WIM System Field Calibration and Validation Summary Report

Pennsylvania SPS-6
SHRP ID – 420600

Validation Date: October 1, 2013
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1 Executive Summary

A WIM validation was performed on October 1 and 2, 2013 at the Pennsylvania SPS-6 site located on route I-80, milepost 158.2, and 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 Kistler 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 February 8, 2012 and this validation visit, it appears that one of the two sensors that was previously omitted from the system configuration was re-installed as part of the configuration. Three of the four sensors are now being utilized. No other changes have occurred during this time to the basic operating condition of the equipment.

With the exception of the right section of the trailing sensor, 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. The leading WIM sensor has missing eopoxy at the conduit exit in the shoulder. The sensors do not show signs of 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, no distresses were 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 truck dynamics. 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 – Validation Results – 1-Oct-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-0.2 ± 8.1%	Pass
Single Axles	±20 percent	0.1 ± 6.6%	Pass
Tandem Axles	±15 percent	0.9 ± 5.7%	Pass
GVW	±10 percent	0.7 ± 4.3%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	-0.8 ± 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 0.2 ± 2.0 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 0.9% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 1.7% from the 119 vehicle sample (Class 4 – 13) was due to one Class 5 vehicle that was misclassified as a Class 4 vehicle, and one Class 13 that was not classified by the system (Class 15).

There were two test trucks used for the 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 barriers.

- 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 standard tandem on the trailer. The Secondary truck was loaded with concrete barriers.

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 validation test truck weights and measurements are provided in Table 1-2.

Table 1-2 – 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	78.1	10.7	16.7	16.7	17.0	17.0	16.2	4.3	40.0	4.6	65.1	69.7
2	62.9	9.9	13.4	13.4	13.1	13.1	15.9	4.3	27.5	10.2	57.9	65.5

The posted speed limit at the site is 65 mph. During the testing, the speed of the test trucks ranged from to 53 to 66 mph, a variance of 13 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The validation pavement surface temperatures varied from 68.4 to 106.0 degrees Fahrenheit, a range of 37.6 degrees Fahrenheit. The sunny weather conditions provided the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 27 shows that there are 6 years of level “E” WIM data for this site. This site does not require any additional years of data to meet the minimum of five years of research quality data.

2 WIM System Data Availability and Pre-Visit Data Analysis

To assess the quality of the current traffic data, a pre-visit analysis was conducted by comparing a two-week data sample from August 12, 2013 (Data) to the most recent Comparison Data Set (CDS) from February 6, 2012. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 27 shows that there are 6 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	211	8
2008	362	12
2009	362	12
2010	360	12
2011	365	12
2012	232	8

As shown in the table, this site does not require any additional years of data to meet the minimum of five years of research quality data.

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

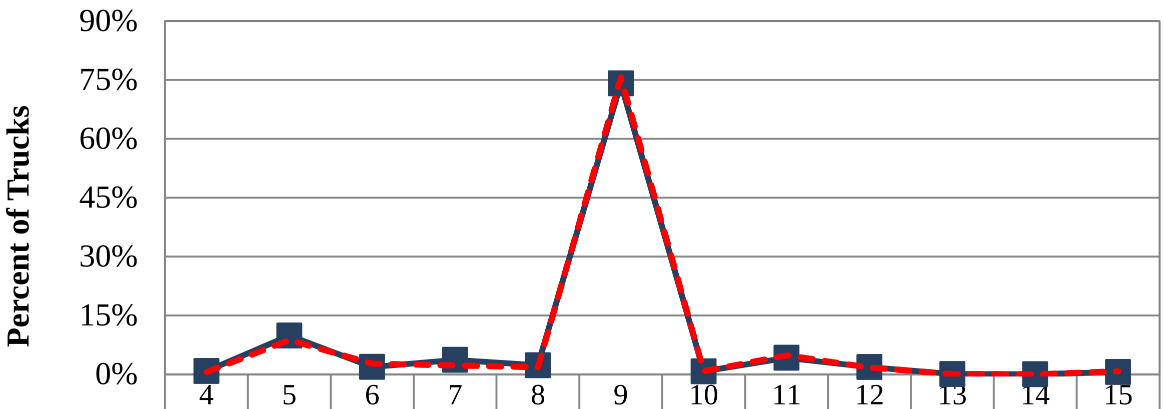
Table 2-2 – LTPP Data Availability by Month

Year	Month												No. of Months
	1	2	3	4	5	6	7	8	9	10	11	12	
2007					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	27	30	30	31	30	31	29	30	31	29	31	12
2011	31	28	31	30	31	30	31	31	30	31	30	31	12
2012	31	29	31	30	31	30	31	19					8

2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site.

Figure 2-1 provides a comparison of the truck type distributions between the sample dataset from August 12, 2013 (Data) and the most recent comparison Data Set (CDS) from February 6, 2012.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	0.8%	9.9%	1.9%	3.7%	2.3%	74.1%	0.7%	4.2%	1.8%	0.1%	0.0%	0.6%
CDS	0.5%	8.8%	2.7%	2.3%	1.8%	75.7%	0.8%	4.8%	1.7%	0.1%	0.0%	0.8%

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 (74.1%) and Class 5 (9.9%) 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 0.6 percent of the vehicles at this site are unclassified.

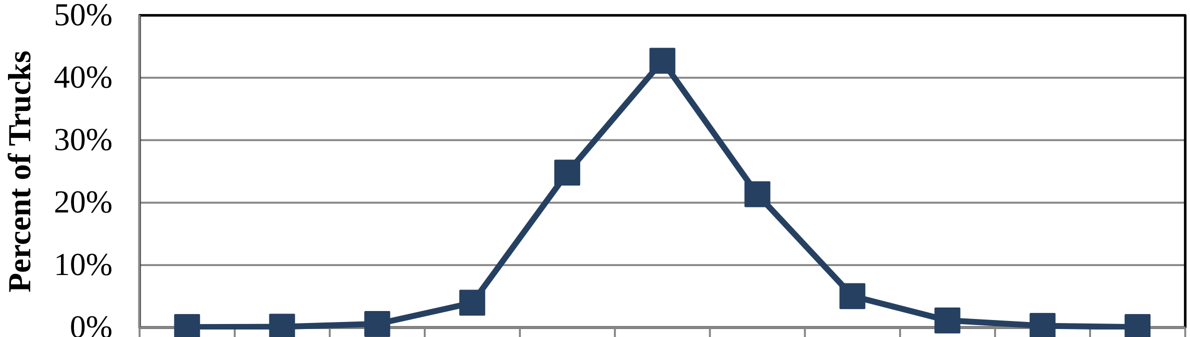
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	2/6/2012		8/12/2013		
4	357	0.5%	528	0.8%	0.3%
5	5699	8.8%	6404	9.9%	1.1%
6	1767	2.7%	1215	1.9%	-0.8%
7	1473	2.3%	2387	3.7%	1.4%
8	1177	1.8%	1498	2.3%	0.5%
9	49176	75.7%	48164	74.1%	-1.6%
10	512	0.8%	486	0.7%	0.0%
11	3147	4.8%	2724	4.2%	-0.7%
12	1133	1.7%	1189	1.8%	0.1%
13	33	0.1%	38	0.1%	0.0%
14	0	0.0%	0	0.0%	0.0%
15	525	0.8%	366	0.6%	-0.2%

From the table it can be seen that the percentage of Class 9 vehicles has decreased by 1.6 percent from February 2012 and August 2013. Changes in the percentage of heavier trucks may be attributed to natural and seasonal variations in truck distributions and a decrease in goods movement during current economic cycle. During the same time period, the percentage of Class 5 trucks increased by 1.1 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

2.3 Speed Data Analysis

The traffic data received from the Phase II Contractor was analyzed to determine the expected truck speed distributions. This will provide a basis for determining the speed of the test trucks during validation testing. The CDS distribution of speeds is shown in Figure 2-2.



	45	50	55	60	65	70	75	80	85	90	95
Data	0.1%	0.1%	0.6%	3.9%	24.8%	42.7%	21.3%	5.0%	1.1%	0.3%	0.1%

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

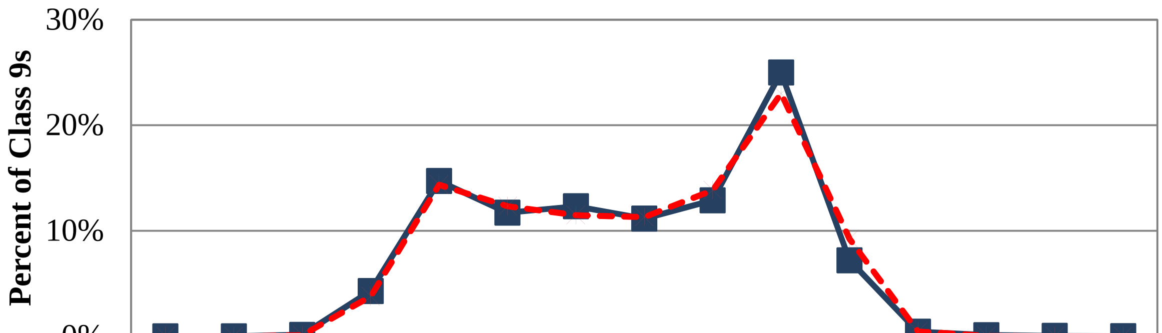
As shown in Figure 2-2, the majority of the trucks at this site are traveling between 65 and 75 mph. The posted speed limit at this site is 65 and the 85th percentile speed for trucks at this site is 73 mph. The expected range of truck speeds for the validation is 55 to 65 mph.

