WIM System Field Calibration and Validation Summary Report

Pennsylvania SPS-6
SHRP ID – 420600

Validation Date: February 08, 2012
Submitted: March 1, 2012

Table of Contents

List of Figures

List of Tables

1 Executive Summary

A WIM validation was performed on February 7 and 8, 2012 at the Pennsylvania SPS-6 site located on route I-80, milepost 158.2, 0.54 miles east of exit 158.

This site was installed on May 2, 2007. The in-road sensors are installed in the westbound, righthand driving lane. The site is equipped with quartz WIM sensors and an IRD iSINC WIM controller. The LTPP lane is identified as lane 4 in the WIM controller.

From a comparison between the report of the most recent validation of this equipment on November 23, 2010 and this validation visit, a 4” section of the epoxy covering the leading WIM sensor in the left wheel path has broken free. Further examination of the WIM system showed that the sensor was disabled and is not being used to collect vehicle data. No other changes have occurred during this time to the basic operating condition of the equipment.

With the exception of the disabled sensor, the equipment is in working order. Electronic and electrical checks of the WIM components determined that the equipment is operating within manufacturer’s tolerances. 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. Even though the site passed accuracy requirements during field calibration, there is no guarantee that the site will continue to produce research quality data over time due to disabled sensor and altered data collection process.

Table 1-1 – Post-Validation Results – 08-Feb-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	2.2 ± 9.1%	Pass
Single Axles	±20 percent	1.4 ± 10.1%	Pass
Tandem Axles	±15 percent	1.1 ± 7.2%	Pass
GVW	±10 percent	1.0 ± 5.6%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	-0.6 ± 1.0 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.2 ± 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 0.3 ± 4.7 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 0.2 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 1.1% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 3.0% from the 100 truck sample (Class 4 – 13) was due to the misclassification of one Class 3, one Class 5, and one Class 10 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 concrete blocks.

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

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 7). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Axle spacing lengths 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	76.6	11.3	16.0	16.0	16.6	16.6	20.0	4.3	37.9	4.2	66.3	71.4
2	64.2	10.3	11.6	11.6	15.3	15.3	17.3	4.3	30.0	10.0	61.6	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 28.5 to 35.6 degrees Fahrenheit, a range of 7.1 degrees Fahrenheit. The cloud cover and the snow prevented the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 25 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 January 16, 2012 (Data) to the most recent Comparison Data Set (CDS) from December 20, 2010. The assessments performed prior to the site visits are used to develop reasonable expectations for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 25 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 2011.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2007	211	8
2008	362	12
2009	362	12
2010	333	12
2011	262	9

As shown in the table, this site requires no additional years of data to meet the minimum of five years of research quality data.

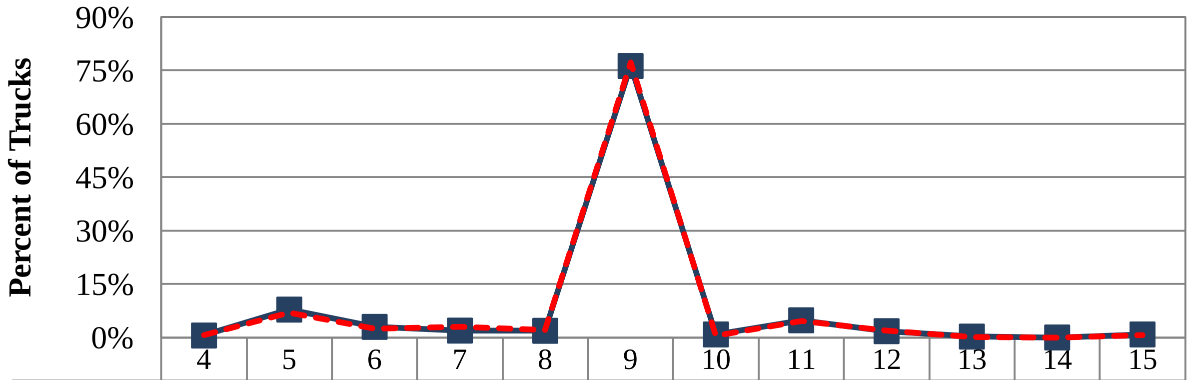
Table 2-2 provides a monthly breakdown of the available data for years 2007 through 2011.

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					2	30	30	30	30	31	30	28	8
2008	31	27	31	29	31	30	31	31	30	31	30	30	12
2009	28	28	31	30	31	30	31	31	30	31	30	31	12
2010	31	17	20	29	31	30	31	28	30	31	24	31	12
2011	31	28	31	30	31	30	31	31	19				9

2.2 Classification Data Analysis

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



	4	5	6	7	8	9	10	11	12	13	14	15
Data	0.5%	7.8%	3.0%	1.9%	1.9%	76.3%	0.9%	4.8%	1.8%	0.3%	0.0%	0.8%
CDS	0.6%	7.0%	2.5%	2.9%	2.0%	77.3%	0.5%	4.6%	1.9%	0.1%	0.0%	0.7%

Figure 2-1 – Comparison of Truck Distribution

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the most frequent truck types crossing the WIM scale are Class 9 (76.3%) and Class 5 (7.8%). 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 0.8 percent of the vehicles at this site are unclassified.

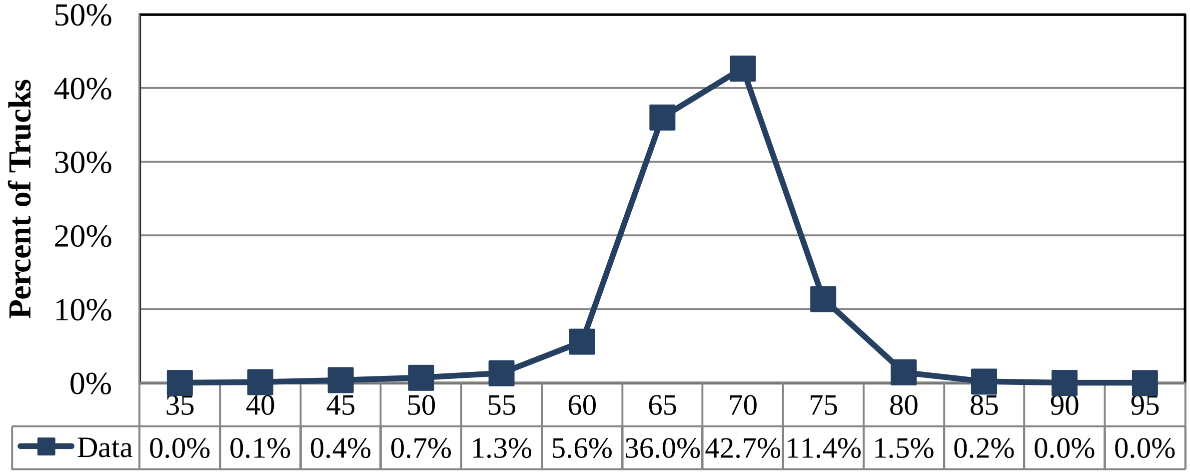
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	12/20/2010		1/16/2012		
4	280	0.6%	324	0.5%	-0.1%
5	3202	7.0%	4632	7.8%	0.9%
6	1128	2.5%	1759	3.0%	0.5%
7	1352	2.9%	1142	1.9%	-1.0%
8	913	2.0%	1108	1.9%	-0.1%
9	35489	77.3%	45101	76.3%	-1.0%
10	224	0.5%	504	0.9%	0.4%
11	2091	4.6%	2856	4.8%	0.3%
12	884	1.9%	1046	1.8%	-0.2%
13	37	0.1%	148	0.3%	0.2%
14	0	0.0%	0	0.0%	0.0%
15	301	0.7%	502	0.8%	0.2%

From the table it can be seen that the percentage of Class 9 vehicles has decreased by 1.0 percent from December 2010 and January 2012. Changes in the number of heavier trucks may be attributed to natural and seasonal variations in truck distributions. During the same time period, the number of Class 5 trucks increased by 0.9 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 distribution of speeds from the recent data sample (Data) is shown in Figure 2-2.



	35	40	45	50	55	60	65	70	75	80	85	90	95
Data	0.0%	0.1%	0.4%	0.7%	1.3%	5.6%	36.0%	42.7%	11.4%	1.5%	0.2%	0.0%	0.0%

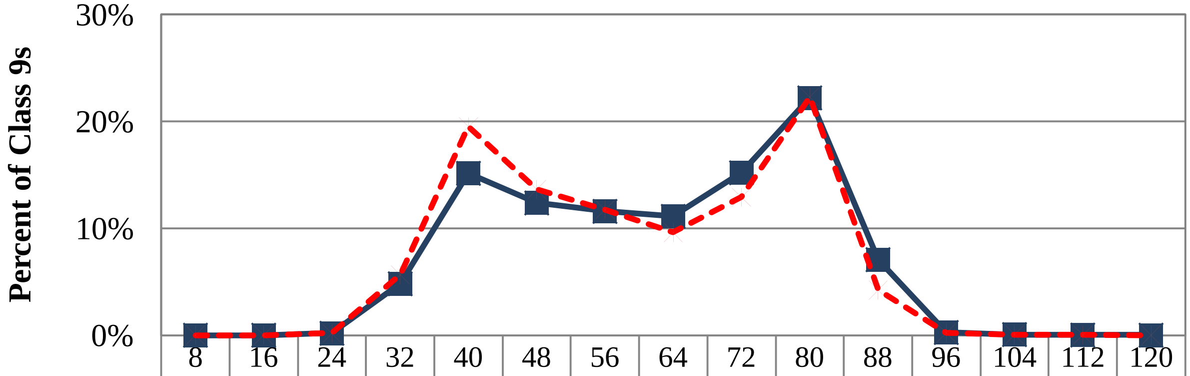
Figure 2-2 – Truck Speed Distribution – 17-Jan-12

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 70 mph. The range of truck speeds for the validation will be 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 January 2012 and the Comparison Data Set from December 2010.

As shown in Figure 2-3, there is a downward shift for the unloaded peaks between the December 2010 Comparison Data Set (CDS) and the January 2012 two-week sample W-card dataset (Data). The loaded peak for the W-card dataset (Data) is similar to the Comparison Data Set (CDS).



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.2%	4.8%	15.1	12.4	11.6	11.1	15.2	22.2	7.1%	0.3%	0.1%	0.0%	0.0%
CDS	0.0%	0.0%	0.2%	5.7%	19.5	13.6	11.7	9.6%	12.9	22.3	4.2%	0.2%	0.0%	0.0%	0.0%

Figure 2-3 – Comparison of Class 9 GVW Distribution

Table 2-4 is provided to show the statistical comparison for Class 9 GVW between the Comparison Data Set (CDS) and the Sample Data Set (Data).

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

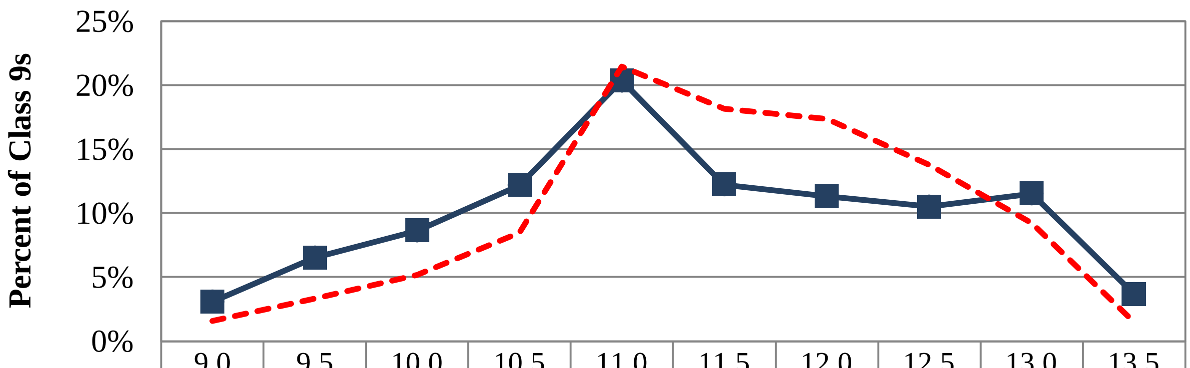
GVW weight bins (kips)	CDS		Data		Change
	Date				
	12/20/2010		1/16/2012		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	64	0.2%	82	0.2%	0.0%
32	2004	5.7%	2167	4.8%	-0.8%
40	6919	19.5%	6819	15.1%	-4.4%
48	4829	13.6%	5571	12.4%	-1.3%
56	4157	11.7%	5215	11.6%	-0.1%
64	3404	9.6%	5005	11.1%	1.5%
72	4572	12.9%	6841	15.2%	2.3%
80	7898	22.3%	9997	22.2%	-0.1%
88	1494	4.2%	3183	7.1%	2.9%
96	71	0.2%	115	0.3%	0.1%
104	17	0.0%	27	0.1%	0.0%
112	11	0.0%	5	0.0%	0.0%
120	0	0.0%	1	0.0%	0.0%
Average =	56.0 kips		58.4 kips		2.4 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 4.4 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 0.1 percent. During this time period the number of overweight trucks increased by 3.0 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 4.3 percent, from 56.0 kips to 58.4 kips kips.

2.5 Class 9 Steering Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 steering axle weight plots generated by using the two week W-card sample from January 2012 and the Comparison Data Set from December 2010. The percentage of light axles (9.5 to 10.5 kips) increased by approximately 7.1% and the percentage of heavy axles (12.0 to 13.0 kips) decreased by approximately 1.0%, indicating a possible negative bias (underestimation of loads) in steering axle measurement.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	3.1%	6.5%	8.6%	12.2%	20.3%	12.2%	11.3%	10.5%	11.5%	3.7%
CDS	1.6%	3.3%	5.2%	8.5%	21.5%	18.2%	17.4%	13.8%	9.2%	1.5%

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

It can be seen in the figure that the greatest percentage of trucks have steering axle weights measuring between 10.5 and 11.5 kips. The percentage of trucks in this range has decreased by 7.2 percent between the December 2010 Comparison Data Set (CDS) and the January 2012 dataset (Data).

Table 2-5 provides the Class 9 steering axle weight distribution data for the December 2010 Comparison Data Set (CDS) and the January 2012 dataset (Data).

