WIM System Field Calibration and Validation Summary Report - Amended

Delaware SPS-1
SHRP ID – 100100

Validation Date: July 14, 2010
Submitted: 1/6/2011

Table of Contents

List of Figures

List of Tables

1 Executive Summary

A WIM validation was performed on July 13 and 14, 2010 at the Delaware SPS-1 site located on route US-113 at milepost 25.2, 3.1 miles south of SR 16.

This site was installed on July 11, 2007. The in-road sensors are installed in the southbound lane. It is equipped with quartz WIM sensors and IRD iSINC WIM controller. The LTPP lane is identified as lane 1 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on March 21, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

The equipment is in working order. Electronic and electrical checks of all WIM components determined that the insulation resistance measurement for the leading loop was lower than expected, but was functioning properly. All other equipment was operating within tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, a transition from asphalt to PCC pavement was identified at a location approximately 250 feet prior to the WIM scale area. This may have affected the wide variance in steering axle errors that resulted from the validation. Truck observations did detect vertical truck movement at the transition, but the truck movement appeared to diminish prior to the trucks traveling over the WIM scales. 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 – 14-Jul-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.0 ± 9.1%	Pass
Tandem Axles	±15 percent	0.3 ± 7.6%	Pass
GVW	±10 percent	0.3 ± 6.0%	Pass
Vehicle Length	±3 percent (1.8 ft)	-0.3 ± 1.5 ft	Pass
Axle Spacing Length	± 0.5 ft [150mm]	-0.1 ± 0.3 ft	Pass

Test truck speeds were manually collected for each test run by a speed detection device and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was -0.3 ± 2.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length within specified tolerances, and the two 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 an acceptable range.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 1.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 10.8% from the 102 truck (Class 4 – 13) sample collected was due to the ten cross-classifications of Class 3, 4, 5, and 8 vehicles.

There were two test trucks used for the post-validation. They were configured and loaded as follows:

- The *Primary* truck was a Class 9 with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with concrete blocks and a crane counterweight loaded mid trailer.

- The *Secondary* truck was a Class 9, with air spring suspension on the tractor tandem, steel spring on the trailer tandem, standard tandem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with crane counterweights situated over front two-thirds of trailer.

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 collected (see Section 7). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last 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 and tenths)					
	GVW	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	1-2	2-3	3-4	4-5	AL	OL
1	76.7	10.1	16.3	16.3	17.0	17.0	12.1	4.2	37.7	4.0	58.0	63.0
2	67.4	9.2	15.0	15.0	14.1	14.1	12.8	4.2	28.6	4.0	49.6	57.0

The posted speed limit at the site is 55 mph. During the testing, the speed of the test trucks ranged from to 44 to 55 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 86.8 to 99.4 degrees Fahrenheit, a range of 12.6 degrees Fahrenheit. The intermittent rain showers and cloud cover prevented the optimal 30 degree range in temperatures. Further pre- and post-validation and calibration discussion is provided in Section 5.

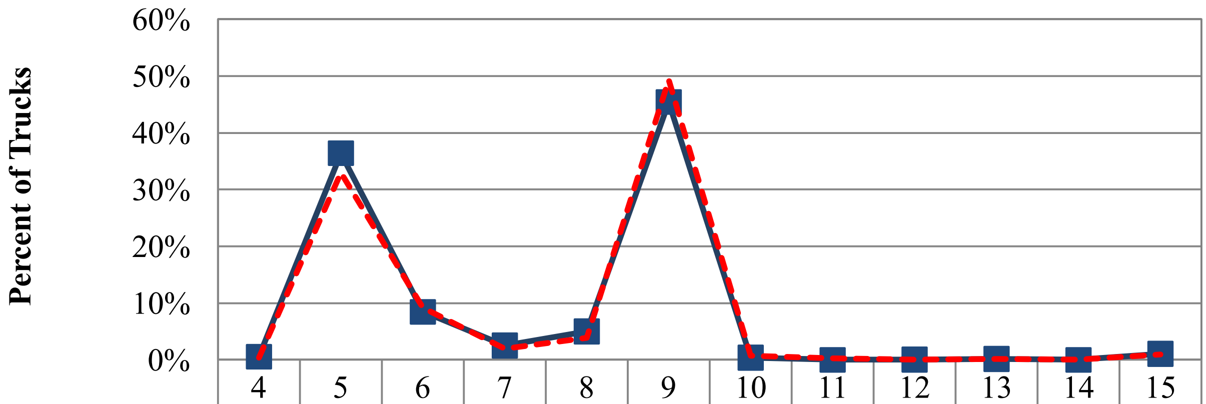
A review of the LTPP Standard Release Database 24 shows that there are 35 consecutive months of level "E" WIM data for this site. If the historical data has been verified to be of research quality, this site requires 2 additional years of data to meet the minimum of five years of research quality data.

2 Pre-Visit Data Analysis

To assess the quality of the current data, a pre-visit analysis was conducted by comparing a two-week data sample beginning June 14, 2010 to the most recent Comparison Data Set (CDS) beginning March 17, 2008.

2.1 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 will be conducted on site. Figure 2-1 provides a comparison of the truck type distributions for the two datasets.



	4	5	6	7	8	9	10	11	12	13	14	15
Data Class	0.6%	36.4	8.5%	2.5%	5.0%	45.4	0.4%	0.0%	0.0%	0.1%	0.0%	1.1%
CDS Class	0.4%	33.0	9.2%	2.0%	3.9%	49.3	0.8%	0.3%	0.0%	0.2%	0.0%	1.0%

Figure 2-1 – Truck Distribution from W-Card

Table 2-1 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 current data, the majority of the trucks crossing the WIM scale are Class 9 (45.4%) or Class 5 (36.4%). It also indicates that 1.1 percent of the vehicles at this site are unclassified. During the classification study, observations of Class 15 vehicles are made to determine if unclassified vehicles are valid, as in the case of oversized vehicles with irregular trailer axle spacings. The results of the classification study are described in Section 5.3.4.

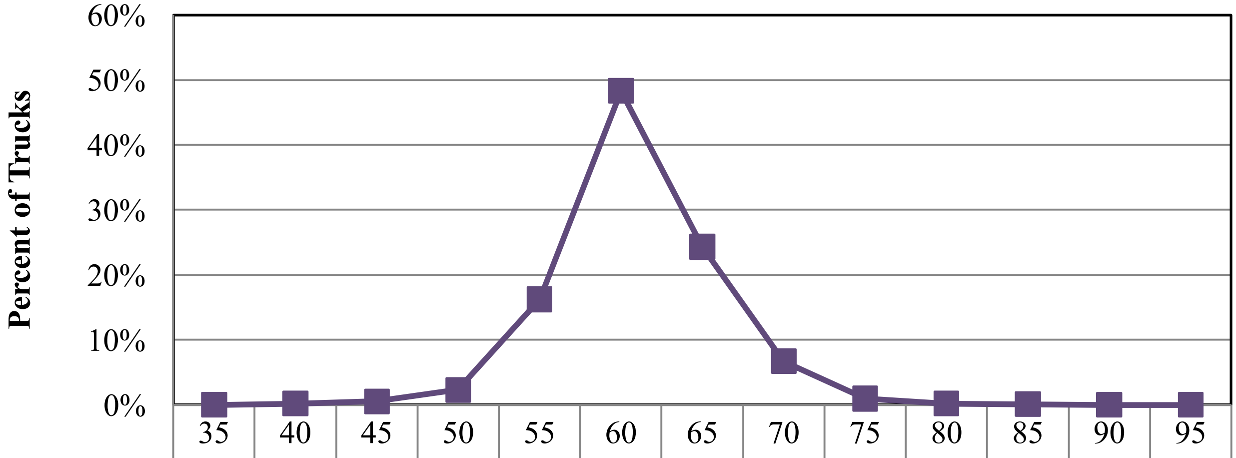
Table 2-1 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		% Change
	Date				
	3/17/2008		6/14/2010		
4	45	0.4%	63	0.6%	0.1%
5	3399	33.0%	4070	36.4%	3.4%
6	945	9.2%	947	8.5%	-0.7%
7	203	2.0%	282	2.5%	0.6%
8	397	3.9%	560	5.0%	1.2%
9	5082	49.3%	5079	45.4%	-3.9%
10	79	0.8%	40	0.4%	-0.4%
11	26	0.3%	2	0.0%	-0.2%
12	4	0.0%	5	0.0%	0.0%
13	18	0.2%	16	0.1%	0.0%
14	0	0.0%	0	0.0%	0.0%
15	103	1.0%	120	1.1%	0.1%

The table shows that the number of Class 5 vehicles has decreased by 3.4 percent from March 2008 and June 2010. These differences may be attributed to small sample size used to develop vehicle class distributions, decreased use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes. During the same time period, there was a decrease of 3.9 percent in the number of Class 9 trucks. Small increases in the number of heavier trucks may be attributed to seasonal variations in truck distributions.

2.2 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 the speed of the test trucks and for the required speeds to be covered by the post-visit Applied Calibration.