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 August 2013 and the Comparison Data Set from February 2012.

As shown in the figure, the loaded and unloaded peaks between the February 2012 Comparison Data Set (CDS) and the August 2013 two-week sample W-card dataset (Data) are similar.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.1%	4.3%	14.7	11.7	12.3	11.2	12.9	25.0	7.2%	0.4%	0.1%	0.0%	0.0%
CDS	0.0%	0.0%	0.1%	3.8%	14.4	12.3	11.5	11.3	13.9	23.0	9.2%	0.5%	0.1%	0.0%	0.0%

GVW in Kips

Figure 2-3 – Comparison of Class 9 GVW Distribution

Table 2-4 is provided to show the statistical comparison for Class 9 GVW between the Comparison Data Set and the current dataset.

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

GVW weight bins (kips)	CDS		Data		Change
	Date				
	2/6/2012		8/12/2013		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	51	0.1%	66	0.1%	0.0%
32	1865	3.8%	2063	4.3%	0.5%
40	7057	14.4%	7073	14.7%	0.3%
48	6059	12.3%	5630	11.7%	-0.6%
56	5637	11.5%	5921	12.3%	0.8%
64	5552	11.3%	5360	11.2%	-0.2%
72	6804	13.9%	6193	12.9%	-1.0%
80	11305	23.0%	12013	25.0%	2.0%
88	4528	9.2%	3461	7.2%	-2.0%
96	225	0.5%	206	0.4%	0.0%
104	25	0.1%	52	0.1%	0.1%
112	7	0.0%	16	0.0%	0.0%
120	1	0.0%	5	0.0%	0.0%
Average =	59.6 kips		59.2 kips		-0.4 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range increased by 0.3 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range increased by 2.0 percent. During this time period, the percentage of overweight trucks decreased by 1.9 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site decreased by 0.6 percent, from 59.6 to 59.2 kips.

2.5 Class 9 Front Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from August 2013 and the Comparison Data Set from February 2012. The percentage of light axles (9.5 to 10.5 kips) increased by approximately 1.2 percent and the percentage of heavy axles (11.5 to 12.5 kips) increased by approximately 5.1%.

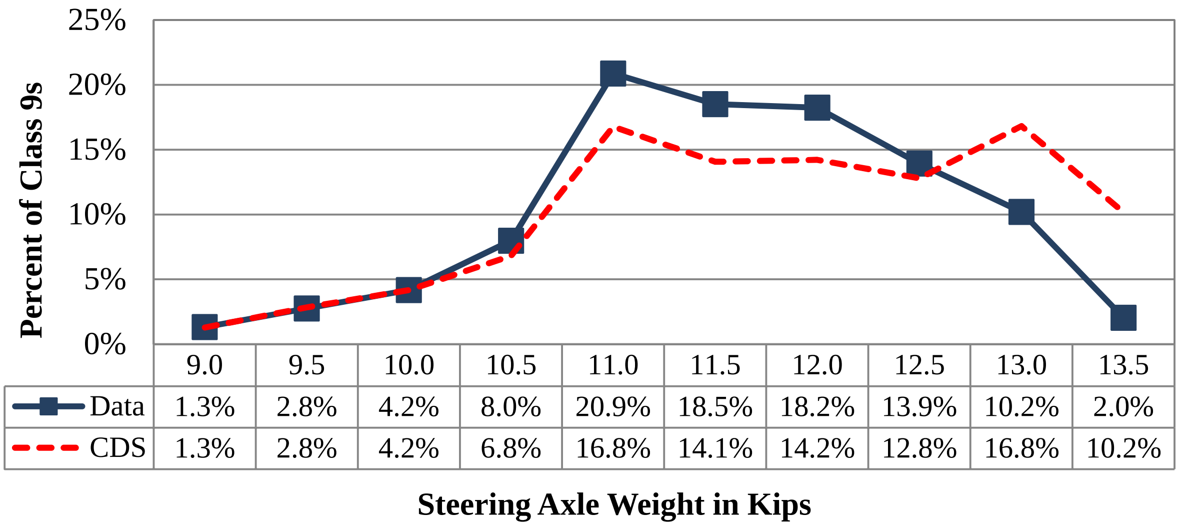


Figure 2-4 – Distribution of Class 9 Front Axle Weights

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 11.0 and 12.0 kips. The percentage of trucks in this range has increased between the February 2012 Comparison Data Set (CDS) and the August 2013 dataset (Data).

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

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

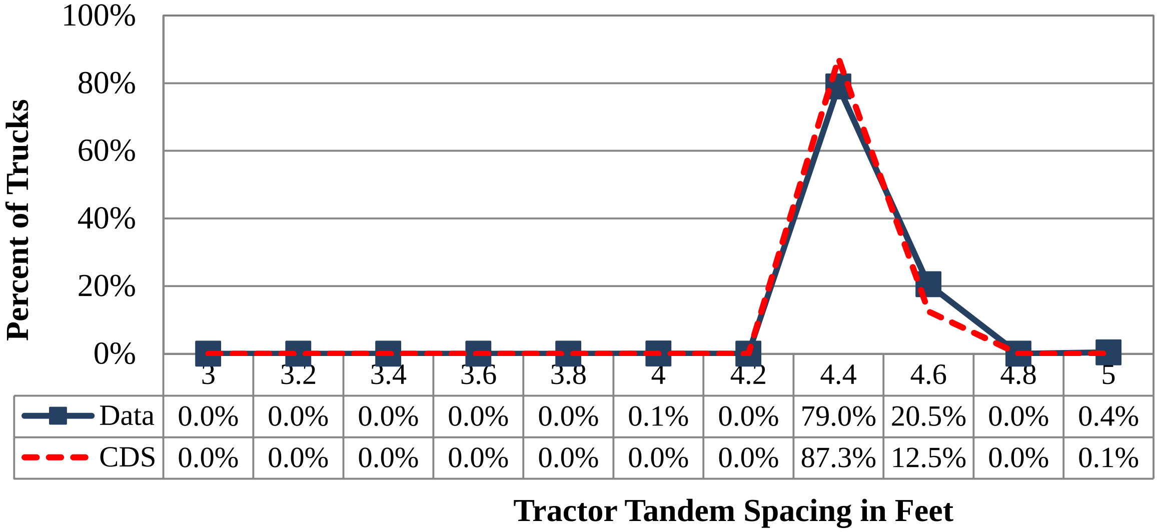
F/A weight bins (kips)	CDS		Data		Change
	Date				
	2/6/2012		8/12/2013		
9.0	539	1.3%	622	1.3%	0.0%
9.5	1193	2.8%	1307	2.8%	-0.1%
10.0	1749	4.2%	1979	4.2%	0.0%
10.5	2858	6.8%	3785	8.0%	1.2%
11.0	7035	16.8%	9902	20.9%	4.1%
11.5	5903	14.1%	8779	18.5%	4.4%
12.0	5965	14.2%	8650	18.2%	4.0%
12.5	5366	12.8%	6607	13.9%	1.1%
13.0	7056	16.8%	4839	10.2%	-6.6%
13.5	4270	10.2%	966	2.0%	-8.1%
Average =	12.0 kips		11.4 kips		-0.6 kips

The table shows that the average front axle weight for Class 9 trucks has decreased by 0.6 kips, or 5.0 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.4 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

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

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



	3	3.2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5
Data	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	79.0%	20.5%	0.0%	0.4%
CDS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	87.3%	12.5%	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 February 2012 Comparison Data Set and the August 2013 Data are similar.

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				
	2/6/2012		8/12/2013		
3.0	0	0.0%	1	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	0	0.0%	4	0.0%	0.0%
4.0	13	0.0%	25	0.1%	0.0%
4.2	0	0.0%	0	0.0%	0.0%
4.4	44253	87.3%	37581	79.0%	-8.3%
4.6	6351	12.5%	9771	20.5%	8.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	76	0.1%	192	0.4%	0.3%
Average =	4.4 feet		4.4 feet		0.0 feet

From the table it can be seen that the majority of drive tandem spacings for Class 9 trucks at this site are between 4.4 and 4.6 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.4, which is identical to the expected average of 4.4 from the CDS per vehicle records. However, based on the increase of spacings in the 4.4 to 4.6 foot range that the tractor tandem spacing has increased slightly. Further axle spacing analyses are performed during the validation and validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (February 2012) based on the last calibration with the most recent two-week WIM data sample from the site (August 2013). Comparison of vehicle class distribution data indicates a 1.6 percent decrease in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have decreased by 5.0 percent and average Class 9 GVW has decreased by 0.6 percent for the August 2013 data. The data indicates an average truck tandem spacing of 4.4 feet, which is identical to the expected average of 4.4 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on February 8, 2012 and this validation visit, it appears that one of the two WIM sensor segments that was removed from the operational setup due to failure was returned to the setup. It appears that 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 2, 2007 by International Road Dynamics. It is instrumented with Kistler 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 validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented after Section 8.

