# WIM System Field Calibration and Validation Summary Report

Texas SPS-1
SHRP ID – 480100

Validation Date: January 25, 2011
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# 1 Executive Summary

A WIM validation was performed on January 25 and 26, 2011 at the Texas SPS-1 site located on route US-281 at milepost 34.0, 9.2 miles north of SR 186.

This site was installed in February, 2005. The in-road sensors are installed in the southbound lane. The site is equipped with bending plate WIM sensors and IRD DAW WIM controller. The LTPP lane is identified as lane 4 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on December 10, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

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, cracking in the pavement across both lanes in the LTPP direction and within the WIM Scale area was noted. A visual observation of the trucks as they approach, traverse, and leave the sensor area indicate some bouncing in LTPP lane as trucks cross the transition from asphalt to PCC pavement surfaces. The truck dynamics do appear to diminish prior to the WIM scale sensors. 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 – 25-Jan-11**

| **Parameter** | **95% Confidence Limit of Error** | **Site Values** | **Pass/Fail** |
|---|---|---|---|
| Steering Axles | ±20 percent | -2.4 ± 6.6% | Pass |
| Single Axles | ±20 percent | 0.7 ± 7.9% | Pass |
| Tandem Axles | ±15 percent | 1.5 ± 3.6% | Pass |
| GVW | ±10 percent | 0.3 ± 2.9% | Pass |
| Vehicle Length | ±3 percent (2 ft) | 0.0 ± 0.8 ft | Pass |
| Axle Length | ± 0.5 ft [150mm] | -0.1 ± 0.1 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 1.6 ± 3.6 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 -0.1 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 not providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 4.1% is greater than the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 4.0% from the 100 truck sample (Class 4 – 13) was due to misclassifications of Class 6 and Class 9 trucks as well as cross-classifications of Class 3, 4, 5, and 8 vehicles.

Based on these findings, it is recommended that an expanded investigation focusing on vehicle classification issues indicated in this report be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

There were three 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 on the trailer tandem, standard tandem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with dry bulk sand.

- The *Third* truck was a Class 9 vehicle, with air suspension on the tractor tandem, air on the trailer tandem, standard tandem spacing on the tractor and split tandem on the trailer. The truck was an empty flatbed equipped with a boom.

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. 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 | 77.8 | 10.4 | 16.6 | 16.6 | 17.1 | 17.1 | 12.0 | 4.3 | 31.1 | 4.0 | 51.4 | 58.2 |
| 2 | 77.9 | 11.4 | 16.7 | 16.7 | 16.6 | 16.6 | 15.1 | 4.4 | 32.0 | 4.1 | 55.6 | 61.8 |
| 3 | 65.4 | 24.8 | 14.1 | 14.1 | 6.2 | 6.2 | 23.8 | 4.5 | 33.0 | 10.2 | 71.5 | 79.8 |

The posted speed limit at the site is 70 mph. During the testing, the speed of the test trucks ranged from to 59 to 70 mph, a variance of 11 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 49.2 to 75.1

degrees Fahrenheit, a range of 25.9 degrees Fahrenheit. The sunny weather conditions nearly provided for attaining the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 24 shows that there are 33 consecutive months of level "E" WIM data for this site. This site requires at least 2 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 November 10, 2010 (Data) to the most recent Comparison Data Set (CDS) from January 10, 2009. 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 3 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2005 through 2009.

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

| Year | Total Number of Days in Year | Number of Months |
|---|---|---|
| 2005 | 30 | 1 |
| 2006 | 272 | 10 |
| 2007 | 246 | 10 |
| 2008 | 211 | 7 |
| 2009 | 138 | 5 |

As shown in the table, 2005 and 2009 data do not meet the 210-day minimum requirement for a calendar year. Consequently, this site requires 2 additional years of data to meet the minimum of five years of research quality data.

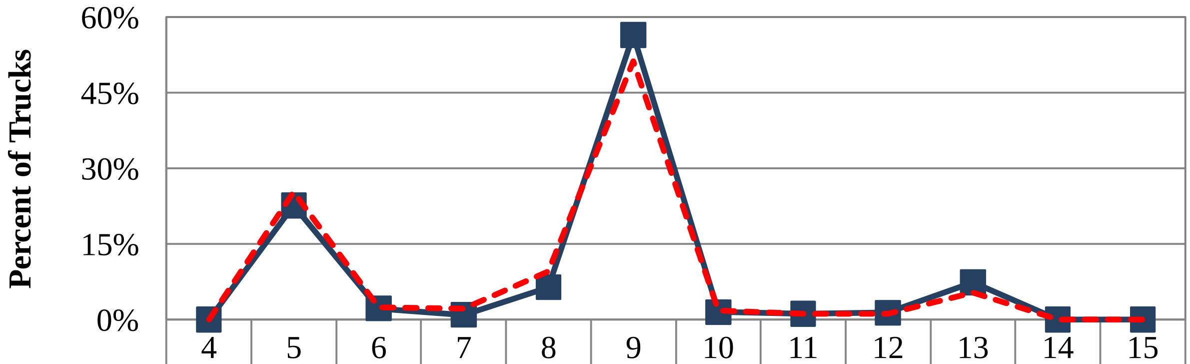
Table 2-2 provides a monthly breakdown of the available data for years 2005 through 2009.

**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 | |
| 2005 | | | | | | | | | 30 | | | | 1 |
| 2006 | 31 | 28 | 31 | 30 | | | 18 | 24 | 23 | 31 | 29 | 27 | 10 |
| 2007 | 3 | 21 | | 29 | 19 | 27 | 31 | 31 | 24 | 31 | 30 | | 10 |
| 2008 | | 29 | | 30 | | 30 | | 31 | 30 | 31 | 30 | | 7 |
| 2009 | 31 | 28 | 29 | 23 | 27 | | | | | | | | 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.




| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data | 0.0% | 22.6% | 2.2% | 0.9% | 6.4% | 56.5% | 1.5% | 1.2% | 1.4% | 7.3% | 0.0% | 0.0% |
| CDS | 0.0% | 25.3% | 2.4% | 2.1% | 9.5% | 51.2% | 1.7% | 1.2% | 1.1% | 5.4% | 0.0% | 0.0% |

**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. 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 shows that according to the most recent data, the most frequent truck types crossing the WIM scale are Class 9 (56.5%) and Class 5 (22.6%). Table 2-3 also provides data for vehicle Classes 14 and 15. The table indicates that 0.0 percent of the vehicles at this site are unclassified.

From the table it can be seen that the percentage of Class 9 vehicles has increased by 5.2 percent from January 2009 and November 2010. Changes in the percentage of heavier trucks may be attributed to seasonal variations in truck distributions. During the same time period, the percentage of Class 5 trucks decreased by 2.7 percent. These differences may be attributed to small sample size used to develop vehicle class distributions, 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.

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

| Vehicle Classification | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 1/10/2009 | | 11/10/2010 | | |
| 4 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 5 | 1192 | 25.3% | 835 | 22.6% | -2.7% |
| 6 | 115 | 2.4% | 81 | 2.2% | -0.2% |
| 7 | 101 | 2.1% | 34 | 0.9% | -1.2% |
| 8 | 446 | 9.5% | 236 | 6.4% | -3.1% |
| 9 | 2412 | 51.2% | 2083 | 56.5% | 5.2% |
| 10 | 81 | 1.7% | 55 | 1.5% | -0.2% |
| 11 | 55 | 1.2% | 43 | 1.2% | 0.0% |
| 12 | 52 | 1.1% | 50 | 1.4% | 0.3% |
| 13 | 254 | 5.4% | 271 | 7.3% | 2.0% |
| 14 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 15 | 0 | 0.0% | 0 | 0.0% | 0.0% |

## 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.

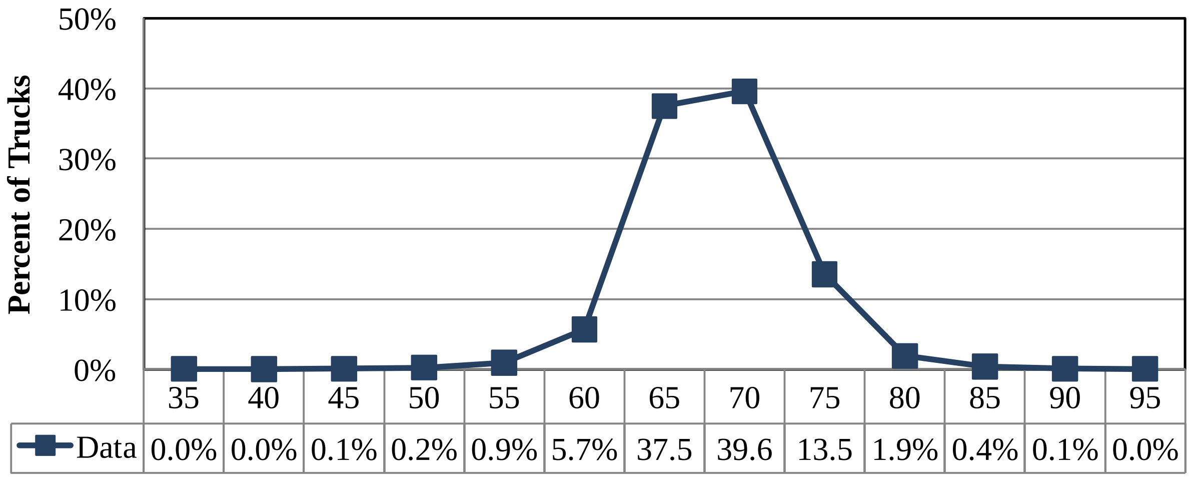


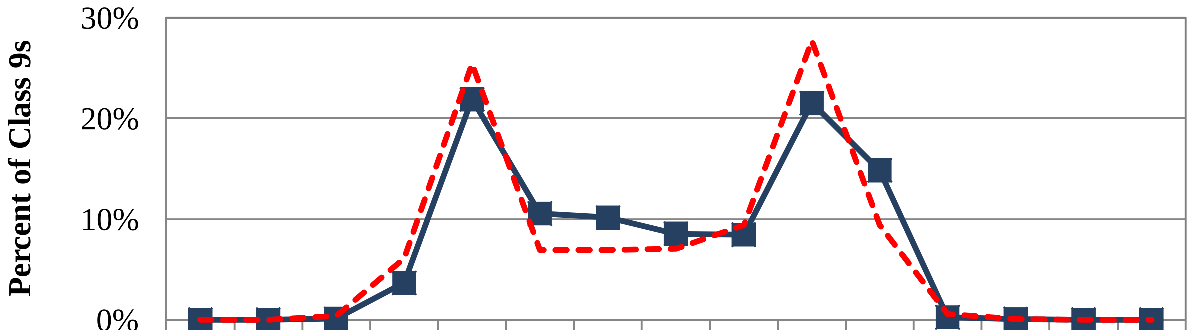

**Figure 2-2 – Truck Speed Distribution – 01-Jan-11**

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 65 and 75 mph. The posted speed limit at this site is 70 and the 85th percentile speed for trucks at this site is 71 mph. The range of truck speeds for the validation will be 60 to 70 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 November 2010 and the Comparison Data Set from January 2009.