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

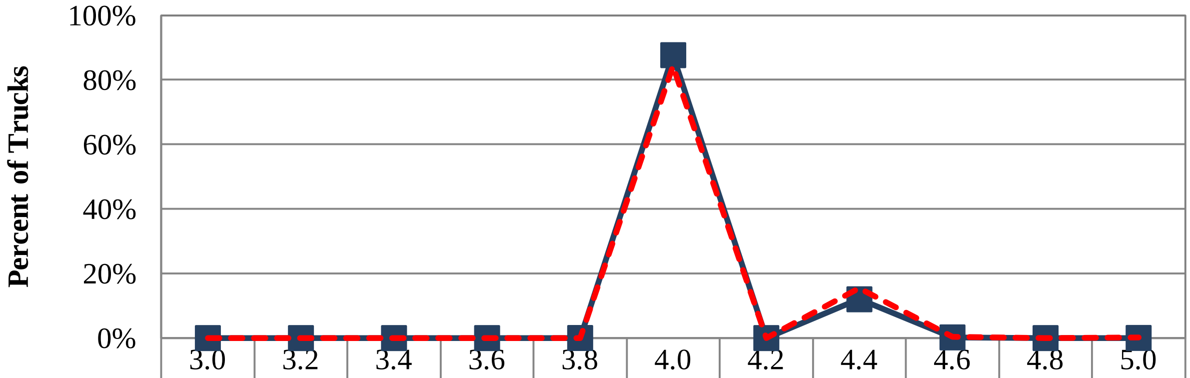
F/A weight bins (kips)	CDS		Data		Change
	Date				
	12/20/2010		1/16/2012		
9.0	547	1.6%	1359	3.1%	1.5%
9.5	1169	3.3%	2876	6.5%	3.2%
10.0	1827	5.2%	3812	8.6%	3.4%
10.5	2981	8.5%	5380	12.2%	3.7%
11.0	7557	21.5%	8982	20.3%	-1.1%
11.5	6395	18.2%	5403	12.2%	-5.9%
12.0	6111	17.4%	4996	11.3%	-6.1%
12.5	4838	13.8%	4635	10.5%	-3.3%
13.0	3244	9.2%	5091	11.5%	2.3%
13.5	512	1.5%	1617	3.7%	2.2%
Average =	11.3 kips		11.2 kips		-0.1 kips

The table shows that the average steering axle weight for Class 9 trucks has decreased by 0.1 kips, or 0.9 percent. According to the values from the per vehicle records, the average steering axle weight for Class 9 trucks is 11.2 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

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

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



	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Data	0.0%	0.0%	0.0%	0.0%	0.0%	87.7%	0.0%	12.0%	0.2%	0.0%	0.0%
CDS	0.0%	0.0%	0.0%	0.0%	0.0%	84.2%	0.0%	15.4%	0.3%	0.0%	0.1%

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

As seen in the figure, the Class 9 tractor tandem spacings for the December 2010 Comparison Data Set and the January 2012 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				
	12/20/2010		1/16/2012		
3.0	0	0.0%	0	0.0%	0.0%
3.2	0	0.0%	0	0.0%	0.0%
3.4	0	0.0%	0	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	5	0.0%	12	0.0%	0.0%
4.0	29853	84.2%	39489	87.7%	3.5%
4.2	0	0.0%	0	0.0%	0.0%
4.4	5447	15.4%	5415	12.0%	-3.3%
4.6	92	0.3%	95	0.2%	0.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	44	0.1%	19	0.0%	-0.1%
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 feet, which is identical to the expected average of 4.0 feet 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 (December 2010) based on the last calibration with the most recent two-week WIM data sample from the site (January 2012). Comparison of vehicle class distribution data indicates a 1.0 percent decrease in the number of Class 9 vehicles. Analysis of Class 9 weight data indicates that steering axle weights have decreased by 0.1 kips and average Class 9 GVW has increased by 4.3 percent for the January 2012 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical the expected average of 4.0 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on November 23, 2010 and this validation visit, a 4” section of the epoxy covering the leading WIM sensor in the left wheel path has broken free. Further examination of the WIM system showed that the sensor was disabled and is not being used to collect vehicle data. No other changes have occurred during this time to the basic operating condition of the equipment.

3.1 Description

This site was installed on May 02, 2007 by International Road Dynamics. It is instrumented with quartz 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. It was found that a 4” section of the epoxy covering the leading WIM sensor in the left wheel path has broken free, as shown in Photo 3-1.

Photo 3-1 – Damaged Kistler Sensor

Additional photographs of the damaged sensor and all other system components were taken and are presented after Section 7.

3.3 Electronic and Electrical Testing

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

3.4 Equipment Troubleshooting and Diagnostics

During further analysis of the WIM system parameters associated with the damaged sensor, it was determined that the sensor was disabled in the WIM Controller operating system prior to the date of the validation. No further troubleshooting was performed.

3.5 Recommended Equipment Maintenance

It is recommended that the damaged sensor be repaired and enabled in the WIM system to improve the accuracy of the WIM system.

4 Pavement Discussion

4.1 Pavement Condition Survey

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

4.2 Profile and Vehicle Interaction

Profile data was collected on March 15, 2011 by the North Atlantic 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 153 in/mi and is located approximately 867 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 61 in/mi and is located approximately 329 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 a bridge deck is located approximately 870 feet prior to the WIM scales, the truck dynamics observed at this location appeared to diminish prior to the trucks passing over the WIM scales, and so did not appear to influence the WIM system accuracies.

Additionally, a visual observation of the trucks as they approach, traverse and leave the sensor area did not indicate any visible motion of the trucks that would affect the performance of the WIM scales. Trucks appear to track down the center of the lane.

4.3 LTPP Pavement Profile Data Analysis

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

Table 4-1 – Recommended WIM Smoothness Index Thresholds

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

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

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the 3 left, 3 right and 5 center profiler runs are presented in Table 4-2.

Table 4-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass 5**	**Avg**
Left	LWP	LRI (m/km)	0.386	0.417	0.414			0.406
		SRI (m/km)	0.247	0.443	0.299			0.330
		Peak LRI (m/km)	0.541	0.565	0.529			0.545
		Peak SRI (m/km)	0.533	0.476	0.503			0.504
	RWP	LRI (m/km)	0.400	0.399	0.410			0.403
		SRI (m/km)	0.323	0.372	0.289			0.328
		Peak LRI (m/km)	0.437	0.399	0.418			0.418
		Peak SRI (m/km)	*0.476*	*0.524*	*0.563*			*0.521*
Center	LWP	LRI (m/km)	0.502	0.539	0.545	0.505	0.552	0.523
		SRI (m/km)	0.565	0.450	0.466	0.693	0.497	0.544
		Peak LRI (m/km)	0.502	0.559	0.545	0.530	0.586	0.534
		Peak SRI (m/km)	***0.712***	***0.684***	***0.625***	***0.738***	***0.626***	***0.690***
	RWP	LRI (m/km)	0.375	0.391	0.432	0.389	0.378	0.397
		SRI (m/km)	0.281	0.189	0.155	0.181	0.283	0.202
		Peak LRI (m/km)	0.479	0.502	0.490	0.459	0.513	0.483
		Peak SRI (m/km)	*0.399*	*0.385*	*0.369*	*0.365*	*0.405*	*0.380*
Right	LWP	LRI (m/km)	0.523	0.525	0.473			0.507
		SRI (m/km)	0.439	0.434	0.392			0.422
		Peak LRI (m/km)	0.558	0.590	0.531			0.560
		Peak SRI (m/km)	*0.572*	*0.698*	*0.471*			*0.580*
	RWP	LRI (m/km)	0.420	0.414	0.421			0.418
		SRI (m/km)	0.287	0.194	0.327			0.269
		Peak LRI (m/km)	0.504	0.459	0.484			0.482
		Peak SRI (m/km)	*0.350*	*0.361*	*0.348*			*0.353*

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

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

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

5.1 Pre-Validation

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

The 48 pre-validation test truck runs were conducted on February 7, 2012, beginning at approximately 10:17 AM and continuing until 5:08 PM.

The two test trucks consisted of:

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

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on the tractor, steel spring 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	76.9	11.5	16.1	16.1	16.6	16.6	20.0	4.3	37.9	4.2	66.3	71.4
2	63.7	10.1	11.5	11.5	15.3	15.3	17.3	4.3	30.0	10.0	61.6	67.0

Test truck speeds varied by 10 mph, from 55 to 65 mph. The measured pre-validation pavement temperatures varied 8.4 degrees Fahrenheit, from 41.6 to 50.0. The overcast weather conditions prevented the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

As shown in Table 5-2, the site did not meet the LTPP requirements for vehicle length measurement as a result of the pre-validation test truck runs. The site also shows excessive negative bias for the steering axle weight measurements.

Table 5-2 – Pre-Validation Overall Results – 07-Feb-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-6.9 ± 10.7%	Pass
Single Axles	±20 percent	-2.0 ± 9.9%	Pass
Tandem Axles	±15 percent	1.4 ± 8.1%	Pass
GVW	±10 percent	-0.2 ± 5.7%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	4.1 ± 0.9 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.2 ± 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 0.7 ± 3.9 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 0.2 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 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 – 07-Feb-12

Parameter	95% Confidence Limit of Error	Low	Medium	High
		55.0 to 58.3 mph	58.4 to 61.8 mph	61.9 to 65.0 mph
Steering Axles	±20 percent	-6.1 ± 7.3%	-9.0 ± 5.5%	-5.9 ± 15.3%
Single Axles	±20 percent	-1.4 ± 9.4%	-2.0 ± 7.3%	-2.3 ± 12.1%
Tandem Axles	±15 percent	1.6 ± 10.1%	1.4 ± 4.6%	1.2 ± 10.6%
GVW	±10 percent	0.0 ± 6.4%	-0.1 ± 2.5%	-0.5 ± 7.6%
Vehicle Length	±3.0 percent (2.1 ft)	4.1 ± 1.0 ft	4.0 ± 1.2 ft	4.1 ± 0.8 ft
Vehicle Speed	± 1.0 mph	0.7 ± 2.6 mph	0.4 ± 5.4 mph	1.0 ± 4.0 mph
Axle Length	± 0.5 ft [150mm]	0.2 ± 0.1 ft	0.2 ± 0.1 ft	0.2 ± 0.1 ft

From the table, it can be seen that, on average, the WIM equipment underestimates steering and single axle weights and overestimates vehicle length at all speeds. The range in error for steering and single axles appears to be greater at the lower and upper ends of the speed range.

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

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment estimated GVW with similar accuracy at all speeds. The range in error is higher at low and high speeds when compared to medium speeds.

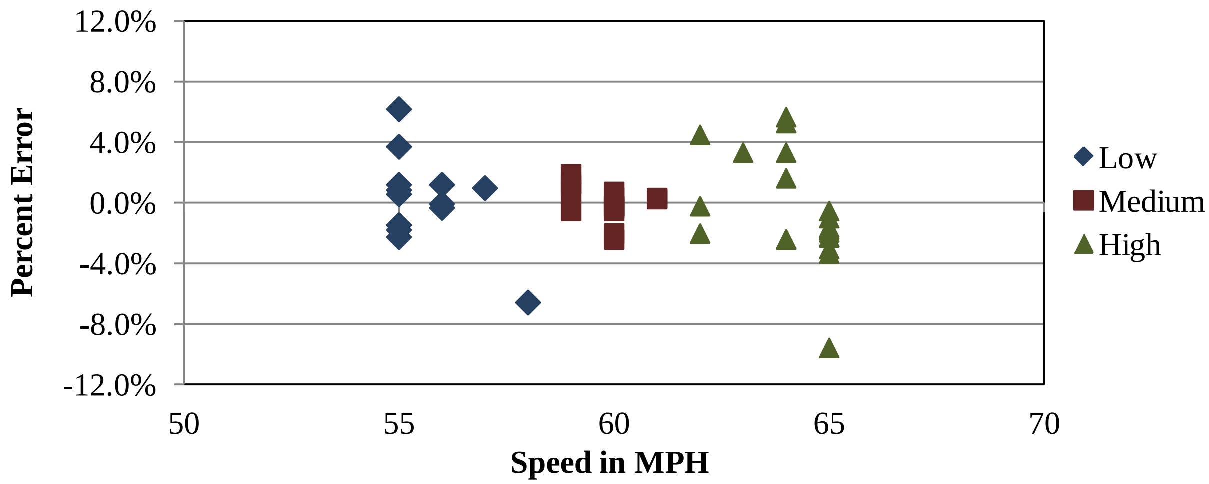


Figure 5-1 – Pre-Validation GVW Error by Speed – 07-Feb-12

5.1.1.2 Steering Axle Weight Errors by Speed

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

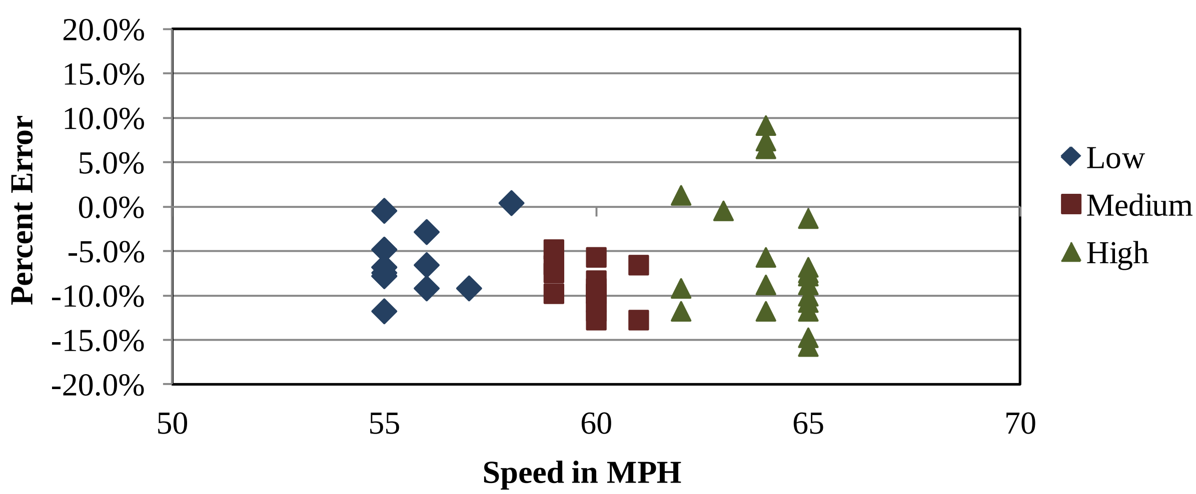


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 07-Feb-12

5.1.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment estimates single axle weights with fairly similar bias at all speeds. The range in error is higher at high speeds.

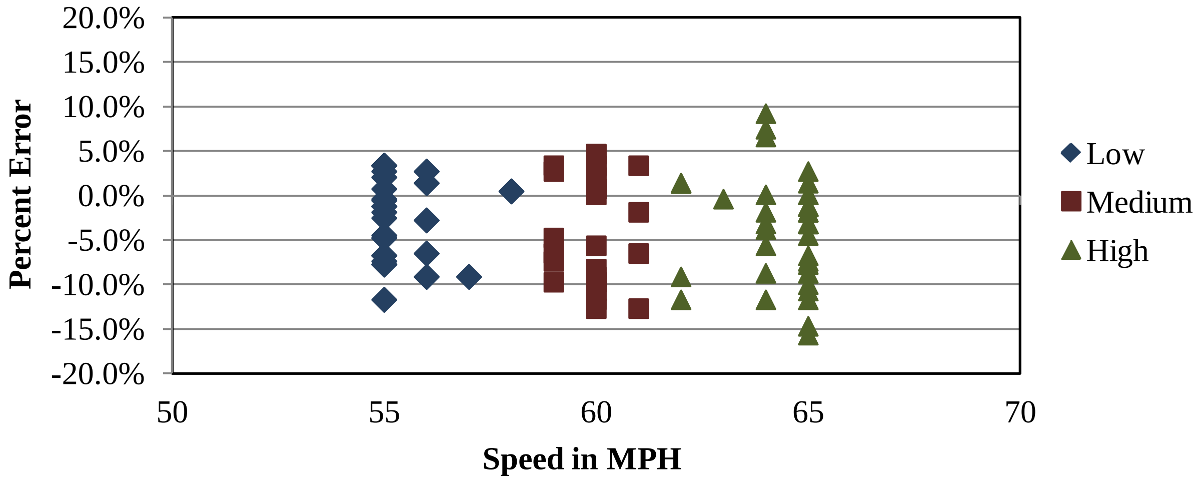


Figure 5-3 – Pre-Validation Single Axle Weight Errors by Speed – 07-Feb-12

5.1.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment estimates tandem axle weights with similar bias at all speeds. The range in error is greater at low and high speeds when compared to medium speeds.