3.3 Electronic and Electrical Testing

Electronic and electrical checks of all system components were conducted prior to the 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 with the exception of WIM sensor 3, which is the right sensor segment for the trailing WIM sensor. With this sensor installed in the operating parameters the system demonstrated intermittent vehicle measurement and reporting errors, and so it was removed from the system setup by the Phase II contractor. Electronic tests of the power and communication devices indicated that they were operating normally.

3.4 Equipment Troubleshooting and Diagnostics

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

3.5 Recommended Equipment Maintenance

Replacing the sensor that demonstrates intermittent errors may improve system precision. No other unscheduled equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

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

4.2 LTPP Pavement Profile Data Analysis

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

Table 4-1 – Recommended WIM Smoothness Index Thresholds

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

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

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

Table 4-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass 5**	**Avg**
Left	LWP	LRI (m/km)	*0.404*	*0.378*	*0.370*			*0.384*
		SRI (m/km)	*0.289*	*0.186*	*0.206*			*0.227*
		Peak LRI (m/km)	0.541	0.558	0.532			0.544
		Peak SRI (m/km)	*0.512*	*0.331*	*0.395*			*0.413*
	RWP	LRI (m/km)	*0.476*	*0.424*	*0.455*			*0.452*
		SRI (m/km)	*0.405*	*0.315*	*0.306*			*0.342*
		Peak LRI (m/km)	*0.492*	0.501	*0.469*			*0.487*
		Peak SRI (m/km)	*0.710*	*0.557*	*0.624*			*0.630*
Center	LWP	LRI (m/km)	0.579	0.573	0.545	0.505	0.539	0.548
		SRI (m/km)	0.628	0.566	0.583	0.646	0.750	0.635
		Peak LRI (m/km)	0.579	0.573	0.545	0.536	0.540	0.555
		Peak SRI (m/km)	**0.848**	**0.761**	***0.747***	**0.810**	**0.837**	**0.801**
	RWP	LRI (m/km)	*0.377*	*0.354*	*0.382*	*0.435*	*0.417*	*0.393*
		SRI (m/km)	*0.225*	*0.273*	*0.254*	*0.322*	*0.326*	*0.280*
		Peak LRI (m/km)	*0.495*	0.500	*0.489*	*0.470*	0.544	*0.500*
		Peak SRI (m/km)	*0.462*	*0.296*	*0.383*	*0.477*	*0.405*	*0.405*
Right	LWP	LRI (m/km)	0.549	0.572	0.556			0.559
		SRI (m/km)	*0.471*	0.547	*0.457*			*0.492*
		Peak LRI (m/km)	0.600	0.572	0.563			0.578
		Peak SRI (m/km)	*0.712*	*0.615*	*0.659*			*0.662*
	RWP	LRI (m/km)	*0.379*	*0.395*	*0.412*			*0.395*
		SRI (m/km)	*0.140*	*0.244*	*0.184*			*0.189*
		Peak LRI (m/km)	0.553	*0.480*	*0.477*			0.503
		Peak SRI (m/km)	*0.282*	*0.495*	*0.291*			*0.356*

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

4.3 Profile and Vehicle Interaction

Profile data was collected on July 9th, 2012 by the North Central Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, beginning 900 feet prior to WIM scales and ending 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 1000 foot WIM section is 229 in/mi and is located approximately 881 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 68 in/mi and is located approximately 130 feet prior to the WIM scale. These areas of the pavement were closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed at these locations that would influence truck dynamics in the WIM scale area.

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

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

The following section provides summaries of data collected during the 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 Validation

The 43 validation test truck runs were conducted on October 1, 2013, beginning at approximately 10:12 AM and continuing until 3:33 PM.

The two test trucks consisted of:

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

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

Table 5-1 - 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	78.1	10.7	16.7	16.7	17.0	17.0	16.2	4.3	40.0	4.6	65.1	69.7
2	62.9	9.9	13.4	13.4	13.1	13.1	15.9	4.3	27.5	10.2	57.9	65.5

Test truck speeds varied by 13 mph, from 53 to 66 mph. The measured validation pavement temperatures varied 37.6 degrees Fahrenheit, from 68.4 to 106.0. The partly cloudy weather conditions provided the desired minimum 30 degree temperature range. Table 5-2 is a summary of post validation results.

Table 5-2 – Validation Overall Results – 1-Oct-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	+20 percent	-0.2 ± 8.1%	Pass
Single Axles	+20 percent	0.1 ± 6.6%	Pass
Tandem Axles	+15 percent	0.9 ± 5.7%	Pass
GVW	+10 percent	0.7 ± 4.3%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	-0.8 ± 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 0.2 ± 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 0.2 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 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 – Validation Results by Speed – 1-Oct-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		53.0 to 57.3 mph	57.4 to 61.8 mph	61.9 to 66.0 mph
Steering Axles	+20 percent	0.7 ± 9.7%	-1.2 ± 7.9%	-0.4 ± 7.7%
Single Axles	+20 percent	1.2 ± 7.0%	0.3 ± 5.9%	-1.4 ± 7.3%
Tandem Axles	+15 percent	2.2 ± 4.1%	0.6 ± 6.2%	-0.4 ± 5.9%
GVW	+10 percent	2.0 ± 3.9%	0.4 ± 5.4%	-0.4 ± 3.2%
Vehicle Length	±3.0 percent (2.0 ft)	-0.8 ± 1.2 ft	-0.7 ± 1.1 ft	-0.9 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.1 ± 2.6 mph	0.2 ± 1.8 mph	0.2 ± 1.7 mph
Axle Length	+ 0.5 ft [150mm]	0.2 ± 0.1 ft	0.2 ± 0.0 ft	0.2 ± 0.1 ft

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

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

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment estimated GVW with small positive bias at low speeds and small negative bias at high speeds. The range in error appears to be greater at the medium speeds when compared with the low and high speeds.