As shown in Figure 2-3, there is downward shift for the unloaded and loaded peaks between the January 2009 Comparison Data Set (CDS) and the November 2010 two-week sample W-card dataset (Data) where the percentage of unloaded and loaded trucks has decreased.




| | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 112 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data | 0.0% | 0.0% | 0.1% | 3.7% | 21.9 | 10.5 | 10.2 | 8.5% | 8.4% | 21.5 | 14.8 | 0.2% | 0.0% | 0.0% | 0.0% |
| CDS | 0.0% | 0.0% | 0.4% | 6.1% | 25.4 | 6.9% | 6.9% | 7.1% | 9.4% | 27.7 | 9.4% | 0.6% | 0.0% | 0.0% | 0.0% |

**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. As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 3.5 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 6.2 percent. The percentage of overweight trucks increased during this time period by 5.1 percent and based on the average Class 9 GVW values from the per vehicle records, the overall GVW average for this site increased from 57.8 kips to 58.8 kips.

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

| GVW weight bins (kips) | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 1/10/2009 | | 11/10/2010 | | |
| 8 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 16 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 24 | 9 | 0.4% | 2 | 0.1% | -0.3% |
| 32 | 143 | 6.1% | 75 | 3.7% | -2.4% |
| 40 | 596 | 25.4% | 449 | 21.9% | -3.5% |
| 48 | 162 | 6.9% | 216 | 10.5% | 3.6% |
| 56 | 162 | 6.9% | 208 | 10.2% | 3.2% |
| 64 | 166 | 7.1% | 175 | 8.5% | 1.5% |
| 72 | 221 | 9.4% | 173 | 8.4% | -1.0% |
| 80 | 649 | 27.7% | 441 | 21.5% | -6.2% |
| 88 | 221 | 9.4% | 304 | 14.8% | 5.4% |
| 96 | 13 | 0.6% | 5 | 0.2% | -0.3% |
| 104 | 1 | 0.0% | 1 | 0.0% | 0.0% |
| 112 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| 120 | 0 | 0.0% | 0 | 0.0% | 0.0% |
| Average = | 57.8 | | 58.8 | | 1.0 |

## 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 November 2010 and the Comparison Data Set from January 2009.

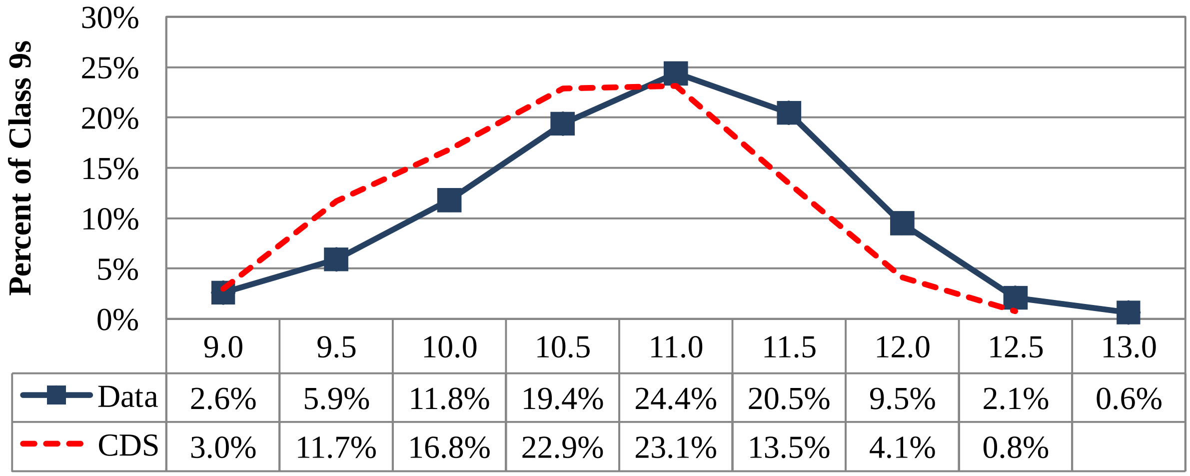



**Figure 2-4 – Distribution of Class 9 Front Axle Weights**

It can be seen in the figure that the front axle weights have increased between the January 2009 Comparison Data Set (CDS) and the November 2010 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the January 2009 Comparison Data Set (CDS) and the November 2010 dataset (Data).

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

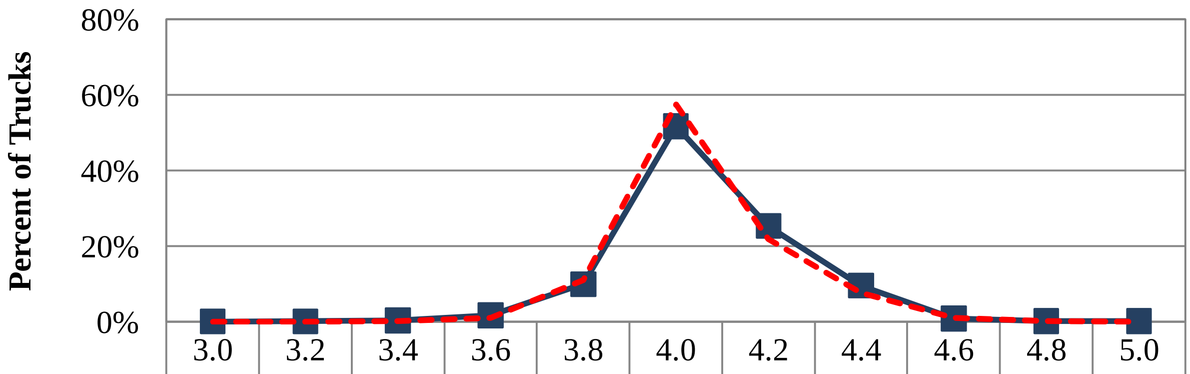
| F/A weight bins (kips) | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 1/10/2009 | | 11/10/2010 | | |
| 9.0 | 91 | 3.9% | 65 | 3.2% | -0.7% |
| 9.5 | 70 | 3.0% | 53 | 2.6% | -0.4% |
| 10.0 | 272 | 11.7% | 121 | 5.9% | -5.7% |
| 10.5 | 392 | 16.8% | 241 | 11.8% | -5.0% |
| 11.0 | 533 | 22.9% | 396 | 19.4% | -3.5% |
| 11.5 | 539 | 23.1% | 498 | 24.4% | 1.3% |
| 12.0 | 314 | 13.5% | 418 | 20.5% | 7.0% |
| 12.5 | 96 | 4.1% | 194 | 9.5% | 5.4% |
| 13.0 | 18 | 0.8% | 43 | 2.1% | 1.3% |
| 13.5 | 5 | 0.2% | 13 | 0.6% | 0.4% |
| Average = | 10.8 | | 11.1 | | 0.3 |

The table shows that the average front axle weight for Class 9 trucks has increased by 0.3 kips, or 2.7 percent. According to the current data, the majority of the Class 9 front axle weights are between 11.0 and 11.5 kips and based on the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.1 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 with the expected average tractor tandem spacing from the comparison data set.

The class 9 tractor tandem spacing plots in Figure 2-5 are 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% | 0.3% | 1.7% | 10.0% | 51.7% | 25.3% | 9.6% | 0.9% | 0.1% | 0.2% |
| CDS | 0.0% | 0.0% | 0.1% | 0.9% | 11.0% | 57.5% | 21.9% | 7.6% | 0.9% | 0.1% | 0.0% |

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

As seen in the figure, the Class 9 tractor tandem spacing for the January 2009 Comparison Data Set and the November 2010 Data are nearly identical.

Table 2-6 shows the Class 9 axle spacings between the second and third axles. From the table, it can be seen that the spacing of the tractor tandems for Class 9 trucks at this site is between 3.8 and 4.4 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.0 feet, which is identical to the expected average of 4.0 feet from the CDS per vehicle records. Further analyses are performed during the validation and post-validation analysis.

**Table 2-6 – Class 9 Axle 3 to 4 Spacing from W-Card**

| Tandem 1 spacing bins (feet) | CDS | | Data | | Change |
|---|---|---|---|---|---|
| | Date | | | | |
| | 1/10/2009 | | 11/10/2010 | | |
| 3.0 | 0 | 0.0% | 1 | 0.0% | 0.0% |
| 3.2 | 0 | 0.0% | 2 | 0.1% | 0.1% |
| 3.4 | 2 | 0.1% | 7 | 0.3% | 0.3% |
| 3.6 | 22 | 0.9% | 35 | 1.7% | 0.8% |
| 3.8 | 257 | 11.0% | 204 | 10.0% | -1.0% |
| 4.0 | 1347 | 57.5% | 1060 | 51.7% | -5.8% |
| 4.2 | 512 | 21.9% | 519 | 25.3% | 3.5% |
| 4.4 | 178 | 7.6% | 196 | 9.6% | 2.0% |
| 4.6 | 22 | 0.9% | 18 | 0.9% | -0.1% |
| 4.8 | 2 | 0.1% | 3 | 0.1% | 0.1% |
| 5.0 | 1 | 0.0% | 4 | 0.2% | 0.2% |
| Average = | 4.0 | | 4.0 | | 0.0 |

## 2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (January 2009) based on the last calibration with the most recent two-week WIM data sample from the site (November 2010). Comparison of vehicle class distribution data indicates a 5.2 percent increased in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that the average front axle weights have decreased by 0.3 percent and average Class 9 GVW has increased by 1.7 percent for the November 2010 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical to 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 December 10, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

## 3.1 Description

This site was installed on February, 2005 by Texas DOT. It is instrumented with bending plate weighing sensors and IRD DAW WIM Controller. Texas DOT 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 vehcile measurments normally. No troubleshooting actions were taken.

