WIM System Field Calibration and Validation Summary Report

Minnesota SPS-5
SHRP ID – 270500

Validation Date: April 17, 2013
Submitted: May 29, 2013

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1 Executive Summary

A WIM validation was performed on April 17, 2013 at the Minnesota SPS-5 site located on route US-2, milepost 91.8, 3.3 miles west of SR 2.

This site was installed on October 6, 2006. 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 April 4, 2012 and this validation visit, it appears that a replacement of the WIM sensors has occurred during this time.

The equipment is in working order. Electronic and electrical checks of the WIM components determined that the the equipment is operating within the manufacturer's tolerances. None of the in-road sensors show signs of damage or excessive wear and appear to be fully secured in the pavement. The new sensors were installed immediately following the old sensors. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, There were no pavement distresses noted that may affect the accuracies of the WIM system. A visual observation of the trucks as they approach, traverse, and leave the sensor area did not indicate any adverse dynamics that would affect the accuracy of the WIM system. The trucks appear to track down the center of the lane. Further pavement condition discussion is provided in Section 4.

Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is providing research quality loading data. The summary results of the validation are provided in Table 1-1 below.

Table 1-1 – Post-Validation Results – 17-Apr-13

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	0.3 ± 5.4%	Pass
Tandem Axles	±15 percent	1.1 ± 6.6%	Pass
GVW	±10 percent	0.5 ± 5.0%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	0.8 ± 1.2 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was 0.8 ± 2.9 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate and overall misclassification rate of 0.0% are within the 2.0% acceptability criterion for LTPP SPS WIM sites.

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 palletized bags of wood chips.

- The Secondary truck was a Class 9 vehicle with air suspension on the tractor tandem, mechanical suspension on the trailer tandem, and standard tandem spacing on the tractor and trailer. The Secondary truck was loaded with palletized bads of wood chips.

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 spacings were measured from the center hub of the each axle to the center hub of the subsequent axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average post-validation test truck weights and measurements are provided in Table 1-2.

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	79.5	12.3	16.1	16.1	17.3	17.3	17.1	4.3	33.0	4.1	58.5	66.5
2	72.4	11.7	15.3	15.3	15.1	15.1	19.5	4.3	36.3	4.1	64.2	72.6

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 40.7 to 47.5 degrees Fahrenheit, a range of 6.8 degrees Fahrenheit. The overcast weather conditions 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 February 11, 2013 (Data) to the most recent Comparison Data Set (CDS) from April 5, 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 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 2006 to 2011.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2006	55	2
2007	363	12
2008	366	12
2009	365	12
2010	364	12
2011	273	10

As shown in the table, this site requires no additional years of data to meet the minimum of five years of research quality data. The data does not meet the 210-day minimum requirement for calendar year 2006.

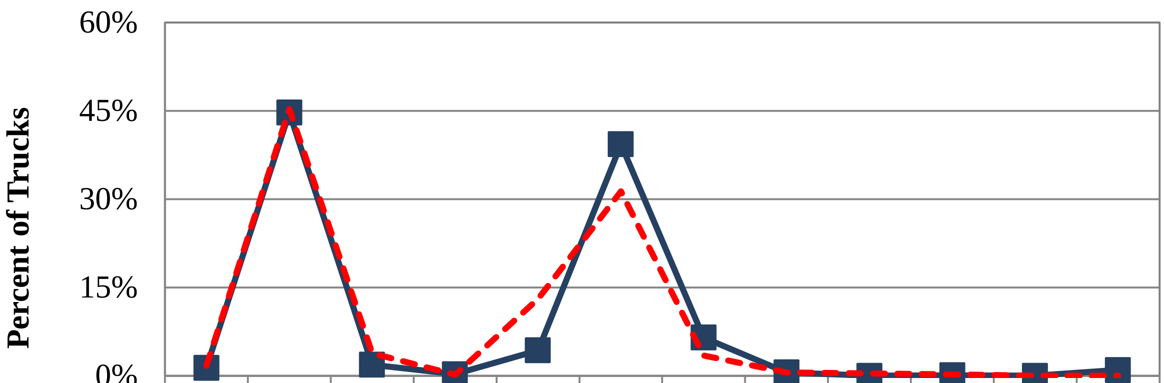
Table 2-2 provides a monthly breakdown of the available data for years 2006 through 2011.

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	
2006											25	30	2
2007	29	28	31	30	31	30	31	31	30	31	30	31	12
2008	31	29	31	30	31	30	31	31	30	31	30	31	12
2009	31	28	31	30	31	30	31	31	30	31	30	31	12
2010	30	28	31	30	31	30	31	31	30	31	30	31	12
2011	31	28	30	30	31	30	30	31	30	2			10

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 between the sample dataset from February 11, 2013 (Data) and the most recent comparison Data Set (CDS) from April 5, 2012.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	1.4%	44.7%	1.9%	0.3%	4.3%	39.3%	6.5%	0.6%	0.0%	0.1%	0.0%	1.0%
CDS	1.7%	45.3%	3.8%	0.2%	13.1%	31.3%	3.4%	0.5%	0.4%	0.2%	0.0%	0.0%

Truck Classifications

Figure 2-1 – Comparison of Truck Distribution

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the two most frequent truck types crossing the WIM scale are Class 5 (44.7%) and Class 9 (39.3%) 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 1.0 percent of the vehicles at this site are unclassified.

Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	4/5/2012		2/11/2013		
4	67	1.7%	47	1.4%	-0.4%
5	1772	45.3%	1543	44.7%	-0.6%
6	149	3.8%	65	1.9%	-1.9%
7	8	0.2%	9	0.3%	0.1%
8	511	13.1%	149	4.3%	-8.7%
9	1227	31.3%	1358	39.3%	8.0%
10	135	3.4%	224	6.5%	3.0%
11	21	0.5%	20	0.6%	0.0%
12	15	0.4%	0	0.0%	-0.4%
13	9	0.2%	3	0.1%	-0.1%
14	0	0.0%	0	0.0%	0.0%
15	0	0.0%	34	1.0%	1.0%

From the table it can be seen that the percentage of Class 5 vehicles has decreased by 0.6 percent from April 2012 to February 2013. These differences may be attributed to natural variations in truck volumes. During the same time period, the percentage of Class 9 trucks increased by 8.0 percent. Changes in the percentage of heavier trucks may also be attributed to natural and seasonal variations in truck distributions and an increase in goods movement during current economic cycle.

2.3 Speed Data Analysis

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

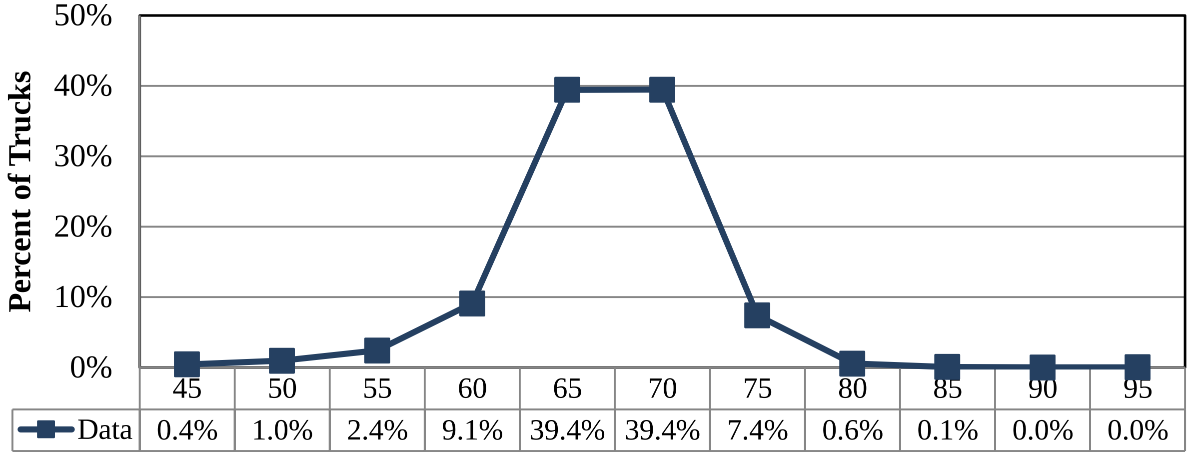


Figure 2-2 – Truck Speed Distribution – 30-Mar-13

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 65 and 70 mph. The posted speed limit at this site is 65 and the 85th percentile speed for trucks at this site is 68 mph. The 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 February 2013 and the Comparison Data Set from April 2012.

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

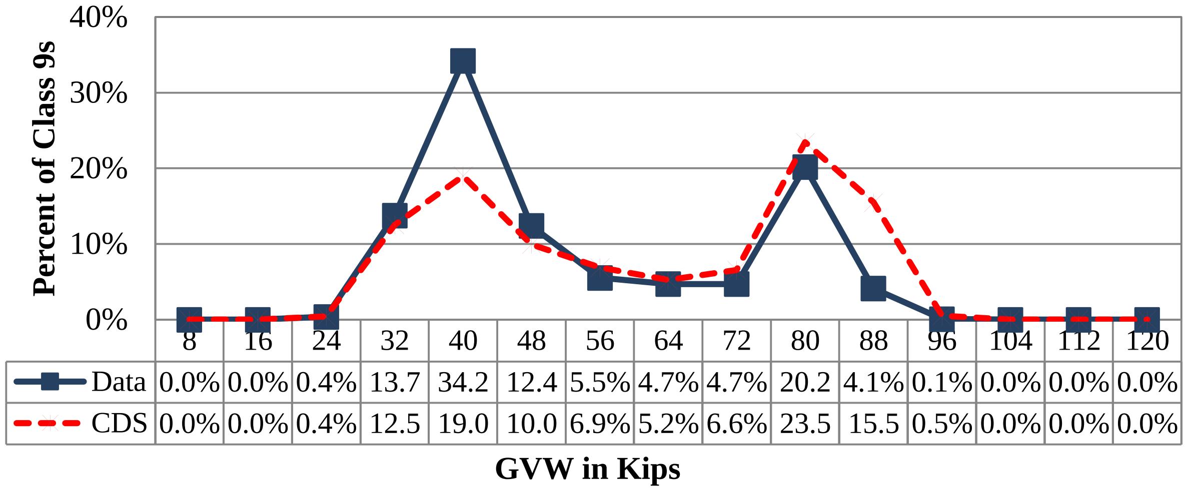


Figure 2-3 – Comparison of Class 9 GVW Distribution

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

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

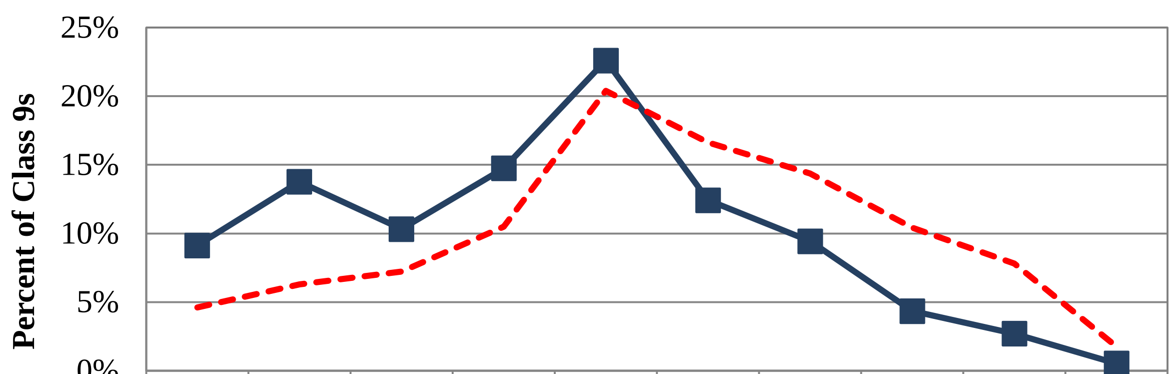
GVW weight bins (kips)	CDS		Data		Change
	Date				
	4/5/2012		2/11/2013		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	5	0.4%	5	0.4%	0.0%
32	151	12.5%	184	13.7%	1.2%
40	229	19.0%	458	34.2%	15.2%
48	120	10.0%	166	12.4%	2.4%
56	83	6.9%	74	5.5%	-1.4%
64	63	5.2%	63	4.7%	-0.5%
72	79	6.6%	63	4.7%	-1.8%
80	283	23.5%	270	20.2%	-3.3%
88	187	15.5%	55	4.1%	-11.4%
96	6	0.5%	1	0.1%	-0.4%
104	0	0.0%	0	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	64.0 kips		62.3 kips		-1.7 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range increased by 15.2 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 3.3 percent. During this time period the percentage of overweight trucks decreased by 11.8 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site decreased by 2.6 percent, from 64.0 to 62.3 kips.