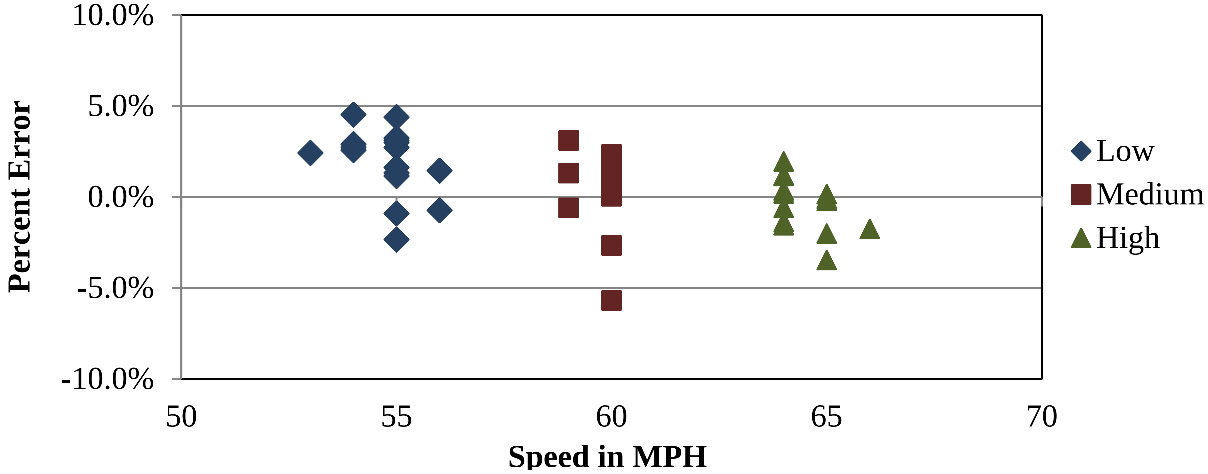


Figure 5-1 – Validation GVW Errors by Speed – 1-Oct-13

5.1.1.2 Steering Axle Weight Errors by Speed

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

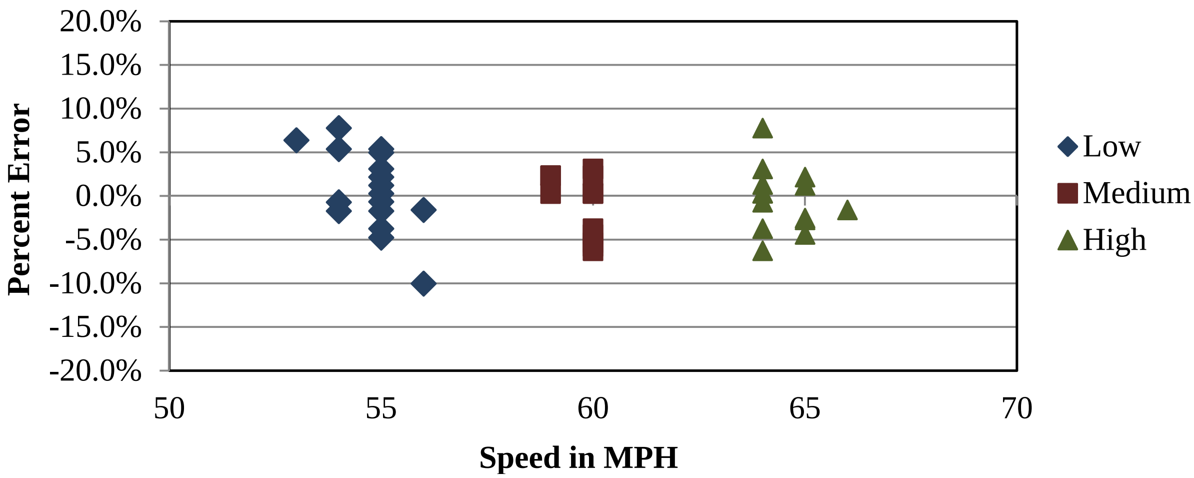


Figure 5-2 – Validation Steering Axle Weight Errors by Speed – 1-Oct-13

5.1.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment estimated single axle weights with similar accuracy at all speeds. The range in error is greater at the low and high speeds when compared with the medium speeds.

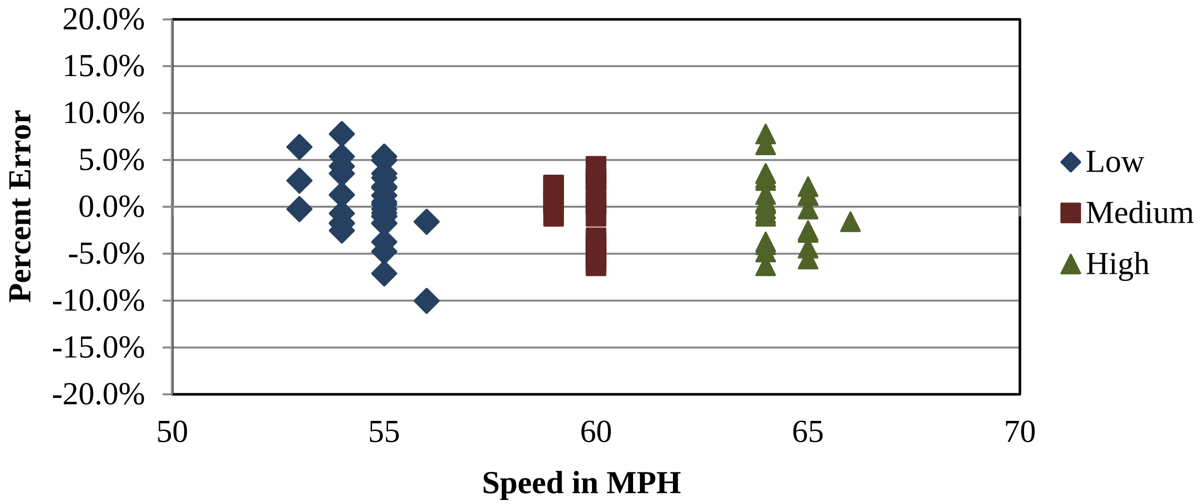


Figure 5-3 – Validation Single Axle Weight Errors by Speed – 1-Oct-13

5.1.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment estimated tandem axle weights with similar accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

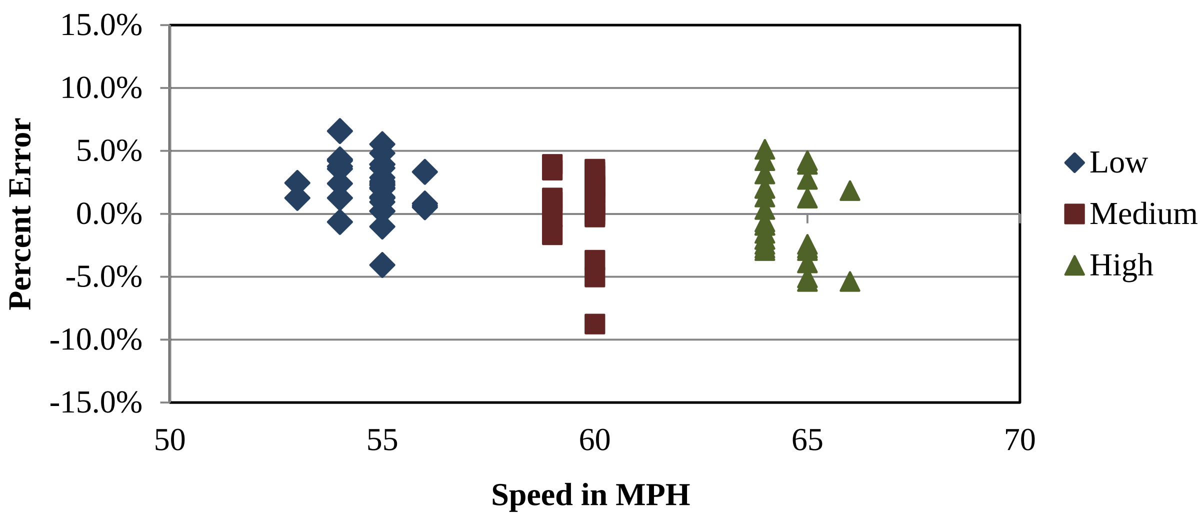


Figure 5-4 – Validation Tandem Axle Weight Errors by Speed – 1-Oct-13

5.1.1.5 GVW Errors by Speed and Truck Type

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

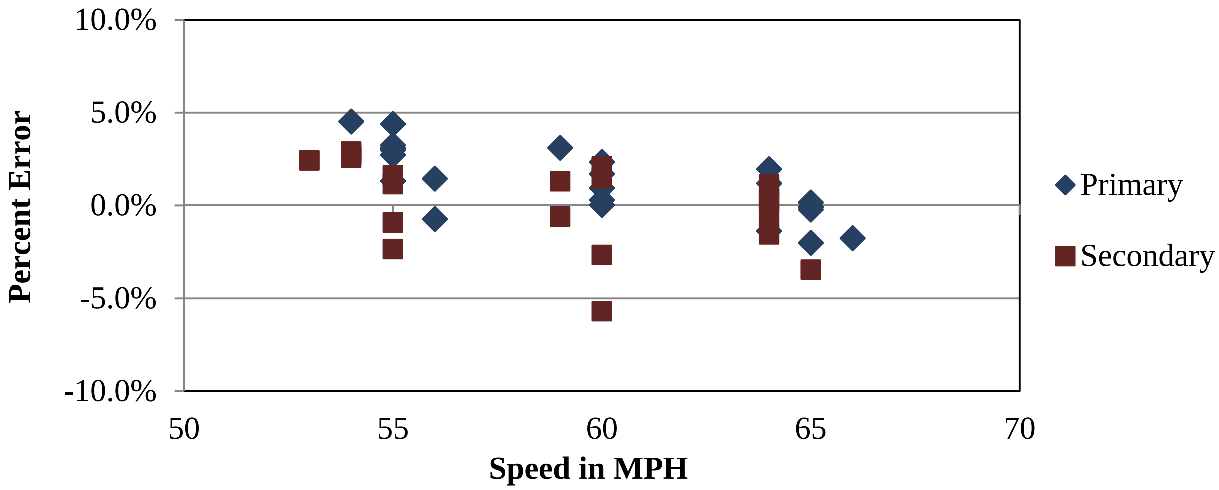


Figure 5-5 – Validation GVW Error by Truck and Speed – 1-Oct-13

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 was from 0.2 feet to 0.3 feet. Distribution of errors is shown graphically in Figure 5-6.