## 3.5 Recommended Equipment Maintenance

No 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, cracking in the WIM scale area was noted, however, the areas of pavement distress did not appear to affect the accuracy of the WIM sensors.

## 4.2 Profile and Vehicle Interaction

Profile data was collected on May 12, 2008 by the Southern 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, 11 profile passes were made, 5 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 1000 foot WIM section and the 400 foot approach section was 585 in/mi and is located approximately 345 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. Patching in the area of the transition from asphalt to concrete was noted in this area; however, the distresses do not appear to 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 5 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** | **Pass 5** | **Avg** |
|---|---|---|---|---|---|---|---|---|
| Left | LWP | LRI (m/km) | 0.876 | 0.889 | 0.889 | | | 0.885 |
| | | SRI (m/km) | 1.028 | 0.791 | 0.996 | | | 0.938 |
| | | Peak LRI (m/km) | 0.876 | 0.896 | 0.899 | | | 0.890 |
| | | Peak SRI (m/km) | 1.129 | 0.956 | 0.996 | | | 1.027 |
| | RWP | LRI (m/km) | 0.777 | 0.864 | 0.951 | | | 0.864 |
| | | SRI (m/km) | 0.886 | 0.801 | 0.877 | | | 0.855 |
| | | Peak LRI (m/km) | 0.866 | 0.936 | 1.041 | | | 0.948 |
| | | Peak SRI (m/km) | 0.974 | 0.861 | 1.043 | | | 0.959 |
| Center | LWP | LRI (m/km) | 0.755 | 0.860 | 0.819 | 0.782 | 0.737 | 0.804 |
| | | SRI (m/km) | 1.057 | 0.824 | 0.743 | 1.071 | 0.816 | 0.924 |
| | | Peak LRI (m/km) | 0.850 | 0.861 | 0.864 | 0.861 | 1.000 | 0.859 |
| | | Peak SRI (m/km) | 1.074 | 1.153 | 1.093 | 1.175 | 0.887 | 1.124 |
| | RWP | LRI (m/km) | 0.887 | 0.884 | 0.887 | 0.990 | 1.153 | 0.912 |
| | | SRI (m/km) | 0.772 | 0.774 | 0.938 | 0.744 | **3.004** | 0.807 |
| | | Peak LRI (m/km) | 0.933 | 0.913 | 0.922 | 1.092 | 1.177 | 0.965 |
| | | Peak SRI (m/km) | 0.870 | 0.820 | 1.058 | 0.782 | **3.037** | 0.883 |
| Right | LWP | LRI (m/km) | 0.959 | 0.945 | 1.131 | | | 1.012 |
| | | SRI (m/km) | 0.705 | 1.252 | 1.528 | | | 1.162 |
| | | Peak LRI (m/km) | 1.034 | 0.989 | 1.146 | | | 1.056 |
| | | Peak SRI (m/km) | 0.834 | 1.567 | 1.598 | | | 1.333 |
| | RWP | LRI (m/km) | 1.026 | 0.830 | 0.902 | | | 0.919 |
| | | SRI (m/km) | 1.128 | 1.049 | 1.198 | | | 1.125 |
| | | Peak LRI (m/km) | 1.061 | 0.879 | 0.993 | | | 0.978 |
| | | Peak SRI (m/km) | 1.228 | 1.219 | 1.252 | | | 1.233 |

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 over the upper threshold. The highest values, on average, are the Peak SRI values in the left wheel path of the right shift passes. The SRI and Peak SRI values shown in bold appear to be anomalies since the other values for these runs appear to be well within tolerances.

## 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 January 25, 2011, beginning at approximately 9:28 AM and continuing until 1:30 PM.

The three 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, 5-axle truck, loaded with dry bulk sand, 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.
- A Class 9, 5-axle truck, equipped with a boom on an empty flatbed trailer, with air suspension on the tractor, air suspension on the trailer, standard tandem spacing on the tractor and split 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 | 77.8 | 10.4 | 16.6 | 16.6 | 17.1 | 17.1 | 12.0 | 4.3 | 31.1 | 4.0 | 51.4 | 58.2 |
| 2 | 77.9 | 11.4 | 16.7 | 16.7 | 16.6 | 16.6 | 15.1 | 4.4 | 32.0 | 4.1 | 55.6 | 61.8 |
| 3 | 65.4 | 24.8 | 14.1 | 14.1 | 6.2 | 6.2 | 23.8 | 4.5 | 33.0 | 10.2 | 71.5 | 79.8 |

Test truck speeds varied by 11 mph, from 59 to 70 mph. The measured pre-validation pavement temperatures varied 25.9 degrees Fahrenheit, from 49.2 to 75.1. The sunny weather conditions nearly provided for 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 – 25-Jan-11**

| Parameter | 95% Confidence Limit of Error | Site Values | Pass/Fail |
|---|---|---|---|
| Steering Axles | ±20 percent | -2.4 ± 6.6% | Pass |
| Single Axles | ±20 percent | 0.7 ± 7.9% | Pass |
| Tandem Axles | ±15 percent | 1.5 ± 3.6% | Pass |
| GVW | ±10 percent | 0.3 ± 2.9% | Pass |
| Vehicle Length | ±3 percent (2 ft) | 0.0 ± 0.8 ft | Pass |
| Axle Length | ± 0.5 ft [150mm] | -0.1 ± 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 1.6 ± 3.6 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 -0.1, 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 70 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3 below.

**Table 5-3 – Pre-Validation Results by Speed – 25-Jan-11**

| Parameter | 95% Confidence Limit of Error | Low | Medium | High |
|---|---|---|---|---|
| | | 59.0 to 62.7 mph | 62.8 to 66.4 mph | 66.5 to 70.0 mph |
| Steering Axles | ±20 percent | -2.3 ± 6.1% | -2.6 ± 6.0% | -2.3 ± 9.7% |
| Single Axles | ±20 percent | -0.2 ± 7.3% | 1.4 ± 8.6% | 1.1 ± 9.3% |
| Tandem Axles | ±15 percent | 1.3 ± 3.4% | 0.5 ± 3.2% | 2.4 ± 4.1% |
| GVW | ±10 percent | 0.1 ± 3.0% | -0.1 ± 2.2% | 0.8 ± 3.9% |
| Vehicle Length | ±3.0 percent (2.0 ft) | 0.1 ± 0.8 ft | 0.0 ± 0.7 ft | -0.1 ± 1.2 ft |
| Vehicle Speed | ± 1.0 mph | 1.6 ± 3.0 mph | 1.5 ± 5.0 mph | 1.7 ± 3.9 mph |
| Axle Length | ± 0.5 ft | 0.0 ± 0.1 ft | 0.0 ± 0.1 ft | 0.0 ± 0.2 ft |

From the table, it can be seen that the WIM equipment estimates all weights with reasonable accuracy and the range 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 sections.

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment estimated GVW with reasonable accuracy at all speeds. The range in error is greater at the higher speeds when compared with low and medium speeds. There does not appear to be a correlation between speed and GVW estimates at this site.

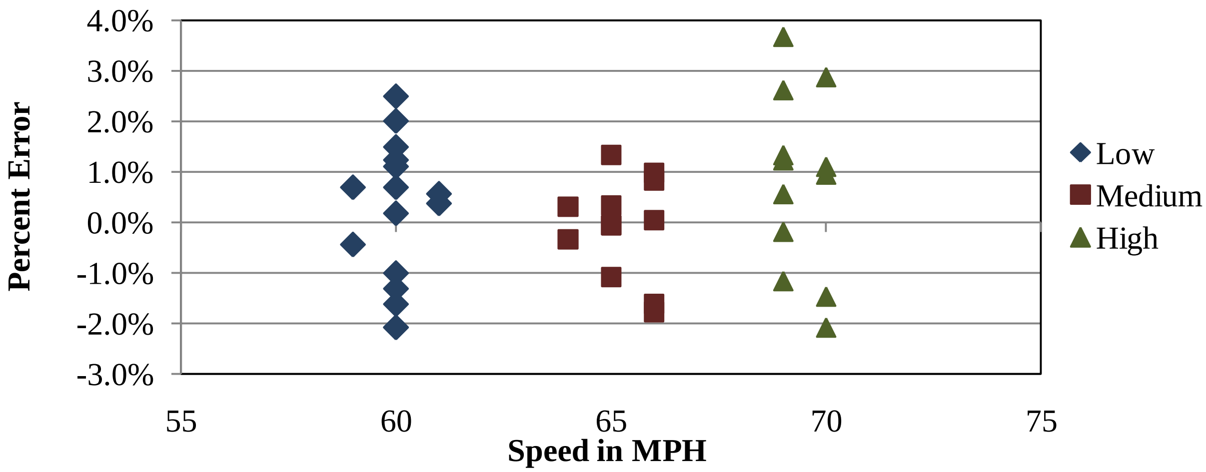



**Figure 5-1 – Pre-Validation GVW Error by Speed – 25-Jan-11**

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment underestimates steering axle weights with similar bias at all speeds. The range in error appears to be consistent throughout the entire speed range.

