WIM System Field Calibration and Validation Summary Report

Kansas SPS-2
SHRP ID – 200200

Validation Date: August 28, 2013
Submitted: October 10, 2013

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1 Executive Summary

A WIM validation was performed on August 27 and 28, 2013 at the Kansas SPS-2 site located on route I-70, milepost 287.5, 7.6 miles west of US 77.

This site was installed on June 8, 2006. The in-road sensors are installed in the westbound, 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 November 15, 2011 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 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 was pavement distress noted that may affect the accuracies of the WIM system. However, 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 and distance measurement data. The summary results of the validation are provided in Table 1-1 below.

Table 1-1 – Post-Validation Results – 28-Aug-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.2 ± 3.0%	Pass
Tandem Axles	±15 percent	0.5 ± 2.8%	Pass
GVW	±10 percent	0.6 ± 1.8%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.1 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 0.2 ± 3.4 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 providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 1.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 9.4% from the 127 vehicle sample (Class 3 – 13) was primarily due to cross-classifications of Class 3, 4, 5, and 8 vehicles. Additionally, one Class 8 vehicle was misclassified as a Class 5 and one Class 8 was not classified by the equipment.

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 grain.

- The Secondary truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems and standard tandem spacing on the tractor and trailer. The Secondary truck was loaded with grain.

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	76.3	11.7	16.1	16.1	16.2	16.2	18.5	4.3	31.2	4.1	58.1	62.5
2	65.7	10.9	13.7	13.7	13.7	13.7	18.5	4.4	31.7	4.2	58.8	62.9

The posted speed limit at the site is 75 mph. During the testing, the speed of the test trucks ranged from to 59 to 72 mph, a range of 13 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 75.0 to 116.2 degrees Fahrenheit, a range of 41.2 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 August 5, 2013 (Data) to the most recent Comparison Data Set (CDS) from November 17, 2011. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation.

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 2006 to 2012.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2006	207	7
2007	206	8
2008	366	12
2009	365	12
2010	365	12
2011	362	12
2012	232	8

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 years 2006 and 2007.

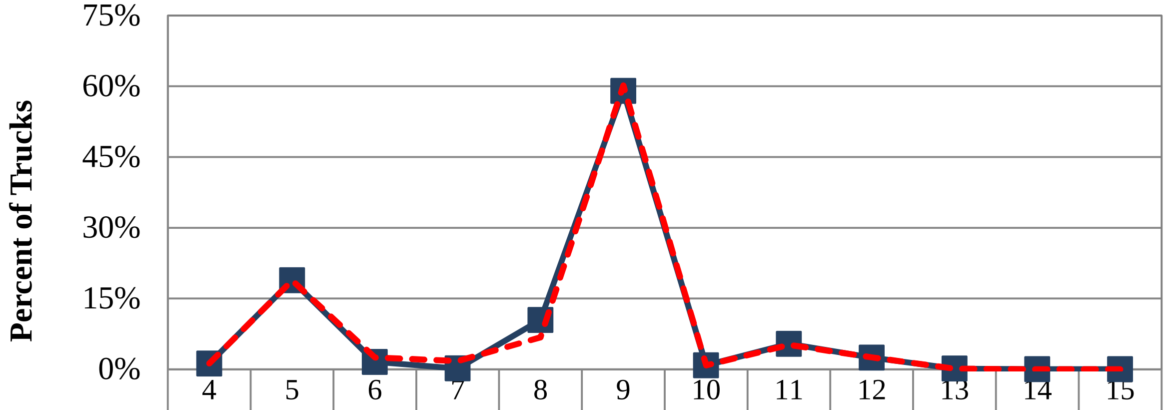
Table 2-2 provides a monthly breakdown of the available data for years 2006 through 2012.

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	
2006						23	31	31	30	31	30	31	7
2007	31	28	31	18					7	31	30	30	8
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	30	31	12
2010	31	28	31	30	31	30	31	31	30	31	30	31	12
2011	31	28	31	30	31	30	31	30	28	31	30	31	12
2012	31	29	31	30	31	30	31	19					8

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 August 5, 2013 (Data) and the most recent comparison Data Set (CDS) from November 17, 2011.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	1.2%	18.8%	1.5%	0.2%	10.4%	59.0%	0.8%	5.4%	2.5%	0.1%	0.0%	0.0%
CDS	1.2%	18.9%	2.5%	1.7%	6.8%	60.2%	0.8%	5.2%	2.5%	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 (59.0%) and Class 5 (18.8%) 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				
	11/17/2011		8/5/2013		
4	227	1.2%	281	1.2%	0.0%
5	3456	18.9%	4386	18.8%	0.0%
6	459	2.5%	359	1.5%	-1.0%
7	320	1.7%	38	0.2%	-1.6%
8	1245	6.8%	2430	10.4%	3.6%
9	11034	60.2%	13738	59.0%	-1.2%
10	153	0.8%	191	0.8%	0.0%
11	952	5.2%	1253	5.4%	0.2%
12	466	2.5%	573	2.5%	-0.1%
13	20	0.1%	30	0.1%	0.0%
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 decreased by 1.2 percent from November 2011 and August 2013. Changes in the percentage of heavier trucks may be attributed to natural and seasonal variations in truck distributions. During the same time period, the percentage of Class 5 trucks remained the same and volume of Class 8 trucks rose 3.6%.

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.

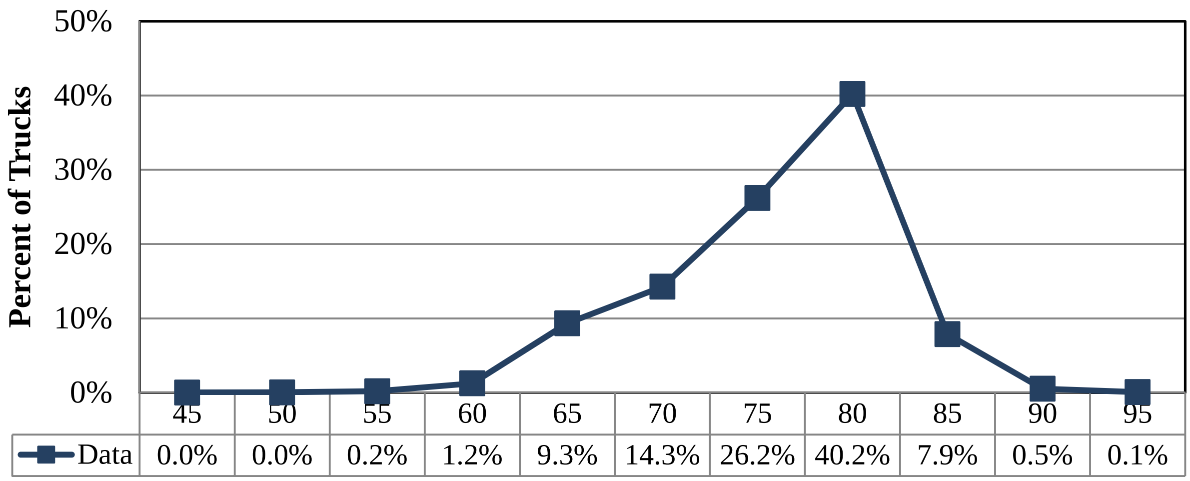


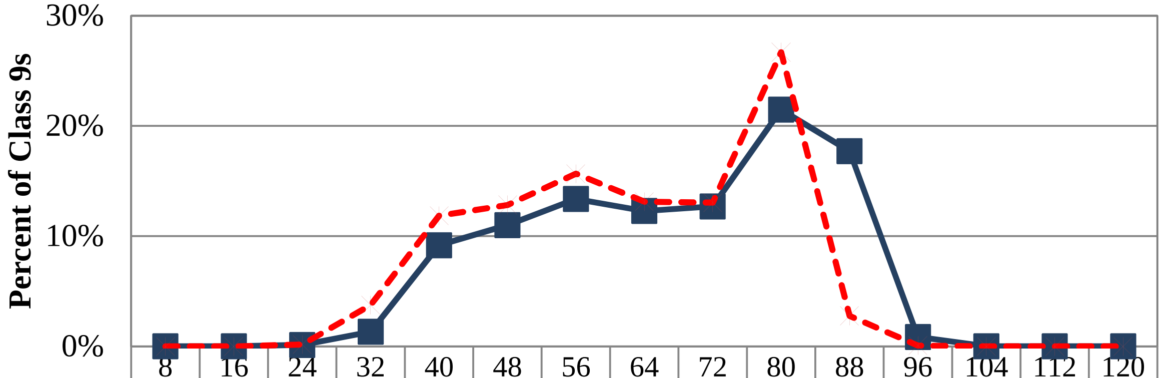
Figure 2-2 – Truck Speed Distribution – 5-Aug-13

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 70 and 80 mph. The posted speed limit at this site is 75 and the 85th percentile speed for trucks at this site is 80 mph. The range of truck speeds for the validation are expected to be between 65 and 75 mph.

2.4 GVW Data Analysis

The traffic CDS data received from the Regional Support Contractor was analyzed to determine the expected Class 9 GVW distributions. Figure 2-3 shows a comparison between GVW plots generated using a two-week W-card sample from August 2013 and the Comparison Data Set from November 2011.

As shown in Figure 2-3, there is a significant increase in the percentage of axles over 80 kips from the November 2011 Comparison Data Set (CDS) and the August 2013 two-week sample W-card dataset (Data). The results indicate that there may be a positive bias (overestimation of loads), a change in pavement condition or sensor deterioration.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.1%	1.3%	9.2%	11.0	13.4	12.3	12.7	21.5	17.7	0.8%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.2%	3.8%	11.9	12.8	15.7	13.1	13.0	26.7	2.8%	0.1%	0.0%	0.0%	0.0%

GVW in Kips

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				
	11/17/2011		8/5/2013		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	19	0.2%	17	0.1%	0.0%
32	409	3.8%	179	1.3%	-2.4%
40	1291	11.9%	1243	9.2%	-2.7%
48	1397	12.8%	1491	11.0%	-1.8%
56	1706	15.7%	1812	13.4%	-2.3%
64	1430	13.1%	1665	12.3%	-0.9%
72	1421	13.0%	1721	12.7%	-0.4%
80	2906	26.7%	2911	21.5%	-5.2%
88	302	2.8%	2401	17.7%	14.9%
96	8	0.1%	115	0.8%	0.8%
104	0	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 =	58.6 kips		63.5 kips		4.9 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 2.7 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 5.2 percent. During this time period the percentage of overweight trucks increased by 15.7 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 7.7 percent, from 58.6 to 63.5 kips.

2.5 Class 9 Front Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from August 2013 and the Comparison Data Set from November 2011. The percentage of light axles (10.0 to 11.0 kips) decreased by approximately 16.2% and the percentage of heavy axles (12.0 to 13.0 kips) increased by approximately 28.6%, indicating possible positive bias (overestimation of loads) in front axle measurement.

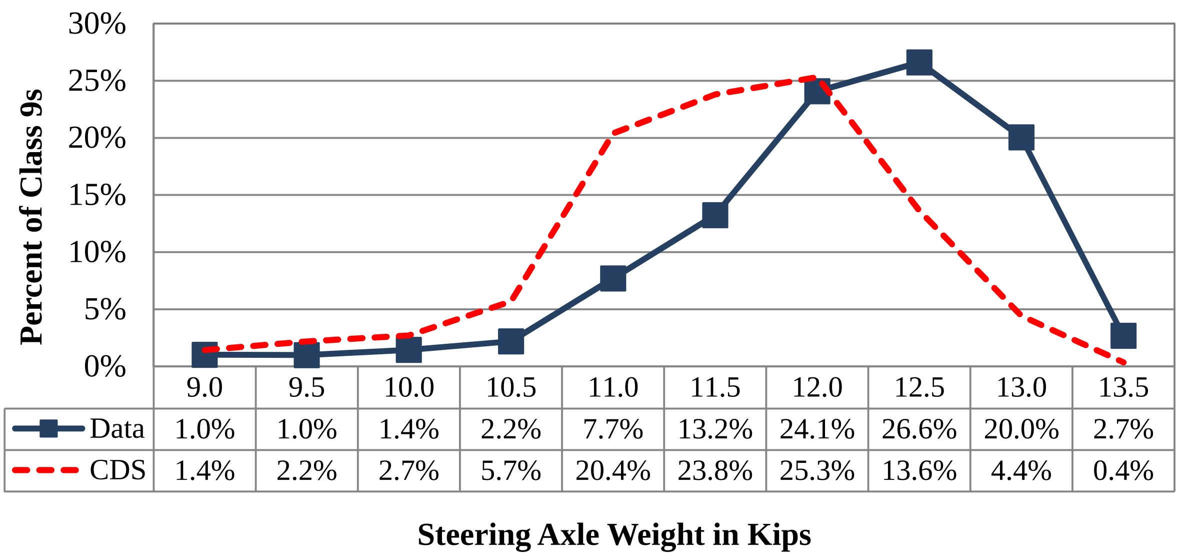


Figure 2-4 – Distribution of Class 9 Front Axle Weights

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 November 2011 Comparison Data Set (CDS) and the August 2013 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the November 2011 Comparison Data Set (CDS) and the August 2013 dataset (Data).