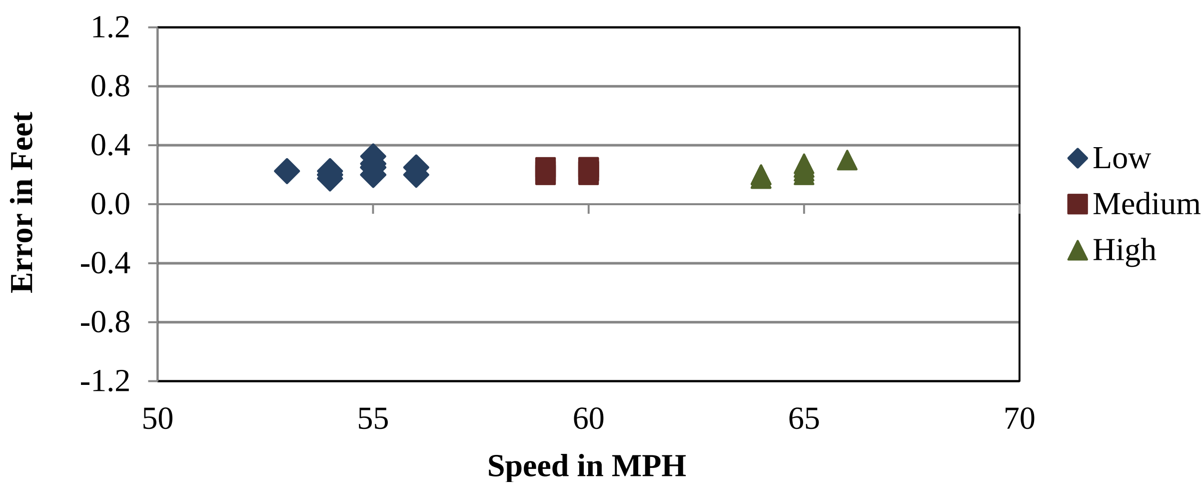


Figure 5-6 – Validation Axle Length Error by Speed – 1-Oct-13

5.1.1.7 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 -1.7 to 0.3 feet. Distribution of errors is shown graphically in Figure 5-7.

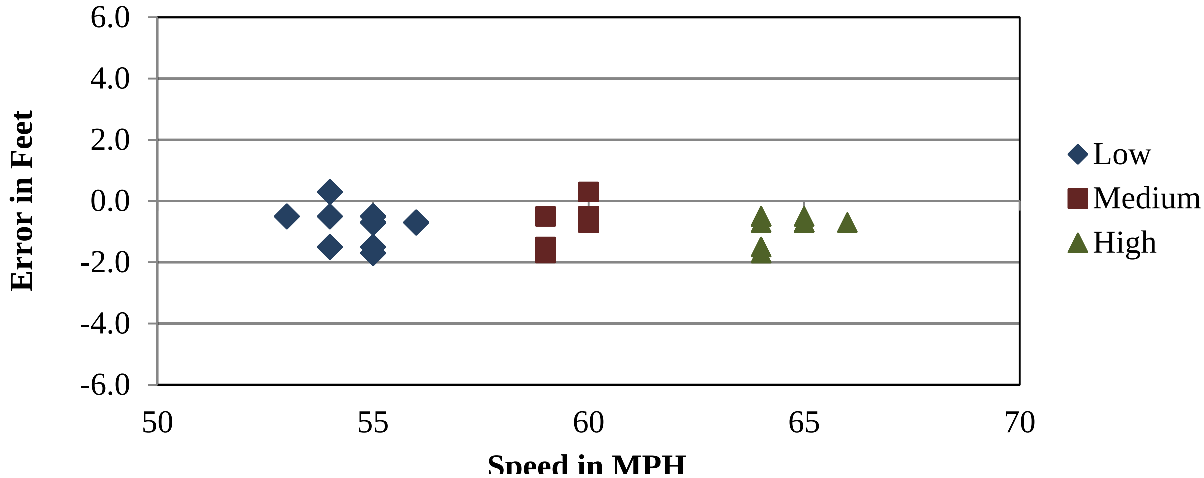


Figure 5-7 – Validation Overall Length Error by Speed – 1-Oct-13

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 37.6 degrees, from 68.4 to 106.0 degrees Fahrenheit. The validation test runs are reported under three temperature groups – low, medium and high, as shown in Table 5-4 below.

Table 5-4 – Validation Results by Temperature – 1-Oct-13

Parameter	95% Confidence Limit of Error	Low 68.4 to 81.0 degF	Medium 92.1 to 106.0 degF	High 92.1 to 106.0 degF
Steering Axles	+20 percent	1.6 ± 9.2%	2.4 ± 6.6%	-2.0 ± 7.5%
Single Axles	+20 percent	1.6 ± 8.5%	1.1 ± 6.4%	-0.8 ± 7.0%
Tandem Axles	+15 percent	2.0 ± 5.3%	1.6 ± 5.4%	0.2 ± 6.2%
GVW	+10 percent	1.9 ± 4.4%	1.7 ± 3.5%	-0.1 ± 4.5%
Vehicle Length	±3.0 percent (2.0 ft)	-1.0 ± 1.4 ft	-0.8 ± 1.3 ft	-0.8 ± 0.9 ft
Vehicle Speed	± 1.0 mph	-0.3 ± 1.1 mph	0.0 ± 1.0 mph	0.4 ± 2.5 mph
Axle Length	+ 0.5 ft [150mm]	0.2 ± 0.1 ft	0.2 ± 0.1 ft	0.2 ± 0.1 ft

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

5.1.2.1 GVW Errors by Temperature

From Figure 5-8, it can be seen that the equipment appears to estimate GVW with similar accuracy for the low and medium temperatures observed in the field. Due to a few underestimations, the range in error appears to be greater at the higher temperatures.

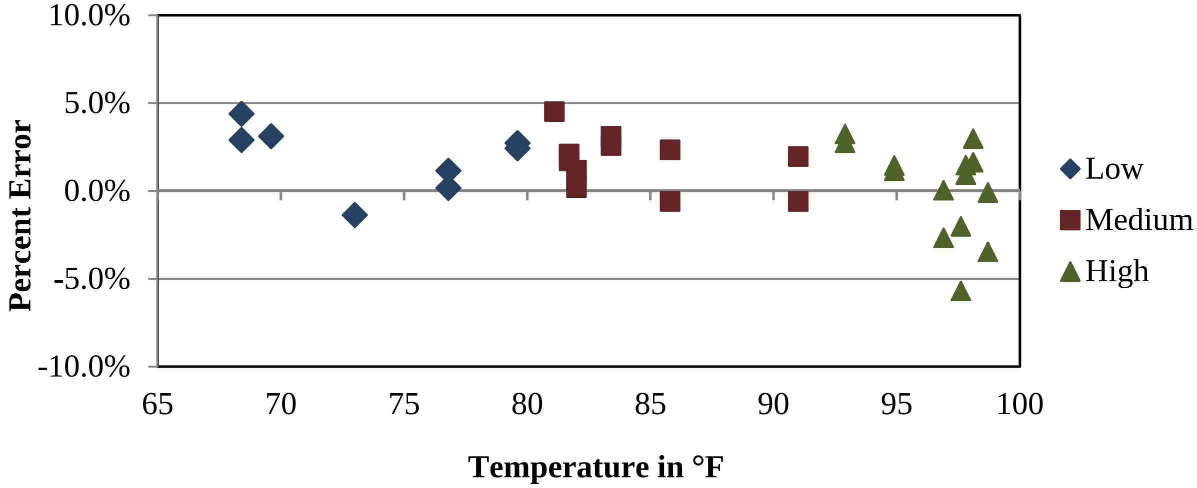


Figure 5-8 – Validation GVW Errors by Temperature – 1-Oct-13

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 demonstrates that for steering axles, the WIM equipment appears to estimate weights with similar accuracy across the range of temperatures observed in the field. The range in error appears to be greater at the low and high temperatures.

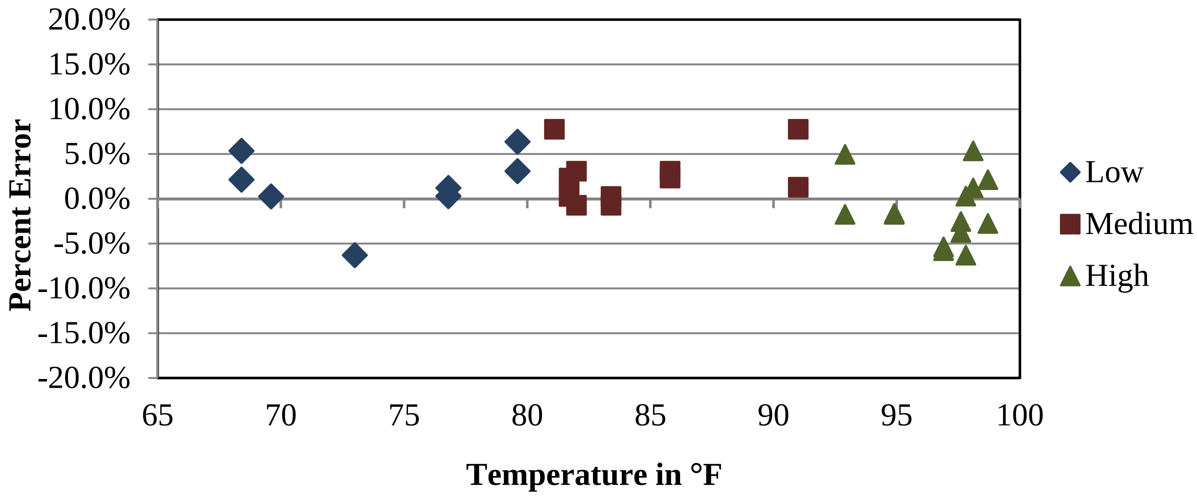


Figure 5-9 – Validation Steering Axle Weight Errors by Temperature – 1-Oct-13

5.1.2.3 Single Axle Weight Errors by Temperature

Figure 5-10 demonstrates that for loaded single axles, the WIM equipment appears to estimate single axle weights with similar accuracy across the range of temperatures observed in the field. The range in error is similar for different temperature groups.