	35	40	45	50	55	60	65	70	75	80	85	90	95
Trucks	0.0%	0.2%	0.5%	2.3%	16.2	48.3	24.3	6.7%	0.9%	0.2%	0.1%	0.0%	0.0%

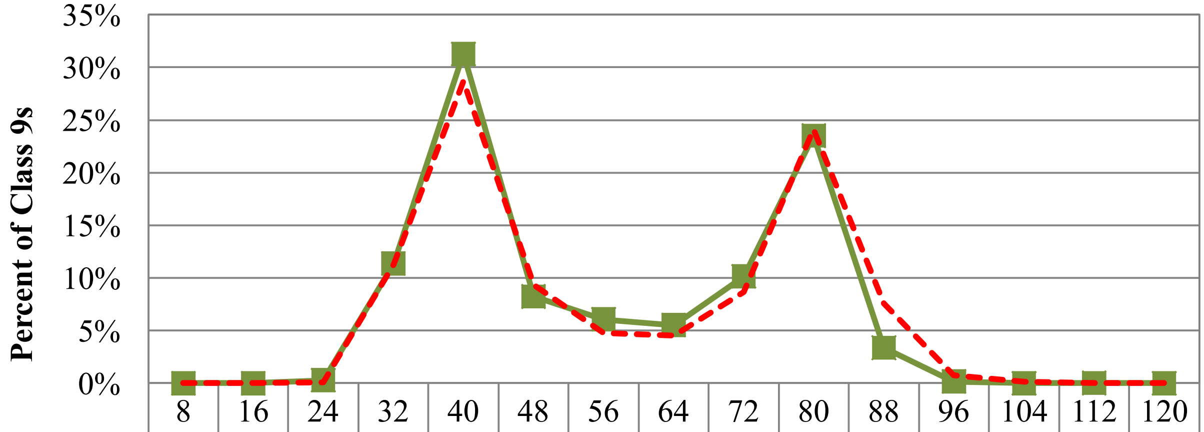
Figure 2-2 – Truck Speed Distribution from ASCII File

As shown in the figure, the majority of the trucks at this site are traveling between 55 and 65 mph. The posted speed limit at this site is 55 and the 85th percentile speed for trucks at this site is 63 mph. The coverage of truck speeds for the validation will be 45 and 55 mph. Since the 85th percentile speeds for trucks is above the posted speed limit and the highest test truck speed, the post-visit applied calibration will be used to develop compensation factors for speed points from 55 to 65 mph.

2.3 GVW Data Analysis

The traffic 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 one week W-card samples in June 2010 and March 2008 and are used to indicate possible drifting in WIM weight measurement accuracy.

As shown in the figure, there is no significant shift in loaded and unloaded peaks between the March 2008 comparison dataset (CDS) and the June 2010 sample W-card dataset (Data). However, the percentage of class 9 trucks at the unloaded peak range increased from 28.7% to 31.3% while the percentage of class 9 trucks at the loaded peak range decreased from 24.1% to 23.5%.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.3%	11.4	31.3	8.2%	6.1%	5.5%	10.2	23.5	3.4%	0.2%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.1%	11.3	28.7	9.3%	4.8%	4.5%	8.6%	24.1	7.6%	0.7%	0.2%	0.0%	0.0%

Figure 2-3 – Class 9 GVW Distribution from W-Card

Table 2-2 is provided to demonstrate the statistical comparison between the comparison dataset and the current dataset. The table shows that the majority of unloaded trucks weigh approximately 40,000 lbs and the majority of loaded trucks weigh approximately 80,000 lbs. According to the sample data set, 3.6% of the trucks at this site are overloaded (greater than 80,000 lbs), 4.9% lower than the current comparison data set indicates.

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

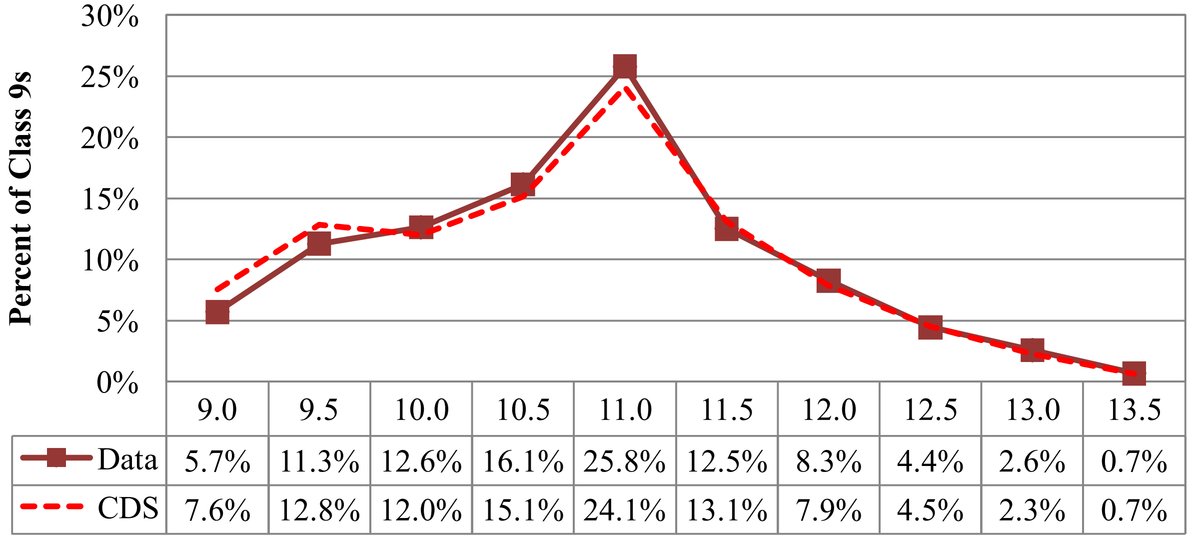
GVW weight bins (kips)	CDS		Data		Change
	Date				
	3/17/2008		6/14/2010		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	6	0.1%	15	0.3%	0.2%
32	569	11.3%	574	11.4%	0.1%
40	1449	28.7%	1580	31.3%	2.6%
48	472	9.3%	416	8.2%	-1.1%
56	242	4.8%	307	6.1%	1.3%
64	228	4.5%	279	5.5%	1.0%
72	437	8.6%	513	10.2%	1.5%
80	1220	24.1%	1188	23.5%	-0.6%
88	382	7.6%	170	3.4%	-4.2%
96	37	0.7%	9	0.2%	-0.6%
104	9	0.2%	0	0.0%	-0.2%
112	2	0.0%	1	0.0%	0.0%
120	1	0.0%	0	0.0%	0.0%
Average =	54.4		52.7		1.7

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range increased by 2.6 percent while the number of class 9 trucks in the 72 to 80 kips range decreased by 0.6 percent. The number of overweight trucks decreased during this time period by 4.9 percent and the overall GVW average for this site decreased from 54.4 kips to 52.7 kips.

2.4 Class 9 Front Axle Weight Data Analysis

The traffic 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 with the expected front axle weight average for Class 9 trucks of 10.3 kips.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using one week W-card samples in June 2010 and March 2008. The class 9 front axle weight plot is provided to indicate possible drifting in WIM weight measurement accuracies.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	5.7%	11.3%	12.6%	16.1%	25.8%	12.5%	8.3%	4.4%	2.6%	0.7%
CDS	7.6%	12.8%	12.0%	15.1%	24.1%	13.1%	7.9%	4.5%	2.3%	0.7%

Figure 2-4 – Class 9 Front Axle Weight from W-Card

As can be seen in the figure, there is no significant difference between the March 2008 Comparison Data Set (CDS) and the June 2010 dataset (Data).

Table 2-3 indicates that the average front axle weight for Class 9 trucks has not changed. According to the current data, the majority of the Class 9 front axle weights are between 10.5 and 11.0 kips and the average front axle weight for Class 9 trucks is 10.5 kips.

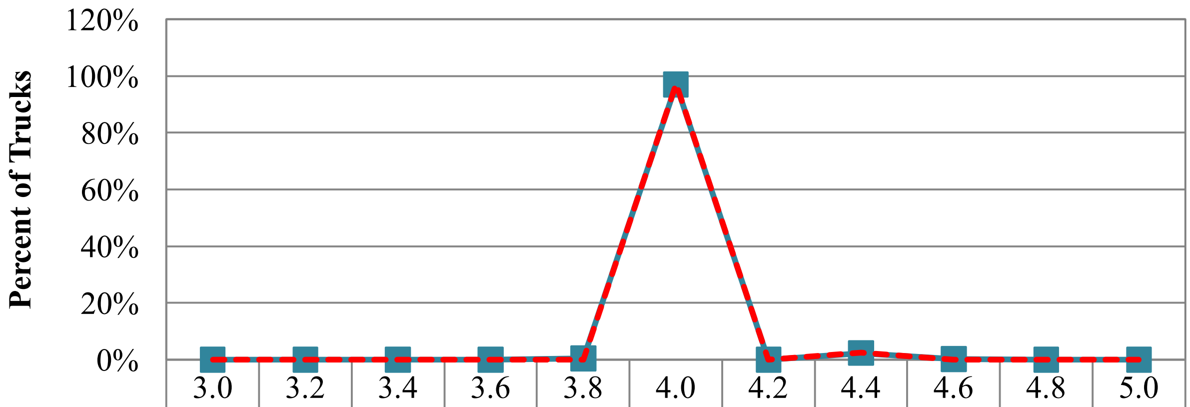
Table 2-3 – Class 9 Front Axle Weight Distribution from W-Card

F/A weight bins (kips)	CDS		Data		Change
	Date				
	3/17/2008		6/14/2010		
9.0	381	7.6%	286	5.7%	-1.9%
9.5	645	12.8%	567	11.3%	-1.5%
10.0	604	12.0%	634	12.6%	0.6%
10.5	761	15.1%	811	16.1%	1.0%
11.0	1212	24.1%	1295	25.8%	1.7%
11.5	658	13.1%	628	12.5%	-0.6%
12.0	395	7.9%	415	8.3%	0.4%
12.5	227	4.5%	223	4.4%	-0.1%
13.0	115	2.3%	130	2.6%	0.3%
13.5	33	0.7%	34	0.7%	0.0%
Average =	10.5		10.5		0.0

2.5 Class 9 Tractor Tandem Spacing Data Analysis

The traffic 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 average tractor tandem spacing from the equipment with the expected average tractor tandem spacing of 4.25 feet.