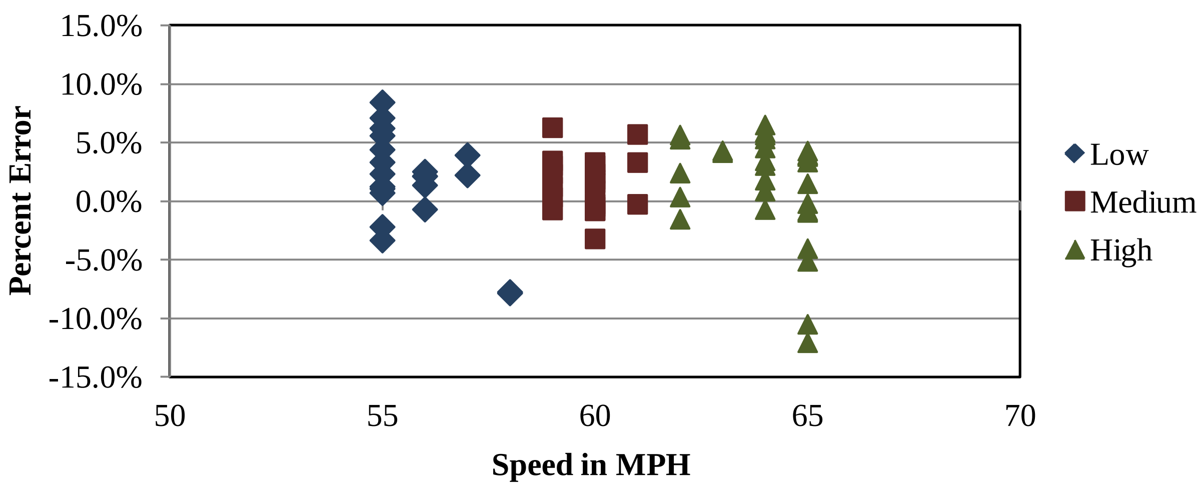


Figure 5-4 – Pre-Validation Tandem Axle Weight Errors by Speed – 07-Feb-12

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 estimates weights with greater accuracy for the partially loaded (Secondary) truck than the heavily loaded (Primary) truck at all speeds (Figure 5-5). The range in errors is greater for the heavily loaded (Primary) truck. Distribution of errors is shown graphically in Figure 5-5.

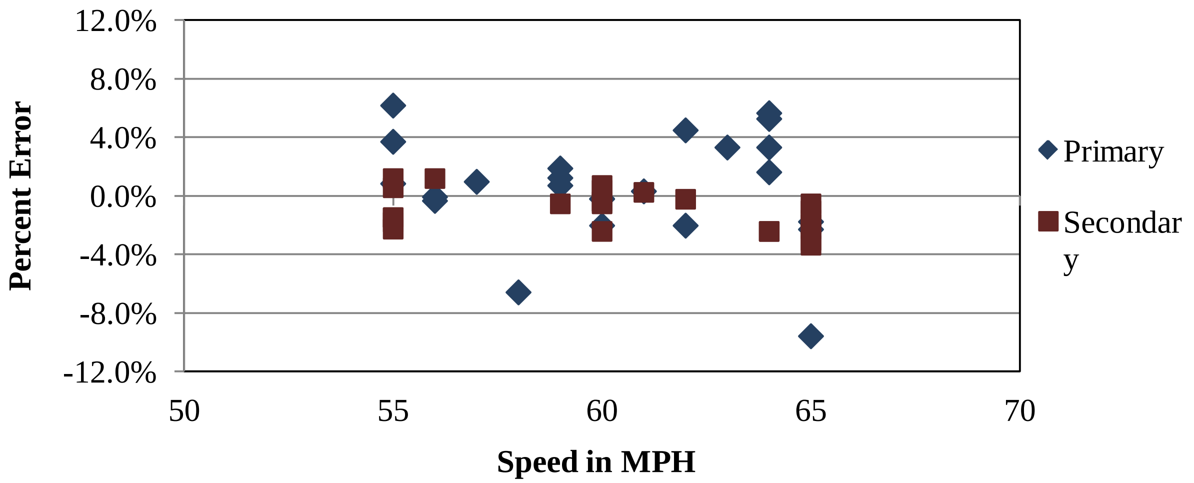


Figure 5-5 – Pre-Validation GVW Errors by Truck and Speed – 07-Feb-12

5.1.1.6 Steering Axle Errors by Speed and Truck Type

When the Steering Axle error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment estimates weights with greater accuracy for the partially loaded (Secondary) truck than the heavily loaded (Primary) truck at all speeds (Figure 5-5). The range in errors is greater for the heavily loaded (Primary) truck. Distribution of errors is shown graphically in Figure 5-7. Secondary truck shows higher negative bias in measurements compared to the Primary truck.

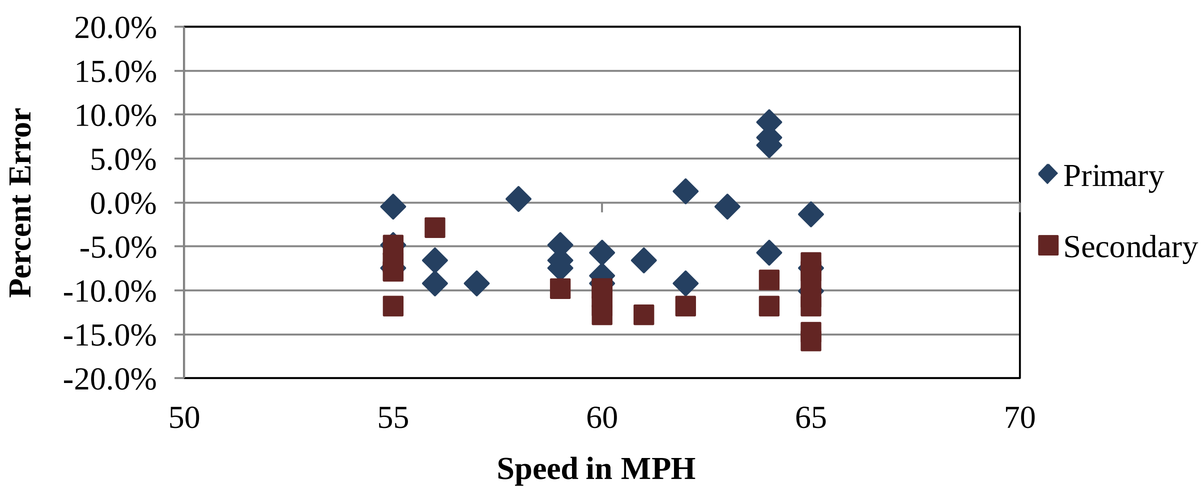


Figure 5-6 – Pre-Validation Steering Axle Errors by Truck and Speed – 07-Feb-12

5.1.1.7 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 0.0 feet to 0.3 feet. Distribution of errors is shown graphically in Figure 5-7.

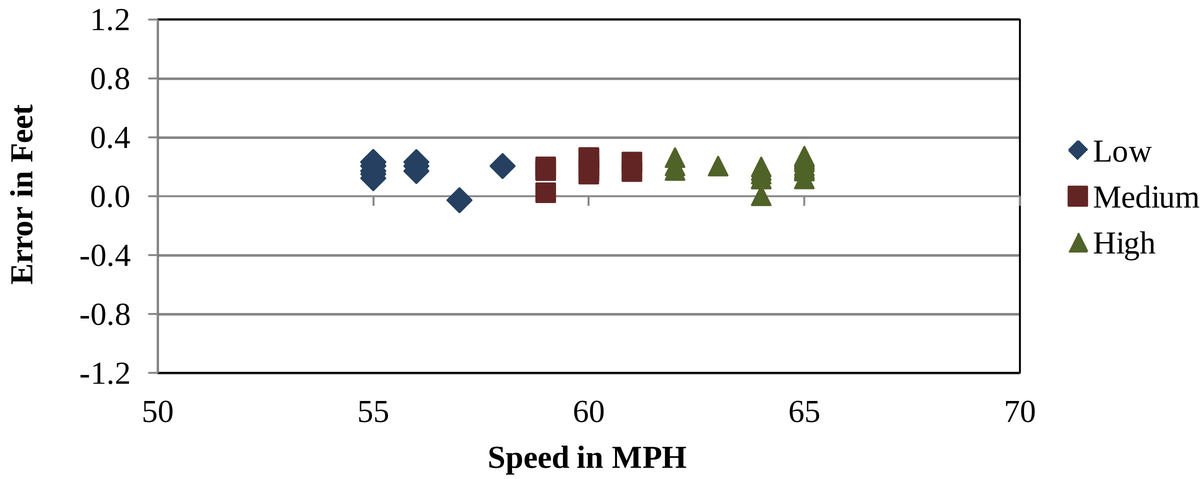


Figure 5-7 – Pre-Validation Axle Length Errors by Speed – 07-Feb-12

5.1.1.8 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 3.0 to 4.6 feet. Distribution of errors is shown graphically in Figure 5-8.

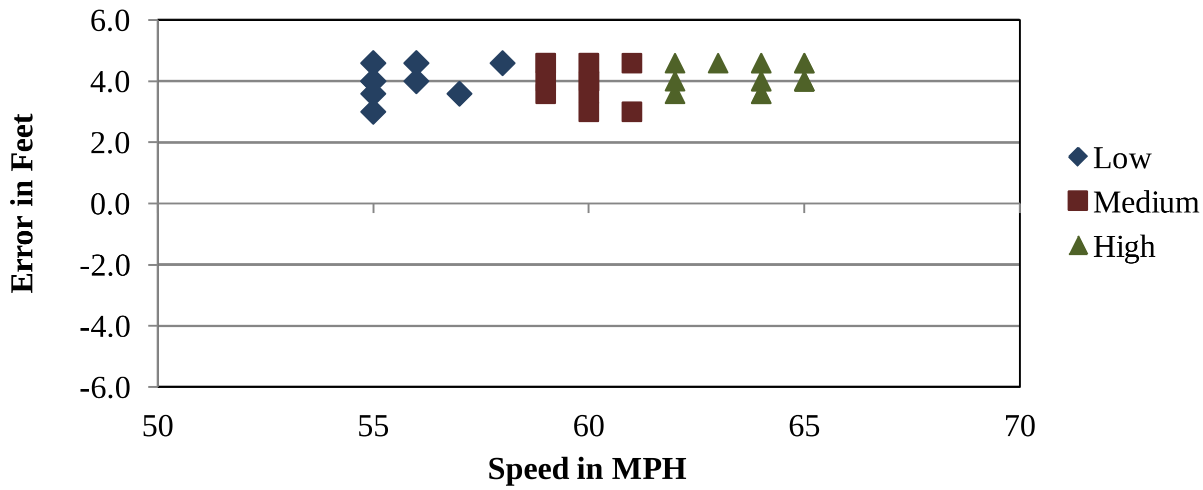


Figure 5-8 – Pre-Validation Overall Length Error by Speed – 07-Feb-12

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 8.4 degrees, from 41.6 to 50.0 degrees Fahrenheit. Since the desired 30 degree temperature range was not met, the pre-validation test runs are being reported under one temperature group – medium, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 07-Feb-12

Parameter	**95% Confidence Limit of Error**	**Medium**
		41.6 to 50 degF
Steering Axles	±20 percent	-6.9 ± 10.7%
Single Axles	±20 percent	-2.0 ± 9.9%
Tandem Axles	±15 percent	1.4 ± 8.1%
GVW	±10 percent	-0.2 ± 5.7%
Vehicle Length	±3.0 percent (2.1 ft)	4.1 ± 0.9 ft
Vehicle Speed	± 1.0 mph	0.7 ± 3.9 mph
Axle Length	± 0.5 ft [150mm]	0.2 ± 0.1 ft

Although the temperature analysis was very limited due to the small range of temperatures, 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 5-9, it can be seen that the equipment generally estimates GVW with similar bias across the range of temperatures observed in the field.

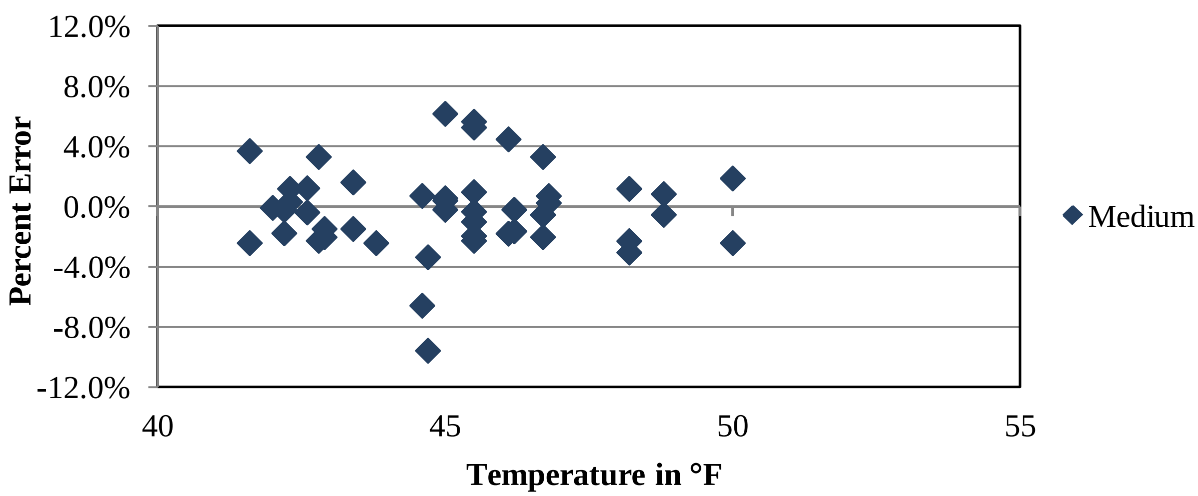


Figure 5-9 – Pre-Validation GVW Errors by Temperature – 07-Feb-12

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-10 illustrates that for steering axles, the WIM equipment generally underestimates weights across the range of pavement temperatures observed in the field.

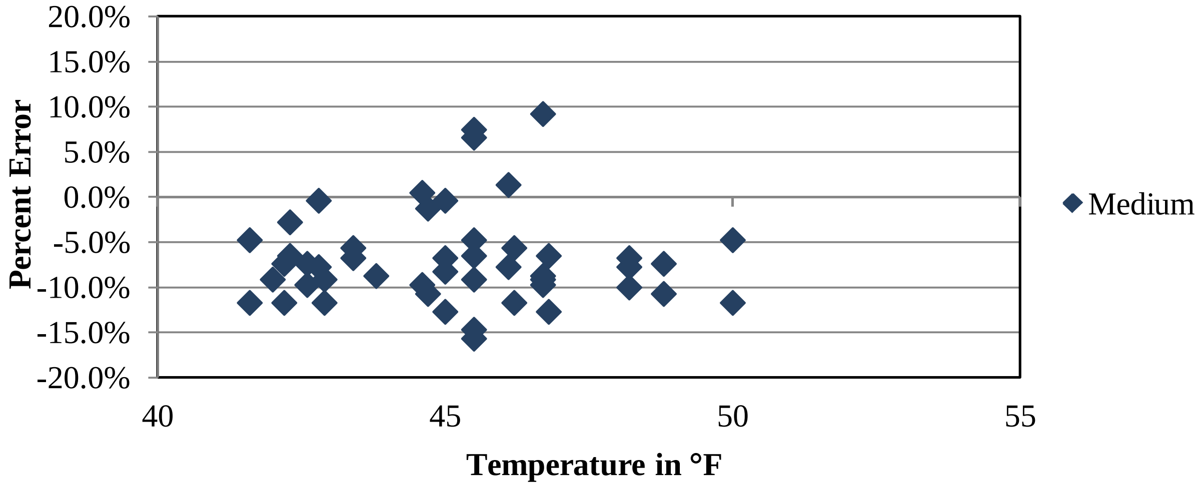


Figure 5-10 – Pre-Validation Steering Axle Weight Errors by Temperature – 07-Feb-12

5.1.2.3 Single Axle Weight Errors by Temperature

Figure 5-11 illustrates that for single axles, the WIM equipment generally underestimates weights at all temperatures.