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

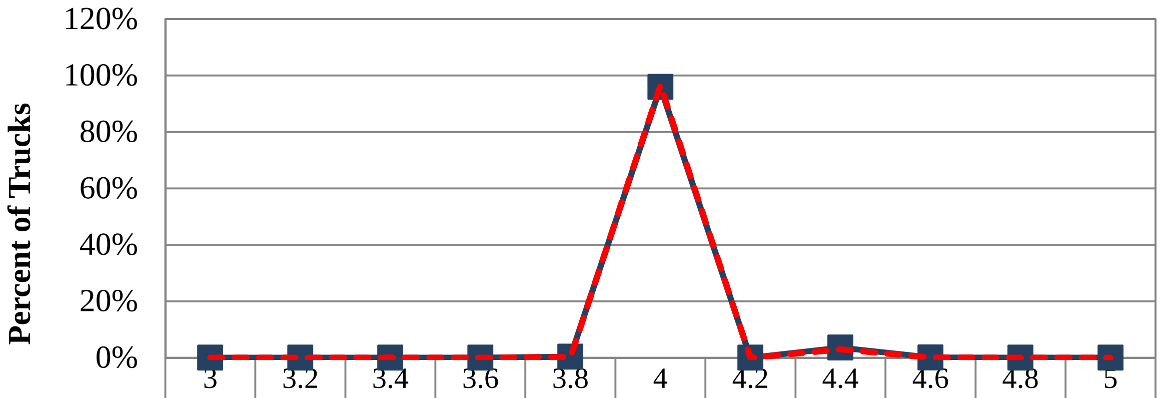
F/A weight bins (kips)	CDS		Data		Change
	Date				
	11/17/2011		8/5/2013		
9.0	157	1.4%	136	1.0%	-0.4%
9.5	239	2.2%	132	1.0%	-1.2%
10.0	295	2.7%	193	1.4%	-1.3%
10.5	618	5.7%	293	2.2%	-3.5%
11.0	2213	20.4%	1028	7.7%	-12.7%
11.5	2582	23.8%	1766	13.2%	-10.6%
12.0	2746	25.3%	3211	24.1%	-1.2%
12.5	1479	13.6%	3549	26.6%	13.0%
13.0	480	4.4%	2674	20.0%	15.6%
13.5	39	0.4%	358	2.7%	2.3%
Average =	11.3 kips		11.9 kips		0.6 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.6 kips, or 5.3 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.9 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

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

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



	3	3.2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5
Data	0.0%	0.0%	0.0%	0.0%	0.4%	95.9%	0.0%	3.6%	0.1%	0.0%	0.0%
CDS	0.0%	0.0%	0.0%	0.0%	0.3%	96.6%	0.0%	3.0%	0.1%	0.0%	0.0%

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

As seen in the figure, the Class 9 tractor tandem spacings for the November 2011 Comparison Data Set and the August 2013 Data are nearly identical.

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

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

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	11/17/2011		8/5/2013		
3.0	1	0.0%	1	0.0%	0.0%
3.2	1	0.0%	2	0.0%	0.0%
3.4	3	0.0%	2	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	28	0.3%	48	0.4%	0.1%
4.0	10522	96.6%	13004	95.9%	-0.7%
4.2	0	0.0%	0	0.0%	0.0%
4.4	325	3.0%	485	3.6%	0.6%
4.6	9	0.1%	14	0.1%	0.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	0	0.0%	0	0.0%	0.0%
Average =	4.0 feet		4.0 feet		0.0 feet

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

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (November 2011) based on the last calibration with the most recent two-week WIM data sample from the site (August 2013). Comparison of vehicle class distribution data indicates a 1.2 percent decrease in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 5.3 percent and average Class 9 GVW has increased by 7.7 percent for the August 2013 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 November 15, 2011 and this validation visit, it was noted that the factors that were left in place at the end of the last validation were different than the factors that were in place at the beginning of this validation.

3.1 Description

This site was installed on June 8, 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 after 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, the distress shown in Photo 4-1 and Photo 4-2 was noted at a location 82 feet prior to the WIM scales. No adverse truck dynamics were noted in this area. The distress did not appear to affect the accuracy of the WIM sensors.

Photo 4-1 – Pavement Distress 82 Feet Prior to WIM

Photo 4-2 – Pavement Distress 82 Feet Prior to WIM

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 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)	1.051	0.988	1.160			1.066
		SRI (m/km)	0.976	0.684	0.994			0.885
		Peak LRI (m/km)	1.075	1.044	1.196			1.105
		Peak SRI (m/km)	1.061	1.261	1.177			1.166
	RWP	LRI (m/km)	0.897	1.000	1.019			0.972
		SRI (m/km)	1.072	1.442	1.261			1.258
		Peak LRI (m/km)	1.454	1.457	1.391			1.434
		Peak SRI (m/km)	1.076	1.469	1.394			1.313
Center	LWP	LRI (m/km)	0.859	1.093	1.154	0.792	0.840	0.948
		SRI (m/km)	0.879	0.716	1.251	0.907	1.089	0.968
		Peak LRI (m/km)	1.012	1.179	1.225	0.970	0.967	1.071
		Peak SRI (m/km)	0.959	1.130	1.264	0.922	1.137	1.082
	RWP	LRI (m/km)	1.334	0.991	1.051	0.981	0.952	1.062
		SRI (m/km)	**2.168**	1.012	0.822	0.697	0.758	1.091
		Peak LRI (m/km)	1.352	1.153	1.150	1.163	1.058	1.175
		Peak SRI (m/km)	***3.928***	***1.147***	***0.957***	***1.175***	***0.871***	***1.616***
Right	LWP	LRI (m/km)	1.298	1.112	1.044			1.151
		SRI (m/km)	1.140	1.218	1.405			1.254
		Peak LRI (m/km)	1.772	1.463	1.233			1.489
		Peak SRI (m/km)	1.327	1.397	1.412			1.379
	RWP	LRI (m/km)	1.654	1.091	0.947			1.231
		SRI (m/km)	1.719	0.717	0.862			1.099
		Peak LRI (m/km)	1.654	1.121	0.997			1.257
		Peak SRI (m/km)	1.939	1.589	1.202			1.577

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. Indices that are above the upper thresholds are shown in bold. The highest values, on average, are the Peak SRI values in the right wheel path of the center passes (shown in bold and italics).

4.3 Profile and Vehicle Interaction

Profile data was collected on September 21, 2012 by the North Central 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, 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 is 146 in/mi and is located approximately 662 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 166 in/mi and is located approximately 88 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. Although pavement distress was observed at a location 85 feet prior to the WIM scales, it did 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.

4.4 Recommended Pavement Remediation

It is recommended that the distress noted above be patched to prevent further damage. No other 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 August 27, 2013, beginning at approximately 9:20 AM and continuing until 2:50 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with grain, 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 grain, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on 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	76.3	11.7	16.1	16.1	16.2	16.2	18.5	4.3	31.2	4.1	58.1	62.5
2	65.8	10.9	13.8	13.8	13.7	13.7	18.5	4.4	31.7	4.2	58.8	62.9

Test truck speeds varied by 18 mph, from 54 to 72 mph. The measured pre-validation pavement temperatures varied 30.1 degrees Fahrenheit, from 84.4 to 114.5. The sunny weather conditions provided 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 accuracy and distance measurement as a result of the pre-validation test truck runs. However, a significant bias was observed in all weight measurements. Therefore, it was determined that a calibration of the system should be performed to improve the performance of the system.

Table 5-2 – Pre-Validation Overall Results – 28-Aug-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	5.1 ± 4.8%	Pass
Tandem Axles	±15 percent	5.0 ± 3.8%	Pass
GVW	±10 percent	5.0 ± 2.9%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	-0.6 ± 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 0.2 ± 3.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of -0.1 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 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 75 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 – 28-Aug-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		54.0 to 60.0 mph	60.1 to 66.1 mph	66.2 to 72.0 mph
Steering Axles	±20 percent	7.0 ± 5.2%	5.3 ± 3.3%	2.9 ± 2.1%
Tandem Axles	±15 percent	4.9 ± 5.1%	4.3 ± 3.0%	6.0 ± 2.9%
GVW	±10 percent	5.3 ± 4.5%	4.5 ± 2.2%	5.5 ± 1.6%
Vehicle Length	±3.0 percent (1.9 ft)	-0.6 ± 0.7 ft	-0.5 ± 0.8 ft	-0.5 ± 1.1 ft
Vehicle Speed	± 1.0 mph	-1.2 ± 3.5 mph	-0.7 ± 2.1 mph	-0.9 ± 3.7 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft

From the table, it can be seen that, on average, the WIM equipment overestimates all weights at all speeds. The range in error appears to decrease with increase in speed.

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 all speeds. The range in error is greater at low and medium speeds when compared to high speeds.

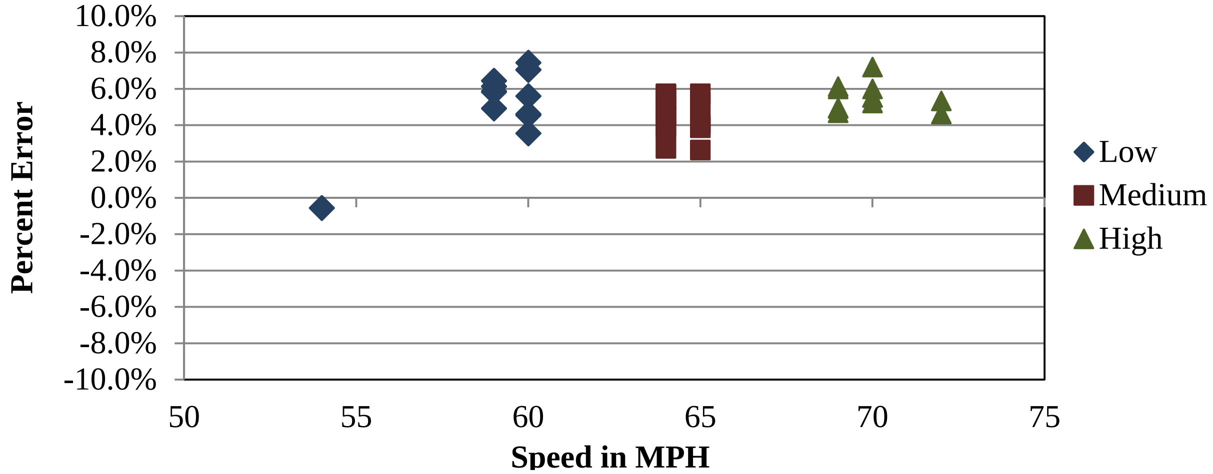


Figure 5-1 – Pre-Validation GVW Error by Speed – 28-Aug-13

5.1.1.2 Steering Axle Weight Errors by Speed

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

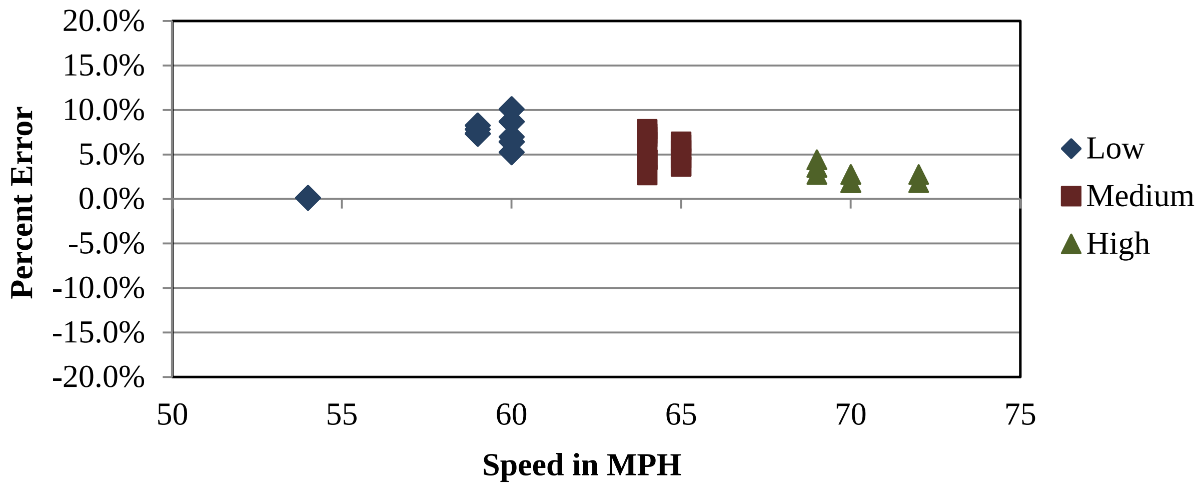


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 28-Aug-13

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment overestimates tandem axle weights at all speeds. The range in error is greater at low and medium speeds when compared to high speeds.

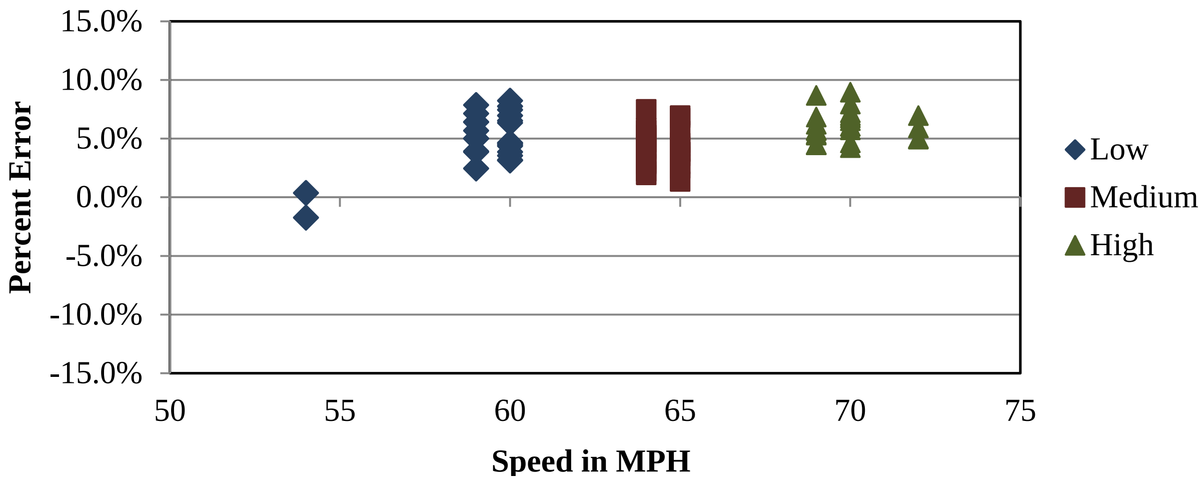


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 28-Aug-13

5.1.1.4 GVW Errors by Speed and Truck Type

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

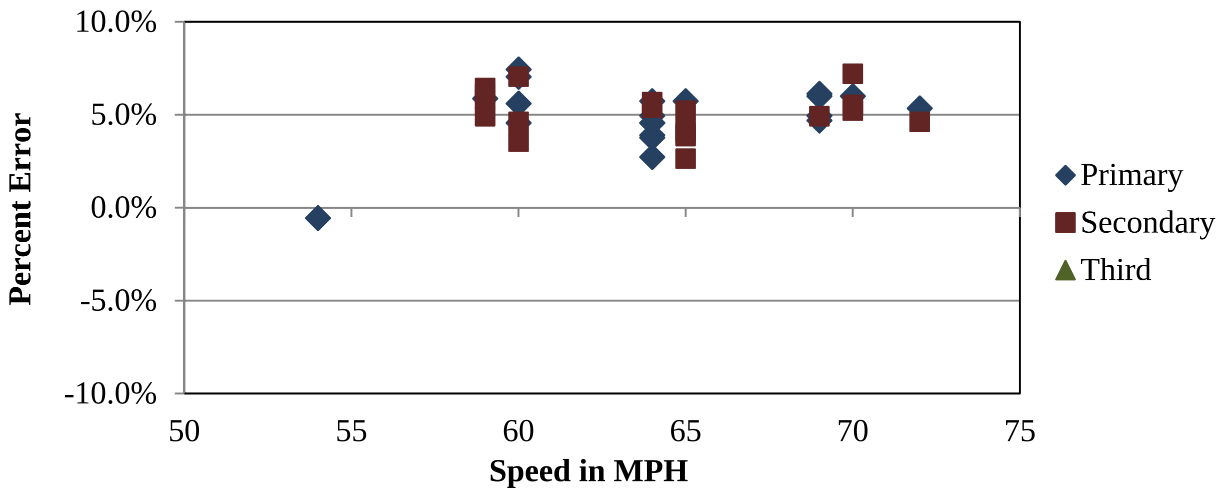


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 28-Aug-13

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

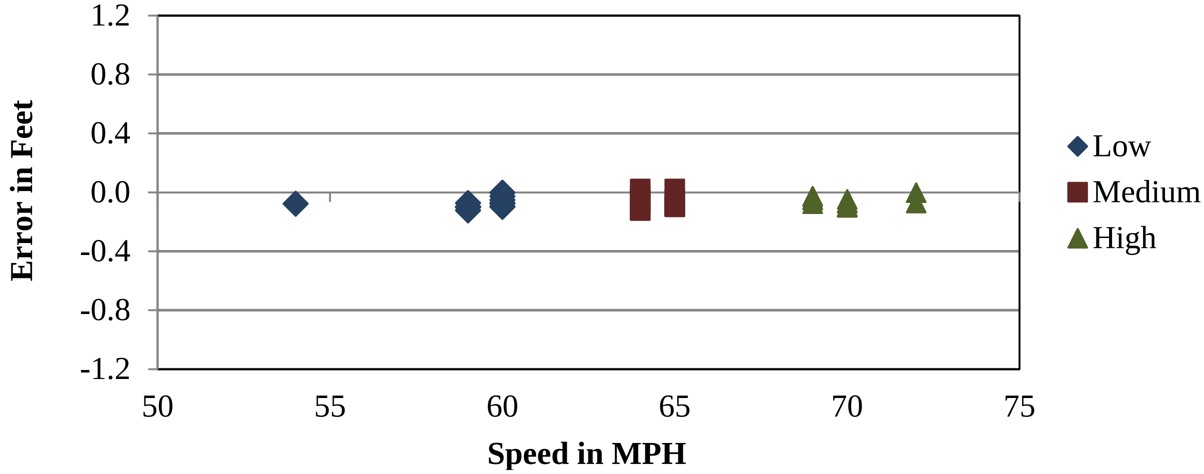


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 28-Aug-13

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 -1.5 to 0.1 feet. Distribution of errors is shown graphically in Figure 5-6.

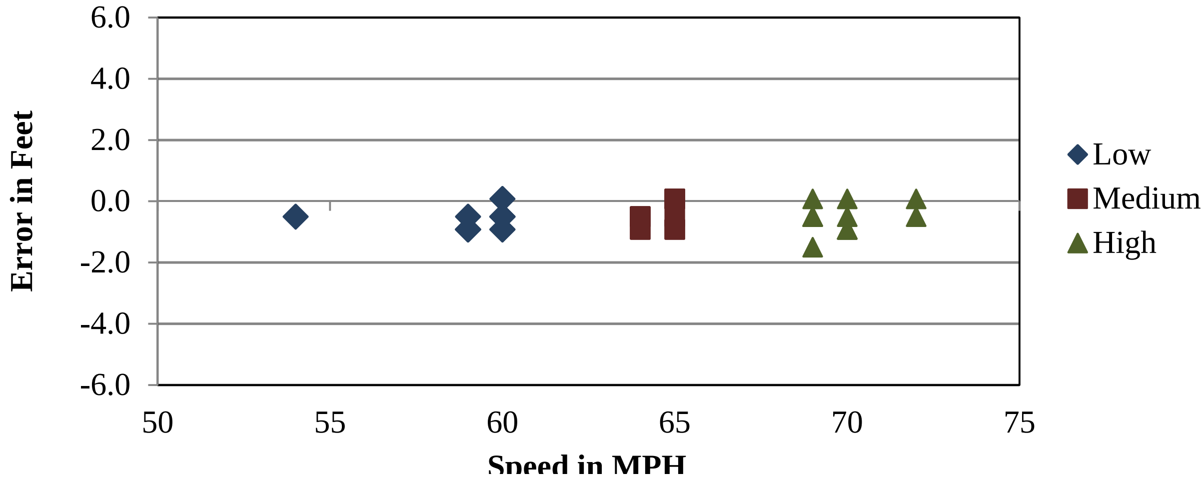


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 28-Aug-13

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 30.1 degrees, from 84.4 to 114.5 degrees Fahrenheit. Since the desired 30 degree temperature range was met, the pre-validation test runs are being reported under three temperature groups – low, medium and high, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 28-Aug-13

Parameter	**95% Confidence Limit of Error**	**Low**	**Medium**	**High**
		84.4 to 94.4 degF	**94.5 to 104.6 degF**	**104.7 to 114.5 degF**
Steering Axles	±20 percent	6.7 ± 5.9%	5.5 ± 5.6%	4.2 ± 3.9%
Tandem Axles	±15 percent	6.3 ± 3.3%	4.6 ± 4.1%	4.6 ± 3.8%
GVW	±10 percent	6.3 ± 1.7%	4.8 ± 2.9%	4.5 ± 2.9%
Vehicle Length	±3.0 percent (1.9 ft)	-0.6 ± 0.7 ft	-0.7 ± 0.5 ft	-0.5 ± 0.9 ft
Vehicle Speed	± 1.0 mph	-1.4 ± 4.2 mph	-0.8 ± 1.7 mph	-0.7 ± 2.9 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft

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

5.1.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment overestimates GVW across the range of temperatures observed in the field. The range in error is greater at the higher temperatures due to an outlier.

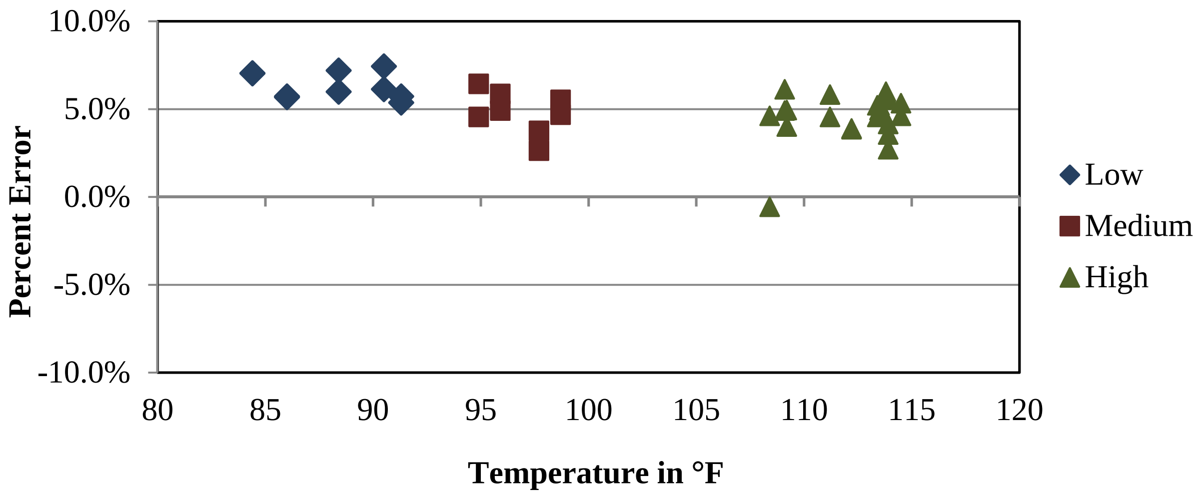


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 28-Aug-13

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 illustrates that for steering axles, the equipment overestimates across the range of temperatures observed in the field. The range in error is similar for each of the temperature groups.

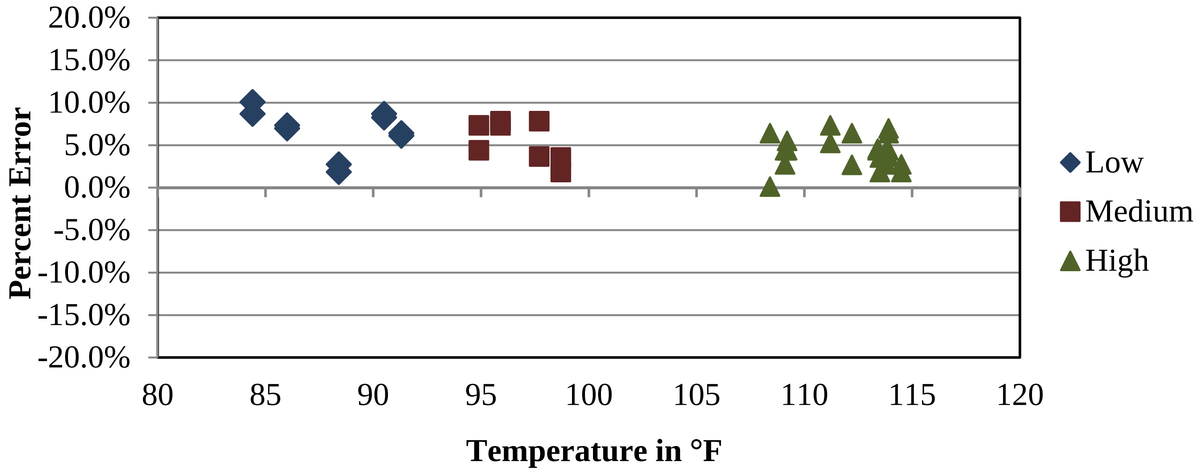


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 28-Aug-13

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment overestimates tandem axle weights across the range of temperatures observed in the field. The range in tandem axle errors is greater for the higher temperature group.