2.5 Class 9 Front Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from February 2013 and the Comparison Data Set from April 2012. The percentage of light axles (10.0 to 10.5 kips) increased by approximately 4.3 percent and the percentage of heavy axles (12.0 to 12.5 kips) decreased by approximately 6.1 percent, indicating possible negative bias (underestimation of loads) in front axle measurement.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	9.1%	13.8%	10.3%	14.7%	22.6%	12.4%	9.4%	4.3%	2.7%	0.5%
CDS	4.6%	6.3%	7.2%	10.5%	20.4%	16.6%	14.4%	10.4%	7.8%	1.8%

Steering Axle Weight in Kips

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

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 10.5 and 11.5 kips. The percentage of trucks in this range has decreased by 2.0 percent between the April 2012 Comparison Data Set (CDS) and the February 2013 dataset (Data).

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

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

F/A weight bins (kips)	CDS		Data		Change
	Date				
	4/5/2012		2/11/2013		
9.0	55	4.6%	122	9.1%	4.5%
9.5	75	6.3%	184	13.8%	7.5%
10.0	86	7.2%	138	10.3%	3.1%
10.5	125	10.5%	197	14.7%	4.3%
11.0	243	20.4%	302	22.6%	2.2%
11.5	198	16.6%	166	12.4%	-4.2%
12.0	171	14.4%	126	9.4%	-4.9%
12.5	124	10.4%	58	4.3%	-6.1%
13.0	93	7.8%	36	2.7%	-5.1%
13.5	21	1.8%	7	0.5%	-1.2%
Average =	11.5 kips		11.3 kips		-0.2 kips

The table shows that the average front axle weight for Class 9 trucks has decreased by 0.2 kips, or 1.7 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.3 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

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

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

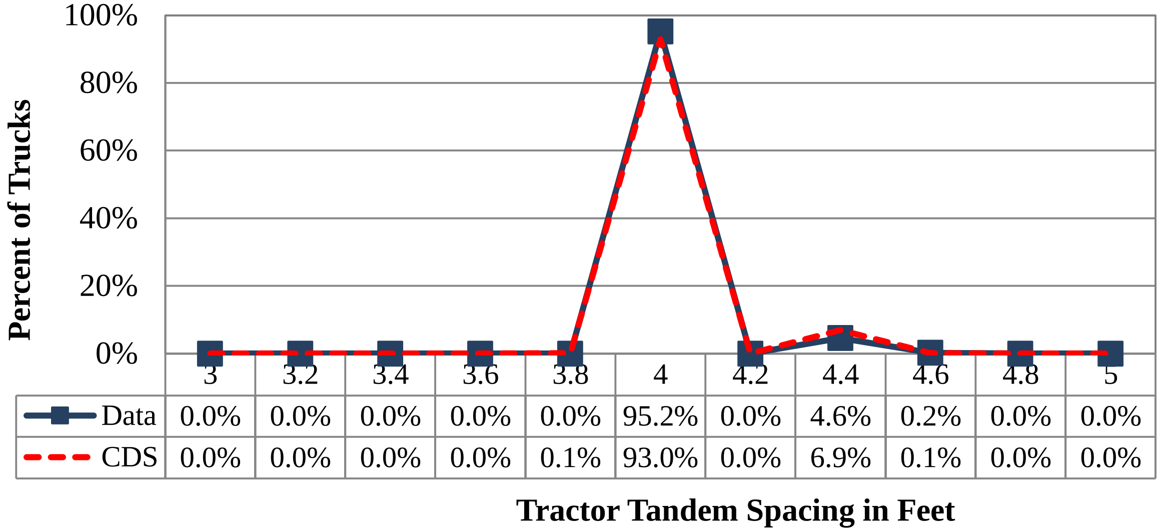


Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacings for the April 2012 Comparison Data Set and the February 2013 Data are very 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				
	4/5/2012		2/11/2013		
3.0	0	0.0%	0	0.0%	0.0%
3.2	0	0.0%	0	0.0%	0.0%
3.4	0	0.0%	0	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	1	0.1%	0	0.0%	-0.1%
4.0	1121	93.0%	1275	95.2%	2.3%
4.2	0	0.0%	0	0.0%	0.0%
4.4	83	6.9%	61	4.6%	-2.3%
4.6	1	0.1%	3	0.2%	0.1%
4.8	0	0.0%	0	0.0%	0.0%
5.0	0	0.0%	0	0.0%	0.0%
Average =	4.0 feet		4.0 feet		0.0 feet

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

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (April 2012) based on the last calibration with the most recent two-week WIM data sample from the site (February 2013). Comparison of vehicle class distribution data indicates an 8.0 percent increase in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have decreased by 1.7 percent and average Class 9 GVW has decreased by 2.6 percent for the February 2013 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical to the expected average of 4.0 feet.

3 Pavement Discussion

3.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, the type of distress shown in Photo 3-1 was noted at several locations prior to the WIM scales. No adverse truck dynamics were noted in the WIM approach area. The distress did not appear to affect the accuracy of the WIM sensors.

Photo 3-1 – Pavement Distress in WIM Approach Area

3.2 LTPP Pavement Profile Data Analysis

The IRI data files are processed using the WIM Smoothness Index software. The indices produced by the software provide an indication of whether or not the pavement roughness may affect the operation of the WIM equipment. The recommended thresholds for WIM Site pavement smoothness are provided in Table 3-1.

Table 3-1 – Recommended WIM Smoothness Index Thresholds

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

When all values are less than the lower threshold shown in Table 3-1, it is unlikely that pavement conditions will significantly influence sensor output. Values between the threshold values may or may not influence the accuracy of the sensor output and values above the upper threshold would lead to sensor output that would preclude achieving the research quality loading data.

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

Table 3-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass5**	**Avg**
left shift	left wheel path	LRI	0.655	0.565	0.570			0.597
left shift	left wheel path	SRI	*0.410*	*0.419*	*0.278*			*0.369*
left shift	left wheel path	Peak LRI	0.749	0.670	0.725			0.715
left shift	left wheel path	Peak SRI	*0.521*	*0.444*	*0.338*			*0.434*
left shift	right wheel path	LRI	0.781	0.694	0.638			0.704
left shift	right wheel path	SRI	0.541	*0.370*	*0.325*			*0.412*
left shift	right wheel path	Peak LRI	0.794	0.702	0.712			0.736
left shift	right wheel path	Peak SRI	0.771	*0.701*	*0.643*			*0.705*
center	left wheel path	LRI	0.642	*0.457*	*0.466*	*0.459*	*0.476*	0.500
center	left wheel path	SRI	0.513	*0.274*	*0.356*	*0.376*	*0.324*	*0.369*
center	left wheel path	Peak LRI	0.642	0.571	0.551	0.609	0.610	0.597
center	left wheel path	Peak SRI	0.846	*0.344*	*0.413*	*0.495*	*0.424*	*0.504*
center	right wheel path	LRI	0.621	0.653	0.603	0.614	0.625	0.623
center	right wheel path	SRI	0.607	0.755	0.761	0.761	0.718	0.720
center	right wheel path	Peak LRI	0.760	0.793	0.811	0.807	0.825	0.799
center	right wheel path	Peak SRI	0.796	0.922	0.868	0.880	0.911	0.875
right shift	left wheel path	LRI	0.703	0.731	0.672			0.702
right shift	left wheel path	SRI	0.581	0.560	0.714			0.618
right shift	left wheel path	Peak LRI	0.754	0.766	0.681			0.734
right shift	left wheel path	Peak SRI	*0.626*	*0.611*	*0.728*			*0.655*
right shift	right wheel path	LRI	0.816	0.842	0.823			0.827
right shift	right wheel path	SRI	0.585	0.614	0.671			0.623
right shift	right wheel path	Peak LRI	**0.998**	**1.019**	**1.054**			**1.024**
right shift	right wheel path	Peak SRI	*0.704*	0.780	*0.711*			*0.732*

From Table 3-2 it can be seen that majority 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 LRI values in the right wheel path of the right shift passes (shown in bold).

3.3 Profile and Vehicle Interaction

Profile data was collected on August 9, 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 3 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 142 in/mi and is located approximately 438 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 106 in/mi and is located approximately 347 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 transverse cracks observed at these locations, however, they did not appear to influence truck dynamics in the WIM scale area.

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

3.4 Recommended Pavement Remediation

No pavement remediation is recommended.

4 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on April 4, 2012 and this validation visit, it appears that the WIM array, which includes the WIM sensors and the inductive loops, were replaced during the time between the prior validation and this validation.

4.1 Description

This site was originally installed on October 6, 2006 by International Road Dynamics. The array was replaced by the state on August 7, 2012. It is instrumented with quartz weighing sensors and an IRD iSINC WIM Controller. As the installation contractor, IRD performs routine equipment maintenance and data quality checks of the WIM data.

4.2 Physical Inspection

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented after Section 7.

4.3 Electronic and Electrical Testing

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

4.4 Equipment Troubleshooting and Diagnostics

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

4.5 Recommended Equipment Maintenance

No unscheduled equipment maintenance actions are recommended.

5 Statistical Reliability of the WIM Equipment

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

5.1 Pre-Validation

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

The 41 pre-validation test truck runs were conducted on April 17, 2013, beginning at approximately 8:23 AM and continuing until 1:19 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with palletized bags of wood chips, 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 palletized bads of wood chips, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and the trailer.

The test trucks were weighed prior to the pre-validation and were re-weighed at the conclusion of the post-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	79.8	12.5	16.2	16.2	17.3	17.3	17.1	4.3	33.0	4.1	58.5	66.5
2	72.8	11.9	15.4	15.4	15.1	15.1	19.5	4.3	36.3	4.1	64.2	72.6

Test truck speeds varied by 11 mph, from 54 to 65 mph. The measured pre-validation pavement temperatures varied 15.1 degrees Fahrenheit, from 31.3 to 46.4. 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 met all LTPP requirements for loading and distance measurement as a result of the pre-validation test truck runs. All weight measurements showed significant negative bias. The system failed for overall length measurement due to incorrect loop width factors installed in the system.

Table 5-2 – Pre-Validation Overall Results – 17-Apr-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-7.5 ± 4.2%	Pass
Tandem Axles	±15 percent	-2.5 ± 4.5%	Pass
GVW	±10 percent	-6.7 ± 3.3%	FAIL
Vehicle Length	±3.0 percent (2.1 ft)	2.0 ± 0.9 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was 0.6 ± 2.0 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.1 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within similar acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 65 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3.

Table 5-3 – Pre-Validation Results by Speed – 17-Apr-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		54.0 to 57.7 mph	57.8 to 61.4 mph	61.5 to 65.0 mph
Steering Axles	±20 percent	-9.0 ± 3.7%	-6.9 ± 3.0%	-6.3 ± 4.6%
Tandem Axles	±15 percent	-6.8 ± 4.6%	-6.5 ± 4.9%	-6.4 ± 5.0%
GVW	±10 percent	-7.1 ± 3.2%	-6.6 ± 3.9%	-6.4 ± 3.8%
Vehicle Length	±3.0 percent (2.1 ft)	2.0 ± 1.0 ft	1.9 ± 1.0 ft	2.0 ± 1.0 ft
Vehicle Speed	± 1.0 mph	1.3 ± 2.3 mph	0.1 ± 1.4 mph	0.3 ± 1.7 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.1 ft	0.1 ± 0.1 ft

From the table, it can be seen that the WIM equipment underestimates all weights at all speeds. The range in error appears to be consistent for all speed groups.

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

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment underestimated GVW at all speeds. The range in error appears to be consistent for all speed groups.