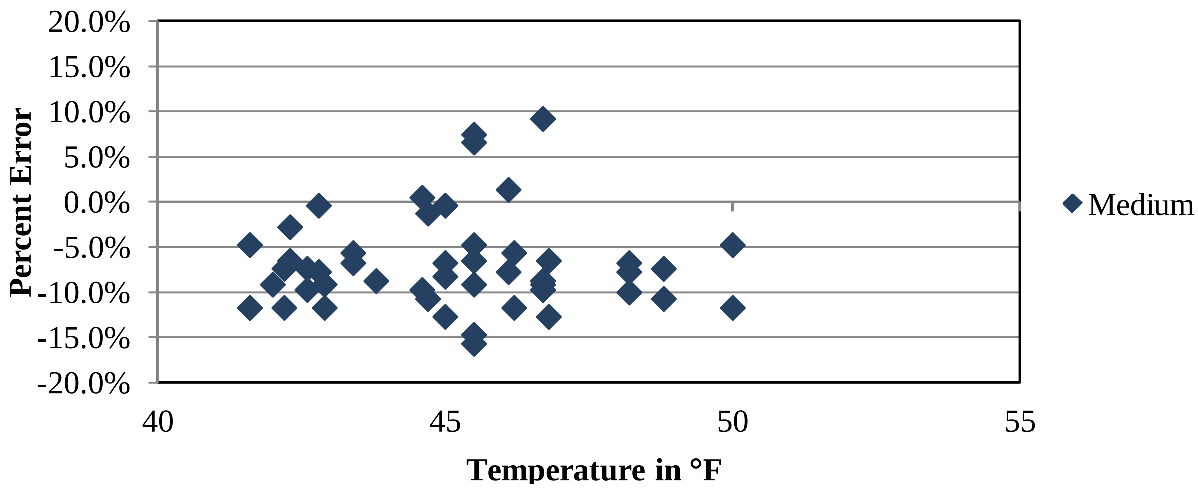


Figure 5-11 – Pre-Validation Single Axle Weight Errors by Temperature – 07-Feb-12

5.1.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-12, the WIM equipment generally estimates tandem axle weights with similar bias across the range of temperatures observed in the field.

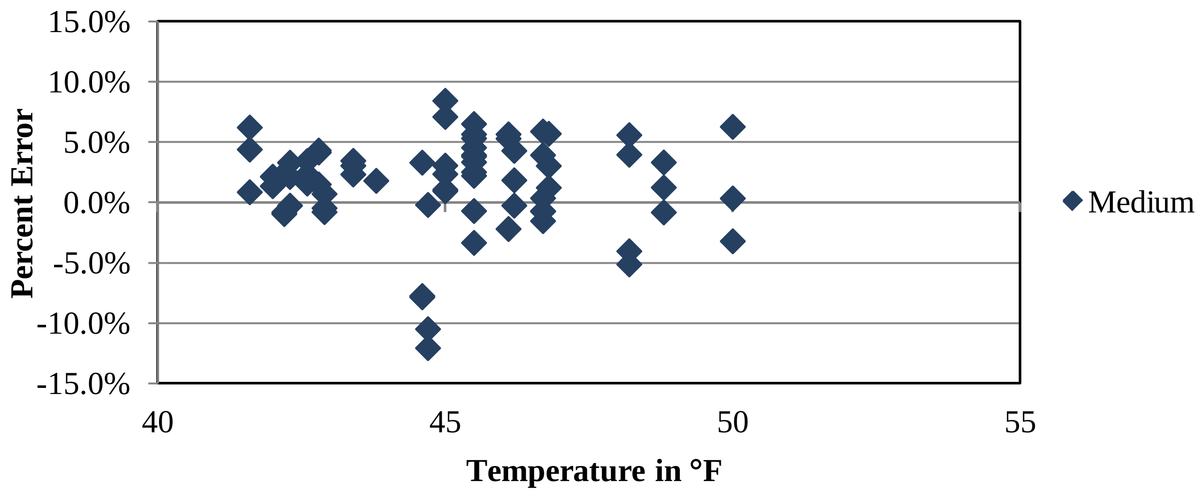


Figure 5-12 – Pre-Validation Tandem Axle Weight Errors by Temperature – 07-Feb-12

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 estimates weights with greater accuracy for the partially loaded (Secondary) truck than the heavily loaded (Primary) truck at all temperatures. The range in errors is greater for the heavily loaded (Primary) truck. Distribution of errors is shown graphically in Figure 5-13.

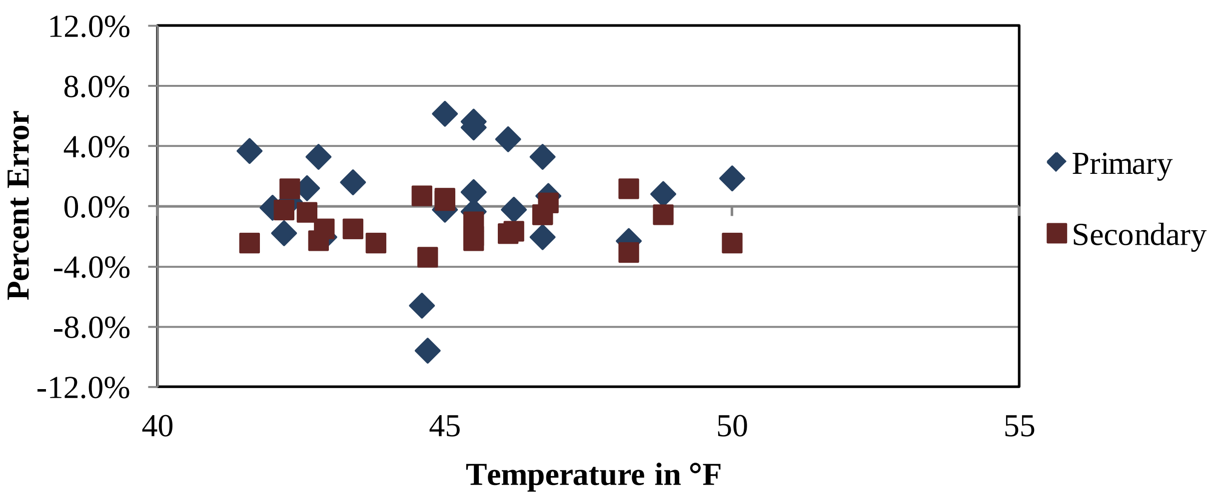


Figure 5-13 – Pre-Validation GVW Error by Truck and Temperature – 07-Feb-12

5.1.3 Classification and Speed Evaluation

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

For the pre-validation classification study at this site, a manual sample of 103 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

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 WIM equipment for the manual classification study. As shown in Table 5-5, three Class 3 vehicles were misclassified as Class 5 vehicles and two Class 5 vehicles were misclassified as Class 8 vehicles by the equipment.

Table 5-5 – Pre-Validation Misclassifications by Pair – 07-Feb-12

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

As shown in the table, a total of 5 vehicles, including 0 heavy trucks (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the pre-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 4.9%.

The causes for the misclassifications were not investigated in the field. A post-visit investigation of misclassified vehicles was performed using the collected video. The analysis determined that the three Class 3s that were identified as Class 5s by the WIM equipment were all full-size pick-ups with fully loaded beds. Both of the Class 5s that were identified by the equipment as Class 8s were dump trucks towing wood chipping machines.

As shown in Table 5-6, the combined results produced an undercount of three Class 3 vehicles, and an overcount of one Class 5 vehicle and two Class 8 vehicles. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-6 – Pre-Validation Classification Study Results – 07-Feb-12

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	3	0	9	5	6	0	71	3	3	3	0
WIM Count	0	0	10	5	6	2	71	3	3	3	0
Observed Percent	2.9	0.0	8.7	4.9	5.8	0.0	68.9	2.9	2.9	2.9	0.0
WIM Percent	0.0	0.0	9.7	4.9	5.8	1.9	68.9	2.9	2.9	2.9	0.0
Misclassified Count	3	0	2	0	0	0	0	0	0	0	0
Misclassified Percent	100.0	0.0	22.2	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. The unclassified vehicles by pair are provided in Table 5-7.

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 07-Feb-12

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

Based on the manually collected sample of the 100 trucks, none of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 0.8 mph; the range of errors was 1.9 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 – 08-Feb-12

Speed Point	MPH	Left		Right	
		1	3	2	4
80	50	3239	3239	3717	3312
88	55	3221	3221	3687	3275
96	60	3184	3184	3644	3248
104	65	3172	3172	3631	3235
112	70	3095	3095	3542	3156
Axle Distance (cm)		246			
Dynamic Comp (%)		103			
Loop Width (cm)		183			

5.2.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of -0.2% and errors of 0.0%, -0.1%, and -0.5% at the 55, 60 and 65 mph speed points respectively. The errors for the 55 mph and 65 mph speed points were extrapolated to derive new compensation factors for the 50 mph and 70 mph speed points. To compensate for these errors, adjustments to the Axle Distance, Dynamic Compensation and Loop Width factors were made, as shown in Table 5-9.

Table 5-9 – Calibration Equipment Factor Changes – 08-Feb-12

Speed Points	MPH	Old Factors				New Factors			
		Left		Right		Left		Right	
		1	3	2	4	1	3	2	4
80	50	3239	3239	3717	3312	3239	3239	3717	3312
88	55	3221	3221	3687	3275	3221	3221	3687	3275
96	60	3184	3184	3644	3248	3184	3184	3644	3248
104	65	3172	3172	3631	3235	3172	3172	3631	3235
112	70	3095	3095	3542	3156	3095	3095	3542	3156
Axle Distance (cm)		246				245			
Dynamic Comp (%)		103				112			
Loop Width (cm)		183				325			

5.2.2 Calibration Results

The results of the 12 calibration verification runs are provided in Table 5-10 and Figure 5-15. As can be seen in the table, the mean error of Steering Axle estimates and the Vehicle Length estimate was reduced as a result of the first calibration.

Table 5-10 – Calibration Results – 08-Feb-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.5 ± 4.3%	Pass
Single Axles	±20 percent	1.7 ± 8.1%	Pass
Tandem Axles	±15 percent	2.1 ± 6.8%	Pass
GVW	±10 percent	1.3 ± 5.5%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	-0.5 ± 1.3 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.2 ± 0.1 ft	Pass

Figure 5-15 shows that the WIM equipment is estimating GVW with reasonable accuracy at all speeds.

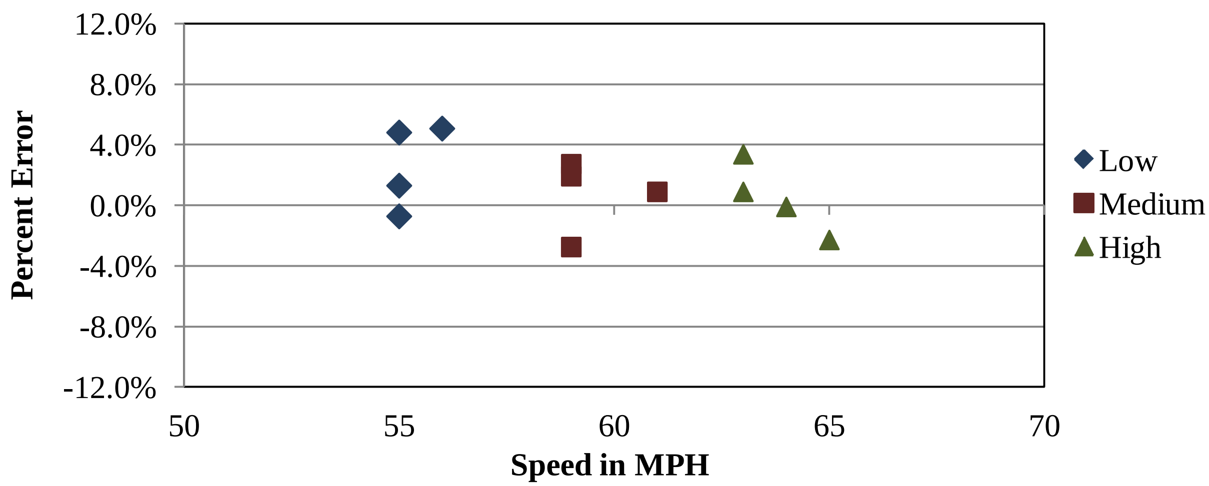


Figure 5-14 – Calibration Steering Axle Error by Speed – 08-Feb-12

Figure 5-15 shows that the WIM equipment is estimating steering axles with reasonable accuracy at all speeds.

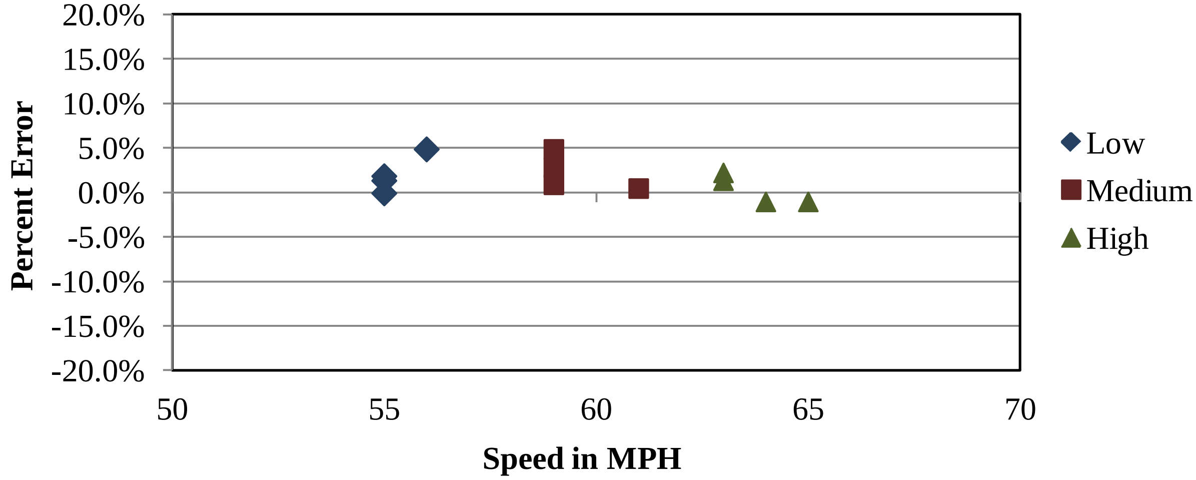


Figure 5-15 – Calibration Steering Axle Error by Speed – 08-Feb-12

Based on the results of the calibration, where GVW bias was 1.3 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 February 8, 2012, beginning at approximately 9:32 AM and continuing until 2:08 PM.

The two test trucks consisted of:

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

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on the tractor, steel spring 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	76.6	11.3	16.0	16.0	16.6	16.6	20.0	4.3	37.9	4.2	66.3	71.4
2	64.2	10.3	11.6	11.6	15.3	15.3	17.3	4.3	30.0	10.0	61.6	67.0

Test truck speeds varied by 11 mph, from 54 to 65 mph. The measured post-validation pavement temperatures varied 7.1 degrees Fahrenheit, from 28.5 to 35.6. The cloud cover and snow prevented the desired minimum 30 degree temperature range. Table 5-12 is a summary of post validation results.