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



	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Data	0.0%	0.0%	0.0%	0.0%	0.5%	97.0%	0.0%	2.3%	0.2%	0.0%	0.0%
CDS	0.0%	0.0%	0.0%	0.0%	0.1%	97.3%	0.0%	2.5%	0.1%	0.0%	0.0%

Figure 2-5 – Class 9 Tractor Tandem Spacing from W-Card

As seen in the figure, the Class 9 tractor tandem spacing for the March 2008 comparison dataset and the June 2010 dataset are nearly identical.

Table 2-4 indicates that the spacing of the tractor tandems for Class 9 trucks at this site is between 3.8 and 4.0 feet. The average tractor tandem spacing is 4.0 feet. This is below the expected average of 4.25 feet. Further analyses are performed during the validation and during analysis of the post-visit traffic data. These results are presented in Section 5.3.

Table 2-4 – Class 9 Axle 3 to 4 Spacing from W-Card

Tandem 1 spacing bins (feet)	CDS		Data		Change
	3/17/2008		6/14/2010		
	Date				
3.0	0	0.0%	0	0.0%	0.0%
3.2	0	0.0%	1	0.0%	0.0%
3.4	0	0.0%	1	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	5	0.1%	24	0.5%	0.4%
4.0	4919	97.3%	4900	97.0%	-0.3%
4.2	0	0.0%	0	0.0%	0.0%
4.4	125	2.5%	117	2.3%	-0.2%
4.6	4	0.1%	9	0.2%	0.1%
4.8	0	0.0%	0	0.0%	0.0%
5.0	2	0.0%	0	0.0%	0.0%
Average =	4.0		4.0		0.0

2.6 Data Analysis Summary

Historical data analysis involved the comparison of the most recent comparison data set (March 2008) based on the last calibration with the most recent 2-week WIM data sample from the site (June 2010). Comparison of vehicle class distribution indicated an increase in Class 5 vehicles and a decrease in the number of Class 9 vehicles. Analysis of Class 9 GVW indicated a decrease in these weights as reported by the WIM equipment. The Class 9 tractor tandem spacing did not indicate any significant deviation in the WIM equipment performance.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on March 21, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

3.1 Description

This site was installed on July 11, 2007 by International Road Dynamics (IRD). It is instrumented with quartz weighing sensors and IRD iSINC WIM Controller. As the installation contractor, IRD also performs routine equipment maintenance and data quality checks of the WIM data.

3.2 Physical Inspection

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

3.3 Electronic and Electrical Testing

Electronic and electrical checks of all system components were conducted prior to the pre-validation test truck runs. Dynamic and static electronic checks of the in-road sensors were performed. All insulation resistive and capacitive values for the quartz sensors were within tolerances. Loop tests indicated that the insulation resistance for the leading loop was lower than expected. Electronic tests of the electric and telephone services 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

It is recommended that the insulation resistance values for the leading loop be investigated to determine the cause of the low readings. No other 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, two areas of pavement distress were noted and photographed:

- At a location 100 feet prior to the WIM scale, a series of classification sensors are currently installed. One of the sensors has been partially removed and road surface was patched as shown below.

Figure 4-1 – Sensor Patch - 13-Jul-10

- At a location approximately 250 feet prior to the WIM scale, there is a transition from asphalt to PCC pavement.

Figure 4-2 – Asphalt to PCC Transition - 13-Jul-10

- A popout was noted approximately 180 feet prior to the WIM scales.

Figure 4-3 – Popout - 13-Jul-10

None of the distresses noted appeared to influence truck movements as trucks crossed the WIM scale area. Additional pavement photographs are presented in Section 7.

4.2 Profile and Vehicle Interaction

Profile data collected on November 18, 2009 by the North Atlantic Regional Support Contractor was obtained using a high-speed profiler, where the operator travels over the entire one-thousand foot WIM Section, 900 feet prior to WIM scales and 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left (LWP) and right (RWP) 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 values within the 1000 foot WIM section were 209 in/mi and are located approximately 770 feet prior to the WIM scale. The highest IRI values within the 400 foot approach section were 101 in/mi and are located approximately 217 feet prior to the WIM scale. This area of pavement was closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed that would influence truck dynamics in the WIM scale area.

During the on-site pavement evaluation, it was determined that the higher IRI values were a result of a transition from asphalt to PCC pavement located approximately 250 feet prior the WIM scale. Truck observations determined that although the trucks tended to bounce at the transition, the effects were diminished prior to traversing the WIM sensor area. The patch of a partially removed classification sensor located approximately 100 feet prior to the WIM scale area did not appear to affect truck dynamics at the area of the patch or at the WIM scale area.

There were no other distresses observed that would influence truck dynamics in the WIM scale area.

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

4.3 LTPP Pavement Profile Data Analysis

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

Table 4-1 – Recommended WIM Smoothness Index Thresholds

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

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

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the three left, three right, and five 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)	0.635	0.674	0.724			0.678
		SRI (m/km)	0.657	0.620	0.740			0.672
		Peak LRI (m/km)	0.699	0.740	0.773			0.737
		Peak SRI (m/km)	0.764	0.673	0.779			0.739
	RWP	LRI (m/km)	0.603	0.629	0.598			0.610
		SRI (m/km)	0.676	0.696	0.765			0.712
		Peak LRI (m/km)	0.629	0.635	0.633			0.632
		Peak SRI (m/km)	*0.680*	0.860	0.801			0.780
Center	LWP	LRI (m/km)	0.632	0.607	0.627	0.591	0.651	0.614
		SRI (m/km)	0.636	0.519	0.563	0.599	0.703	0.579
		Peak LRI (m/km)	0.651	0.657	0.673	0.659	0.651	0.660
		Peak SRI (m/km)	*0.684*	*0.608*	*0.617*	*0.644*	*0.745*	*0.638*
	RWP	LRI (m/km)	0.627	0.600	0.636	0.640	0.613	0.626
		SRI (m/km)	0.676	0.615	0.555	0.564	0.560	0.603
		Peak LRI (m/km)	*0.458*	0.661	0.706	0.665	0.656	0.623
		Peak SRI (m/km)	*0.632*	*0.679*	*0.606*	*0.669*	*0.617*	*0.647*
Right	LWP	LRI (m/km)	0.651	0.644	0.627			0.641
		SRI (m/km)	0.630	0.715	0.593			0.646
		Peak LRI (m/km)	0.673	0.701	0.703			0.692
		Peak SRI (m/km)	*0.748*	0.826	*0.715*			0.763
	RWP	LRI (m/km)	0.795	0.678	0.685			0.719
		SRI (m/km)	1.072	0.564	0.604			0.747
		Peak LRI (m/km)	0.802	0.774	0.772			0.783
		Peak SRI (m/km)	1.362	*0.697*	*0.648*			0.902

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 falling under the lower threshold, as indicated in italics in the table above. Based on the WIM Smoothness thresholds and the expected impact of the indices on the accuracy of the WIM system, these values indicate that the pavement may or may not influence the accuracy of the sensor output.

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

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

5.1 Pre-Validation

The first set of tests provides a general overview of system performance, given all of the environmental and vehicle speed conditions that are present during the testing.

The 40 pre-validation test truck runs were conducted on July 12, 2010, beginning at approximately 8:22 AM and continuing until 4:04 PM.

The two test trucks consisted of:

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

- A Class 9, 5-axle truck, loaded with crane counterweights over the front two-thirds of the trailer and equipped with air spring suspension on the tractor, steel spring suspension on the trailer, with a standard tandem spacing on the tractor and a standard tandem spacing on the trailer.

Prior to the pre-validation, the test trucks were weighed and measured, tire pressures were taken, and photographs of the trucks, loads and suspensions were collected (see Section 7). The test trucks were re-weighed at the conclusion of the pre-validation. The average pre-validation test truck weights and measurements are provided in Table 5-1.

Table 5-1 – Pre-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet and tenths)					
	GVW	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	1-2	2-3	3-4	4-5	AL	OL
1	76.5	10.0	16.3	16.3	17.0	17.0	12.1	4.2	37.7	4.0	58.0	63.0
2	67.4	9.2	15.0	15.0	14.1	14.1	12.8	4.2	28.6	4.0	49.6	57.0

Test truck speeds varied by 13 mph, from 42 to 55 mph. The measured pre-validation pavement temperatures varied 19.1 degrees Fahrenheit, from 86.3 to 105.4. The intermittent rain showers weather conditions prevented for reaching the desired 30 degree temperature range. Table 5-2 is a summary of post validation results.

