WIM System Field Calibration and Validation Summary Report

Arizona SPS-1
SHRP ID – 040100

Validation Date: October 16, 2013
Submitted: November 13, 2013

Table of Contents

List of Figures

List of Tables

1 Executive Summary

A WIM validation was performed on October 15 and 16, 2013 at the Arizona SPS-1 site located on route US-93, milepost 52.6, .25 miles north of SR 125.

This site was installed on November 30, 2006. The in-road sensors are installed in the northbound, righthand driving lane. The site is equipped with bending plate WIM sensors and an IRD iSINC 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 August 21, 2012 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. None of the in-road sensors show signs of damage or excessive wear and appear to be fully secured in the pavement. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, there were no pavement distresses 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 – 16-Oct-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	0.6 ± 6.2%	Pass
Tandem Axles	±15 percent	-0.2 ± 6.4%	Pass
GVW	±10 percent	-0.1 ± 2.6%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.2 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 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 0.4 ± 1.8 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 0.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 8.2% from the 109 vehicle sample (Class 4 – 13) was due to the 9 cross-classifications of Class 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 residential waste.

- 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 residential waste.

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 8). 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	77.5	11.7	16.2	16.2	16.7	16.7	14.8	4.4	33.2	4.1	56.5	61.8
2	68.0	11.8	13.7	13.7	14.4	14.4	13.4	4.3	33.5	4.2	55.4	62.5

The posted speed limit at the site is 65 mph. During the testing, the speed of the test trucks ranged from to 44 to 65 mph, a variance of 21 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 50.5 to 83.4 degrees Fahrenheit, a range of 32.9 degrees Fahrenheit. The sunny weather conditions provided the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 27 shows that there are 5 years of level “E” WIM data for this site. This site does not require any 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 September 14, 2013 (Data) to the most recent Comparison Data Set (CDS) from August 22, 2012. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics 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 27 shows that there are 5 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2007 to 2012.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2007	126	5
2008	366	12
2009	322	12
2010	359	12
2011	364	12
2012	253	9

As shown in the table, this site does not require any additional years of data to meet the minimum of five years of research quality data. The data does not meet the 210-day minimum requirement for calendar year 2007.

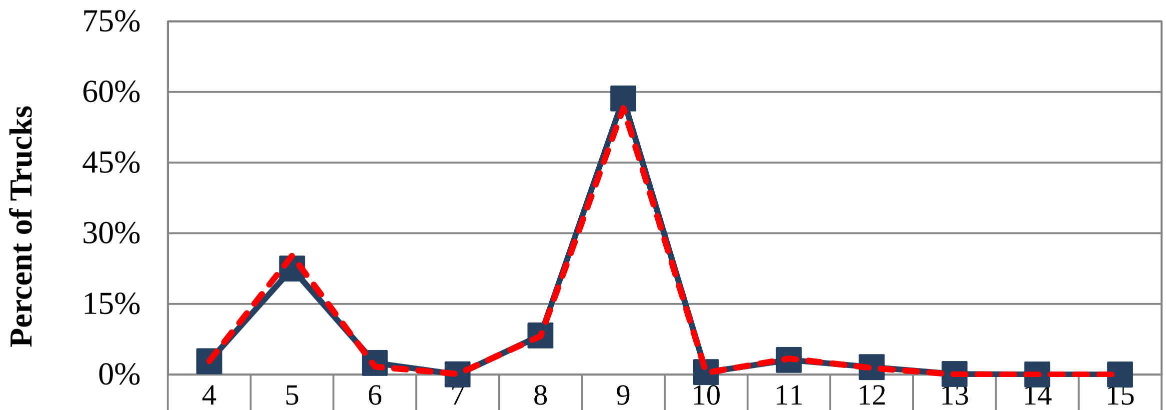
Table 2-2 provides a monthly breakdown of the available data for years 2007 through 2012.

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	
2007					27	30				8	30	31	5
2008	31	29	31	30	31	30	31	31	30	31	30	31	12
2009	31	28	31	30	31	30	31	31	30	31	2	16	12
2010	30	28	31	30	31	30	31	31	30	31	30	26	12
2011	31	28	30	30	31	30	31	31	30	31	30	31	12
2012	31	29	31	30	31	30	31	31	9				9

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 between the sample dataset from September 14, 2013 (Data) and the most recent comparison Data Set (CDS) from August 22, 2012.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	2.8%	22.5%	2.5%	0.0%	8.3%	58.6%	0.5%	3.1%	1.6%	0.1%	0.0%	0.0%
CDS	2.9%	25.2%	1.7%	0.2%	8.2%	56.6%	0.4%	3.4%	1.4%	0.1%	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. The table shows that according to the most recent data, the two most frequent truck types crossing the WIM scale are Class 9 (58.6%) and Class 5 (22.5%) vehicles.

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.

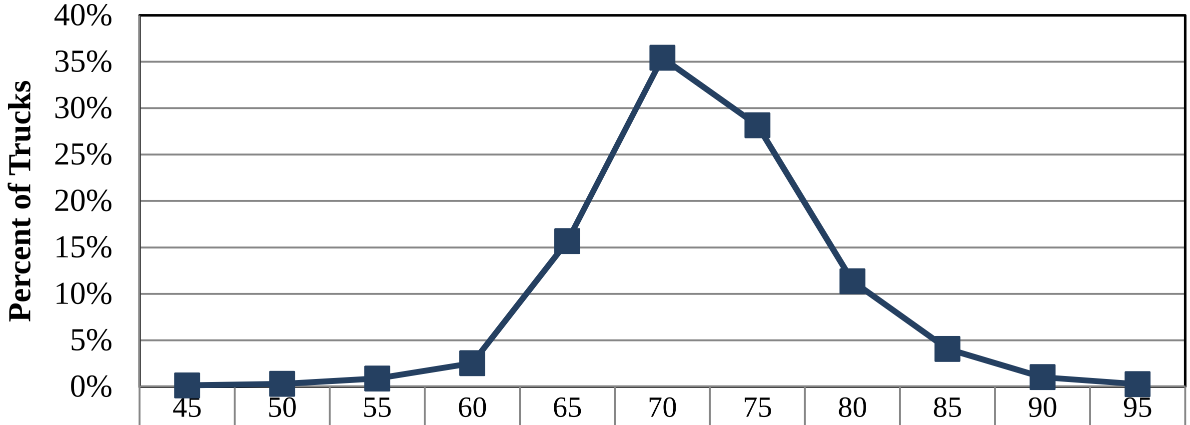
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	8/22/2012		9/14/2013		
4	368	2.9%	431	2.8%	0.0%
5	3235	25.2%	3421	22.5%	-2.7%
6	217	1.7%	373	2.5%	0.8%
7	22	0.2%	3	0.0%	-0.2%
8	1048	8.2%	1261	8.3%	0.1%
9	7251	56.6%	8907	58.6%	2.0%
10	49	0.4%	77	0.5%	0.1%
11	439	3.4%	472	3.1%	-0.3%
12	179	1.4%	240	1.6%	0.2%
13	7	0.1%	17	0.1%	0.1%
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 percentage of Class 9 vehicles has increased by 2.0 percent from August 2012 and September 2013. Changes in the percentage of heavier trucks may be attributed to natural and seasonal variations in truck distributions and an increase in goods movement during current economic cycle. During the same time period, the percentage of Class 5 trucks decreased by 2.7 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.

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.



	45	50	55	60	65	70	75	80	85	90	95
Data	0.1%	0.3%	0.9%	2.5%	15.7%	35.4%	28.2%	11.4%	4.1%	1.0%	0.3%

Figure 2-2 – Truck Speed Distribution – 14-Sep-13

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 65 and the 85th percentile speed for trucks at this site is 76 mph. The expected range of test truck speeds for the validation is 45 to 65 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 September 2013 and the Comparison Data Set from August 2012.

As shown in Figure 2-3, there is an upward shift to the right for the loaded peak between the August 2012 Comparison Data Set (CDS) and the September 2013 two-week sample W-card dataset (Data). The results indicate that there may have been a small change in the type of commodity being transported by trucks traveling over the WIM system or a small possible positive bias (overestimation of loads), a change in pavement condition, or sensor deterioration.

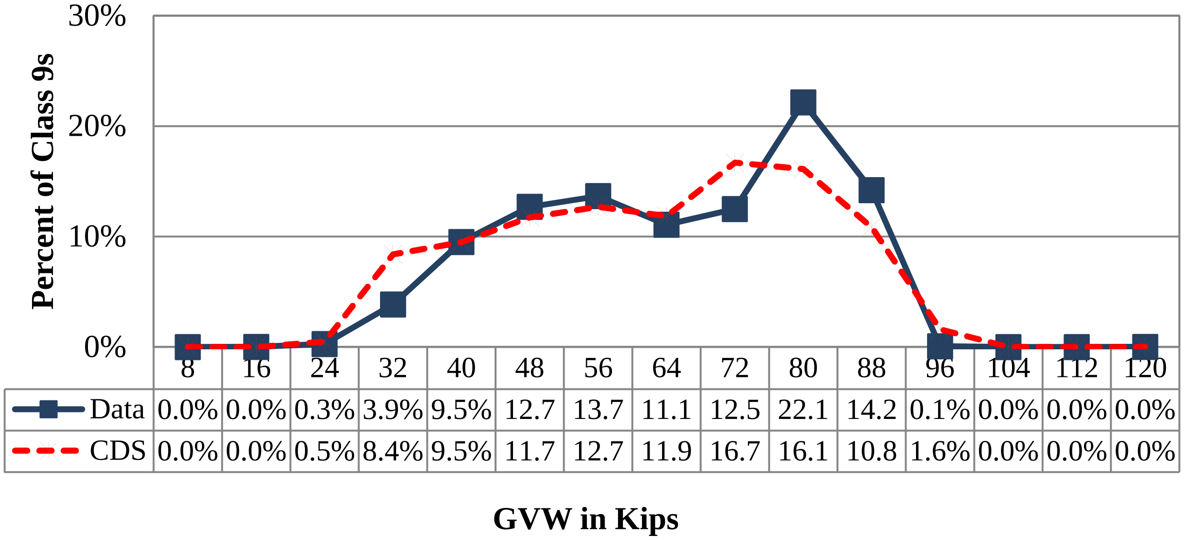


Figure 2-3 – Comparison of Class 9 GVW Distribution

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

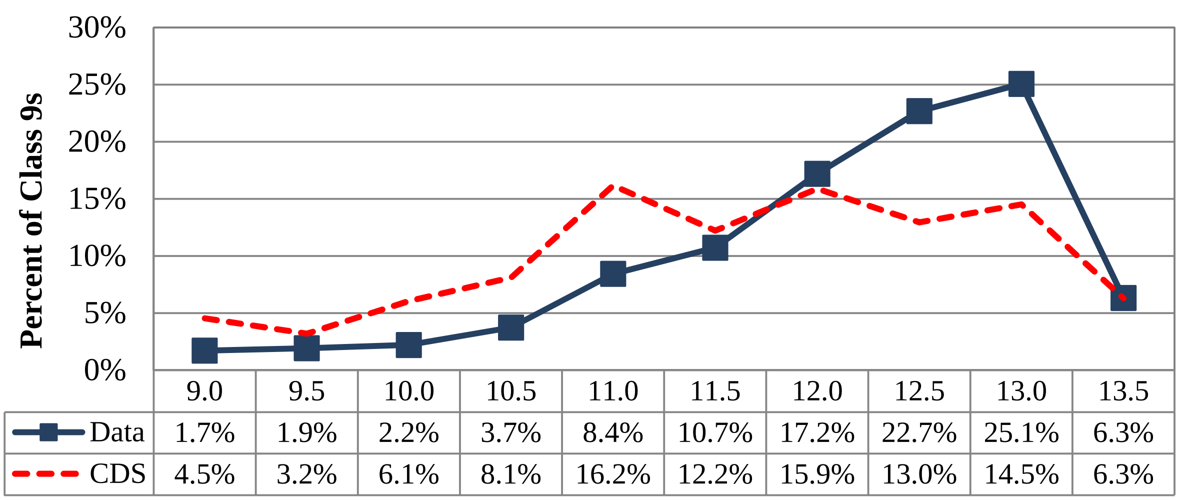
GVW weight bins (kips)	CDS		Data		Change
	Date				
	8/22/2012		9/14/2013		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	1	0.0%	0.0%
24	35	0.5%	24	0.3%	-0.2%
32	601	8.4%	337	3.9%	-4.5%
40	680	9.5%	832	9.5%	0.0%
48	841	11.7%	1110	12.7%	0.9%
56	909	12.7%	1195	13.7%	1.0%
64	849	11.9%	969	11.1%	-0.8%
72	1196	16.7%	1093	12.5%	-4.2%
80	1154	16.1%	1937	22.1%	6.0%
88	776	10.8%	1243	14.2%	3.4%
96	115	1.6%	6	0.1%	-1.5%
104	1	0.0%	0	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	1	0.0%	1	0.0%	0.0%
Average =	58.9 kips		61.3 kips		2.4 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range remained the same while the percentage of loaded class 9 trucks in the 72 to 80 kips range increased by 6.0 percent. During this time period the percentage of overweight trucks increased by 1.9 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 4.1 percent, from 58.9 to 61.3 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 September 2013 and the Comparison Data Set from August 2012. The percentage of light axles (10.5 to 11.5 kips) decreased by approximately 9.2% and the percentage of heavy axles (12.5 to 13.5 kips) increased by approximately 10.5%, indicating possible positive bias (overestimation of loads) in front axle measurement.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	1.7%	1.9%	2.2%	3.7%	8.4%	10.7%	17.2%	22.7%	25.1%	6.3%
CDS	4.5%	3.2%	6.1%	8.1%	16.2%	12.2%	15.9%	13.0%	14.5%	6.3%

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 12.0 and 13.0 kips. The percentage of trucks in this range has increased between the August 2012 Comparison Data Set (CDS) and the September 2013 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the August 2012 Comparison Data Set (CDS) and the September 2013 dataset (Data).