Table 5-12 – Post-Validation Overall Results – 08-Feb-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	2.2 ± 9.1%	Pass
Single Axles	±20 percent	1.4 ± 10.1%	Pass
Tandem Axles	±15 percent	1.1 ± 7.2%	Pass
GVW	±10 percent	1.0 ± 5.6%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	-0.6 ± 1.0 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.2 ± 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 0.3 ± 4.7 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 0.2 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 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 – 08-Feb-12

Parameter	95% Confidence Limit of Error	Low 54.0 to 57.7 mph	Medium 57.8 to 61.4 mph	High 61.5 to 65.0 mph
Steering Axles	±20 percent	3.0 ± 14.6%	1.9 ± 5.9%	1.7 ± 6.4%
Single Axles	±20 percent	2.2 ± 13.0%	1.7 ± 7.9%	0.2 ± 9.7%
Tandem Axles	±15 percent	1.8 ± 10.9%	0.4 ± 5.6%	1.0 ± 6.6%
GVW	±10 percent	1.7 ± 7.3%	1.1 ± 3.4%	0.0 ± 6.3%
Vehicle Length	±3.0 percent (2.1 ft)	-0.6 ± 1.3 ft	-0.7 ± 0.8 ft	-0.6 ± 1.2 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 7.9 mph	0.2 ± 2.5 mph	0.9 ± 2.3 mph
Axle Length	± 0.5 ft [150mm]	0.2 ± 0.1 ft	0.2 ± 0.1 ft	0.2 ± 0.1 ft

From the table, it can be seen that the WIM equipment estimates all weights with better accuracy at medium and high speeds. The range of errors is greater at the lower speeds for all weight errors.

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 5-16, the equipment estimated GVW with similar accuracy at all speeds. The range in error is higher at low speeds.

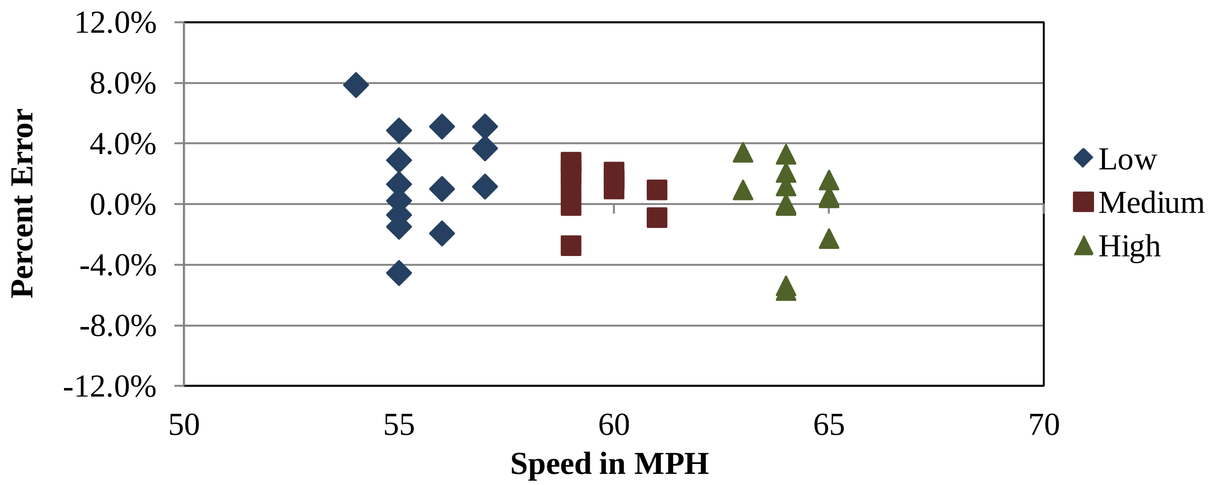


Figure 5-16 – Post-Validation GVW Errors by Speed – 08-Feb-12

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-17, the equipment estimated steering axle weights with similar accuracy at medium and high speeds. The range in error is the heist at the low speed range.

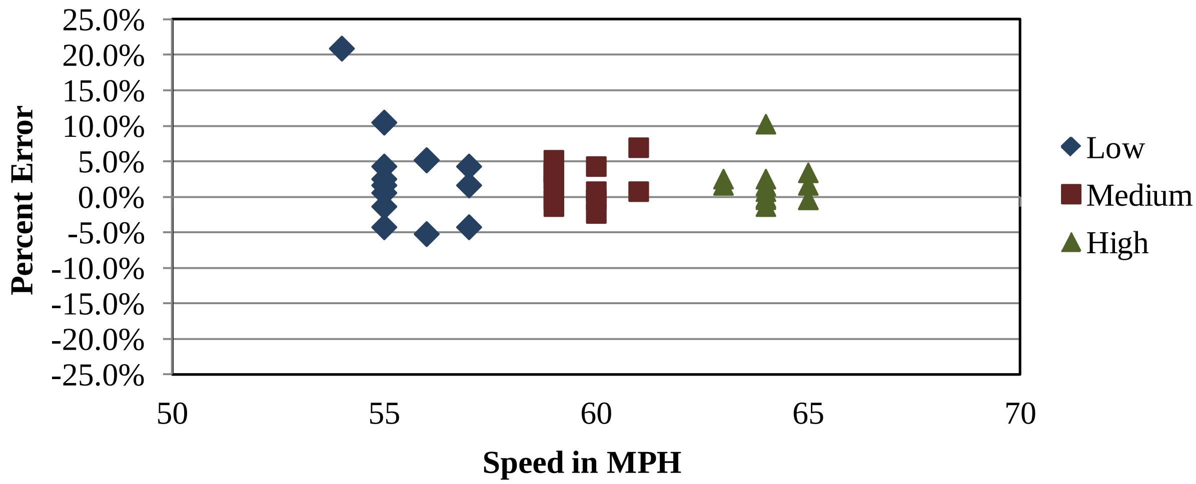


Figure 5-17 – Post-Validation Steering Axle Weight Errors by Speed – 08-Feb-12

5.3.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-18, the equipment estimated single axle weights with similar accuracy at all speeds. The range in error is higher at low and high speeds in comparison to medium speeds.

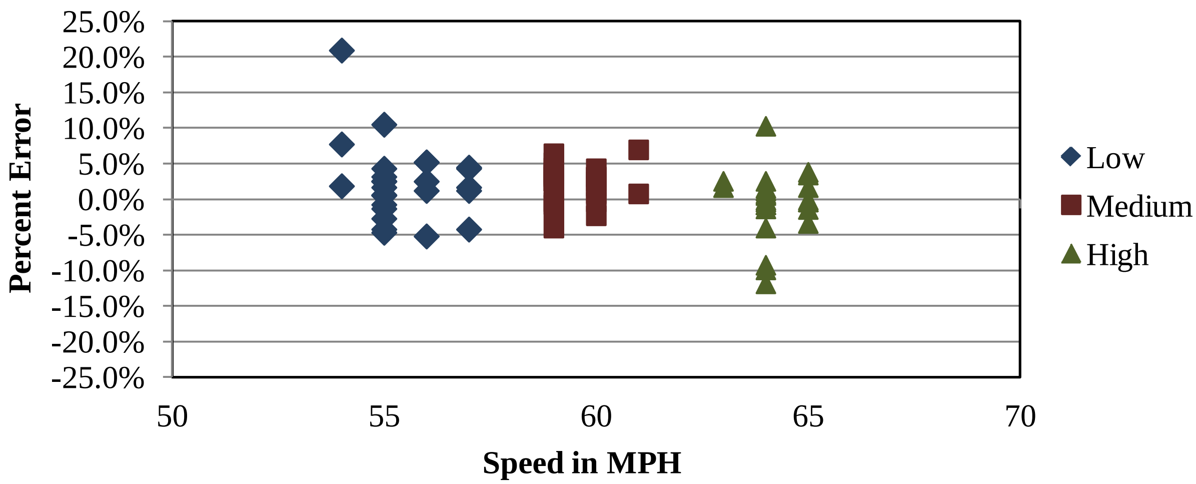


Figure 5-18 – Post-Validation Single Axle Weight Errors by Speed – 08-Feb-12

5.3.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-19, the equipment estimated tandem axle weights with similar accuracy at all speeds. The range in error appears to be greater at the low and high speeds.

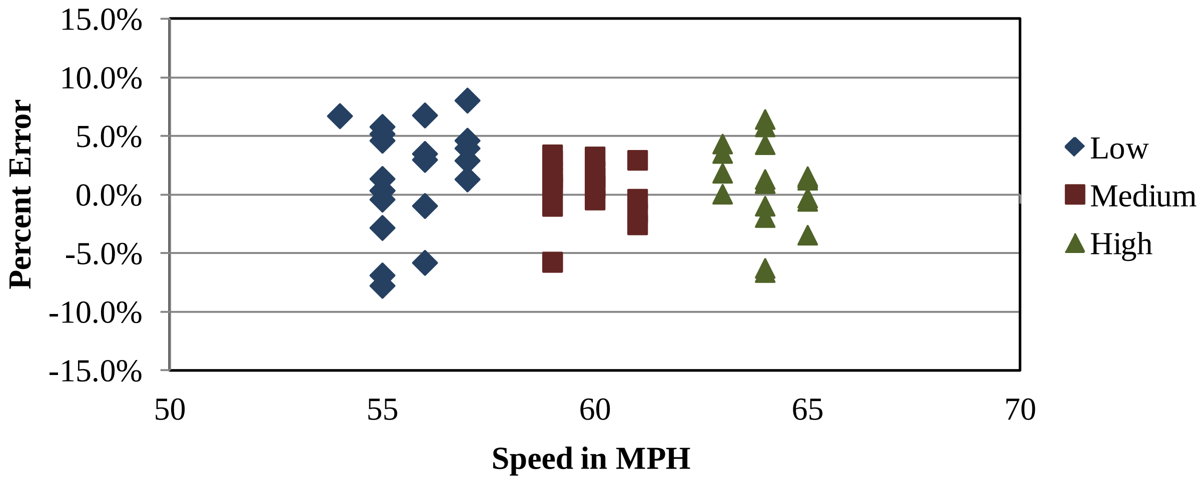


Figure 5-19 – Post-Validation Tandem Axle Weight Errors by Speed – 08-Feb-12

5.3.1.5 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-20 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. There may be some reverse correlation between speed and measurement bias for the secondary truck.

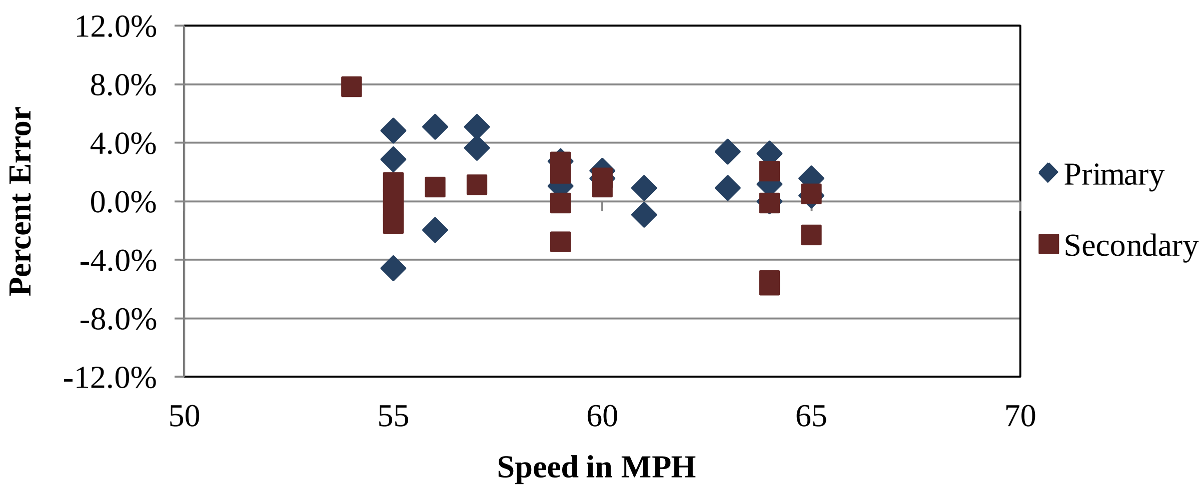


Figure 5-20 – Post-Validation GVW Error by Truck and Speed – 08-Feb-12

5.3.1.6 Steering Axle Errors by Speed and Truck Type

It can be seen in Figure 5-21 that when the Steering Axle 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. For secondary truck, range of errors is slightly higher at low speeds.

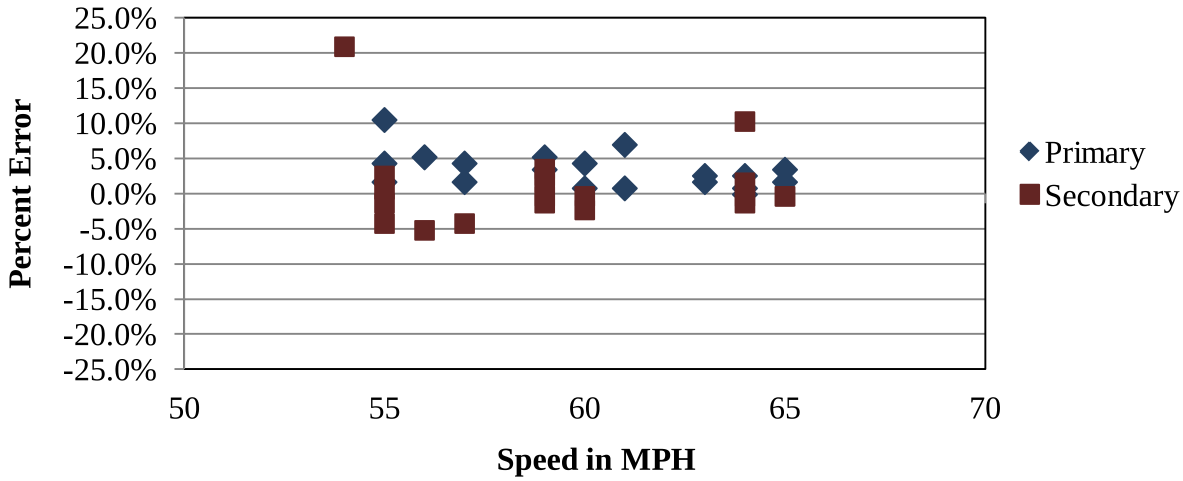


Figure 5-21 – Post-Validation Steering Axle Error by Truck and Speed – 08-Feb-12

5.3.1.7 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from 0.0 feet to 0.3 feet. Distribution of errors is shown graphically in Figure 5-22.