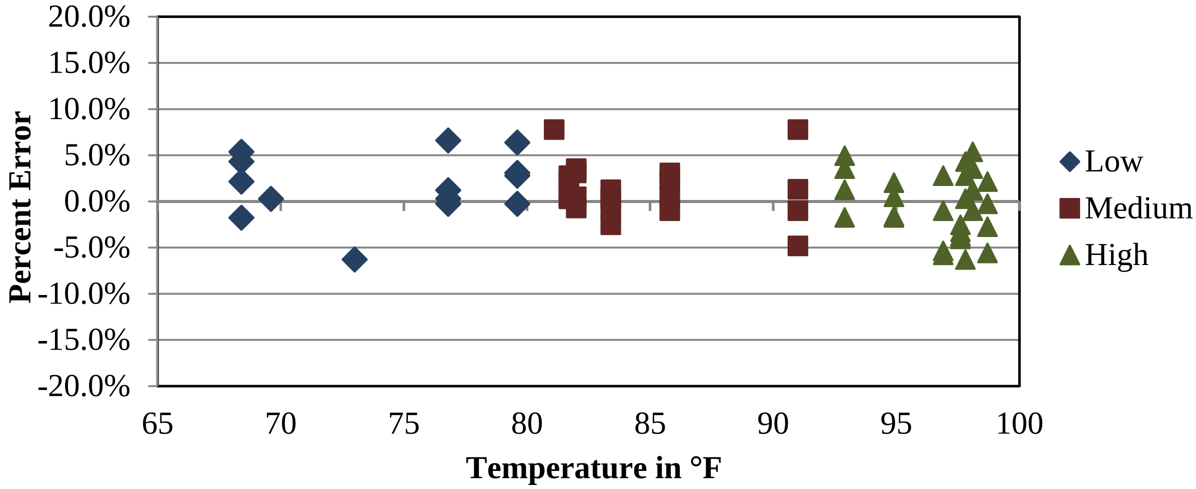


Figure 5-10 – Validation Single Axle Weight Errors by Temperature – 1-Oct-13

5.1.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-11, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. The range in tandem axle errors is greater at the higher temperatures.

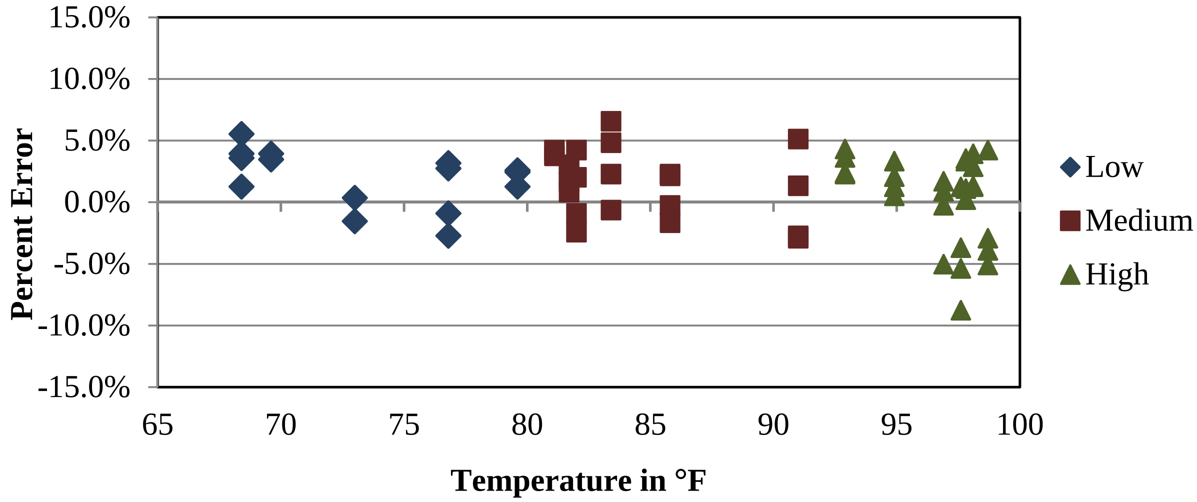


Figure 5-11 – Validation Tandem Axle Weight Errors by Temperature – 1-Oct-13

5.1.2.5 GVW Errors by Temperature and Truck Type

As shown in

Figure 5-12 – Validation GVW Error by Truck and Temperature – 1-Oct-13

, when analyzed by truck type, the equipment appears to measure GVW for both trucks similarly.

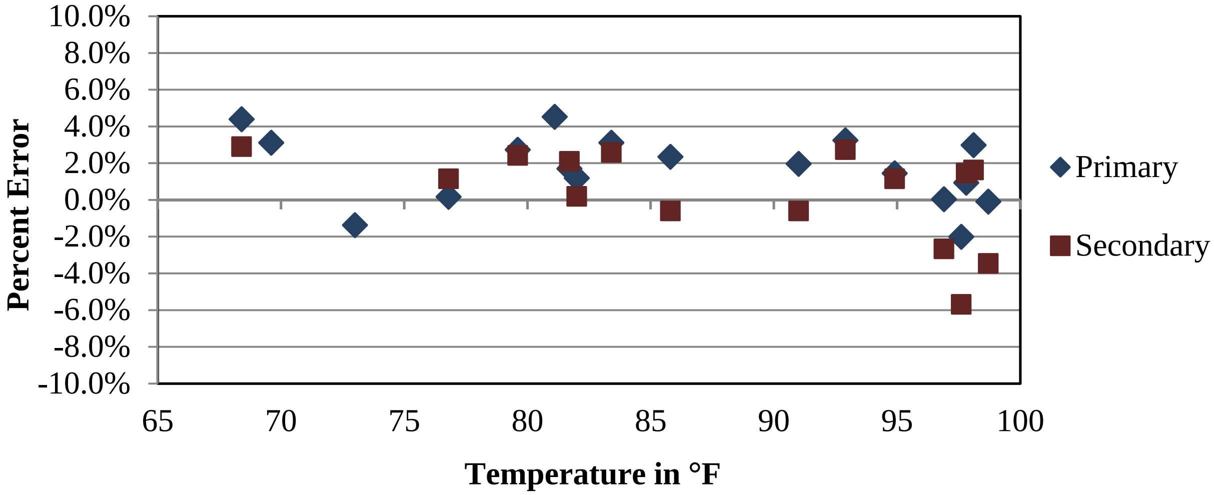


Figure 5-12 – Validation GVW Error by Truck and Temperature – 1-Oct-13

5.1.3 Classification and Speed Evaluation

The 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 validation classification study at this site, a manual sample of 119 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 5-5. 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 5 vehicle was misclassified as a Class 4 vehicle, and one Class 10 was not classified by the system (Class 15).

Table 5-5 – Validation Misclassifications by Pair – 1-Oct-13

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

As shown in the table, a total of 2 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the validation study, the misclassification percentage is 0.9% 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 1.7 percent, due to the misclassification of one Class 5 vehicle as a Class 4 vehicle and one Class 10 vehicle not being classified by the equipment (Class 15).

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 5 was a delivery truck with a long axle spacing, and the unclassified Class 10 was a single trailer, 10-axle truck.

The combined results of the misclassifications resulted in an undercount of one Class 5 and one Class 10 vehicle, and an overcount of one Class 4 vehicle, as shown in Table 5-6. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-6 – Validation Classification Study Results – 1-Oct-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	0	1	7	3	0	3	99	1	3	2	0
WIM Count	0	2	6	3	0	3	99	0	3	2	0
Observed Percent	0.0	0.8	5.9	2.5	0.0	2.5	83.2	0.8	2.5	1.7	0.0
WIM Percent	0.0	1.7	5.0	2.5	0.0	2.5	83.2	0.0	2.5	1.7	0.0
Misclassified Count	0	0	1	0	0	0	0	0	0	0	0
Misclassified Percent	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	1	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 – Validation Unclassified Trucks by Pair – 1-Oct-13

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

Based on the manually collected sample of the 119 trucks, 0.8 percent of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 1.2 mph; the range of errors was 1.3 mph.

Since the equipment is measuring all weight and distance parameters within the LTPP requirements for SPS WIM sites and with a very low bias (the average measurement error for GVW is 0.7 percent), a calibration of the system was not required and therefore was not carried out.

5.1.4 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-8.

Table 5-8 – Final Factors

Speed Point	MPH	Left		Right	
		1	3	2	4
80	50	3239	3239	3727	3312
88	55	3221	3221	3697	3275
96	60	3184	3184	3653	3248
104	65	3172	3172	3641	3235
112	70	3095	3095	3551	3156
Axle Distance (cm)		240			
Dynamic Comp (%)		100			
Loop Width (cm)		250			

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 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 53 to 66 mph.
- Pavement temperature. Pavement temperature ranged from 68.4 to 106.0 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	22.5772	3.8814	5.8168	1.22E-06
Speed	-0.2404	0.0603	-3.9831	0.0003
Temp	-0.0772	0.0219	-3.5159	0.0012
Truck	-1.1201	0.5001	-2.2398	0.0314

Assuming that p-values equal or less than 0.05 indicate statistical significance, speed, temperature, and truck type had the statistically significant effect on the GVW measurement errors. The lowest probability value given in Table 6-1 was 0.0003 for speed. This means that there is about 0.03 percent chance that the value of regression coefficient for speed (-0.2404) can occur by chance alone.