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

F/A weight bins (kips)	CDS		Data		Change
	Date				
	8/22/2012		9/14/2013		
9.0	304	4.5%	144	1.7%	-2.8%
9.5	214	3.2%	162	1.9%	-1.3%
10.0	405	6.1%	186	2.2%	-3.9%
10.5	542	8.1%	315	3.7%	-4.4%
11.0	1081	16.2%	712	8.4%	-7.7%
11.5	817	12.2%	905	10.7%	-1.5%
12.0	1063	15.9%	1451	17.2%	1.3%
12.5	866	13.0%	1914	22.7%	9.7%
13.0	971	14.5%	2116	25.1%	10.5%
13.5	421	6.3%	534	6.3%	0.0%
Average =	11.6 kips		12.1 kips		0.5 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.5 kips, or 4.3 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 12.1 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 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.

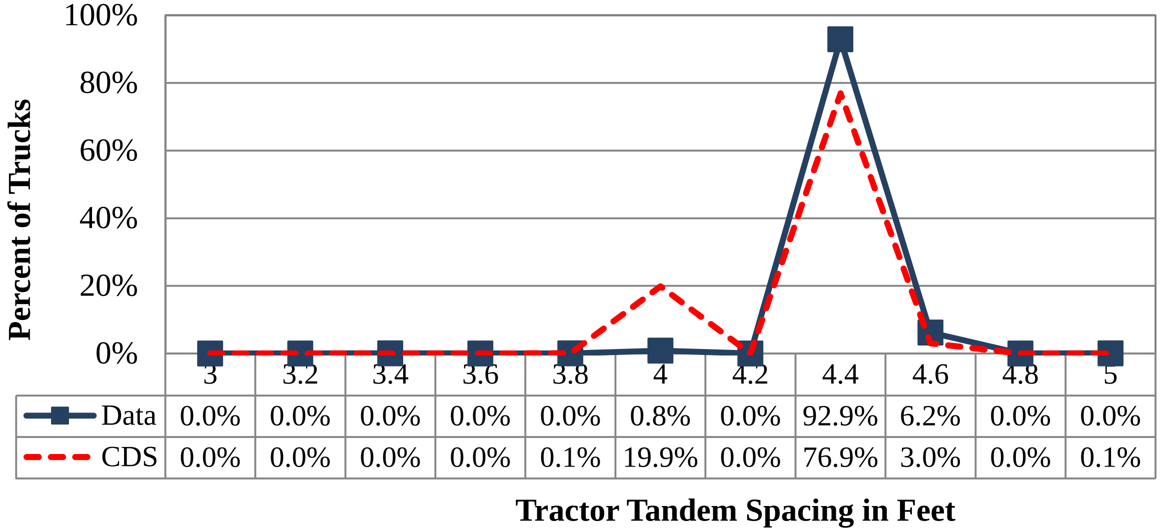


Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacings for the August 2012 Comparison Data Set indicate that almost 20% of the Class 9 trucks had tandem axle spacing measuring 4.0 feet while only 0.8% of trucks in the September 2013 Data set had this axle spacing. Majority of tandem axle spacings at this site are 4.4 feet.

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				
	8/22/2012		9/14/2013		
3.0	0	0.0%	0	0.0%	0.0%
3.2	0	0.0%	0	0.0%	0.0%
3.4	0	0.0%	4	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	8	0.1%	2	0.0%	-0.1%
4.0	1422	19.9%	72	0.8%	-19.0%
4.2	0	0.0%	0	0.0%	0.0%
4.4	5504	76.9%	8124	92.9%	16.0%
4.6	218	3.0%	542	6.2%	3.2%
4.8	0	0.0%	0	0.0%	0.0%
5.0	5	0.1%	3	0.0%	0.0%
Average =	4.3 feet		4.4 feet		0.1 feet

From the table it can be seen that the drive tandem spacing of Class 9 trucks at this site is between 4.0 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 4.4, which is above the average of 4.3 from the CDS per vehicle records. This is due to the near absence of the 4.0 tandem axle spacings observed in the Comparison Data Set. Further axle spacing analyses was 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 (August 2012) based on the last calibration with the most recent two-week WIM data sample from the site (September 2013). Comparison of vehicle class distribution data indicates a 2.0 percent increase in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 4.3 percent and average Class 9 GVW has increased by 4.1 percent for the September 2013 data. The data indicates an average truck tandem spacing of 4.4 feet, which is above the average of 4.3 feet observed in CDS.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on August 21, 2012 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 November 30, 2006 by International Road Dynamics. It is instrumented with bending plate weighing sensors and an IRD iSINC WIM Controller. As the installation contractor, IRD 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 in Section 8.

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, There were no pavement distresses noted that may affect the accuracies of the WIM system..

4.2 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**	**Avg**
Left	LWP	LRI (m/km)	0.897	0.878	0.816		0.864
		SRI (m/km)	0.709	0.647	0.700		0.685
		Peak LRI (m/km)	0.947	1.055	1.149		1.050
		Peak SRI (m/km)	1.662	1.562	0.979		1.401
	RWP	LRI (m/km)	0.852	0.947	0.990		0.930
		SRI (m/km)	*0.432*	0.513	0.958		0.634
		Peak LRI (m/km)	0.939	0.947	0.990		0.959
		Peak SRI (m/km)	1.176	1.268	1.403		1.282
Center	LWP	LRI (m/km)	0.766	0.777	0.806	0.807	0.789
		SRI (m/km)	0.540	0.535	0.621	0.651	0.587
		Peak LRI (m/km)	0.813	0.937	0.941	0.937	0.907
		Peak SRI (m/km)	1.579	1.483	1.548	1.695	1.576
	RWP	LRI (m/km)	1.167	1.008	1.102	1.076	1.088
		SRI (m/km)	1.105	0.728	0.899	0.810	0.886
		Peak LRI (m/km)	1.167	1.010	1.115	1.076	1.092
		Peak SRI (m/km)	1.342	1.361	1.407	1.245	1.339
Right	LWP	LRI (m/km)	0.968	0.853	0.881		0.901
		SRI (m/km)	0.691	0.720	*0.433*		0.615
		Peak LRI (m/km)	1.031	0.930	0.892		0.951
		Peak SRI (m/km)	**1.628**	**1.743**	**1.528**		**1.633**
	RWP	LRI (m/km)	1.175	1.148	1.032		1.118
		SRI (m/km)	1.166	1.264	0.996		1.142
		Peak LRI (m/km)	1.188	1.148	1.033		1.123
		Peak SRI (m/km)	1.435	1.448	1.278		1.387

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. Indices that are below the lower thresholds are shown in italics. The highest values, on average, are the Peak SRI values in the left wheel path of the right shift passes (shown in bold).

4.3 Profile and Vehicle Interaction

Profile data was collected on December 4, 2012 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, beginning 900 feet prior to WIM scales and ending 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 1000 foot WIM section is 279 in/mi and is located approximately 528 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 169 in/mi and is located approximately 392 feet prior to the WIM scale. These areas of the pavement were closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed at these locations 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.

4.4 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 October 15, 2013, beginning at approximately 10:04 AM and continuing until 3:26 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with residential waste, and equipped with air suspension on the tractor and trailer tandems, with standard tandem spacings on both the tractor and trailer.
- A Class 9 truck, loaded with residential waste, and equipped with air suspension on the tractor and trailer tandems, with standard tandem spacings on both the tractor and 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	77.6	11.5	16.3	16.3	16.8	16.8	14.8	4.4	33.2	4.1	56.5	61.8
2	67.9	11.6	13.6	13.6	14.5	14.5	13.4	4.3	33.5	4.2	55.4	62.5

Test truck speeds varied by 21 mph, from 44 to 65 mph. The measured pre-validation pavement temperatures varied 15.2 degrees Fahrenheit, from 67.2 to 82.4. The mild ambient temperatures prevented the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

As shown in Table 5-2, the site met all LTPP requirements for loading and distance measurement as a result of the pre-validation test truck runs.

Table 5-2 – Pre-Validation Overall Results – 15-Oct-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.0 ± 6.4%	Pass
Tandem Axles	±15 percent	2.2 ± 7.1%	Pass
GVW	±10 percent	2.0 ± 4.9%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.4 ± 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 0.3 ± 2.3 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 similar 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 65 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 – 15-Oct-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		44.0 to 51.0 mph	51.1 to 58.1 mph	58.2 to 65.0 mph
Steering Axles	±20 percent	2.8 ± 7.0%	-1.1 ± 5.8%	1.4 ± 5.1%
Tandem Axles	±15 percent	1.0 ± 2.4%	0.2 ± 5.0%	5.5 ± 2.8%
GVW	±10 percent	1.2 ± 2.1%	-0.1 ± 2.9%	5.0 ± 1.9%
Vehicle Length	±3.0 percent (1.9 ft)	0.1 ± 1.3 ft	0.4 ± 1.5 ft	0.6 ± 1.1 ft
Vehicle Speed	± 1.0 mph	0.3 ± 1.3 mph	0.1 ± 3.6 mph	0.6 ± 1.9 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.0 ft	0.0 ± 0.1 ft

From the table, it can be seen that the WIM equipment overestimates all weights at the high speeds. The range in error appears to be greater at the lower speeds for steering axles, and at the medium speeds for tandem axles and GVW.

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 overestimated GVW at the high speeds. The range in error is slightly greater at the medium speeds.

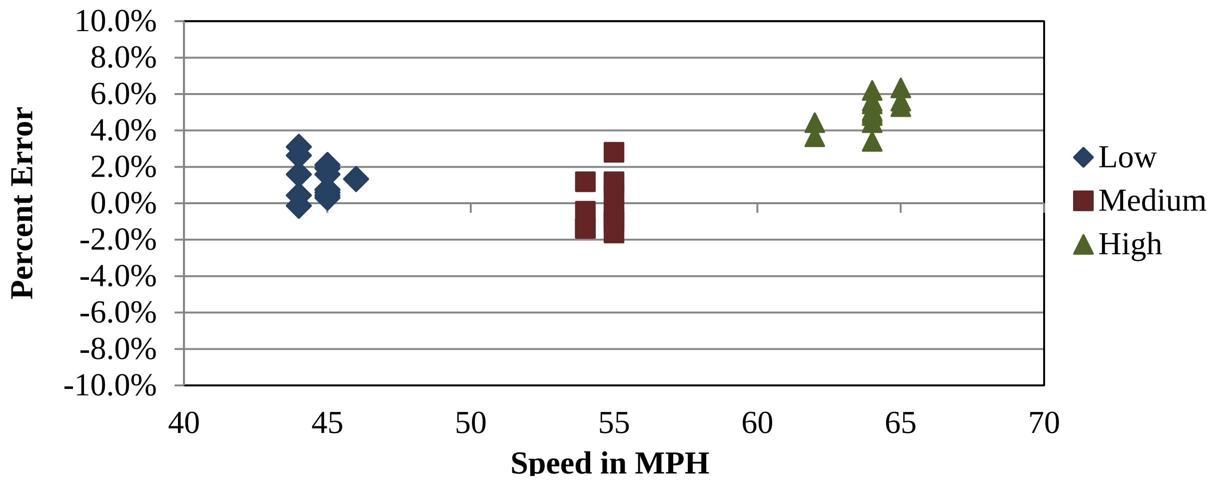


Figure 5-1 – Pre-Validation GVW Error by Speed – 15-Oct-13

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment generally overestimates steering axle weights at the low and high speeds. The range in error is greater at the lower speeds when compared with medium and high speeds.

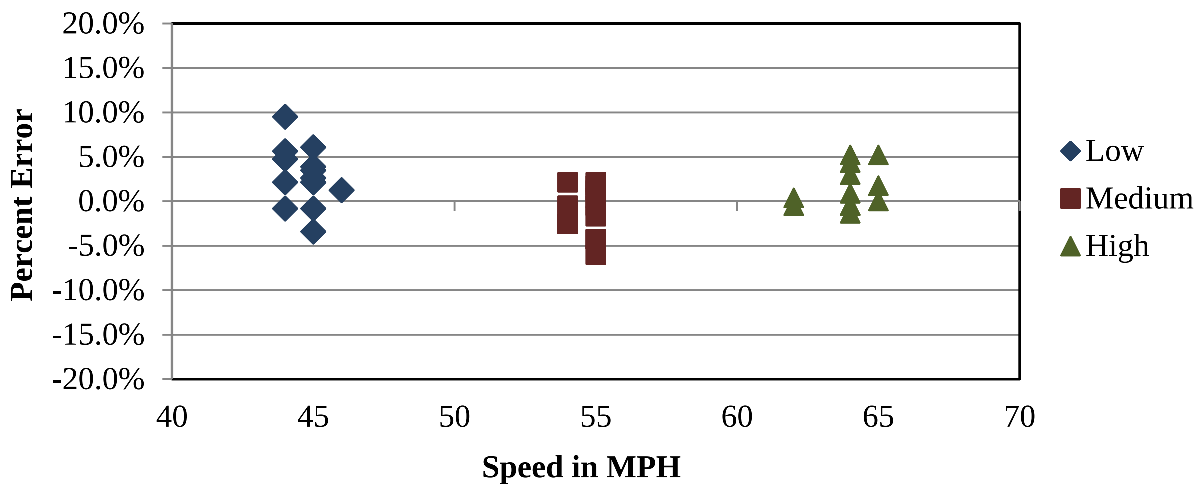


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 15-Oct-13

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment estimates tandem axle weights with similar accuracy at the low and medium speeds. At the higher speeds, the equipment appears to overestimate a portion of the tandem axles, increasing the range of errors at those speeds. The results obtained for the high speed group represent two distinct portions, an overestimated portion and a portion of measurements without bias.

