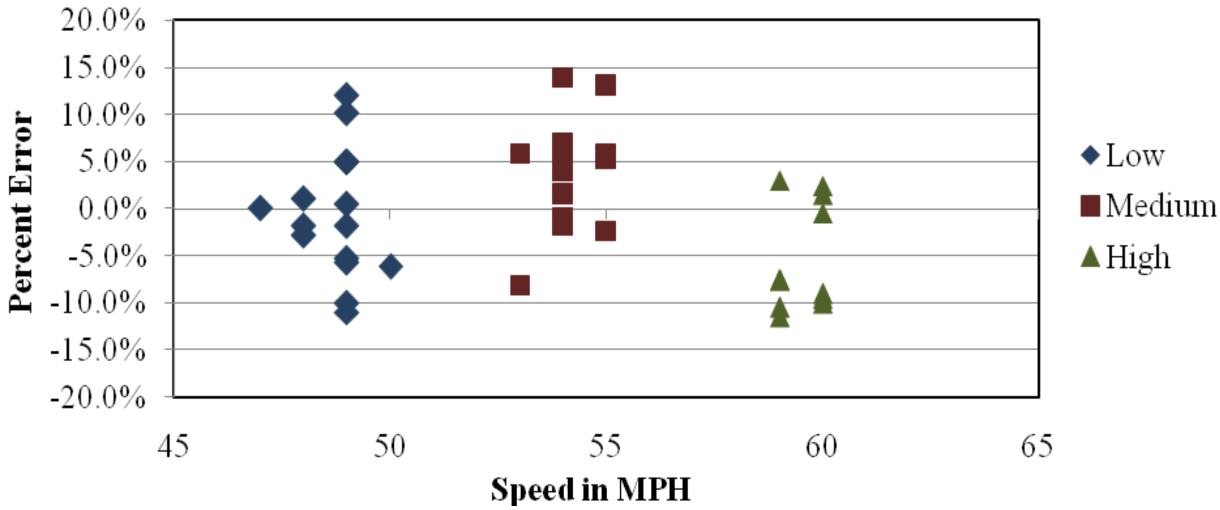



**Figure 5-14 – Post-Validation Steering Axle Weight Errors by Speed – 30-Mar-11**

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-15, the equipment estimated tandem axle weights with similar accuracy at all speed groups. The range in error and bias was similar throughout the entire speed range.

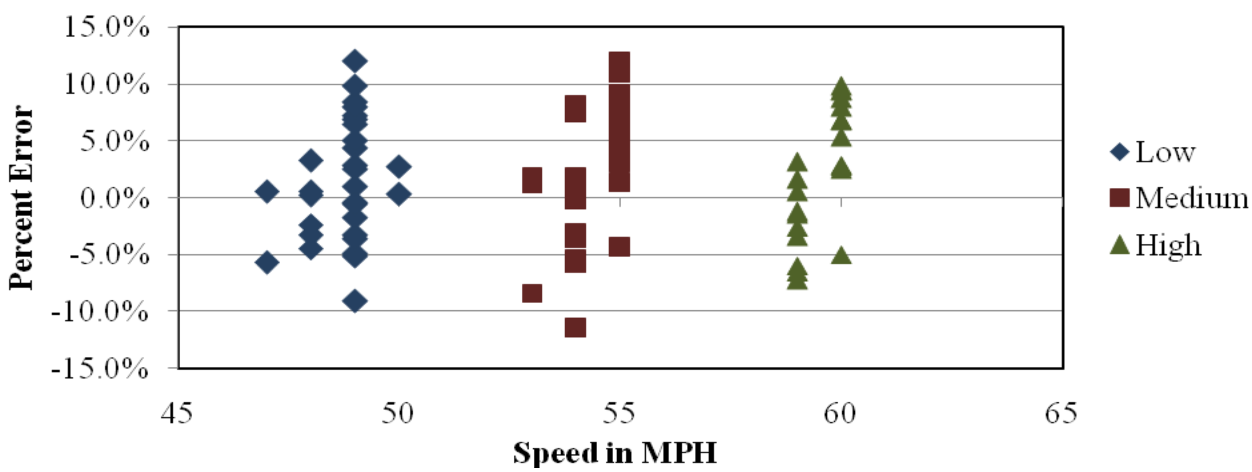



**Figure 5-15 – Post-Validation Tandem Axle Weight Errors by Speed – 30-Mar-11**

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-16 that when the GVW errors are analyzed by truck type, GVW is generally overestimated for the (Secondary) truck and underestimated for the heavily loaded (Primary) truck. Range in GVW error was similar for each truck.

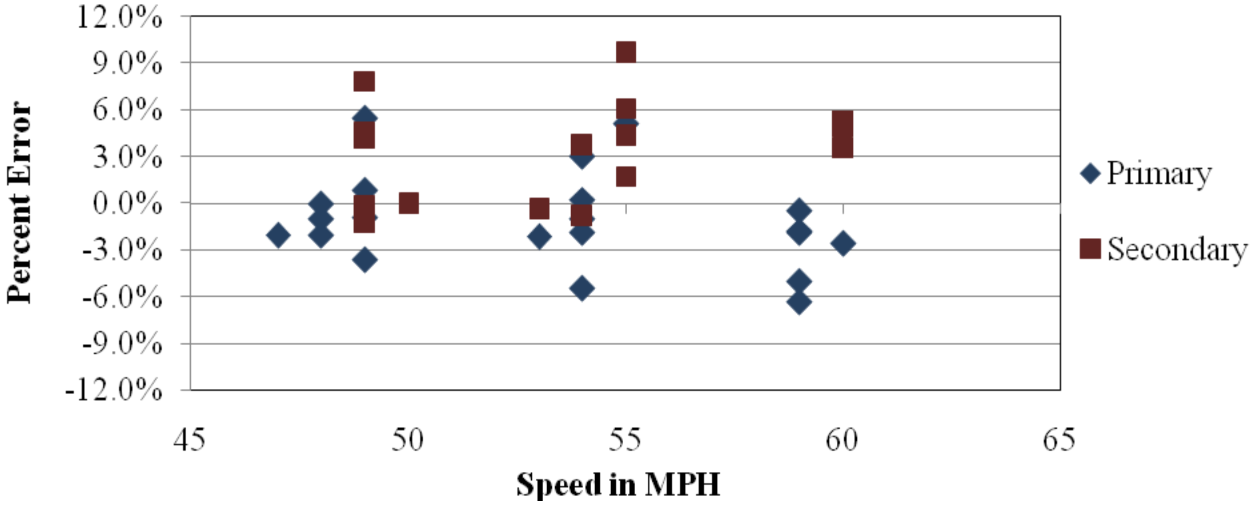



**Figure 5-16 – Post-Validation GVW Error by Truck and Speed – 30-Mar-11**

5.3.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from -0.2 feet to 0.2 feet. Distribution of errors is shown graphically in Figure 5-17.

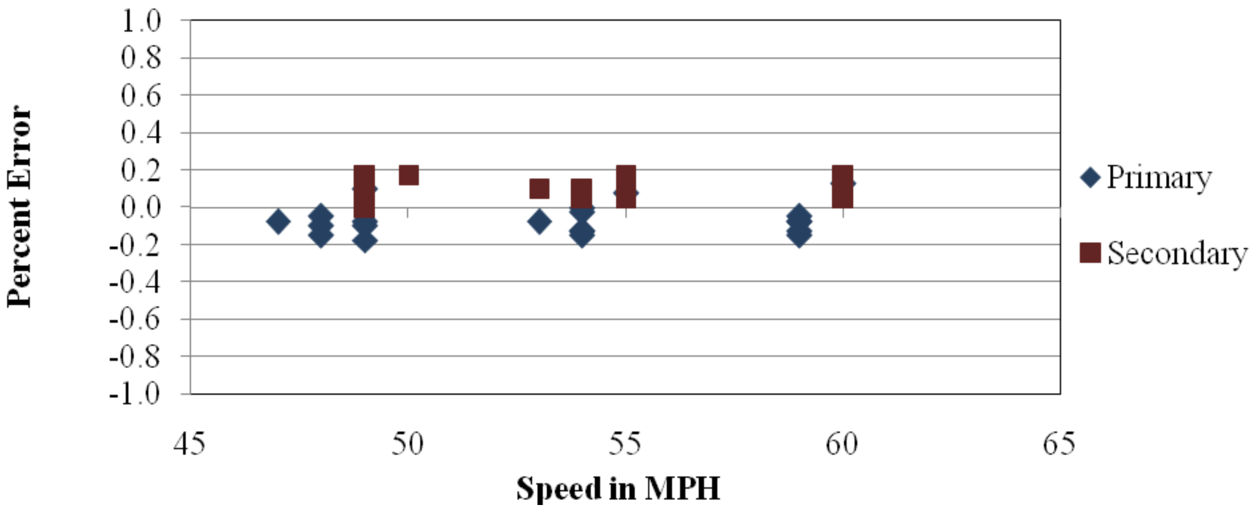



**Figure 5-17 – Post-Validation Axle Length Error by Speed – 30-Mar-11**

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measured overall length consistently over the entire range of speeds, with errors ranging from -0.8 to 1.5 feet. Distribution of errors is shown graphically in Figure 5-18.