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

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-2.9 ± 9.3%	Pass
Tandem Axles	±15 percent	-2.4 ± 6.3%	Pass
GVW	±10 percent	-2.4 ± 4.7%	Pass
Vehicle Length	±3 percent (1.8 ft)	-0.4 ± 1.0 ft	Pass
Axle Spacing Length	± 0.5 ft [150mm]	-0.2 ± 0.3 ft	FAIL

Truck speed was manually collected for each test run by a handheld radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was -0.2 ± 1.9 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 within specified tolerances, and the two measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relation exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 55 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in the table below.

Table 5-3 – Pre-Validation Results by Speed – 13-Jul-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		42.0 to 46.3 mph	46.4 to 50.8 mph	50.9 to 55.0 mph
Steering Axles	±20 percent	-5.3 ± 9.1%	-1.8 ± 10.0%	-2.1 ± 9.7%
Tandem Axles	±15 percent	-3.9 ± 8.4%	-1.0 ± 6.1%	-2.4 ± 4.5%
GVW	±10 percent	-4.0 ± 5.9%	-1.1 ± 4.1%	-2.3 ± 3.6%
Vehicle Length	±3 percent (1.8 ft)	-0.4 ± 1.1 ft	-0.5 ± 1.1 ft	-0.3 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.0 ± 1.6 mph	-0.4 ± 2.6 mph	-0.3 ± 1.9 mph
Axle Spacing Length	± 0.5 ft [150mm]	-0.2 ± 0.3 ft	-0.2 ± 0.3 ft	-0.2 ± 0.4 ft

From the table, it can be seen that the WIM equipment underestimated, on average, all weight measurements at all speeds. The underestimation of all weights was greater at the lower speeds when compared with medium and high speeds. The range of steering axle error was consistent over all speeds. For tandem axles and GVW, the range of values decreased as speed increased.

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 by the negative percent errors in the following figure, the equipment underestimated GVW at all speeds. The range in error is greater at the lower speeds when compared with medium and high speeds.

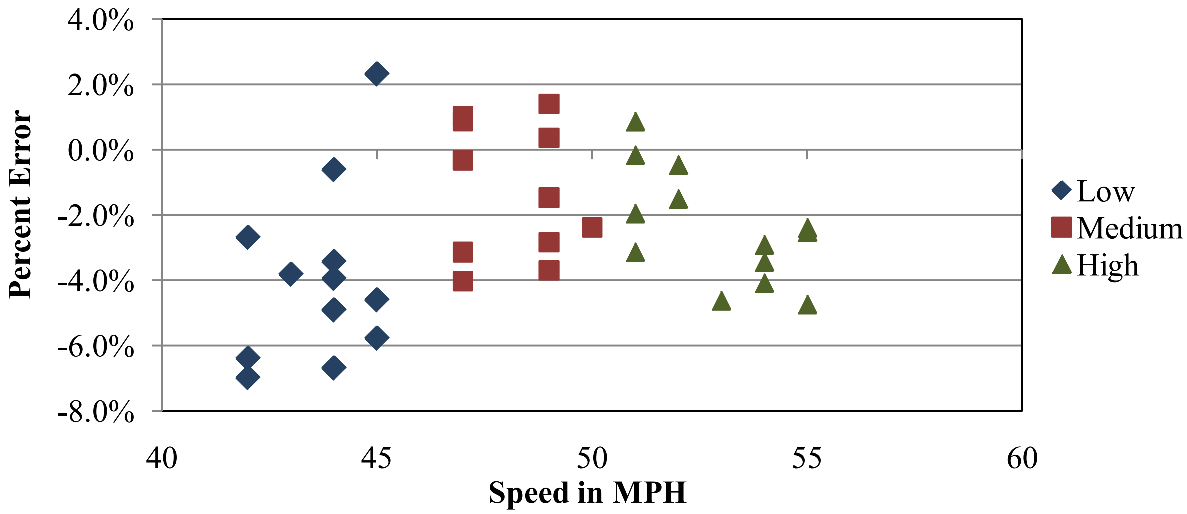


Figure 5-1 – Pre-Validation GVW Error by Speed – 13-Jul-10

5.1.1.2 Steering Axle Errors by Speed

As shown by the high number of the negative percent error occurrences in the following figure, the equipment generally underestimates steering axle weights at all speeds, with greater underestimations at the lower speeds. Negative bias in steering axle weight appears to be consistent throughout the entire speed range.

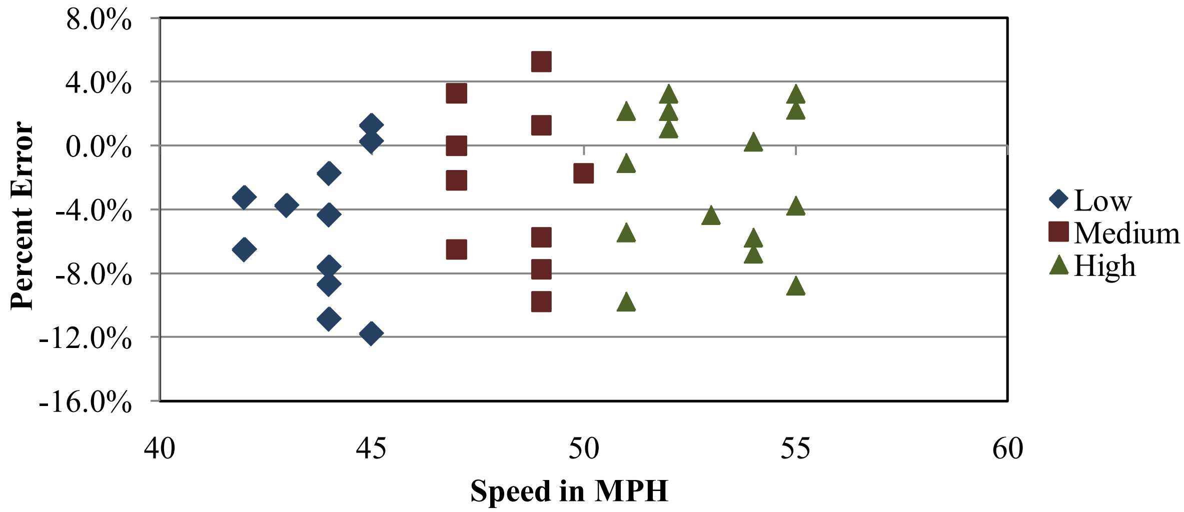


Figure 5-2 – Pre-Validation Steering Axle Error by Speed – 13-Jul-10

5.1.1.3 Tandem Axle Errors by Speed

As shown by the high number of the negative percent error occurrences in the following figure, the equipment generally underestimates tandem axle weights at all speeds. The range in error is similar throughout the entire speed range.

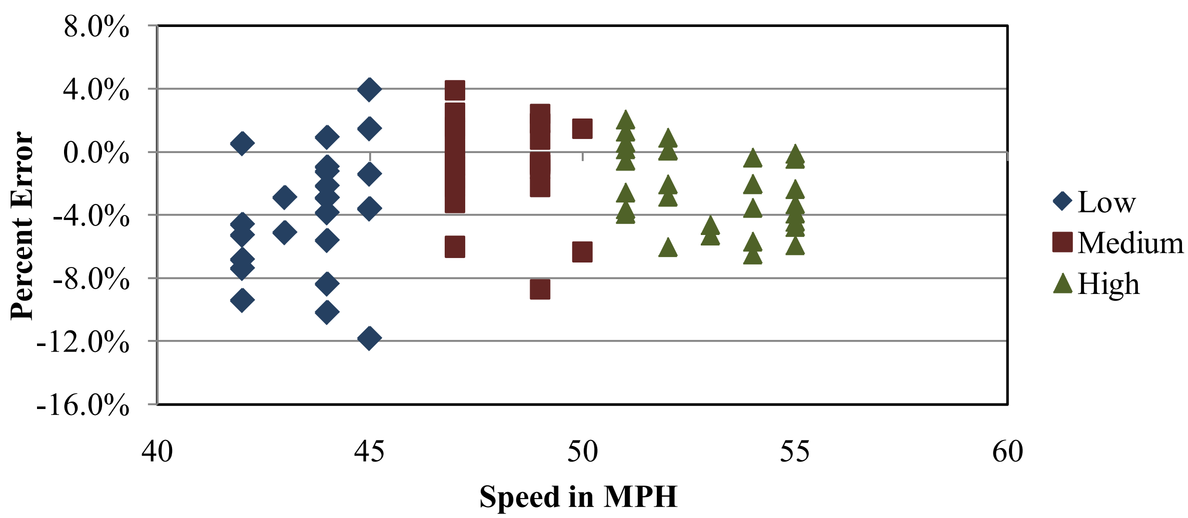


Figure 5-3 – Pre-Validation Tandem Axle Error by Speed – 13-Jul-10

5.1.1.4 Individual Truck GVW Errors by Speed

When the GVW errors for each truck are analyzed independently, it can be seen that the trends related to the WIM system underestimation of GVW at all speeds for the heavily loaded (Primary) truck is similar to the partially loaded (Secondary) truck, as shown in the following figure. The spread of errors for GVW measurement is also similar between the two trucks, as shown in the following figure.