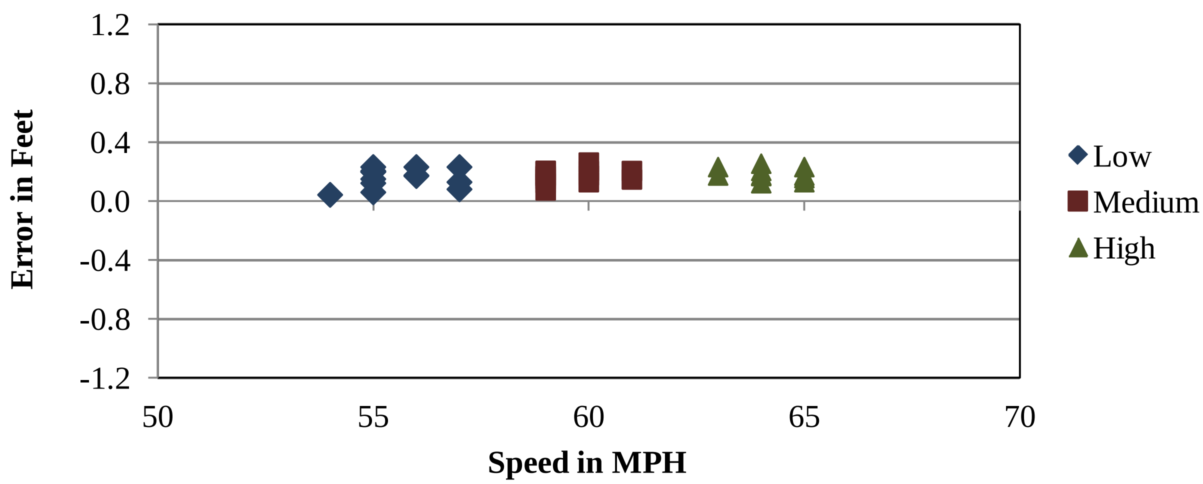


Figure 5-22 – Post-Validation Axle Length Error by Speed – 08-Feb-12

5.3.1.8 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 0.6 to -2.0 feet. Distribution of errors is shown graphically in Figure 5-23.

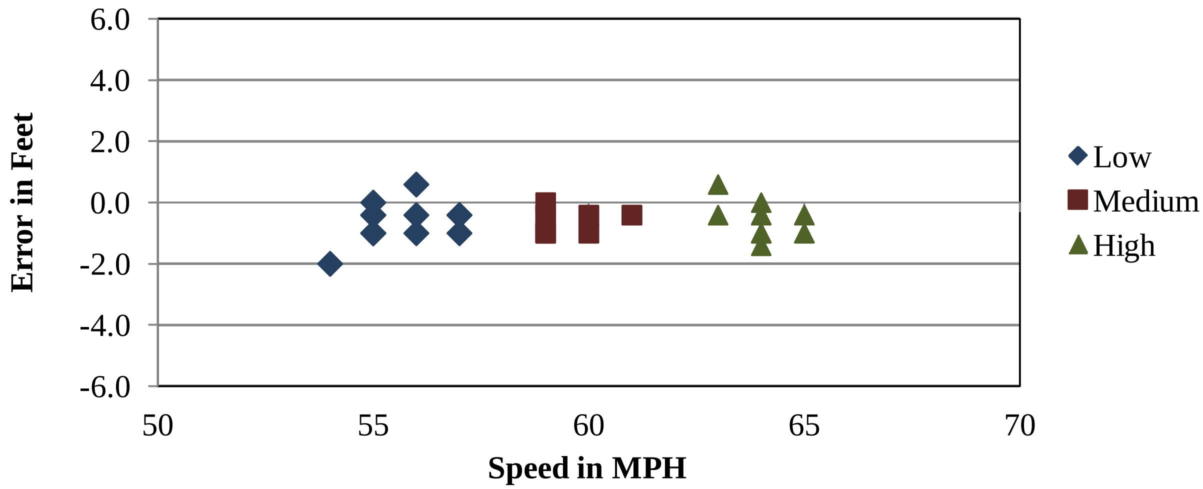


Figure 5-23 – Post-Validation Overall Length Error by Speed – 08-Feb-12

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 7.1 degrees, from 28.5 to 35.6 degrees Fahrenheit. Due to the small range of temperatures, the post-validation test runs are reported under one temperature group – medium, as shown in Table 5-14 below.

Table 5-14 – Post-Validation Results by Temperature – 08-Feb-12

Parameter	95% Confidence Limit of Error	Medium
		28.5 to 35.6 degF
Steering Axles	+20 percent	2.2 ± 9.1%
Single Axles	+20 percent	1.4 ± 10.1%
Tandem Axles	+15 percent	1.1 ± 7.2%
GVW	+10 percent	1.0 ± 5.6%
Vehicle Length	±3.0 percent (2.1 ft)	-0.6 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.3 ± 4.7 mph
Axle Length	+ 0.5 ft [150mm]	0.2 ± 0.1 ft

Although the temperature analysis was limited by the small range of temperatures, 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 5-24, it can be seen that the equipment appears to estimate GVW with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

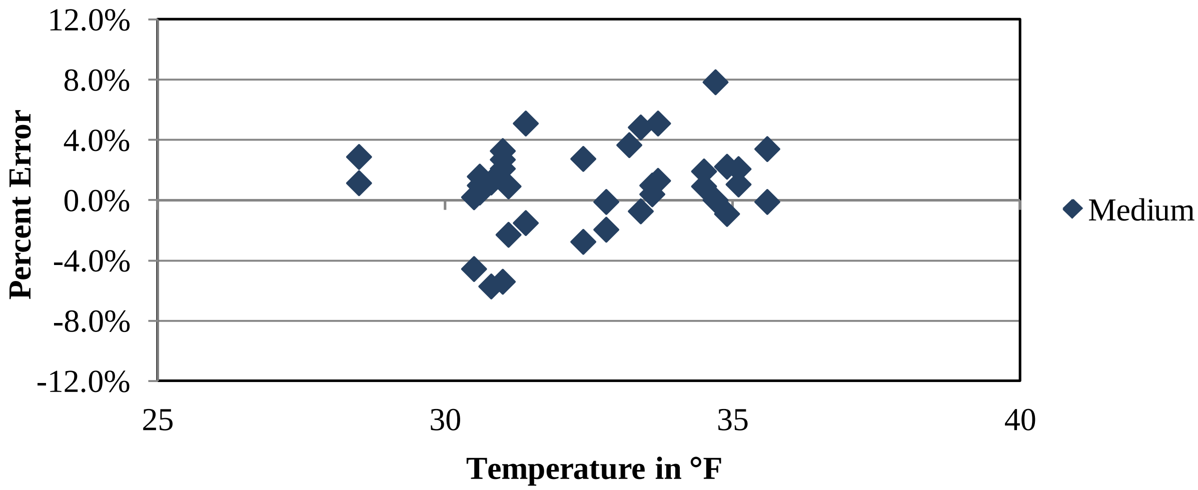


Figure 5-24 – Post-Validation GVW Errors by Temperature – 08-Feb-12

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-25 demonstrates that for steering axles, the WIM equipment appears to estimate weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and steering axle weight estimates at this site.

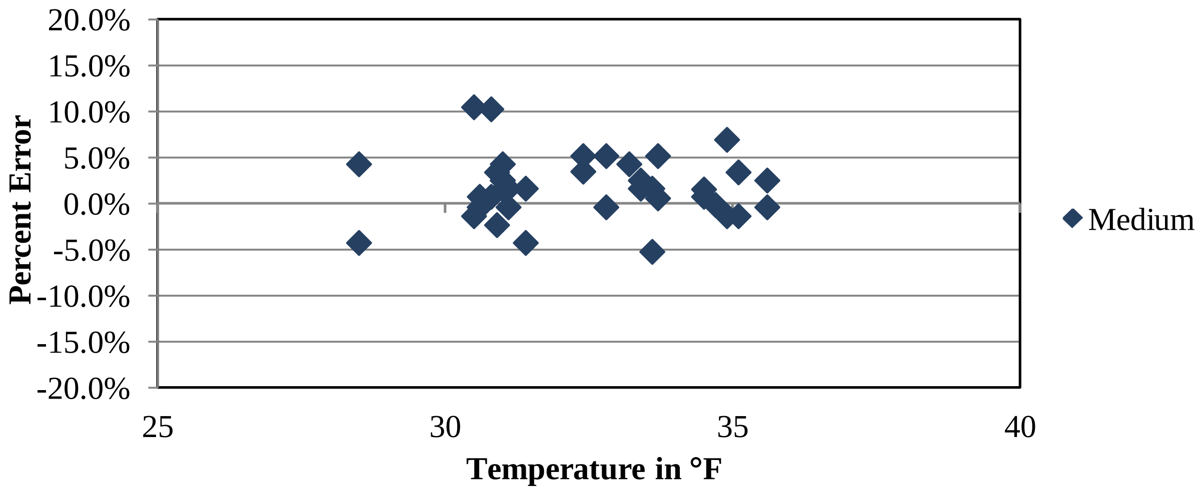


Figure 5-25 – Post-Validation Steering Axle Weight Errors by Temperature – 08-Feb-12

5.3.2.3 Single Axle Weight Errors by Temperature

Figure 5-26 demonstrates that for loaded single axles, the WIM equipment appears to estimate single 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 single axle weight estimates at this site.

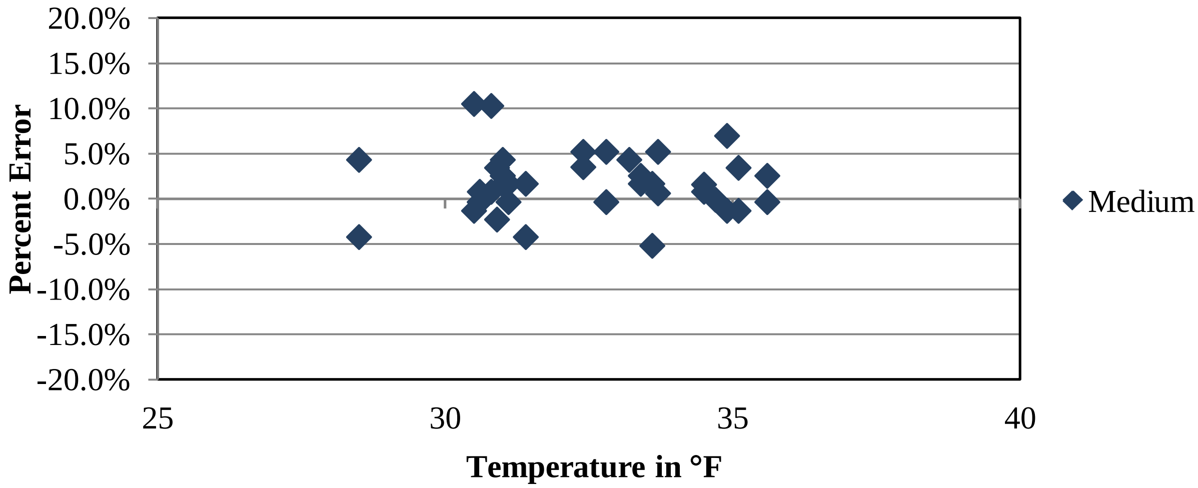


Figure 5-26 – Post-Validation Single Axle Weight Errors by Temperature – 08-Feb-12

5.3.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-27, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and tandem axle weight estimates at this site.

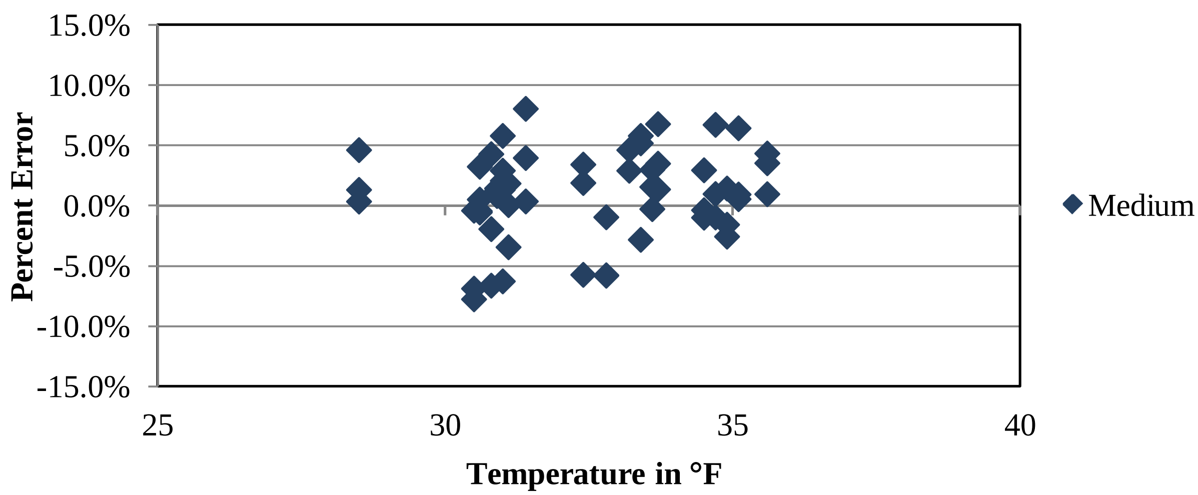


Figure 5-27 – Post-Validation Tandem Axle Weight Errors by Temperature – 08-Feb-12

5.3.2.5 GVW Errors by Temperature and Truck Type

As shown in Figure 5-28, when analyzed by truck type, GVW measurement errors for both trucks are similar at all temperatures.

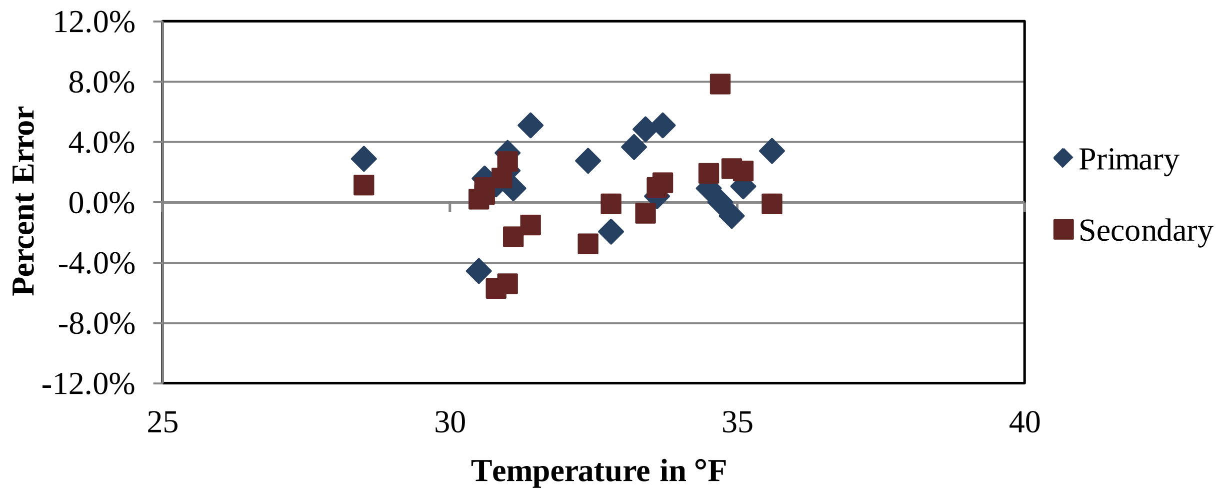


Figure 5-28 – Post-Validation GVW Error by Truck and Temperature – 08-Feb-12

5.3.3 GVW and Steering Axle Trends

Figure 5-29 is provided to illustrate the predicted GVW error with respect to the post-validation weight errors by speed.