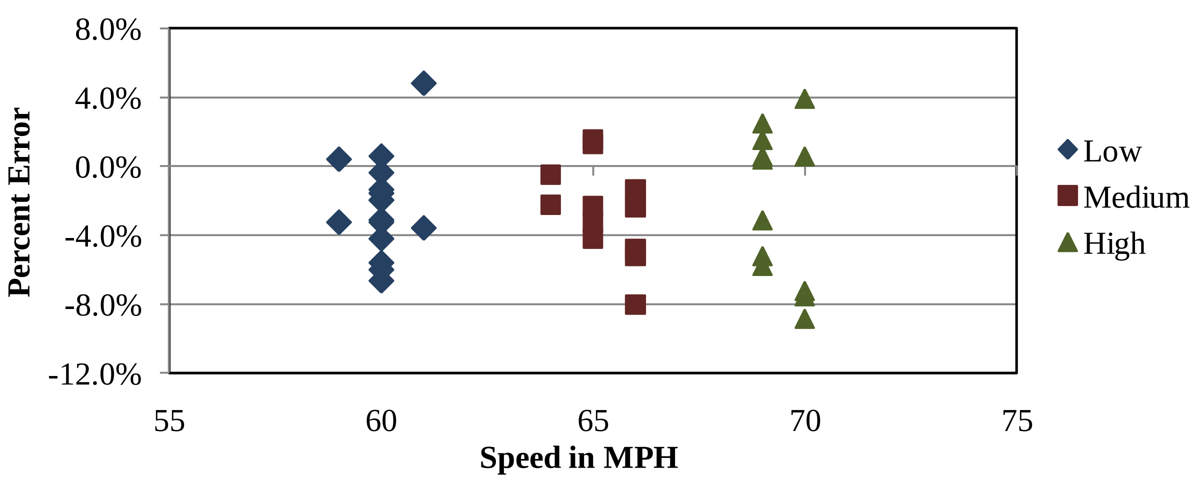



**Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 25-Jan-11**

#### 5.1.1.3 Single Axle Weight Errors by Speed

Single axles include the steering axles and any axles pairs on the either the truck or trailer that are separated by more than 10 feet. As shown in Figure 5-3, the equipment estimates single axle weights with similar accuracy at all speeds. The range in error is greater at the medium speeds.

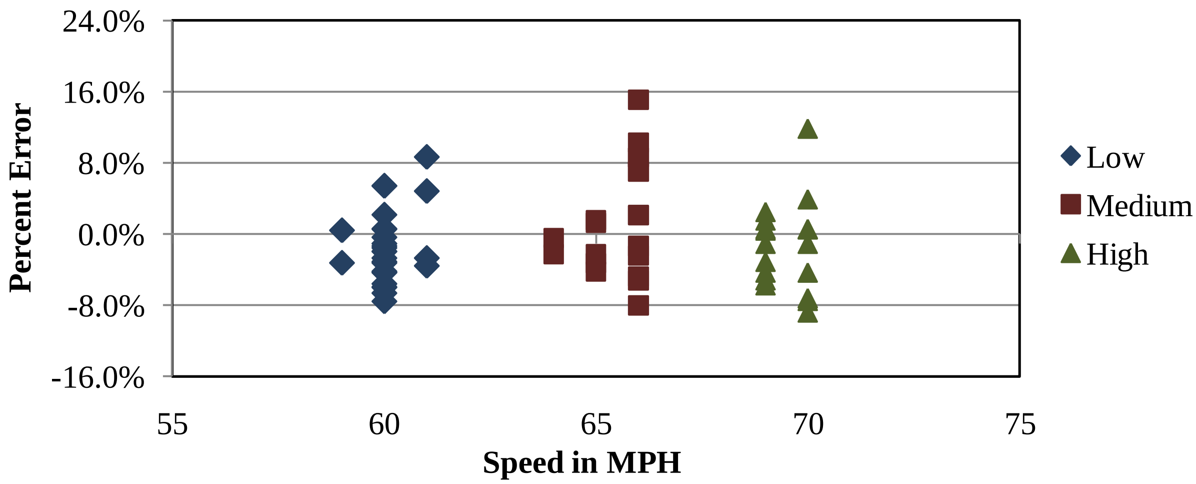



**Figure 5-3 – Pre-Validation Single Axle Weight Errors by Speed – 25-Jan-11**

#### 5.1.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment overestimates tandem axle weights with similar bias at the low and medium speeds, and overestimates by a greater degree at the higher speeds. The range in error is also greater at the higher speeds.

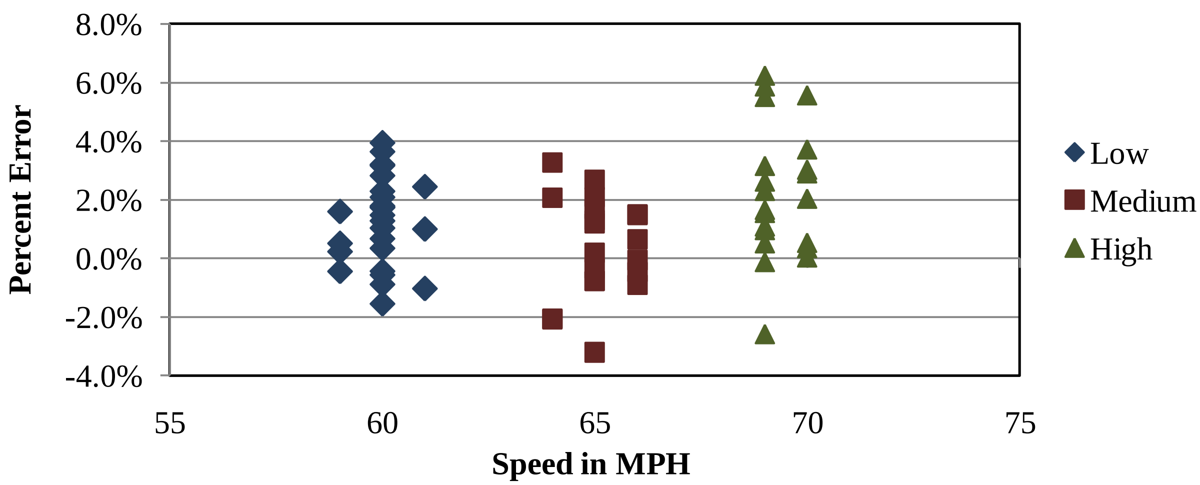



**Figure 5-4 – Pre-Validation Tandem Axle Weight Errors by Speed – 25-Jan-11**

5.1.1.5 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 not similar for each truck. For the heavily loaded Primary truck, the equipment mostly overestimates GVW at low and high speeds and more accurate and medium speeds. For the heavily loaded Secondary truck, the equipment generally overestimates GVW at all speeds, with highest overestimation at high speed. GVW for the partially loaded Third truck is generally underestimated at all speeds. Range in error for each truck is greater at the higher speeds. There does appear to be a relationship between truck type and the error in the GVW estimation at this site. Distribution of errors is shown graphically in Figure 5-5.

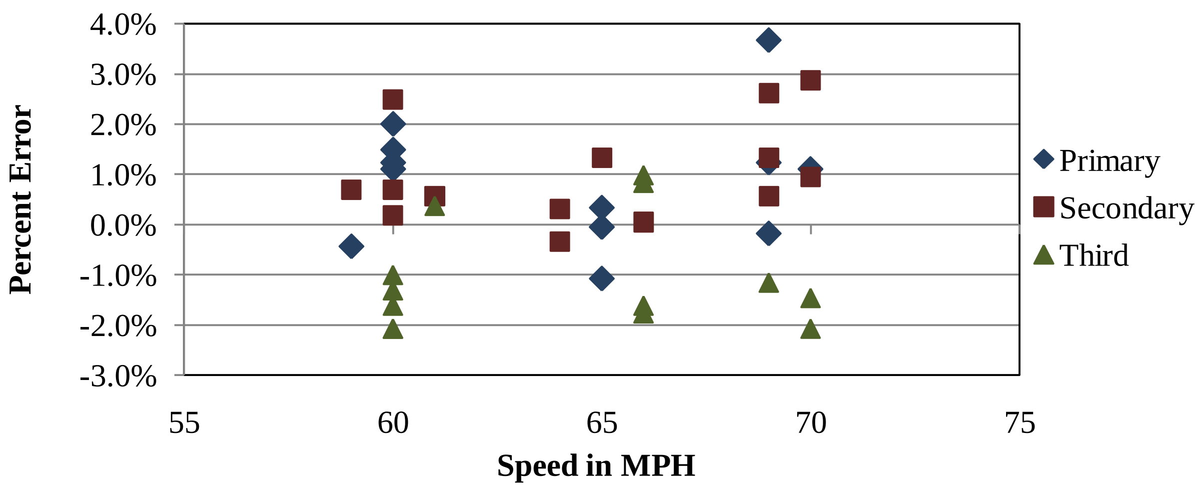



**Figure 5-5 – Pre-Validation GVW Errors by Truck and Speed – 25-Jan-11**

5.1.1.6 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 approximately -0.2 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-6.

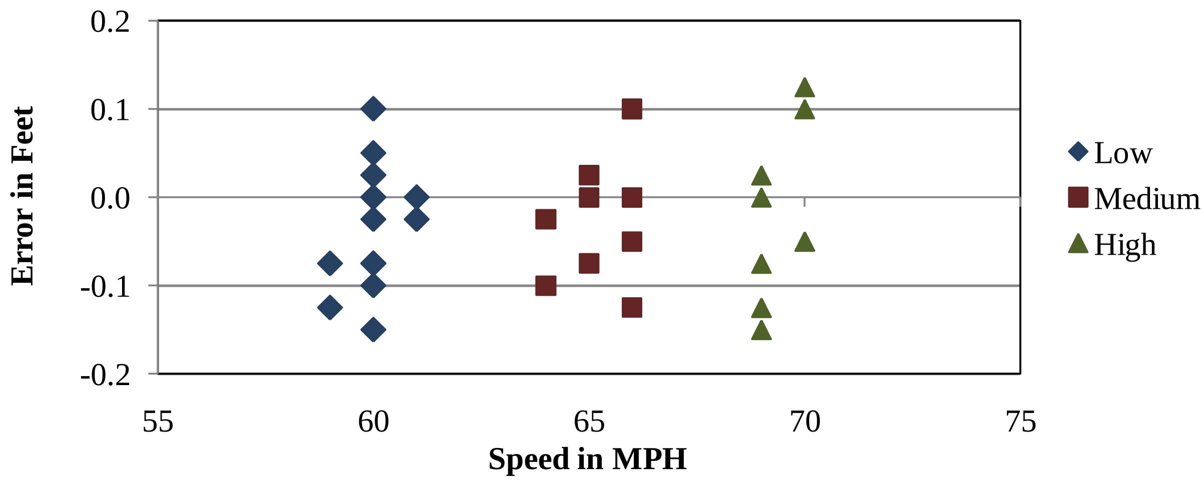



**Figure 5-6 – Pre-Validation Axle Length Errors by Speed – 25-Jan-11**

5.1.1.7 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 -1.4 to 0.8 feet. Distribution of errors is shown graphically in Figure 5-7.