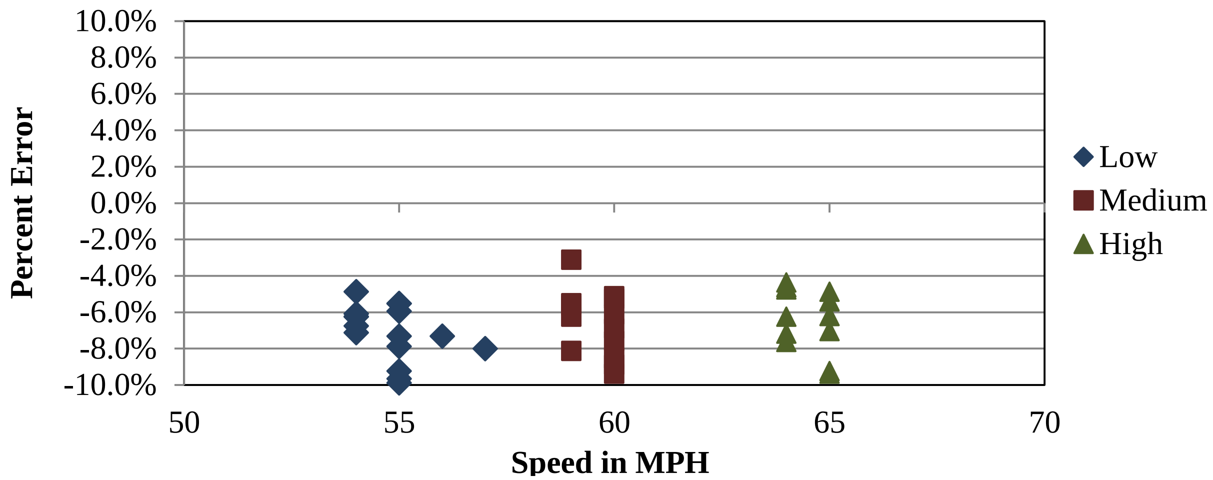


Figure 5-1 – Pre-Validation GVW Error by Speed – 17-Apr-13

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment underestimates steering axle weights with similar bias at the medium and high speeds. The negative bias is greater at the low speeds.

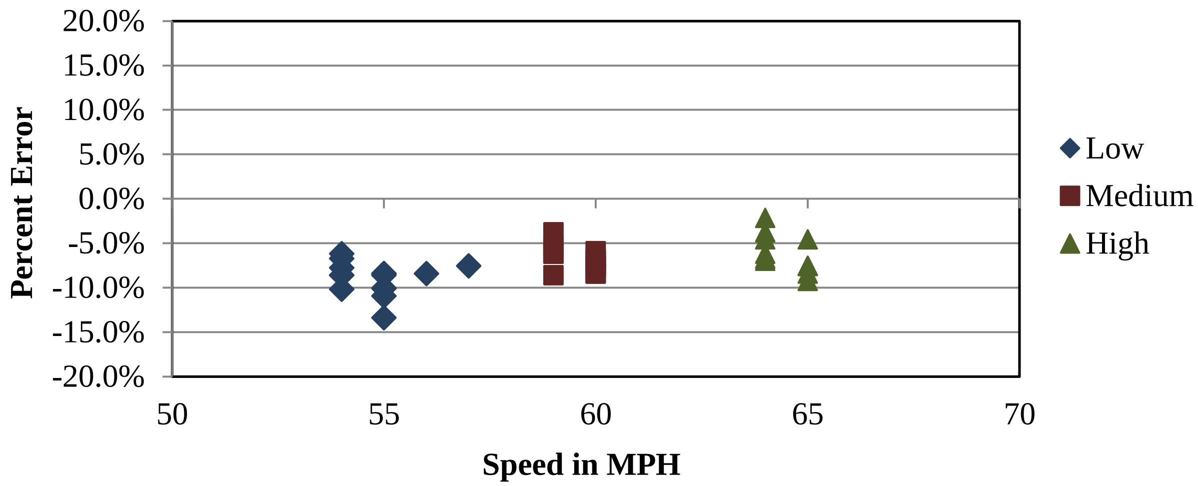


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 17-Apr-13

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment underestimates tandem axle weights with similar bias at all speeds. The range in error is similar throughout the entire speed range.

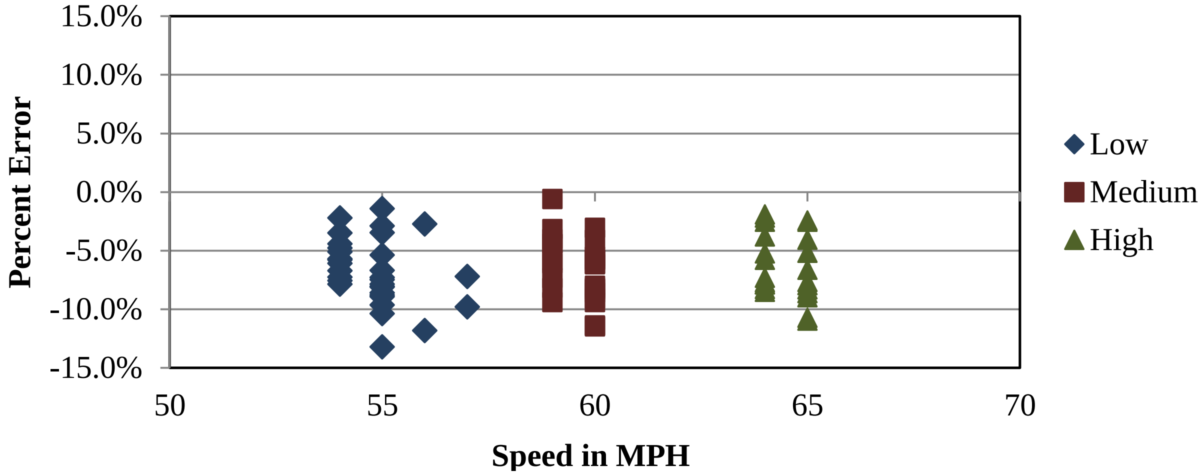


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 17-Apr-13

5.1.1.4 GVW Errors by Speed and Truck Type

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

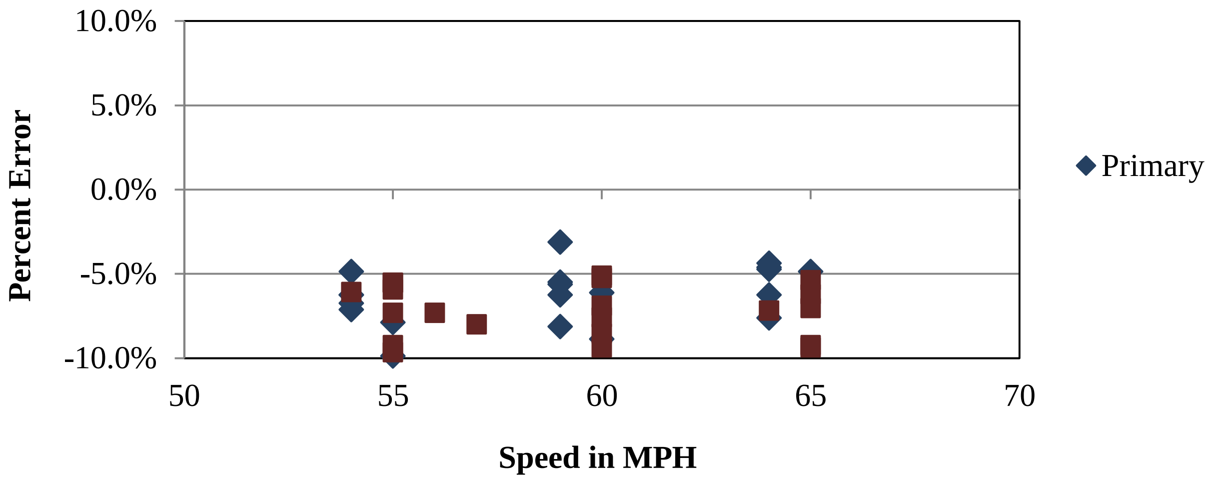


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 17-Apr-13

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from 0.0 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-5.

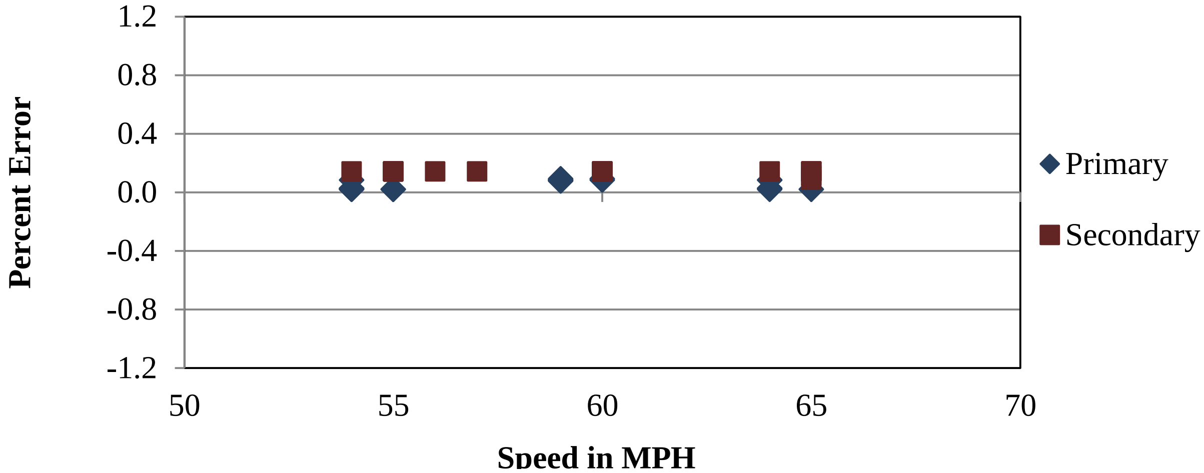


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 17-Apr-13

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment overestimated overall vehicle length consistently over the entire range of speeds, with an error range of 1.5 to 2.5 feet. This is typically due to incorrect loop width setting in the system operating parameters. Distribution of errors is shown graphically in Figure 5-6.

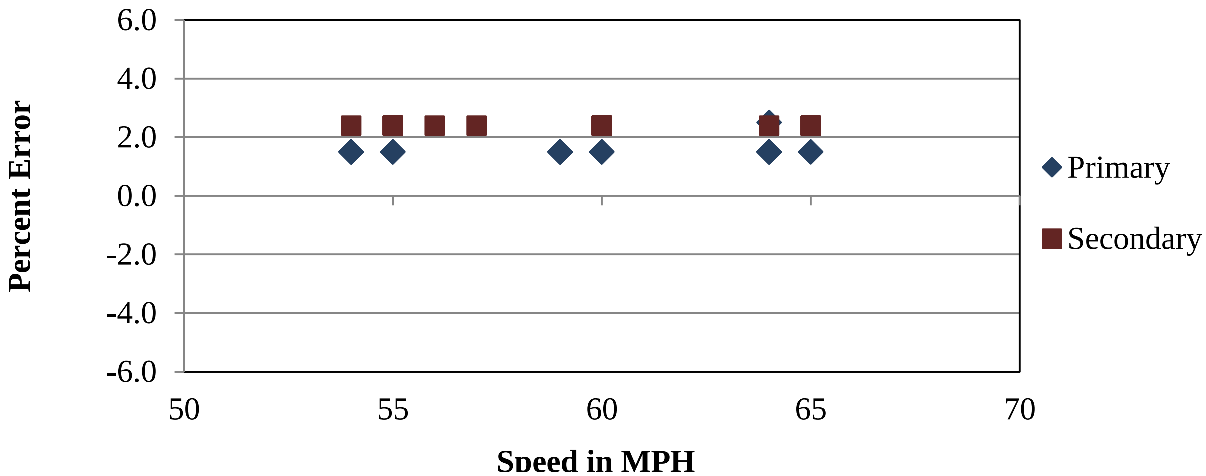


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 17-Apr-13

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 15.1 degrees, from 31.3 to 46.4 degrees Fahrenheit. The desired 30 degree temperature range was not met, and the pre-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 17-Apr-13

Parameter	95% Confidence Limit of Error	Low	High
		31.3 to 38 degF	38.1 to 47.0 degF
Steering Axles	±20 percent	-6.9 ± 3.9%	-8.2 ± 4.5%
Tandem Axles	±15 percent	-6.5 ± 4.6%	-6.6 ± 4.8%
GVW	±10 percent	-6.6 ± 3.4%	-6.9 ± 3.6%
Vehicle Length	±3.0 percent (2.1 ft)	2.0 ± 1.0 ft	2.0 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.5 ± 2.0 mph	0.8 ± 2.2 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.1 ft

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

5.1.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment underestimates GVW across the range of temperatures observed in the field. The range in error is similar for different temperature groups.