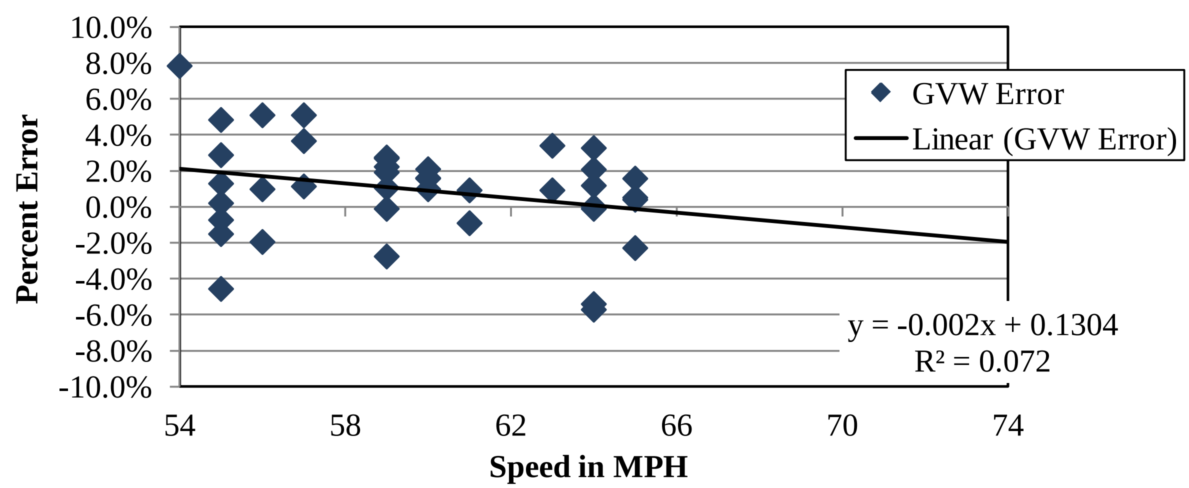


Figure 5-29 – GVW Error Trend by Speed

Figure 5-30 is provided to illustrate the predicted Steering Axle error with respect to the post-validation weight errors by speed.

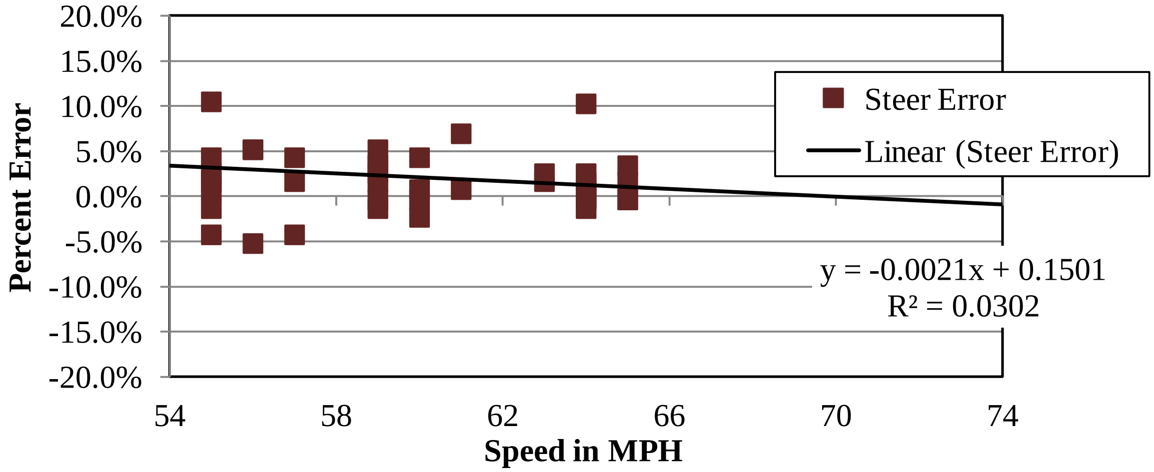


Figure 5-30 – Steering Axle Trend by Speed

5.3.4 Multivariable 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.

5.3.4.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. 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 28.5 to 35.6 degrees Fahrenheit.

5.3.4.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-15. The value of regression coefficients defines the slope of the relationship between the error in GVW and the predictor variables (speed, temperature, and truck type). The values of the t-distribution (for the regression coefficients) given in Table 5-15 are for the null hypothesis that assumes that the regression coefficients are equal to zero. The probability value reported in Table 5-15 is for the probability that the regression coefficients, given in Table 5-5, occur by chance alone.

Table 5-15 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	**Regression coefficients**	**Standard error**	**Value of t-distribution**	**Probability value (p-value)**
Intercept	4.9082	9.5197	0.5156	0.6093
Speed	-0.2245	0.1129	-1.9888	0.0544
Temp	0.3145	0.2125	1.4804	0.1475
Truck	-1.5057	0.8146	-1.8483	0.0728

The lowest probability value given in Table 5-15 was 0.0544 for speed. This means that there is about 5 percent chance that the value of regression coefficient for speed (-0.2245) can occur by chance alone. Overall, speed and truck type have most significant effect on the GVW measurement errors.

The relationship between speed and GVW measurement error is shown in Figure 5-31. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 5-31 provides quantification and statistical assessment of the relationship.

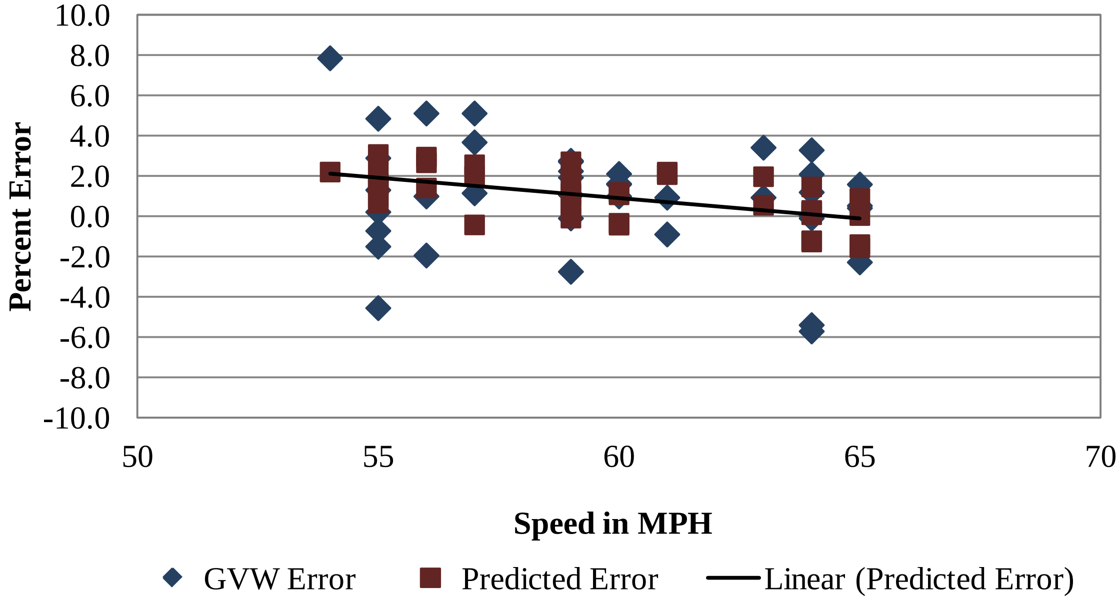


Figure 5-31 – Influence of Speed on the Measurement Error of GVW

The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.2245 (in Table 5-15). This means, for example, that for a 10 mph increase in speed, the error is decreased by about 2.2 percent (-0.2245 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0544) and is statistically significant.

5.3.4.3 Summary Results

Table 5-16 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 5-16 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-16 – 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	-0.2245	0.0544	0.3145	0.1475	-1.5057	0.0728
Steering axle	–	–	–	–	-2.3509	0.1029
Tandem axle tractor	–	–	0.4569	0.1437	-1.6737	0.1619
Tandem axle trailer	–	–	–	–	not applicable	not applicable

5.3.4.4 Conclusions

1. Speed had statistically significant effect on GVW measurement errors only.

2. The effect of temperature on weight measurement errors was not statistically significant. However, the range of pavement temperature was only 7.1 °F.

3. Truck type had statistically significant effect on GVW measurement errors only at 0.07 probability value. The regression coefficients for truck type in Table 5-16 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.). For example, the mean measurement error in GVW for the Primary truck was about 1.5 % larger than the error for the Secondary truck.

4. Even though speed and truck type 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.

5.3.5 Classification and Speed Evaluation

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

For the post-validation classification study at this site, a manual sample of 101 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

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 5-17. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-17, one Class 3 vehicle was misclassified as a Class 5 vehicle, one Class 5 vehicle was misclassified as a Class 4 vehicle, and one Class 10 vehicle was misclassified as a Class 14 vehicle by the equipment.

Table 5-17 – Post-Validation Misclassifications by Pair – 08-Feb-12

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

As shown in the table, a total of 3 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the post-validation study, the misclassification percentage is 1.1% 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 3.0%.

The causes for the misclassifications were not investigated in the field. A post-visit investigation of misclassified vehicles was performed using the collected video. The analysis determined that the Class 3 that was a full-size pick-up with a utility body. The Class 5 that was identified by the equipment as a Class 4 was a box truck with a sleeper cab. The cause of the Class 10 being identified as a Class 14 could not be determined.

The combined results of the misclassifications resulted in an undercount of one Class 3, and one Class 10 vehicle, and an overcount of one Class 4 vehicle, as shown in Table 5-18. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-18 – Post-Validation Classification Study Results – 08-Feb-12

Class	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Observed Count	1	1	4	5	8	4	65	2	7	4	0
WIM Count	0	2	4	5	8	4	65	1	7	4	0
Observed Percent	1.0	1.0	4.0	5.0	7.9	4.0	64.4	2.0	6.9	4.0	0.0
WIM Percent	0.0	2.0	4.0	5.0	7.9	4.0	64.4	1.0	6.9	4.0	0.0
Misclassified Count	1	0	1	0	0	0	0	1	0	0	0
Misclassified Percent	100.0	0.0	25.0	0.0	0.0	0.0	0.0	50.0	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. The unclassified vehicles by pair are provided in Table 5-19.

Table 5-19 – Post-Validation Unclassified Trucks by Pair – 08-Feb-12

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

Based on the manually collected sample of the 100 trucks, 0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites. For speed, the mean error for WIM equipment speed measurement was 0.6 mph; the range of errors was 4.5 mph.

6 Previous WIM Site Validation Information

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

6.1 Sheet 16s

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

Table 6-1 – Classification Validation History

Date	Misclassification Percentage by Class										Pct Unclass
	4	5	6	7	8	9	10	11	12	13	
29-May-07	100	50	50	0	0	0	-	-	-	0	0.0
30-May-07	100	17	40	0	0	0	0	0	0	-	0.0
4-Nov-08	-	0	0	0	-	0	0	0	0	0	0.0
5-Nov-08	-	0	-	-	-	0	-	-	-	-	0.0
23-Nov-10	-	0	0	0	0	0	75	0	0	-	1.0
24-Nov-10	-	0	0	0	0	0	75	0	0	-	1.0
7-Feb-12	0	22	0	0	0	0	0	0	0	0	0.0
8-Feb-12	0	25	0	0	0	0	50	0	0	0	0.0

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

Table 6-2 – Weight Validation History

Date	Mean Error and 1SD		
	GVW	Single Axles	Tandem
29-May-07	-2.3 ± 2.6	-2.7 ± 4.5	-2.6 ± 3.7
30-May-07	-0.1 ± 2.0	-1.3 ± 5.7	0.2 ± 3.4
4-Nov-08	-2.6 ± 1.9	-2.1 ± 7.4	-3.7 ± 2.4
5-Nov-08	-1.7 ± 2.0	-0.2 ± 7.5	-3.4 ± 2.4
23-Nov-10	0.8 ± 3.0	2.2 ± 4.7	0.5 ± 3.9
24-Nov-10	0.8 ± 3.0	2.2 ± 4.7	0.5 ± 3.9
7-Feb-12	-0.2 ± 2.8	-2.0 ± 4.9	1.4 ± 4.0
8-Feb-12	1.0 ± 2.8	1.4 ± 5.0	1.1 ± 3.5

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 underestimation of weights over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations to within LTPP SPS WIM equipment tolerances.

6.2 Comparison of Past Validation Results

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

Table 6-3 – Comparison of Post-Validation Results

Parameter	95 % Confidence Limit of Error	Site Values (Mean Error and 95% Confidence Interval)			
		30-May-07	5-Nov-08	24-Nov-10	8-Feb-12
Steering Axles	±20 percent	-1.3 ± 11.5	-0.2 ± 15.2	2.2 ± 9.5	1.4 ± 10.1
Tandem Axles	±15 percent	0.2 ± 6.9	-3.4 ± 4.8	0.5 ± 7.9	1.1 ± 7.2
GVW	±10 percent	-0.1 ± 4.0	-1.7 ± 4.0	0.8 ± 6.1	1.0 ± 5.6

From Table 6-3, it appears that the mean error and the 95% confidence interval have remained reasonably consistent for all weights since the equipment was installed.

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

Table 6-4 – Final Factors

Speed Point	MPH	Left		Right	
		1	3	2	4
80	50	3239	3239	3717	3312
88	55	3221	3221	3687	3275
96	60	3184	3184	3644	3248
104	65	3172	3172	3631	3235
112	70	3095	3095	3542	3156
Axle Distance (cm)		246			
Dynamic Comp (%)		112			
Loop Width (cm)		325			

A review of the LTPP Standard Release Database 25 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.

7 Post Visit Data Analysis

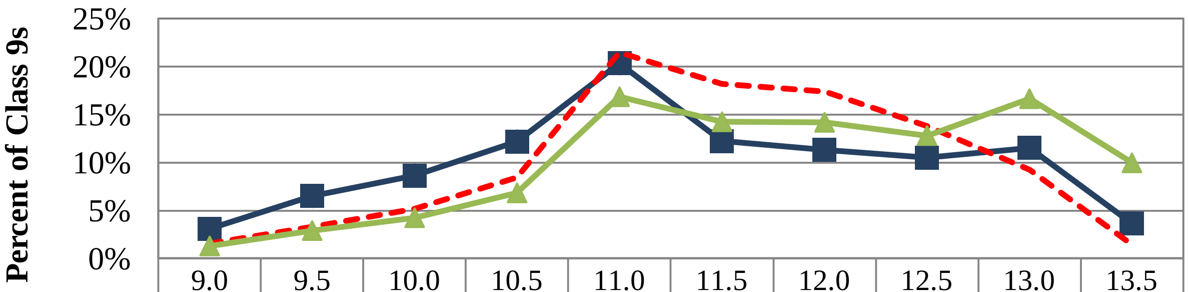
As part of the Post-Visit Data Analysis, conducted 7 days after the validation of a site where a calibration was conducted, data from the site is compared with the pre-visit data to determine if the calibration was successful in making the Class 9 GVW and Steering Axle weights consistent with the Comparison Data Set.

Prior to conducting the Post-Visit analysis, it was reported by IRD, who performs data quality checks, that the average steering axle weights have increased beyond expected parameters as a result of the calibration. As shown in Table 7-1, the average steering axle weight increased by 7.1 percent between the Pre-Validation Data Sample and the Post-validation Data Sample.

Figure 7-1 – Class 9 Steering Axle Weights

	Pre-Val (Jan, 2012)	Post-Val (Feb, 2012)
Average Steer Axle	11.2	12.0

In performing the Post-Visit analysis, it was determined that the percentage of light axles decreased and the percentage of heavy axles increased, as expected. The percentage of very heavy steering axles (13 kips and over), increased substantially as a result of the calibration. This increase is driving the increase in average steering axle weights, since over 25 percent of the trucks fall into this category.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	3.1%	6.5%	8.6%	12.2%	20.3%	12.2%	11.3%	10.5%	11.5%	3.7%
CDS	1.6%	3.3%	5.2%	8.5%	21.5%	18.2%	17.4%	13.8%	9.2%	1.5%
Post	1.3%	2.9%	4.2%	6.8%	16.9%	14.2%	14.2%	12.8%	16.6%	10.0%

Figure 7-2 – Class 9 Steering Axle Weights

Additionally, it was reported by IRD that the damaged axle sensor discussed earlier in this report was disabled in January, 2011. This was shortly after the Validation of November, 2010, and after the Comparison Data Set was developed. The Pre-Validation Sample Data (Data) plots in the figure above indicate that this may have had an effect on the steering axle weights where the percentage of light axles decreased and the percentage of heavy axles decreased. These two affects appeared to have canceled one another out, and the average steering axle weight remained consistent with the Comparison Data Set (CDS) value, which was not detected during regular data QA checks.