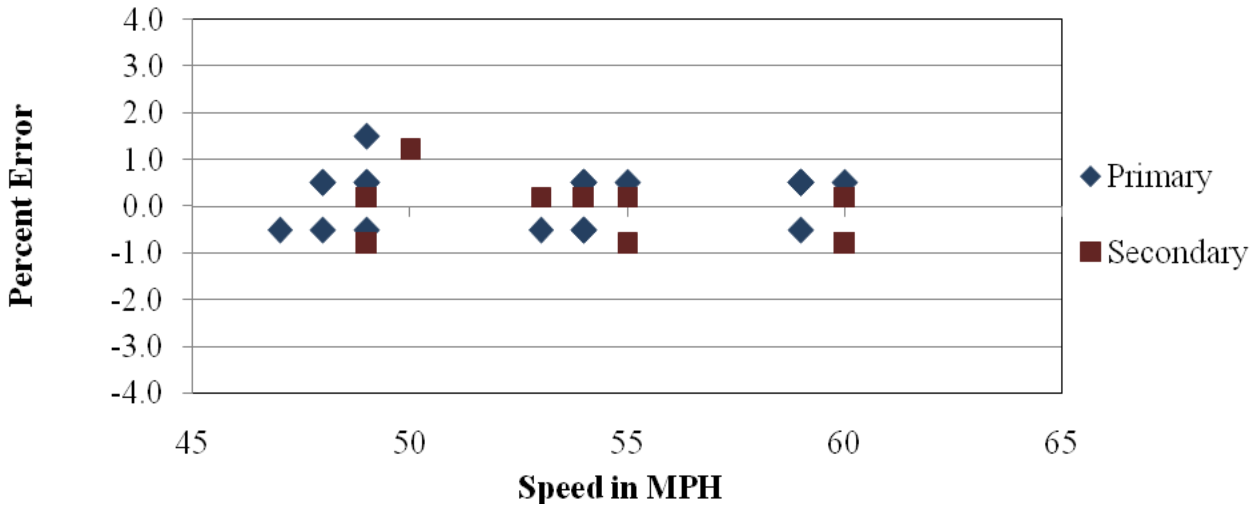



**Figure 5-18 – Post-Validation Overall Length Error by Speed – 30-Mar-11**

### *5.3.2 Statistical Temperature Analysis*

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 11.1 degrees, from 54.2 to 65.3 degrees Fahrenheit. Because of the small temperature range, the post-validation test runs are reported under one temperature group - medium temperature, as shown in Table 5-16 below.

**Table 5-16 – Post-Validation Results by Temperature – 30-Mar-11**

| Parameter | 95% Confidence Limit of Error | Medium |
|---|---|---|
| | | 54.2 to 65.3 degF |
| Steering Axles | +20 percent | -0.4 ± 14.2% |
| Tandem Axles | +15 percent | 1.4 ± 9.5% |
| GVW | +10 percent | 1.0 ± 7.6% |
| Vehicle Length | ±3.0 percent (2.0 ft) | 0.1 ± 1.1 ft |
| Vehicle Speed | ± 1.0 mph | -0.4 ± 2.6 mph |
| Axle Length | + 0.5 ft [150mm] | 0.0 ± 0.2 ft |

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle weights, and axle group weights.

#### 5.3.2.1 GVW Errors by Temperature

From Figure 5-19, it can be seen that the equipment appears to estimate GVW with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

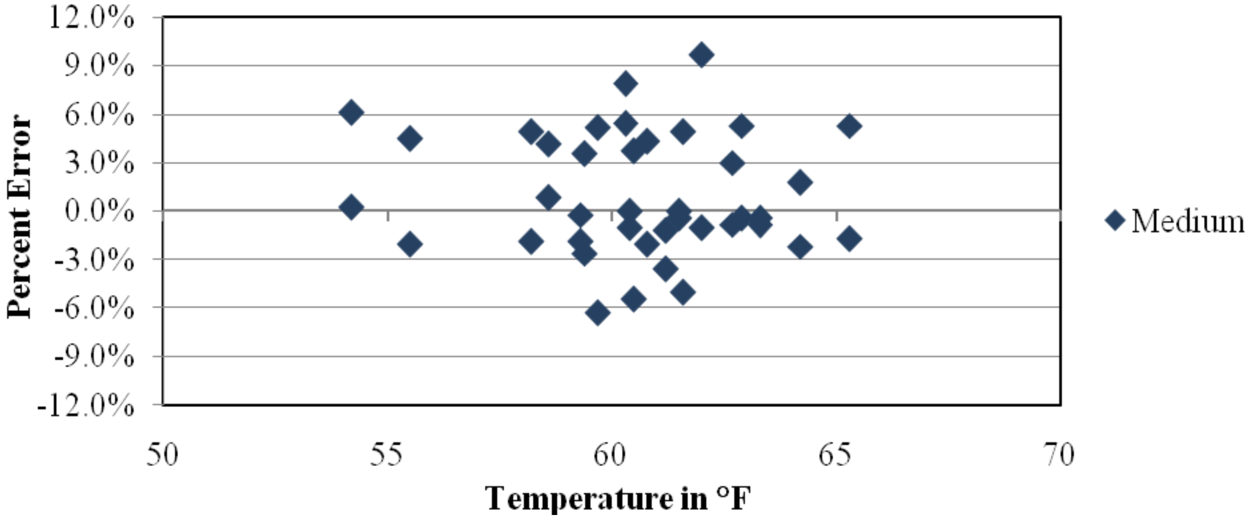



**Figure 5-19 – Post-Validation GVW Errors by Temperature – 30-Mar-11**

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-20 demonstrates that the WIM equipment appears to estimate steering axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and steering axle weight estimates at this site.

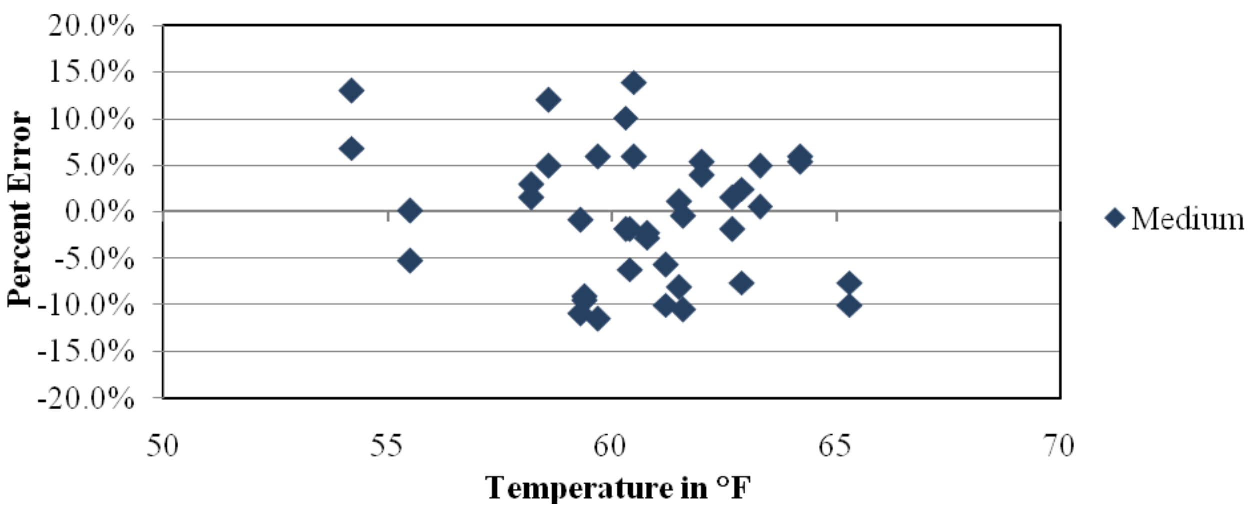



**Figure 5-20 – Post-Validation Steering Axle Weight Errors by Temperature – 30-Mar-11**

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-21, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and tandem axle weight estimates at this site.