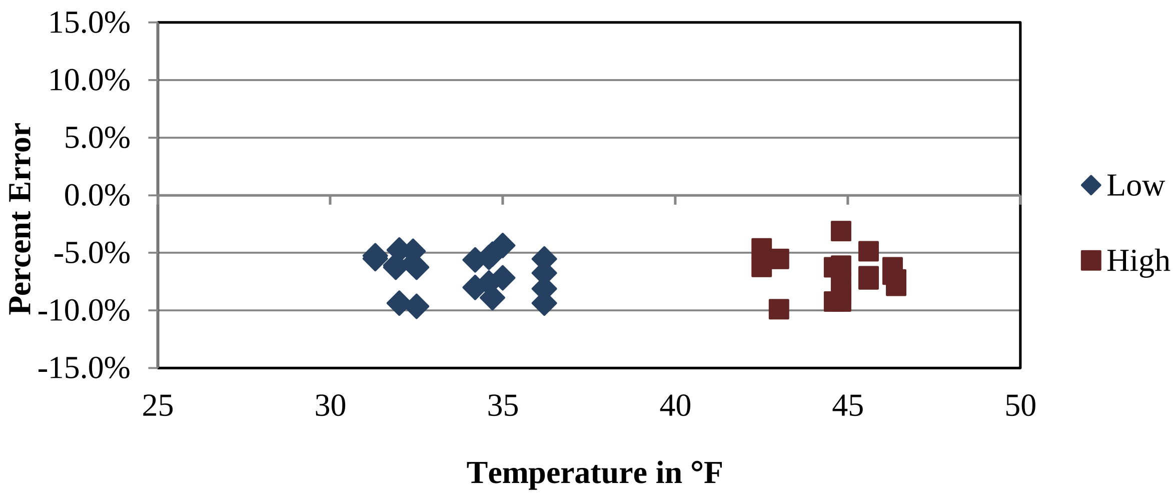


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 17-Apr-13

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 illustrates that for steering axles, the WIM equipment underestimates weights at all temperatures observed in the field. The range in error is similar for different temperature groups.

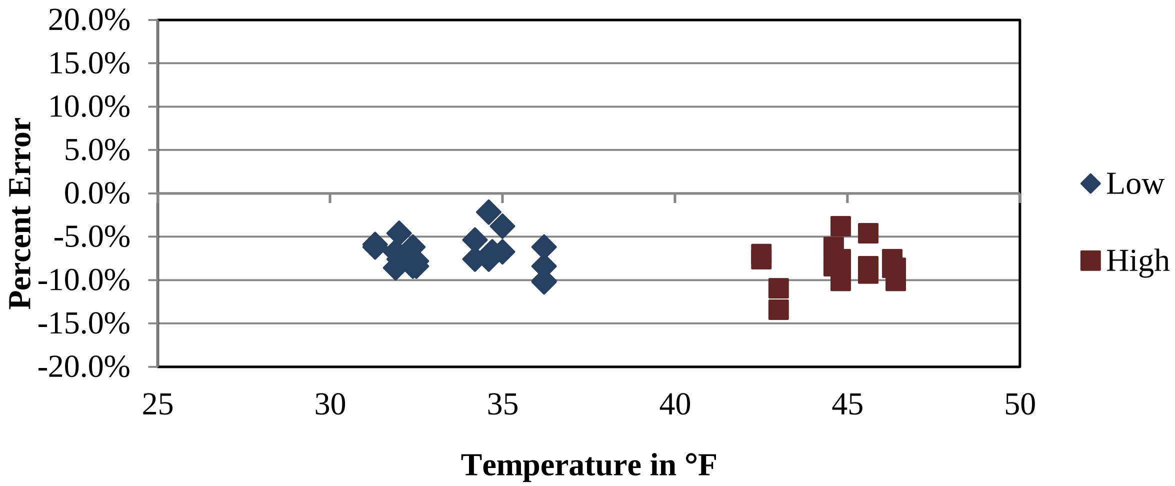


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 17-Apr-13

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment underestimates tandem axle weights across the range of temperatures observed in the field. The range in tandem axle errors is consistent for the two temperature groups.

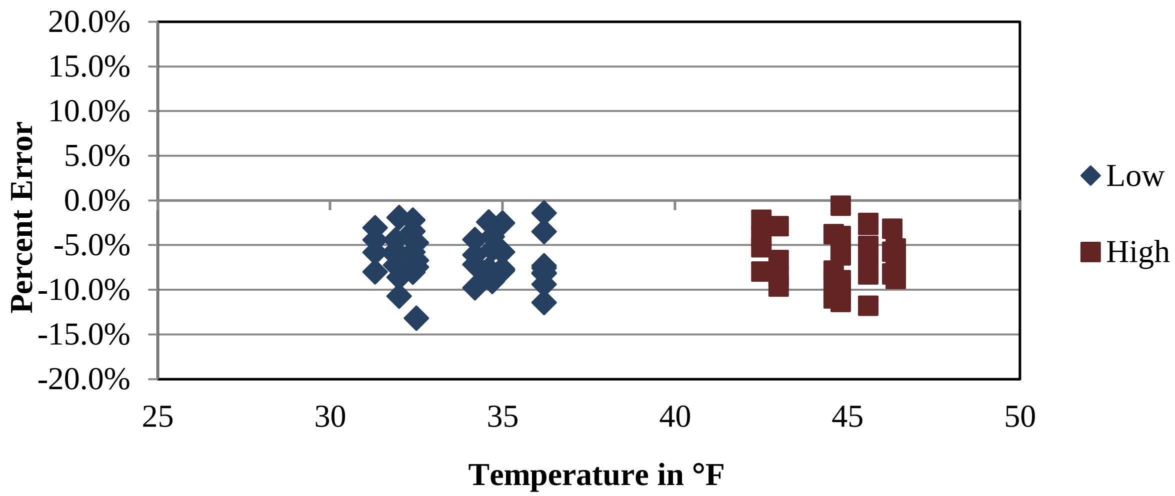


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 17-Apr-13

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, it can be seen that the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. For both trucks, the range of errors and bias are consistent over the range of temperatures. Distribution of errors is shown graphically in Figure 5-10.

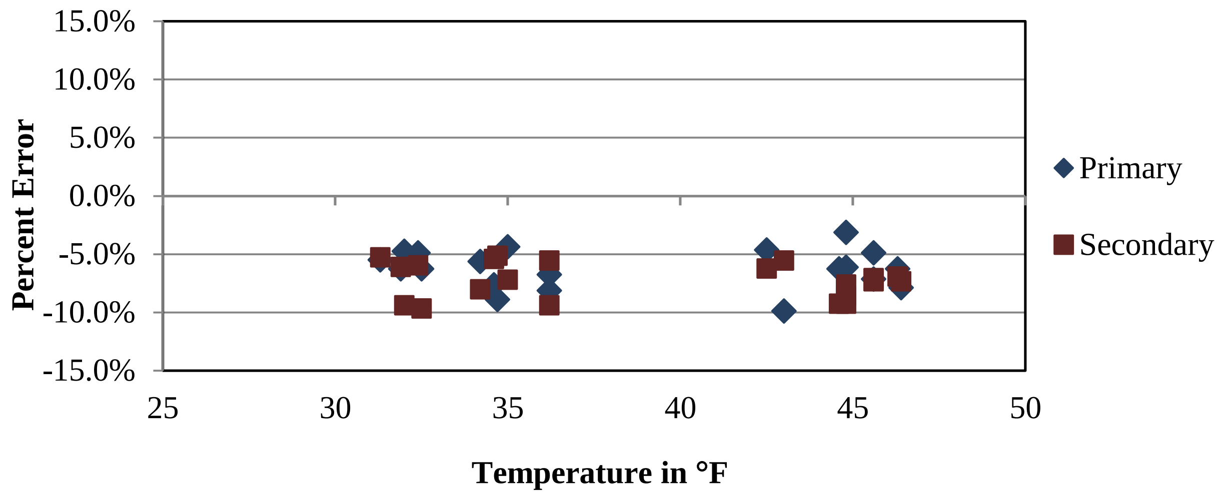


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 17-Apr-13

5.1.3 Classification and Speed Evaluation

The pre-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment. The winter weather conditions provided for only a small sample of trucks from this typically low truck volume site.

For the pre-validation classification study at this site, a manual sample of 41 vehicles including 41 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. There were no observed misclassifications of trucks during the study.

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), and 0.0% for all vehicles are within the 2.0% acceptability criteria for LTPP SPS WIM sites.

The results of the classification study are presented in Table 5-5. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-5 – Pre-Validation Classification Study Results – 17-Apr-13

Class	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Observed Count	0	0	21	6	0	2	10	2	0	0	0
WIM Count	0	0	21	6	0	2	10	2	0	0	0
Observed Percent	0.0	0.0	51.2	14.6	0.0	4.9	24.4	4.9	0.0	0.0	0.0
WIM Percent	0.0	0.0	51.2	14.6	0.0	4.9	24.4	4.9	0.0	0.0	0.0
Misclassified Count	0	0	0	0	0	0	0	0	0	0	0
Misclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. Based on the manually collected sample of the 41 trucks, 0.0 percent of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was -0.3 mph; the range of errors was ±0.9 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 5-6.

Table 5-6 – Initial System Parameters – 17-Apr-13

Speed Point	MPH	Left		Right	
		1	3	2	4
64	40	3087	3087	2862	2862
80	50	3087	3087	2862	2862
96	60	3087	3087	2862	2862
112	70	3087	3087	2862	2862
128	80	3087	3087	2862	2862
Axle Distance (cm)		366			
Dynamic Comp (%)		102			
Loop Width (cm)		183			

5.2.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of -6.7% and errors of -6.07%, -6.65%, and -6.87% at the 55, 60 and 65 mph speed points respectively. To compensate for these errors, the changes in Table 5-7 were made to the compensation factors.

Table 5-7 – Calibration 1 Equipment Factor Changes – 17-Apr-13

Speed Points	Old Factors				New Factors			
	Left		Right		Left		Right	
	1	3	2	4	1	3	2	4
64	3087	3087	2862	2862	3286	3286	3047	3047
80	3087	3087	2862	2862	3286	3286	3047	3047
96	3087	3087	2862	2862	3307	3307	3066	3066
112	3087	3087	2862	2862	3315	3315	3073	3073
128	3087	3087	2862	2862	3315	3315	3073	3073
Axle Distance (cm)	366				365			
Dynamic Comp (%)	102				103			
Loop Width (cm)	183				244			

5.2.2 Calibration Results

The results of the 12 calibration verification runs are provided in Table 5-8 and Figure 5-11. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the calibration.

Table 5-8 – Calibration Results – 17-Apr-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.5 ± 5.6%	Pass
Tandem Axles	±15 percent	0.7 ± 6.7%	Pass
GVW	±10 percent	-0.8 ± 5.0%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	0.6 ± 1.5 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Figure 5-11 shows that the WIM equipment is estimating GVW with reasonable accuracy at all speeds. The system weight compensation and loop width factors were adjusted to improve system measurement accuracies for weight and overall length.

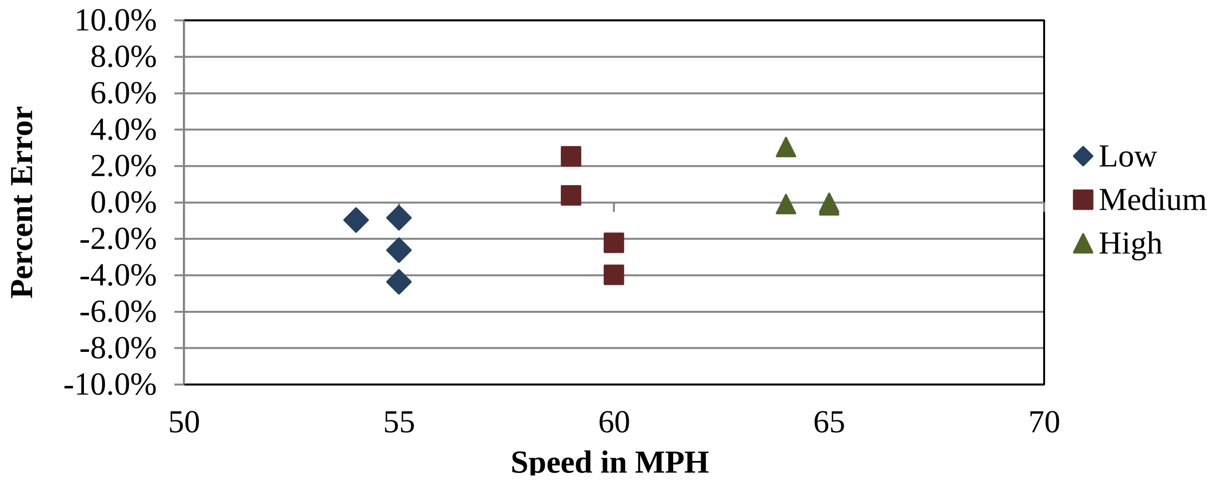


Figure 5-11 – Calibration GVW Error by Speed – 17-Apr-13

Based on the results of the calibration, where mean GVW estimate bias decreased to -0.8 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. Although the system demonstrates a minor speed dependency, the analysis was based on a limited number of samples and further adjustment was not deemed necessary.

5.3 Post-Validation

The 40 post-validation test truck runs were conducted on April 17, 2013, beginning at approximately 1:33 PM and continuing until 6:39 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with palletized bags of wood chips, 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 palletized bads of wood chips, and equipped with air suspension on the tractor, mechanical suspension on the trailer, with standard tandem spacing on the tractor and the trailer.

The test trucks were weighed prior to the pre-validation and re-weighed at the conclusion of the post-validation. The average test truck weights and measurements are provided in Table 5-9.

Table 5-9 – 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	79.5	12.3	16.1	16.1	17.3	17.3	17.1	4.3	33.0	4.1	58.5	66.5
2	72.4	11.7	15.3	15.3	15.1	15.1	19.5	4.3	36.3	4.1	64.2	72.6

Test truck speeds varied by 11 mph, from 54 to 65 mph. The measured post-validation pavement temperatures varied 6.8 degrees Fahrenheit, from 40.7 to 47.5. The overcast weather conditions prevented the desired minimum 30 degree temperature range. Table 5-10 is a summary of post validation results.

Table 5-10 – Post-Validation Overall Results – 17-Apr-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	+20 percent	0.3 ± 5.4%	Pass
Tandem Axles	+15 percent	1.1 ± 6.6%	Pass
GVW	+10 percent	0.5 ± 5.0%	Pass
Vehicle Length	±3.0 percent (2.1 ft)	0.8 ± 1.2 ft	Pass
Axle Length	+ 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was 0.8 ± 2.9 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 0.0 feet, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within similar acceptable ranges.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 65 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-11.

Table 5-11 – Post-Validation Results by Speed – 17-Apr-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		54.0 to 57.7 mph	57.8 to 61.4 mph	61.5 to 65.0 mph
Steering Axles	±20 percent	-0.9 ± 5.4%	-0.2 ± 6.2%	2.0 ± 4.0%
Tandem Axles	±15 percent	0.2 ± 7.7%	0.5 ± 7.2%	1.5 ± 6.4%
GVW	±10 percent	0.0 ± 6.0%	0.2 ± 4.7%	1.3 ± 5.1%
Vehicle Length	±3.0 percent (2.1 ft)	0.8 ± 1.3 ft	0.6 ± 1.5 ft	0.8 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.2 ± 1.7 mph	1.0 ± 3.3 mph	1.1 ± 3.9 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.1 ft

From the table, it can be seen that the WIM equipment estimates all weights with similar accuracy at all speeds, with slight positive bias at the higher speeds. The relationship between weight estimates and speed at this site is very low.

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

5.3.1.1 GVW Errors by Speed

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

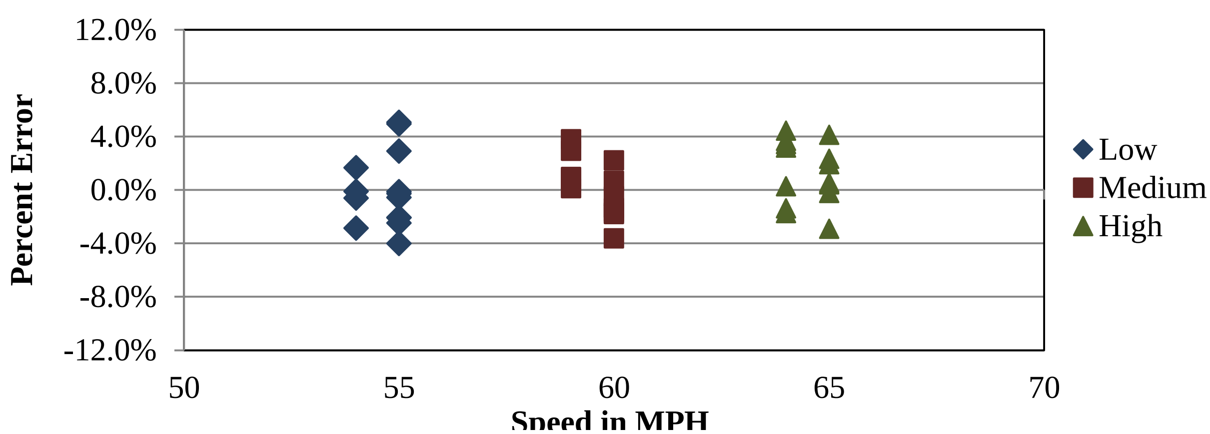


Figure 5-12 – Post-Validation GVW Errors by Speed – 17-Apr-13

5.3.1.2 Steering Axle Weight Errors by Speed

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

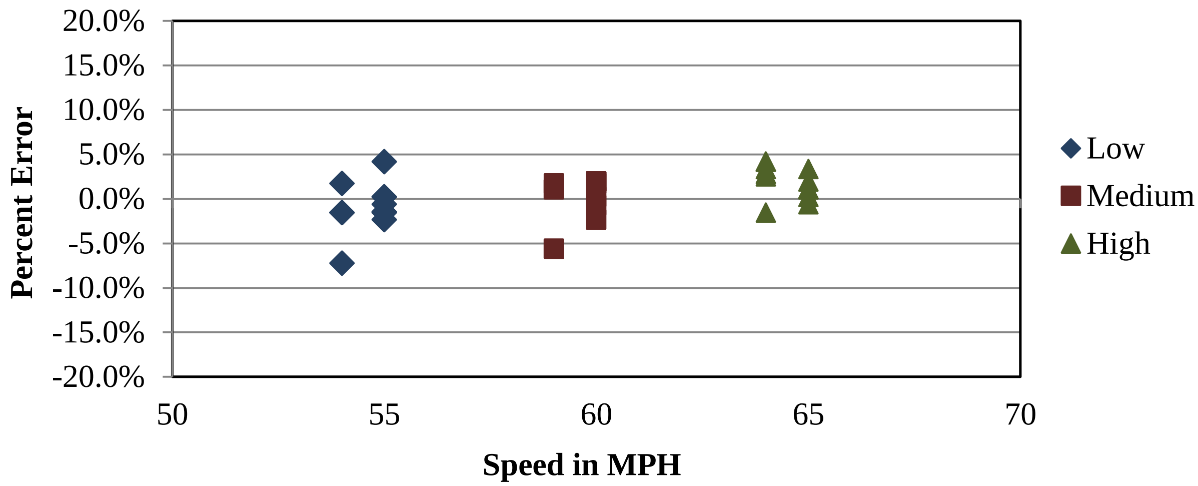


Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 17-Apr-13

5.3.1.3 Tandem Axle Weight Errors by Speed

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

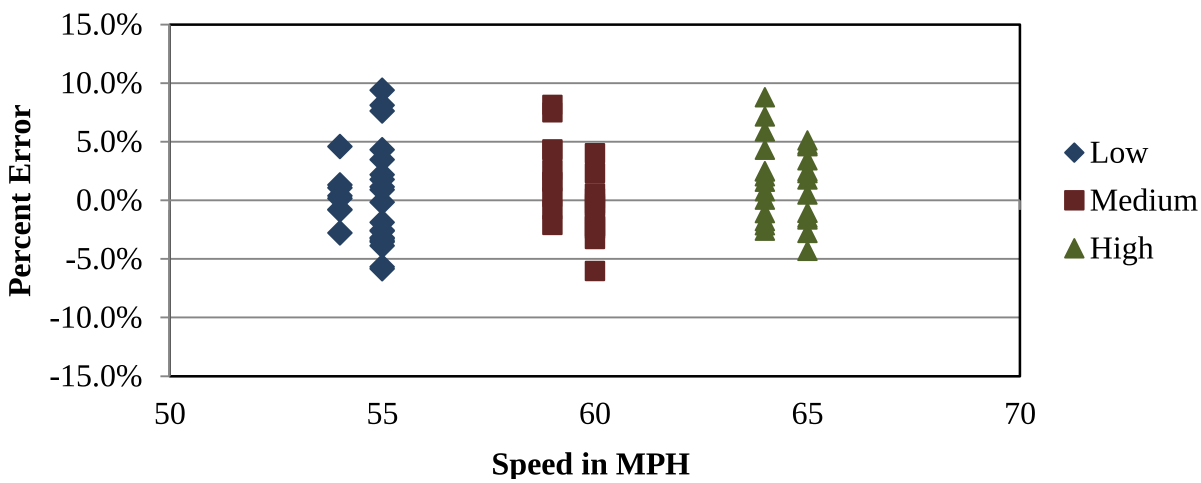


Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 17-Apr-13

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-15 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck.

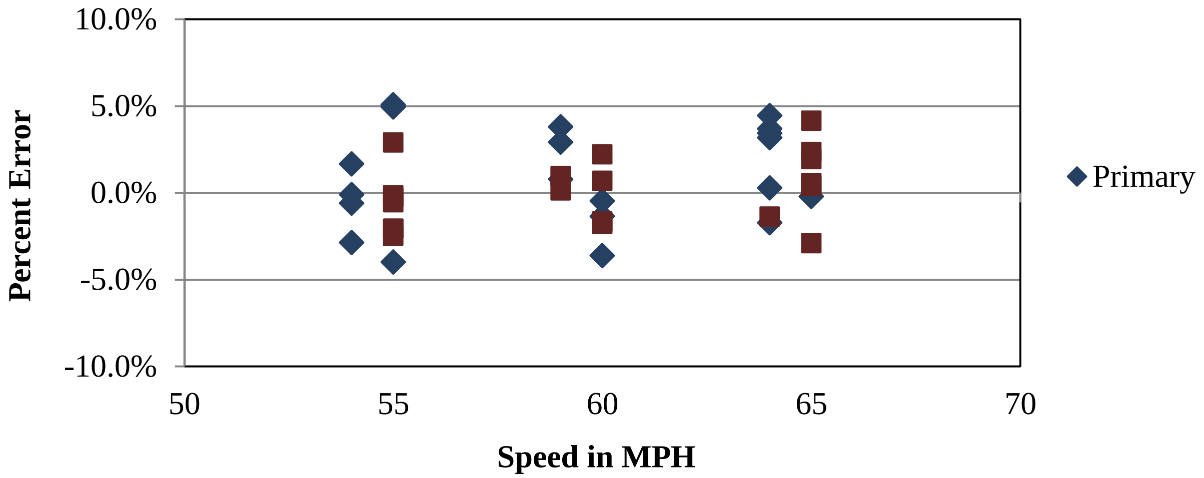


Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 17-Apr-13

5.3.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from -0.1 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-16.

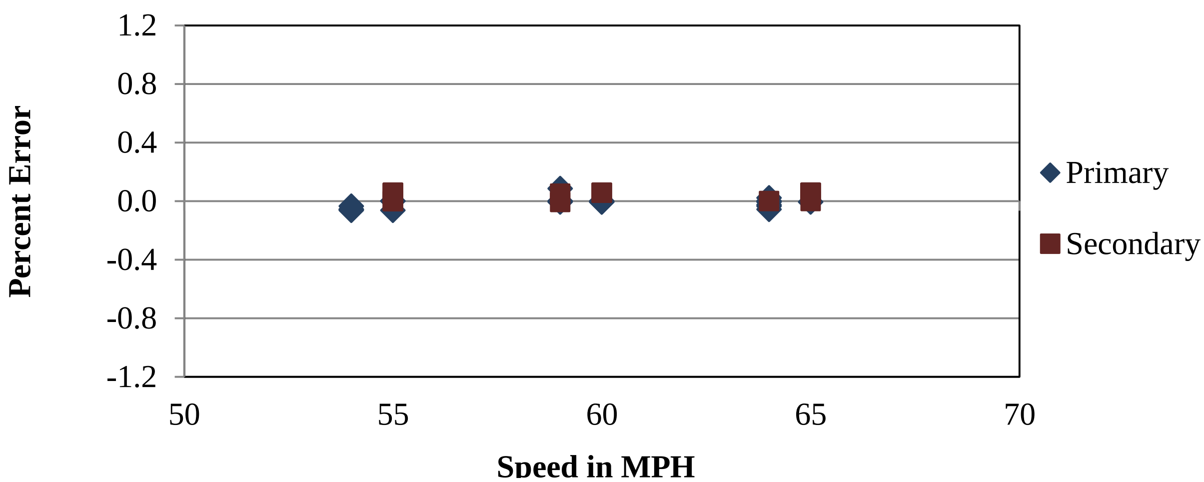


Figure 5-16 – Post-Validation Axle Length Error by Speed – 17-Apr-13

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length consistently over the entire range of speeds, with errors ranging from -0.5 to 1.4 feet. Distribution of errors is shown graphically in Figure 5-17.

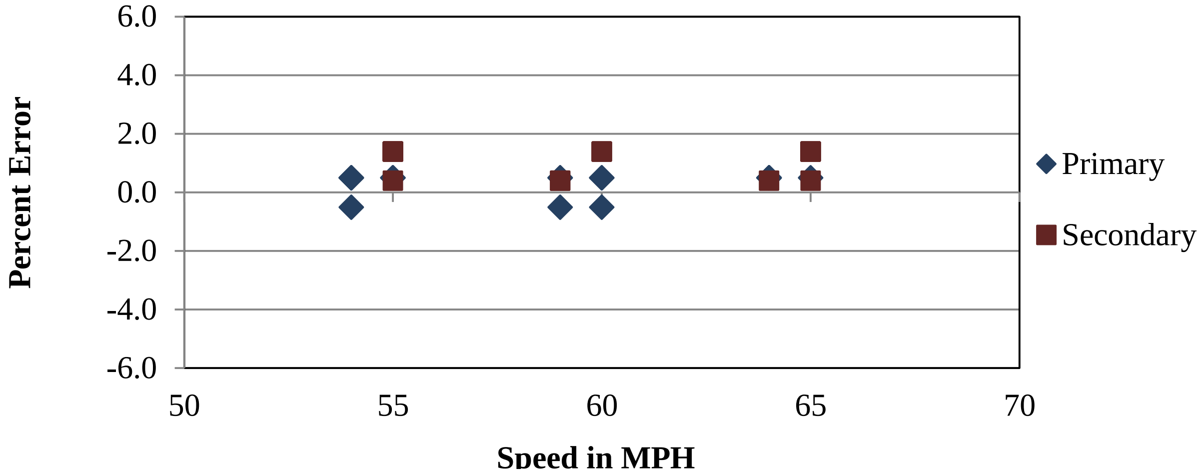


Figure 5-17 – Post-Validation Overall Length Error by Speed – 17-Apr-13

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 6.8 degrees, from 40.7 to 47.5 degrees Fahrenheit. Due to the small range of temperatures observed, the post-validation test runs are reported under one temperature groups – low, as shown in Table 5-12 below.

Table 5-12 – Post-Validation Results by Temperature – 17-Apr-13

Parameter	95% Confidence Limit of Error	Medium
		40.7 to 47.5 degF
Steering Axles	±20 percent	0.3 ± 5.4%
Tandem Axles	±15 percent	0.7 ± 6.6%
GVW	±10 percent	0.5 ± 5.0%
Vehicle Length	±3.0 percent (2.1 ft)	0.8 ± 1.2 ft
Vehicle Speed	± 1.0 mph	0.8 ± 2.9 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft

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

5.3.2.1 GVW Errors by Temperature

From Figure 5-18, it can be seen that the equipment appears to estimate GVW with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

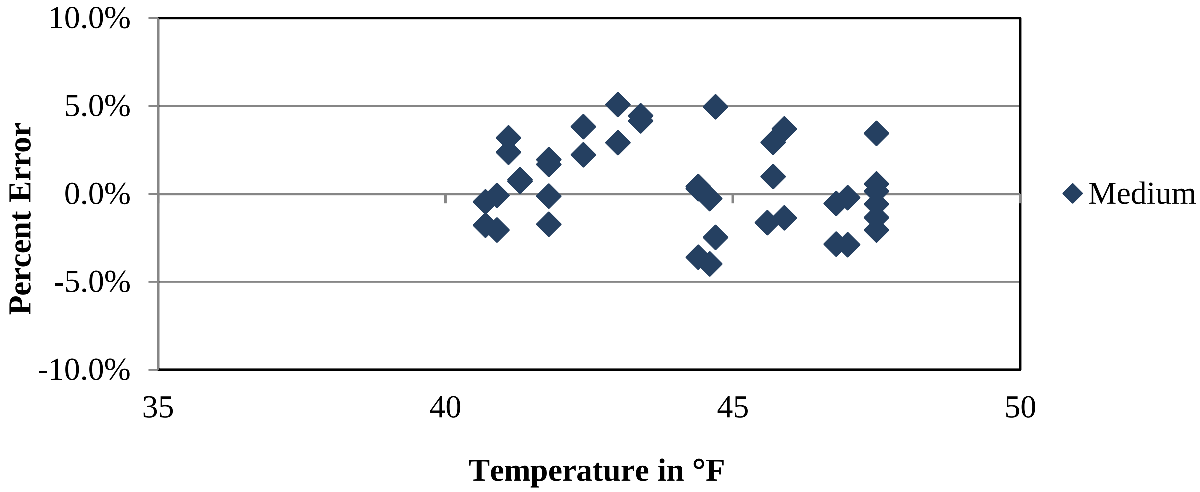


Figure 5-18 – Post-Validation GVW Errors by Temperature – 17-Apr-13

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-19 demonstrates that for steering axles, the WIM equipment appears to estimate weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and steering axle weight estimates at this site. The range in steering axle errors is consistent across the one temperature group.

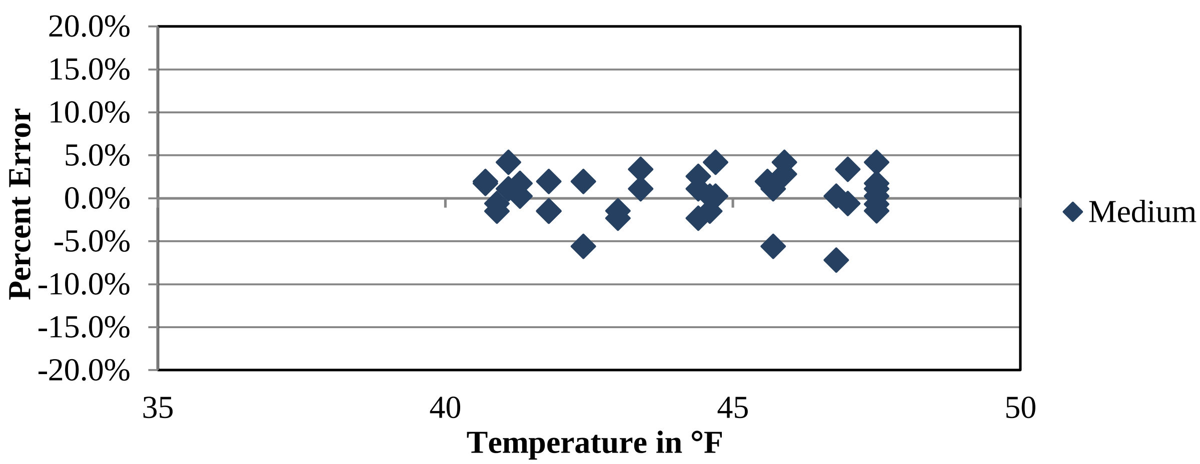


Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 17-Apr-13

5.3.2.3 Tandem Axle Weight Errors by Temperature

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

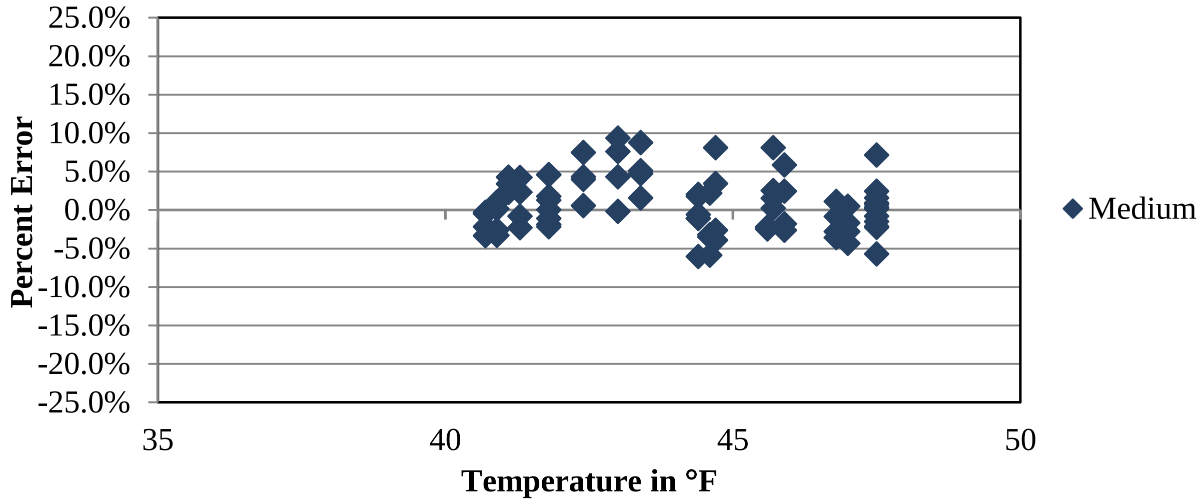


Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 17-Apr-13

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, when analyzed by truck type, GVW measurement errors for both trucks are similar at all temperatures. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures.

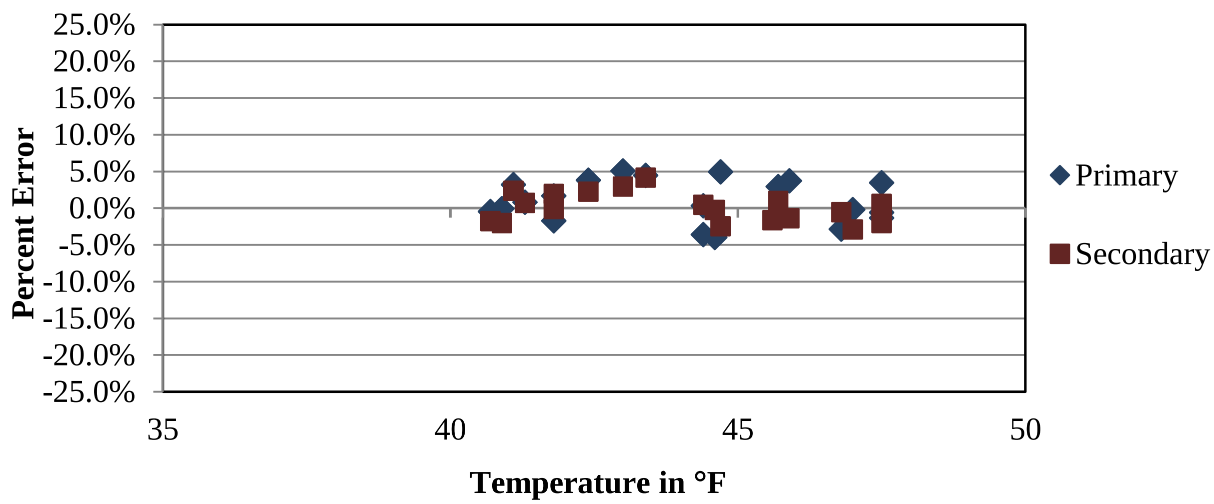


Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 17-Apr-13

5.3.3 Classification and Speed Evaluation

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

For the post-validation classification study at this site, a manual sample of 42 vehicles including 42 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. There were no misclassifications observed during the post-validation classification study.

Based on the vehicles observed during the post-validation study, the misclassification percentage is 0.0% for heavy trucks (vehicle classes 6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is also 0.0 percent.

The results of the classification study are shown in Table 5-13. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-13 – Post-Validation Classification Study Results – 17-Apr-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	0	0	21	2	0	4	15	0	0	0	0
WIM Count	0	0	21	2	0	4	15	0	0	0	0
Observed Percent	0.0	0.0	50.0	4.8	0.0	9.5	35.7	0.0	0.0	0.0	0.0
WIM Percent	0.0	0.0	50.0	4.8	0.0	9.5	35.7	0.0	0.0	0.0	0.0
Misclassified Count	0	0	0	0	0	0	0	0	0	0	0
Misclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. Based on the manually collected sample of the 42 trucks, 0.0 percent of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 0.4 mph; the range of errors was ± 0.7 mph.

5.3.4 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-14.

Table 5-14 – Final Factors

Speed Point	MPH	Left		Right	
		1	3	2	4
64	40	3286	3286	3047	3047
80	50	3286	3286	3047	3047
96	60	3306	3306	3065	3065
112	70	3315	3315	3073	3073
128	80	3315	3315	3073	3073
Axle Distance (cm)		365			
Dynamic Comp (%)		103			
Loop Width (cm)		244			

6 Post-Visit Data Analysis

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

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

6.1 Regression Analysis

This section provides additional results for the analysis carried out to determine the influence of truck type, speed and pavement temperature on WIM measurement errors. Multivariable linear regression analysis was applied to WIM data collected during calibration procedures. The same calibration data analyzed and discussed previously was used for this analysis; however a more comprehensive statistical methodology was applied. The objective of the additional analysis is to investigate if the trends identified using previous analyses are statistically significant, and to quantify these trends.

Multivariable analysis provides additional insight on how factors like speed, temperature, and truck type may affect weight measurement errors for a specific WIM site. It is expected that multivariable analysis done systematically for many sites may reveal overall trends.

6.1.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. The weight of "axle group" was evaluated separately for tandem axles on tractors and on trailers. The separate evaluation was carried out because the tandem axles on trailers may have different dynamic response to loads than tandem axles on tractors.

The measurement errors were statistically attributed to the following variables or factors:

- Truck type. Primary truck and Secondary truck.
- Truck test speed. Truck test speed ranged from 54 to 65 mph.
- Pavement temperature. Pavement temperature ranged from 40.7 to 47.5 degrees Fahrenheit.

6.1.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 6-1. The value of regression coefficients defines the slope of the relationship between the % error in GVW and the predictor variables (speed, temperature, and truck type). The values of the t-distribution (for the regression coefficients) given in Table 6-1 are for the null hypothesis that assumes that the regression coefficients are equal to zero. The p-value reported in Table 6-1 is for the probability that the regression coefficient, given in Table 5-5, occur by chance alone.

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

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value (p-value)
Intercept	2.6941	8.7983	0.3062	0.7612
Speed	0.1343	0.0922	1.4570	0.1538
Temp	-0.2195	0.1604	-1.3682	0.1797
Truck	-0.9665	0.7594	-1.2728	0.2112

The lowest probability value given in Table 6-1 was 0.1538 for speed. This means that there is about a 15 percent chance that the value of regression coefficient for speed (0.1343) can occur by chance alone. The relationship between speed and GVW measurement error is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 6-1 provides quantification and statistical assessment of the relationship.

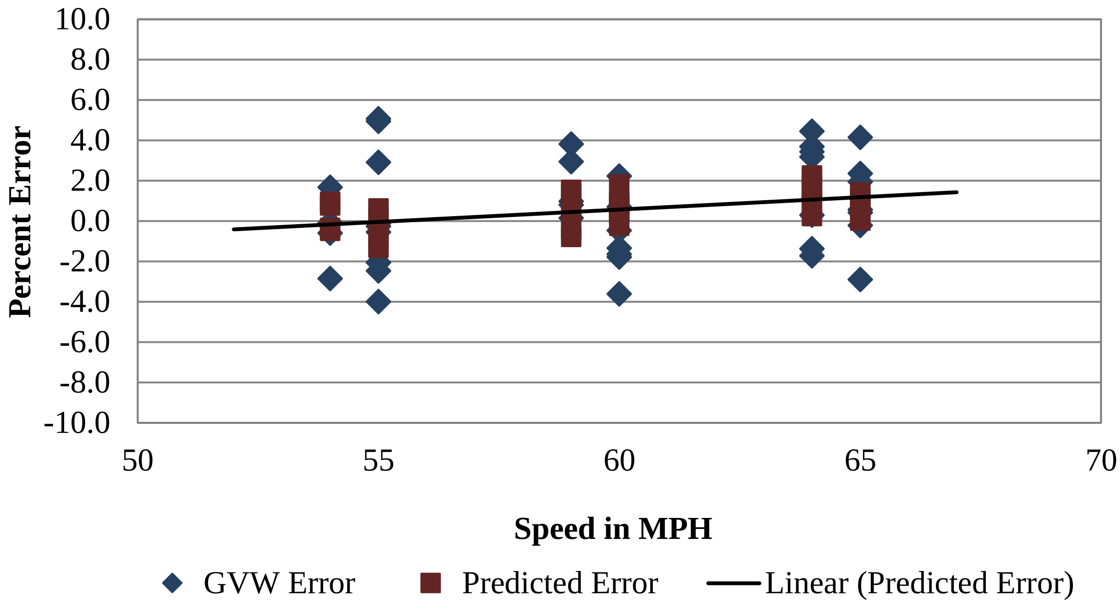


Figure 6-1 – Influence of Speed on the Measurement Error of GVW

The quantification of the relationship is provided by the value of the regression coefficient, in this case 0.1343 (in Table 6-1). This means, for example, that for a 10 mph increase in speed, the error is increased by about 1.3 percent (0.1343 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.1538) and is not statistically significant (values equal or less than 0.05 would indicate statistical significance in this case).

6.1.3 Summary Results

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

Table 6-2 – Summary of Regression Analysis

Parameter	Factor					
	Speed		Temperature		Truck type	
	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)
GVW	0.1343	0.1538	-0.2195	0.1797	-	-
Steering axle	0.2972	0.0031	-	-	-	-
Tandem axle tractor	-	-	-	-	-2.4683	0.0400
Tandem axle trailer	0.1655	0.0988	-0.3719	0.0353	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on the measurement of steering axles only. This assumes that p-value must be smaller than 0.05 for the effect to be statistically significant.

2. Temperature had a statistically significant effect on the measurement error of trailer tandem axles only. Even though the effect on the measurement errors was statistically significant, the values of the regression coefficients were small (0.1655) indicating that this effect has no practical significance. In addition, the range of pavement temperatures was too small (6.8 ºF) to investigate the effect of pavement temperature on measurement errors.

3. Truck type had statistically significant effect only on tractor tandem axle measurement errors at 0.04 probability value. The regression coefficients for truck type in Table 6-1 and Table 6-2 represent the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1). Thus, for example, the difference in the average measurement error for GVW between the Primary and Secondary trucks was about 1 % (0.9665 in Table 6-1). The effect of truck type is further analyzed in Section 6.1.5.

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

6.1.5 Contribution of Two Trucks to Calibration

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

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

Figure 6-2 and associated statistical analysis show that speed had similar influences on the GVW measurement for each truck and that trends in GVW errors are similar for both trucks with primary truck showing slightly greater negative bias (difference in bias values about 2 percent). Overall GVW error dependency on speed was very low for both trucks.

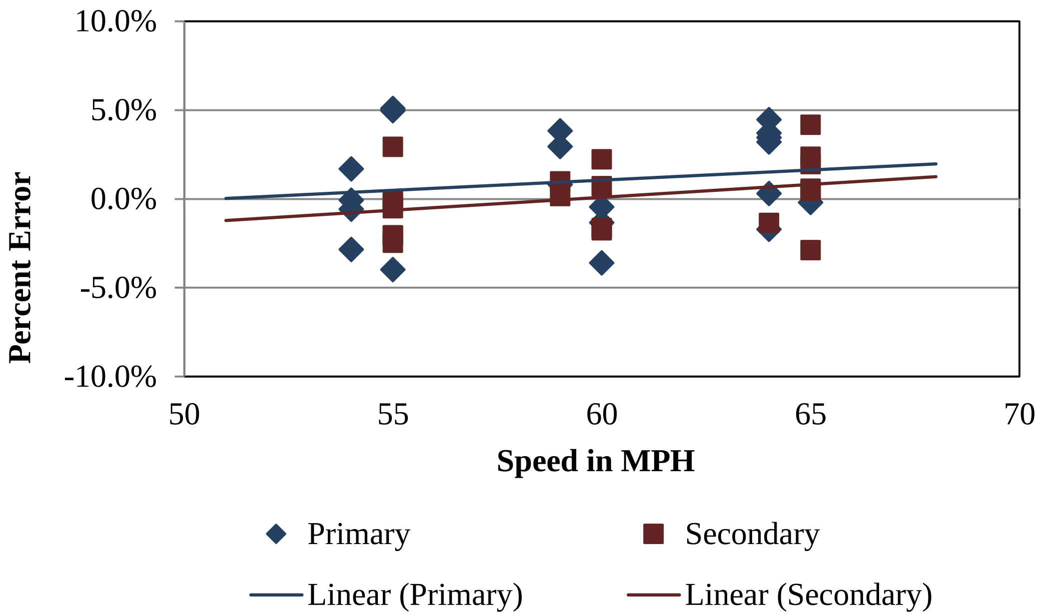


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

The use of two calibration trucks provided verification of the trends and speeded up the time required to obtain 40 pre-validation runs. However for this site, the use of only one of the trucks

(Primary or Secondary) with 20 calibration runs would have resulted in similar verification and calibration results, based on similarities in observed errors for both trucks.

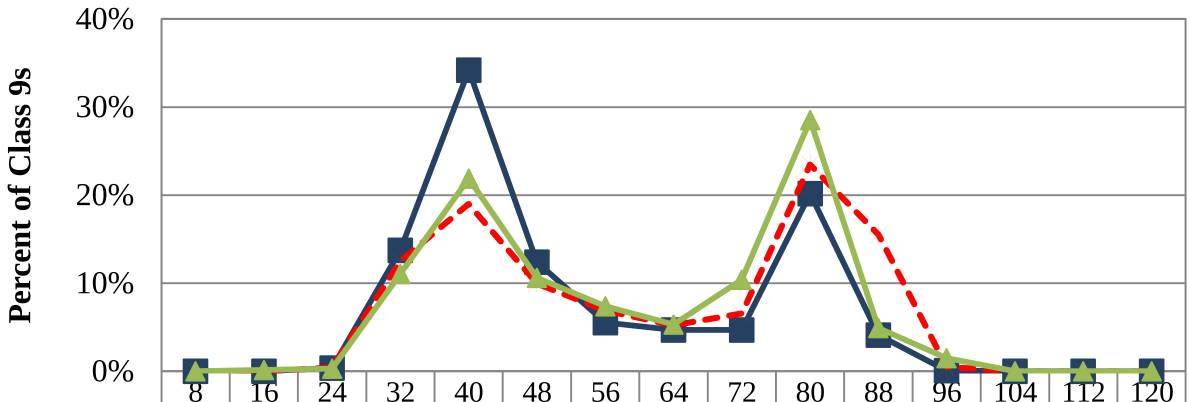
It should be noted that the analysis presented in this section are based on the post-validation test truck data. It is probable that somewhat different results would be obtained using both pre-and-post-validation data.

More detailed analysis of the influence of calibration trucks on the verification/calibration results would be beneficial. In this case, the Primary and the Secondary trucks had similar dimensions and suspension systems, and also similar influence on the verification/calibration results.

6.2 Traffic Data Analysis

A post-visit data analysis was conducted on data collected during the two-week period immediately following the validation to determine the effects of the calibration and to develop possible recommendations for further adjustments to the site operating factors, if necessary.

Figure 6-3 illustrates that for GVW, the calibration was effective in returning the distribution of Class 9 truck weights to similar values as those provided by the Data Comparison Set (CDS).



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.4%	13.7	34.2	12.4	5.5%	4.7%	4.7%	20.2	4.1%	0.1%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.4%	12.5	19.0	10.0	6.9%	5.2%	6.6%	23.5	15.5	0.5%	0.0%	0.0%	0.0%
Post	0.0%	0.1%	0.3%	11.1	21.9	10.6	7.4%	5.3%	10.4	28.5	4.9%	1.5%	0.0%	0.0%	0.0%

Figure 6-3 – Post Visit GVW Distribution

6.2.1 Average GVW and Steering Axle Weights

As a result of the Post-Visit Traffic Data Analysis, it appears that the calibration adjustments brought the average GVW and Steering Axle weights for the site more in line with the Comparison Data Set from March 10, 2011, as shown in Table 6-3.

Table 6-3 – Average GVW and Steering Axle Weights

Data Set	Date	Average GVW (kips)	Average Steering Axle (kips)
Comparison Data Set	April 05, 2012	64.0 kips	11.5 kips
Pre-Visit Sample	April 31, 2013	55.9 kips	10.7 kips
Post-Visit Sample	May 19, 2013	58.2 kips	11.6 kips

6.2.2 Imbalance

Due to the low truck volumes at this site, the results of the post-visit data analysis could not be used to develop a recommendation for making adjustments to the system factors.

6.2.3 WIM System Factor Adjustments

Since the average GVW and steering axle weights provided during the Post-Visit data analysis are reasonably similar to those provided by the Comparison Data Set, and recommendations for imbalance adjustments cannot be made, no adjustments to the WIM system factors are recommended.

7 Previous WIM Site Validation Information

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

7.1 Classification

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

Table 7-1 – Classification Validation History

Date	Misclassification Percentage by Class											Pct Unclass
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
13-Dec-06	-	0	0	0	-	-	0	0	-	-	-	0
14-Dec-06	-	0	0	0	-	-	0	0	-	-	-	0
28-Aug-07	-	100	0	0	0	50	0	0	-	-	-	0
29-Aug-07	-	-	0	0	0	0	0	0	-	-	-	0
11-Nov-08	-	100	25	25	-	100	0	-	-	-	-	0
12-Nov-08	-	0	0	0	-	0	0	0	-	-	-	0
0-Jan-00	0	0	0	0	0	0	0	0	0	0	0	0
26-Apr-11	-	100	0	0	0	0	0	0	0	0	0	0
3-Apr-12	33	0	11	0	0	0	0	0	0	0	0	0
4-Apr-12	0	100	45	0	0	0	0	0	0	0	0	0
17-Apr-13 (Pre)	0	0	0	0	0	0	0	0	0	0	0	0
17-Apr-13 (Post)	0	0	0	0	0	0	0	0	0	0	0	0

7.2 Weight

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

Table 7-2 – Weight Validation History

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
13-Dec-06	-0.6 ± 6.3	-5.2 ± 7.3	1.6 ± 5.4
14-Dec-06	3.0 ± 3.1	-1.6 ± 6.8	4.6 ± 3.7
28-Aug-07	-4.2 ± 5.8	-4.8 ± 8.0	-3.5 ± 9.2
29-Aug-07	-2.6 ± 5.4	-2.4 ± 9.2	-2.3 ± 9.0
11-Nov-08	-6.2 ± 4.7	-6.6 ± 6.9	-6.2 ± 5.2
12-Nov-08	-0.2 ± 4.6	-0.4 ± 7.9	-0.2 ± 5.4
26-Apr-11	-0.5 ± 2.7	-1.2 ± 6.2	-0.4 ± 4.0
3-Apr-12	-3.7 ± 3.5	-4.9 ± 6.4	-1.4 ± 5.7
4-Apr-12	-0.4 ± 3.0	-1.3 ± 5.7	0.9 ± 4.6
17-Apr-13 (Pre)	-6.7 ± 3.3	-7.5 ± 4.2	-2.5 ± 4.5
17-Apr-13 (Post)	0.5 ± 5.0	0.3 ± 5.4	1.1 ± 6.6

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an underestimation of GVW over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

8 Additional Information

The following information is provided in the attached appendix:

- Site Photographs
    - Equipment
    - Test Trucks
    - Pavement Condition
- Pre-validation Sheet 16 – Site Calibration Summary
- Post-validation Sheet 16 – Site Calibration Summary
- Pre-validation Sheet 20 – Classification and Speed Study
- Post-validation Sheet 20 – Classification and Speed Study

Additional information is available upon request through LTPP INFO at ltppinfo@dot.gov, or telephone (202) 493-3035. This information includes:

- Sheet 17 – WIM Site Inventory
- Sheet 18 – WIM Site Coordination
- Sheet 19 – Validation Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 24A/B/C – Site Photograph Logs
- Updated Handout Guide

WIM System Field Calibration and Validation - Photos

Minnesota, SPS-5
SHRP ID: 270500

Validation Date: April 17, 2013

Photo 1 – Cabinet Exterior

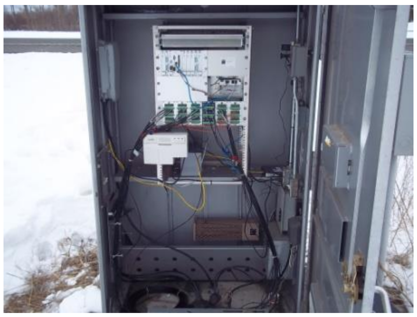


Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior Second

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Power Service Box

Photo 9 – Telephone Service Box

Photo 10 – Downstream

Photo 11 – Upstream

Photo 12 – Truck 1

Photo 13 – Truck 1 Tractor

Photo 14 – Truck 1 Trailer and Load

Photo 15 – Truck 1 Suspension 1

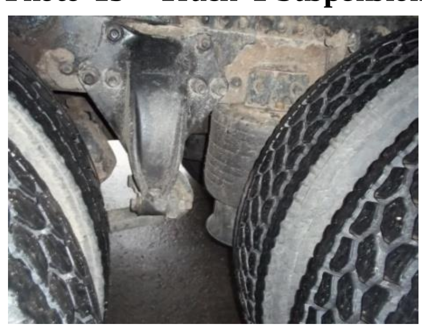


Photo 16 – Truck 1 Suspension 2

Photo 17 – Truck 1 Suspension 3

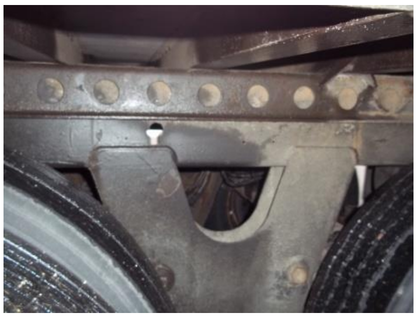


Photo 18 – Truck 1 Suspension 4

Photo 19 – Truck 1 Suspension 5

Photo 20 – Truck 2

Photo 21 – Truck 2 Tractor

Photo 22 – Truck 2 Trailer and Load

Photo 23 – Truck 2 Suspension 1

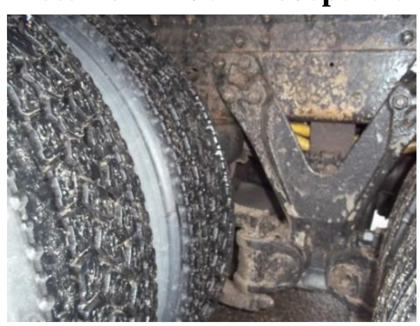


Photo 24 – Truck 2 Suspension 2

Photo 25 – Truck 2 Suspension 3

Photo 26 – Truck 2 Suspension 5

Photo 27 – Truck 2 Suspension 4

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE:	27
	SPS WIM ID:	270500
	DATE (mm/dd/yyyy)	4/17/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 4/17/13

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

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

4. **SENSORS INSTALLED IN LTPP LANE AT THIS SITE** (Select all that apply):
   a. Inductance Loops
   b. 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: 21

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

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

Mean Difference Between -

Dynamic and Static GVW:	-6.7%	Standard Deviation:	1.7%
Dynamic and Static Single Axle:	-7.5%	Standard Deviation:	2.1%
Dynamic and Static Double Axles:	-2.5%	Standard Deviation:	2.2%

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	16
b.	Medium	-	57.8	to	61.4	13
c.	High	-	61.5	to	65.0	12
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	27
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	270500
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	4/17/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3087 | 2862

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: Time

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	0.0	FHWA Class	5	-	0.0
FHWA Class 8:	0.0	FHWA Class	7	-	0.0
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 16		
LTPP MONITORED TRAFFIC DATA	STATE CODE:	27
SITE CALIBRATION SUMMARY	SPS WIM ID:	270500
	DATE (mm/dd/yyyy)	4/17/2013

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 4/17/13

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: 20

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

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

Mean Difference Between -

	Mean		Standard Deviation
Dynamic and Static GVW:	0.5%	Standard Deviation:	2.5%
Dynamic and Static Single Axle:	0.3%	Standard Deviation:	2.7%
Dynamic and Static Double Axles:	1.1%	Standard Deviation:	3.3%

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	12
c.	High	-	61.5	to	65.0	14
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	27 270500 4/17/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3315 | 3073

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: Time

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

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

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 27 SPS WIM ID: 270500 DATE (mm/dd/yyyy) 4/17/2013

Count - 41 Time = 4:55:20 Trucks (4-15) - 41 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
61	6	54662	61	6	68	5	55647	66	5
65	6	54692	64	6	69	5	55672	68	5
65	5	54705	65	5	60	10	55683	61	10
61	5	54764	60	5	58	9	55707	58	9
65	5	54906	63	5	55	9	55752	55	9
64	9	54948	65	9	65	5	55793	64	5
65	5	54961	65	5	73	5	55794	71	5
60	8	54973	60	8	66	6	55864	65	6
65	9	55033	65	9	62	9	55887	62	9
72	5	55038	70	5	63	5	55900	63	5
65	5	55124	66	5	62	5	55935	63	5
65	5	55160	66	5	70	9	55965	69	9
65	9	55213	65	9	60	5	55971	60	5
57	6	55227	57	6	68	5	56145	68	5
66	9	55239	65	9	61	9	56157	60	9
60	5	55283	60	5	71	5	56207	71	5
64	5	55392	63	5					
65	10	55412	63	10					
66	8	55426	66	8					
66	5	55440	65	5					
63	6	55459	63	6					
65	5	55537	65	5					
62	5	55571	62	5					
59	6	55582	60	6					
65	9	55619	65	9					

Sheet 1 - 0 to 50 Start: 8:17:26 Stop: 13:12:46

Recorded By: gah Verified By: djw

Validation Test Truck Run Set - Pre

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 27 SPS WIM ID: 270500 DATE (mm/dd/yyyy) 4/17/2013

Count - 42 Time = 5:19:39 Trucks (4-15) - 42 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
66	5	56343	65	5	67	5	57327	65	5
65	5	56392	65	5	65	8	57402	65	8
69	5	56504	70	5	71	9	57409	71	9
62	9	56518	60	9	60	9	57620	60	9
63	9	56519	62	9	64	9	57762	64	9
62	9	56520	62	9	64	5	57773	64	5
69	5	56535	68	5	66	5	57781	65	5
61	9	56545	61	9	60	8	57799	60	8
63	6	56558	63	6	68	5	57810	68	5
66	9	56574	65	9	66	5	57840	66	5
66	5	56583	65	5	58	5	57874	58	5
70	8	56618	70	8	65	9	57877	63	9
71	5	56623	70	5	60	5	58168	60	5
71	5	56652	70	5	65	5	58227	65	5
65	9	56663	65	9	65	5	58281	65	5
69	5	56679	68	5	68	9	58292	67	9
66	9	56926	65	9	63	8	58299	63	8
70	5	57053	70	5					
70	5	57067	70	5					
66	6	57102	65	6					
65	9	57167	65	9					
65	5	57195	65	5					
65	5	57268	65	5					
60	9	57313	59	9					
60	9	57314	60	9					

Sheet 1 - 0 to 50 Start: 13:39:05 Stop: 18:58:44

Recorded By: gah Verified By: djw

Validation Test Truck Run Set - Post