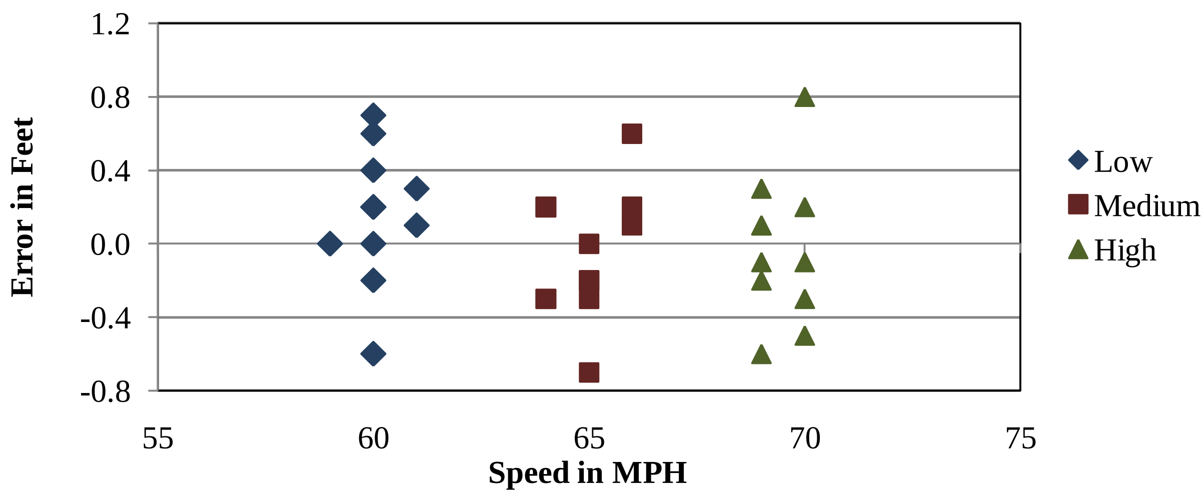



**Figure 5-7 – Pre-Validation Overall Length Error by Speed – 25-Jan-11**

### *5.1.2 Statistical Temperature Analysis*

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 25.9 degrees, from 49.2 to 75.1 degrees

Fahrenheit. The pre-validation test runs are being reported under two temperature groups as shown in Table 5-4.

**Table 5-4 – Pre-Validation Results by Temperature – 25-Jan-11**

| Parameter | 95% Confidence Limit of Error | Low | High |
|---|---|---|---|
| | | 49.2 to 62.2 degF | 62.3 to 75.2 degF |
| Steering Axles | ±20 percent | -1.4 ± 6.4% | -2.8 ± 7.0% |
| Single Axles | ±20 percent | 0.7 ± 7.2% | 0.7 ± 8.4% |
| Tandem Axles | ±15 percent | 1.5 ± 4.5% | 1.4 ± 3.6% |
| GVW | ±10 percent | 0.4 ± 4.4% | 0.2 ± 2.5% |
| Vehicle Length | ±3.0 percent (2.0 ft) | -0.1 ± 1.2 ft | 0.0 ± 0.7 ft |
| Vehicle Speed | ± 1.0 mph | 1.1 ± 3.6 mph | 1.8 ± 3.7 mph |
| Axle Length | ± 0.5 ft | 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 5-8, it can be seen that the equipment appears to estimate GVW with reasonable accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and GVW estimates at this site.

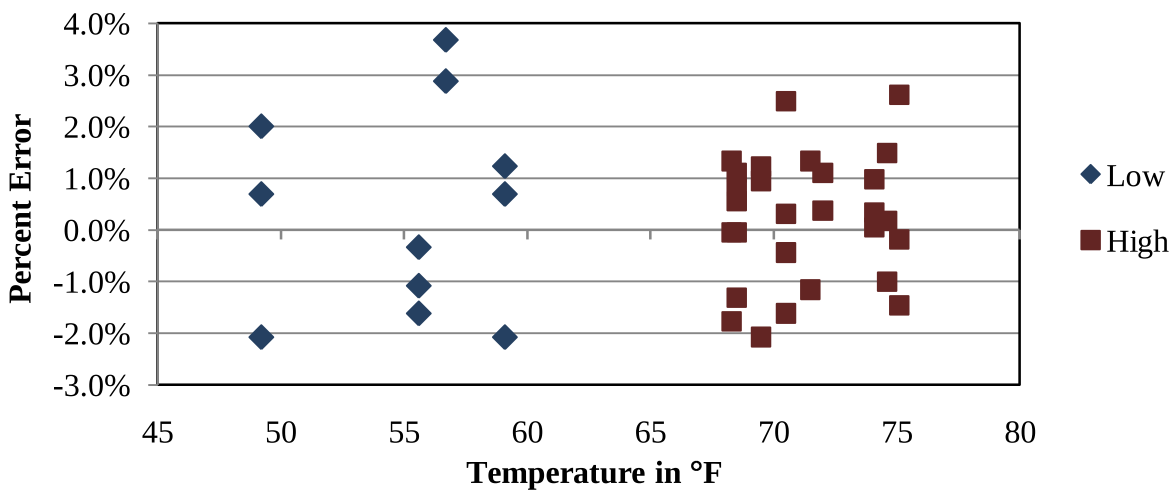



**Figure 5-8 – Pre-Validation GVW Errors by Temperature – 25-Jan-11**

#### 5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 demonstrates that for steering axles, the WIM equipment appears to underestimate with similar bias across the range of temperatures observed in the field. The range in error is greater at the higher temperatures.

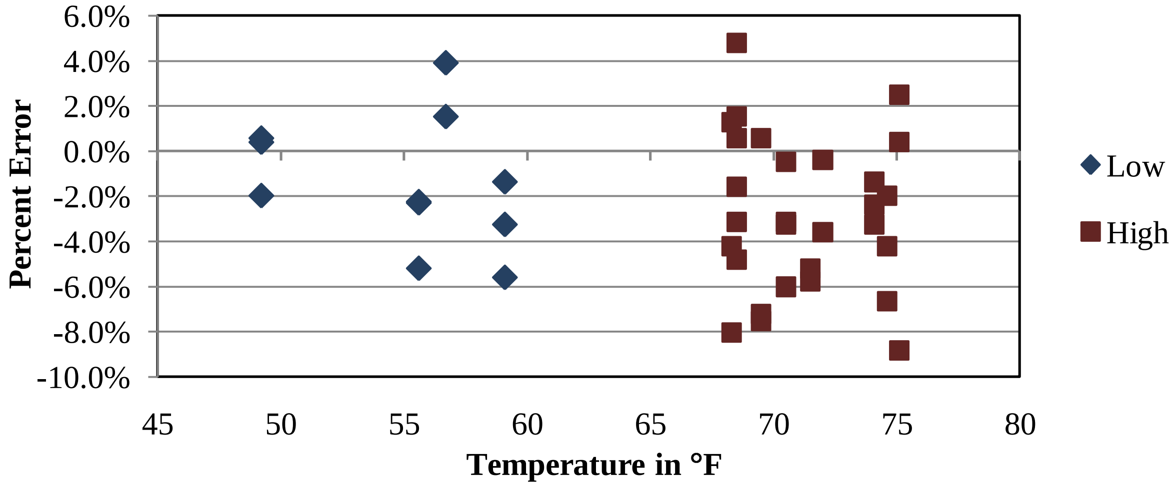



**Figure 5-9 – Pre-Validation Steering Axle Weight Errors by Temperature – 25-Jan-11**

5.1.2.3 Single Axle Weight Errors by Temperature

Figure 5-10 demonstrates that for loaded single axles, the WIM equipment appears to estimate with reasonable accuracy across the range of temperatures observed in the field. The range in error is greater at the higher temperatures.

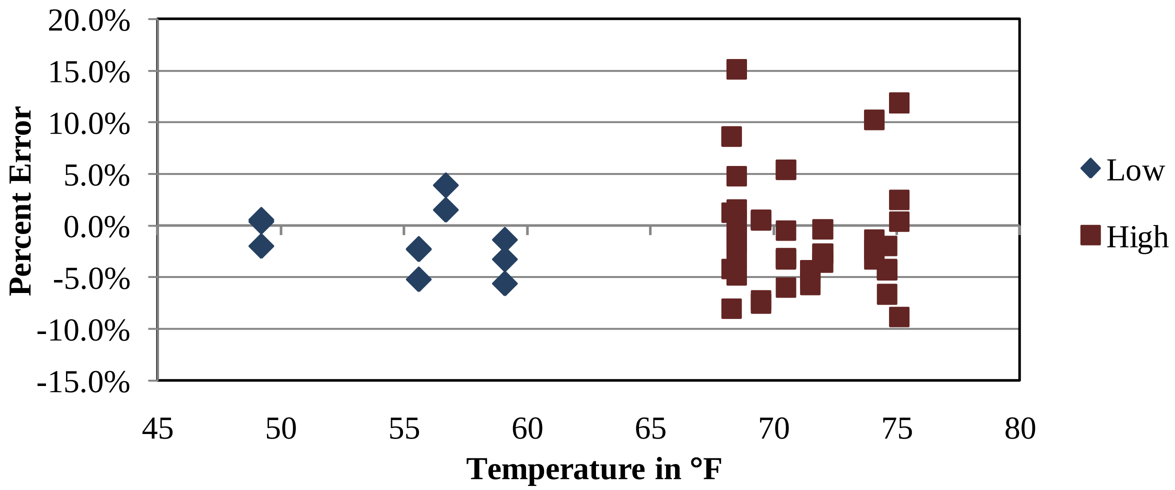



**Figure 5-10 – Pre-Validation Single Axle Weight Errors by Temperature – 25-Jan-11**

5.1.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-11, the WIM equipment appears to estimate tandem axle weights with reasonable accuracy across the range of temperatures observed in the field. The range in tandem axle errors is consistent for the two temperature groups.