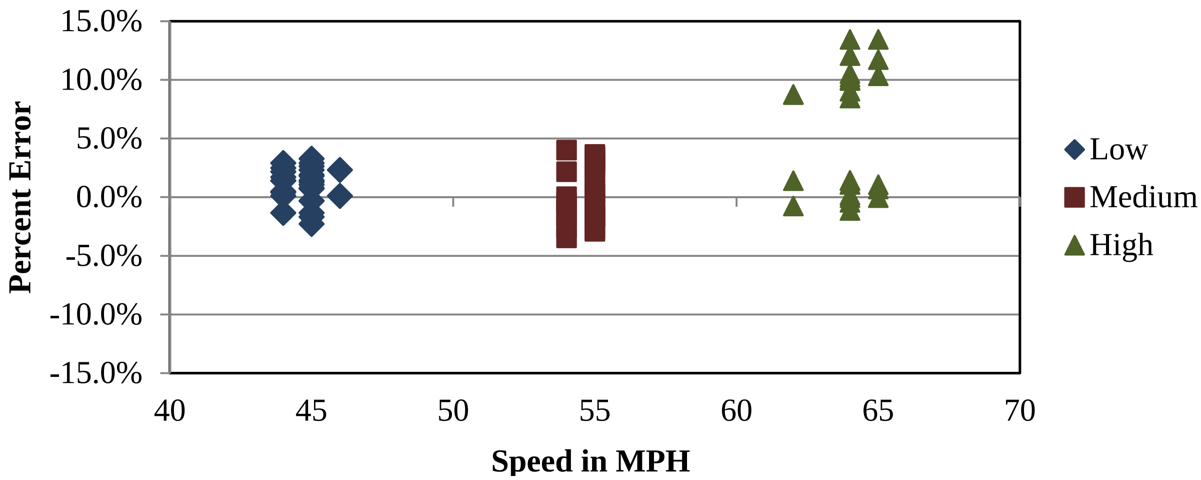


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 15-Oct-13

To further analyze the tandem axle error, Figure 5-4 was developed. As shown in the figure, the equipment overestimates a portion of the tandem weights (for both trucks) for the high speed group. The overestimated portion belongs to Tandem 2 axles, i.e., tandem axles on the trailers. This may be due to adverse truck dynamics affecting only tandem axles on the trailers. The 10 percent overestimation of Tandem 2 axle weights shown in Figure 5-3 contributes to the 5 percent overestimation of GVW for the high speed group (Figure 5-1 and Figure 5-5).

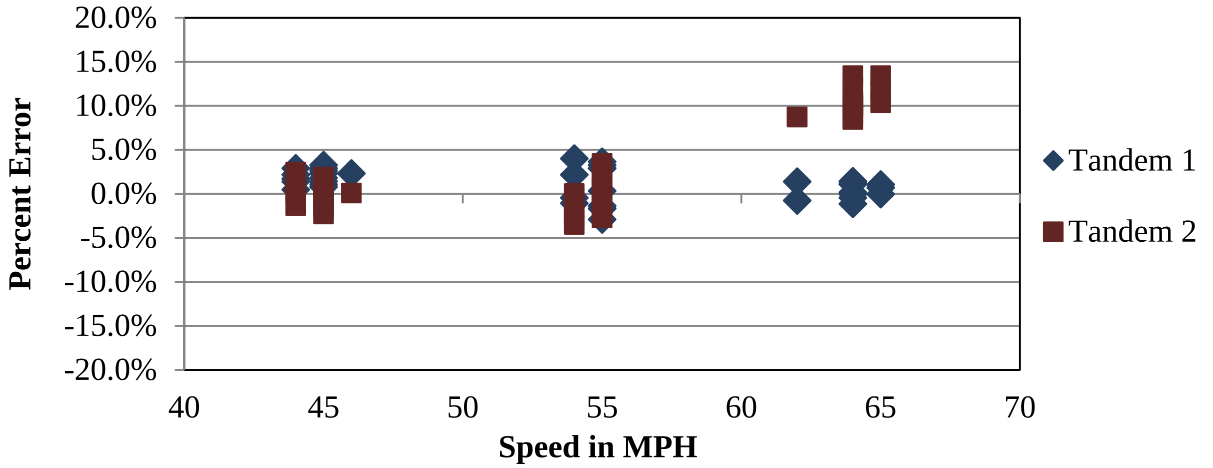


Figure 5-4 – Pre-Validation Tandem Axle Weight Errors by Group and Speed – 15-Oct-13

5.1.1.4 GVW Errors by Speed and Truck Type

As shown in Figure 5-5, when the GVW error for each truck is analyzed as a function of speed, it can be seen that at the low speeds, the WIM equipment precision and bias are similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. At the medium and high speeds, GVW is estimated slightly higher for the Secondary truck than for the Primary Truck. The highest GVW errors for both truck types were obtained for the high speed group.

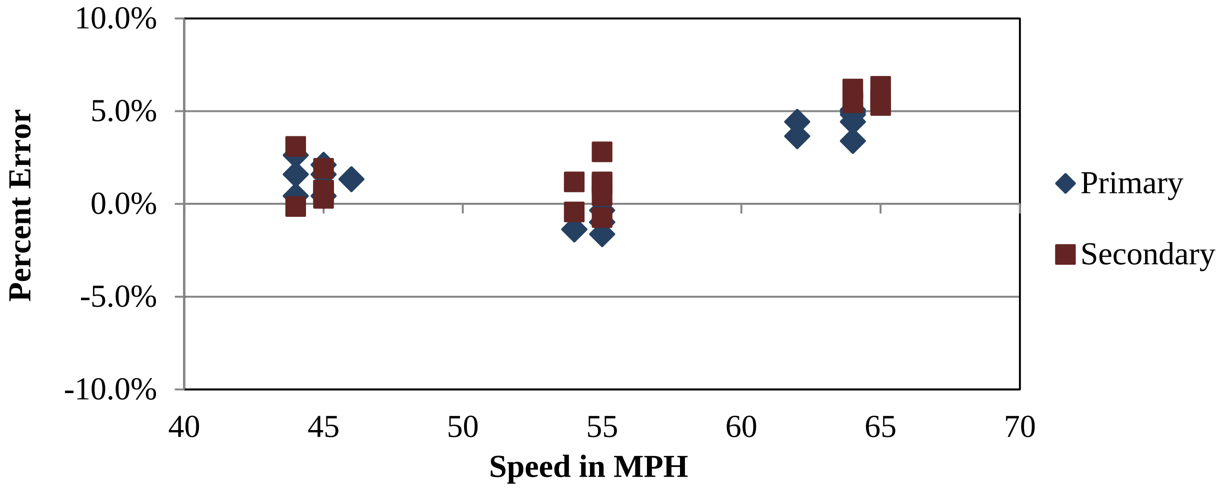


Figure 5-5 – Pre-Validation GVW Errors by Truck and Speed – 15-Oct-13

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 0.1 feet. Distribution of errors is shown graphically in Figure 5-6.

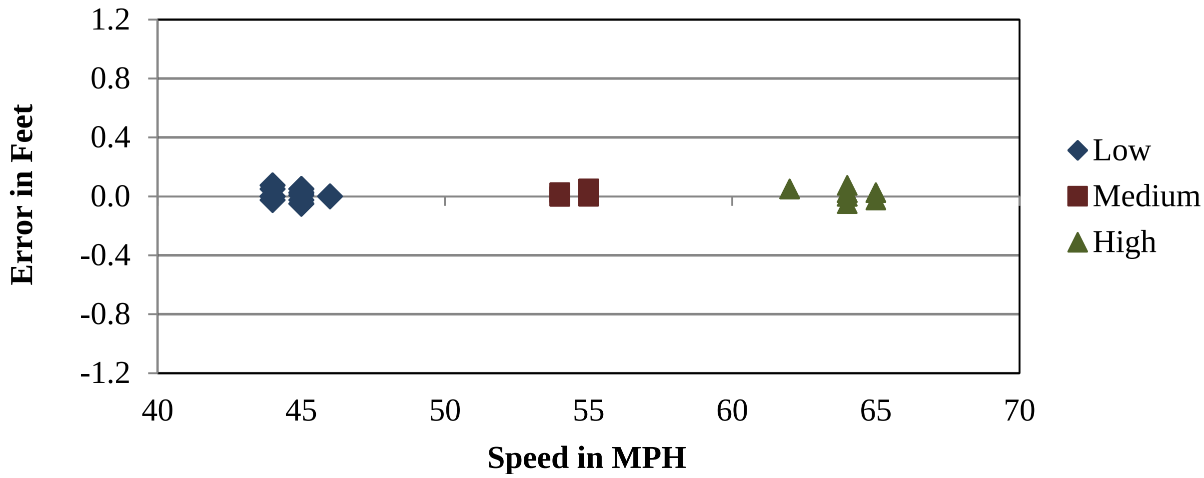


Figure 5-6 – Pre-Validation Axle Length Errors by Speed – 15-Oct-13

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment overestimated overall vehicle length consistently over the entire range of speeds, with an error range of -0.5 to 1.2 feet. Distribution of errors is shown graphically in Figure 5-7.

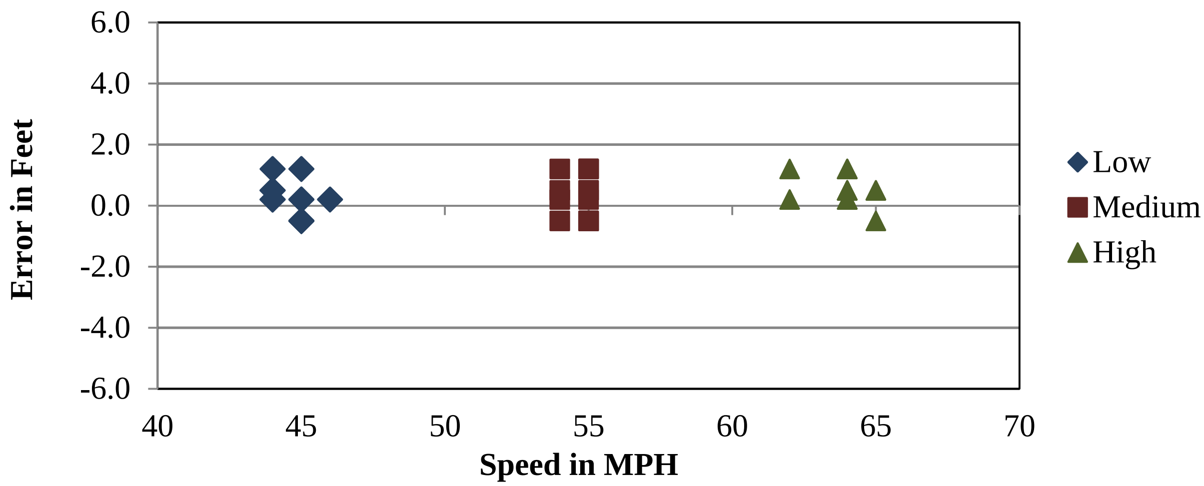


Figure 5-7 – Pre-Validation Overall Length Error by Speed – 15-Oct-13

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 15.2 degrees, from 67.2 to 82.4 degrees Fahrenheit. Since the desired 30 degree temperature range was not met, the pre-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 15-Oct-13

Parameter	95% Confidence Limit of Error	Low	High
		67.2 to 75.0 degF	75.1 to 79.1 degF
Steering Axles	±20 percent	1.3 ± 8.8%	1.0 ± 7.0%
Tandem Axles	±15 percent	1.6 ± 6.8%	2.7 ± 7.8%
GVW	±10 percent	1.5 ± 4.9%	2.5 ± 5.6%
Vehicle Length	±3.0 percent (1.9 ft)	0.1 ± 1.4 ft	0.6 ± 1.5 ft
Vehicle Speed	± 1.0 mph	0.0 ± 3.9 mph	0.7 ± 1.6 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 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 generally overestimates GVW across the range of temperatures observed in the field. The range in error is slightly greater at high temperatures.

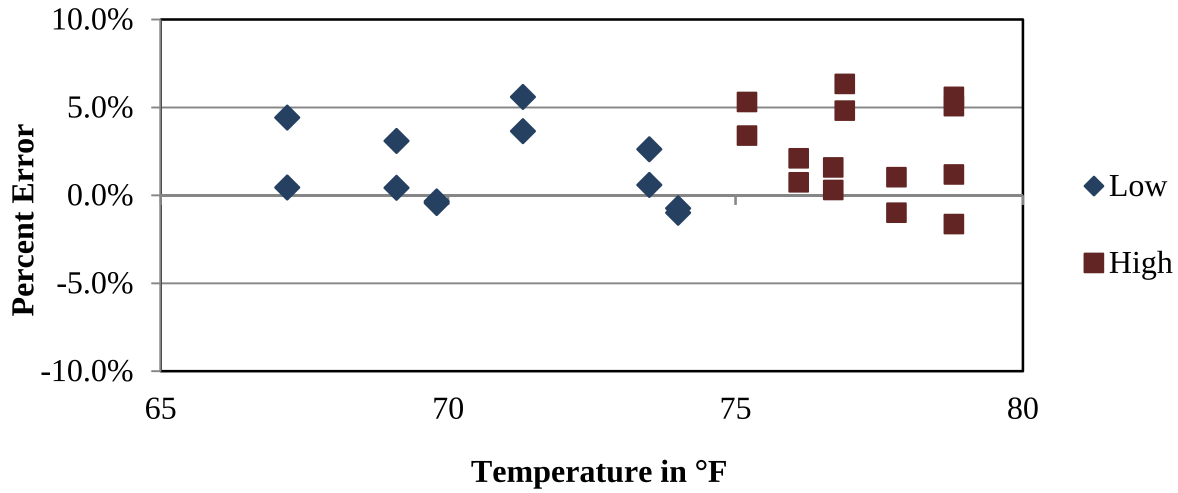


Figure 5-8 – Pre-Validation GVW Errors by Temperature – 15-Oct-13

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 illustrates that for steering axles, the WIM equipment slightly overestimates weights at all temperatures. The range in error is similar for different temperature groups.

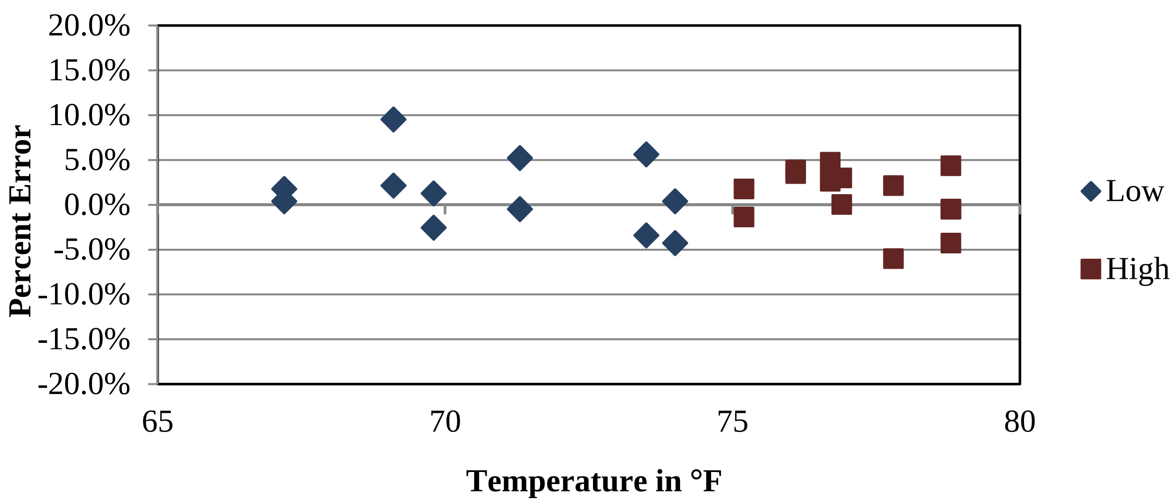


Figure 5-9 – Pre-Validation Steering Axle Weight Errors by Temperature – 15-Oct-13

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-10, the WIM equipment generally overestimates tandem axle weights across the range of temperatures observed in the field. The range in tandem axle errors is slightly greater at high temperatures.

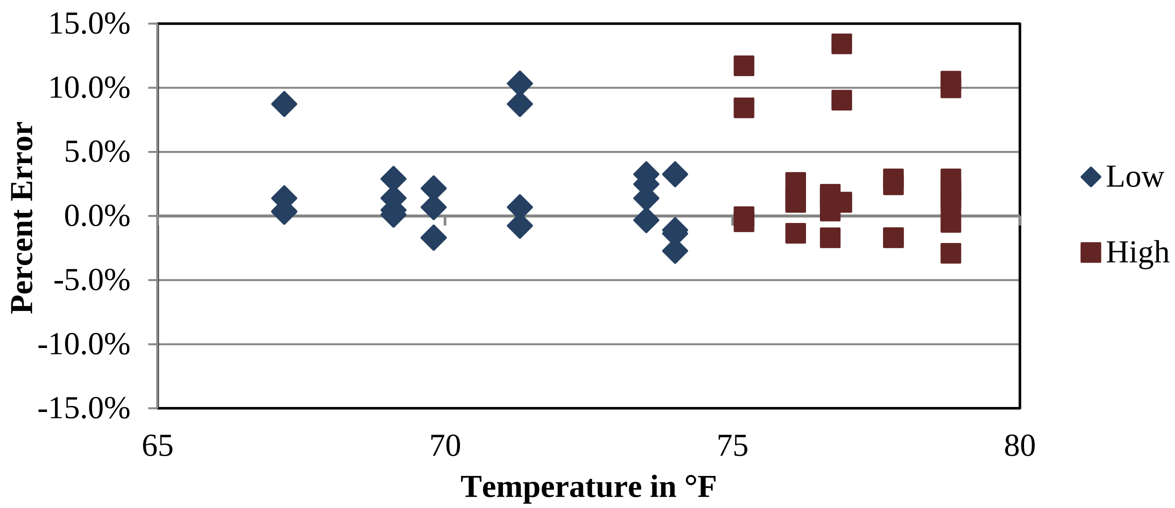


Figure 5-10 – Pre-Validation Tandem Axle Weight Errors by Temperature – 15-Oct-13

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, 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. For both trucks, the range of errors and bias are consistent over the range of temperatures. Distribution of errors is shown graphically in Figure 5-11.

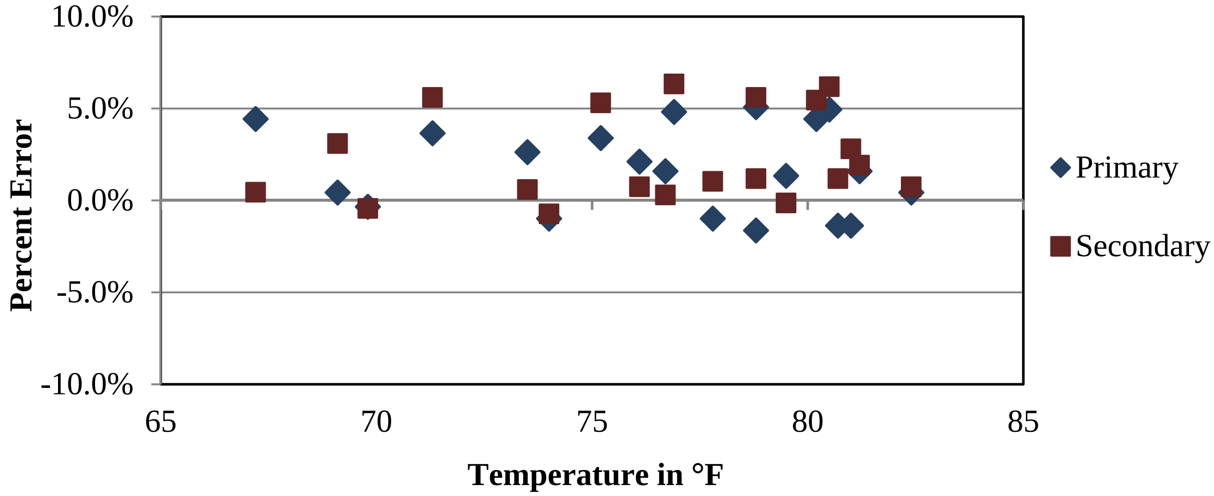


Figure 5-11 – Pre-Validation GVW Error by Truck and Temperature – 15-Oct-13

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 107 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.

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 misclassifications by pair are provided in Table 5-5. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-5, two Class 4 vehicles were misclassified as a Class 5 vehicles, one Class 4 vehicle was misclassified as a Class 8 vehicle, and one Class 5 vehicle was misclassified as a Class 8 vehicle by the equipment. One Class 13 was not classified by the equipment (Class 15).

Table 5-5 – Pre-Validation Misclassifications by Pair – 15-Oct-13

		WIM												
		3	4	5	6	7	8	9	10	11	12	13	14	15
Observed	3	-												
	4		-	2			1							
	5			-			1							
	6				-									
	7					-								
	8						-							
	9							-						
	10								-					
	11									-				
	12										-			
	13											-		1

As shown in the table, a total of 5 vehicles, including 1 heavy trucks (vehicle classes 6 – 13) were misclassified by the equipment. Based on the vehicles observed during the pre-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 4.7%, primarily due to misclassification of lightweight vehicles in Class 4 and Class 5. The causes for the misclassifications were not investigated in the field.

The combined results produced an undercount of three Class 4 vehicles and one Class 13 vehicle, and an overcount of one Class 5 and two Class 8 vehicles, as shown in Table 5-6. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-6 – Pre-Validation Classification Study Results – 15-Oct-13

Class	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Observed Count	0	4	19	1	0	3	74	2	2	0	2
WIM Count	0	1	20	1	0	5	74	2	2	0	1
Observed Percent	0.0	3.7	17.8	0.9	0.0	2.8	69.2	1.9	1.9	0.0	1.9
WIM Percent	0.0	0.9	18.7	0.9	0.0	4.7	69.2	1.9	1.9	0.0	0.9
Misclassified Count	0	3	1	0	0	0	0	0	0	0	1
Misclassified Percent	0.0	75.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	1
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

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 – 15-Oct-13

Observed Class	Unclassified	Observed Class	Unclassified	Observed Class	Unclassified
3	0	7	0	11	0
4	0	8	0	12	0
5	0	9	0	13	1
6	0	10	0		

Based on the manually collected sample of the 107 trucks, 0.9 percent 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 1.0 mph; the range of errors was 1.6 mph.

5.2 Calibration

The WIM equipment required one calibration iteration 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 – 16-Oct-13

Speed Point	MPH	Left	Right
		1	2
72	45	3312	3667
80	50	3334	3692
88	55	3231	3577
96	60	3269	3619
104	65	3245	3593
Axle Distance (cm)		372	
Dynamic Comp (%)		103	
Loop Width (cm)		313	

5.2.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of 2.0% and errors of 1.4%, .06%, and 5.1% at the 45, 55 and 65 mph speed points respectively. To compensate for these errors, the changes in Table 5-9 were made to the compensation factors.

Table 5-9 – Calibration Equipment Factor Changes – 16-Oct-13

Speed Points	Old Factors		New Factors	
	Left	Right	Left	Right
	1	2	1	2
72	3312	3667	3266	3616
80	3334	3692	3310	3665
88	3231	3577	3229	3575
96	3269	3619	3183	3523
104	3245	3593	3080	3410
Axle Distance (cm)	372		372	
Dynamic Comp (%)	103		104	
Loop Width (cm)	313		324	

5.2.2 Calibration Results

The results of the 12 calibration verification runs are provided in Table 5-10 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 calibration iteration.

Table 5-10 – Calibration Results – 16-Oct-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.1 ± 5.0%	Pass
Tandem Axles	±15 percent	-0.6 ± 6.8%	Pass
GVW	±10 percent	-0.6 ± 3.1%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.2 ± 1.3 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Figure 5-12 shows that the WIM equipment is estimating GVW with similar accuracy at all speeds.

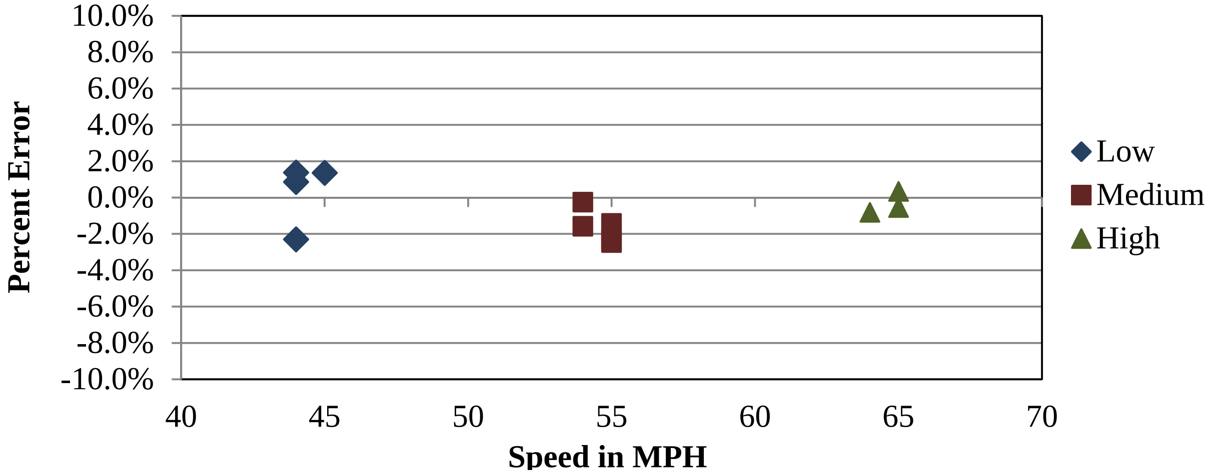


Figure 5-12 – Calibration GVW Error by Speed – 16-Oct-13

Based on the results of the calibration, where GVW estimate bias decreased to -0.6 percent, a second calibration was not considered to be necessary. The 12 calibration runs were combined with 28 additional post-validation runs to complete the WIM system validation.

5.3 Post-Validation

The 40 post-validation test truck runs were conducted on October 16, 2013, beginning at approximately 8:46 AM and continuing until 2:12 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with trash, 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 trash, 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 5-11.

Table 5-11 – 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	77.5	11.7	16.2	16.2	16.7	16.7	14.8	4.4	33.2	4.1	56.5	61.8
2	68.0	11.8	13.7	13.7	14.4	14.4	13.4	4.3	33.5	4.2	55.4	62.5

Test truck speeds varied by 21 mph, from 44 to 65 mph. The measured post-validation pavement temperatures varied 32.9 degrees Fahrenheit, from 50.5 to 83.4. The sunny weather conditions provided the desired minimum 30 degree temperature range. Table 5-12 is a summary of post validation results.

Table 5-12 – Post-Validation Overall Results – 16-Oct-13

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	0.6 ± 6.2%	Pass
Tandem Axles	±15 percent	-0.2 ± 6.4%	Pass
GVW	±10 percent	-0.1 ± 2.6%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.2 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 for all speeds was 0.4 ± 1.8 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 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 similar 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 65 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-13.

Table 5-13 – Post-Validation Results by Speed – 16-Oct-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		44.0 to 51.0 mph	51.1 to 58.1 mph	58.2 to 65.0 mph
Steering Axles	±20 percent	3.2 ± 5.6%	-0.4 ± 4.4%	-1.3 ± 5.5%
Tandem Axles	±15 percent	0.0 ± 4.5%	-0.6 ± 4.1%	0.0 ± 2.8%
GVW	±10 percent	0.6 ± 3.5%	-0.7 ± 2.4%	-0.2 ± 1.0%
Vehicle Length	±3.0 percent (1.9 ft)	-0.1 ± 1.2 ft	-0.1 ± 1.2 ft	0.1 ± 1.4 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 1.6 mph	0.6 ± 2.1 mph	0.5 ± 1.9 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.0 ft

From the table, it can be seen that the WIM equipment overestimates steering axle weights at the low speeds and estimates all other weights with similar accuracy at all speeds. There does not appear to be a relationship between weight estimates and speed at this site except for the steering axles.

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, as it relates to bias, at all speeds. The range in error is greater for the lower speeds.

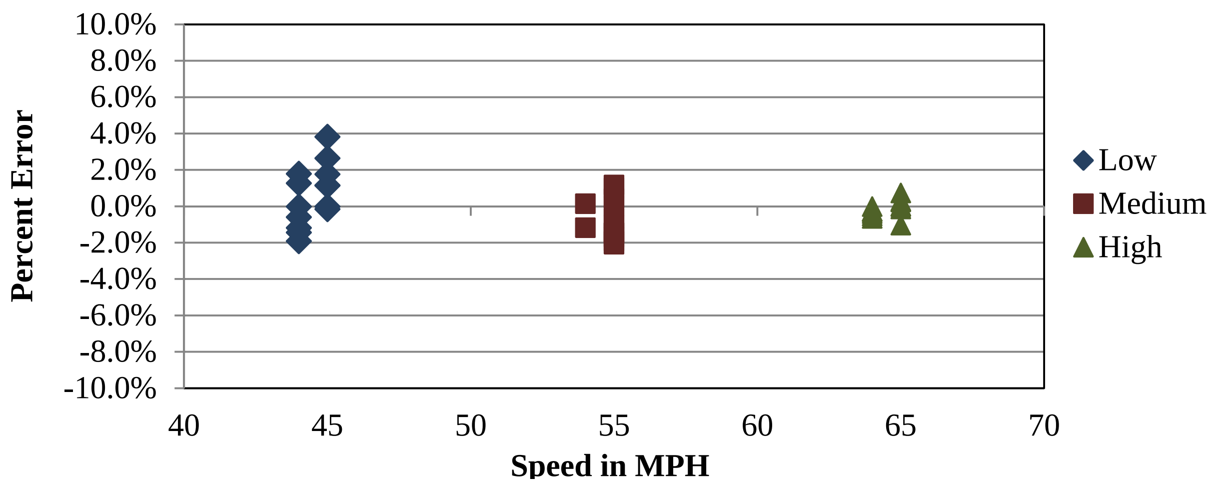


Figure 5-13 – Post-Validation GVW Errors by Speed – 16-Oct-13

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-14, the equipment overestimated steering axle weights at the low speeds, and estimated weights with similar accuracy at the medium and high speeds. The range in error is similar throughout the entire speed range. There does appear to be a slight correlation between speed and steering axle weight estimates at this site.

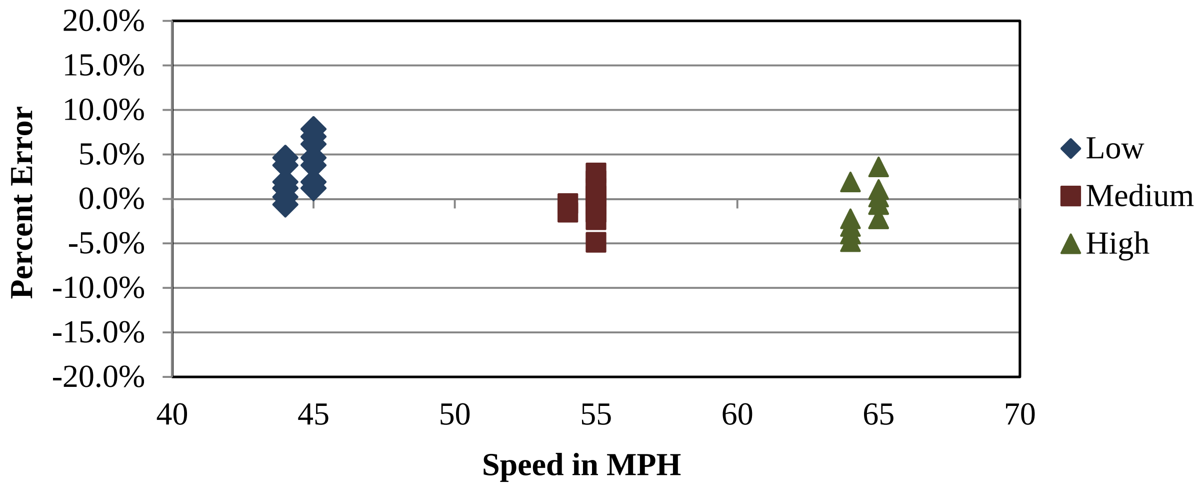


Figure 5-14 – Post-Validation Steering Axle Weight Errors by Speed – 16-Oct-13

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, as it relates to bias, at all speeds. The range in error is greater at the higher speeds, due to half of the tandem axle weights being underestimated and half of the tandem axle weights being overestimated. As discussed in Section 5.1.1.4, the overestimated half of the tandem axles for the high speed group belongs to tandem axles on the trailers.

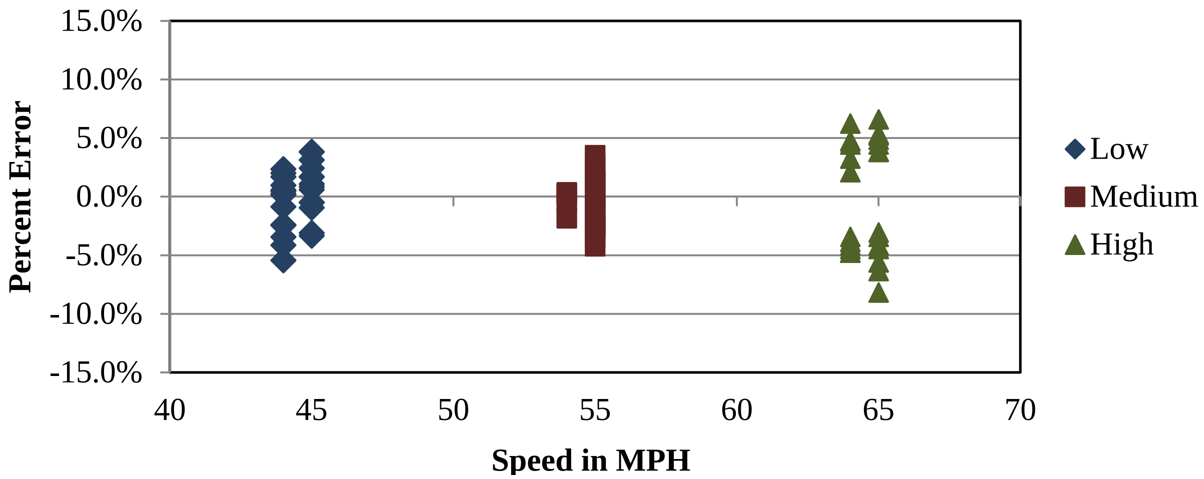


Figure 5-15 – Post-Validation Tandem Axle Weight Errors by Speed – 16-Oct-13

Figure 5-16 was developed to further investigate the Tandem Axle weight results. As shown in the figure, the tractor tandem axle weights (Tandem 1) are underestimated and the tractor tandem axle weights are overestimated. The calibration was able to minimize tandem axle bias by creating equal absolute bias for the two axle groups (Tandem 1 and Tandem 2).

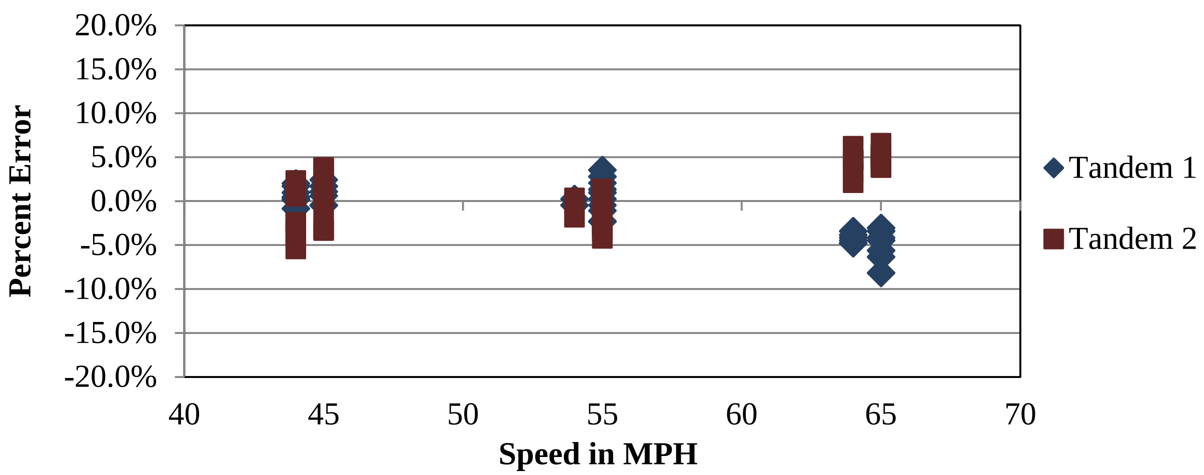


Figure 5-16 – Post-Validation Tandem Axle Weight Errors by Group and Speed – 16-Oct-13

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-17 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck.

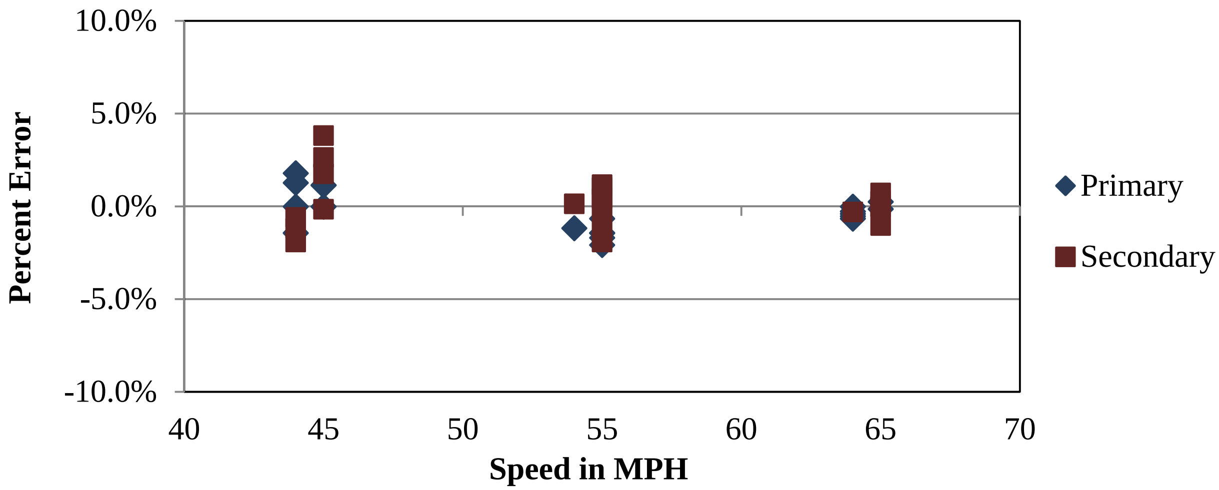


Figure 5-17 – Post-Validation GVW Error by Truck and Speed – 16-Oct-13

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 0.0 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-18.