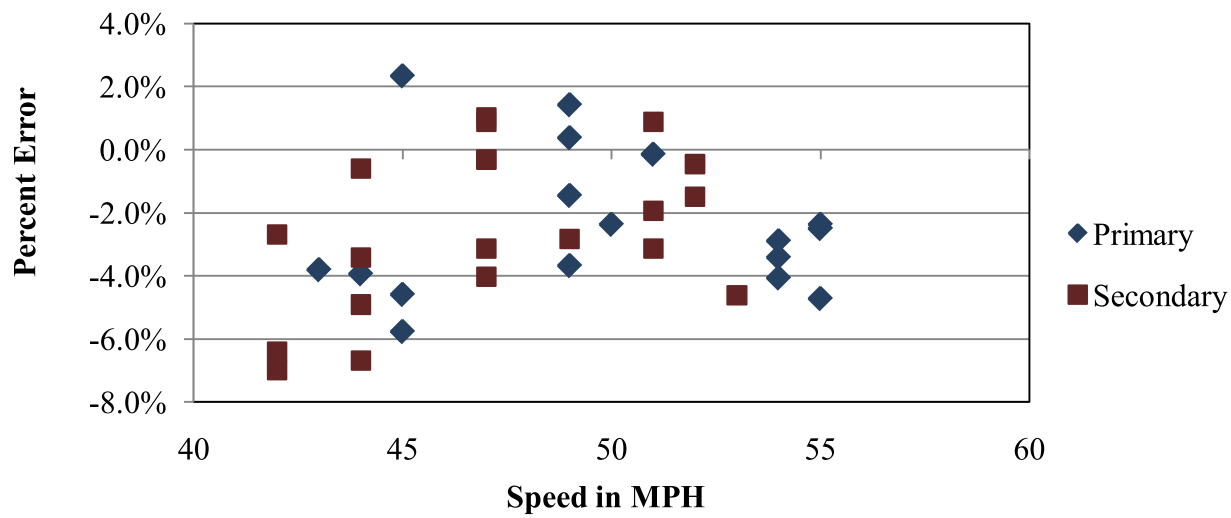


Figure 5-4 – Pre-Validation GVW Error by Truck and Speed – 13-Jul-10

5.1.1.5 Axle Length GVW Errors by Speed

For this site, the error in this measurement was consistent at all speeds. The range in axle length measurement error ranged from +0.1 feet to -0.6 feet, as can be seen in the following figure. The acceptable range of error for axle length is ±.5 feet. All measurements with exception of one observation were within the acceptable range.

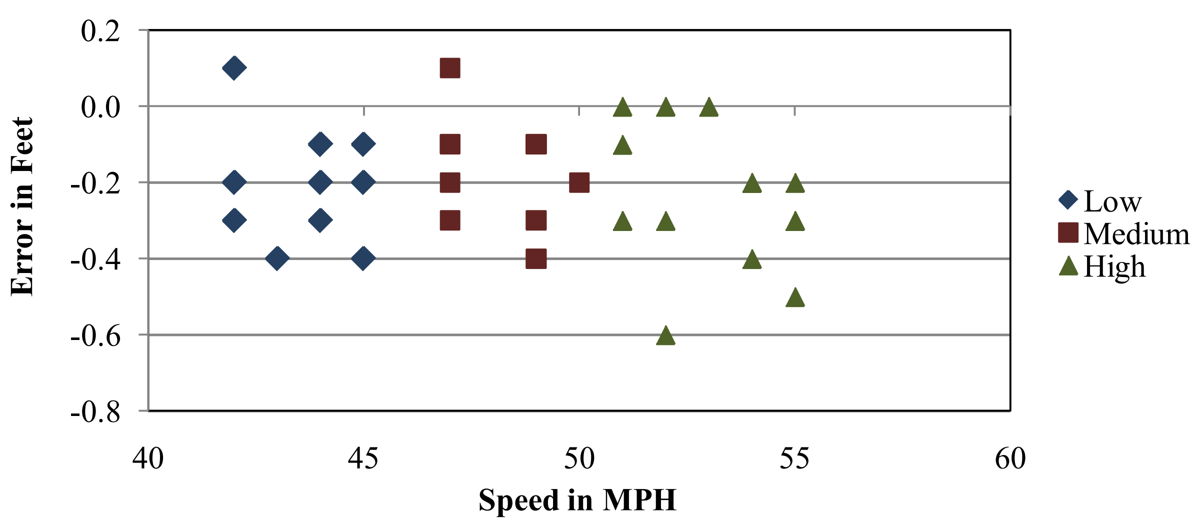


Figure 5-5 – Pre-Validation Axle Length Error by Speed – 13-Jul-10

5.1.1.6 Overall Length Errors by Speed

The overall length of the truck is measured from the front of the truck to the rear of the trailer. The WIM equipment generally measured overall length accurately over the entire range of speeds, with greatest error being -1.0 feet. Distribution of errors is shown graphically in the following figure.

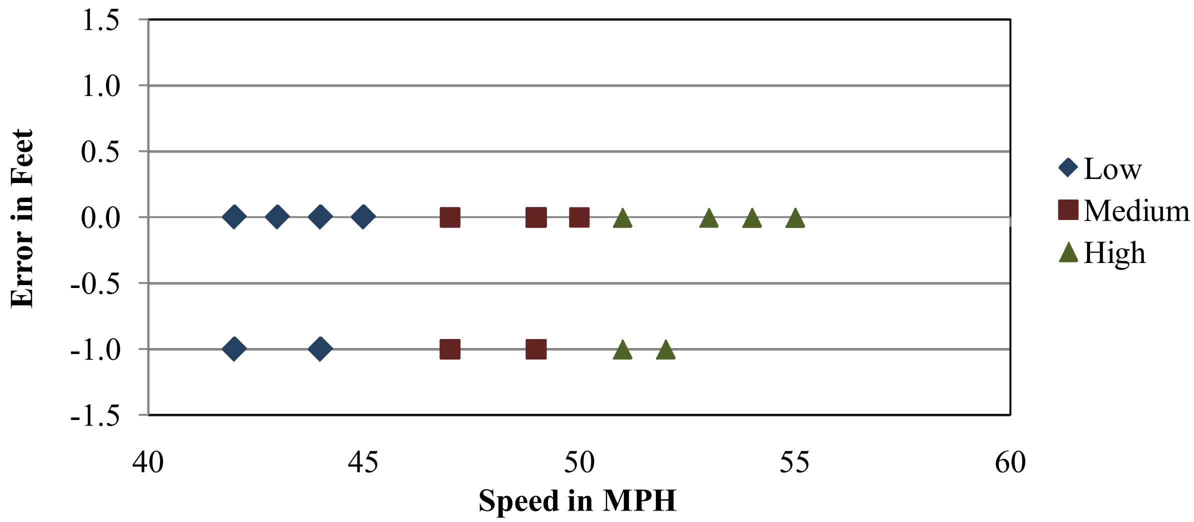


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 13-Jul-10

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 19.1 degrees, from 86.3 to 105.4 degrees Fahrenheit. The pre-validation test runs are being reported under two temperature groups as shown in the table below.

Table 5-4 – Pre-validation Results by Temperature – 13-Jul-10

Parameter	**95% Confidence Limit of Error**	**Low**	**Medium**
		86.3 to 95.9 degF	**96.0 to 105.5 degF**
Steering Axles	±20 percent	-3.9 ± 9.5%	-1.8 ± 9.5%
Tandem Axles	±15 percent	-2.4 ± 7.0%	-2.4 ± 5.7%
GVW	±10 percent	-2.6 ± 4.9%	-2.2 ± 5.0%
Vehicle Length	±3 percent (1.8 ft)	-0.4 ± 1.0 ft	-0.4 ± 1.1 ft
Vehicle Speed	± 1.0 mph	0.0 ± 1.6 mph	-0.5 ± 2.3 mph
Axle Spacing Length	± 0.5 ft [150mm]	-0.2 ± 0.3 ft	-0.3 ± 0.3 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. There does not appear to be a correlation between temperature and weight estimates.