As an example, the relationship between speed and measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.2404 (in Table 6-1). This means, for example, that for a 10 mph increase in speed, the error is decreased by about 2.4 percent (0.2404 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0003) and is statistically significant.

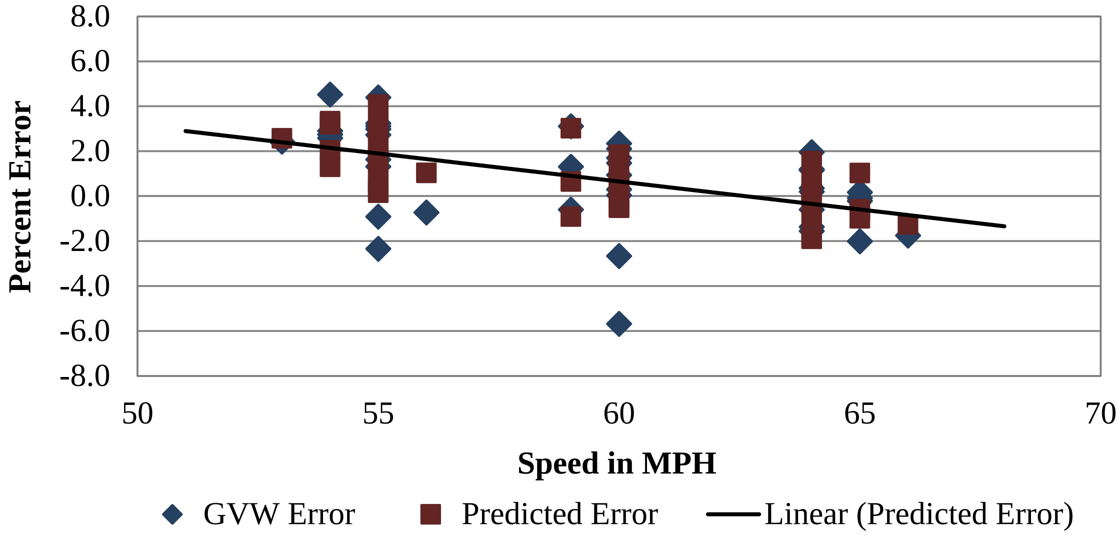


Figure 6-1 – Influence of Speed on the Measurement Error of GVW

6.1.3 Summary Results

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

Table 6-2 – Summary of Regression Analysis

Parameter	**Factor**					
	Speed		**Temperature**		**Truck type**	
	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)
GVW	-0.2404	0.0003	-0.0772	0.0012	-1.1201	0.0314
Steering axle	-	-	-0.1542	0.0067	-	-
Tandem axle tractor	-0.1841	0.0563	-0.0595	0.0880	-2.8155	0.0008
Tandem axle trailer	-0.3280	0.0007	-0.0694	0.0368	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on GVW and both the tractor and trailer tandem measurement errors.

2. Temperature had statistically significant effect on GVW, steering axle, and trailer tandem axle weight measurement errors.

3. Truck type had statistically significant effect on GVW measurement errors at 0.0314 probability value and tractor tandem axles at 0.0008 probability value. The regression coefficients for truck type represent the difference between the mean errors for the Primary and Secondary trucks. (Truck type was modeled an indicator variable with values of 0 or 1). Thus, the average GVW measurement error for the Secondary truck was about 1.1 percent lower than the corresponding error for the Primary truck. The influence of truck type is further discussed in Section 6.1.

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 WIM system calibration tolerances was small, as shown by the small values of regression coefficients, and does not affect the validity of the validation.

6.1.5 Contribution of Two Trucks to Calibration

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

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

Figure 6-2 shows that speed had influences on the GVW measurement for each truck, with both the Primary truck and Secondary truck showing a negative correlation with speed. The trend lines for the two trucks are statistically significant. Combined, the overall GVW error dependency on speed was also statistically significant (at 0.03 percent significance level).

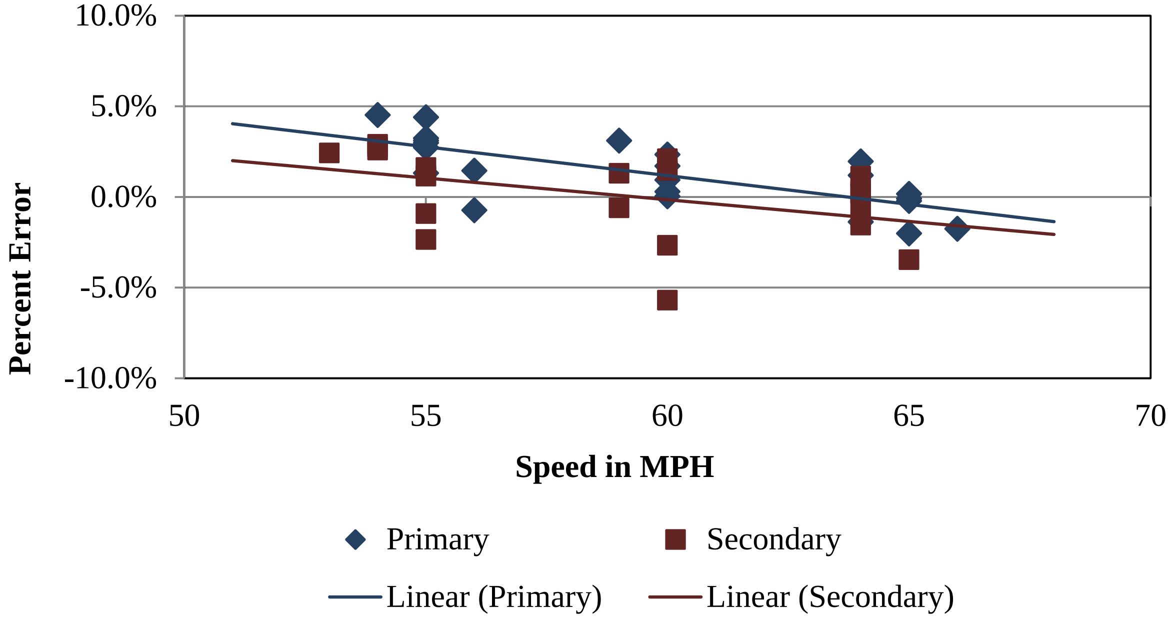


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

The use of two calibration trucks provided verification of the trends and speeded up the time required to obtain 40 pre-validation runs. For this site, the use of only one of the trucks (Primary or Secondary) would have resulted in similar verification and calibration results, based on the similar GVW mean errors for both trucks as shown in Table 6-3, based on the similar GVW mean errors for both trucks, and the similar correlations between speed and GVW errors for the two trucks shown in Figure 6-2.

Table 6-3 – Validation Results by Truck Type – 1-Oct-13

Parameter	95% Confidence Limit of Error	Primary	Secondary	Combined
Steering Axles	±20 percent	-0.2 ± 9.3%	-0.2 ± 7.3%	-0.2 ± 8.1%
Single Axles	±20 percent	0.0 ± 7.4%	0.2 ± 6.3%	0.1 ± 6.6%
Tandem Axles	±15 percent	1.5 ± 4.8%	0.2 ± 5.9%	0.9 ± 5.7%
GVW	±10 percent	1.3 ± 3.9%	0.1 ± 4.9%	0.7 ± 4.3%
Vehicle Length	±3.0 percent (2.0 ft)	-0.8 ± 1.1 ft	-0.8 ± 1.0 ft	-0.8 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.4 ± 1.5 mph	-0.1 ± 2.4 mph	0.2 ± 2.0 mph
Axle Length	± 0.5 ft [150mm]	0.2 ± 0.1 ft	0.2 ± 0.1 ft	0.2 ± 0.1 ft

6.2 Misclassification Analysis

A post-visit analysis was conducted on the truck misclassifications identified during the validation conducted in the field. For this site, a total of 2 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. The single truck misclassification was a Class 10 which was not classified by the WIM system (Class 15). According to the Sheet 20, this vehicle was vehicle number 16955. The capture of the real-time record for vehicle 16955 is provided in Figure 6-3.