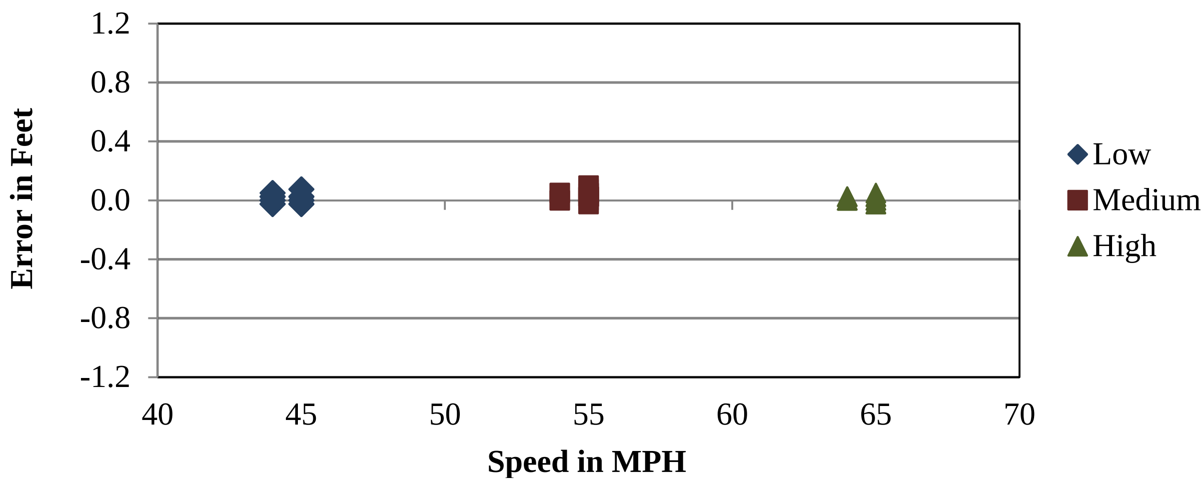


Figure 5-18 – Post-Validation Axle Length Error by Speed – 16-Oct-13

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length consistently over the entire range of speeds, with errors ranging from -1.5 to 1.2 feet. Distribution of errors is shown graphically in Figure 5-19.

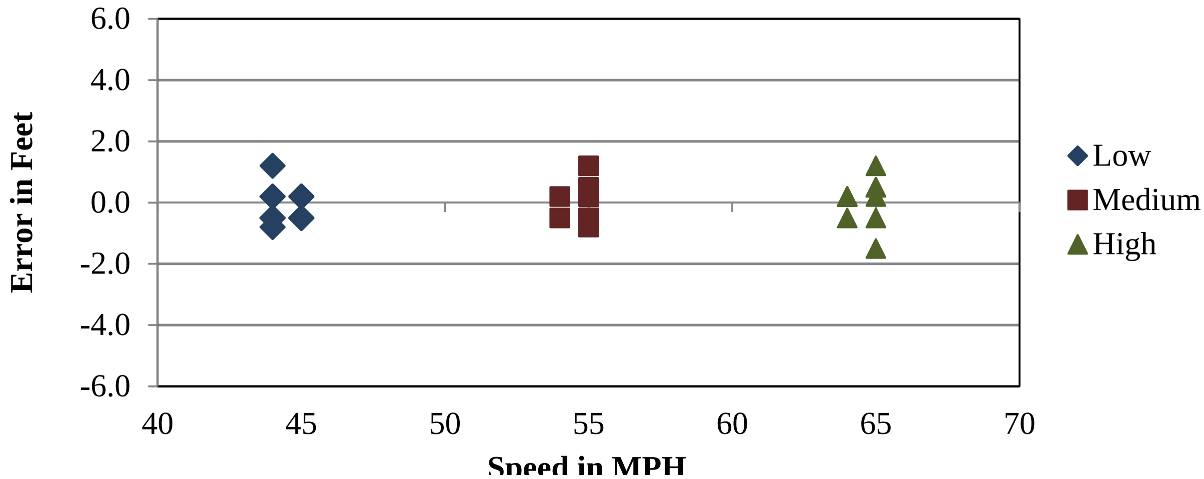


Figure 5-19 – Post-Validation Overall Length Error by Speed – 16-Oct-13

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 32.9 degrees, from 50.5 to 83.4 degrees Fahrenheit. The post-validation test runs are reported under three temperature groups – *low, medium and high*, as shown in Table 5-14 below.

Table 5-14 – Post-Validation Results by Temperature – 16-Oct-13

Parameter	95% Confidence Limit of Error	Low 50.5 to 71.2 degF	Medium 71.3 to 79.4 degF	High 79.5 to 83.4 degF
Steering Axles	±20 percent	-0.2 ± 5.2%	1.0 ± 6.4%	0.9 ± 8.6%
Tandem Axles	±15 percent	-0.3 ± 7.1%	-0.6 ± 7.1%	0.3 ± 6.4%
GVW	±10 percent	-0.2 ± 2.8%	-0.4 ± 2.4%	0.4 ± 3.0%
Vehicle Length	±3.0 percent (1.9 ft)	0.1 ± 1.6 ft	-0.1 ± 1.2 ft	-0.1 ± 0.9 ft
Vehicle Speed	± 1.0 mph	0.4 ± 2.8 mph	0.2 ± 1.5 mph	0.5 ± 1.1 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.0 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 5-20, 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.

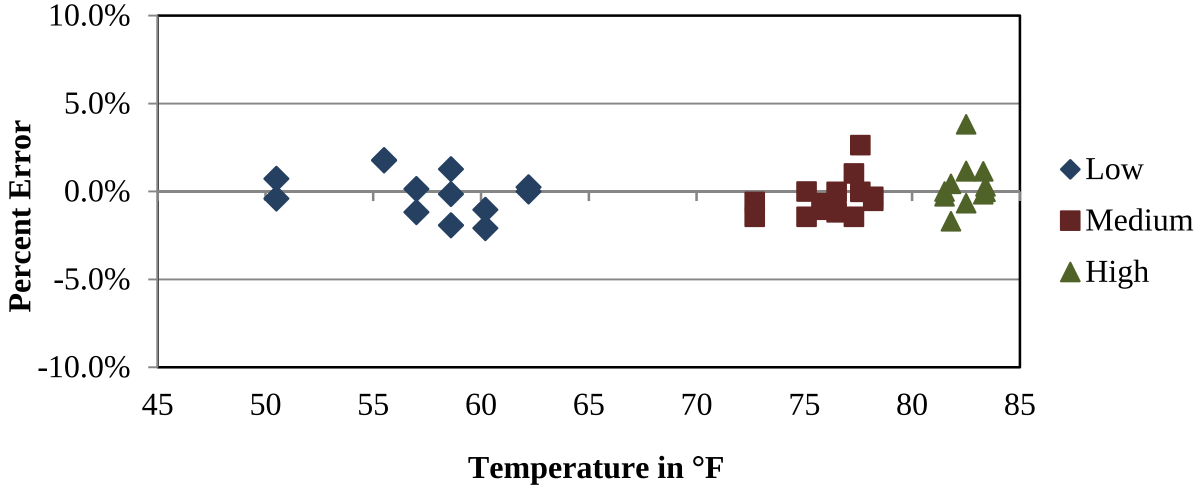


Figure 5-20 – Post-Validation GVW Errors by Temperature – 16-Oct-13

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-21 demonstrates that for steering axles, the WIM equipment appears to estimate weights with similar accuracy across the range of temperatures observed in the field. The range in error is slightly higher at higher temperatures.

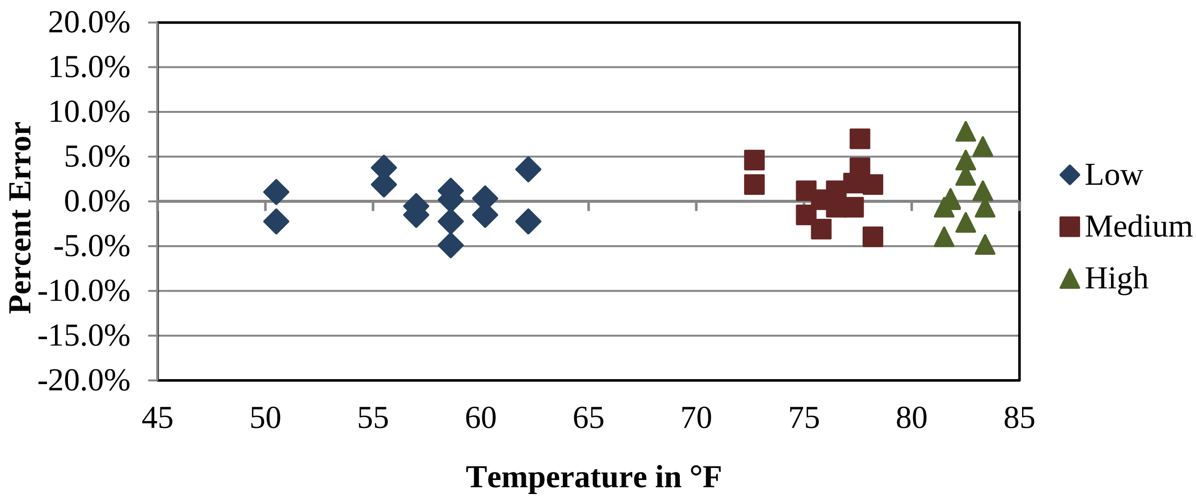


Figure 5-21 – Post-Validation Steering Axle Weight Errors by Temperature – 16-Oct-13

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-22, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. The range in tandem axle errors is consistent for the three temperature groups.

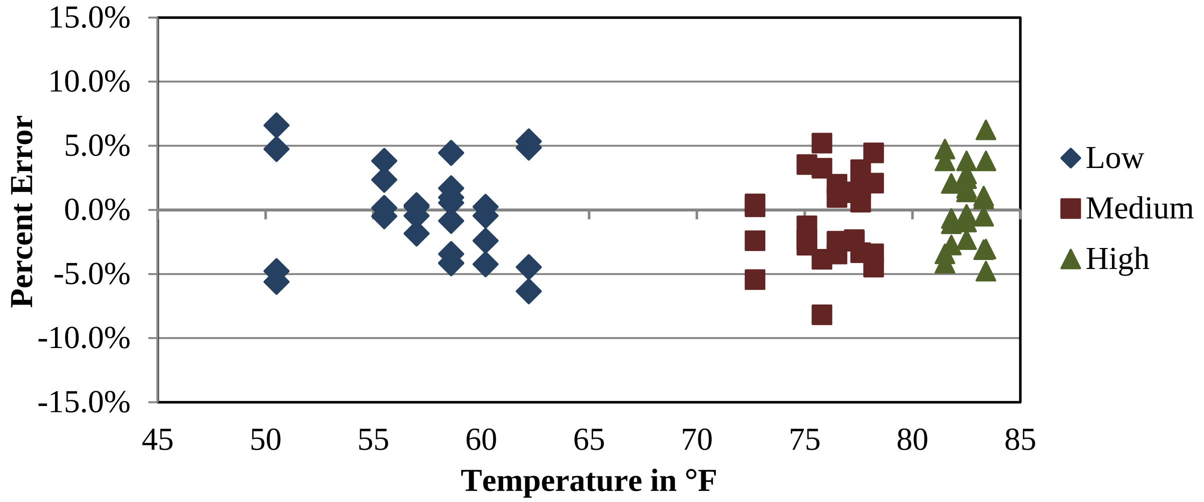


Figure 5-22 – Post-Validation Tandem Axle Weight Errors by Temperature – 16-Oct-13

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-23, when analyzed by truck type, GVW measurement errors for both trucks are similar at all temperatures. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures.

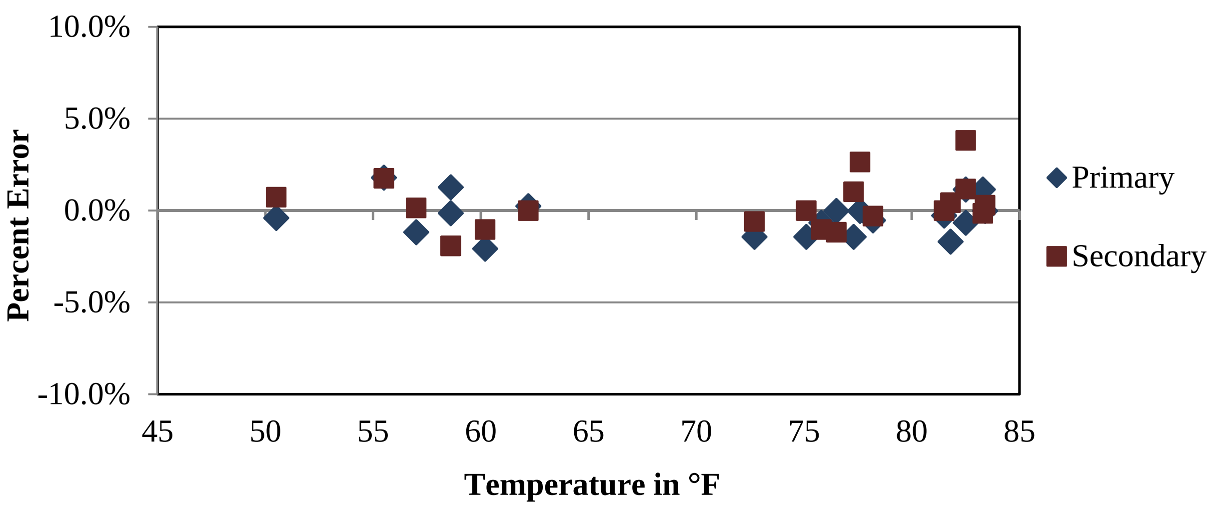


Figure 5-23 – Post-Validation GVW Error by Truck and Temperature – 16-Oct-13

5.3.3 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 109 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.

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. The misclassifications by pair are provided in Table 5-15. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-15, four Class 5 vehicles were misclassified as Class 8 vehicles by the equipment.

Table 5-15 – Post-Validation Misclassifications by Pair – 16-Oct-13

	WIM											
		3	4	5	6	7	8	9	10	11	12	13	14
Observed	3	-											
	4		-										
	5			-			4						
	6				-								
	7					-							
	8						-						
	9							-					
	10								-				
	11									-			
	12										-		
	13											-	-

As shown in the table, a total of 4 vehicles, including 0 heavy trucks (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the post-validation study, the misclassification percentage is 0.0% for heavy trucks (vehicle classes 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 3.6 percent, due to the misclassification of lightweight vehicles in Class 5. The causes for the misclassifications were not investigated in the field.

The combined results of the misclassifications resulted in an undercount of four Class 5 vehicles and an overcount of four Class 8 vehicles, as shown in Table 5-16. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-16 – Post-Validation Classification Study Results – 16-Oct-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	0	2	28	0	1	1	72	0	3	2	0
WIM Count	0	2	24	0	1	5	72	0	3	2	0
Observed Percent	0.0	1.8	25.5	0.0	0.9	0.9	65.5	0.0	2.7	1.8	0.0
WIM Percent	0.0	1.8	21.8	0.0	0.9	4.5	65.5	0.0	2.7	1.8	0.0
Misclassified Count	0	0	4	0	0	0	0	0	0	0	0
Misclassified Percent	0.0	0.0	14.3	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

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. Based on the manually collected sample of the 109 trucks, 0.0 percent 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 1.0 mph; the range of errors was 4.9 mph.

5.3.4 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-17.

Table 5-17 – Final Factors

Speed Point	MPH	Left	Right
		1	2
72	45	3266	3616
80	50	3310	3665
88	55	3229	3575
96	60	3183	3523
104	65	3080	3410
Axle Distance (cm)		372	
Dynamic Comp (%)		104	
Loop Width (cm)		324	

6 Post-Visit Data Analysis

A post-visit data analysis is conducted to further evaluate the validation truck data to determine if any relationships exist between WIM system weight and distance measurement error based on speed, temperature and/or truck type. Additionally, an analysis of the post-visit misclassifications noted during the post-validation classification and speed study is conducted to possibly determine the cause of each truck misclassification.

If necessary, a traffic data sample from the days immediately following the validation to the date of the report submission may be conducted to further investigate anomalies in the traffic data that may have resulted from the calibration of the system or any other changes to the WIM system

6.1 Regression Analysis

This section provides additional results for the analysis carried out to determine the influence of truck type, speed and pavement temperature on WIM measurement errors. Multivariable linear regression analysis was applied to WIM data collected during calibration procedures. The same calibration data analyzed and discussed previously was used for this analysis; however a more comprehensive statistical methodology was applied. 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 analysis provides additional insight on how factors like speed, temperature, and truck type may affect weight measurement errors for a specific WIM site. It is expected that multivariable analysis done systematically for many sites may reveal overall trends.

6.1.1 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. 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 44 to 65 mph.
- Pavement temperature. Pavement temperature ranged from 50.5 to 83.4 degrees Fahrenheit.

6.1.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 6-1. 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 6-1 are for the null hypothesis that assumes that the regression coefficients are equal to zero. The p-value reported in Table 6-1 is for the probability that the regression coefficient, given in Table 5-5, occur by chance alone.

Table 6-1 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value (p-value)
Intercept	0.7021	1.9004	0.3694	0.7140
Speed	-0.0356	0.0239	-1.4884	0.1453
Temp	0.0128	0.0182	0.7040	0.4860
Truck	0.5048	0.3937	1.2821	0.2080

The lowest probability value given in Table 6-1 was 0.1453 for speed. This means that there is about a 14.5 percent chance that the value of regression coefficient for speed (-0.0356) can occur by chance alone. Assuming that p-values equal or less than 0.05 indicate statistical significance, none of the parameters in Table 6-1 had a statistically significant effect on the GVW measurement errors.

The relationship between speed and GVW measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error.

The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.0356 (in Table 6-1). This means, for example, that for a 10 mph change in speed, the error is changed by about -0.4 percent (-0.0356 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.1453) and is not statistically significant.

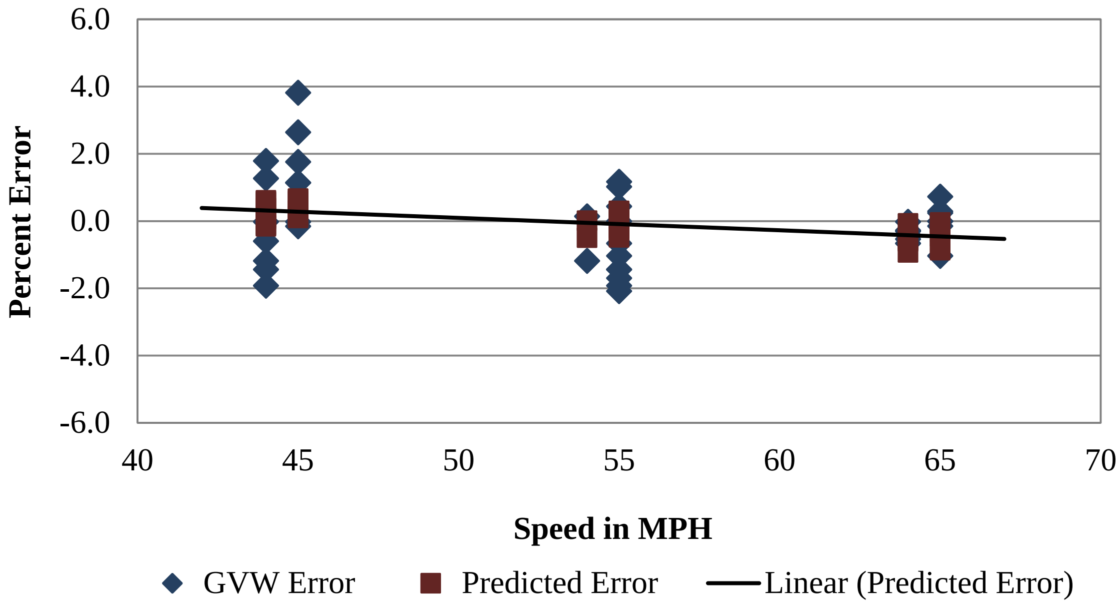


Figure 6-1 – Influence of Speed on the Measurement Error of GVW

6.1.3 Summary Results

Table 6-2 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 6-2 indicates that the probability that the relationship can occur by chance alone was greater than 20 percent.

Table 6-2 – Summary of Regression Analysis

Parameter	**Factor**					
	Speed		**Temperature**		**Truck type**	
	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)
GVW	-0.0356	0.1453	-	-	-	-
Steering axle	-0.2171	0.0001	-	-	-	-
Tandem axle tractor	-0.2651	0.0000	-	-	-	-
Tandem axle trailer	0.2617	0.0000	-	-	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on weight measurement errors for steering axles and tandem axles. However, the practical effect (although statistically significant) was very small as indicated by the small values of the regression coefficients.

2. Temperature and Truck Type did not have a statistically significant effect on the measurement error of any of the weights.

3. Even though speed had statistically significant effect on measurement errors of all of the parameters, the practical significance of this effect on WIM system calibration tolerances was small and does not affect the validity of the validation.

6.1.5 Contribution of Two Trucks to Calibration

Calibration of WIM systems installed in LTPP lanes is carried out by adjusting calibration factors based on measurement errors of GVW obtained for calibration trucks. During the calibration process, the GVW measurement errors obtained for two calibration trucks are combined when calculating and setting calibration factors. Different calibration factors are used for different speed points (truck speeds). The question addressed in this section is: What would be the calibration factors (calibration results) if only one truck (either Primary or Secondary) was used?

The contribution of using Primary and Secondary trucks for the calibration of the WIM system is illustrated using Figure 6-2 and supported by the associated statistical analysis. It is noted that the influence of pavement temperature is not directly used in the calibration process and thus not considered in this analysis.

Figure 6-2 shows that speed had similar influences on the GVW measurement for each truck. Combined, the overall GVW error dependency on speed was not statistically significant at 95% level of significance. The probability that the effect of speed was random was 14.5 percent.

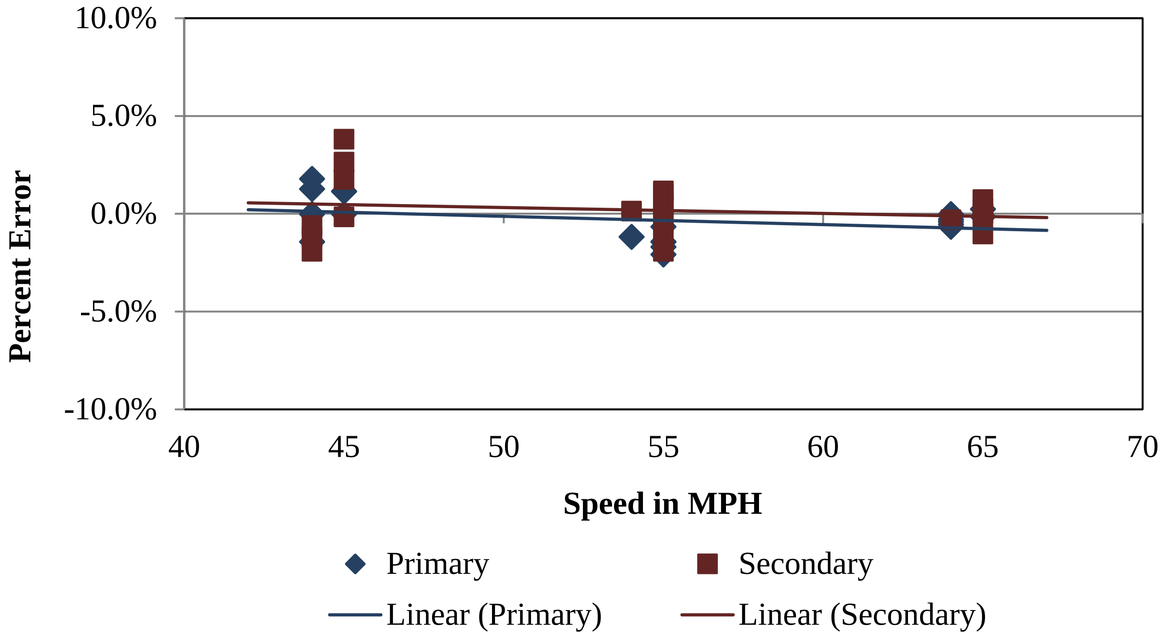


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

The use of two calibration trucks provided verification of the trends and speeded up the time required to obtain 40 pre-validation runs. For this site, the use of only one of the trucks (Primary or Secondary) would have resulted in similar verification and calibration results. As shown in Table 6-3, the mean errors for each of the weight parameters is similar for each of the trucks. Consequently, the use of either one of the calibration trucks alone would have produced similar calibration results.

Table 6-3 – Post-Validation Results by Truck Type – 15-Aug-13

Parameter	95% Confidence Limit of Error	Primary	Secondary	Combined
Steering Axles	±20 percent	0.2 ± 6.2%	0.9 ± 6.7%	0.6 ± 6.2%
Tandem Axles	±15 percent	-0.5 ± 6.4%	0.0 ± 6.9%	-0.2 ± 6.4%
GVW	±10 percent	-0.3 ± 2.2%	0.2 ± 3.0%	-0.1 ± 2.6%
Vehicle Length	±3.0 percent (1.9 ft)	0.3 ± 1.1 ft	-0.4 ± 1.0 ft	0.0 ± 1.2 ft
Vehicle Speed	± 1.0 mph	0.3 ± 2.0 mph	0.4 ± 1.7 mph	0.0 ± 0.1 ft
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.6 ± 6.2%

6.2 Misclassification Analysis

Since no heavy trucks were misclassified during the post-validation classification and speed study, a post-visit misclassification analysis was not conducted.

6.3 Traffic Data Analysis

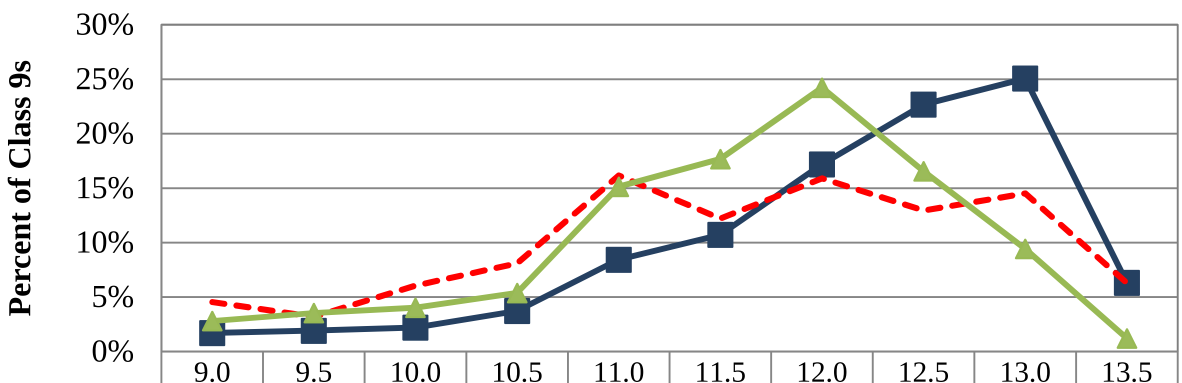
6.3.1 Average GVW and Steering Axle Weights

As a result of the Post-Visit Traffic Data Analysis, it appears that the calibration adjustments brought the average GVW and Steering Axle weights for the site more in line with the Comparison Data Set from January 27, 2011, as shown in Table 6-4**Error! Reference source not found.**.

Table 6-4 – Average GVW and Steering Axle Weights

Data Set	Date	Average GVW (kips)	Average Steering Axle (kips)
Comparison Data Set	August 22, 2012	58.9 kips	11.5 kips
Pre-Visit Sample	September 27, 2013	61.4 kips	12.0 kips
Post-Visit Sample	October 27, 2013	57.8 kips	11.4 kips

As shown in Figure 6-3, the loaded front axle weights for the post-visit data are more similar to the Comparison Data Set as a result of the calibration adjustments.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	1.7%	1.9%	2.2%	3.7%	8.4%	10.7%	17.2%	22.7%	25.1%	6.3%
CDS	4.5%	3.2%	6.1%	8.1%	16.2%	12.2%	15.9%	13.0%	14.5%	6.3%
Post	2.8%	3.5%	4.0%	5.4%	15.1%	17.7%	24.2%	16.6%	9.4%	1.2%

Figure 6-3 – Post-Visit Front Axle Comparison

6.3.2 Imbalance

The left-to-right imbalance percentage cannot be developed from test trucks runs due to the limited sample. Consequently, free flow truck traffic must be used.

A post-visit data analysis was conducted using the data immediately following the date of the validation. The results of the post-visit imbalance analysis are presented in Table 6-5.

Table 6-5 – Front Axle Weight Imbalance

Data Set	Date	Left	Right	Imbalance	PCT
Pre-Visit Sample	September 27, 2013	5.55	6.06	Right	8.5%
Post-Visit Sample	October 27, 2013	5.94	5.74	Left	3.4%

As shown in the table, the pre-visit data showed that the right side weights were 8.5 percent greater than the left side weights. The post-visit data shows that the left weights are 3.4 percent greater than the right side weights. The post-visit imbalance is not significant. Therefore, it is not recommended that the calibration factors be adjusted.

6.3.3 WIM System Factor Adjustments

Since the average GVW and steering axle weights provided during the Post-Visit data analysis are reasonably similar to those provided by the Comparison Data Set, and the front axle does not demonstrate a significant imbalance, no adjustments to the WIM system factors are recommended.

7 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.

7.1 Classification

The information in Table 7-1 data was extracted from the most recent previous validation and was updated to include the results of this validation.

Table 7-1 – Classification Validation History

Date	Misclassification Percentage by Class											Pct Unclass
	3	4	5	6	7	8	9	10	11	12	13	
2-May-07	0	0	0	0	0	0	0	0	0	0	0	0.0
3-May-07	0	0	0	0	0	0	0	0	0	0	0	0.0
13-Feb-08	0	0	13	0	0	22	0	0	0	0	0	0.0
14-Feb-08	0	0	27	0	0	38	0	0	0	0	0	0.0
15-Sep-10	0	100	22	0	0	0	0	0	0	0	0	0.0
16-Sep-10	0	100	33	0	0	0	10	0	0	0	0	4.8
21-Aug-12	100	0	4	0	0	0	0	0	0	0	0	0.0
15-Oct-13	0	75	5	0	0	0	0	0	0	0	50	0.9
16-Oct-13	0	0	14	0	0	0	0	0	0	0	0	0.0

7.2 Weight

Table 7-2 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, steering and single axles and tandems for prior pre- and post-validations.

Table 7-2 – Weight Validation History

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
2-May-07	-26.1 ± 14.7	-22.4 ± 17.2	-26.5 ± 18.4
3-May-07	0.3 ± 5.9	-0.6 ± 8.5	0.5 ± 11.7
13-Feb-08	-2.6 ± 4.0	-3.4 ± 6.9	-2.4 ± 6.1
14-Feb-08	-2.1 ± 4.6	-2.6 ± 7.3	-2.0 ± 6.9
15-Sep-10	7.0 ± 7.7	4.4 ± 8.5	7.7 ± 8.9
16-Sep-10	0.9 ± 3.2	0.1 ± 7.1	1.0 ± 4.6
21-Aug-12	1.7 ± 3.9	3.7 ± 8.5	1.3 ± 8.3
15-Oct-13	2.0 ± 4.9	1.0 ± 6.4	2.2 ± 7.1
16-Oct-13	-0.1 ± 2.6	0.6 ± 6.2	-0.2 ± 6.4

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated, with the exception of September 15, 2010 values. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

8 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

Arizona, SPS-1
SHRP ID: 040100

Validation Date: October 16, 2013

APPLIED RESEARCH ASSOCIATES, INC.

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior (Back)

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Solar Panel

Photo 9 – Telephone Box

Photo 10 – Downstream

Photo 11 – Upstream

Photo 12 – Truck 1 Tractor

Photo 13 – Truck 1 Trailer

Photo 14 – Truck 1 Suspension 1

Photo 15 – Truck 1 Suspension 2

Photo 16 – Truck 1 Suspension 3

Photo 17 – Truck 1 Suspension 4

Photo 18 – Truck 1 Suspension 5

Photo 19 – Truck 2 Tractor

Photo 20 – Truck 2 Trailer and Load

Photo 21 – Truck 2 Suspension 1

Photo 22 – Truck 2 Suspension 2

Photo 23 – Truck 2 Suspension 3

Photo 24 – Truck 2 Suspension 4

Photo 25 – Truck 2 Suspension 4

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/15/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 10/15/13

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. Bending Plates d. ______

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

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:	2.0%	Standard Deviation:	2.4%
Dynamic and Static Single Axle:	1.0%	Standard Deviation:	3.2%
Dynamic and Static Double Axles:	2.2%	Standard Deviation:	3.5%

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

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

			Low		High	Runs
a.	Low	-	44.0	to	51.0	14
b.	Medium	-	51.1	to	58.1	13
c.	High	-	58.2	to	65.0	13
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	04 040100 10/15/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3245 | 3593

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:

13. METHOD TO DETERMINE LENGTH OF COUNT:

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	0.0	FHWA Class	5	-	5.0
FHWA Class 8:	67.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.9%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort:

Contact Information: Phone:

E-mail:

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/16/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 10/16/13

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 iSINC

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:	-0.1%	Standard Deviation:	1.3%
Dynamic and Static Single Axle:	0.6%	Standard Deviation:	3.1%
Dynamic and Static Double Axles:	-0.2%	Standard Deviation:	3.2%

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

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

			Low		High	Runs
a.	Low	-	44.0	to	51.0	14
b.	Medium	-	51.1	to	58.1	13
c.	High	-	58.2	to	65.0	13
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/16/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3080 | 3410

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: ____________

13. METHOD TO DETERMINE LENGTH OF COUNT: ____________

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	0.0	FHWA Class	5	-	-14.0
FHWA Class 8:	400.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Cal 1

Person Leading Calibration Effort: ____________

Contact Information: Phone: ____________

E-mail: ____________

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/15/2013

Count - 107 Time = 1:51:35 Trucks (4-15) - 107 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	5	17937	62	5	62	8	18035	62	8
68	9	17939	68	9	62	5	18037	62	5
63	9	17947	58	9	54	9	18045	54	9
65	9	17952	66	9	67	9	18051	66	9
65	9	17955	64	9	69	9	18061	67	9
62	9	17970	62	9	61	9	18062	63	9
64	9	17971	64	9	66	9	18071	63	9
62	9	17972	59	9	65	5	18073	63	5
63	9	17982	65	9	67	9	18080	65	9
72	6	17983	68	6	65	9	18082	65	9
70	5	17984	69	5	64	9	18084	63	9
64	9	17988	66	9	**60**	**15**	**18090**	**59**	**13**
63	9	17993	63	9	67	11	18102	67	11
64	9	18002	63	9	67	10	18103	64	10
64	9	18003	63	9	64	9	18115	64	9
64	9	18004	63	9	64	9	18127	64	9
67	9	18009	64	9	65	9	18142	65	9
65	9	18012	62	9	66	9	18146	66	9
65	9	18013	63	9	67	9	18149	62	9
62	9	18014	60	9	**49**	**5**	**18151**	**44**	**4**
63	9	18022	63	9	64	8	18165	60	8
62	9	18028	61	9	65	9	18167	63	9
64	9	18030	63	9	67	9	18171	65	9
69	9	18031	68	9	68	9	18172	68	9
68	9	18033	68	9	63	9	18186	67	9

Sheet 1 - 1 to 50 Start: 12:01:39 Stop: 12:54:34

Recorded By: ABL Verified By: GAH

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/15/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
69	5	18187	70	5	57	9	18324	56	9
67	9	18191	67	9	64	9	18325	63	9
65	9	18195	62	9	65	9	18326	63	9
66	9	18207	64	9	67	9	18330	66	9
60	9	18208	64	9	65	9	18332	65	9
68	4	18220	66	4	**70**	**5**	**18334**	**70**	**4**
70	9	18223	67	9	64	9	18336	64	9
70	9	18224	64	9	69	9	18339	69	9
65	9	18225	62	9	68	5	18351	67	5
53	**8**	**18231**	**52**	**5**	69	5	18356	69	5
67	9	18232	65	9	54	9	18358	54	9
67	13	18236	65	13	75	9	18361	75	9
78	5	18240	75	5	64	9	18378	63	9
63	9	18248	62	9	62	9	18394	63	9
69	9	18250	68	9	65	9	18395	64	9
68	9	18259	67	9	70	10	18401	70	10
68	9	18266	68	9	62	9	18402	62	9
63	5	18278	59	5	**62**	**8**	**18403**	**61**	**4**
67	5	18281	64	5	65	9	18408	63	9
69	5	18283	66	5	66	5	18412	64	5
67	5	18294	66	5	65	9	18413	65	9
70	5	18305	69	5	69	9	18414	68	9
65	9	18310	63	9	69	5	18417	69	5
66	9	18317	65	9	61	5	18424	60	5
67	9	18323	67	9	67	8	18428	67	8

Sheet 2 - 51 to 100 Start: 12:54:40 Stop: 13:43:29

Recorded By: ABL GAH

Validation Test Truck Run Set - Pre

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/15/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
70	9	18437	69	9					
55	5	18440	54	5					
64	9	18443	64	9					
68	5	18455	68	5					
65	9	18459	65	9					
64	9	18460	64	9					
66	11	18476	64	11					

Sheet 3 - 101 to 150 Start: 13:45:39 Stop: 13:53:14

Recorded By: ABL GAH

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/16/2013

Count - 110 Time = 3:20:59 Trucks (4-15) - 110 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
68	9	21088	68	9	62	12	21186	12	12
68	9	21089	68	9	64	11	21188	65	11
60	5	21090	57	5	62	11	21192	59	11
65	9	21094	65	9	68	4	21197	67	4
60	5	21096	60	5	67	9	21219	67	9
64	9	21098	65	9	67	9	21220	67	9
65	9	21100	62	9	67	9	21223	67	9
68	9	21113	67	9	64	9	21227	64	9
64	8	21117	63	5	64	9	21228	64	9
64	9	21118	66	9	65	5	21229	64	5
62	11	21119	60	11	65	9	21230	64	9
65	9	21123	65	9	65	9	21232	65	9
64	9	21124	62	9	61	9	21242	61	9
66	9	21128	67	9	68	9	21247	67	9
71	9	21129	70	9	65	9	21248	63	9
68	9	21135	67	9	64	5	21251	64	5
61	9	21138	61	9	68	9	21261	67	9
65	8	21144	66	5	67	8	21263	66	5
70	9	21145	70	9	68	9	21272	73	9
68	9	21151	68	9	60	9	21274	60	9
62	9	21154	61	9	72	9	21279	72	9
64	9	21155	61	9	59	8	21280	59	5
62	9	21156	62	9	64	9	21284	63	9
68	9	21165	67	9	60	8	21289	64	8
65	9	21178	64	9	66	5	21290	65	5

Sheet 1 - 1 to 50 Start: 9:51:34 Stop: 10:50:19

Recorded By: ABL Verified By: GAH

Validation Test Truck Run Set - Cal 1

Traffic Sheet 20	STATE CODE:	04
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	040100
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy)	10/16/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
68	9	21601	68	9	70	5	21703	68	5
59	9	21602	59	9	67	5	21704	67	5
67	9	21605	67	9	67	4	21737	66	4
55	9	21615	54	9	64	7	21746	65	7
55	9	21616	54	9	68	9	21748	66	9
68	5	21618	68	5	68	9	21749	66	9
70	9	21621	69	9	65	9	21750	63	9
62	5	21625	61	5	74	5	21761	74	5
65	5	21630	63	5	56	9	21763	55	9
36	9	21631	36	9	70	9	21765	69	9
58	9	21635	57	9	69	9	21766	69	9
57	5	21644	54	5	70	9	21768	69	9
66	9	21654	67	9	65	9	21777	65	9
66	9	21662	66	9	64	9	21778	65	9
68	9	21663	66	9	64	9	21784	64	9
64	5	21664	65	5	57	15	21786	57	15
66	5	21665	66	5	65	9	21788	65	9
67	9	21669	66	9	68	5	21789	67	5
67	5	21672	67	5	64	9	21791	64	9
66	9	21674	65	9	64	12	21792	64	12
65	9	21684	65	9	65	5	21794	64	5
65	5	21686	64	5	66	9	21795	66	9
67	9	21696	65	9	67	5	21796	65	5
60	9	21697	59	9	69	9	21797	68	9
48	5	21700	48	5	65	5	21810	65	5

Sheet 2 - 51 to 100 Start: 12:06:12 Stop: 12:53:08

Recorded By: ABL GAH

Validation Test Truck Run Set - Cal 1

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 04 SPS WIM ID: 040100 DATE (mm/dd/yyyy) 10/16/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
64	9	21812	64	9					
70	9	21814	69	9					
64	9	21856	64	9					
68	5	21869	67	5					
68	9	21880	64	9					
73	5	21887	73	5					
67	9	21890	67	9					
67	9	21898	65	9					
64	9	21899	63	9					
80	5	21904	80	5					

Sheet 3 - 101 to 150 Start: 12:53:48 Stop: 13:12:33

Recorded By: ABL GAH