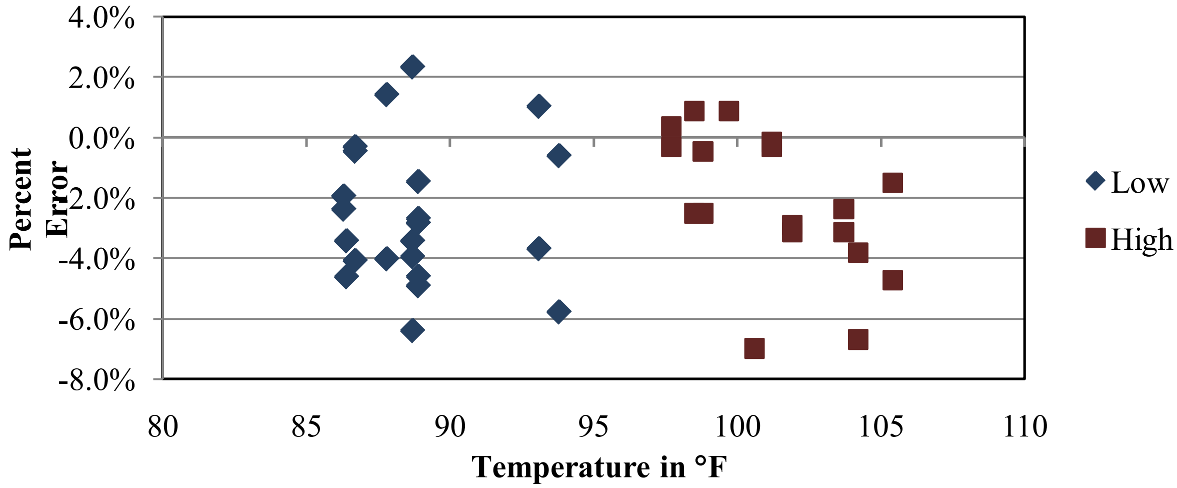


Figure 5-7 – Pre-Validation GVW Error by Temperature – 13-Jul-10

5.1.2.2 Steering Axle Errors by Temperature

Figure 5-8 demonstrates that for loaded steering axles, the WIM equipment appears to generally underestimate steering axle weights at all temperatures.

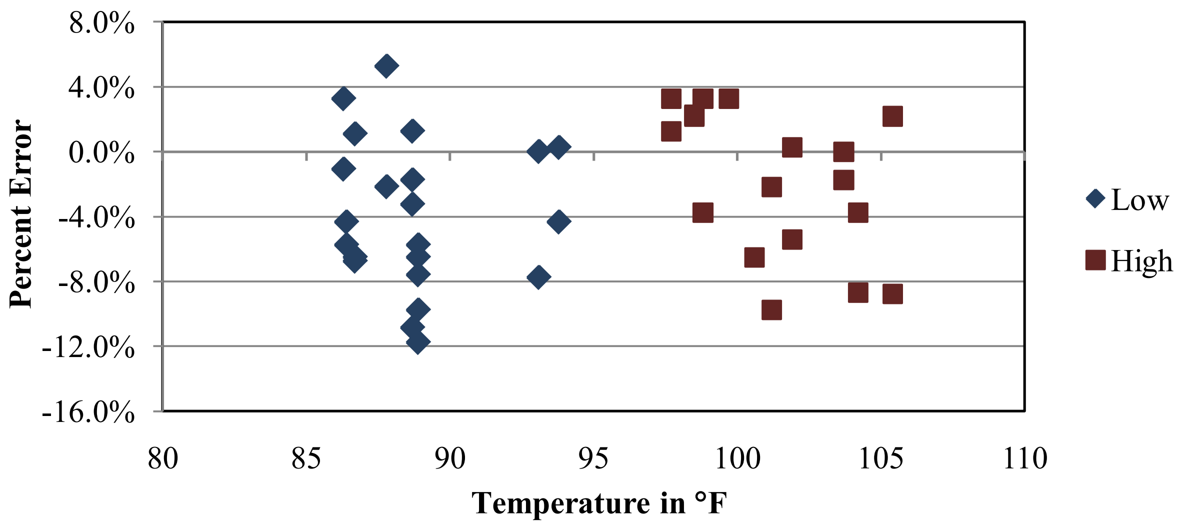


Figure 5-8 – Pre-Validation Steering Axle Error by Temperature – 13-Jul-10

5.1.2.3 Tandem Axle Errors by Temperature

As shown in the following figure, the WIM equipment appears to underestimate tandem axle weights at all temperatures. The range in error is similar for each of the temperature groups.

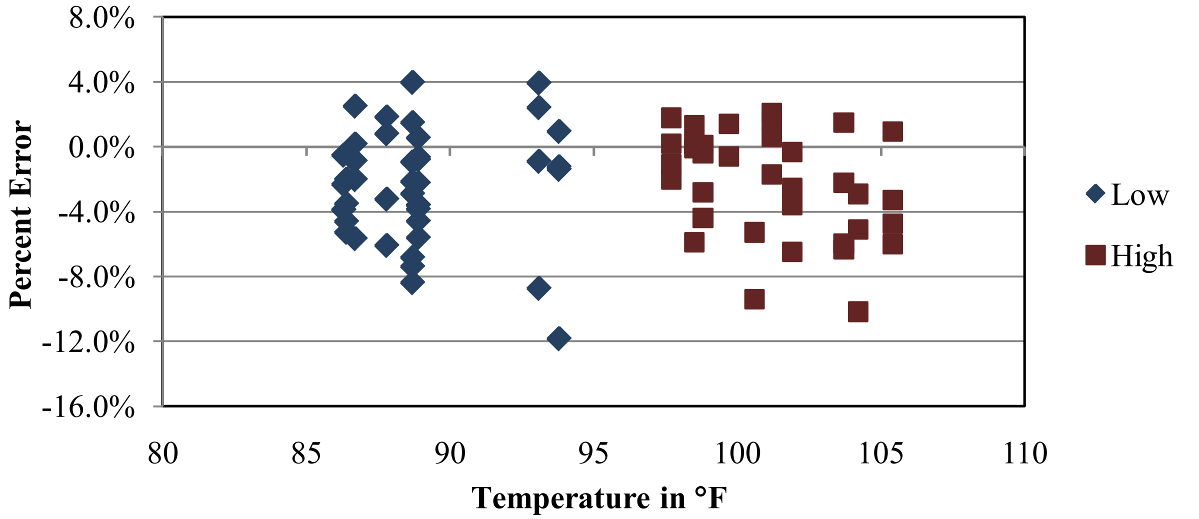


Figure 5-9 – Pre-Validation Tandem Axle Error by Temperature – 13-Jul-10

5.1.2.4 Individual Truck GVW Errors by Temperature

When analyzed for each test truck, GVW measurement errors for both trucks follow similar pattern, where the underestimation and range in error are reasonably consistent over the range of temperatures. Distribution of errors is shown graphically in the following figure.

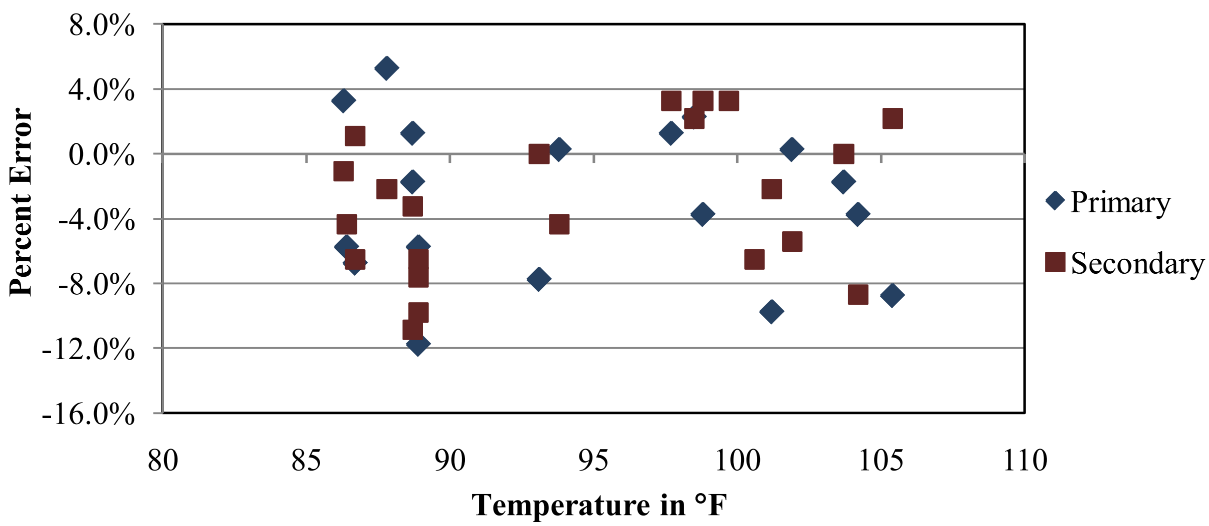


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 13-Jul-10

5.1.3 Classification and Speed Evaluation

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

For the pre-validation classification study at this site, a manual sample of 109 vehicles including 102 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. Table 5-5 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-5 – Pre-Validation Classification Study Results – 13-Jul-10

Class	4	5	6	7	8	9	10	11	12	13
Obs. Distribution (%)	1.8	30.3	10.1	0.9	9.2	41.3	0.0	0.0	0.0	0.0
WIM Distribution (%)	0.0	36.7	11.0	0.0	9.2	41.3	0.0	0.0	0.0	0.0
WIM Count	0	40	12	0	10	45	0	0	0	0
Observed Count	2	33	11	1	10	45	0	0	0	0
Misclassified	2	2	0	1	1	0	0	0	0	0
Misclassified (%)	100	6.1	0.0	100	10.0	0.0	N/A	N/A	N/A	N/A

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 misclassified percentage represents the percent of the observed vehicles that were identified as another vehicle class by the WIM equipment. The misclassifications by pair are provided in Table 5-6.

Table 5-6 – Pre-Validation Misclassifications by Pair – 13-Jul-10

Observed/WIM	Number of Pairs	Observed/WIM	Number of Pairs
3/5	7	8/9	0
3/8	0	9/5	0
4/5	2	9/8	0
4/6	0	9/10	0
5/3	1	10/9	0
5/4	0	10/13	0
5/8	1	11/12	0
6/4	0	12/11	0
7/6	1	13/10	0
8/3	0	13/11	0
8/5	0		

As shown in the table above, a total of 12 vehicles, including 5 trucks (Class 4 – 15) were misclassified by the equipment. For all vehicles, the majority (7) of the misclassifications were Class 3s identified by the WIM equipment as Class 5s. For trucks, both of the Class 4s observed were identified by the WIM equipment as Class 5 and one of the Class 5s was identified as a Class 3. For heavy trucks (Class 6 – 15), the single Class 7 truck was classified by the WIM equipment as a Class 6. All trucks Class 8 and above were manually observed and identified by the WIM equipment similarly.

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 1.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 11.0% for all vehicles and 4.9% for trucks.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-7.

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 13-Jul-10

Observed/WIM	Number of Pairs	Observed/WIM	Number of Pairs
3/15	0	9/15	0
4/15	0	10/15	0
5/15	0	11/15	0
6/15	0	12/15	0
7/15	0	13/15	0
8/15	1		

Based on the manually collected sample of the 102 trucks, 1.0% of the vehicles at this site were reported as unclassified during the study with only one Class 8 truck identified as a Class 15. This is within the established criteria of 2.0% for LTPP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was -0.5 mph. The range of errors for this study was 1.6 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.

Prior to the calibration, the test trucks were re-weighed. The calibration test truck weights and measurements are provided in Table 5-8.

Table 5-8 – Calibration Test Truck Measurements

Test	Weights (kips)						Spacings (feet and tenths)					
Truck	GVW	Ax 1	Ax 2	Ax 3	Ax 4	Ax 5	1-2	2-3	3-4	4-5	AL	OL
1	76.9	10.2	16.3	16.3	17.0	17.0	12.1	4.2	37.7	4.0	58.0	63.0
2	67.6	9.3	15.1	15.1	14.1	14.1	12.8	4.2	28.6	4.0	49.6	57.0

The operating system weight compensation parameters that were in place prior to the pre-validation are shown in Table 5-9. Note that this system is not utilizing a 60 mph speed point factor, jumping from 55 to 65. Differences in speed points are typically 5 mph, and the basis for the 10 mph difference is not known.

Table 5-9 – Initial System Parameters – 14-Jul-10

Speed Point	**MPH**	**Right**
64	40	3206
72	45	3339
80	50	3477
88	55	3370
105	65	3404
		Left
64	40	3443
72	45	3586
80	50	3735
88	55	3621
105	65	3657
Axle Distance (cm)	-	274
Dynamic Comp (%)	-	103

5.2.1 Calibration Iteration 1

5.2.1.1 Equipment Adjustments

The pre-validation test truck runs produced an overall error of -2.5% and errors of -2.4%, -1.2%, and -3.4% at the 45, 50 and 55 mph speed points respectively. The error for 55 mph was used to derive a new compensation factor for the 65 mph speed point. To compensate for these errors, the following changes to the compensation factors were made:

Table 5-10 – Calibration 1 Equipment Factor Changes – 14-Jul-10

Speed Points (mph)	Error	Old Factors		New Factors	
		Left	Right	Left	Right
64 (40)	-5.36%	3443	3206	3635	3385
72 (45)	-2.35%	3586	3339	3670	3417
80 (50)	-1.18%	3735	3477	3777	3516
88 (55)	-3.39%	3621	3370	3746	3486
105 (65)	-3.39%	3657	3404	3783	3521
Axle Distance (cm)	0.37%	274		275	
Dynamic Comp (%)	-2.95%	103		104	

5.2.1.2 Calibration 1 Results

The results of the first calibration verification runs are provided in Table 5-11 and Figure 5-11. As can be seen in the table, the variation in error doubled as a result of the first calibration iteration. From the figure, it can be seen that the underestimation of the GVW weights at the lower speeds increased, and GVW at the medium speeds were overestimated. The WIM equipment appears to be measuring GVW accurately at the high speeds.

Table 5-11 – Calibration 1 Results – 14-Jul-10

Parameter	95 % Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.5 ± 17.8%	Pass
Tandem Axles	±15 percent	-2.1 ± 10.0%	Pass
Gross Vehicle Weights	±10 percent	-2.0 ± 9.2%	FAIL
Vehicle Length	±3 percent (1.8 ft)	-0.2 ± 1.5 ft	Pass
Axle Spacing Length	± 0.5 ft	-0.1 ± 0.3 ft	Pass

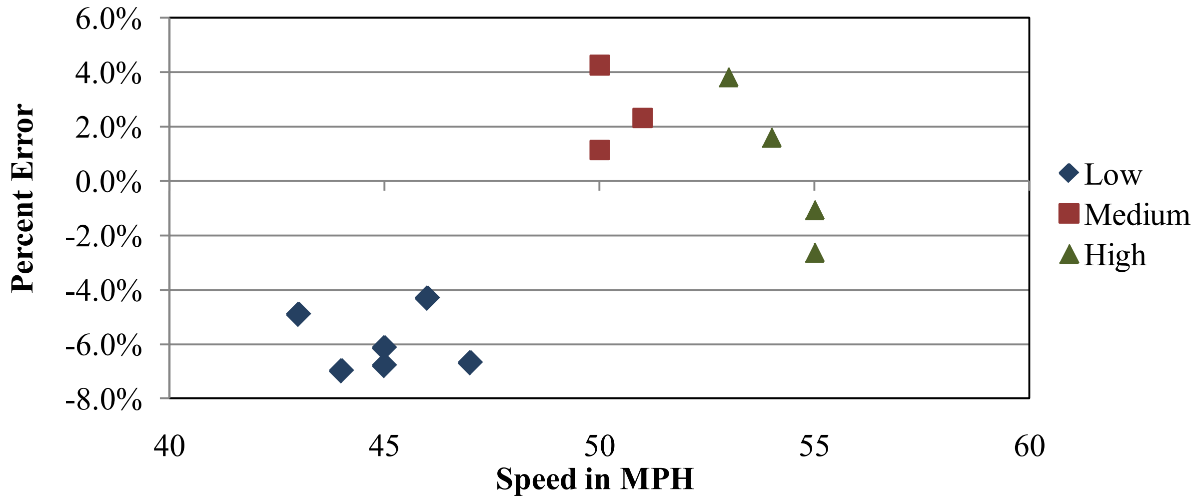


Figure 5-11 – Calibration 1 GVW Error by Speed – 14-Jul-10

The results of the first calibration show that GVW was being underestimated at the low speeds and overestimated at the medium speeds. Based on the results of the first calibration, a second calibration was considered to be necessary.

5.2.2 Calibration Iteration 2

5.2.2.1 Equipment Adjustments

The first calibration test truck runs produced an overall error of 1.0% and errors of -5.9%, 2.7%, and 0.5% at the 45, 50 and 55 mph speed points, respectively. The error for 55 mph was used to derive a new compensation factor for the 65 mph speed point. To compensate for these errors, the following changes to the compensation factors were made:

Table 5-12 – Calibration 2 Equipment Factor Changes – 14-Jul-10

Speed Points (mph)	Error	Old Factors		New Factors	
		Left	Right	Left	Right
64 (40)	-5.89%	3635	3385	3863	3597
72 (45)	-5.89%	3670	3417	3900	3631
80 (50)	2.65%	3777	3516	3680	3426
88 (55)	0.51%	3746	3486	3727	3468
105 (65)	0.51%	3783	3521	3764	3503
Axle Distance (cm)	0.18%	275		276	
Dynamic Comp (%)	-1.57%	104		105	

5.2.2.2 Calibration 2 Results

The results of the second calibration verification runs are provided in Table 5-13 – Calibration 2 Results – 14-Jul-10 and Figure 5-12.

Table 5-13 – Calibration 2 Results – 14-Jul-10

Parameter	95 % Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.9 ± 9.6%	Pass
Tandem Axles	±15 percent	1.3 ± 7.6%	Pass
Gross Vehicle Weights	±10 percent	1.2 ± 5.2%	Pass
Vehicle Length	±3 percent (1.8 ft)	-0.3 ± 1.0 ft	Pass
Axle Spacing Length	± 0.5 ft	-0.1 ± 0.3 ft	Pass

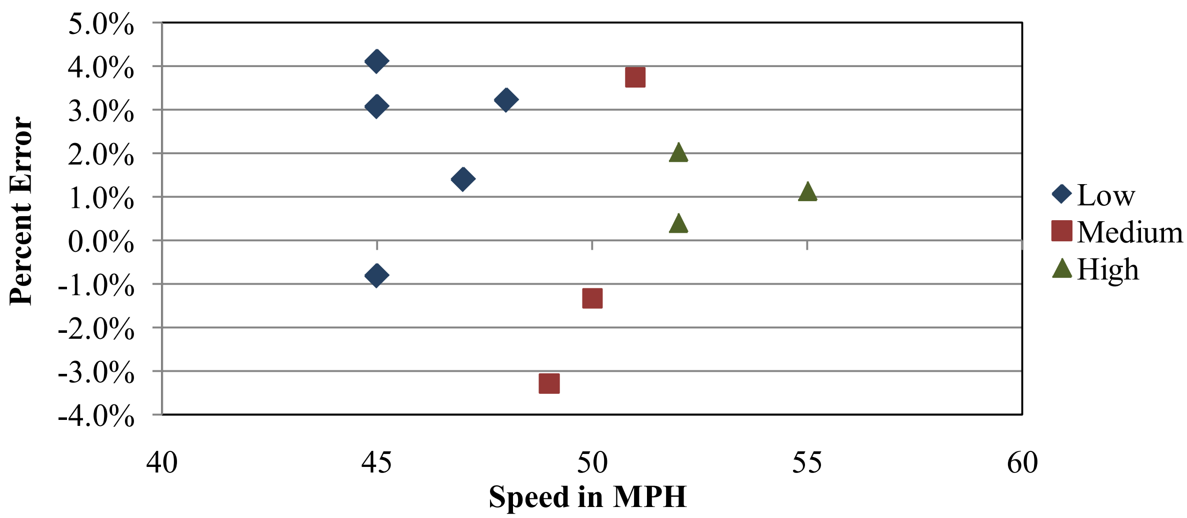


Figure 5-12 – Calibration 2 GVW Error by Speed – – 14-Jul-10

Based on the results of the second calibration, no further adjustments to system settings were deemed necessary, and 29 additional test runs were conducted to complete the minimum 40 post-validation test truck runs. The analysis of the combined Calibration 2 test truck runs and the additional 29 Post-Validation test runs are provided in Section 5.3.