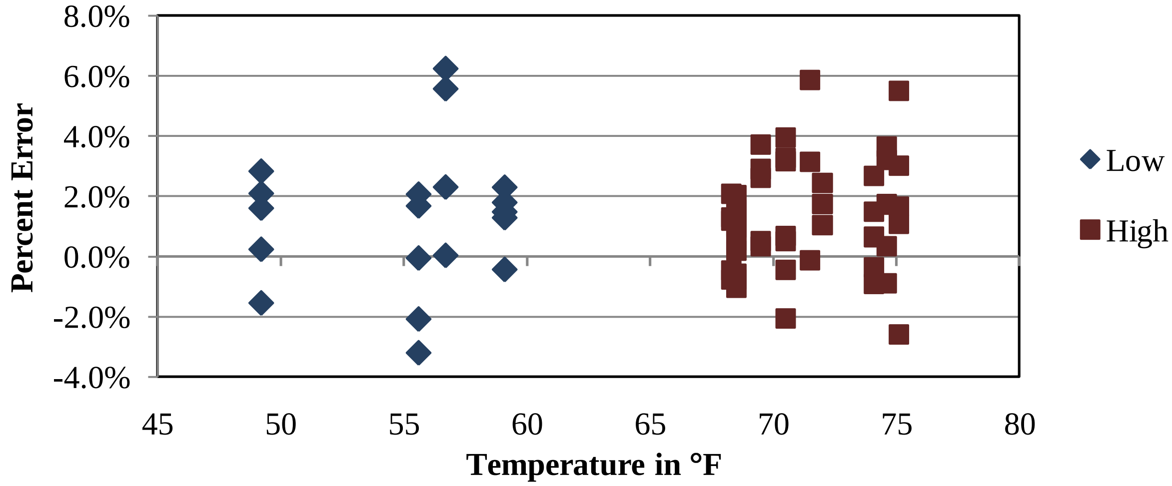



**Figure 5-11 – Pre-Validation Tandem Axle Weight Errors by Temperature – 25-Jan-11**

5.1.2.5 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, GVW measurement errors for all three test trucks do not follow similar patterns. The system estimates GVW for the Primary truck with reasonable accuracy at all temperatures, GVW for the Secondary truck is overestimated, and GVW for the Third truck is underestimated. The range of GVW errors for all trucks is consistent over the range of temperatures. Distribution of GVW errors is shown graphically in Figure 5-12.

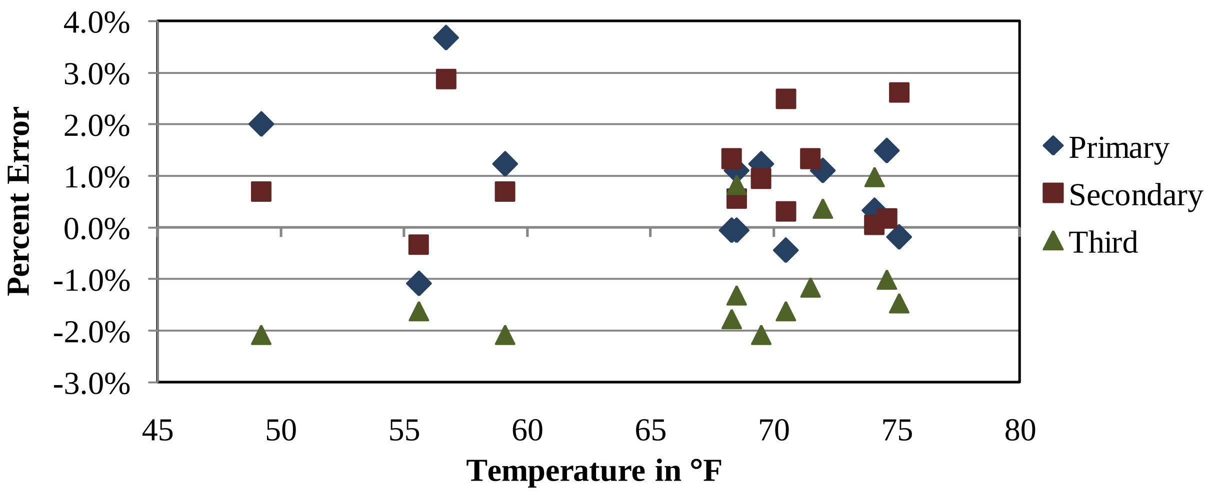



**Figure 5-12 – Pre-Validation GVW Error by Truck and Temperature – 25-Jan-11**

### *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 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 5-5 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

**Table 5-5 – Pre-Validation Classification Study Results – 25-Jan-11**

| Class | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Observed Count | 2 | 25 | 7 | 0 | 1 | 64 | 0 | 1 | 0 | 0 |
| WIM Count | 2 | 23 | 6 | 0 | 3 | 61 | 1 | 1 | 0 | 0 |
| Observed Percent | 2.0 | 25.0 | 7.0 | 0.0 | 1.0 | 64.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| WIM Percent | 2.0 | 23.0 | 6.0 | 0.0 | 3.0 | 61.0 | 1.0 | 1.0 | 0.0 | 0.0 |
| Misclassified Count | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Misclassified Percent | 0.0 | 4.0 | 14.3 | 0.0 | 0.0 | 3.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Unclassified Count | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Unclassified Percent | 0.0 | 4.3 | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 | 0.0 | 0.0 | 0.0 |

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

**Table 5-6 – Pre-Validation Misclassifications by Pair – 25-Jan-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 | 1 |
| 4/6 | 0 | 6/8 | 0 | 9/10 | 1 |
| 5/3 | 0 | 6/9 | 1 | 10/9 | 0 |
| 5/4 | 0 | 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 | 1 | 8/5 | 0 | 13/10 | 0 |
| 5/9 | 0 | 8/9 | 0 | 13/11 | 0 |

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 4.1% for heavy trucks (6 – 13), which is greater than the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 4.0%.

As shown in the table, a total of 4 vehicles, including 3 heavy trucks (6 – 13) were misclassified by the equipment. One of the misclassifications was a Class 5 identified by the equipment as a Class 8. For heavy trucks, one Class 6 was identified by the equipment as a Class 9, and two Class 9s were misclassified – one as Class 8, and another as a Class 10. The causes for the misclassifications were not investigated in the field.

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 shown in Table 5-5 are broken down by pair are provided in Table 5-7.

**Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 25-Jan-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 | 1 | 9/15 | 2 | 13/15 | 0 |
| 6/15 | 0 | 10/15 | 0 | | |

Based on the manually collected sample of the 100 trucks, 3.0% of the vehicles at this site were reported as unclassified during the study. This is not within the established criteria of 2.0% for LTTP SPS WIM sites. The unclassified vehicles were one Class 5 and two Class 9s which could not be identified by the WIM equipment. The cause of the unclassification was not investigated in the field. For speed, the mean error for WIM equipment speed measurement was -0.3 mph; the range of errors was 4.0 mph.

Based on these findings, it is recommended that an expanded investigation focusing on vehicle classification issues indicated in this report be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

### *5.1.4 Calibration*

For GVW, the pre-validation test truck runs produced an overall error of 0.3% and errors of 0.1%, -0.1%, and 0.8% at the 60, 65 and 70 mph speed points respectively. Consequently, the WIM equipment required no calibration iterations following the pre-validations.

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

**Table 5-8 – Initial System Parameters – 26-Jan-11**

| | | |
|---|---|---|
| **Overall -** | | 2600 |
| **F/A -** | | 1000 |
| **Left -** | | 1000 |
| **Right -** | | 1000 |
| **SP1 -** | **50** | 925 |
| **SP2 -** | **60** | 925 |
| **SP3 -** | **70** | 960 |
| **Sensor Distance -** | | 1640 |
| **Loop Width -** | | 600 |

### *5.1.5 GVW and Steering Axle Trends*

Figure 5-13 is provided to illustrate the predicted GVW error with respect to the pre-validation errors by speed.

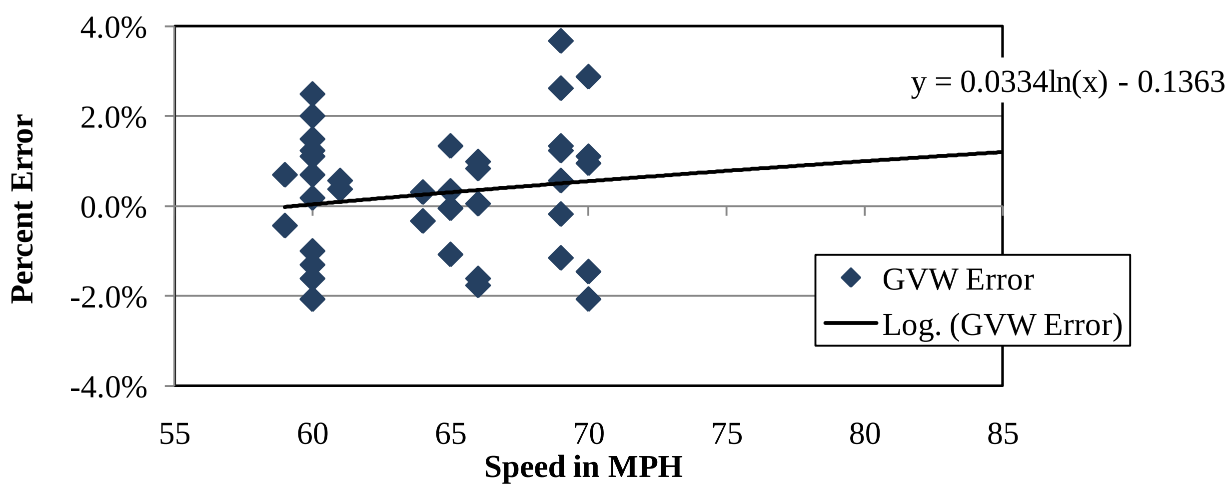



**Figure 5-13 - GVW Error Trend by Speed**

Figure 5-14 is provided to illustrate the predicted Steering Axle error with respect to the pre-validation errors by speed.

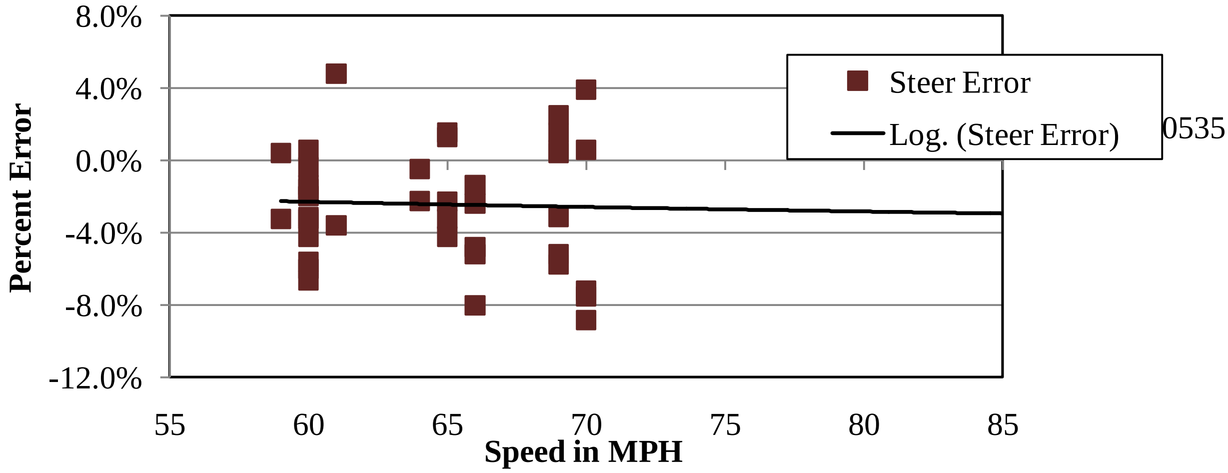



**Figure 5-14 - Steering Axle Trend by Speed**

### *5.1.6 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.

#### 5.1.6.1 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 59 to 70 mph.
- Pavement temperature. Pavement temperature ranged from 49.2 to 75.1 degrees Fahrenheit.

- Interaction between the factors such as the interaction between speed and pavement temperature.

5.1.6.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-9. 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 5-9 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 5-9 – Table of Regression Coefficients for Measurement Error of GVW**

| Parameter | Regression coefficients | Standard error | Value of t-distribution | Probability value |
|---|---|---|---|---|
| Intercept | -1.2693 | 3.2010 | -0.3965 | 0.6940 |
| Speed | 0.0412 | 0.0485 | 0.8493 | 0.4013 |
| Temp | -0.0017 | 0.0247 | -0.0675 | 0.9466 |
| Truck | -1.0261 | 0.2290 | -4.4799 | 0.0001 |

The relationship between truck type and GVW measurement errors is shown in Figure 5-15. The figure includes trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 5-15 provides quantification and statistical assessment of the relationship.

The quantification is provided by the value of the regression coefficient, in this case --1.0261 (in Table 5-9). The regression coefficient for truck type represent the difference in mean GVW errors for the Primary, Secondary, and Third trucks. (Truck type is an indicator variable with values of 0, 1, and 2). The statistical assessment of the relationship is provided by the probability value of the regression coefficient.

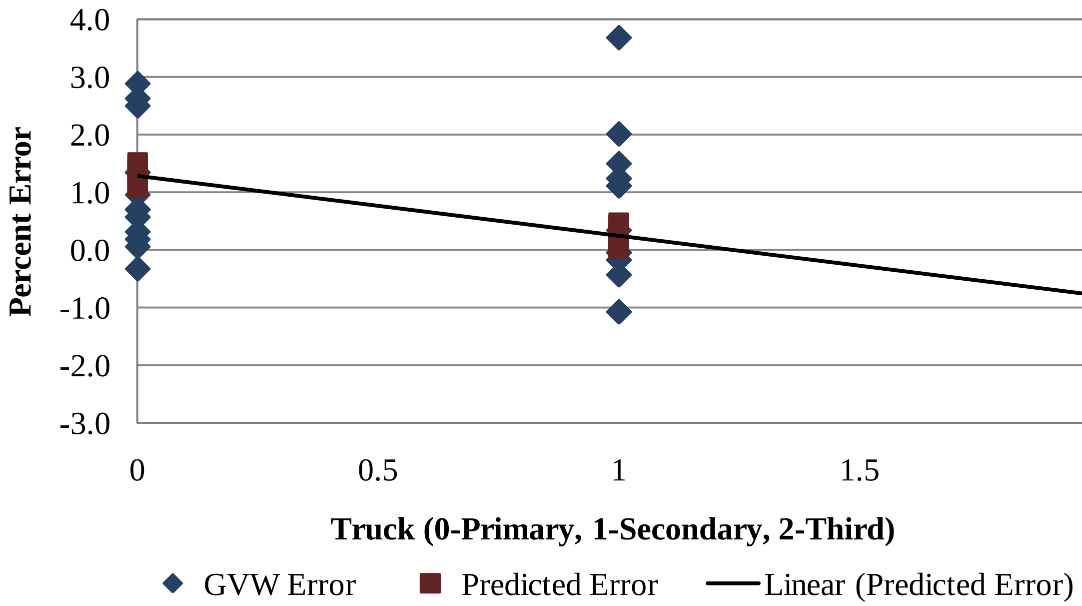



**Figure 5-15 – Influence of Truck Type on the Measurement Error of GVW**

The effect of speed and temperature on GVW was not statistically significant. For example, the probability that the regression coefficient for speed (0.0412 in Table 5-9) is not different from zero was 0.4013. In other words, there is about 40 percent chance that the value of the regression coefficient is due to the chance alone.

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.

#### 5.1.6.3 Summary Results

Table 5-10 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 5-10 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

**Table 5-10 – Summary of Regression Analysis**

| | **Factor** | | | | | |
|---|---|---|---|---|---|---|
| | **Speed** | | **Temperature** | | **Truck type** | |
| Weight, % error | Regression coefficient | Probability value | Regression coefficient | Probability value | Regression coefficient | Probability value |
| GVW | - | - | - | - | -1.0261 | 0.0001 |
| Steering axle | - | - | -0.0874 | 0.1748 | -1.5950 | 0.0099 |
| Tandem axle tractor | - | - | - | - | - | - |
| Tandem axle trailer | 0.2657 | 0.0674 | - | - | - | - |

5.1.6.4 Conclusions

1. Speed had statistically significant effect on measurement errors of only tandem axles on trailers (at 7% probability level).

2. Temperature did not have statistically significant effect on measurement errors.

3. Truck type had statistically significant effect on GVW and steering axle weight errors.

4. Even though speed and truck type had statistically significant effect on the measurement errors for some of the factors, the practical significance of these errors is small and does not affect the validity of the calibration.

# 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 four 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 | |
| 26-Apr-05 | N/A | 13 | 0 | N/A | 40 | 5 | 25 | 0 | 0 | N/A | 1 |
| 28-Apr-05 | 100 | 33 | 0 | N/A | 67 | 6 | N/A | N/A | N/A | 25 | 1 |
| 9-May-06 | 100 | 38 | 50 | N/A | 75 | 5 | 0 | N/A | N/A | N/A | 2 |
| 11-May-06 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-Nov-07 | 0 | 0 | 0 | N/A | 20 | 3 | 50 | N/A | N/A | N/A | 2 |
| 7-Nov-07 | 0 | -15 | 0 | N/A | 0 | -1 | -100 | N/A | N/A | N/A | 3 |
| 9-Dec-08 | 100 | 15 | 0 | N/A | 100 | 1 | 0 | 0 | 0 | N/A | 2 |
| 10-Dec-08 | 67 | 17 | 20 | N/A | 75 | 0 | 0 | N/A | N/A | 0 | 4 |
| 25-Jan-11 | 0 | 4 | 0 | N/A | 0 | 3 | N/A | 0 | N/A | N/A | 3 |

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 |
| 26-Apr-05 | 0.5 ± 2.0 | -2.5 ± 2.5 | 0.5 ± 3.4 |
| 27-Apr-05 | 1.4 ± 1.3 | -4.9 ± 3.1 | 1.8 ± 3.3 |
| 9-May-06 | 0.5 ± 2.4 | -2.4 ± 2.2 | 1.2 ± 6.1 |
| 10-May-06 | -0.5 ± 1.8 | -2.6 ± 2.8 | -0.1 ± 4.4 |
| 6-Nov-07 | 1.0 ± 1.6 | -1.5 ± 3.1 | 1.5 ± 2.8 |
| 7-Nov-07 | 1.3 ± 1.8 | -1.2 ± 3.1 | 1.8 ± 2.8 |
| 9-Dec-08 | 0.2 ± 1.4 | -2.7 ± 2.9 | 0.6 ± 2.7 |
| 10-Dec-08 | 0.7 ± 1.4 | -3.1 ± 3.5 | 1.4 ± 2.5 |
| 25-Jan-11 | 0.3 ± 1.4 | -2.4 ± 3.3 | 1.5 ± 1.8 |

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. The table demonstrates the effectiveness of the validations in bringing the weight estimations to 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) | | | | |
|---|---|---|---|---|---|---|
| | | 27-Apr-05 | 10-May-06 | 7-Nov-07 | 10-Dec-08 | 25-Jan-11 |
| Steering Axles | ±20 percent | -4.9 ± 6.3 | -2.6 ± 5.7 | -1.2 ± 6.2 | -3.1 ± 5.9 | -2.4 ± 6.6 |
| Tandem Axles | ±15 percent | 1.8 ± 6.6 | -0.1 ± 8.7 | 1.8 ± 5.6 | 1.4 ± 5.3 | 1.5 ± 3.6 |
| GVW | ±10 percent | 1.4 ± 3.9 | -0.5 ± 3.6 | 1.3 ± 3.6 | 0.7 ± 2.8 | 0.3 ± 2.9 |

From the table, it appears that the variance for all weights has remained reasonably consistent since the equipment was installed.

A review of the LTPP Standard Release Database 24 shows that there are 3 years of level “E” WIM data for this site. This site requires 2 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
- Pre-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 – Calibration 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

Texas, SPS-1
SHRP ID: 480100

Validation Date: January 25, 2011


**Photo 1 – Cabinet Exterior**

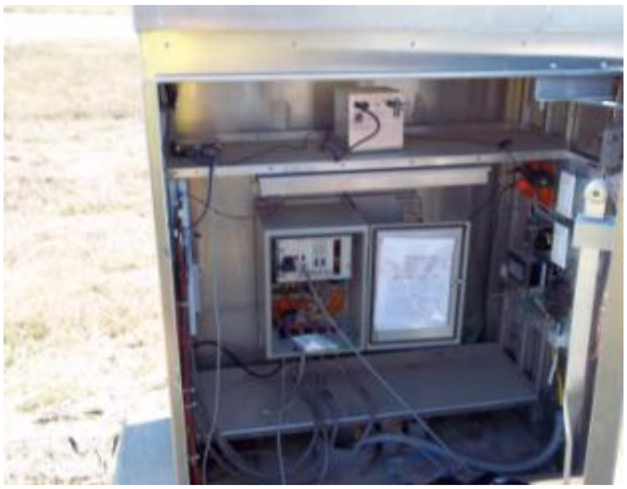


**Photo 2 – Cabinet Interior (Front)**


**Photo 3 – Power Feed**


**Photo 4 – Leading Loop**


**Photo 5 – Leading WIM Sensor**


**Photo 6 – Trailing WIM Sensor**

**Photo 7 – Trailing Loop Sensor**

**Photo 9 – Downstream**

**Photo 8 – Cellular Modem**

**Photo 8 – Upstream**

**Photo 11 – Truck 1**

**Photo 9 – Truck 1 Tractor**


**Photo 10 – Truck 1 Trailer and Load**


**Photo 12 – Truck 1 Suspension 2**


**Photo 11 – Truck 1 Suspension 1**


**Photo 13 – Truck 1 Suspension 3**


**Photo 14 – Truck 1 Suspension 4**


**Photo 18 – Truck 1 Suspension 5**


**Photo 19 – Truck 2**

**Photo 17 – Truck 2 Suspension 1**

**Photo 15 – Truck 2 Tractor**

**Photo 18 – Truck 2 Suspension 2**


**Photo 16 – Truck 2 Trailer and Load**

**Photo 19 – Truck 2 Suspension 3**

**Photo 20 – Truck 2 Suspension 4**

**Photo 21 – Truck 2 Suspension 5**

**Photo 27– Truck 3**

**Photo 29 – Truck 3 Trailer and Load**

**Photo 28 – Truck 3 Tractor**

**Photo 30 – Truck 3 Suspension 1**


Photo 31 – Truck 3 Suspension 2


Photo 32 – Truck 3 Suspension 3


Photo 33 – Truck 3 Suspension 4


Photo 34 – Truck 3 Suspension 5

| Traffic Sheet 16 | | |
|---|---|---|
| **LTPP MONITORED TRAFFIC DATA** | STATE CODE: | 48 |
| **SITE CALIBRATION SUMMARY** | SPS WIM ID: | 480100 |
| | DATE (mm/dd/yyyy) | 1/25/2011 |

## SITE CALIBRATION INFORMATION

**1. DATE OF CALIBRATION** {mm/dd/yy} 1/25/11

**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. Bending Plates
c.
d.

**5. EQUIPMENT MANUFACTURER:** IRD DAW

## WIM SYSTEM CALIBRATION SPECIFICS

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

Number of Trucks Compared:
Number of Test Trucks Used: 3
Passes Per Truck: 13

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

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

Mean Difference Between -

| | Mean | | Standard Deviation |
|---|---|---|---|
| Dynamic and Static GVW: | 0.3% | Standard Deviation: | 1.4% |
| Dynamic and Static Single Axle: | 0.7% | Standard Deviation: | 3.9% |
| Dynamic and Static Double Axles: | 1.5% | Standard Deviation: | 1.8% |

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

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

| | | | Low | | High | Runs |
|---|---|---|---|---|---|---|
| a. | Low | - | 59.0 | to | 62.7 | 16 |
| b. | Medium | - | 62.8 | to | 66.4 | 12 |
| c. | High | - | 66.5 | to | 70.0 | 12 |
| d. | | - | | to | | |
| e. | | - | | to | | |

| Traffic Sheet 16 | STATE CODE: | 48 |
|---|---|---|
| LTPP MONITORED TRAFFIC DATA | SPS WIM ID: | 480100 |
| SITE CALIBRATION SUMMARY | DATE (mm/dd/yyyy) | 1/25/2011 |

**10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED)** 956

**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: | -5.0 | FHWA Class | 5 | - | -8.0 |
| FHWA Class 8: | 200.0 | FHWA Class | | - | |
| | | FHWA Class | | - | |
| | | FHWA Class | | - | |

Percent of "Unclassified" Vehicles: 3.0%

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 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 48<br>SPS WIM ID: 480100<br>DATE (mm/dd/yyyy) 1/25/2011 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 5 | 3133 | 60 | 5 | 65 | 9 | 3401 | 65 | 9 |
| **38** | **15** | **3136** | **67** | **9** | 71 | 9 | 3413 | 71 | 9 |
| 73 | 5 | 3145 | 71 | 5 | 71 | 9 | 3416 | 71 | 9 |
| 56 | 6 | 3153 | 54 | 6 | 69 | 9 | 3429 | 67 | 9 |
| 65 | 9 | 3154 | 63 | 9 | 72 | 9 | 3440 | 71 | 9 |
| 69 | 5 | 3157 | 62 | 5 | 75 | 5 | 3451 | 73 | 5 |
| 69 | 5 | 3160 | 69 | 5 | 68 | 9 | 3455 | 68 | 9 |
| 67 | 9 | 3164 | 65 | 9 | 72 | 9 | 3463 | 71 | 9 |
| 67 | 9 | 3176 | 67 | 9 | 52 | 6 | 3471 | 58 | 6 |
| 70 | 5 | 3259 | 68 | 5 | 72 | 5 | 3479 | 69 | 5 |
| 69 | 5 | 3275 | 72 | 5 | 69 | 9 | 3480 | 68 | 9 |
| 72 | 9 | 3277 | 72 | 9 | 70 | 5 | 3482 | 67 | 5 |
| 65 | 5 | 3283 | 65 | 5 | 66 | 9 | 3484 | 64 | 9 |
| 70 | 9 | 3284 | 70 | 9 | 70 | 9 | 3517 | 69 | 9 |
| 65 | 5 | 3288 | 65 | 5 | 66 | 9 | 3534 | 65 | 9 |
| 77 | 5 | 3304 | 73 | 5 | 70 | 5 | 3541 | 73 | 5 |
| 70 | 9 | 3311 | 66 | 9 | 63 | 5 | 3547 | 66 | 5 |
| 73 | 9 | 3315 | 71 | 9 | 70 | 6 | 3548 | 69 | 6 |
| 64 | 9 | 3341 | 62 | 9 | 63 | 6 | 3568 | 64 | 6 |
| **62** | **15** | **3346** | **61** | **5** | 57 | 9 | 3571 | 64 | 9 |
| 70 | 9 | 3360 | 70 | 9 | 61 | 9 | 3574 | 63 | 9 |
| 65 | 9 | 3363 | 65 | 9 | 66 | 9 | 3576 | 64 | 9 |
| 63 | 9 | 3368 | 63 | 9 | 66 | 9 | 3592 | 65 | 9 |
| 74 | 5 | 3373 | 74 | 5 | 67 | 5 | 3607 | 70 | 5 |
| 70 | 6 | 3387 | 69 | 6 | 63 | 9 | 3625 | 63 | 9 |

Sheet 1 - 0 to 50 Start: 10:30:00 Stop: 11:39:00

Recorded By: kt Verified By: djw

Validation Test Truck Run Set - Pre

| Traffic Sheet 20<br>LTPP MONITORED TRAFFIC DATA<br>SPEED AND CLASSIFICATION STUDIES | STATE CODE: 48<br>SPS WIM ID: 480100<br>DATE (mm/dd/yyyy) 1/25/2011 |
|---|---|

| WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class | WIM speed | WIM class | WIM Record | Obs. Speed | Obs. Class |
|---|---|---|---|---|---|---|---|---|---|
| 67 | 9 | 3627 | 67 | 9 | 65 | 9 | 3796 | 65 | 9 |
| 63 | 8 | 3629 | 73 | 8 | 68 | 9 | 3798 | 67 | 9 |
| 69 | 5 | 3640 | 67 | 5 | 70 | 9 | 3800 | 70 | 9 |
| 60 | 9 | 3641 | 58 | 9 | 66 | 9 | 3801 | 66 | 9 |
| 62 | 5 | 3654 | 63 | 5 | 66 | 9 | 3802 | 66 | 9 |
| 69 | 9 | 3667 | 67 | 9 | 70 | 9 | 3803 | 70 | 9 |
| **64** | **10** | **3671** | **67** | **9** | 71 | 9 | 3814 | 70 | 9 |
| 68 | 9 | 3673 | 69 | 9 | 63 | 9 | 3818 | 62 | 9 |
| 65 | 5 | 3677 | 63 | 5 | 65 | 9 | 3821 | 65 | 9 |
| 64 | 9 | 3679 | 64 | 9 | 64 | 9 | 3825 | 64 | 9 |
| 57 | 5 | 3683 | 67 | 5 | 65 | 6 | 3833 | 66 | 6 |
| 74 | 9 | 3708 | 74 | 9 | 63 | 11 | 3844 | 62 | 11 |
| 62 | 9 | 3711 | 64 | 9 | 76 | 4 | 3846 | 75 | 4 |
| 67 | 9 | 3718 | 67 | 9 | 76 | 4 | 3847 | 75 | 4 |
| 69 | 9 | 3722 | 70 | 9 | 71 | 9 | 3858 | 71 | 9 |
| 68 | 9 | 3730 | 67 | 9 | 70 | 9 | 3859 | 68 | 9 |
| 64 | 9 | 3742 | 65 | 9 | **57** | **8** | **3860** | **57** | **5** |
| 70 | 9 | 3743 | 69 | 9 | 66 | 9 | 3869 | 68 | 9 |
| **69** | **9** | **3747** | **67** | **6** | 65 | 9 | 3877 | 64 | 9 |
| 65 | 9 | 3757 | 64 | 9 | **64** | **15** | **3892** | **67** | **9** |
| 66 | 5 | 3759 | 72 | 5 | 71 | 9 | 3894 | 70 | 9 |
| 73 | 9 | 3762 | 72 | 9 | 58 | 5 | 3917 | 58 | 5 |
| **65** | **8** | **3771** | **71** | **9** | 69 | 9 | 3930 | 66 | 9 |
| 69 | 5 | 3785 | 70 | 5 | 67 | 9 | 3938 | 66 | 9 |
| 65 | 9 | 3795 | 65 | 9 | 63 | 9 | 3939 | 61 | 9 |

Sheet 2 - 51 to 100 Start: 11:39:00 Stop: 12:18:00

Recorded By: kt Verified By: djw

Validation Test Truck Run Set - Pre