As a result of the Pre-Validation, where the steering axle weight of the Primary Truck was 11.5 kips, and the steering axle weight of the Secondary truck was 10.1, the steering axle error trends based on speed for each truck were opposite. As shown in Figure 7-3, the steering axle weights of the fully loaded Primary truck increased as speed increased, and the steering axle weights of the Secondary truck decreased as speed increased.

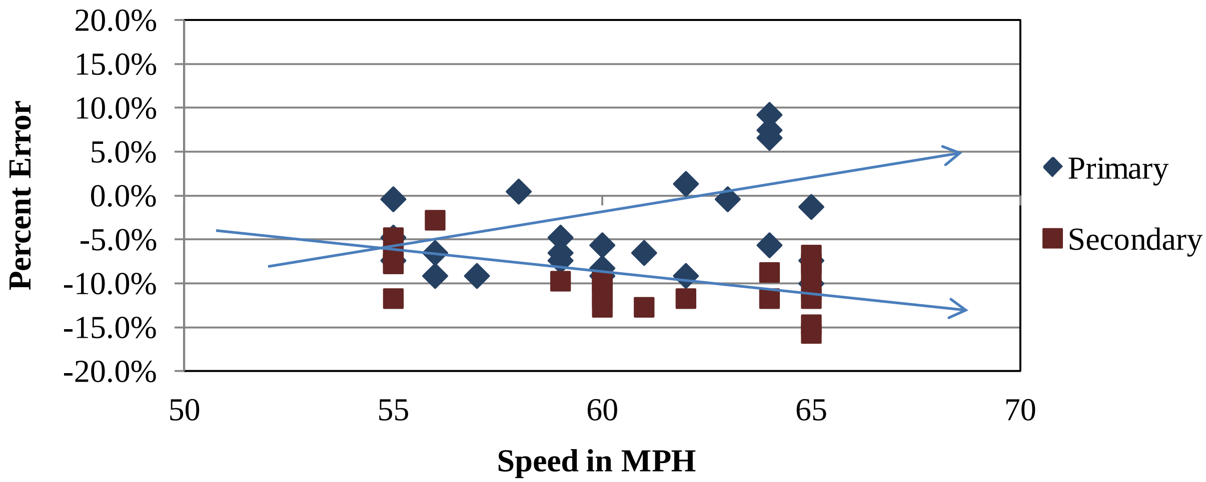


Figure 7-3 – Pre-Validation Steering Axle Error Trend by Speed

For the calibration, where there is a single adjustment factor (Dynamic Compensation Factor) for all steering axle errors, the measurement error for both trucks at all speeds was averaged, and the steering axle compensation factor was increased by 9 percent. The results of the Post-Validation, as shown in Figure 7-4, indicate that the adjustment to the steering axle correction factor not only decreased the bias of the system in measuring steering axle errors for both trucks, the error trend for each truck was nearly removed.

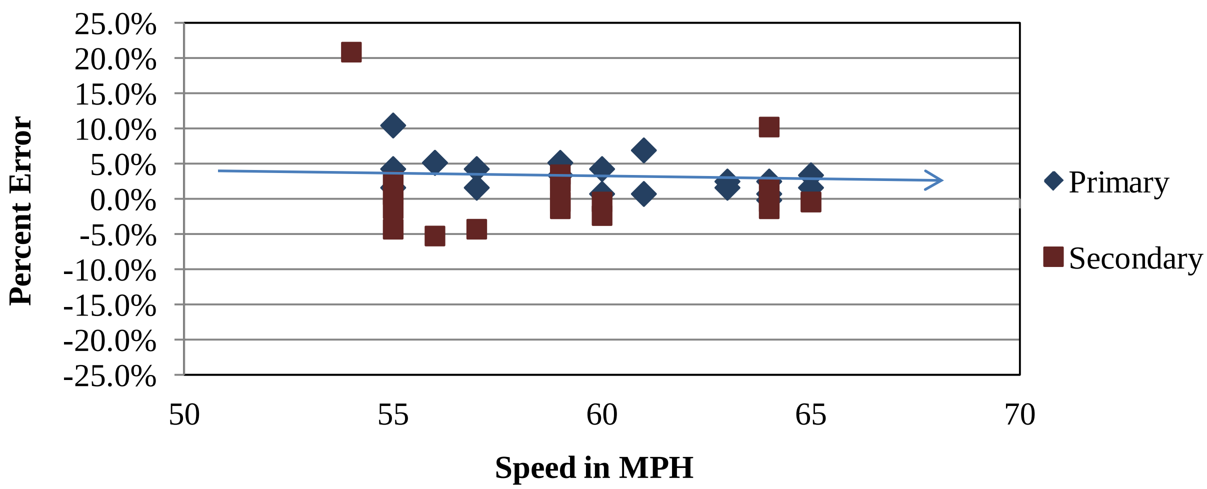


Figure 7-4 – Post-Validation Steering Axle Error by Speed by Truck

It appears that although the adjustment to the steering axle correction factor improved the ability to estimates steering axle weights for the validation test trucks, the adjustment has increased the weights of all steering axle weights, including those that were not affected by the disabling of the axle sensor.

Therefore, it is recommended that equipment repairs be performed to return the equipment to full operating condition and then a validation of the WIM system be conducted. Until such time as the sensor can be replaced, it is recommended that the Dynamic Compensation Factor be reset to where it was prior to the validation. However, this action could result in excessive negative bias in steering axle weight measurement observed prior to the latest system calibration.

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

Pennsylvania, SPS-6
SHRP ID: 420600

Validation Date: February 7, 2012

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior (Back)

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

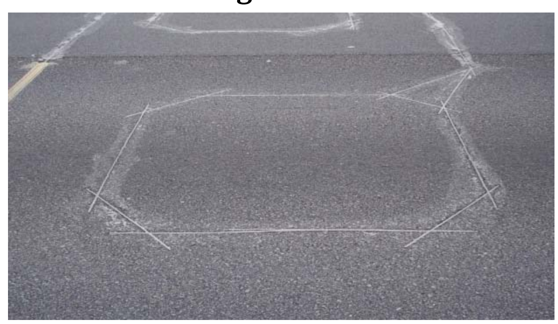


Photo 7 – Trailing Loop Sensor

Photo 8 – Solar Panel

Photo 9 – Cellular Modem

Photo 10 – Downstream

Photo 11 – Upstream

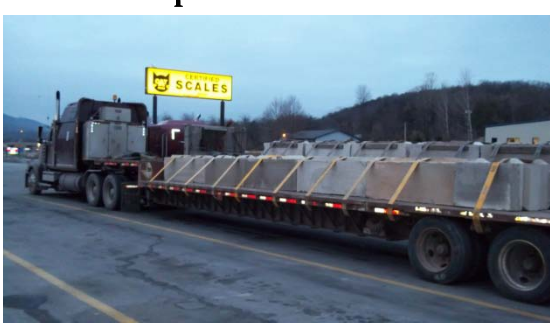


Photo 12 – Truck 1

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

Photo 27- Kistler Sensor Damage

Photo 28_Kistler Sensor Damage-2

Traffic Sheet 16	STATE CODE:	42
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	420600
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	2/8/2012

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 2/8/12

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

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

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

5. EQUIPMENT MANUFACTURER: IRD 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	steel spring
Truck 3:			

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

Mean Difference Between -

	Mean		Standard Deviation
Dynamic and Static GVW:	1.0%	Standard Deviation:	2.8%
Dynamic and Static Single Axle:	1.4%	Standard Deviation:	5.0%
Dynamic and Static Double Axles:	1.1%	Standard Deviation:	3.5%

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

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	54.0	to	57.7	14
b.	Medium	-	57.8	to	61.4	13
c.	High	-	61.5	to	65.0	13
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	42
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	420600
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	2/8/2012

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3184 | 3644

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 - Post

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: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/7/2012

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 2/7/12

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

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

4. **SENSORS INSTALLED IN LTPP LANE AT THIS SITE** (Select all that apply):
   a. Inductance Loops
   b. Quartz Piezo
   c.
   d.

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

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

Number of Trucks Compared:
Number of Test Trucks Used: 2
Passes Per Truck: 24

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air	air
Truck 2:	9	air	steel spring
Truck 3:			

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

Mean Difference Between -

Dynamic and Static GVW:	-0.2%	Standard Deviation:	2.8%
Dynamic and Static Single Axle:	-2.0%	Standard Deviation:	4.9%
Dynamic and Static Double Axles:	1.4%	Standard Deviation:	4.0%

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

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

			Low		High	Runs
a.	Low	-	55.0	to	58.3	14
b.	Medium	-	58.4	to	61.8	14
c.	High	-	61.9	to	65.0	20
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/7/2012

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3184 | 3644

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:	-1.0	FHWA Class		-	
FHWA Class 8:	Unk	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: 717-975-3448

E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/8/2012

Count - 101 Time = 1:04:52 Trucks (4-15) - 100 Class 3s - 1

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	9	7675	62	9	59	9	7926	57	9
65	7	7727	65	7	64	10	8013	63	10
62	7	7729	66	7	57	5	8016	54	5
65	6	7747	64	6	**59**	**4**	**8018**	**59**	**5**
64	9	7761	66	9	70	9	8030	69	9
64	9	7795	61	9	64	8	8033	64	8
68	5	7797	63	5	62	11	8083	63	11
65	9	7801	64	9	64	12	8085	62	12
63	9	7813	64	9	62	9	8095	61	9
66	9	7816	64	9	60	9	8096	59	9
47	6	7820	46	6	62	9	8101	66	9
64	7	7831	63	7	65	9	8104	63	9
67	**5**	**7852**	**66**	**3**	64	9	8138	64	9
66	7	7857	64	7	54	9	8140	53	9
66	9	7866	66	9	75	9	8146	72	9
60	9	7869	60	9	68	9	8159	67	9
60	9	7870	60	9	62	9	8163	62	9
67	9	7874	66	9	64	9	8165	62	9
65	9	7894	65	9	66	9	8167	63	9
61	11	7895	62	11	55	8	8176	55	8
68	11	7901	62	11	62	9	8191	57	9
65	9	7906	65	9	59	9	8194	60	9
65	11	7909	65	11	62	9	8206	63	9
65	4	7910	64	4	65	9	8207	62	9
65	11	7920	62	11	62	9	8209	62	9

Sheet 1 - 0 to 50 Start: 11:48:30 Stop: 12:18:59

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Post

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/8/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	9	8253	65	9	61	11	8447	60	11
71	9	8254	69	9	65	9	8449	64	9
65	9	8261	67	9	64	7	8450	60	7
70	9	8265	70	9	64	9	8462	66	9
67	9	8266	65	9	66	9	8463	65	9
64	9	8269	62	9	64	9	8467	69	9
47	6	8272	46	6	70	11	8610	68	11
68	8	8317	66	8	61	9	8615	60	9
31	**14**	**8344**	**71**	**10**	69	9	8621	67	9
65	6	8353	65	6	68	9	8623	67	9
59	9	8356	58	9	72	9	8683	71	9
69	9	8365	66	9	55	6	8691	55	6
72	9	8370	70	9	61	9	8692	57	9
72	9	8371	69	9	62	9	8715	63	9
64	9	8380	64	9	67	9	8719	67	9
61	7	8386	59	7	62	9	8720	62	9
65	9	8389	62	9	62	12	8725	64	12
65	9	8392	63	9	56	9	8729	54	9
68	8	8395	66	8	57	9	8730	54	9
66	5	8402	67	5	57	7	8734	55	7
70	7	8403	66	7	65	9	8740	70	9
62	12	8423	59	12	74	9	8756	73	9
67	9	8424	63	9	66	9	8760	64	9
69	9	8426	69	9	68	9	8777	67	9
64	9	8433	64	9	65	12	8786	62	12

Sheet 2 - 51 to 100 Start: 12:21:40 Stop: 12:52:24

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Post

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/8/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	9	8811	61	9					

Sheet 3 - 101 - 150 Start: 12:53:22 Stop: 12:53:22

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Post

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/7/2012

Count - 103 Time = 3:17:25 Trucks (4-15) - 100 Class 3s - 3

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
67	9	770	67	9	62	9	1448	61	9
62	9	776	60	9	65	9	1453	63	9
69	7	784	69	7	69	9	1456	70	9
65	9	787	63	9	68	9	1489	65	9
66	9	791	65	9	65	9	1496	68	9
66	9	800	64	9	67	7	1500	66	7
73	9	819	73	9	64	5	1510	63	5
67	9	822	60	9	72	9	1512	72	9
68	9	833	65	9	**66**	**5**	**1519**	**63**	**3**
62	9	836	65	9	65	9	1521	65	9
65	9	839	66	9	65	10	1524	63	10
69	6	841	69	6	73	9	1546	70	9
68	6	842	65	6	55	6	2287	55	6
66	9	854	65	9	66	9	2293	66	9
62	9	855	60	9	67	10	2319	66	10
56	5	866	58	5	65	7	2321	63	7
62	9	868	62	9	67	9	2349	68	9
71	9	874	68	9	70	9	2355	70	9
70	12	880	69	12	71	9	2360	72	9
67	9	886	66	9	60	9	2366	60	9
65	11	888	65	11	64	9	2372	63	9
65	9	898	65	9	65	5	2381	63	5
62	9	1427	62	9	64	6	2382	63	6
65	9	1436	64	9	67	9	2389	65	9
62	9	1441	65	9	65	9	2393	66	9

Sheet 1 - 0 to 50 Start: 13:11:59 Stop: 14:40:48

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/7/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
60	9	2413	61	9	67	9	4553	65	9
62	9	2445	61	9	67	9	4558	66	9
64	9	2448	65	9	60	9	4560	58	9
59	9	2450	59	9	65	9	4576	65	9
64	7	2452	63	7	65	9	4583	66	9
67	9	2459	67	9	63	9	4588	60	9
64	5	2466	64	5	68	9	4591	66	9
65	9	2477	65	9	67	9	4597	65	9
63	9	2479	64	9	69	9	4635	68	9
55	10	2487	53	10	65	9	4647	67	9
67	5	2502	66	5	69	9	4650	67	9
65	9	2505	65	9	68	12	4652	68	12
59	9	2518	55	9	62	11	4692	65	11
62	9	2523	58	9	65	9	4695	63	9
64	9	2527	67	9	67	9	4708	65	9
62	9	2530	59	9	69	9	4716	70	9
65	**5**	**2538**	**65**	**3**	69	5	4719	66	5
67	**8**	**2541**	**58**	**5**	68	7	4720	68	7
62	**8**	**2541**	**56**	**5**	70	9	4728	70	9
67	9	4466	67	9	65	9	4729	65	9
68	9	4504	68	9	68	9	4747	66	9
62	5	4507	62	5	64	9	4756	65	9
67	9	4515	67	9	65	6	4760	63	6
62	11	4516	62	11	59	9	4769	59	9
70	**5**	**4535**	**68**	**3**	70	9	4774	71	9

Sheet 2 - 51 to 100 Start: 14:41:23 Stop: 16:27:07

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 2/7/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	12	4788	63	12					
62	9	4806	62	9					
68	7	4836	65	7					

Sheet 3 - 101 - 150 Start: 16:27:37 Stop: 16:29:24

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre