WIM System Field Calibration and Validation Summary Report

Arkansas SPS-5
SHRP ID – 050200

Validation Date: July 11, 2013
Submitted: August 28, 2013

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1 Executive Summary

A WIM validation was performed on July 9 through July 11, 2013 at the Arkansas SPS-5 site located on route I-30, milepost 101.8, 2.2 miles east of US 270.

This site was installed on June 28, 2005. 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 October 18, 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 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 – 11-Jul-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.0 ± 7.7%	Pass
Single Axles*	±20 percent	-0.4 ± 7.9%	Pass
Tandem Axles	±15 percent	0.8 ± 5.6%	Pass
GVW	±10 percent	-0.1 ± 4.1%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.5 ± 1.0 ft	Pass
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.2 ft	Pass

**Single Axles include steering axles and the spread tandem on the Secondary truck.*

This site continues to demonstrate a strong dependency of steering axle weight measurements on speed. While every attempt has been made to mitigate the error during the validation visits, this problem persists at this site. We recommended that the Phase II contractor visit the site to evaluate the WIM sensor installation to determine if the effects can be mitigated through hardware adjustments or other modifications to site set-up.

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 -0.1 ± 4.8 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 -0.1 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 0.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 2.0% from the 100 vehicle sample (Class 4 – 13) was due to misclassification of one Class 4 and one Class 5 vehicle.

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 crane weights and wooden beams.

- The Secondary truck was a Class 9 vehicle with air suspension on the tractor tandem, air suspension on the trailer tandem, standard tandem spacing on the tractor and split tandem on the trailer. The Secondary truck was loaded with crane weights.

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	74.9	11.6	15.3	15.3	16.4	16.4	15.2	4.3	34.5	4.2	58.2	63.0
2	65.4	12.8	14.5	14.5	11.8	11.8	20.2	4.6	29.5	10.2	64.5	67.0

The posted speed limit at the site is 65 mph. During the testing, the speed of the test trucks ranged from to 54 to 65 mph, a variance of 11 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 72.7 to 126.3 degrees Fahrenheit, a range of 53.6 degrees Fahrenheit. The post-validation runs were conducted during the late afternoon hours on July 10 and completed during the morning hours of July 11. These 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 requires no 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 June 18, 2013 (Data) to the most recent Comparison Data Set (CDS) from October 18, 2011. 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	330	12
2008	348	12
2009	347	12
2010	37	3
2011	335	12
2012	211	7

As shown in the table, this site requires no 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 2010.

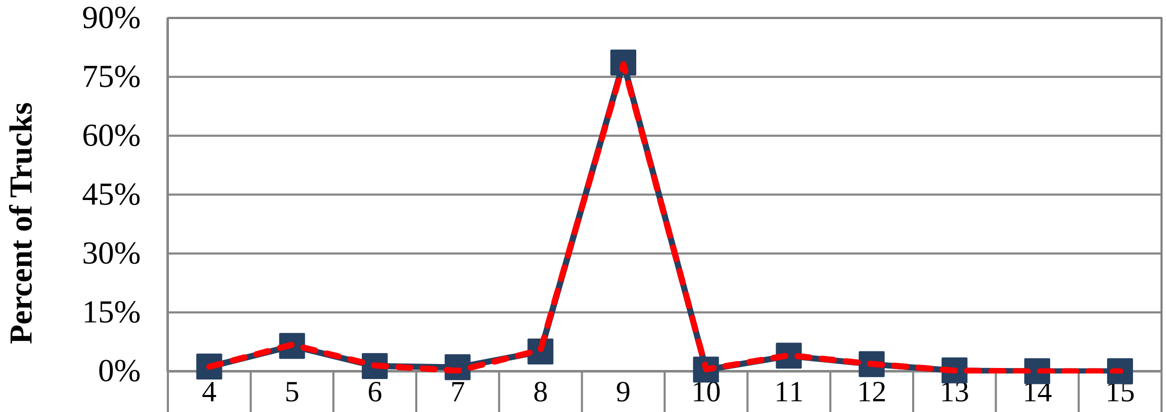
Table 2-2 provides a monthly breakdown of the available data for years 2007 through 2012.

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	17	28	31	30	31	30	31	31	30	31	18	22	12
2008	28	29	31	30	31	30	24	24	30	30	30	31	12
2009	31	28	31	30	31	19	31	31	30	31	29	25	12
2010	3										23	11	3
2011	1	28	31	30	31	30	31	31	30	31	30	31	12
2012	31	29	31	30	31	30	29						7

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 June 18, 2013 (Data) and the most recent Comparison Data Set (CDS) from October 18, 2011.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	1.2%	6.5%	1.3%	1.0%	5.0%	78.7%	0.4%	4.0%	1.8%	0.2%	0.0%	0.0%
CDS	1.2%	6.8%	1.5%	0.1%	5.5%	78.3%	0.5%	4.1%	1.9%	0.2%	0.0%	0.0%

Truck Classifications

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 (78.7%) and Class 5 (6.5%) 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.

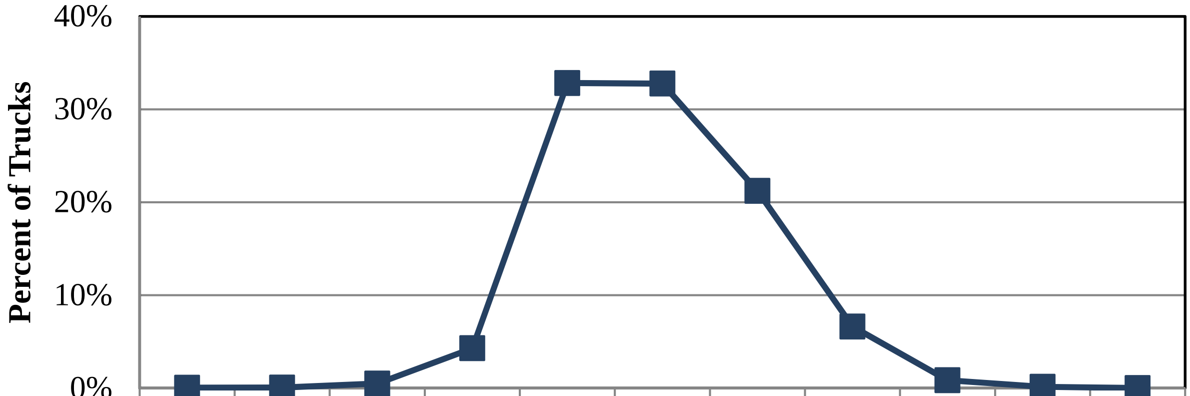
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	10/18/2011		6/18/2013		
4	766	1.2%	759	1.2%	0.0%
5	4404	6.8%	4197	6.5%	-0.3%
6	963	1.5%	859	1.3%	-0.2%
7	83	0.1%	658	1.0%	0.9%
8	3547	5.5%	3270	5.0%	-0.4%
9	50872	78.3%	51122	78.7%	0.4%
10	330	0.5%	256	0.4%	-0.1%
11	2673	4.1%	2571	4.0%	-0.2%
12	1241	1.9%	1179	1.8%	-0.1%
13	120	0.2%	128	0.2%	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 increased by 0.4 percent from October 2011 and June 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 0.3 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

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.



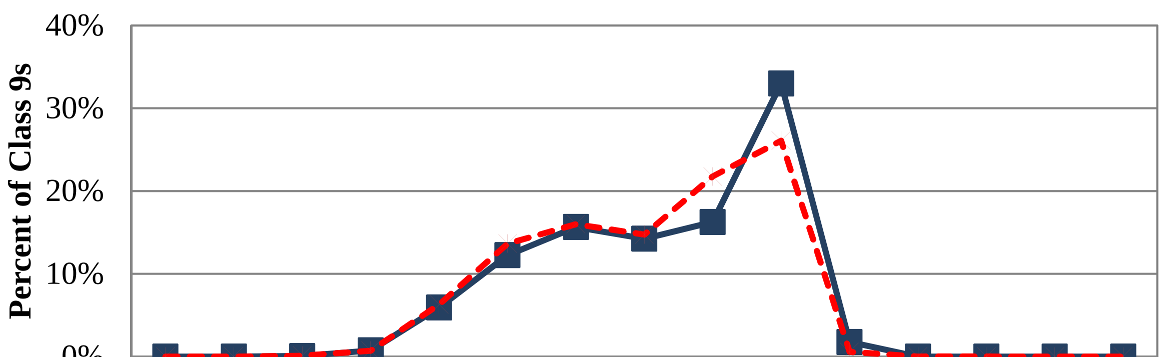
	45	50	55	60	65	70	75	80	85	90	95
Data	0.0%	0.1%	0.5%	4.3%	32.8%	32.8%	21.2%	6.6%	0.9%	0.1%	0.0%

Figure 2-2 – Truck Speed Distribution – 18-Jun-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 73 mph. The range of truck speeds for the validation are 55 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 June 2013 and the Comparison Data Set from October 2011.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.1%	0.8%	5.9%	12.3	15.7	14.2	16.3	33.0	1.8%	0.0%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.1%	0.7%	6.3%	13.6	16.0	14.7	21.8	26.1	0.6%	0.0%	0.0%	0.0%	0.0%

GVW in Kips

Figure 2-3 – Comparison of Class 9 GVW Distribution

As shown in Figure 2-3, there is an upward shift to the right for the loaded peak between the October 2011 Comparison Data Set (CDS) and the June 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 possible positive bias (overestimation of loads) or pavement condition or sensor deterioration.

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

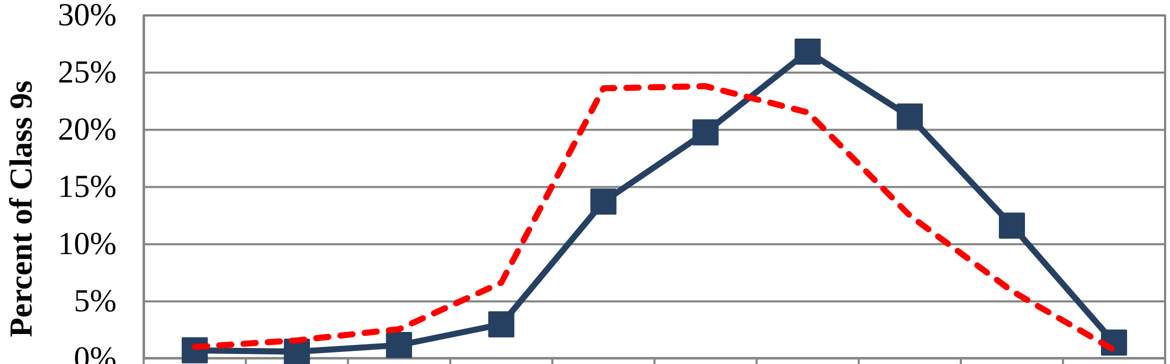
GVW weight bins (kips)	CDS		Data		Change
	Date				
	10/18/2011		6/18/2013		
8	0	0.0%	0	0.0%	0.0%
16	1	0.0%	1	0.0%	0.0%
24	53	0.1%	37	0.1%	0.0%
32	360	0.7%	385	0.8%	0.0%
40	3175	6.3%	3014	5.9%	-0.4%
48	6879	13.6%	6225	12.3%	-1.4%
56	8066	16.0%	7953	15.7%	-0.3%
64	7431	14.7%	7235	14.2%	-0.5%
72	10977	21.8%	8263	16.3%	-5.5%
80	13156	26.1%	16766	33.0%	6.9%
88	291	0.6%	902	1.8%	1.2%
96	12	0.0%	4	0.0%	0.0%
104	6	0.0%	0	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	61.0 kips		62.1 kips		1.1 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 0.4 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range increased by 6.9 percent. During this time period the percentage of overweight trucks increased by 1.2 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 1.8 percent, from 61.0 to 62.1 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 June 2013 and the Comparison Data Set from October 2011. The percentage of light axles (10.5 to 11.5 kips) decreased by approximately 14.0% and the percentage of heavy axles (12.5 to 13.5 kips) increased by approximately 6.3%, 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	0.7%	0.6%	1.2%	3.0%	13.7%	19.8%	26.8%	21.2%	11.6%	1.4%
CDS	1.0%	1.6%	2.6%	6.6%	23.6%	23.8%	21.5%	12.5%	5.9%	0.8%

Steering Axle Weight in Kips

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 11.5 and 12.5 kips. The percentage of trucks in this range has increased between the October 2011 Comparison Data Set (CDS) and the June 2013 dataset (Data).

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

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

F/A weight bins (kips)	CDS		Data		Change
	Date				
	10/18/2011		6/18/2013		
9.0	514	1.0%	362	0.7%	-0.3%
9.5	799	1.6%	301	0.6%	-1.0%
10.0	1293	2.6%	596	1.2%	-1.4%
10.5	3334	6.6%	1514	3.0%	-3.6%
11.0	11873	23.6%	6932	13.7%	-9.9%
11.5	11965	23.8%	9994	19.8%	-4.0%
12.0	10819	21.5%	13563	26.8%	5.3%
12.5	6286	12.5%	10692	21.2%	8.6%
13.0	2968	5.9%	5872	11.6%	5.7%
13.5	381	0.8%	704	1.4%	0.6%
Average =	11.4 kips		11.7 kips		0.3 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.3 kips, or 2.6 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.7 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.

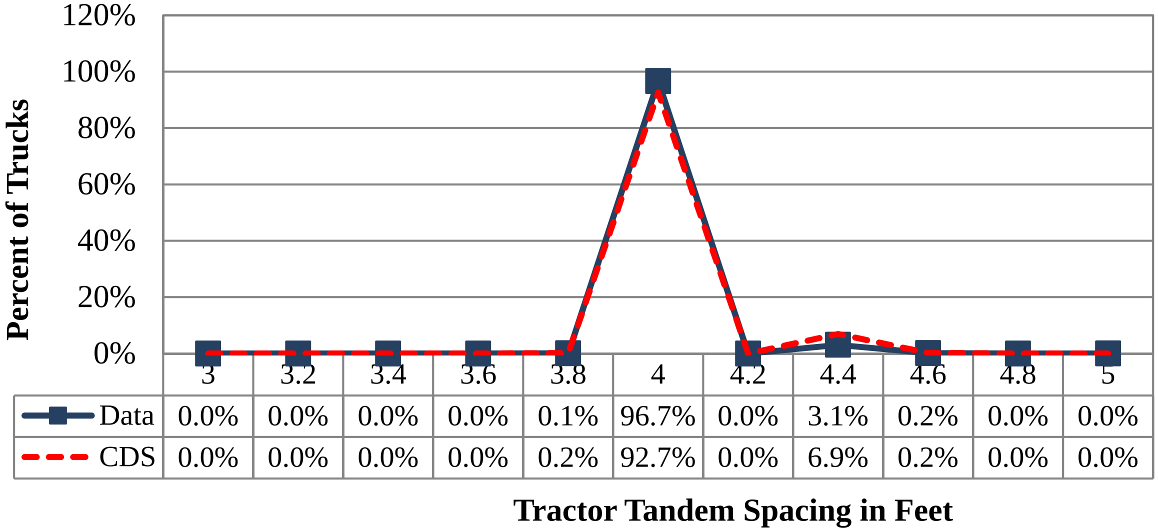


Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacings for the October 2011 Comparison Data Set and the June 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				
	10/18/2011		6/18/2013		
3.0	1	0.0%	1	0.0%	0.0%
3.2	1	0.0%	0	0.0%	0.0%
3.4	6	0.0%	2	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	76	0.2%	35	0.1%	-0.1%
4.0	46710	92.7%	49094	96.7%	4.0%
4.2	0	0.0%	0	0.0%	0.0%
4.4	3489	6.9%	1570	3.1%	-3.8%
4.6	113	0.2%	79	0.2%	-0.1%
4.8	0	0.0%	0	0.0%	0.0%
5.0	11	0.0%	4	0.0%	0.0%
Average =	4.0 feet		4.0 feet		0.0 feet

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

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (October 2011) based on the last calibration with the most recent two-week WIM data sample from the site (June 2013). Comparison of vehicle class distribution data indicates a 0.4 percent increase in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 2.6 percent and average Class 9 GVW has increased by 1.8 percent for the June 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 Pavement Discussion

3.1 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.

3.2 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 3-1.

Table 3-1 – 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 3-1, 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 3-2.

Table 3-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass 5**	**Avg**
Left	LWP	LRI (m/km)	1.152	1.042	1.046			1.080
		SRI (m/km)	0.967	0.971	0.810			0.916
		Peak LRI (m/km)	1.292	1.222	1.242			1.252
		Peak SRI (m/km)	1.180	1.379	1.311			1.290
	RWP	LRI (m/km)	1.058	0.881	1.089			1.009
		SRI (m/km)	0.967	0.980	0.814			0.920
		Peak LRI (m/km)	1.130	1.160	1.187			1.159
		Peak SRI (m/km)	1.074	1.285	1.029			1.129
Center	LWP	LRI (m/km)	1.087	1.001	0.984	0.984	0.947	1.001
		SRI (m/km)	0.931	0.638	0.613	0.613	1.024	0.764
		Peak LRI (m/km)	1.224	1.185	1.159	1.159	1.105	1.166
		Peak SRI (m/km)	0.988	0.997	0.949	0.949	1.252	1.027
	RWP	LRI (m/km)	1.116	1.097	1.089	1.089	1.053	1.089
		SRI (m/km)	1.163	1.583	1.409	1.409	1.096	1.332
		Peak LRI (m/km)	1.336	1.271	1.298	1.298	1.175	1.276
		Peak SRI (m/km)	***1.319***	***1.902***	***1.876***	***1.876***	***1.190***	***1.633***
Right	LWP	LRI (m/km)	0.971	0.972	0.987			0.977
		SRI (m/km)	0.779	1.012	0.724			0.838
		Peak LRI (m/km)	1.223	1.126	1.127			1.159
		Peak SRI (m/km)	1.062	1.065	0.829			0.985
	RWP	LRI (m/km)	0.951	1.000	0.956			0.969
		SRI (m/km)	1.350	1.263	1.290			1.301
		Peak LRI (m/km)	1.165	1.153	1.176			1.165
		Peak SRI (m/km)	1.491	1.468	1.479			1.479

From Table 3-2 it can be seen that all indices computed from the profiles are between the upper and lower threshold values. The highest values, on average, are the Peak SRI values in the right wheel path of the center passes (shown in bold and italics).

3.3 Profile and Vehicle Interaction

Profile data was collected on January 19, 2012 by the Southern Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, 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 126 in/mi and is located approximately 844 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 114 in/mi and is located approximately 154 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.

3.4 Recommended Pavement Remediation

No pavement remediation is recommended.

4 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on October 18, 2011 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

4.1 Description

This site was installed on June 28, 2005 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.

4.2 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.

4.3 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.

4.4 Equipment Troubleshooting and Diagnostics

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

4.5 Recommended Equipment Maintenance

No unscheduled equipment maintenance actions are 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 July 10, 2013, beginning at approximately 7:09 AM and continuing until 12:41 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with crane weights and wooden beams, and equipped with air suspension on truck and trailer tandems with standard tandem spacings on both the tractor and trailer.

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

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

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

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	74.8	11.5	15.3	15.3	16.3	16.3	15.2	4.3	34.5	4.2	58.2	63.0
2	65.0	12.6	14.3	14.3	11.9	11.9	20.2	4.6	29.5	10.2	64.5	67.0

Test truck speeds varied by 11 mph, from 54 to 65 mph. The measured pre-validation pavement temperatures varied 53.6 degrees Fahrenheit, from 72.7 to 126.3. 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, however, it did not meet the requirement for Vehicle Length as a result of the pre-validation test truck runs.

Table 5-2 – Pre-Validation Overall Results – 10-Jul-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail*
Steering Axles	±20 percent	7.5 ± 5.6%	Pass
Single Axles**	±20 percent	4.7 ± 8.7%	Pass
Tandem Axles	±15 percent	1.6 ± 5.7%	Pass
GVW	±10 percent	2.4 ± 4.8%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	-1.2 ± 1.5 ft	FAIL
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.2 ft	Pass

** Pass/Fail evaluation is based on the overall error value. Single, steering, and GVW measurements have significant bias.*
***Single Axles include steering axles and the spread tandem on the Secondary truck.*

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 0.0 ± 2.0 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 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 – 10-Jul-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		54.0 to 57.3 mph	57.4 to 60.8 mph	60.9 to 64.0 mph
Steering Axles	±20 percent	8.9 ± 4.6%	8.2 ± 5.2%	4.6 ± 3.6%
Single Axles*	±20 percent	1.5 ± 7.0%	7.1 ± 10.1%	5.2 ± 7.8%
Tandem Axles	±15 percent	0.1 ± 4.4%	1.0 ± 5.4%	-1.6 ± 4.7%
GVW	±10 percent	1.5 ± 2.6%	4.0 ± 5.4%	1.9 ± 6.0%
Vehicle Length	±3.0 percent (2.0 ft)	-0.9 ± 2.1 ft	-1.4 ± 1.1 ft	-1.3 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.2 ± 1.4 mph	-0.4 ± 3.3 mph	0.1 ± 0.7 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	-0.1 ± 0.2 ft	-0.1 ± 0.3 ft

**Single Axles include steering axles and the spread tandem on the Secondary truck.*

From the table, it can be seen that, on average, the WIM equipment overestimates steering axle weights, single axle weights and GVW at all speeds. The equipment overestimates tandem axle weights at the low and medium speeds and underestimates tandem axle weights at the high speeds. The range in error is reasonably consistent over the range of speeds for steering axles and tandem axles. For GVW and single axles the range in error is greater at the medium and high speeds when compared with low speeds.

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

5.1.1.1 GVW Errors by Speed

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

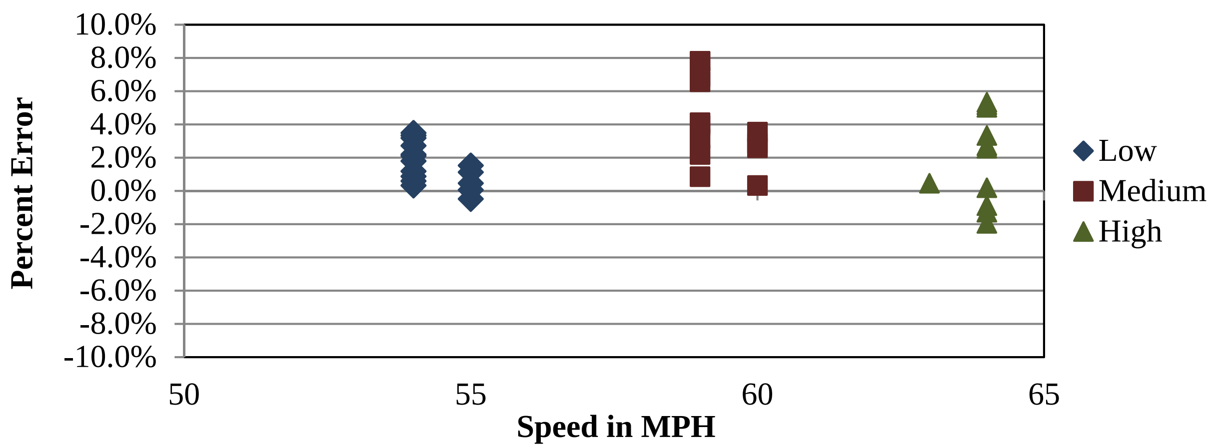


Figure 5-1 – Pre-Validation GVW Error by Speed – 10-Jul-13

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment overestimates steering axle weights with fairly similar bias at the low and medium speeds. The positive bias appears to be smaller at the higher speeds. The range in error is similar across the range of speeds.

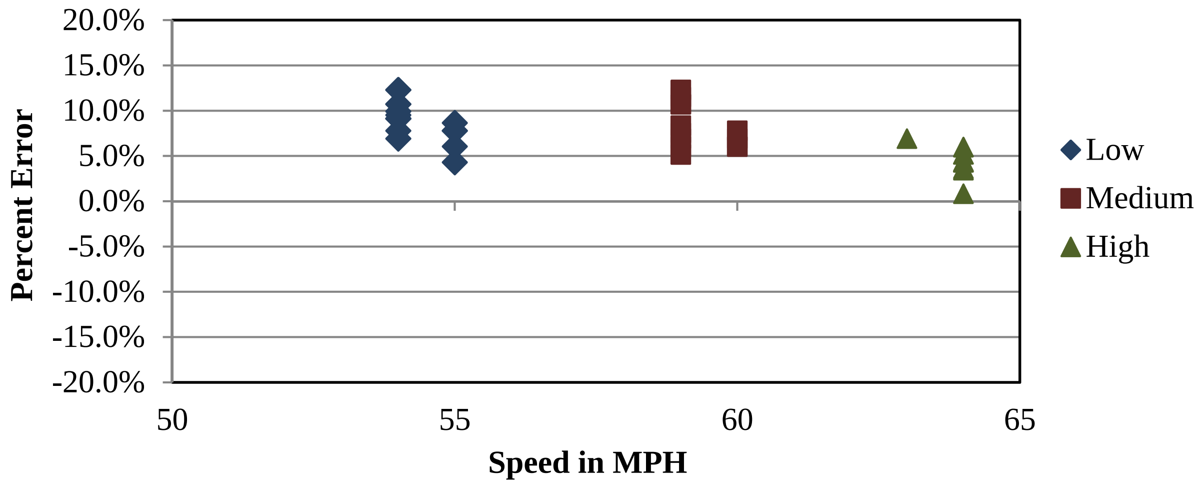


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 10-Jul-13

5.1.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment progresses from an unbiased estimate of single axle weights at the lower speeds to an overestimate of single axle weights at the higher speeds. The range in error is greater at the lower speeds when compared to medium and high speeds.

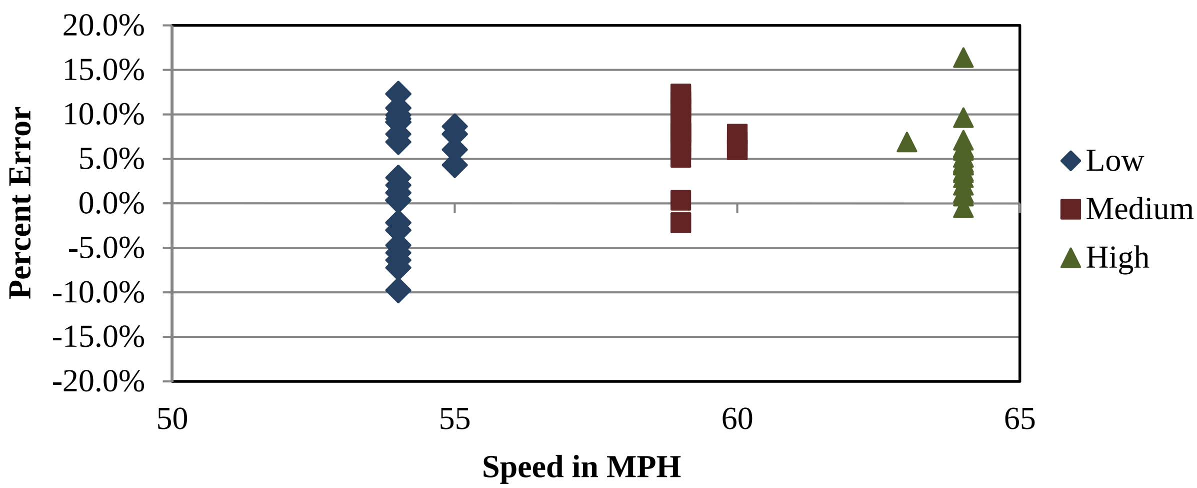


Figure 5-3 – Pre-Validation Single Axle Weight Errors by Speed – 10-Jul-13

5.1.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment estimates tandem axle weights with higher accuracy at low speeds. The range in error is greater at the medium and high speeds.

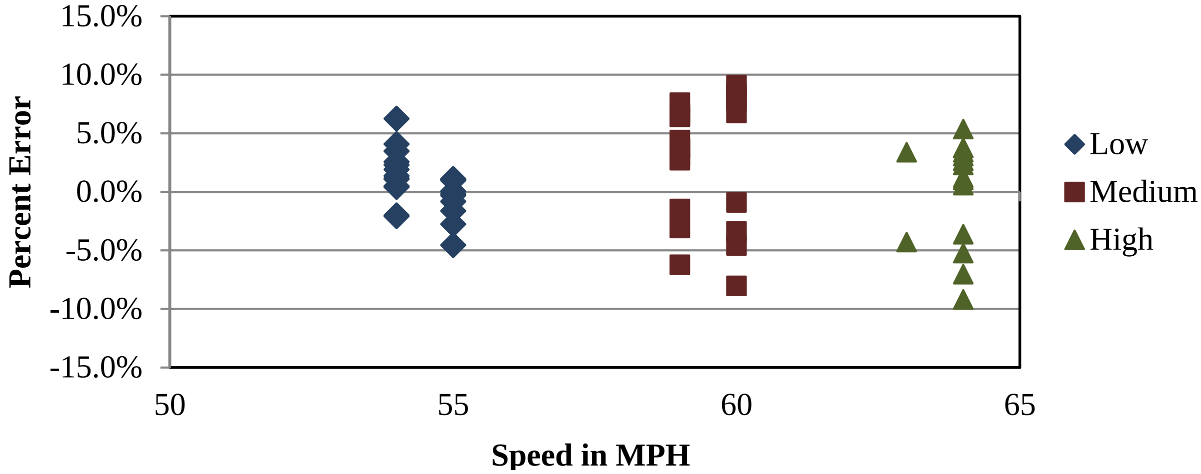


Figure 5-4 – Pre-Validation Tandem Axle Weight Errors by Speed – 10-Jul-13

5.1.1.5 GVW Errors by Speed and Truck Type

When the GVW error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment precision and bias is different for the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. The spread of errors is greater at the medium and high speeds due to the overestimation of GVW for the Secondary Truck at those speeds, as shown graphically in Figure 5-5.

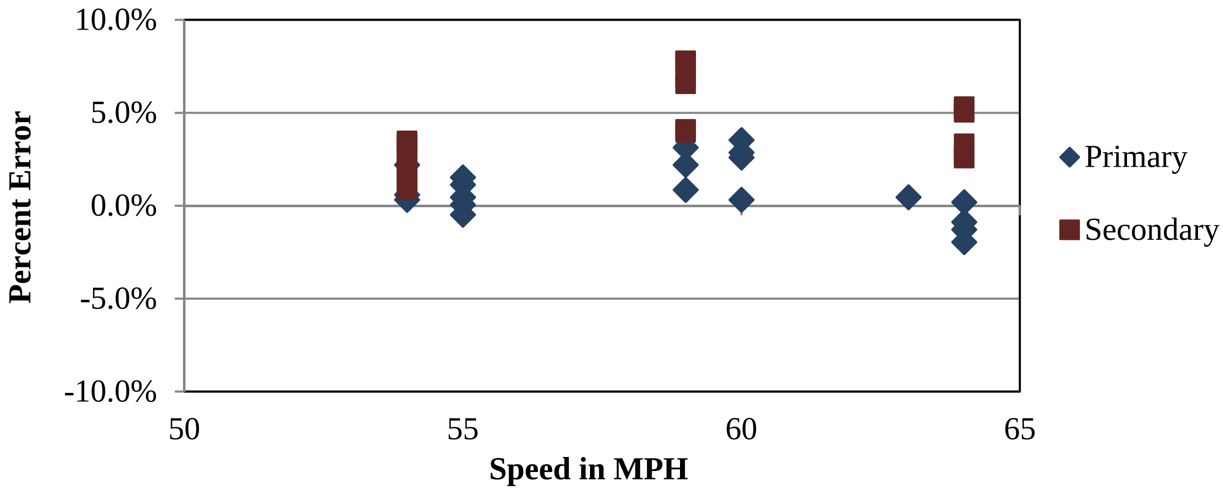


Figure 5-5 – Pre-Validation GVW Errors by Truck and Speed – 10-Jul-13

5.1.1.6 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from -0.3 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-6.

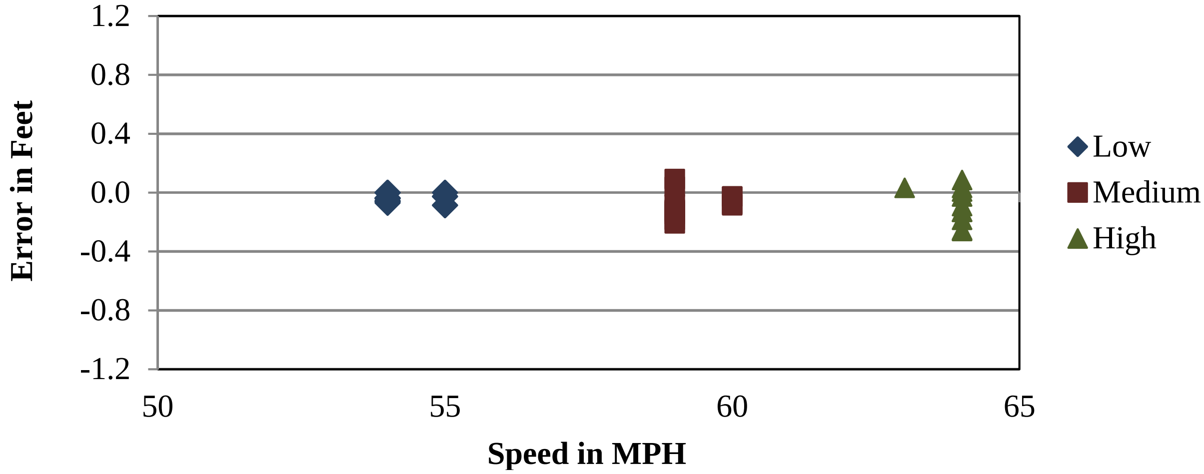


Figure 5-6 – Pre-Validation Axle Length Errors by Speed – 10-Jul-13

5.1.1.7 Overall Length Errors by Speed

For this system, the WIM equipment underestimated overall vehicle length consistently over the entire range of speeds, with an error range of -2.0 to 0.0 feet. Distribution of errors is shown graphically in Figure 5-7.

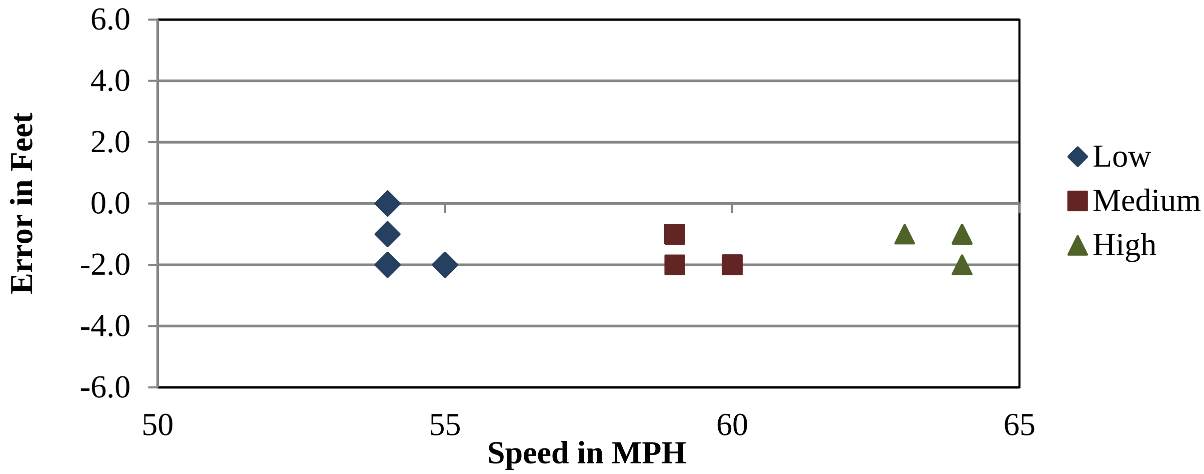


Figure 5-7 – Pre-Validation Overall Length Error by Speed – 10-Jul-13

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 53.6 degrees, from 72.7 to 126.3 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 – 10-Jul-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		81.0 to 93.8 degF	93.9 to 106.7 degF	106.8 to 119.4 degF
Steering Axles	+20 percent	7.6 ± 6.3%	7.6 ± 5.4%	7.0 ± 6.1%
Single Axles	+20 percent	4.6 ± 11.7%	4.1 ± 15.8%	4.0 ± 9.5%
Tandem Axles	+15 percent	0.0 ± 6.5%	-0.1 ± 3.6%	0.1 ± 8.4%
GVW	+10 percent	2.6 ± 5.2%	2.1 ± 5.2%	2.5 ± 5.6%
Vehicle Length	±3.0 percent (2.0 ft)	-1.2 ± 1.6 ft	-0.9 ± 1.7 ft	-1.4 ± 1.6 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 1.4 mph	0.3 ± 2.4 mph	-0.3 ± 3.0 mph
Axle Length	+ 0.5 ft [150mm]	-0.1 ± 0.2 ft	0.0 ± 0.2 ft	-0.1 ± 0.2 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 with similar bias across the range of temperatures observed in the field.

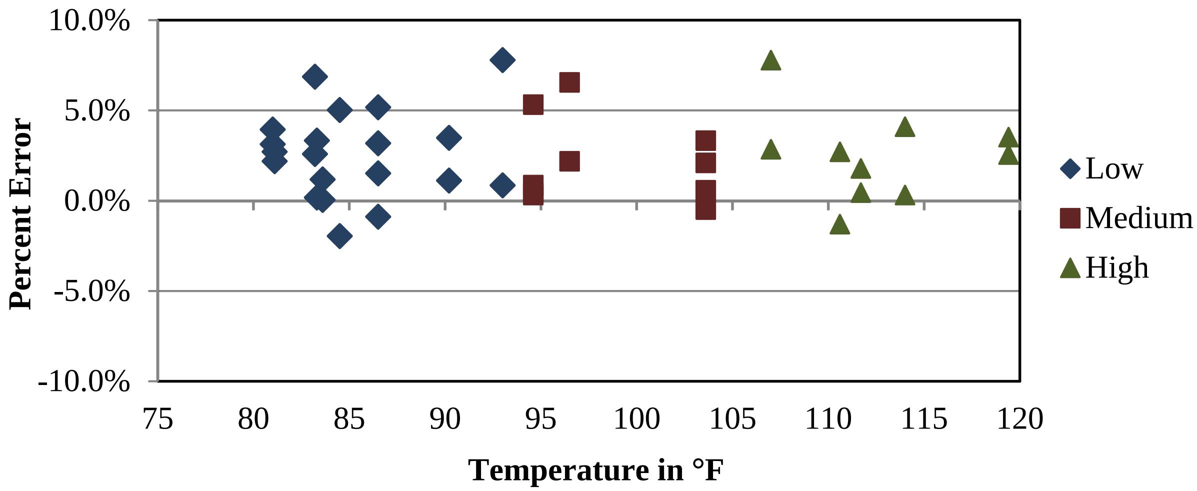


Figure 5-8 – Pre-Validation GVW Errors by Temperature – 10-Jul-13

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 illustrates that for steering axles, the WIM equipment overestimates weights at all temperatures with similar bias.

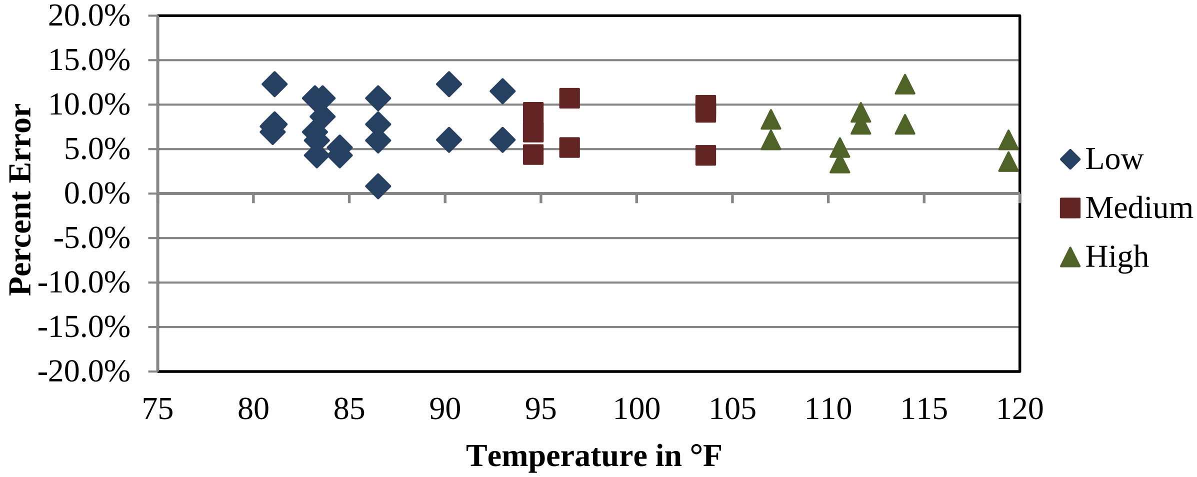


Figure 5-9 – Pre-Validation Steering Axle Weight Errors by Temperature – 10-Jul-13

5.1.2.3 Single Axle Weight Errors by Temperature

Figure 5-10 illustrates that for single axles, on average, the WIM equipment overestimates single axle weights. The range in error is greater at the low and medium temperatures.

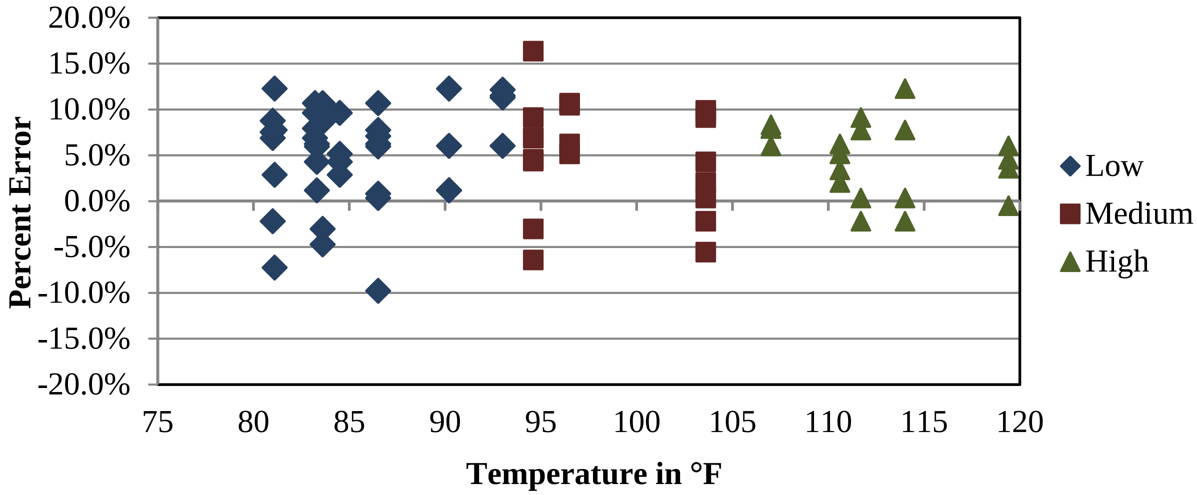


Figure 5-10 – Pre-Validation Single Axle Weight Errors by Temperature – 10-Jul-13

5.1.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-11, the WIM equipment estimates tandem axle weights with similar accuracy across the range of temperatures observed in the field. The range in tandem axle errors is lower for the medium temperature group.

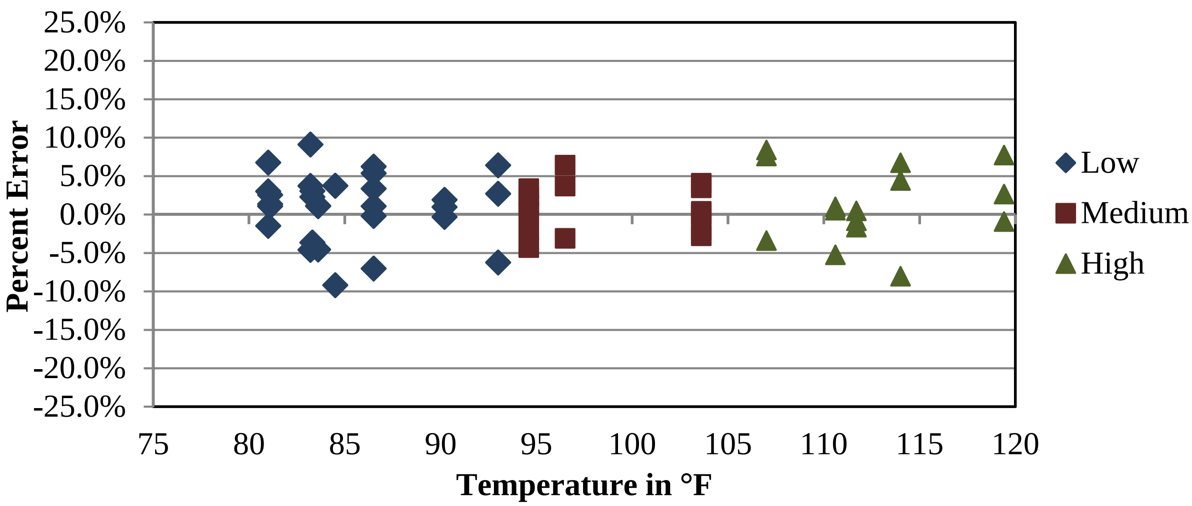


Figure 5-11 – Pre-Validation Tandem Axle Weight Errors by Temperature – 10-Jul-13

5.1.2.5 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, it can be seen that the WIM equipment bias is different for the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. The equipment appears to estimate GVW for the Primary Truck without bias at all temperatures while GVW of the secondary truck appears to be overestimated at all temperatures. The spread of errors is similar for both trucks, as shown graphically in Figure 5-12.

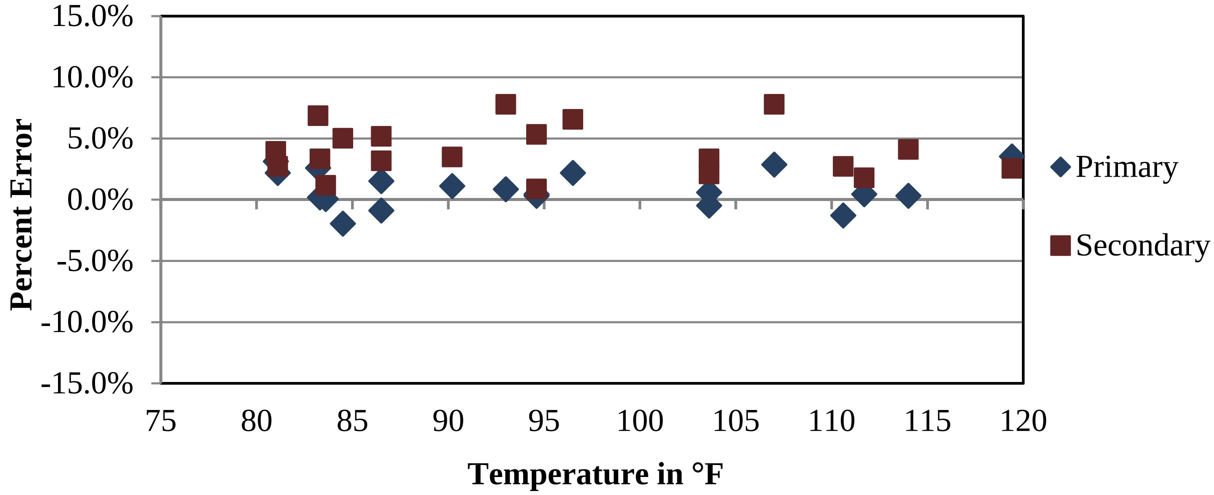


Figure 5-12 – Pre-Validation GVW Error by Truck and Temperature – 10-Jul-13

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 112 vehicles including 112 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, one Class 4 vehicle was misclassified as a Class 5 vehicle, one Class 5 vehicle was misclassified as a Class 8 vehicle by the equipment.

Table 5-5 – Pre-Validation Misclassifications by Pair – 9-Jul-13

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

As shown in the table, a total of 3 vehicles, including no heavy trucks (vehicle classes 6 – 13) were misclassified by the equipment. Two Class 4 vehicles were identified as Class 5 vehicles and one Class 5 was identified as a Class 8 by the system. One Class 7 and one Class 10 were unclassified by the system. Based on the vehicles observed during the pre-validation study, the misclassification percentage is 2.0% 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 4.5%, due to the three misclassifications of lightweight vehicles. The causes for the misclassifications were not investigated in the field.

The combined results produced an undercount of two Class 4s, one Class 7 and one Class 10 vehicle and an overcount of one Class 5 and one Class 8 vehicle, 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 – 9-Jul-13

Class	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Observed Count	0	3	8	0	2	0	92	3	4	4	0
WIM Count	0	1	9	0	1	1	92	2	4	4	0
Observed Percent	0.0	2.6	6.9	0.0	1.7	0.0	79.3	2.6	3.4	3.4	0.0
WIM Percent	0.0	0.9	7.8	0.0	0.9	0.9	79.3	1.7	3.4	3.4	0.0
Misclassified Count	0	2	1	0	1	0	0	1	0	0	0
Misclassified Percent	0.0	66.7	12.5	0.0	50.0	0.0	0.0	33.3	0.0	0.0	0.0
Unclassified Count	0	0	0	0	1	0	0	1	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	100.0	0.0	0.0	50.0	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 5-7.

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 9-Jul-13

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

Based on the manually collected sample of the 112 trucks, 1.8 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 -0.4 mph; the range of errors was 1.9 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 – 10-Jul-13

Speed Point	MPH	Left	Right
		2	1
80	50	3011	3082
88	55	3098	3172
96	60	3029	3102
104	65	2918	2987
112	70	2912	2981
Axle Distance (cm)		373	
Dynamic Comp (%)		109	
Loop Width (cm)		211	

5.2.1.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of -0.1% and errors of 0.52%, 0.10%, and -0.25% at the 55, 60 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 1 Equipment Factor Changes – 10-Jul-13

Speed Points	Old Factors		New Factors	
	Left	**Right**	**Left**	**Right**
	2	**1**	**2**	**1**
80	3011	3082	3015	3087
88	3098	3172	3102	3177
96	3029	3102	2938	3009
104	2918	2987	2890	2959
112	2912	2981	2884	2953
Axle Distance (cm)	373		373	
Dynamic Comp (%)	109		103	
Loop Width (cm)	211		165	

5.2.1.2 Calibration Results

The results of the 14 calibration verification runs are provided in Table 5-10 and Figure 5-13. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the calibration.

Table 5-10 – Calibration Results – 10-Jul-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-0.3 ± 7.4%	Pass
Single Axles	±20 percent	-0.9 ± 10.4%	Pass
Tandem Axles	±15 percent	1.0 ± 4.8%	Pass
GVW	±10 percent	0.3 ± 2.9%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.5 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.2 ft	Pass

Figure 5-13 shows that the WIM equipment is estimating GVW with similar accuracy at all speeds.

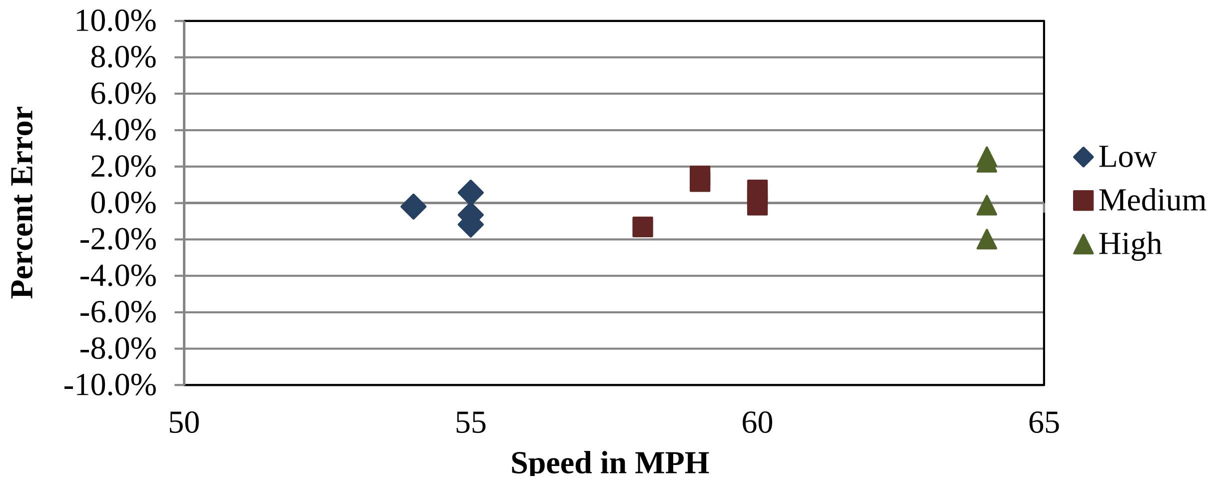


Figure 5-13 – Calibration GVW Error by Speed – 10-Jul-13

Based on the results of the calibration, where GVW estimate bias decreased from 2.4 to 0.3 percent, a second calibration was not considered to be necessary. The 14 calibration runs were combined with 26 additional post-validation runs to complete the WIM system validation.

5.3 Post-Validation

The 40 post-validation test truck runs conducted on July 10, 2013, beginning at approximately 2:12 PM and continuing until 3:50 PM, and on July 11, 2013 starting at 5:19 AM and continuing until 8:30 AM.

The two test trucks consisted of:

- A Class 9 truck, loaded with crane weights and wooden beams 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 crane weights, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and split 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	74.9	11.6	15.3	15.3	16.4	16.4	15.2	4.3	34.5	4.2	58.2	63.0
2	65.4	12.8	14.5	14.5	11.8	11.8	20.2	4.6	29.5	10.2	64.5	67.0

Test truck speeds varied by 11 mph, from 54 to 65 mph. The measured post-validation pavement temperatures varied 53.6 degrees Fahrenheit, from 72.7 to 126.3. The late afternoon temperatures on the first day, combined with the lower temperatures of the second day 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 – 11-Jul-13

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	-1.0 ± 7.7%	Pass
Single Axles*	±20 percent	1.3 ± 7.9%	Pass
Tandem Axles	±15 percent	0.8 ± 5.6%	Pass
GVW	±10 percent	-0.1 ± 4.1%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.5 ± 1.0 ft	Pass
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.2 ft	Pass

**Single Axles include steering axles and the spread tandem on the Secondary truck.*

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 -0.1 ± 4.8 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 -0.1 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 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 – 11-Jul-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		54.0 to 57.7 mph	57.8 to 61.4 mph	61.5 to 65.0 mph
Steering Axles	±20 percent	2.6 ± 5.3%	-1.2 ± 7.1%	-3.8 ± 6.2%
Single Axles*	±20 percent	0.5 ± 5.8%	1.3 ± 7.9%	2.4 ± 8.5%
Tandem Axles	±15 percent	-0.5 ± 3.7%	-2.0 ± 6.6%	-2.6 ± 4.2%
GVW	±10 percent	0.3 ± 2.3%	-0.1 ± 4.1%	-0.4 ± 6.0%
Vehicle Length	±3.0 percent (2.0 ft)	0.5 ± 1.1 ft	0.5 ± 1.1 ft	0.4 ± 1.1 ft
Vehicle Speed	± 1.0 mph	-0.7 ± 2.9 mph	-0.5 ± 3.1 mph	0.9 ± 7.5 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.2 ft	-0.1 ± 0.2 ft	-0.1 ± 0.3 ft

**Single Axles include steering axles and the spread tandem on the Secondary truck.*

There appears to be a relationship between weight estimates and speed at this site. From the table, it can be seen that the negative bias in WIM weight measurements increases with speed.

This site continues to demonstrate a strong dependency of steering axle weight measurements on speed. While every attempt has been made to mitigate the error during this validation, this problem persists at this site. We recommended that the Phase II contractor visit the site to evaluate the WIM sensor installation to determine if the effects can be mitigated through hardware adjustments.

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 5-14, the range in error and negative bias in GVW estimates appear to increase as speed increases. There does appear to be a negative correlation between speed and steering axle weight estimates at this site.

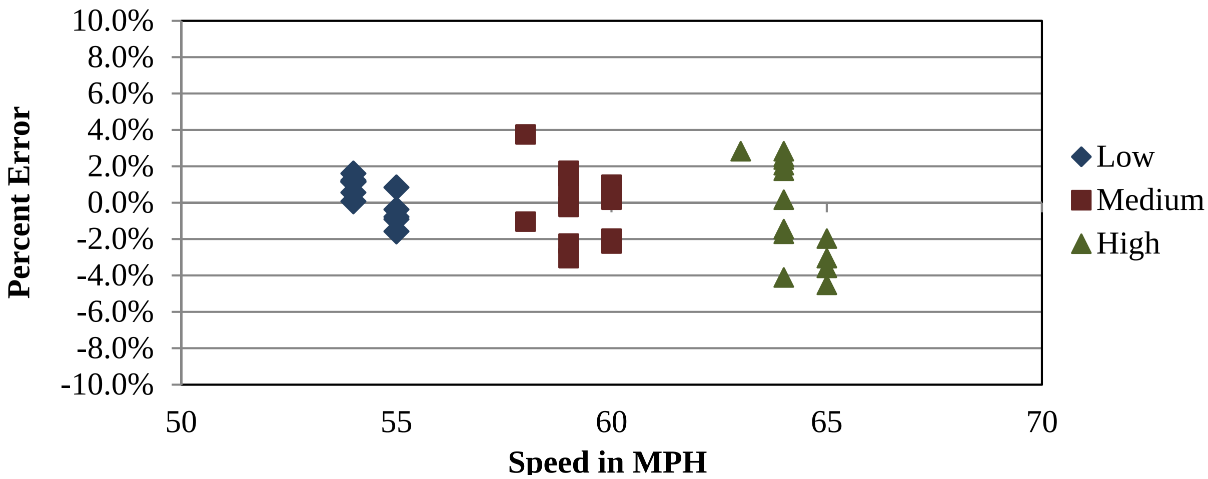


Figure 5-14 – Post-Validation GVW Errors by Speed – 11-Jul-13

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-15, the equipment progressed from an overestimation of steering axle weights at low speeds to an underestimation of weights at the higher speeds. The range in error is similar throughout the entire speed range. There does appear to be a negative correlation between speed and steering axle weight estimates at this site.

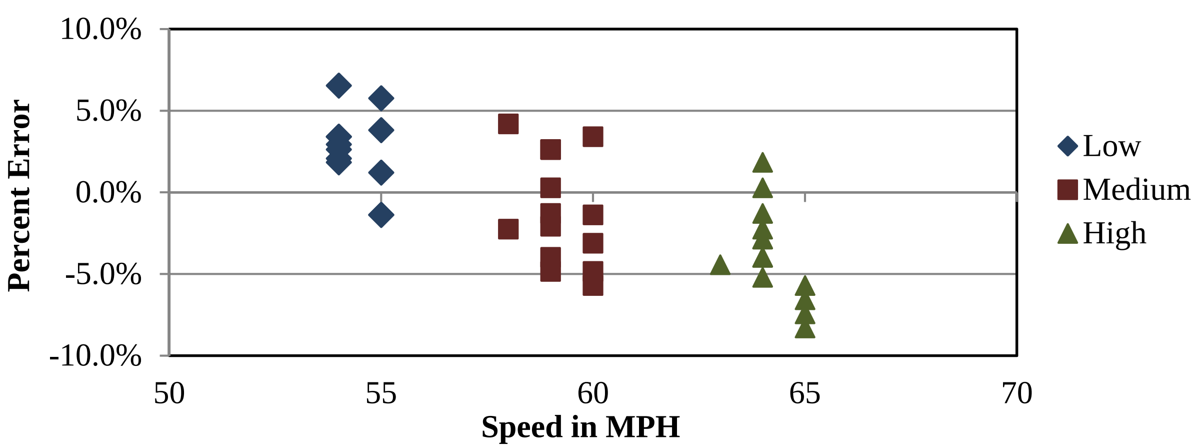


Figure 5-15 – Post-Validation Steering Axle Weight Errors by Speed – 11-Jul-13

5.3.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-16, the equipment estimated single axle weights, on average, without significant bias at all speeds. The range in error appears to increase as speed increases. This is most likely due to opposing trends observed in error dependency on speed for steering axle and single axles that form spread tandem axle.

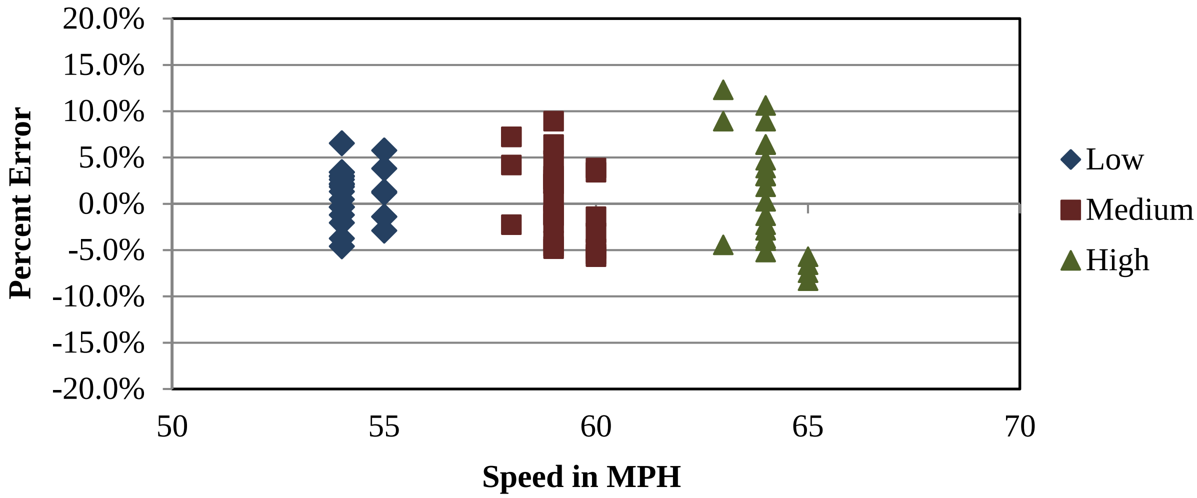


Figure 5-16 – Post-Validation Single Axle Weight Errors by Speed – 11-Jul-13

5.3.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-17, the equipment estimated tandem axle weights, on average, with small negative bias at all speeds. The range in error is greater at the medium and high speeds when compared with low speeds.

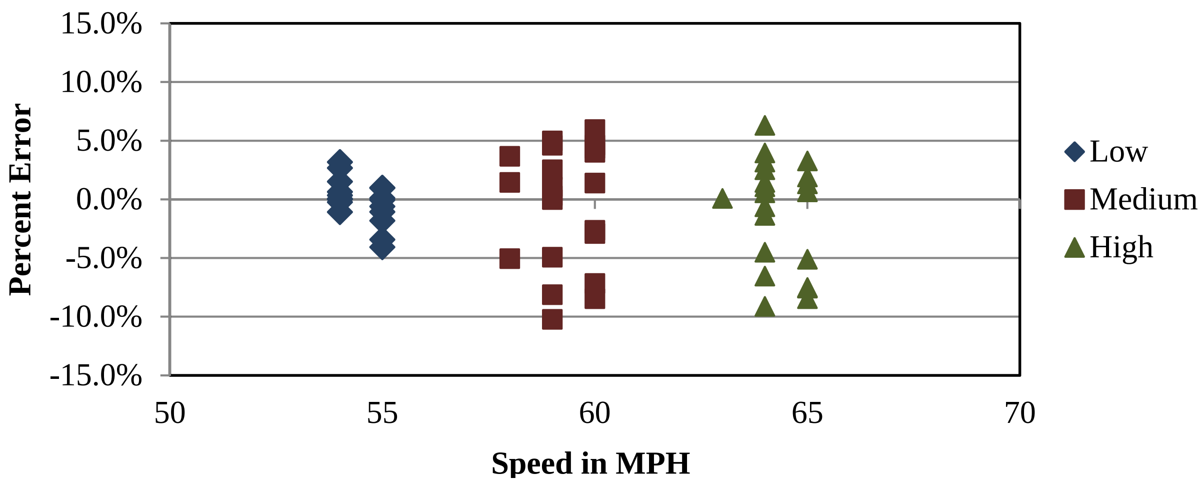


Figure 5-17 – Post-Validation Tandem Axle Weight Errors by Speed – 11-Jul-13

5.3.1.5 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-18 that when the GVW errors are analyzed by truck type, the WIM equipment bias is dissimilar for the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. At the medium and high speeds the Primary truck moves toward an underestimation of GVW while the Secondary truck moves toward an overestimation of GVW.

The range in error for each truck appears to be less at low speeds.

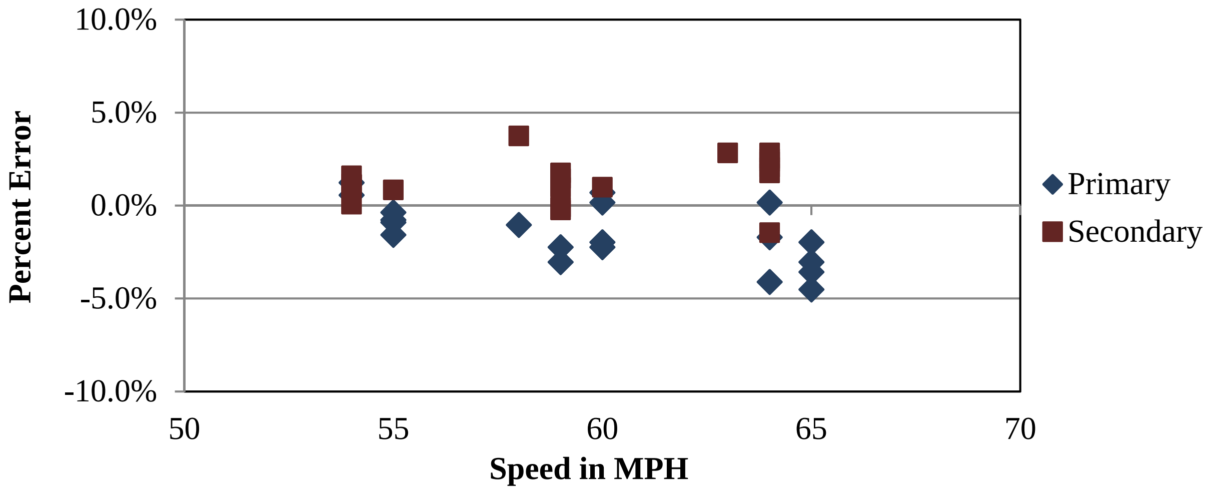


Figure 5-18 – Post-Validation GVW Error by Truck and Speed – 11-Jul-13

5.3.1.6 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from -0.3 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-19.

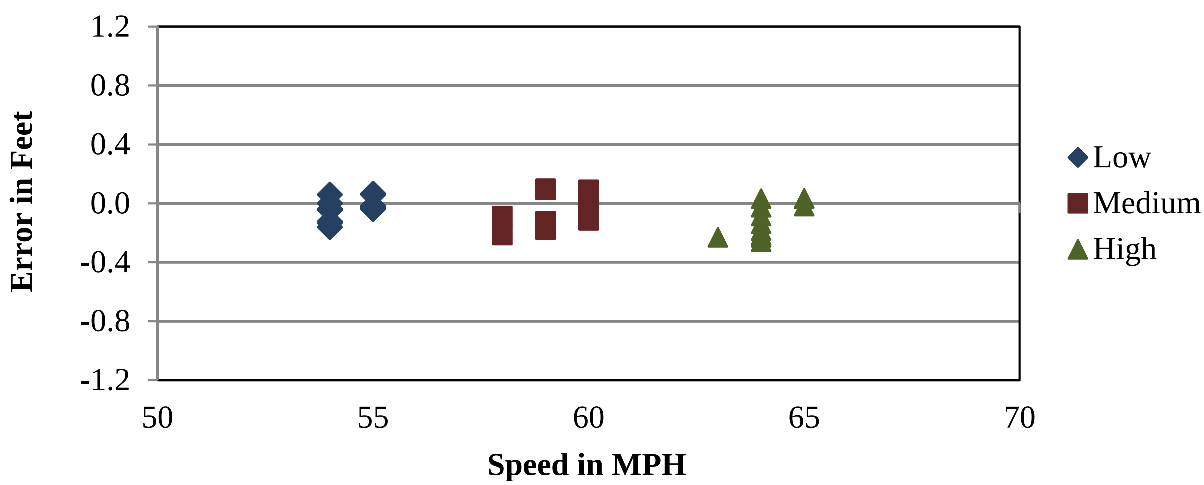


Figure 5-19 – Post-Validation Axle Length Error by Speed – 11-Jul-13

5.3.1.7 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 0.0 to 1.0 feet. Distribution of errors is shown graphically in Figure 5-20.

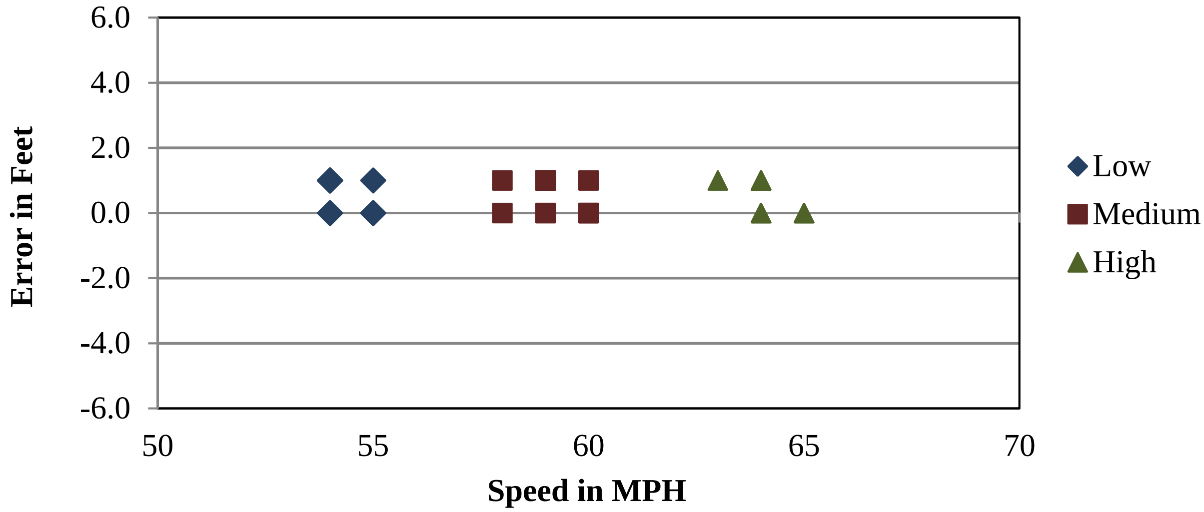


Figure 5-20 – Post-Validation Overall Length Error by Speed – 11-Jul-13

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 53.6 degrees, from 72.7 to 126.3 degrees Fahrenheit. However, due to two data collection periods (afternoon and next day morning), no temperatures in the middle of this range were observed, as demonstrated in figure 5-21. Therefore, the post-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-14 below.

Table 5-14 – Post-Validation Results by Temperature – 11-Jul-13

Parameter	95% Confidence Limit of Error	Low	High
		72.7 to 100 degF	100.1 to 126.3 degF
Steering Axles	+20 percent	-1.8 ± 7.4%	1.0 ± 8.3%
Single Axles*	+20 percent	1.6 ± 8.7%	1.1 ± 9.7%
Tandem Axles	+15 percent	-2.2 ± 5.8%	-0.7 ± 5.3%
GVW	+10 percent	-0.3 ± 4.6%	0.6 ± 2.9%
Vehicle Length	±3.0 percent (2.0 ft)	0.5 ± 1.0 ft	0.5 ± 1.1 ft
Vehicle Speed	± 1.0 mph	-0.2 ± 1.5 mph	0.3 ± 9.6 mph
Axle Length	+ 0.5 ft [150mm]	-0.1 ± 0.2 ft	-0.1 ± 0.2 ft

**Single Axles include steering axles and the spread tandem on the Secondary truck.*

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 5-21, no correlation between temperature and bias in GVW measurements can be seen at this site. However, the range in weight measurement errors appear to be higher at lower temperatures.

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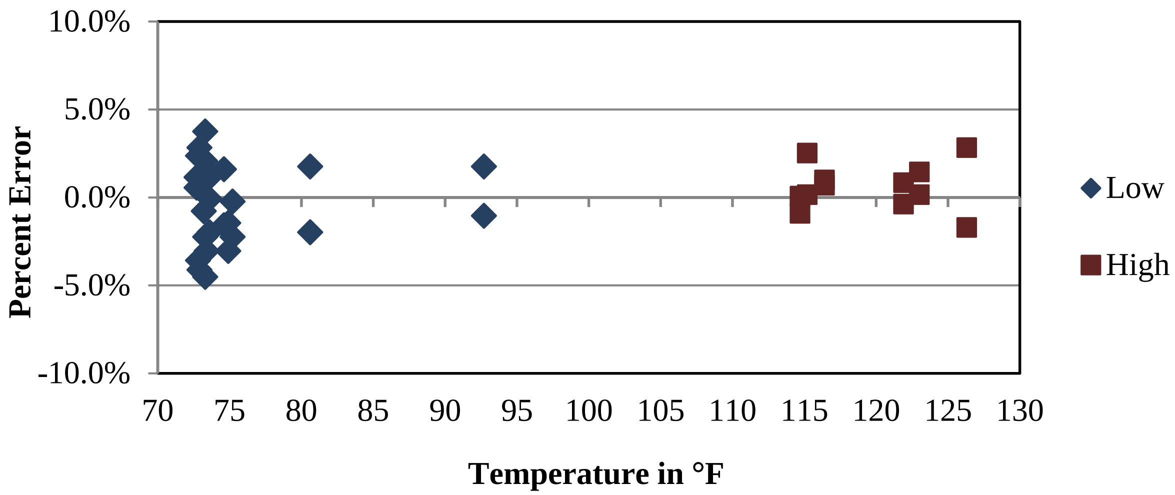

Figure 5-21 – Post-Validation GVW Errors by Temperature – 11-Jul-13

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-22 demonstrates that for steering axles, the WIM equipment appears to underestimate steering axle weights at the lower temperatures, and slightly overestimate steering axle weights at the higher temperatures. There does appear to be a positive correlation between temperature and steering axle weight estimates at this site. The range in error is similar for different temperature groups.

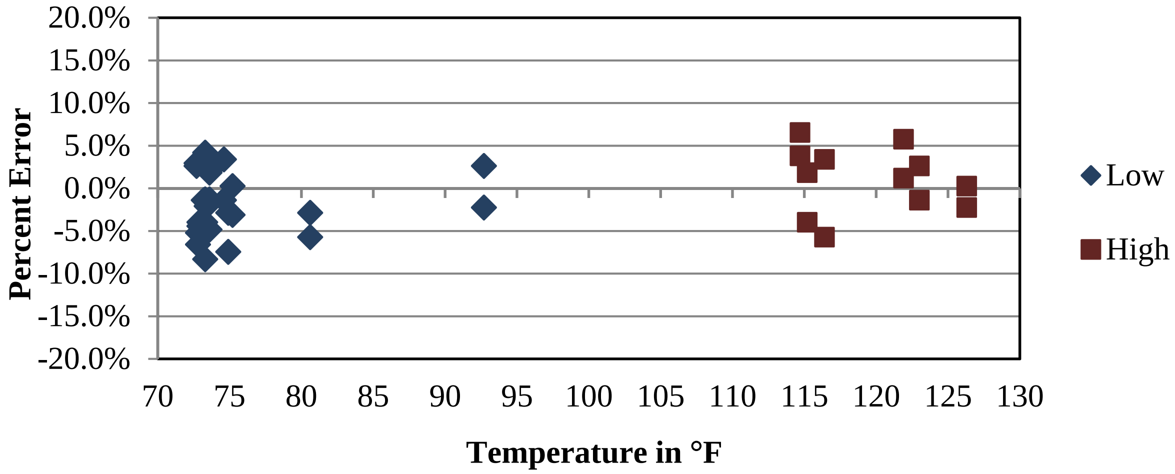

Figure 5-22 – Post-Validation Steering Axle Weight Errors by Temperature – 11-Jul-13

5.3.2.3 Single Axle Weight Errors by Temperature

From Figure 5-23, no correlation between temperature and bias in loaded single axle weight measurements can be seen at this site. However, the range in weight measurement errors appear to be higher at lower temperatures.

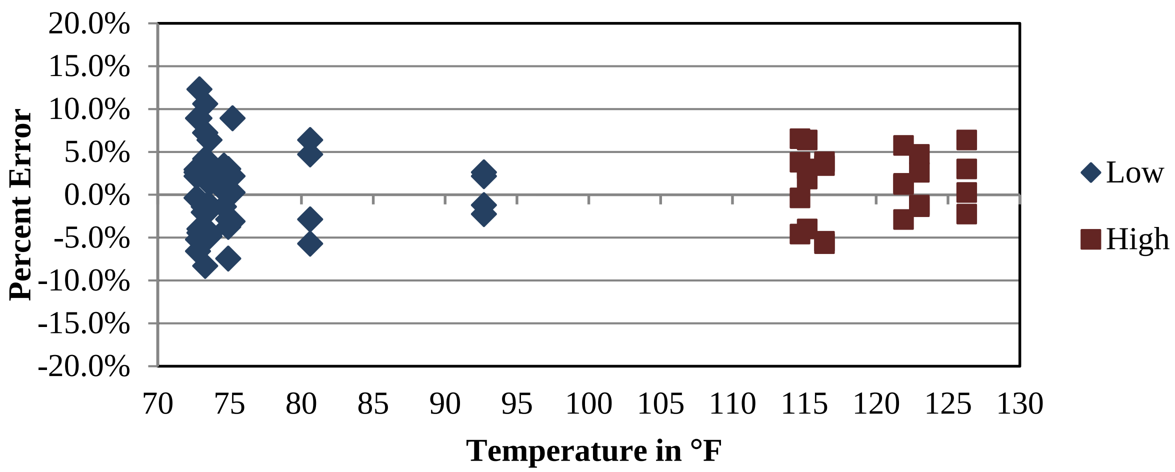

Figure 5-23 – Post-Validation Single Axle Weight Errors by Temperature – 11-Jul-13

5.3.2.4 Tandem Axle Weight Errors by Temperature

Figure 5-24 demonstrates that for tandem axles, the WIM equipment appears to underestimate tandem axle weights at the lower temperatures. The range in error is similar for different temperature groups.

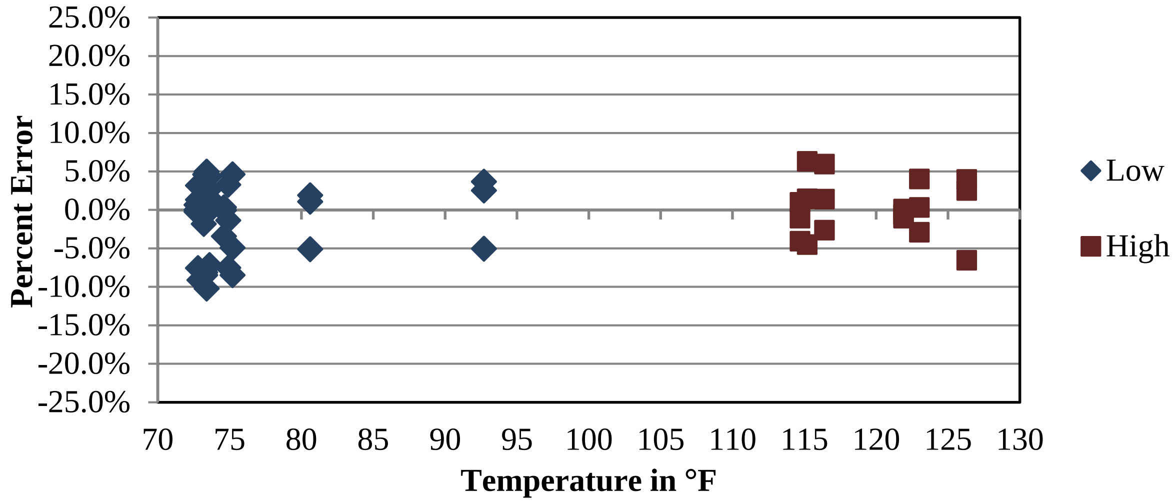

Figure 5-24 – Post-Validation Tandem Axle Weight Errors by Temperature – 11-Jul-13

5.3.2.5 GVW Errors by Temperature and Truck Type

As shown in Figure 5-25, when analyzed by truck type, the equipment appears to underestimate GVW for the Primary Truck and overestimate GVW for the Secondary Truck across the range of temperatures observed. For both trucks, the range of errors are similar.

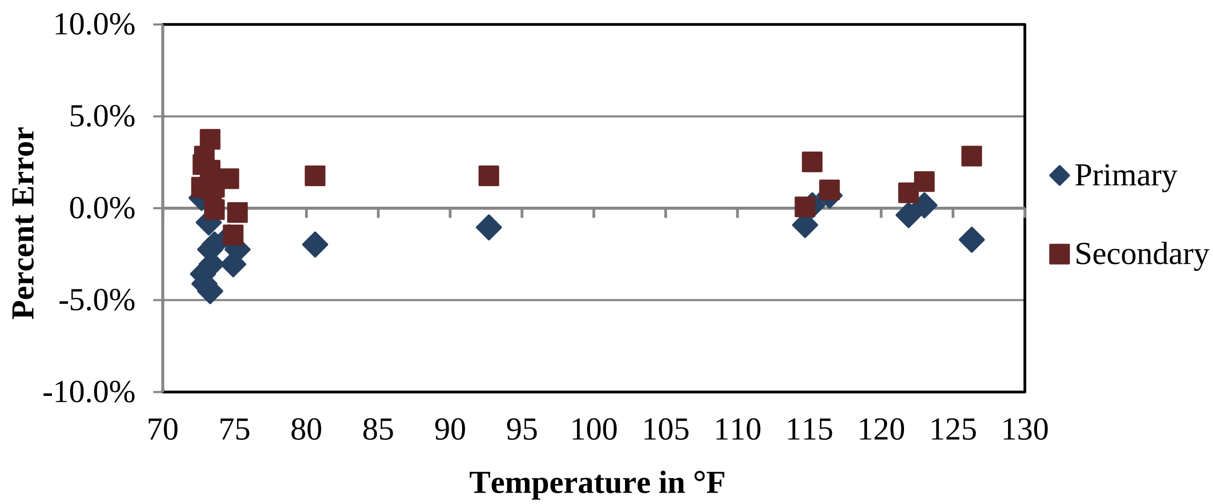

Figure 5-25 – Post-Validation GVW Error by Truck and Temperature – 11-Jul-13

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 116 vehicles including 116 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, one Class 5 vehicle was misclassified as a Class 4 vehicle, and one Class 4 vehicle was misclassified as a Class 5 vehicle by the equipment.

Table 5-15 – Post-Validation Misclassifications by Pair – 11-Jul-13

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

As shown in the table, a total of 2 vehicles, including no 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 2.0 percent, due to misclassification of lightweight vehicles in class 4 and class 5.

The misclassified percentage shown in Table 5-16 represents the percentage of the misclassified vehicles in the manual sample.

Table 5-16 – Post-Validation Classification Study Results – 11-Jul-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	0	1	7	1	0	1	85	1	4	0	0
WIM Count	0	1	7	1	0	1	85	1	4	0	0
Observed Percent	0.0	1.0	7.0	1.0	0.0	1.0	85.0	1.0	4.0	0.0	0.0
WIM Percent	0.0	1.0	7.0	1.0	0.0	1.0	85.0	1.0	4.0	0.0	0.0
Misclassified Count	0	1	1	0	0	0	0	0	0	0	0
Misclassified Percent	0.0	100.0	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 92 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 -0.4 mph; the range of errors was 1.9 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
		2	1
80	50	3015	3087
88	55	3102	3177
96	60	2938	3009
104	65	2890	2959
112	70	2884	2953
Axle Distance (cm)		373	
Dynamic Comp (%)		103	
Loop Width (cm)		165	

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 54 to 65 mph.
- Pavement temperature. Pavement temperature ranged from 72.7 to 126.3 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	2.0730	3.3561	0.6177	0.5407
Speed	-0.0911	0.0540	-1.6849	0.1007
Temp	0.0209	0.0103	2.0249	0.0503
Truck	2.8429	0.4309	6.5975	1.11E-07

The lowest probability value given in Table 6-1 was 0.0012 for truck type. This means that there is about a 0.12 percent chance that the value of regression coefficient for truck type (2.829) can occur by chance alone. This relationship is further investigated in Section 6.1.5. Changes in speed did not show statistically significant effect on changes in GVW measurement error, assuming that values equal or less than 0.05 indicate statistical significance in this case. The effect of temperature was statistically significant; however the value of regression coefficient is very low to have any practical effect on measurement error.

As an example, the relationship between temperature and measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Figure 6-1 provides a visual assessment of the relationship. The quantification of the relationship is provided by the value of the regression coefficient, in this case 0.0209 (in Table 6-1). This means, for example, that for a 10 degree change in temperature, the error is changed by about 0.2 percent (0.0209 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0503) and is statistically significant.

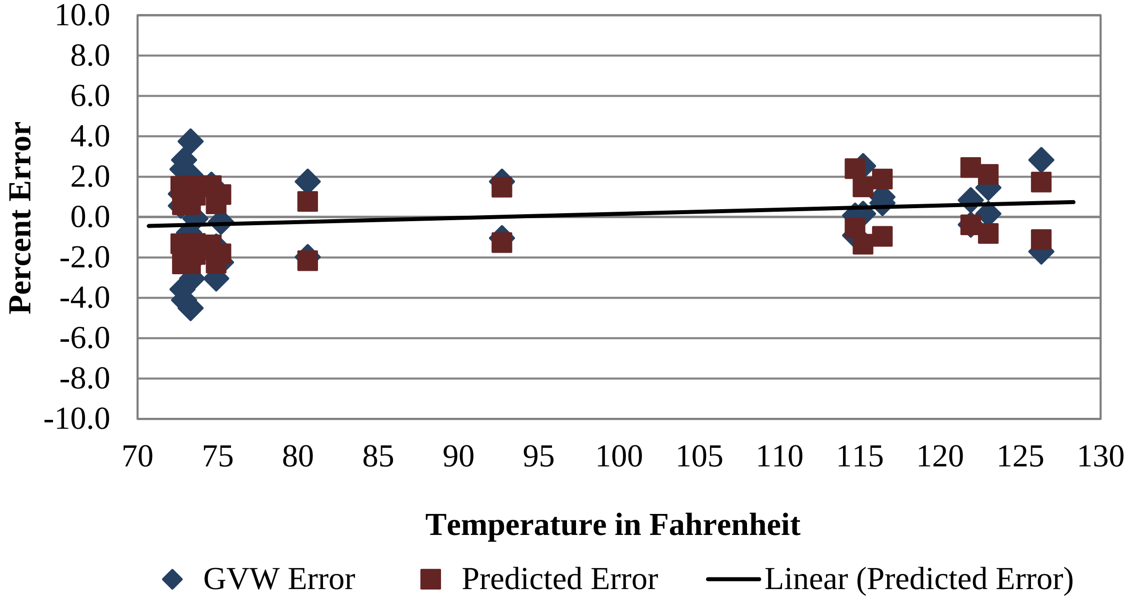

Figure 6-1 – Influence of Temperature on the Measurement Error of GVW

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 dashes in Table 6-2 indicate 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	-0.0911	0.1007	0.0209	0.0503	2.8429	0.0012
Steering axle	-0.6482	7.87E-12	0.0634	1.23E-05	3.4382	1.13E-07
Spread Tandem axles*	0.5866	4.58E-04	-0.0511	8.32E-0.2	N/A	N/A
Tandem axle tractor	-	-	-	-	-2.0588	0.0024
Tandem axle trailer**	-0.5070	0.0009	0.0503	0.0539	N/A	N/A

**Observed on Secondary Truck only. Analyzed as two single axles.*
***Observed on Primary Truck only*

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on the measurement of GVW, steering axles, single axles and tandem axles on trailers (based on probability that the relationship can occur by chance alone less than 20 percent). However, while the effect of speed was statistically significant, the overall size of the effect was small as indicated by the low values of regression coefficient for GVW. Figures 6-2 and 6-3 below illustrate the speed dependency for steering axles and spread tandem axles and demonstrate the opposing trends with regard to speed. For single axle analysis these effects cancel one another out.

2. Temperature had a statistically significant effect on the measurement error of GVW, steering axles, and tandem axles on trailers. Even though the effect on the measurement errors was statistically significant, the values of the regression coefficients were small indicating that this effect has no practical significance.

3. Truck type had statistically significant effect on GVW, steering axles, and tandem axles on tractors. The regression coefficients for truck type in Table 6-1 and 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). Thus, for example, the difference in the average measurement error for GVW between the Primary and Secondary trucks was about 3% (2.8429 in Table 6-1). The effect of truck type is further analyzed in Section 6.1.5.

4. Even though speed, temperature and truck type had statistically significant effect on measurement errors of some of the parameters, the practical significance of these effects on overall WIM system calibration tolerances was small and does not affect the validity of the validation.

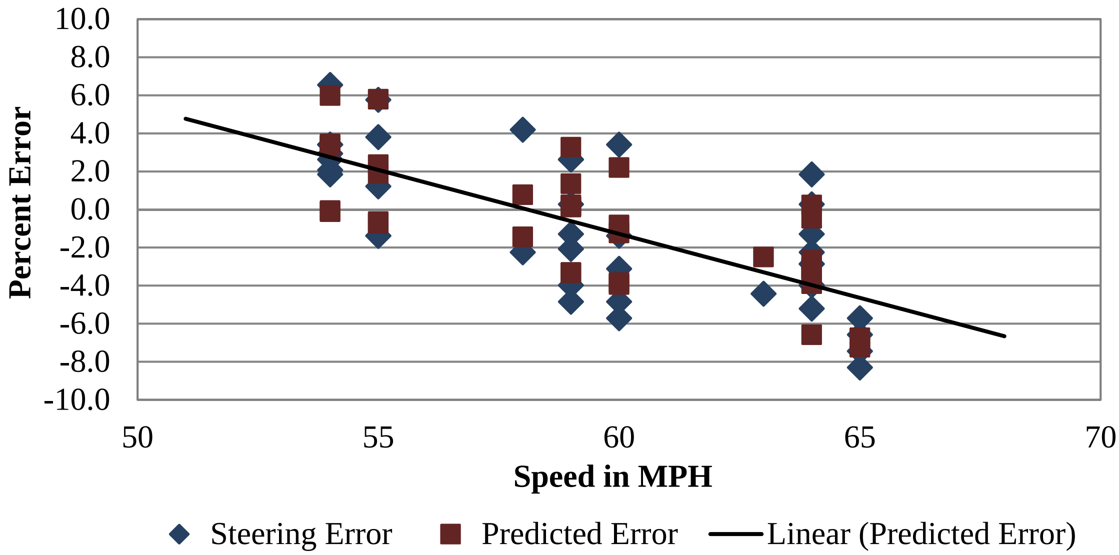

Figure 6-2 – Influence of Speed on the Measurement Error of Steering Axles

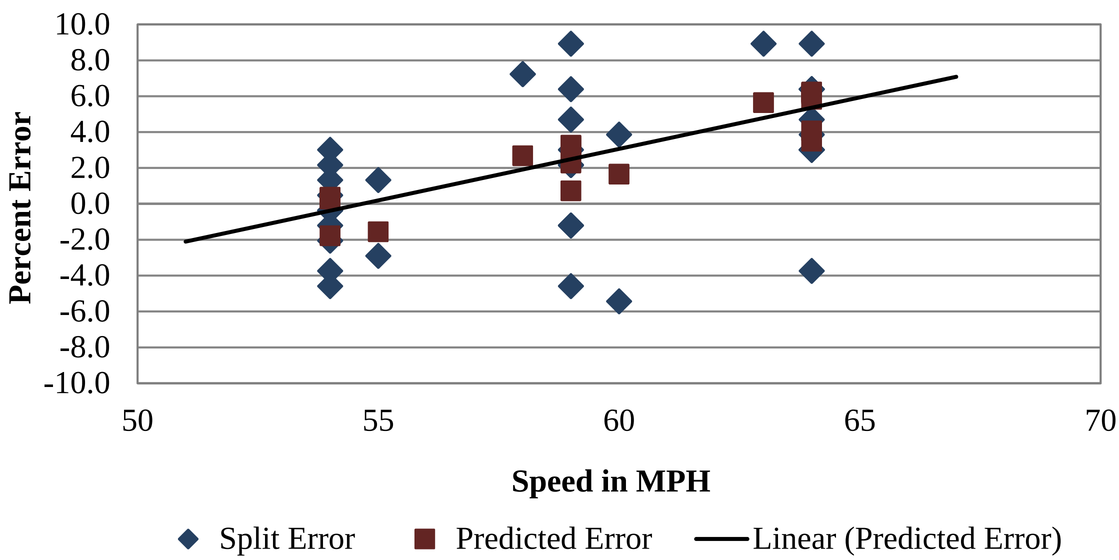

Figure 6-3 – Influence of Speed on the Measurement Error for Single Axles that form Spread Tandem Axle

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 6-4 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 6-4 shows that speed had opposing influences on the GVW measurement for each truck, with Primary truck showing increasingly negative bias as speed increases and the Secondary truck showing increasingly positive bias as speed increases. The trend lines for the two trucks are statistically significant. Combined, the overall GVW error dependency on speed was not statistically significant for 5 percent (by chance alone) level of significance (p-value was 0.1007) and its influence was very low as the two opposing trends canceled each other. The opposing trends demonstrate the advantage of using the two different trucks for the validation for this site.

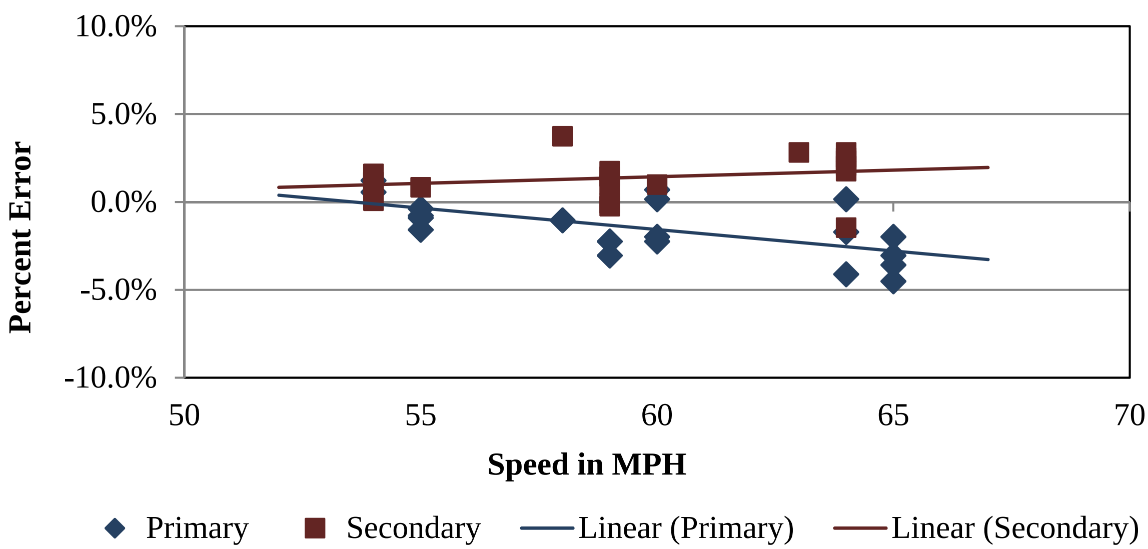

Figure 6-4– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

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 different verification and calibration results at higher speeds, based on opposing correlations between speed and GVW errors for the two trucks.

6.2 Misclassification Analysis

For this site, a total of 2 vehicles, including no heavy trucks (6 – 13) were misclassified by the equipment. Since no heavy trucks were misclassified during the post-validation classification study, a post-visit analysis was not conducted.

6.3 Traffic Data Analysis

An analysis of a 14-day sample of data is performed to determine the effectiveness of the calibration. The effects on GVW, steering axle weights and imbalance is included in the analysis.

6.3.1 Gross Vehicle Weight and Steering Axle Weight

For gross vehicle weight (GVW), the calibration of the system was effective in realigning the average GVW with the Comparison Data Set value. The steering axle weight was reduced to below the Comparison Data Set value by the calibration, where the Dynamic Compensation value was reduced by 6.0%.

The underestimation of steering axle weights may be due to the effect of speed on front axle weights illustrated in Figure 5-15 where front axle weights decrease as speed increases. Since the 85th percentile for speed for this site is 73 mph, a large number of trucks are expected to present low front axle weights.

Table 6-3 – GVW and Front Axle Weights

Data Set	Date	Average GVW (kips)	Average Steering Axle (kips)
Comparison Data Set	October 18, 2011	61.0 kips	11.4 kips
Pre-Visit Sample	June 24, 2013	62.3 kips	11.7 kips
Post-Visit Sample	July 19, 2013	61.0 kips	10.9 kips

6.3.2 Imbalance

The results of the pre-visit data analysis for determining the presence of imbalanced weights demonstrated a 2.0% left/right imbalance for Class 9 trucks. The imbalance was not addressed during the validation. Consequently, the post-visit analysis demonstrated a similar imbalance as shown in **Error! Reference source not found.**.

Table 6-4 – Front Axle Weight Imbalance

Data Set	Date	Left	Right	Imbalance	PCT
Pre-Visit Sample	June 24, 2013	5.83	5.72	Left	2.0%
Post-Visit Sample	July 19, 2013	5.45	5.29	Left	2.9%

6.3.3 WIM System Factor Adjustments

Since the average GVW weights provided during the Post-Visit data analysis are similar to those provided by the Comparison Data Set, no adjustments to the WIM system speed-based compensation factors are recommended.

For steering axle weights, the underestimation at the higher speeds may be reduced by increasing the Dynamic Compensation Factor by 4.0%, from 103 to 107. However, this would result in an overestimation of steering axle weights for all trucks traveling at speeds below 60 mph and is not recommended. Equipment factor adjustment to compensate for the 2.9% imbalance are not 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	
15-May-07	-	100	50	0	-	63	0	-	0	0	-	0.0
16-May-07	-	100	50	-	-	50	0	0	0	0	-	0.0
28-Oct-08	-	0	0	0	-	0	0	0	0	0	-	0.0
29-Oct-08	-	-	-	0	0	0	0	-	0	0	-	0.0
8-Mar-11	-	0	0	0	0	0	0	100	0	0	0	0.0
9-Mar-11	-	0	20	0	0	0	0	0	0	0	0	0.0
20-Mar-12	50	0	40	0	0	0	0	67	0	0	0	0.0
21-Mar-12	33	0	30	0	0	0	0	0	0	0	0	0.0
9-Jul-13	0	67	13	0	50	0	0	33	0	0	0	1.7
11-Jul-13	0	100	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**
15-May-07	2.0 ± 6.4	-0.6 ± 6.7	2.5 ± 8.3
16-May-07	1.1 ± 3.6	-2.0 ± 7.0	1.6 ± 5.7
28-Oct-08	0.9 ± 4.9	-1.0 ± 5.6	1.2 ± 7.7
29-Oct-08	1.3 ± 3.7	-0.7 ± 5.1	1.6 ± 6.7
8-Mar-11	3.6 ± 4.7	1.3 ± 9.0	4.6 ± 6.4
9-Mar-11	1.6 ± 3.9	0.8 ± 10.3	0.9 ± 6.9
20-Mar-12	2.2 ± 4.8	4.9 ± 7.4	1.6 ± 7.0
21-Mar-12	-1.7 ± 4.7	-0.1 ± 6.9	-0.4 ± 6.7
10-Jul-13	2.4 ± 4.8	2.4 ± 10.0	1.6 ± 5.7
11-Jul_13	-0.1 ± 4.1	-1.1 ± 10.1	0.8 ± 5.6

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an overestimation of GVW over time. 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

Arkansas, SPS-2
SHRP ID: 050200

Validation Date: July 9, 2013

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 – Power Service Box

Photo 9 – Telephone Service Box

Photo 10 – Downstream

Photo 11 – Upstream

Photo 12 – Truck 1

Photo 13 – Truck 1 Tractor

Photo 14 – Truck 1 Trailer and Load

Photo 15 – Truck 1 Suspension 1

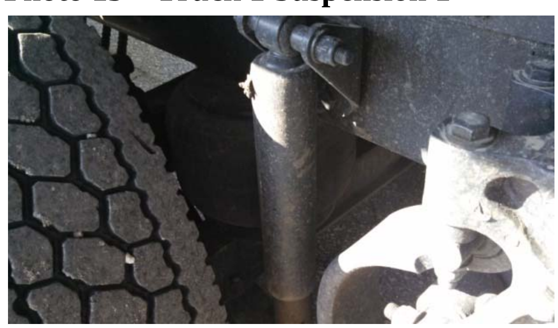

Photo 16 – Truck 1 Suspension 2

Photo 17 – Truck 1 Suspension 3

Photo 18 – Truck 1 Suspension 4

Photo 19 – Truck 1 Suspension 5

Photo 20 – Truck 2

Photo 21 – Truck 2 Tractor

Photo 22 – Truck 2 Trailer and Load

Photo 23 – Truck 2 Suspension 1

Photo 24 – Truck 2 Suspension 2

Photo 25 – Truck 2 Suspension 3

Photo 26 – Truck 2 Suspension 5

Photo 27 – Truck 2 Suspension 4

Traffic Sheet 16	STATE CODE:	05
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	050200
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	7/10/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 7/10/13

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	steel spring	air
Truck 2:	9	steel spring	air
Truck 3:			

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

Mean Difference Between -

Dynamic and Static GVW:	2.4%	Standard Deviation:	2.4%
Dynamic and Static Single Axle:	4.7%	Standard Deviation:	3.6%
Dynamic and Static Double Axles:	1.6%	Standard Deviation:	2.8%

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

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

			Low		High	Runs
a.	Low	-	54.0	to	57.3	16
b.	Medium	-	57.4	to	60.8	13
c.	High	-	60.9	to	64.0	11
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	05 050200 7/10/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 2912 | 2981

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

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

CLASSIFIER TEST SPECIFICS

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

Manual

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

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

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

Percent of "Unclassified" Vehicles: 1.8%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 16	STATE CODE:	05
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	050200
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	7/11/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 7/11/13

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	steel spring	air
Truck 2:	9	steel spring	air
Truck 3:			

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

Mean Difference Between -

Dynamic and Static GVW:	-0.1%	Standard Deviation:	2.0%
Dynamic and Static Single Axle:	1.3%	Standard Deviation:	3.5%
Dynamic and Static Double Axles:	0.8%	Standard Deviation:	2.7%

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

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

			Low		High	Runs
a.	Low	-	54.0	to	57.7	12
b.	Medium	-	57.8	to	61.4	14
c.	High	-	61.5	to	65.0	14
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 05 SPS WIM ID: 050200 DATE (mm/dd/yyyy) 7/11/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 2884 | 2953

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

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

CLASSIFIER TEST SPECIFICS

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

Manual

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

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

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

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 05 SPS WIM ID: 050200 DATE (mm/dd/yyyy) 7/10/2013

Count - 112 Time = 1:01:53 Trucks (4-15) - 112 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
59	5	18714	57	5	55	5	18819	55	5
64	9	18721	65	9	64	9	18842	64	9
59	10	18723	60	10	60	9	18846	67	9
63	9	18724	64	9	63	9	18849	65	9
70	12	18732	70	12	60	9	18850	62	9
62	9	18741	63	9	69	9	18858	68	9
66	9	18742	65	9	63	9	18862	63	9
59	9	18743	62	9	66	5	18866	66	5
68	9	18757	65	9	64	9	18870	65	9
74	5	18758	74	5	75	5	18872	75	5
68	9	18765	67	9	62	9	18877	66	9
61	9	18774	61	9	65	9	18879	64	9
70	12	18775	69	12	62	9	18882	64	9
66	9	18783	65	9	69	11	18884	72	11
65	9	18786	64	9	62	9	18891	62	9
69	9	18790	68	9	68	9	18893	69	9
61	9	18798	61	9	67	9	18898	68	9
63	11	18800	63	11	68	9	18905	68	9
62	9	18804	62	9	66	9	18909	66	9
66	9	18806	66	9	67	9	18910	68	9
68	4	18807	68	4	63	9	18932	64	9
61	9	18811	62	9	63	9	18935	66	9
65	9	18813	66	9	63	9	18952	65	9
62	9	18814	62	9	67	7	18954	67	7
64	9	18818	64	9	67	9	18957	67	9

Sheet 1 - 0 to 50 Start: 12:57:24 Stop: 13:23:25

Recorded By: gh Verified By: kt

Validation Test Truck Run Set - Pre

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 05 SPS WIM ID: 050200 DATE (mm/dd/yyyy) 7/10/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
61	9	18977	61	9	65	10	19123	64	10
66	9	18980	68	9	61	9	19127	67	9
65	9	18985	66	9	64	9	19130	64	9
62	9	18997	62	9	64	9	19134	64	9
64	9	19005	64	9	66	9	19140	74	9
64	9	19015	62	9	62	9	19142	62	9
57	**5**	**19030**	**62**	**4**	68	9	19145	68	9
59	**5**	**19031**	**67**	**4**	59	9	19147	58	9
65	9	19043	66	9	66	9	19149	67	9
62	9	19048	62	9	65	9	19152	65	9
62	9	19049	61	9	62	9	19154	62	9
65	9	19053	65	9	57	9	19163	57	9
67	9	19057	67	9	64	9	19165	63	9
59	9	19061	58	9	57	9	19166	54	9
67	9	19063	68	9	63	12	19202	62	12
65	9	19066	64	9	67	9	19211	64	9
65	9	19071	63	9	70	9	19217	68	9
63	9	19093	63	9	65	9	19219	64	9
62	9	19099	63	9	67	9	19222	66	9
61	11	19100	62	11	64	9	19223	65	9
67	9	19104	67	9	64	9	19225	64	9
62	9	19107	62	9	63	11	19227	63	11
66	9	19110	66	9	62	9	19237	63	9
63	12	19111	63	12	65	9	19253	67	9
59	**8**	**19112**	**58**	**5**	**62**	**15**	**19259**	**66**	**7**

Sheet 2 - 51 to 100 Start: 13:24:43 Stop: 13:53:40

Recorded By: ______________________ ______________________

Validation Test Truck Run Set - Pre

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 05 SPS WIM ID: 050200 DATE (mm/dd/yyyy) 7/10/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	9	19266	65	9					
65	9	19268	65	9					
64	9	19271	65	9					
67	9	19274	67	9					
59	9	19277	58	9					
64	9	19283	65	9					
62	5	19284	65	5					
65	9	19287	64	9					
67	9	19296	67	9					
61	5	19298	61	5					
64	**15**	**19302**	**64**	**10**					
64	9	19314	64	9					

13:54:23 13:59:17

Recorded By: gh Verified By: kt

Traffic Sheet 20					STATE CODE:			05	
LTPP MONITORED TRAFFIC DATA					SPS WIM ID:			050200	
SPEED AND CLASSIFICATION STUDIES					DATE (mm/dd/yyyy)			7/11/2013	

Count - 100 Time = 0:52:06 Trucks (4-15) - 100 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	36312	63	9	64	9	36444	64	9
65	9	36313	65	9	65	9	36452	66	9
68	9	36323	67	9	61	9	36457	61	9
65	9	36328	65	9	64	9	36460	64	9
62	9	36332	63	9	67	9	36463	64	9
66	9	36335	63	9	62	9	36473	62	9
66	9	36338	65	9	64	9	36481	63	9
57	9	36341	57	9	67	9	36482	68	9
66	9	36347	64	9	66	5	36487	65	5
64	9	36355	65	9	63	9	36488	63	9
64	11	36359	64	11	65	9	36491	66	9
62	9	36362	63	9	59	9	36495	57	9
57	5	36399	56	5	**59**	**5**	**36496**	**54**	**4**
59	9	36400	57	9	66	9	36503	65	9
64	9	36404	63	9	62	9	36505	61	9
64	9	36406	64	9	62	11	36533	63	11
63	9	36408	65	9	65	9	36548	65	9
64	9	36411	63	9	60	9	365499	60	9
69	6	36412	68	6	62	9	36556	62	9
68	9	36423	69	9	64	9	36561	65	9
61	9	36427	61	9	60	10	36566	61	10
70	9	36431	69	9	63	9	36572	63	9
66	9	36434	64	9	64	9	36573	62	9
62	9	36441	62	9	64	5	36581	65	5
68	5	36442	68	5	61	11	36583	61	11

Sheet 1 - 0 to 50 Start: 7:01:40 Stop: 7:35:53

Recorded By: gh Verified By: kt

Validation Test Truck Run Set - Post

Traffic Sheet 20	STATE CODE:	05
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	050200
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy)	7/11/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
68	9	36597	68	9	64	9	36905	64	9
63	9	36604	62	9	65	9	36910	66	9
54	9	36611	54	9	70	9	36915	67	9
62	9	36619	63	9	64	9	36918	64	9
65	9	36622	65	9	62	9	36919	63	9
67	9	36626	67	9	64	9	36963	62	9
68	9	36627	68	9	64	9	36965	65	9
65	9	36635	65	9	64	9	36969	65	9
64	9	36640	63	9	67	8	36974	67	8
59	9	36850	60	9	67	9	36982	66	9
62	9	36851	61	9	64	9	36984	65	9
65	9	36852	66	9	72	9	36990	71	9
66	9	36853	66	9	65	9	36993	64	9
65	9	36863	66	9	66	9	36998	66	9
70	9	36868	68	9	63	9	37000	63	9
65	9	36877	64	9	72	5	37008	73	5
64	9	36878	64	9	65	9	37012	65	9
68	9	36879	67	9	64	9	37017	64	9
60	9	36881	60	9	65	9	37024	65	9
67	**4**	**36885**	**68**	**5**	60	5	37024	61	5
64	9	36898	63	9	62	9	37026	62	9
65	9	36893	64	9	64	9	37034	63	9
64	11	36895	64	11	64	9	37036	64	9
64	9	36896	63	9	64	9	37037	64	9
64	9	36904	63	9	62	9	37041	62	9

Sheet 2 - 51 to 100 Start: 7:37:08 Stop: 8:29:14

Recorded By: ____________________