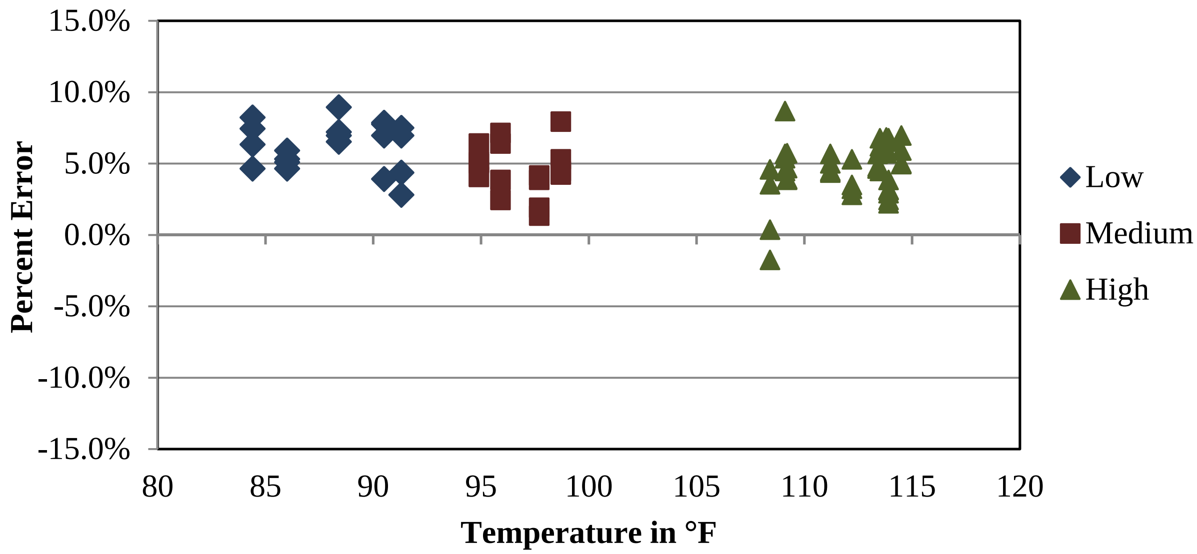


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 28-Aug-13

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 similar over the range of temperatures. Distribution of errors is shown graphically in Figure 5-10.

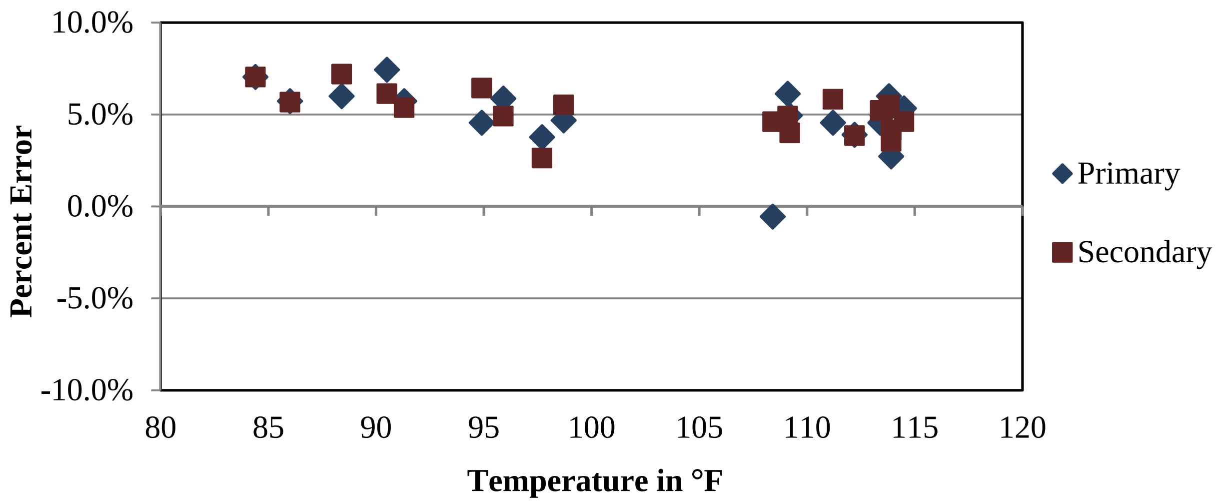


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 28-Aug-13

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 121 vehicles (Class 3 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, eight Class 3 vehicle were misclassified as a Class 5 vehicles, and one Class 3 vehicle was misclassified as a Class 9 vehicle. For Class 4 vehicles, one was misclassified as a Class 6, and one was misclassified as a Class 9.

Table 5-5 – Pre-Validation Misclassifications by Pair – 28-Aug-13

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

As shown in the table, a total of 11 vehicles, including 0 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 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 9.1%, mainly due to misclassification of lightweight vehicles in Class 3 as Class 5.The causes for the misclassifications were not investigated in the field.

The combined results produced an undercount of nine Class 3 vehicles and two Class 4 vehicles and an overcount of eight Class 5 vehicles, one Class 6 and two Class 9 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 – 28-Aug-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	9	2	4	5	2	3	87	3	4	0	1
WIM Count	0	0	12	6	2	3	89	3	4	0	1
Observed Percent	7.4	1.7	3.3	4.1	1.7	2.5	71.9	2.5	3.3	0.0	0.8
WIM Percent	0.0	0.0	9.9	5.0	1.7	2.5	73.6	2.5	3.3	0.0	0.8
Misclassified Count	9	2	0	0	0	0	0	0	0	0	0
Misclassified Percent	100.0	100.0	0.0	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

121 vehicles 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 -0.7 mph; the range of errors was 2.0 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 5-7.

Table 5-7 – Initial System Parameters – 28-Aug-13

Speed Point	MPH	Left	Right
		1	**2**
88	55	3419	3634
96	60	3667	3901
104	65	3622	3852
112	70	3650	3883
120	75	3723	3959
Axle Distance (cm)		370	
Dynamic Comp (%)		101	
Loop Width (cm)		320	

5.2.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall GVW error of 5.0% and errors of 5.3%, 4.5%, and 5.5% at the 60, 65 and 70 mph speed points respectively. To compensate for these errors, the changes in Table 5-8 were made to the compensation factors.

Table 5-8 – Calibration Equipment Factor Changes – 28-Aug-13

Speed Points	Old Factors		New Factors	
	Left	Right	Left	Right
	1	2	1	2
88	3419	3634	3233	3436
96	3667	3901	3468	3689
104	3622	3852	3467	3688
112	3650	3883	3459	3680
120	3723	3959	3529	3752
Axle Distance (cm)	370		370	
Dynamic Comp (%)	101		101	
Loop Width (cm)	320		303	

5.2.2 Calibration Results

The results of the 12 calibration verification runs are provided in Table 5-9 and Figure 5-11. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the calibration.

Table 5-9 – Calibration Results – 28-Aug-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.5 ± 3.0%	Pass
Tandem Axles	±15 percent	0.9 ± 2.8%	Pass
GVW	±10 percent	1.0 ± 1.4%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	-0.2 ± 0.7 ft	Pass
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.1 ft	Pass

Figure 5-11 shows that the WIM equipment is estimating GVW with similar accuracy at all speeds.

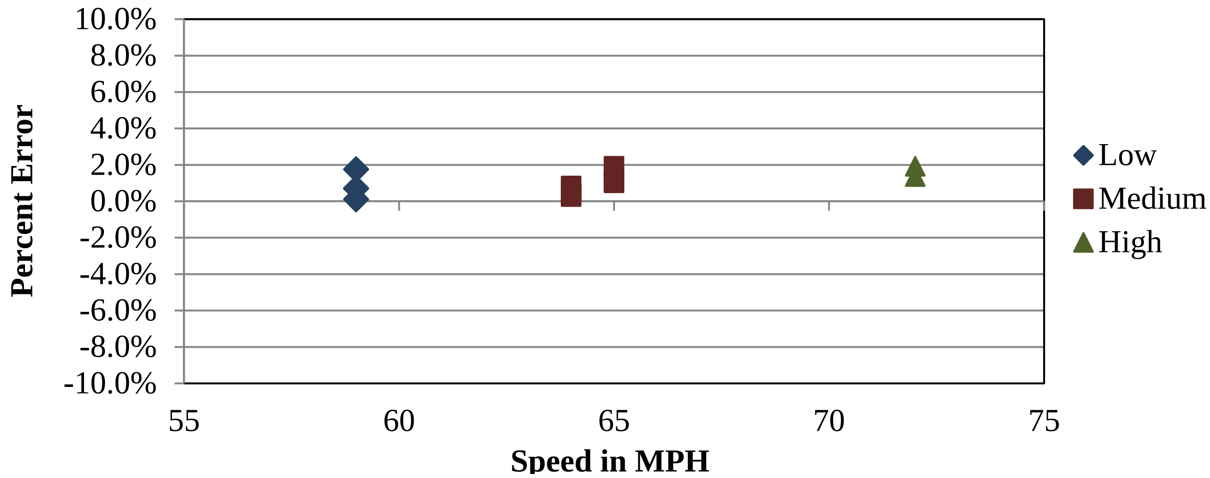


Figure 5-11 – Calibration GVW Error by Speed – 28-Aug-13

Based on the results of the calibration, where GVW estimate bias decreased to 1.0 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 August 28, 2013, beginning at approximately 8:23 AM and continuing until 2:03 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with grain, 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 grain, 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 5-10.

Table 5-10 – 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	76.3	11.7	16.1	16.1	16.2	16.2	18.5	4.3	31.2	4.1	58.1	62.5
2	65.7	10.9	13.7	13.7	13.7	13.7	18.5	4.4	31.7	4.2	58.8	62.9

Test truck speeds varied by 13 mph, from 59 to 72 mph. The measured post-validation pavement temperatures varied 41.2 degrees Fahrenheit, from 75.0 to 116.2. The sunny weather conditions provided the desired minimum 30 degree temperature range. Table 5-11 is a summary of post validation results.

Table 5-11 – Post-Validation Overall Results – 28-Aug-13

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	1.2 ± 3.0%	Pass
Tandem Axles	±15 percent	0.5 ± 2.8%	Pass
GVW	±10 percent	0.6 ± 1.8%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.1 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 for all speeds was 0.2 ± 3.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of -0.1 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 75 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-12.

Table 5-12 – Post-Validation Results by Speed – 28-Aug-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		59.0 to 63.3 mph	63.4 to 67.8 mph	67.9 to 72.0 mph
Steering Axles	+20 percent	1.8 ± 2.1%	1.5 ± 3.0%	-0.3 ± 3.0%
Tandem Axles	+15 percent	0.1 ± 3.0%	0.5 ± 2.4%	1.1 ± 3.4%
GVW	+10 percent	0.4 ± 1.8%	0.7 ± 1.5%	0.8 ± 2.8%
Vehicle Length	±3.0 percent (1.9 ft)	-0.1 ± 0.8 ft	-0.1 ± 1.5 ft	0.1 ± 1.2 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 1.3 mph	-0.8 ± 1.3 mph	1.9 ± 5.8 mph
Axle Length	+ 0.5 ft [150mm]	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft	0.0 ± 0.1 ft

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

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

5.3.1.1 GVW Errors by Speed

As shown in Figure 5-12, the equipment estimated GVW with similar accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

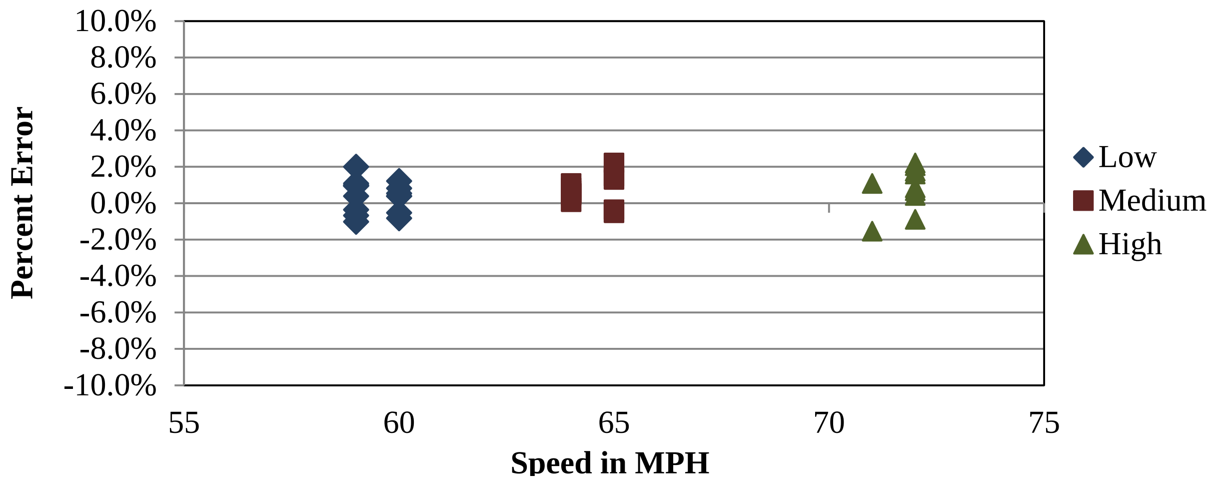


Figure 5-12 – Post-Validation GVW Errors by Speed – 28-Aug-13

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-13, the equipment estimated steering axle weights with similar accuracy at all speeds. The range in error is similar throughout the entire speed range. There does not appear to be a correlation between speed and weight estimates at this site.

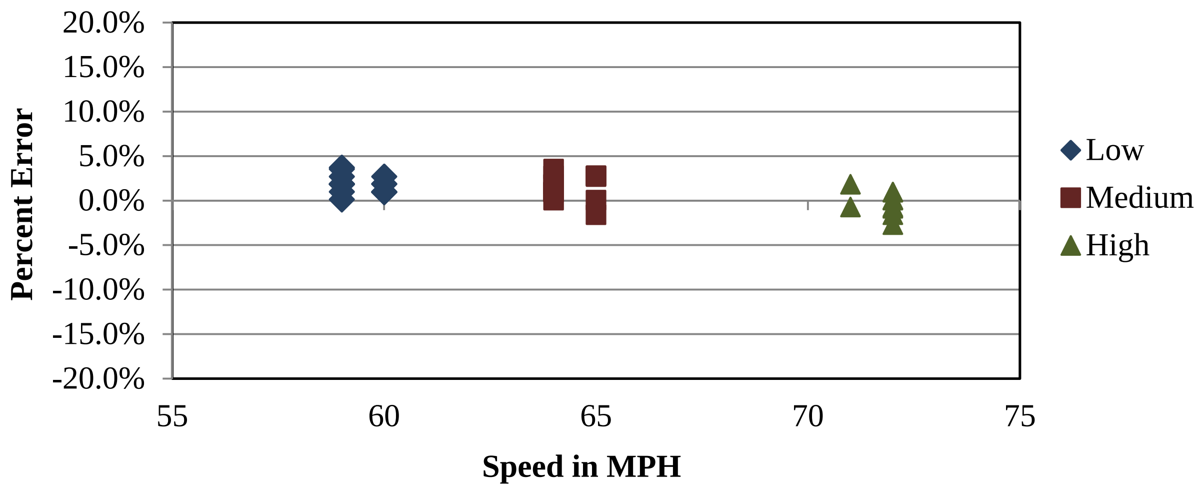


Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 28-Aug-13

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-14, the equipment estimated tandem axle weights with similar accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

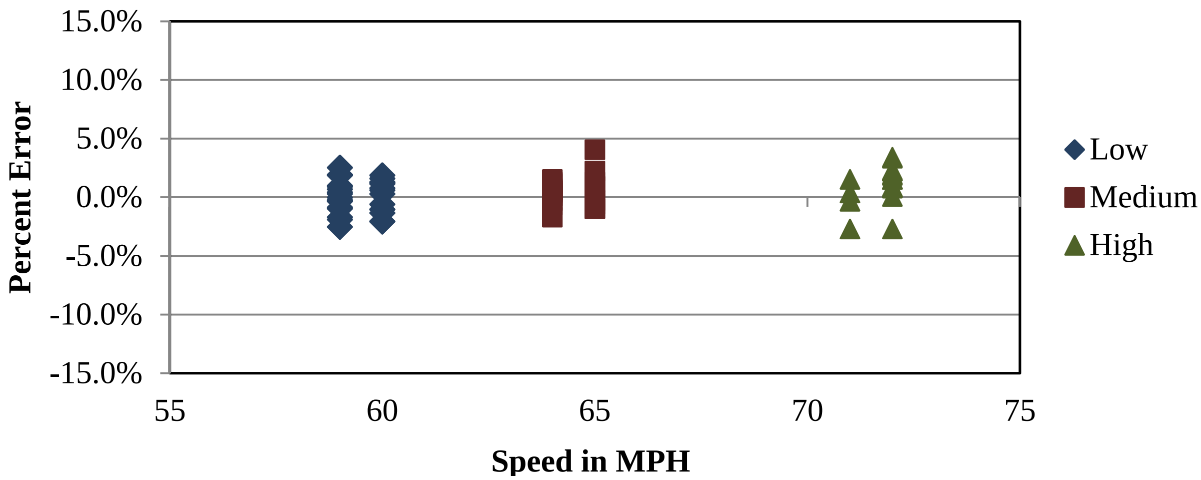


Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 28-Aug-13

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-15 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.

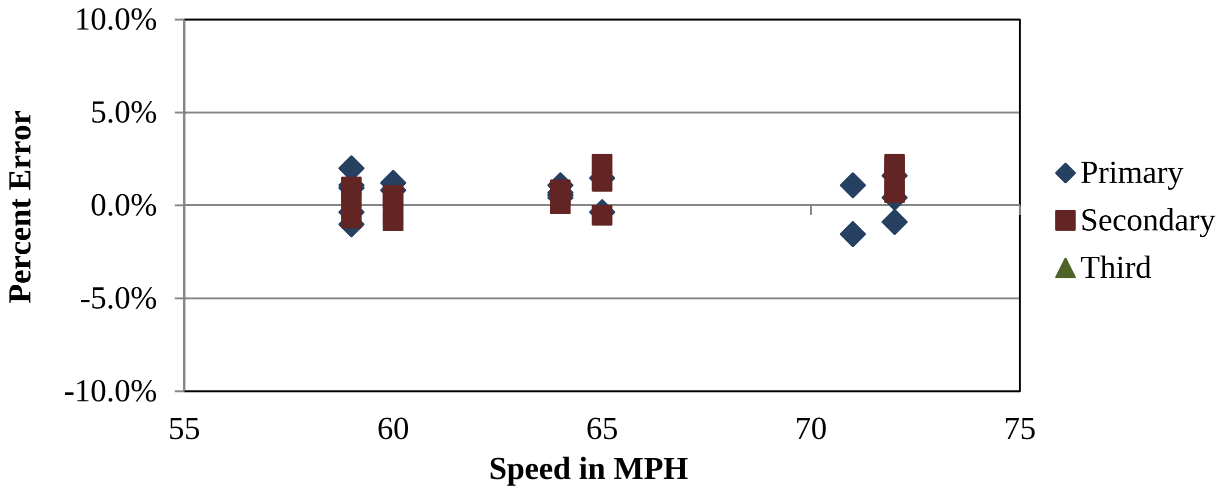


Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 28-Aug-13

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 -0.1 feet to 0.0 feet. Distribution of errors is shown graphically in Figure 5-16.

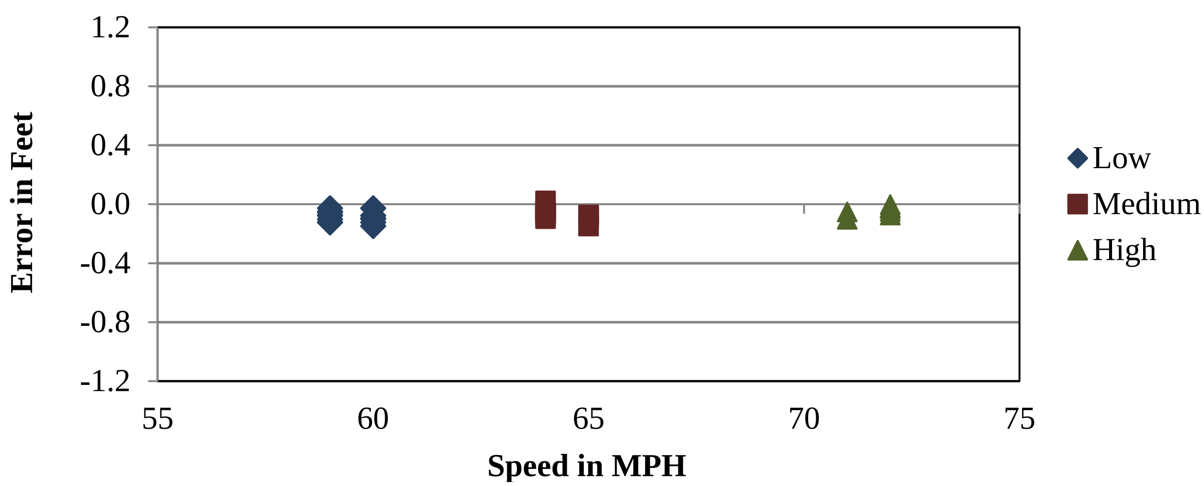


Figure 5-16 – Post-Validation Axle Length Error by Speed – 28-Aug-13

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 -0.5 to 2.1 feet. Distribution of errors is shown graphically in Figure 5-17.

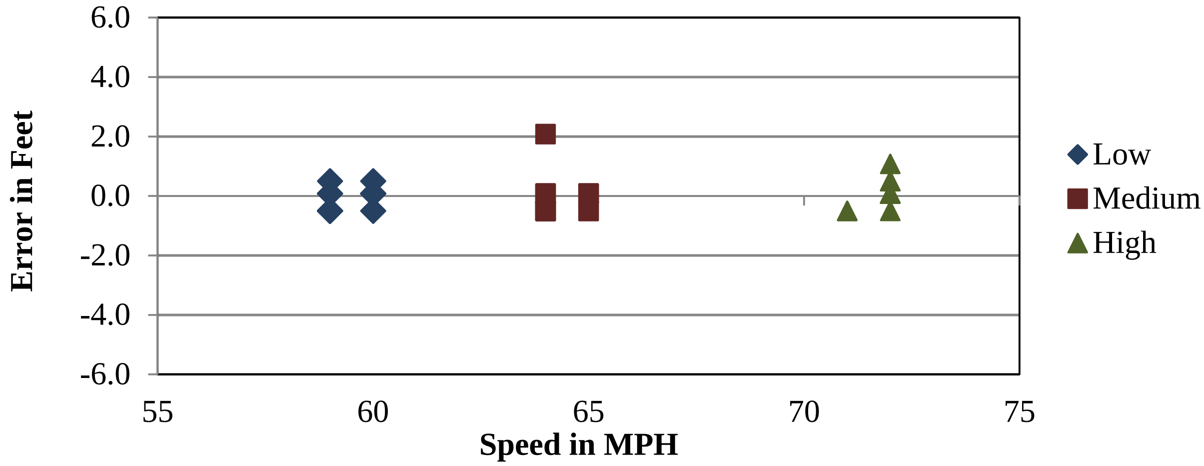


Figure 5-17 – Post-Validation Overall Length Error by Speed – 28-Aug-13

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 41.2 degrees, from 75.0 to 116.2 degrees Fahrenheit. Since the 30-degree desired temperature range was met, the post-validation test runs are reported under three temperature groups – low, medium and high, as shown in Table 5-13 below.

Table 5-13 – Post-Validation Results by Temperature – 28-Aug-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		75.0 to 88.0 degF	88.1 to 105.0 degF	105.1 to 116.2 degF
Steering Axles	±20 percent	2.1 ± 3.0%	1.6 ± 2.3%	0.3 ± 2.8%
Tandem Axles	±15 percent	1.1 ± 2.9%	0.6 ± 1.9%	0.0 ± 3.2%
GVW	±10 percent	1.3 ± 1.4%	0.8 ± 1.1%	0.1 ± 2.0%
Vehicle Length	±3.0 percent (1.9 ft)	-0.2 ± 0.7 ft	0.1 ± 1.8 ft	0.0 ± 1.0 ft
Vehicle Speed	± 1.0 mph	-0.2 ± 2.5 mph	-0.4 ± 1.6 mph	0.7 ± 4.7 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft	-0.1 ± 0.1 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 5-18, it can be seen that the equipment appears to estimate GVW with similar accuracy across the range of temperatures observed in the field, with slight positive bias at the low and medium temperatures. There does not appear to be a significant correlation between temperature and weight estimates at this site.

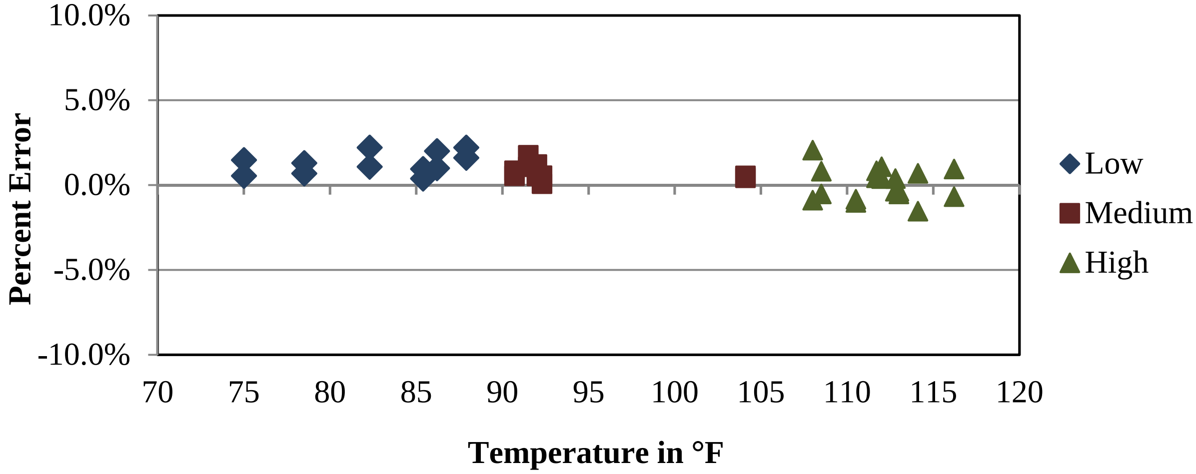


Figure 5-18 – Post-Validation GVW Errors by Temperature – 28-Aug-13

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-19 demonstrates that for steering axles, the WIM equipment appears to estimate weights with similar accuracy across the range of temperatures observed in the field, with slight overestimation at the low and medium temperatures. The range in error is similar for different temperature groups.

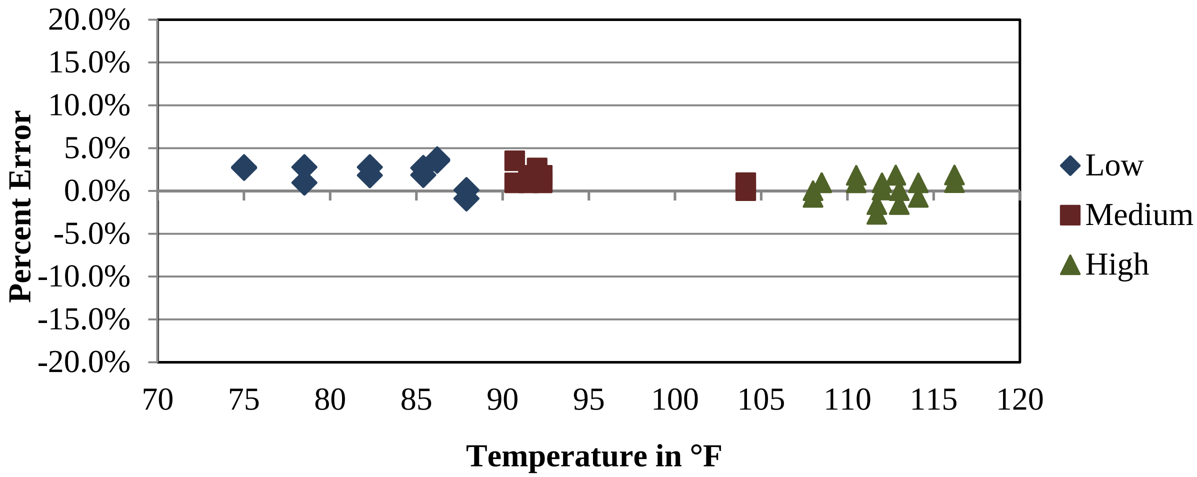


Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 28-Aug-13

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-20, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and tandem axle weight estimates at this site. The range in tandem axle errors is consistent for the three temperature groups.

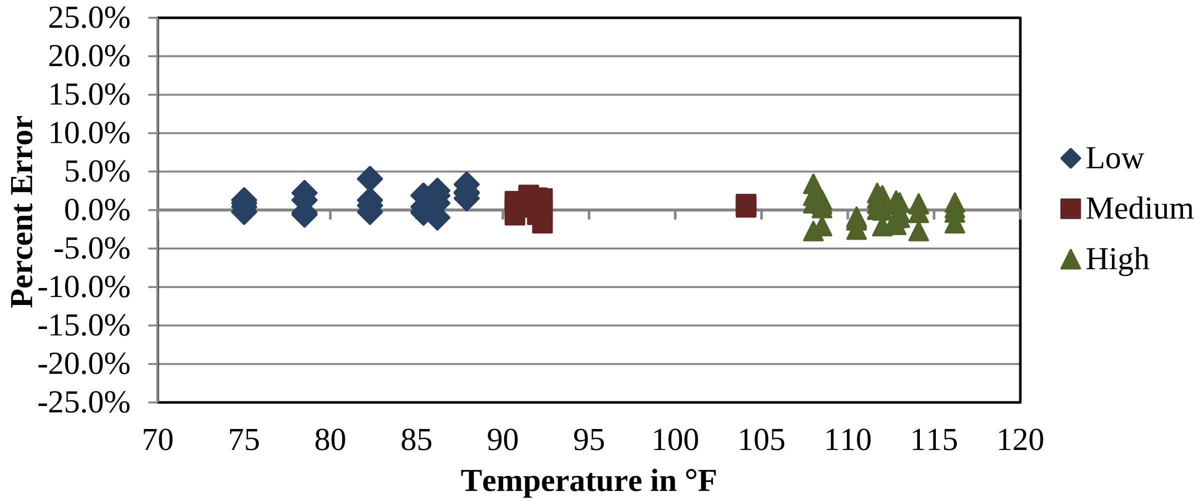


Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 28-Aug-13

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, 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.

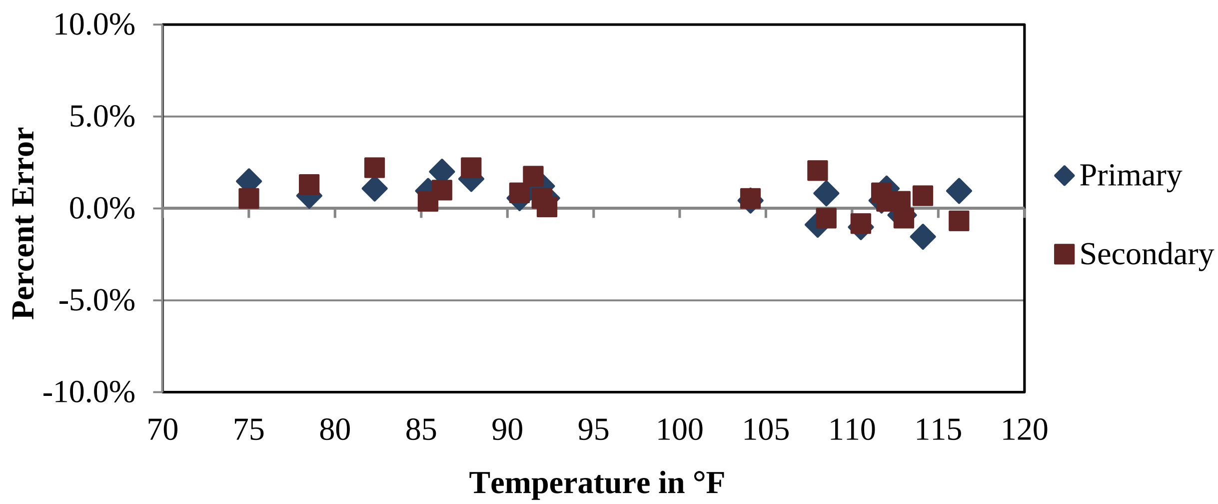


Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 28-Aug-13

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 127 vehicles (Class 3 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 5-14. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-14, six Class 3 vehicles were identified as Class 5s and one Class 3 was identified as a Class 8. For Class 4 vehicles, two were identified as Class 8s and one was identified as a Class 9 by the equipment. One Class 5 was misclassified as a Class 9 and one Class 8 was not classified.

Table 5-14 – Post-Validation Misclassifications by Pair – 28-Aug-13

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

As shown in the table, a total of 12 vehicles, including 1 heavy trucks (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the post-validation study, the misclassification percentage is 1.0% 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 9.4 percent, primarily due to misclassification of lightweight vehicles in Class 3, Class 4 and Class 5. The causes for the misclassifications were not investigated in the field.

The combined results of the misclassifications resulted in an undercount of seven Class 3s and three Class 4s, and an overcount of five Class 5s, two Class 8s, and two Class 9 vehicles, as shown in Table 5-15. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-15 – Post-Validation Classification Study Results – 28-Aug-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	7	3	12	1	0	3	82	3	12	4	0
WIM Count	0	0	17	1	0	5	84	3	12	4	0
Observed Percent	5.5	2.4	9.4	0.8	0.0	2.4	64.6	2.4	9.4	3.1	0.0
WIM Percent	0.0	0.0	13.4	0.8	0.0	3.9	66.1	2.4	9.4	3.1	0.0
Misclassified Count	7	3	1	0	0	1	0	0	0	0	0
Misclassified Percent	100	100	8.3	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	1	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	20.0	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. The unclassified vehicles by pair are provided in Table 5-16.

Table 5-16 – Post-Validation Unclassified Trucks by Pair – 28-Aug-13

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

Based on the manually collected sample of the 127 vehicles, 0.8 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 0.0 mph; the range of errors was 1.8 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
88	55	3233	3436
96	60	3468	3689
104	65	3467	3688
112	70	3459	3680
120	75	3529	3752
Axle Distance (cm)		370	
Dynamic Comp (%)		101	
Loop Width (cm)		303	

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 59 to 72 mph.
- Pavement temperature. Pavement temperature ranged from 75.0 to 116.2 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	2.0226	1.8240	1.1089	0.2748
Speed	0.0358	0.0246	1.4559	0.1541
Temp	-0.0383	0.0090	-4.2528	0.0001
Truck	0.1134	0.2398	0.4729	0.6392

The lowest probability value given in Table 5-15 was 0.0001 for temperature. This means that there is about a .01 percent chance that the value of regression coefficient for truck type (-0.0383) can occur by chance alone.

The relationship between temperature and measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 6-1 provides quantification and statistical assessment of the relationship.

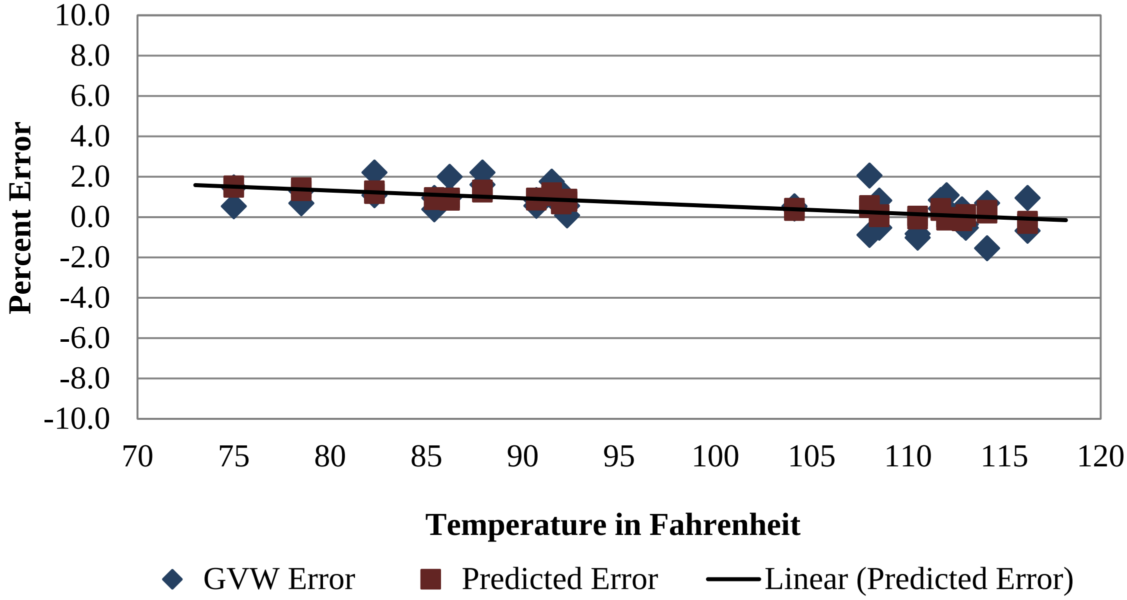


Figure 6-1 – Influence of Temperature on the Measurement Error of GVW

The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.0383 (in Table 6-1). This means, for example, that for a 10 degree change in temperature, the error is changed by about 0.4 percent (-0.0383 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0001) and is statistically significant.