(16955) LANE WBDrive CLASS 15 GVW 170.3 kips LENGTH 104 ft
SPEED 55 mph MAX GVW 0.0 kips Tue Oct 1 2013 17:12:56 (629)

AXLE	SEPARATION (ft)	LEFT WT (kips)	RIGHT WT (kips)	TOTAL WT (kips)	ALLOWABLE (kips)
1 S		5.3	5.9	11.2	
2 D	20.0	8.8	9.4	18.2	
3 D	4.6	9.2	8.9	18.1	
4 T	12.5	7.8	7.6	15.4	
5 T	4.6	9.6	9.3	18.9	
6 T	4.6	9.6	9.3	18.9	
7 T	41.2	8.7	8.9	17.7	
8 T	4.6	8.5	8.9	17.4	
9 T	4.5	8.5	8.8	17.3	
10 S	4.6	8.6	8.5	17.1	

Figure 6-3 – Vehicle Record 16955

As shown in the following 3 photos, this truck consisted of a full tractor and a full trailer and had 10 axles. This vehicle would fit under description “Tractor, Single Trailer with 6 or More Axles” for class 10 vehicles (FHWA scheme) but has unusually large number of axles. Under the current LTPP classification algorithm, class 10 configuration accepts only up to 8 axles. However, based on the axle spacings and number of axles, this vehicle should have been classified as a vehicle type 13, which would have resulted in a misclassification rather than the vehicle not being classified.

Although the truck was blocked by another truck during the video capture, the left wheels for each axle can be seen in the following 3 image captures.

In Photo 6-1, the tractor steering axle and drive tridem can be seen. For this tridem axle configuration, the first axle in the group is lifted and WIM system sees it as tandem axle.

Photo 6-1 – Vehicle #16995 Tractor Steering Axle and Tandem (from Liftable Tridem)

In Photo 6-2, the tridem axle wheels in the front of the trailer are shown by the arrows.

Photo 6-2 – Vehicle #16995 Tridem on the Front of the Trailer

In Photo 6-3, the quad axle wheels from the rear of the trailer can be seen, as well as part of the load.

Photo 6-3 – Vehicle #16995 Rear Quad on the Trailer

6.3 Traffic Data Analysis

Since there was no calibration of the system required, no post-visit data analysis was performed.

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 validation results.

7.1 Classification

The information in Table 7-1 data was extracted from the most recent previous validation and was updated to include the results of this validation. The entries in the table show the percentages of misclassified vehicles observed in the manual sample for each vehicle class. The last column shows the percentage of unclassified vehicles observed in the manual sample.

Table 7-1 – Classification Validation History

Date	Misclassification Percentage by Class											Pct Unclass
	3	4	5	6	7	8	9	10	11	12	13	
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
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
1-Oct-13	0	0	14	0	0	0	0	100	0	0	0	0.8

7.2 Weight

Table 7-2 data was extracted from the previous validation and was updated to include the results of this validation. The table provides the mean error and standard deviation for GVW, steering and single axles and tandems for prior pre- and validations.

Table 7-2 – Weight Validation History

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
29-May-07	-2.3 ± 5.3	-2.7 ± 9.1	-2.6 ± 7.5
30-May-07	-0.1 ± 4.0	-1.3 ± 11.5	0.2 ± 6.9
4-Nov-08	-2.6 ± 3.8	-2.1 ± 14.9	-3.7 ± 4.8
5-Nov-08	-1.7 ± 4.0	-0.2 ± 15.2	-3.4 ± 4.8
23-Nov-10	0.8 ± 6.1	2.2 ± 9.5	0.5 ± 7.9
7-Feb-12	-0.2 ± 5.7	-2.0 ± 9.9	1.4 ± 8.1
8-Feb-12	1.0 ± 5.6	1.4 ± 10.1	1.1 ± 7.2
1-Oct-13	0.7 ± 4.3	0.1 ± 6.6	0.9 ± 5.7

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 standard deviation of errors has remained stable. 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
- Validation Sheet 16 – Site Calibration Summary
- 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: October 1, 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 – Cellular Modem

Photo 9 – Downstream

Photo 10 – Upstream

Photo 11 – Truck 1 Tractor

Photo 12 – Truck 1 Trailer

Photo 13 – Truck 1 Suspension 1

Photo 14 – Truck 1 Suspension 2

Photo 15 – Truck 1 Suspension 3

Photo 16 – Truck 1 Suspension 4

Photo 17 – Truck 1 Suspension 5

Photo 18 – Truck 2 Tractor

Photo 19 – Truck 2 Trailer and Load

Photo 20 – Truck 2 Suspension 1

Photo 21 – Truck 2 Suspension 2

Photo 22 – Truck 2 Suspension 3

Photo 23 – Truck 2 Suspension 4

Photo 24 – Truck 2 Suspension 4

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 10/1/2013

SITE CALIBRATION INFORMATION

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

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. 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: 22

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

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

Mean Difference Between -

	Mean		Standard Deviation
Dynamic and Static GVW:	0.7%	Standard Deviation:	2.1%
Dynamic and Static Single Axle:	0.1%	Standard Deviation:	3.2%
Dynamic and Static Double Axles:	0.9%	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	-	53.0	to	57.3	17
b.	Medium	-	57.4	to	61.8	12
c.	High	-	61.9	to	66.0	14
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	42 420600 10/1/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3095 | 3551

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:	0.0	FHWA Class	FALSE	-	
FHWA Class 8:	0.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.8%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort:

Contact Information: Phone:

E-mail:

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 42 SPS WIM ID: 420600 DATE (mm/dd/yyyy) 10/1/2013

Count - 119 Time = 1:02:02 Trucks (4-15) - 119 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
64	12	15339	63	12	65	9	15677	62	9
61	9	15373	61	9	66	9	15678	65	9
61	9	15381	59	9	68	9	15699	66	9
59	5	15396	56	5	62	9	15709	62	9
65	9	15420	63	9	70	9	15715	69	9
63	9	15422	62	9	65	9	15721	68	9
60	9	15435	59	9	63	9	15728	62	9
66	9	15445	65	9	64	9	15754	64	9
65	9	15464	64	9	65	6	15759	63	6
63	9	15484	61	9	65	9	15769	64	9
63	9	15489	61	9	59	9	15783	58	9
68	9	15496	66	9	65	9	15791	65	9
62	9	15510	61	9	65	9	15808	64	9
66	9	15520	63	9	65	9	15812	65	9
61	9	15525	60	9	64	9	15816	62	9
65	9	15538	62	9	67	5	15834	65	5
70	6	15553	69	6	66	9	15854	65	9
72	9	15563	71	9	65	9	15866	64	9
65	11	15567	63	11	65	9	15871	64	9
57	9	15575	58	9	62	9	15885	62	9
67	9	15607	65	9	67	9	15893	64	9
60	9	15630	61	9	72	9	15911	72	9
70	9	15632	67	9	**64**	**4**	**15918**	**65**	**5**
65	9	15650	65	9	59	4	15924	58	4
67	9	15654	67	9	68	9	15945	66	9

Sheet 1 - 1 to 50 Start: 16:12:02 Stop: 16:34:22

Recorded By: al Verified By: djw

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) 10/1/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
71	9	15959	66	9	61	9	16318	60	9
64	9	15977	64	9	69	9	16330	66	9
66	9	15985	66	9	64	9	16336	63	9
62	9	15992	62	9	65	9	16345	62	9
65	9	15998	63	9	66	9	16355	64	9
68	6	16011	67	6	68	9	16363	67	9
67	9	16021	66	9	67	5	16369	66	5
66	9	16041	65	9	67	9	16374	65	9
68	9	16068	63	9	65	9	16381	63	9
64	9	16088	63	9	59	9	16397	60	9
66	9	16108	63	9	62	9	16425	60	9
66	9	16128	66	9	68	9	16442	65	9
55	11	16135	54	11	62	9	16446	61	9
72	9	16149	71	9	62	9	16479	62	9
70	9	16165	69	9	63	9	16486	65	9
60	9	16188	58	9	67	8	16506	65	8
67	9	16194	63	9	52	5	16517	52	5
65	9	16212	62	9	64	9	16528	64	9
65	9	16225	64	9	67	9	16536	66	9
59	9	16238	56	9	60	9	16556	60	9
55	9	16243	53	9	64	9	16570	64	9
65	9	16254	63	9	75	8	16601	74	8
62	9	16276	64	9	62	9	16614	60	9
57	9	16283	54	9	65	9	16632	63	9
64	9	16296	63	9	64	9	16637	63	9

Sheet 2 - 51 to 100 Start: 16:34:48 Stop: 17:01:33

Recorded By: al djw

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) 10/1/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
58	9	16664	58	9					
60	9	16696	60	9					
59	8	16714	59	8					
62	9	16725	61	9					
62	12	16758	64	12					
55	9	16772	54	9					
65	5	16792	64	5					
57	9	16801	56	9					
64	9	16831	62	9					
64	9	16855	65	9					
68	9	16866	65	9					
62	9	16877	60	9					
69	9	16890	67	9					
62	5	16904	60	5					
64	9	16922	64	9					
65	11	16933	65	11					
68	9	16940	65	9					
55	**15**	**16955**	**55**	**10**					
64	9	16998	63	9					

Sheet 3 - 101 to 150 Start: 17:02:20 Stop: 17:14:04

Recorded By: al djw

Validation Test Truck Run Set - Pre