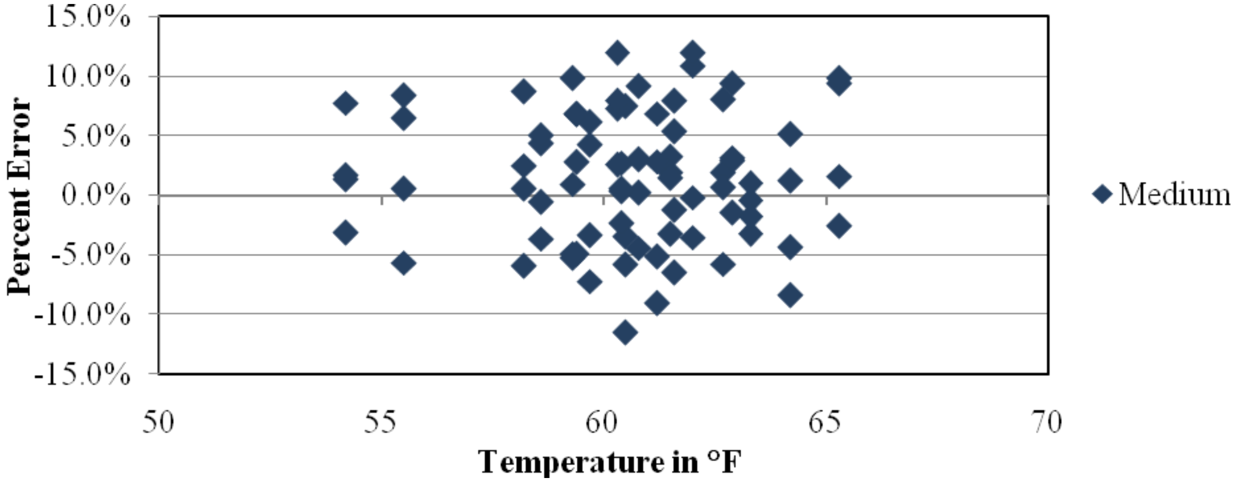



**Figure 5-21 – Post-Validation Tandem Axle Weight Errors by Temperature – 30-Mar-11**

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-22, when analyzed by truck type, the WIM equipment generally overestimates GVW for the partially loaded (Secondary) truck and generally underestimates GVW for the heavily loaded (Primary) truck.

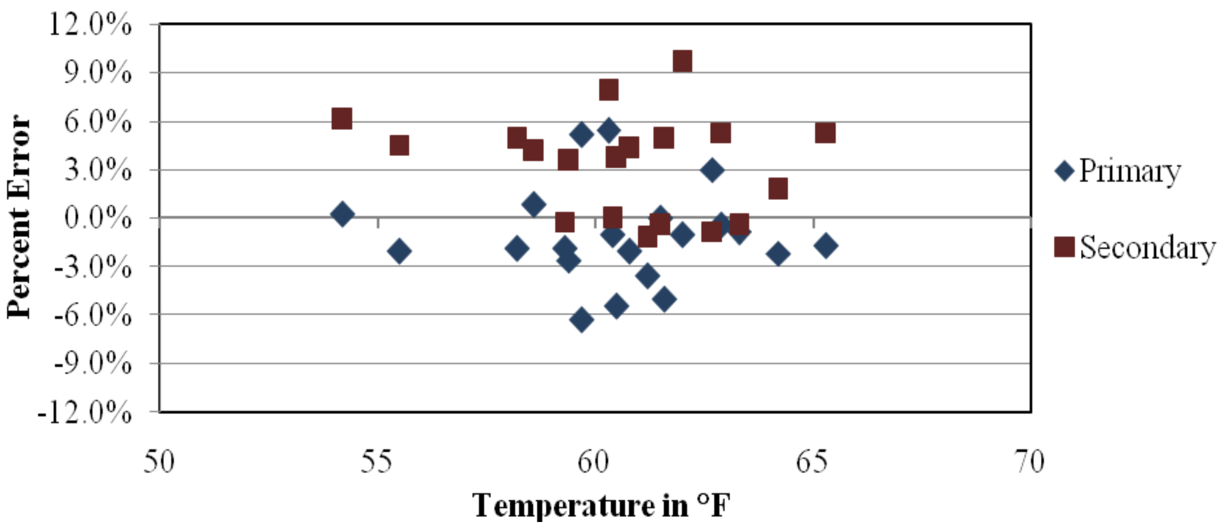



**Figure 5-22 – Post-Validation GVW Error by Truck and Temperature – 30-Mar-11**

### *5.3.3 GVW and Steering Axle Trends*

Figure 5-23 is provided to illustrate the predicted GVW error with respect to the post-validation errors by speed.

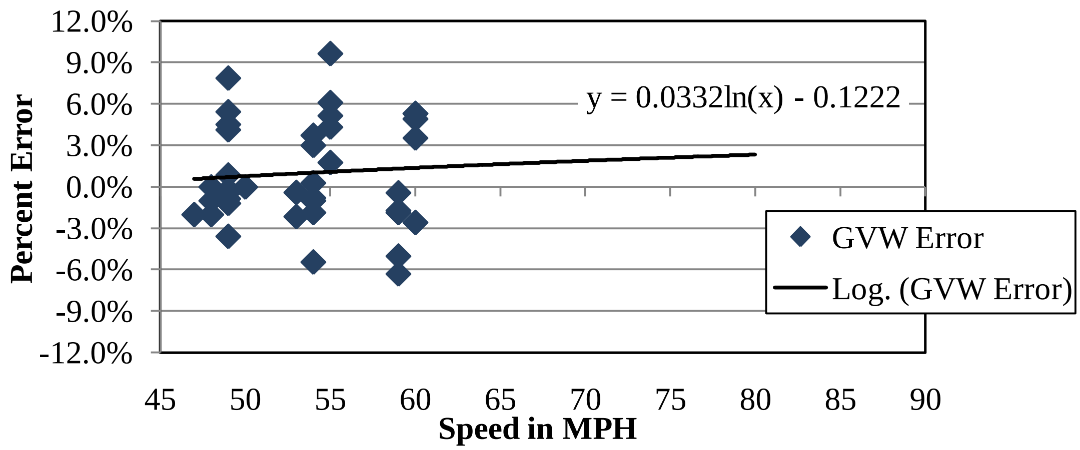



**Figure 5-23 - GVW Error Trend by Speed**

Figure 5-24 is provided to illustrate the predicted Steering Axle error with respect to the post-validation errors by speed.

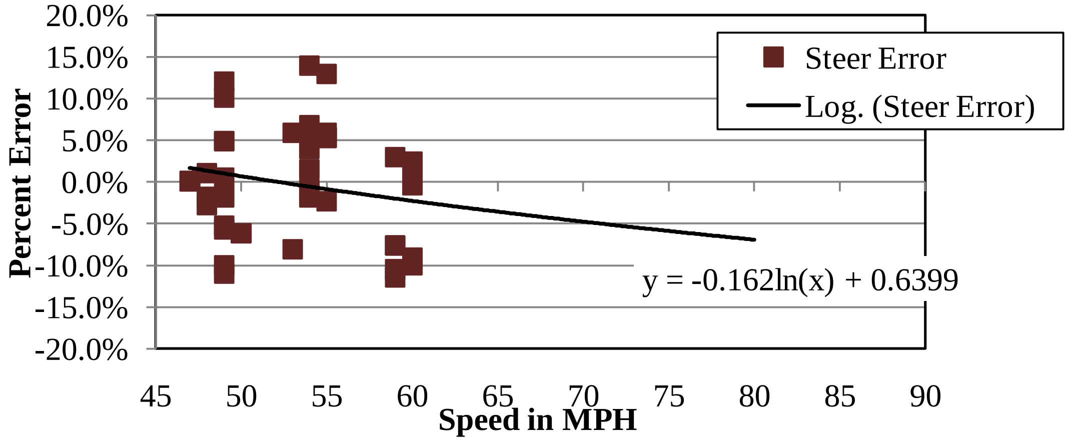



**Figure 5-24 - Steering Axle Trend by Speed**

### *5.3.4 Multivariable Analysis*

This section provides additional analysis of post-validation results using a multivariable statistical technique of multiple linear regression. The same calibration data analyzed and discussed previously are analyzed again, but this time using a more sophisticated statistical methodology. The objective of the additional analysis is to investigate if the trends identified using previous analyses are statistically significant, and to quantify these trends.

Multivariable analyses provide additional insight on how speed, temperature, and truck type affect weight measurement errors for a specific site. It is expected that multivariable analyses done systematically for many sites will reveal overall trends.

#### 5.3.4.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. Compared to analysis described previously, the weight of "axle group" was evaluated separately for tandem axles on tractors and on trailers. The separate evaluation was carried out because the tandem axles on trailers may have different dynamic response to loads than tandem axles on tractors.

The measurement errors were statistically attributed to the following variables or factors:

- Truck type. Primary truck and secondary truck.
- Truck test speed. Truck test speed ranged from 47 to 60 mph.
- Pavement temperature. Pavement temperature ranged from 54.2 to 65.3 degrees Fahrenheit.
- Interaction between the factors such as the interaction between speed and pavement temperature.

#### 5.3.4.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-17. The value of regression coefficients defines the slope of the relationship between the % error in GVW and the predictor variables (speed, temperature, and truck type). The values of the t-distribution (for the regression coefficients) given in Table 5-17 are for the null hypothesis that assumes that the coefficients are equal to zero. Only the effect of truck type was found to be statistically significant. The probability that the effect of truck type on the observed GVW errors occurred by chance alone was less than 1 percent.

**Table 5-17 – Table of Regression Coefficients for Measurement Error of GVW**

| Parameter | Regression coefficients | Standard error | Value of t-distribution | Probability value |
|---|---|---|---|---|
| Intercept | 5.8589 | 12.0846 | 0.4848 | 0.6307 |
| Speed | 0.0422 | 0.1153 | 0.3663 | 0.7163 |
| Temp | -0.1525 | 0.1922 | -0.7933 | 0.4328 |
| Truck | 4.4170 | 0.9909 | 4.4576 | 0.0001 |

The relationship between truck type and measurement errors is shown in **Error! Reference source not found.**. The figure includes trend line for the predicted percent error. Besides the visual assessment of the relationship, **Error! Reference source not found.** provides quantification and statistical assessment of the relationship.

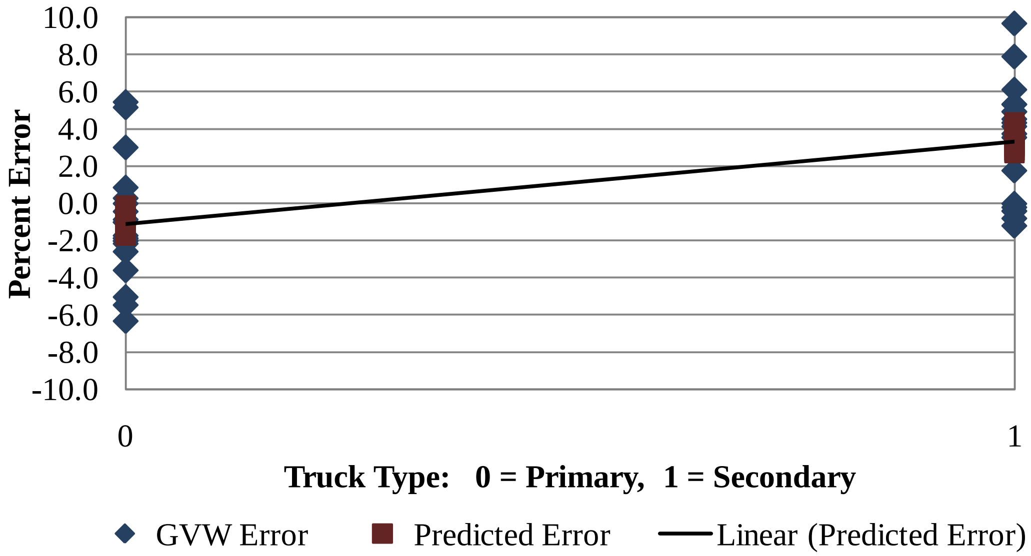



**Figure 5-25 – Influence of Truck Type on the Measurement Error of GVW**

The quantification is provided by the value of the regression coefficient. For example, the regression coefficient temperature (-0.1525 in Table 5-17) means, that for a 10 degree increase in temperature, the % error is decreased by about 1.5 % (-0.1525 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient.

The effect of speed on GVW was not statistically significant. The probability that the regression coefficient for speed is not different from zero was 0.3663. In other words, there is about 36 percent chance that the value of the regression coefficient is due to the chance alone.

The regression coefficient for truck type in Table 5-18 (4.4170), represent the difference between the mean errors for the primary and secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). The mean error in GVW for the secondary truck was about 4.4 % larger than the error for the primary truck. This difference was statistically significant.

The interaction between speed, temperature, and truck type was investigated by adding an interactive variable (or variables) such as the product of speed and temperature. No interactive variables were statistically significant. The intercept was not statistically significant and does not have practical meaning.

#### 5.3.4.3 Summary Results

Table 5-18 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Not listed in the table are factor interactions because the interactions were not statistically significant. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 5-18 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

**Table 5-18 – Summary of Regression Analysis**

| | **Factor** | | | | | |
|---|---|---|---|---|---|---|
| | **Speed** | | **Temperature** | | **Truck type** | |
| Weight, % error | Regression coefficient | Probability value | Regression coefficient | Probability value | Regression coefficient | Probability value |
| GVW | - | - | - | - | 4.4170- | 0.00001 |
| Steering axle | - | - | - | - | - | - |
| Tandem axle tractor | - | - | - | - | 4.4431- | 0.00001 |
| Tandem axle trailer | - | - | - | - | -5.5837 | 0.0006 |

5.3.4.4 Conclusions

1. Speed and temperature had no statistically significant effect on measurement errors.

2. Truck type had statistically significant effect on the GVW, and on the tandem axle trailer weight errors.

3. Even though truck type had statistically significant effect on measurement errors, the practical significance of this effect is small and does not influence the validity of the calibration.

### *5.3.5 Classification and Speed Evaluation*

The post-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment.

For the post-validation classification study at this site, a manual sample of 100 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Table 5-19 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study. Misclassified vehicles are defined as those vehicles that are manually classified by observation as one type of vehicle but identified by the WIM equipment as another type of vehicle. As shown in Table 5-20, six Class 5 vehicles were identified as Class 8 vehicles by the equipment. Additionally, one Class 5 vehicle was identified as a Class 4 (bus) and a Class 6 truck was identified as a Class 9 by the WIM equipment. These misclassifications resulted in an undercount of seven Class 5 vehicles and one Class 6 vehicle, and an overcount of one Class 4 vehicle, six Class 8 vehicles, and one Class 9 vehicle as shown in Table 5-19. There were no unclassified vehicles reported by the equipment.

**Table 5-19 – Post-Validation Classification Study Results – 30-Mar-11**

| Class | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed Count | 0 | 0 | 14 | 6 | 0 | 2 | 49 | 23 | 1 | 1 | 4 |
| WIM Count | 0 | 1 | 7 | 5 | 0 | 8 | 50 | 23 | 1 | 1 | 4 |
| Observed Percent | 0.0 | 0.0 | 14.0 | 6.0 | 0.0 | 2.0 | 49.0 | 23.0 | 1.0 | 1.0 | 4.0 |
| WIM Percent | 0.0 | 1.0 | 7.0 | 5.0 | 0.0 | 8.0 | 50.0 | 23.0 | 1.0 | 1.0 | 4.0 |
| Misclassified Count | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Misclassified Percent | 0.0 | 0.0 | 50.0 | 16.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Unclassified Count | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unclassified Percent | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample. The misclassifications by pair are provided in Table 5-20.

**Table 5-20 – Post-Validation Misclassifications by Pair – 30-Mar-11**

| Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs |
|---|---|---|---|---|---|
| 3/8 | 0 | 6/4 | 0 | 9/5 | 0 |
| 4/5 | 0 | 6/7 | 0 | 9/8 | 0 |
| 4/6 | 0 | 6/8 | 0 | 9/10 | 0 |
| 5/3 | 0 | 6/9 | 1 | 10/9 | 0 |
| 5/4 | 1 | 6/10 | 0 | 10/13 | 0 |
| 5/6 | 0 | 7/6 | 0 | 11/12 | 0 |
| 5/7 | 0 | 8/3 | 0 | 12/11 | 0 |
| 5/8 | 6 | 8/5 | 0 | 13/10 | 0 |
| 5/9 | 0 | 8/9 | 0 | 13/11 | 0 |

Based on the vehicles observed during the post-validation study, the misclassification percentage is 1.2% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 8.0%.

As shown in the table, a total of 8 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. The majority (6) of the misclassifications were Class 5s identified by the WIM equipment as Class 8s. For trucks, a Class 6 truck was identified as a Class 9 by the controller.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-21.

**Table 5-21 – Post-Validation Unclassified Trucks by Pair – 30-Mar-11**

| Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs | Observed/ WIM | Number of Pairs |
|---|---|---|---|---|---|
| 3/15 | 0 | 7/15 | 0 | 11/15 | 0 |
| 4/15 | 0 | 8/15 | 0 | 12/15 | 0 |
| 5/15 | 0 | 9/15 | 0 | 13/15 | 0 |
| 6/15 | 0 | 10/15 | | | |

Based on the manually collected sample of the 100 trucks, 0.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was -0.3 mph; the range of errors was 1.5 mph.

# 6 Previous WIM Site Validation Information

The information reported in this section provides a summary of the performance of the WIM equipment since it was installed or since the first validation was performed on the equipment. The information includes historical data on weight and classification accuracies as well as a comparison of post-validation results.

## 6.1 Sheet 16s

This site has validation information from three previous visits as well as the current one as summarized in the tables below and provided on the Traffic Sheet 16. Table 6-1 data was extracted from the most recent previous validation and was updated to include the results of this validation.

**Table 6-1 – Classification Validation History**

| Date | Misclassification Percentage by Class | | | | | | | | | | Pct Unclass |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
| 28-Nov-06 | N/A | N/A | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 1 |
| 29-Nov-06 | N/A | 0 | 0 | N/A | 50 | 0 | 0 | N/A | 0 | 0 | 1 |
| 11-Jul-07 | N/A | N/A | 0 | N/A | N/A | 0 | 0 | 0 | N/A | N/A | 0 |
| 12-Jul-07 | N/A | N/A | 0 | N/A | 0 | 0 | 0 | 0 | N/A | N/A | 0 |
| 22-Apr-08 | 0 | 33 | 0 | N/A | 50 | 2 | 4 | 0 | N/A | N/A | 0 |
| 23-Apr-08 | 100 | 33 | 100 | N/A | 25 | 2 | 11 | 0 | N/A | N/A | 0 |
| 29-Mar-11 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30-Mar-11 | 0 | 0 | 50 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 6-2 data was extracted from the previous validation and was updated to include the results of this validation. The table provides the mean error and standard deviation for GVW, single axles and tandems for prior pre- and post-validations as reported on the LTPP Traffic Sheet 16s.

**Table 6-2 – Weight Validation History**

| Date | Mean Error and SD | | |
|---|---|---|---|
| | GVW | Single Axles | Tandem |
| 28-Nov-06 | -6.0 ± 4.2 | -12.9 ± 3.6 | -4.5 ± 5.9 |
| 29-Nov-06 | 0.3 ± 3.2 | -3.7 ± 5.7 | 1.2 ± 4.2 |
| 11-Jul-07 | 11.7 ± 2.5 | 6.2 ± 6.6 | 12.7 ± 3.2 |
| 12-Jul-07 | -1.0 ± 2.3 | 0.6 ± 5.5 | -1.2 ± 2.9 |
| 22-Apr-08 | -3.3 ± 2.3 | -2.8 ± 4.6 | -3.2 ± 3.6 |
| 23-Apr-08 | 1.2 ± 3.4 | 3.2 ± 4.8 | 1.0 ± 4.8 |
| 29-Mar-11 | 5.3 ± 3.9 | 4.8 ± 7.1 | 5.3 ± 5.4 |
| 30-Mar-11 | 1.0 ± 3.8 | -0.4 ± 7.0 | 1.4 ± 4.7 |

The variability of the GVW and tandem weight errors appear to have remained reasonably consistent since the site was first validated. Single axle error variability increased for this validation. From the information in the table, it appears that the system does not demonstrate any systematic trend in the estimation of axle weights over time. For example, between the 2006 and 2007 validations, the GVW mean error increased by 11.4 % (0.3 versus 11.7), between 2007 and 2008 it decreased by 2.3 %, and between 2008 and 2011 it increased by 4.1%. The table demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

## 6.2 Comparison of Past Validation Results

A comparison of the post-validation results from previous visits is provided in Table 6-3. The table provides the historical performance of the WIM system with regard to the 95% confidence interval tolerances.

**Table 6-3 – Comparison of Post-Validation Results**

| Parameter | 95 % Confidence Limit of Error | Site Values (Mean Error and 95% Confidence Interval) | | | |
|---|---|---|---|---|---|
| | | **29-Nov-06** | **12-Jul-07** | **23-Apr-08** | **30-Mar-11** |
| Steering Axles | ±20 percent | -3.7 ± 11.5 | 0.6 ± 11.2 | 3.2 ± 9.7 | -0.4 ± 14.2 |
| Tandem Axles | ±15 percent | 1.2 ± 8.4 | -1.2 ± 5.7 | 1.0 ± 9.6 | 1.4 ± 9.5 |
| GVW | ±10 percent | 0.3 ± 6.4 | -1.0 ± 4.7 | 1.2 ± 6.9 | 1.0 ± 7.6 |

From Table 6-3, it appears that the mean errors and the 95% confidence intervals for GVW and tandem axle weights have remained reasonably consistent since the equipment was installed. For steering axle weights, the 95% confidence interval has increased for this validation.

The final factors left in place at the conclusion of the validation are provided in Table 6-4.

**Table 6-4 – Final Factors**

| Speed Point | MPH | Left | Right |
|---|---|---|---|
| | | **1** | **2** |
| 80 | 50 | 6.641266 | 6.641266 |
| 100 | 62 | 6.368410 | 6.368410 |
| 120 | 75 | 6.368410 | 6.368410 |
| **Axle Distance (cm)** | | 119 | |
| **Dynamic Comp (%)** | | 105 | |
| **Loop Width (cm)** | | 98 | |

A review of the LTPP Standard Release Database 24 shows that there are two years of level "E" WIM data for this site. This site requires three additional years of data to meet the minimum of five years of research quality data.

# 7 Additional Information

The following information is provided in the attached appendix:

- Site Photographs
  - Equipment
  - Test Trucks
  - Pavement Condition
- Pre-validation Sheet 16 – Site Calibration Summary
- Post-validation Sheet 16 – Site Calibration Summary
- Pre-validation Sheet 20 – Classification and Speed Study
- Post-validation Sheet 20 – Classification and Speed Study

Additional information is available upon request through LTPP INFO at ltppinfo@dot.gov, or telephone (202) 493-3035. This information includes:

- Sheet 17 – WIM Site Inventory
- Sheet 18 – WIM Site Coordination
- Sheet 19 – Validation Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 24A/B – Site Photograph Logs
- Updated Handout Guide

# WIM System Field Calibration and Validation - Photos

Washington, SPS-2
SHRP ID: 530200

Validation Date: March 30, 2011


**Photo 1 – Cabinet Exterior**

**Photo 2 – Cabinet Interior (Front)**

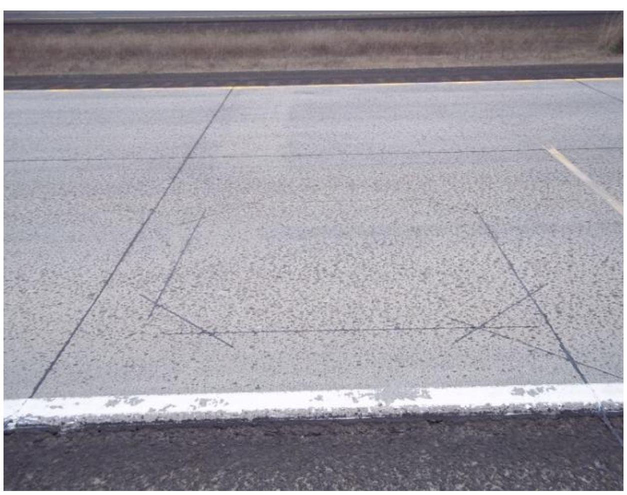


**Photo 3 – Leading Loop**


**Photo 4 – Leading WIM Sensor**


**Photo 5 – Trailing WIM Sensor**

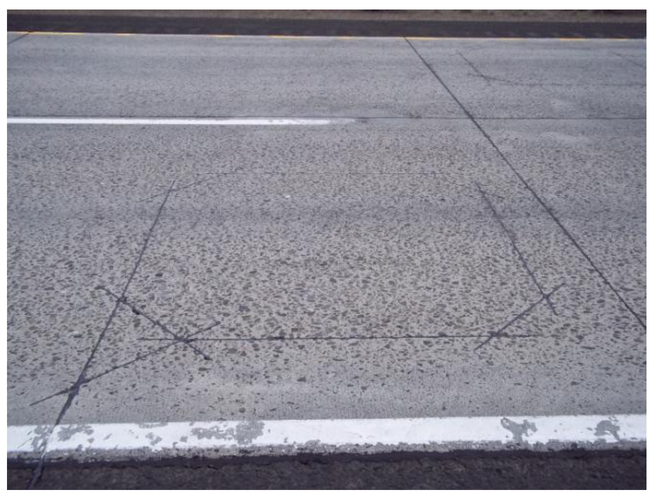


**Photo 6 – Trailing Loop Sensor**

**Photo 7 – Power Service Box**


**Photo 8 – Telephone Service Box**

**Photo 9 – Downstream**

**Photo 10 – Upstream**


**Photo 11 – Truck 1**


**Photo 12 – Truck 1 Tractor**


**Photo 13 – Truck 1 Trailer and Load**

**Photo 14 – Truck 1 Suspension 1**

**Photo 15 – Truck 1 Suspension 2/3**

**Photo 16 – Truck 1 Suspension 4/5**

**Photo 17 – Truck 2**

**Photo 18 – Truck 2 Tractor**

**Photo 19 – Truck 2 Trailer and Load**

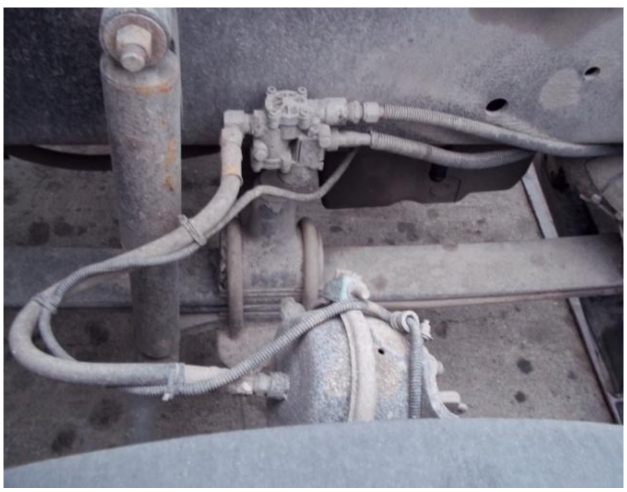


**Photo 20 – Truck 2 Suspension 1**

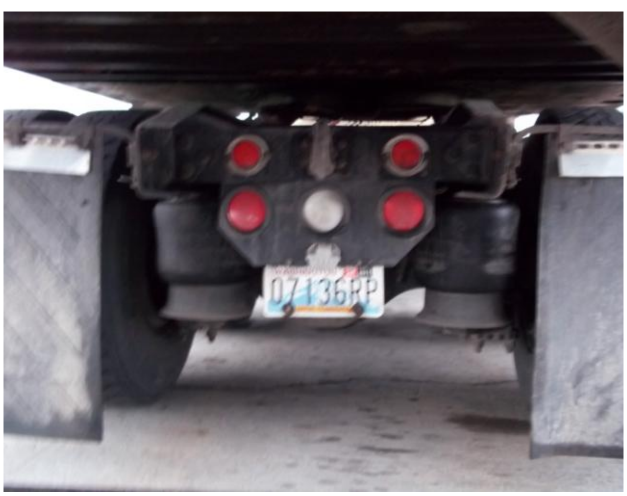


**Photo 21 – Truck 2 Suspension 2/3**

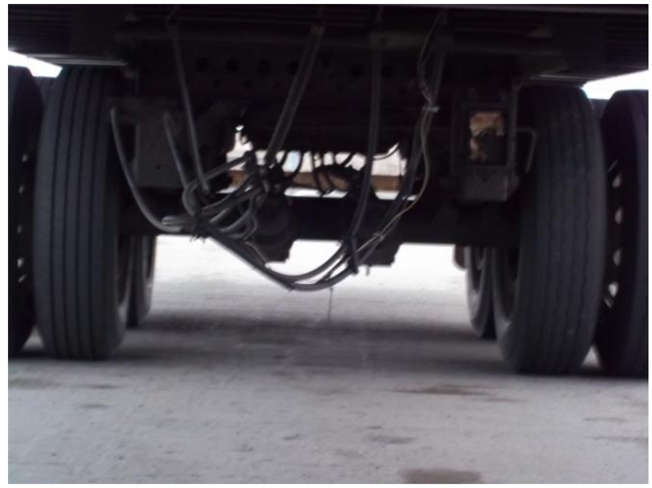


**Photo 22 – Truck 2 Suspension 4/5**

| Traffic Sheet 16 | STATE CODE: | 53 |
|---|---|---|
| LTPP MONITORED TRAFFIC DATA | SPS WIM ID: | 530200 |
| SITE CALIBRATION SUMMARY | DATE (mm/dd/yyyy) | 3/29/2011 |

## SITE CALIBRATION INFORMATION

**1. DATE OF CALIBRATION** {mm/dd/yy} 3/29/11

**2. TYPE OF EQUIPMENT CALIBRATED:** Both

**3. REASON FOR CALIBRATION:** LTPP Validation

**4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE** (Select all that apply):

a. Inductance Loops c. ______

b. Quartz Piezo d. ______

**5. EQUIPMENT MANUFACTURER:** IRD 1060 Series

## WIM SYSTEM CALIBRATION SPECIFICS

**6. CALIBRATION TECHNIQUE USED:** Test Trucks

Number of Trucks Compared: ______

Number of Test Trucks Used: 2

Passes Per Truck: 20

| | Type | Drive Suspension | Trailer Suspension |
|---|---|---|---|
| Truck 1: | 9 | air | air |
| Truck 2: | 9 | air | air |
| Truck 3: | | | |

**7. SUMMARY CALIBRATION RESULTS** (expressed as a %):

Mean Difference Between -

| | | | |
|---|---|---|---|
| Dynamic and Static GVW: | 5.3% | Standard Deviation: | 3.9% |
| Dynamic and Static Single Axle: | 4.8% | Standard Deviation: | 7.1% |
| Dynamic and Static Double Axles: | 5.3% | Standard Deviation: | 5.4% |

**8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED:** 3

**9. DEFINE SPEED RANGES IN MPH:**

| | | | Low | | High | Runs |
|---|---|---|---|---|---|---|
| a. | Low | - | 47.0 | to | 51.3 | 11 |
| b. | Medium | - | 51.4 | to | 55.8 | 15 |
| c. | High | - | 55.9 | to | 60.0 | 14 |
| d. | | - | | to | | |
| e. | | - | | to | | |

| Traffic Sheet 16<br>LTPP MONITORED TRAFFIC DATA<br>SITE CALIBRATION SUMMARY | STATE CODE:<br>SPS WIM ID:<br>DATE (mm/dd/yyyy) | 53<br>530200<br>3/29/2011 |
|---|---|---|

**10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED)** 0 | 0

**11. IS AUTO- CALIBRATION USED AT THIS SITE?** No

If yes , define auto-calibration value(s):

**CLASSIFIER TEST SPECIFICS**

**12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:**

Manual

**13. METHOD TO DETERMINE LENGTH OF COUNT:** Number of Trucks

**14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:**

| | | | | | |
|---|---|---|---|---|---|
| FHWA Class 9: | | FHWA Class | | - | |
| FHWA Class 8: | | FHWA Class | | - | |
| | | FHWA Class | | - | |
| | | FHWA Class | | - | |

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

**Person Leading Calibration Effort:** **Kevin Trousdale**

**Contact Information:** Phone: 717-975-3550

E-mail: ktrousdale@ara.com

| Traffic Sheet 16 | STATE CODE: | 53 |
|---|---|---|
| LTPP MONITORED TRAFFIC DATA | SPS WIM ID: | 530200 |
| SITE CALIBRATION SUMMARY | DATE (mm/dd/yyyy) | 3/30/2011 |

## SITE CALIBRATION INFORMATION

**1. DATE OF CALIBRATION** {mm/dd/yy} 3/30/11

**2. TYPE OF EQUIPMENT CALIBRATED:** Both

**3. REASON FOR CALIBRATION:** LTPP Validation

**4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE** (Select all that apply):

a. Inductance Loops
b. Quartz Piezo
c.
d.

**5. EQUIPMENT MANUFACTURER:** IRD 1060 Series

## WIM SYSTEM CALIBRATION SPECIFICS

**6. CALIBRATION TECHNIQUE USED:** Test Trucks

Number of Trucks Compared:
Number of Test Trucks Used: 2
Passes Per Truck: 20

| | Type | Drive Suspension | Trailer Suspension |
|---|---|---|---|
| Truck 1: | 9 | air | air |
| Truck 2: | 9 | air | air |
| Truck 3: | | | |

**7. SUMMARY CALIBRATION RESULTS** (expressed as a %):

Mean Difference Between -

| | Mean | | Standard Deviation |
|---|---|---|---|
| Dynamic and Static GVW: | 1.0% | Standard Deviation: | 3.8% |
| Dynamic and Static Single Axle: | -0.4% | Standard Deviation: | 7.0% |
| Dynamic and Static Double Axles: | 1.4% | Standard Deviation: | 4.7% |

**8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED:** 3

**9. DEFINE SPEED RANGES IN MPH:**

| | | | Low | | High | Runs |
|---|---|---|---|---|---|---|
| a. | Low | - | 47.0 | to | 51.3 | 15 |
| b. | Medium | - | 51.4 | to | 55.8 | 14 |
| c. | High | - | 55.9 | to | 60.0 | 11 |
| d. | | - | | to | | |
| e. | | - | | to | | |

| Traffic Sheet 16<br>LTPP MONITORED TRAFFIC DATA<br>SITE CALIBRATION SUMMARY | STATE CODE:<br>SPS WIM ID:<br>DATE (mm/dd/yyyy) | 53<br>530200<br>3/30/2011 |
|---|---|---|

**10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED)** 0 | 0

**11. IS AUTO- CALIBRATION USED AT THIS SITE?** No

If yes , define auto-calibration value(s):

**CLASSIFIER TEST SPECIFICS**

**12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:**

Manual

**13. METHOD TO DETERMINE LENGTH OF COUNT:** Number of Trucks

**14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:**

| | | | | | |
|---|---|---|---|---|---|
| FHWA Class 9: | | FHWA Class | 5 | - | |
| FHWA Class 8: | | FHWA Class | | - | |
| | | FHWA Class | | - | |
| | | FHWA Class | | - | |

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Post

**Person Leading Calibration Effort:** **Kevin Trousdale**

**Contact Information:** Phone: 717-975-3550

E-mail: ktrousdale@ara.com

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 53<br>SPS WIM ID: 530200<br>DATE (mm/dd/yyyy) 3/29/2011 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 59 | 13 | 1381 | 60 | 13 | 58 | 10 | 1773 | 58 | 10 |
| 62 | 9 | 1405 | 63 | 9 | 64 | 10 | 1786 | 65 | 10 |
| 60 | 9 | 1412 | 60 | 9 | 63 | 9 | 1789 | 64 | 9 |
| 57 | 9 | 1535 | 62 | 9 | 58 | 9 | 1790 | 59 | 9 |
| 62 | 8 | 1538 | 63 | 5 | 59 | 9 | 1797 | 60 | 9 |
| 59 | 9 | 1546 | 60 | 9 | 60 | 9 | 1798 | 62 | 9 |
| 65 | 10 | 1676 | 67 | 10 | 62 | 9 | 1811 | 61 | 9 |
| 64 | 10 | 1677 | 64 | 10 | 60 | 13 | 1815 | 63 | 13 |
| 62 | 10 | 1679 | 61 | 10 | 61 | 9 | 1818 | 63 | 9 |
| 60 | 10 | 1680 | 61 | 10 | 57 | 9 | 1825 | 59 | 9 |
| 60 | 13 | 1690 | 61 | 13 | 61 | 9 | 1834 | 62 | 9 |
| 60 | 9 | 1705 | 61 | 9 | 59 | 9 | 1839 | 60 | 9 |
| 59 | 9 | 1706 | 58 | 9 | 60 | 10 | 1935 | 60 | 10 |
| 63 | 9 | 1712 | 64 | 9 | 62 | 10 | 1937 | 63 | 10 |
| 59 | 9 | 1706 | 58 | 9 | 61 | 9 | 1945 | 62 | 9 |
| 63 | 9 | 1712 | 64 | 9 | 62 | 10 | 1946 | 63 | 10 |
| 59 | 9 | 1748 | 59 | 9 | 65 | 8 | 1967 | 64 | 5 |
| 59 | 9 | 1755 | 60 | 9 | 60 | 13 | 1979 | 62 | 13 |
| 58 | 9 | 1756 | 61 | 9 | 57 | 9 | 1986 | 55 | 9 |
| 59 | 9 | 1757 | 61 | 9 | 64 | 9 | 1999 | 65 | 9 |
| 59 | 9 | 1758 | 60 | 9 | 60 | 9 | 2079 | 57 | 9 |
| 62 | 9 | 1762 | 63 | 9 | 59 | 9 | 2080 | 56 | 9 |
| 63 | 9 | 1763 | 64 | 9 | 61 | 9 | 2085 | 63 | 9 |
| 59 | 5 | 1769 | 64 | 5 | 60 | 6 | 2086 | 62 | 6 |
| 63 | 9 | 1771 | 64 | 9 | 59 | 9 | 2100 | 58 | 9 |

Sheet 1 - 0 to 50 Start: ____________ Stop: ____________

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 53<br>SPS WIM ID: 530200<br>DATE (mm/dd/yyyy) 3/29/2011 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 61 | 9 | 2103 | 59 | 9 | 57 | 10 | 2354 | 61 | 10 |
| 62 | 9 | 2106 | 60 | 9 | 60 | 9 | 2356 | 61 | 9 |
| 58 | 11 | 2118 | 59 | 11 | 60 | 5 | 2364 | 59 | 5 |
| 59 | 9 | 2122 | 60 | 9 | 64 | 10 | 2365 | 64 | 10 |
| 61 | 10 | 2137 | 62 | 10 | 57 | 9 | 2370 | 59 | 9 |
| 60 | 10 | 2149 | 61 | 10 | 59 | 13 | 2374 | 60 | 13 |
| 57 | 9 | 2151 | 60 | 9 | 59 | 9 | 2385 | 61 | 9 |
| 62 | 9 | 2210 | 64 | 9 | 63 | 8 | 2390 | 62 | 8 |
| 59 | 9 | 2218 | 58 | 9 | 60 | 9 | 2395 | 61 | 9 |
| 60 | 9 | 2221 | 62 | 9 | 63 | 5 | 2404 | 64 | 5 |
| 59 | 4 | 2222 | 58 | 4 | 60 | 13 | 2406 | 61 | 13 |
| 61 | 10 | 2223 | 62 | 10 | 61 | 9 | 2408 | 60 | 9 |
| 60 | 13 | 2239 | 63 | 13 | 60 | 6 | 2410 | 62 | 6 |
| 62 | 10 | 2255 | 63 | 10 | 60 | 9 | 2416 | 65 | 9 |
| 62 | 10 | 2258 | 63 | 10 | 59 | 9 | 2424 | 58 | 9 |
| 59 | 9 | 2259 | 59 | 9 | 59 | 9 | 2499 | 60 | 9 |
| 64 | 9 | 2260 | 62 | 9 | 63 | 9 | 2500 | 61 | 9 |
| 67 | 10 | 2263 | 67 | 10 | 59 | 13 | 2504 | 61 | 13 |
| **64** | **4** | **2328** | **64** | **5** | 57 | 9 | 2507 | 58 | 9 |
| 62 | 5 | 2330 | 62 | 5 | 60 | 9 | 2509 | 60 | 9 |
| 60 | 9 | 2339 | 61 | 9 | 68 | 5 | 2514 | 66 | 5 |
| 60 | 9 | 2341 | 59 | 9 | 61 | 10 | 2516 | 63 | 10 |
| 62 | 9 | 2348 | 63 | 9 | 61 | 9 | 2528 | 64 | 9 |
| 61 | 9 | 2349 | 63 | 9 | 60 | 9 | 2530 | 62 | 9 |
| 63 | 13 | 2350 | 63 | 13 | 58 | 9 | 2535 | 60 | 9 |

Sheet 2 - 51 to 100 Start: ________ Stop: ________

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 53<br>SPS WIM ID: 530200<br>DATE (mm/dd/yyyy) 1/0/1900 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 61 | 12 | 2536 | 62 | 12 | | | | | |
| 62 | 9 | 2539 | 64 | 9 | | | | | |
| 50 | 6 | 2542 | 52 | 6 | | | | | |
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Sheet 3 - 101 - 150 Start: ____________ Stop: ____________

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: | 53 |
|---|---|---|
| | SPS WIM ID: | 530200 |
| | DATE (mm/dd/yyyy) | 1/0/1900 |

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
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Sheet 4 - 151 to 200 Start: ____________ Stop: ____________

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 53<br>SPS WIM ID: 530200<br>DATE (mm/dd/yyyy) 3/30/2011 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 10 | 1298 | 60 | 10 | 59 | 10 | 1485 | 60 | 10 |
| 60 | 11 | 1308 | 61 | 11 | 60 | 9 | 1514 | 60 | 9 |
| 59 | 10 | 1311 | 59 | 10 | 66 | 9 | 1516 | 65 | 9 |
| 56 | 9 | 1323 | 54 | 9 | 60 | 10 | 1535 | 61 | 10 |
| **68** | **8** | **1332** | **64** | **5** | 57 | 10 | 1536 | 59 | 10 |
| 64 | 10 | 1335 | 63 | 10 | 62 | 10 | 1538 | 62 | 10 |
| 63 | 9 | 1341 | 62 | 9 | 65 | 9 | 1548 | 67 | 9 |
| 60 | 9 | 1342 | 60 | 9 | 66 | 10 | 1555 | 72 | 10 |
| 61 | 9 | 1352 | 63 | 9 | **60** | **9** | **1558** | **60** | **6** |
| 58 | 13 | 1359 | 56 | 13 | 57 | 10 | 1559 | 61 | 10 |
| 60 | 10 | 1405 | 61 | 10 | 61 | 9 | 1561 | 61 | 9 |
| 59 | 10 | 1407 | 59 | 10 | 62 | 10 | 1565 | 62 | 10 |
| 57 | 9 | 1413 | 56 | 9 | 60 | 9 | 1574 | 61 | 9 |
| 63 | 9 | 1417 | 64 | 9 | 62 | 9 | 1585 | 65 | 9 |
| 61 | 9 | 1420 | 62 | 9 | 58 | 10 | 1602 | 59 | 10 |
| 56 | 9 | 1421 | 57 | 9 | 62 | 9 | 1605 | 62 | 9 |
| 59 | 10 | 1432 | 60 | 10 | **60** | **4** | **1945** | **58** | **5** |
| 60 | 10 | 1433 | 61 | 10 | 55 | 9 | 1948 | 57 | 9 |
| 65 | 9 | 1437 | 64 | 9 | 62 | 9 | 1950 | 63 | 9 |
| 61 | 9 | 1452 | 61 | 9 | 60 | 10 | 1959 | 61 | 10 |
| 62 | 5 | 1456 | 63 | 5 | 65 | 6 | 1960 | 64 | 6 |
| 58 | 9 | 1460 | 58 | 9 | 65 | 6 | 1961 | 64 | 6 |
| 61 | 9 | 1463 | 62 | 9 | 60 | 9 | 1963 | 60 | 9 |
| 60 | 5 | 1472 | 60 | 5 | 65 | 6 | 1966 | 66 | 6 |
| 60 | 9 | 1475 | 61 | 9 | 62 | 9 | 2037 | 61 | 9 |

Sheet 1 - 0 to 50 Start: 9:09:22 Stop: 10:58:40

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Post Val

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 53<br>SPS WIM ID: 530200<br>DATE (mm/dd/yyyy) 3/30/2011 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 61 | 9 | 2049 | 63 | 9 | 60 | 10 | 2251 | 60 | 10 |
| **57** | **8** | **2067** | **57** | **5** | 64 | 13 | 2255 | 66 | 13 |
| 59 | 9 | 2074 | 59 | 9 | 65 | 8 | 2257 | 65 | 8 |
| 62 | 5 | 2082 | 63 | 5 | 57 | 5 | 2262 | 58 | 5 |
| 57 | 9 | 2090 | 54 | 9 | 61 | 9 | 2271 | 62 | 9 |
| 63 | 9 | 2092 | 63 | 9 | 60 | 9 | 2280 | 62 | 9 |
| 62 | 13 | 2093 | 62 | 13 | 63 | 10 | 2282 | 63 | 10 |
| 59 | 9 | 2095 | 59 | 9 | 60 | 5 | 2338 | 60 | 5 |
| **65** | **8** | **2097** | **67** | **5** | 60 | 9 | 2366 | 58 | 9 |
| **55** | **8** | **2106** | **55** | **5** | 59 | 9 | 2372 | 59 | 9 |
| 58 | 9 | 2112 | 56 | 9 | 61 | 10 | 2374 | 59 | 10 |
| 59 | 9 | 2118 | 62 | 9 | 51 | 6 | 2390 | 51 | 6 |
| 61 | 9 | 2122 | 61 | 9 | 62 | 9 | 2417 | 62 | 9 |
| 63 | 9 | 2126 | 64 | 9 | **70** | **8** | **2452** | **70** | **5** |
| 59 | 10 | 2132 | 59 | 10 | 62 | 9 | 2476 | 62 | 9 |
| 68 | 6 | 2182 | 65 | 6 | 60 | 9 | 2486 | 62 | 9 |
| 63 | 8 | 2183 | 62 | 8 | 59 | 9 | 2493 | 56 | 9 |
| 60 | 12 | 2184 | 57 | 12 | 62 | 9 | 2504 | 59 | 9 |
| 57 | 9 | 2185 | 58 | 9 | 62 | 9 | 2509 | 62 | 9 |
| 62 | 13 | 2190 | 62 | 13 | 62 | 9 | 2512 | 62 | 9 |
| 60 | 9 | 2203 | 61 | 9 | 59 | 9 | 2513 | 60 | 9 |
| 60 | 10 | 2212 | 60 | 10 | 63 | 9 | 2515 | 65 | 9 |
| 68 | 5 | 2224 | 68 | 5 | **60** | **8** | **2542** | **61** | **5** |
| 61 | 10 | 2236 | 62 | 10 | 59 | 9 | 2545 | 59 | 9 |
| 65 | 5 | 2246 | 67 | 5 | 61 | 10 | 2553 | 62 | 10 |

Sheet 2 - 51 to 100    Start: 11:00:06    Stop: 12:10:03

Recorded By: ar    Verified By: dw

Validation Test Truck Run Set - Post Val