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 relationship was not statistically significant (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	0.0358	0.1541	-0.0383	0.0001	-	-
Steering axle	-0.1712	1.61E-06	-0.0618	2.07E-06	-	-
Tandem axle tractor	0.1172	0.0005	-0.0367	0.0024	0.9734	0.0025
Tandem axle trailer	-	-	-0.0270	0.1204	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on GVW, steering axle and tractor tandem axle measurement errors at selected reliability level.

2. Temperature affected measurement error of all axles and thus also the measurement error of the GVW. The regression coefficients ranged from 2.07E-06 for steering axles to 0.1204 for the tandem axle on the trailer. The difference between regression coefficients obtained for different axle types and GVW was not statistically significant. Low values of regression coefficients indicate that while a statistical significance was established, there is almost zero practical significance.

3. Truck type had statistically significant effect on tractor tandem axles only at 0.1204 probability value. The regression coefficients for truck type in Table 6-2 represent the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1).

4. Even though speed, temperature and truck type parameters had statistically significant effect on measurement errors of some of the parameters, the practical significance of these effects 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 minor influences on the GVW measurement for each truck, with the Primary truck showing a slight negative correlation with speed and Secondary truck showing a slight negative correlation with speed. For the speeds observed in the field these effects canceled one another out. Combined, the overall GVW error dependency on speed was not statistically significant for 15.4 percent (by chance alone) level of significance (p-value was 0.1541). Based on the low value of regression coefficient (0.0358), its practical influence was very low.

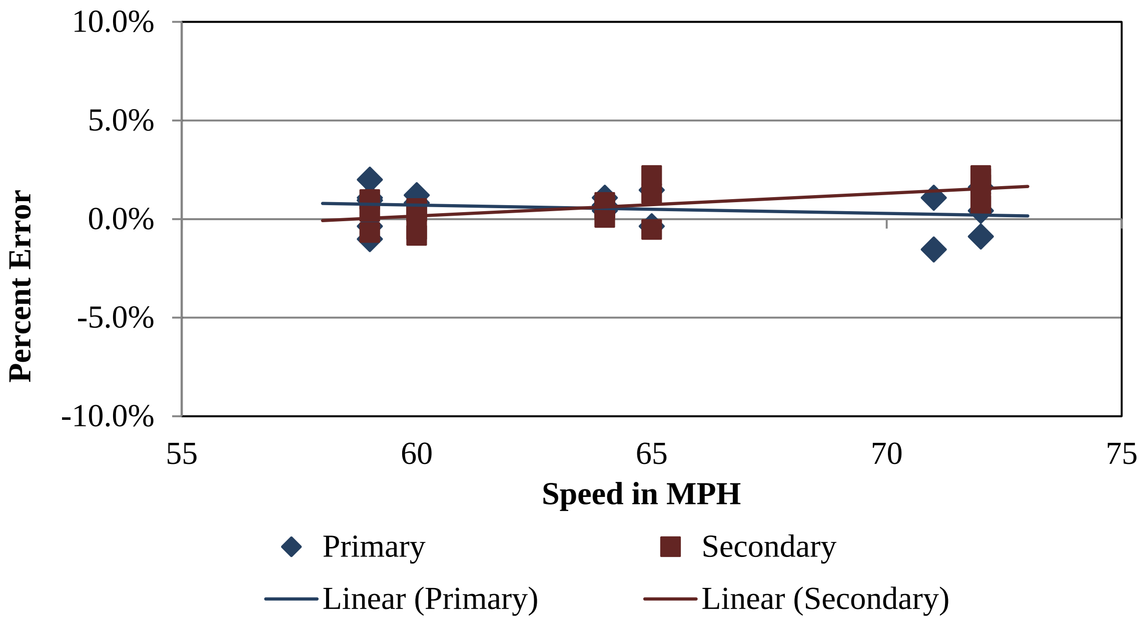


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

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, based on similar correlations between speed and GVW errors for the two trucks. As shown in Table 6-3, the mean errors for all weight parameters for the Primary Truck and Secondary Truck are similar.

Table 6-3 – Post-Validation Results by Truck Type – 28-Aug-13

Parameter	95% Confidence Limit of Error	Primary	Secondary
Steering Axles	±20 percent	1.2 ± 3.2%	1.1 ± 3.0%
Tandem Axles	±15 percent	0.4 ± 2.6%	0.5 ± 2.9%
GVW	±10 percent	0.5 ± 1.9%	0.7 ± 1.9%
Vehicle Length	±3.0 percent (1.9 ft)	-0.3 ± 0.9 ft	0.2 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.1 ± 3.5 mph	0.3 ± 3.7 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.1 ft	-0.1 ± 0.1 ft

6.2 Misclassification Analysis

A post-visit analysis was conducted on the truck misclassifications identified during the post-validation conducted in the field. For this site, a total of 13 vehicles, including no heavy truck (6 – 13) were misclassified by the equipment. The single truck misclassifications was a Class 8 truck that was unclassified by the equipment. According to the Sheet 20, this vehicle was identified as vehicle number 31391. The capture of the real-time record for this vehicle is provided in Figure 6-3.

(31391) LANE #1 CLASS 15 GVW 23.0 kips LENGTH 61 ft
SPEED 73 mph MAX GVW 0.0 kips Wed Aug 28 2013 11:13:44 (2390)

AXLE	SEPARATION (ft)	LEFT WT (kips)	RIGHT WT (kips)	TOTAL WT (kips)	ALLOWABLE (kips)
1 S		2.5	2.8	5.3	
2 S	13.3	2.9	3.1	6.0	
3 D	18.4	2.2	2.0	4.2	
4 D	2.7	2.2	2.1	4.4	
5 S	20.3	1.6	1.5	3.1	

Figure 6-3 – Vehicle Record for Vehicle 31391

The video capture of vehicle 31391 is provided in Photo 6-1. As the photo illustrates, the non-classification involved a single power unit with a single trailer and then another small trailer being towed behind that. The WIM equipment could not classify the system due to additional axles associated with the device attached to the trailer.

Photo 6-1 – Video Capture of Vehicle 31391

6.3 Traffic Data Analysis

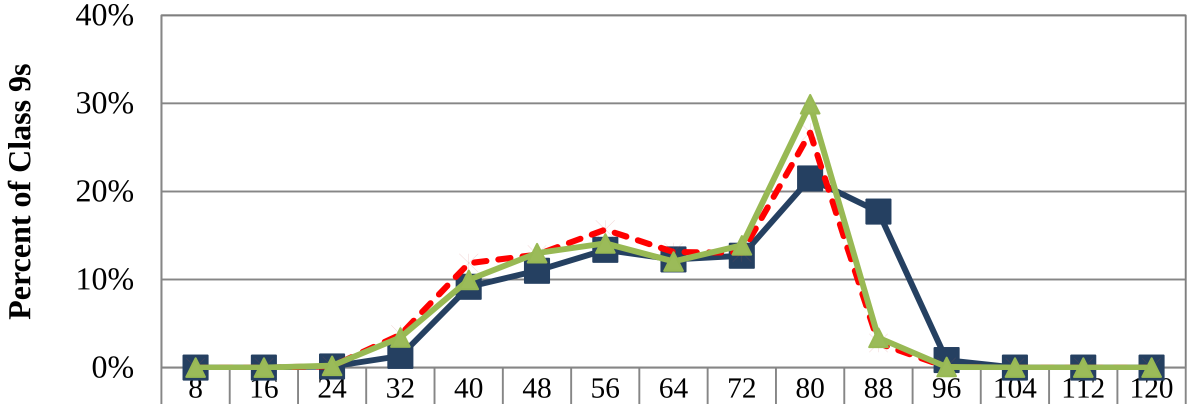
6.3.1 Average GVW and Steering Axle Weights

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 in line with the Comparison Data Set from November 17, 2011, as shown in Table 6-4.

Table 6-4 – Average GVW and Steering Axle Weights

Data Set	Date	Average GVW (kips)	Average Steering Axle (kips)
Comparison Data Set	November 17, 2011	58.6 kips	11.3 kips
Pre-Visit Sample	August 15, 2013	63.5 kips	11.9 kips
Post-Visit Sample	September 13, 2013	60.2 kips	11.5 kips

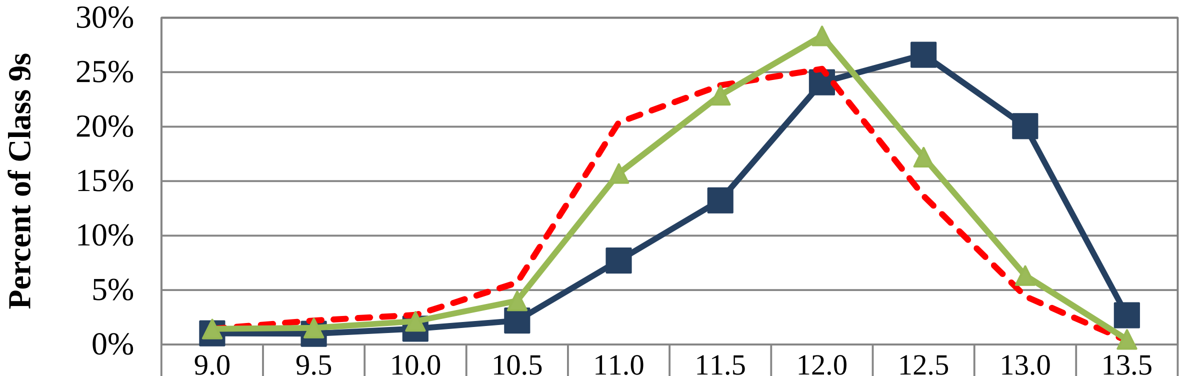
As shown in Figure 6-4, the loaded GVW peak for the post-visit data is similar to the Comparison Data Set.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.1%	1.3%	9.2%	11.0	13.4	12.3	12.7	21.5	17.7	0.8%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.2%	3.8%	11.9	12.8	15.7	13.1	13.0	26.7	2.8%	0.1%	0.0%	0.0%	0.0%
Post	0.0%	0.0%	0.2%	3.4%	10.0	13.0	14.1	12.1	13.9	29.9	3.4%	0.1%	0.0%	0.0%	0.0%

Figure 6-4 – Post-Visit GVW Comparison

As shown in Figure 6-5, the loaded front axle weights are for the post-visit data is similar to the Comparison Data Set.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	1.0%	1.0%	1.4%	2.2%	7.7%	13.2%	24.1%	26.6%	20.0%	2.7%
CDS	1.4%	2.2%	2.7%	5.7%	20.4%	23.8%	25.3%	13.6%	4.4%	0.4%
Post	1.4%	1.5%	2.1%	4.0%	15.7%	22.9%	28.3%	17.2%	6.3%	0.5%

Figure 6-5 – 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	August 15, 2013	5.76	5.86	Right	1.6%
Post-Visit Sample	September 13, 2013	5.44	5.34	Left	1.8%

As shown in the table, the pre-visit data showed that the right side weights were 1.6 greater than the left-side weights. The post-visit data shows that the left weights are 1.8 percent greater than the right side weights. Neither of these imbalances are 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 additional post-validation 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. The entries in the table show the percentages of misclassified vehicles observed in the manual sample for each vehicle class. The last column shows the percentage of unclassified vehicles observed in the manual sample.

Table 7-1 – Classification Validation History

Date	Misclassification Percentage by Class											Pct. Unclass.
	3	4	5	6	7	8	9	10	11	12	13	
31-Oct-06	-	75	50	0	-	18	3	-	25	0	100	0.0
1-Nov-06	-	50	33	0	0	0	1	0	33	0	-	0.0
17-Apr-07	-	-	-	-	-	0	1	-	14	0	-	2.0
18-Apr-07	-	-	0	0	-	0	0	0	0	0	-	0.0
29-Jul-08	-	-	18	0	-	38	0	-	0	-	-	0.0
30-Jul-08	-	0	21	0	-	50	1	-	0	-	-	0.0
21-Dec-10	-	-	0	0	-	11	0	0	0	0	-	0.0
22-Dec-10	-	0	8	0	0	0	0	0	0	0	-	0.0
15-Nov-11	-	18	0	21	0	0	0	0	0	0	0	0.0
27-Aug-13	100	100	0	0	0	0	0	0	0	0	0	0
28-Aug-13	100	100	8	0	0	33	0	0	0	0	0	0.8

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
31-Oct-06	-1.2 ± 6.5	-3.8 ± 9.5	-1.8 ± 13.3
1-Nov-06	-1.6 ± 4.6	-4.8 ± 7.7	-1.1 ± 5.8
17-Apr-07	-1.5 ± 7.9	-3.0 ± 17.5	-1.2 ± 10.9
18-Apr-07	0.5 ± 6.3	-0.3 ± 10.7	0.6 ± 9.2
29-Jul-08	-2.4 ± 2.6	-1.3 ± 4.9	-2.6 ± 3.9
30-Jul-08	0.8 ± 2.9	2.5 ± 6.2	0.5 ± 4.2
21-Dec-10	2.5 ± 2.2	1.6 ± 5.1	2.7 ± 3.1
22-Dec-10	-0.3 ± 2.4	-0.2 ± 5.1	-0.4 ± 3.4
15-Nov-11	-1.9 ± 5.9	-0.9 ± 5.9	-2.1 ± 7.1
27-Aug-13	5.0 ± 2.9	5.1 ± 4.8	5.0 ± 3.8
28-Aug-13	0.6 ± 1.8	1.2 ± 3.0	0.5 ± 2.8

The values of mean weight errors indicate the tendency of the system to shift toward underestimation or overestimation over time. When calibration is done on annual basis, those shifts are minor. However, when the time elapsed between calibrations is close to two years or more, a significant shift in measurements could be observed (i.e. about 7% difference in mean error between 2011 and 2013 calibration cycles). The information presented in this table highlights the need for systematic validation and calibration of the system, preferably with a 1 – 1.5 year frequency.

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

Kansas, SPS-2
SHRP ID: 200200

Validation Date: August 28, 2013

APPLIED RESEARCH ASSOCIATES, INC.

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior Second

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Telephone Pedestal

Photo 9 – Downstream

Photo 10 – Upstream

Photo 11 – Truck 1

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

Photo 20 – Truck 2 Tractor

Photo 21 – Truck 2 Trailer

Photo 22 – Truck 2 Suspension 1

Photo 23 – Truck 2 Suspension 2

Photo 24 – Truck 2 Suspension 3

Photo 25 – Truck 2 Suspension 4

Photo 26 – Truck 2 Suspension 5

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 20 SPS WIM ID: 200200 DATE (mm/dd/yyyy) 8/27/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 8/27/13

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:	5.0%	Standard Deviation:	1.4%
Dynamic and Static Single Axle:	5.1%	Standard Deviation:	2.4%
Dynamic and Static Double Axles:	5.0%	Standard Deviation:	1.9%

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

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

			Low		High	Runs
a.	Low	-	54.0	to	60.0	13
b.	Medium	-	60.1	to	66.1	15
c.	High	-	66.2	to	72.0	12
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 20 SPS WIM ID: 200200 DATE (mm/dd/yyyy) 8/27/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3723 | 3959

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:	2.0	FHWA Class		-	
FHWA Class 8:	0.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean J. Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 20 SPS WIM ID: 200200 DATE (mm/dd/yyyy) 8/28/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 8/28/13

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 -

	Mean		Standard Deviation
Dynamic and Static GVW:	0.6%	Standard Deviation:	0.9%
Dynamic and Static Single Axle:	1.2%	Standard Deviation:	1.5%
Dynamic and Static Double Axles:	0.5%	Standard Deviation:	1.4%

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

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

			Low		High	Runs
a.	Low	-	59.0	to	63.3	16
b.	Medium	-	63.4	to	67.8	14
c.	High	-	67.9	to	72.0	10
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	20 200200 8/28/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3529 | 3752

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:	4.0	FHWA Class	11	-	-8.0
FHWA Class 8:	67.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.8%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean J. Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 20	STATE CODE: 20
LTPP MONITORED TRAFFIC DATA	SPS WIM ID: 200200
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy) 8/27/2013

Count - 121 Time = 1:06:34 Trucks (4-15) - 112 Class 3s - 9

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
63	9	25461	63	9	**69**	**5**	**25532**	**69**	**3**
64	9	25464	64	9	**64**	**5**	**25534**	**64**	**3**
66	9	25466	66	9	62	9	25537	66	9
68	9	25471	68	9	62	9	25538	64	9
70	9	25473	70	9	**66**	**5**	**25539**	**66**	**3**
70	6	25474	70	6	**62**	**5**	**25541**	**65**	**3**
66	9	25482	65	9	**64**	**9**	**25546**	**64**	**4**
60	9	25491	55	9	64	9	25547	63	9
65	11	25493	58	11	**64**	**5**	**25556**	**66**	**3**
69	9	25498	66	9	65	9	25557	66	9
72	9	25499	73	9	64	11	25559	62	11
67	9	25500	69	9	66	9	25561	70	9
72	9	25502	75	9	68	9	25562	68	9
67	**5**	**25504**	**67**	**3**	67	9	25564	67	9
72	9	25506	76	9	63	9	25570	63	9
64	9	25507	65	9	**50**	**5**	**25571**	**53**	**3**
67	9	25514	67	9	64	11	25572	63	11
65	9	25517	69	9	67	10	25576	68	10
75	5	25518	75	5	69	6	25581	69	6
76	9	25519	77	9	67	9	25583	60	9
69	9	25520	70	9	68	9	25587	72	9
64	9	25521	65	9	65	9	25588	66	9
70	9	25525	68	9	66	9	25589	66	9
66	9	25526	68	9	64	9	25593	64	9
65	9	25528	65	9	67	9	25595	66	9

Sheet 1 - 1 to 50 Start: 11:05:39 Stop: 11:28:12

Recorded By: gah Verified By: ar

Validation Test Truck Run Set - Pre

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 20 SPS WIM ID: 200200 DATE (mm/dd/yyyy) 8/27/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	9	25596	63	9	63	9	25707	63	9
75	8	25601	75	8	77	9	25708	75	9
74	8	25602	74	8	70	13	25710	70	13
67	7	25609	70	7	77	9	25717	77	9
65	9	25615	68	9	70	9	25722	70	9
62	9	25619	65	9	68	9	25728	70	9
70	**5**	**25621**	**70**	**3**	70	9	25730	73	9
72	**9**	**25624**	**72**	**3**	70	9	25731	70	9
62	15	25626	62	15	67	9	25732	67	9
65	9	25627	65	9	65	9	25734	65	9
67	9	25630	67	9	65	9	25740	65	9
64	9	25632	61	9	68	9	25743	70	9
68	6	25644	70	6	68	9	257	68	9
77	9	25647	77	9	75	9	25748	75	9
68	9	25650	69	9	65	9	25749	65	9
70	9	25651	71	9	72	9	25750	72	9
61	9	25657	61	9	70	9	25753	70	9
73	9	25665	74	9	60	5	25754	60	5
57	9	25673	61	9	70	9	25755	70	9
62	8	25678	65	8	64	9	25756	68	9
68	9	25681	70	9	67	5	25759	71	5
63	6	25682	62	6	66	9	25766	70	9
55	**6**	**25686**	**55**	**4**	64	9	25570	64	9
75	9	25688	75	9	64	9	25772	64	9
61	9	25704	61	9	68	9	25785	69	9

Sheet 2 - 51 to 100 Start: 11:28:32 Stop: 12:04:16

Recorded By: gah ar

Validation Test Truck Run Set - Pre

Traffic Sheet 20	
LTPP MONITORED TRAFFIC DATA	STATE CODE: 20
SPEED AND CLASSIFICATION STUDIES	SPS WIM ID: 200200
	DATE (mm/dd/yyyy) 8/27/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	9	25789	69	9					
64	9	25790	62	9					
70	9	25794	70	9					
73	9	25795	75	9					
66	9	25796	68	9					
56	6	25799	56	6					
59	11	25800	60	11					
66	9	25802	70	9					
62	9	25803	63	9					
62	9	25807	64	9					
61	9	25810	65	9					
65	9	25811	67	9					
70	9	25812	67	9					
66	9	25814	69	9					
65	9	25816	65	9					
70	9	25818	71	9					
73	7	25821	76	7					
59	10	25823	63	10					
78	10	25824	78	10					
64	9	25828	69	9					
70	5	25831	73	5					

Sheet 3 - 101 to 150 Start: 12:04:48 Stop: 12:12:13

Recorded By: gah ar

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 20 SPS WIM ID: 200200 DATE (mm/dd/yyyy) 8/28/2013

Count - 127 Time = 1:02:41 Trucks (4-15) - 119 Class 3s - 8

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
70	9	31180	66	9	68	9	31248	68	9
68	9	31181	68	9	65	11	31249	65	11
72	9	31188	72	9	62	5	31250	62	5
73	9	31190	74	9	65	11	31252	65	11
60	8	31195	60	3	65	10	31248	66	10
69	9	31196	67	9	73	5	31263	73	3
65	9	31199	62	9	55	9	31264	55	9
70	9	31200	66	9	77	9	31271	77	9
70	9	31201	70	9	67	9	31273	60	9
67	5	31203	67	5	60	9	31274	60	9
69	8	31205	69	8	65	5	31277	65	5
67	9	31214	68	9	69	9	31285	68	9
65	9	31215	67	9	60	9	31288	60	9
68	9	31216	68	9	70	9	31289	67	9
72	9	31220	73	9	68	9	31290	66	9
67	10	31221	66	10	64	9	31292	63	9
65	9	31229	68	9	77	5	31294	77	5
65	9	31230	68	9	70	5	31295	68	3
74	9	31231	76	9	64	11	31300	62	11
62	9	31234	65	9	69	9	31301	69	9
75	10	31237	74	10	73	5	31304	77	5
64	9	31242	64	9	61	9	31305	60	9
59	5	31243	59	5	73	9	31306	73	9
72	9	31245	72	9	64	9	31308	64	11
79	8	31247	79	8	67	9	31315	68	9

Sheet 1 - 1 to 50 Start: 10:36:21 Stop: 10:59:30

Recorded By: gah Verified By: ar

Validation Test Truck Run Set - Post

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 20 SPS WIM ID: 200200 DATE (mm/dd/yyyy) 8/28/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
71	12	31316	73	12	70	12	31389	70	12
61	11	31324	61	11	65	9	31390	65	9
70	6	31326	70	6	**73**	**15**	**31391**	**72**	**3**
60	**5**	**31327**	**60**	**3**	**56**	**5**	**31402**	**55**	**8**
72	9	31329	72	9	55	9	31403	55	9
72	**9**	**31334**	**70**	**4**	64	11	31404	64	11
65	11	31336	64	11	61	9	31406	61	9
70	9	31340	70	9	61	9	31407	61	9
72	9	31342	74	9	66	9	31409	69	9
65	9	31343	65	9	64	9	31414	64	9
60	**5**	**31346**	**59**	**3**	54	9	31415	54	9
63	9	31357	64	9	**64**	**8**	**31419**	**67**	**4**
61	**9**	**31358**	**61**	**5**	67	9	31429	68	9
60	9	31360	60	9	69	9	31425	70	9
75	9	31365	73	9	70	9	31426	67	9
68	9	31368	67	9	65	11	31427	68	11
68	9	31369	69	9	**72**	**5**	**31429**	**72**	**3**
63	9	31370	63	9	62	5	31430	64	5
72	9	31374	71	9	73	9	31432	75	9
59	**5**	**31375**	**59**	**3**	73	9	31433	74	9
65	5	31376	65	5	75	9	31435	74	9
64	11	31377	65	11	65	9	31438	67	9
64	11	31378	64	11	66	9	31439	67	9
60	11	31380	64	11	60	9	31448	59	9
64	9	31385	62	9	**64**	**8**	**31451**	**65**	**4**

Sheet 2 - 51 to 100 Start: 10:59:37 Stop: 11:25:13

Recorded By: gah ar

Validation Test Truck Run Set - Post

Traffic Sheet 20	
LTPP MONITORED TRAFFIC DATA	STATE CODE: 20
SPEED AND CLASSIFICATION STUDIES	SPS WIM ID: 200200
	DATE (mm/dd/yyyy) 8/28/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
77	5	31453	77	5	73	9	31535	70	9
66	12	31454	67	12	67	9	31541	67	9
64	9	31456	67	9					
64	11	31457	65	11					
70	9	31462	71	9					
70	9	31468	71	9					
57	9	31469	57	9					
64	9	31470	66	9					
69	9	31471	65	9					
65	9	31472	64	9					
76	9	31474	76	9					
65	9	31477	68	9					
64	9	31478	61	9					
70	9	31484	71	9					
74	9	31490	73	9					
57	12	31499	61	12					
57	9	31502	57	9					
67	9	31502	67	9					
65	9	31506	61	9					
70	9	31509	70	9					
71	9	31511	71	9					
59	5	31513	59	5					
69	9	31514	72	9					
64	9	31517	61	9					
62	9	31526	65	9					

Sheet 3 - 101 to 150 Start: 11:25:27 Stop: 11:39:02

Recorded By: gah ar