5.3 Post-Validation

The 41 post-validation test truck runs were conducted on July 13, 2010, beginning at approximately 10:43 AM and continuing until 4:09 PM.

The two test trucks consisted of:

- A Class 9 truck was loaded with concrete blocks and a crane counterweight mid trailer. It was equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9, 5-axle truck was loaded with crane counterweights over the front two-thirds of the trailer. It was equipped with air spring suspension on the tractor, steel spring suspension on the trailer, standard tandem spacing on the tractor and standard tandem spacing on the trailer.

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

Table 5-14 - Post-Validation Test Truck Measurements

Test	Weights (kips)						Spacings (feet and tenths)					
Truck	GVW	Ax 1	Ax 2	Ax 3	Ax 4	Ax 5	1-2	2-3	3-4	4-5	AL	OL
1	76.7	10.1	16.3	16.3	17.0	17.0	12.1	4.2	37.7	4.0	58.0	63.0
2	67.4	9.2	15.0	15.0	14.1	14.1	12.8	4.2	28.6	4.0	49.6	57.0

Test truck speeds varied by 11 mph, from 44 to 55 mph. The measured post-validation pavement temperatures varied 12.6 degrees Fahrenheit, from 86.8 to 99.4. The intermittent rain showers weather conditions prevented for reaching the desired 30 degree temperature range. Table 5-15 is a summary of post validation results.

Table 5-15 – Post-Validation Overall Results – 14-Jul-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.0 ± 9.1%	Pass
Tandem Axles	±15 percent	0.3 ± 7.6%	Pass
GVW	±10 percent	0.3 ± 6.0%	Pass
Vehicle Length	±3 percent (1.8 ft)	-0.3 ± 1.5 ft	Pass
Axle Spacing Length	± 0.5 ft [150mm]	-0.1 ± 0.3 ft	Pass

Truck speed was manually collected for each test run by a handheld 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 -0.3 ± 2.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length within specified tolerances, and the two 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 an acceptable range.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relation exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 55 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in the table below.

Table 5-16 – Post-Validation Results by Speed – 14-Jul-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		44.0 to 47.7 mph	47.8 to 51.4 mph	51.5 to 55.0 mph
Steering Axles	±20 percent	0.4 ± 9.8%	1.7 ± 10.2%	1.2 ± 9.7%
Tandem Axles	±15 percent	1.7 ± 7.2%	0.4 ± 7.9%	-1.7 ± 7.5%
GVW	±10 percent	1.5 ± 5.8%	0.5 ± 6.1%	-1.4 ± 6.1%
Vehicle Length	±3 percent (1.8 ft)	-0.2 ± 1.5 ft	-0.3 ± 1.4 ft	-0.4 ± 1.9 ft
Vehicle Speed	± 1.0 mph	0.1 ± 2.5 mph	-0.5 ± 3.6 mph	-0.5 ± 1.4 mph
Axle Spacing Length	± 0.5 ft [150mm]	-0.1 ± 0.3 ft	-0.1 ± 0.3 ft	-0.1 ± 0.3 ft

From the table, it can be seen that the WIM equipment estimates all weights with reasonable accuracy and the range of errors is consistent at all speeds. A small bias in loaded axle group and GVW weight measurements has a relation with the speed: bias changes from positive to negative as speed increases.

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 the following figure, the equipment estimated GVW with reasonable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

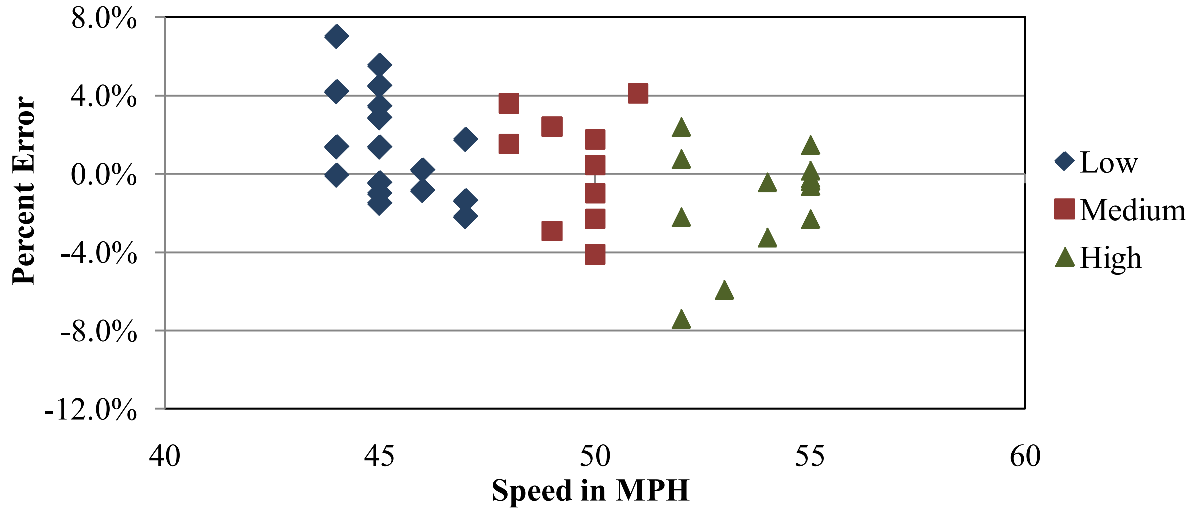


Figure 5-13 – Post-Validation GVW Error by Speed – 14-Jul-10

5.3.1.2 Steering Axle Errors by Speed

As shown in the following figure, the equipment estimates steering axle weights with similar accuracy at all speeds. The range in error appears to be consistent throughout the entire speed range.

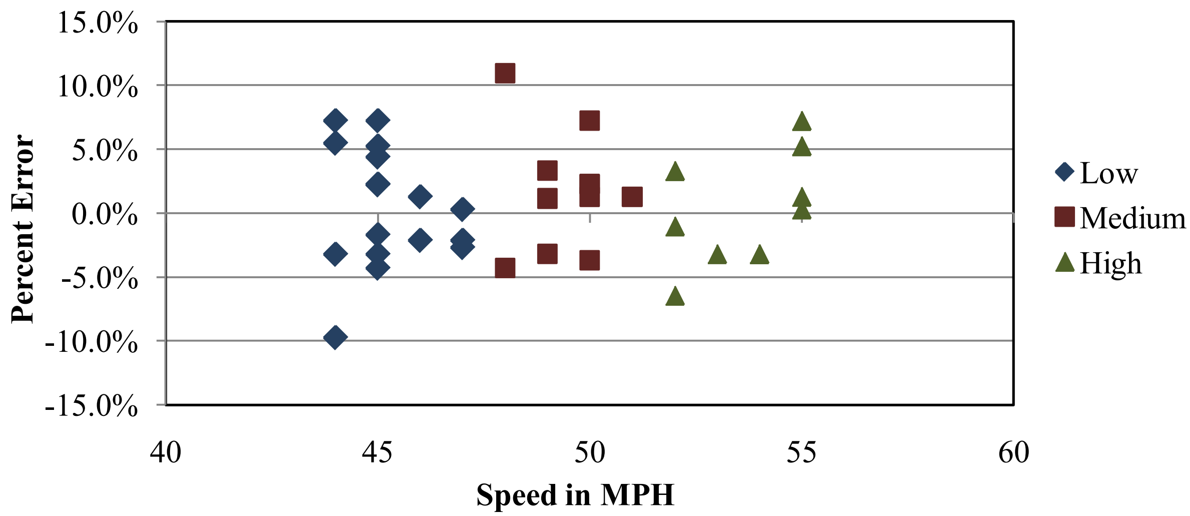


Figure 5-14 – Post-Validation Steering Axle Error by Speed – 14-Jul-10

5.3.1.3 Tandem Axle Errors by Speed

As shown in the following figure, the equipment estimates tandem axle weights with reasonable accuracy at all speeds. The range in error is similar throughout the entire speed range.

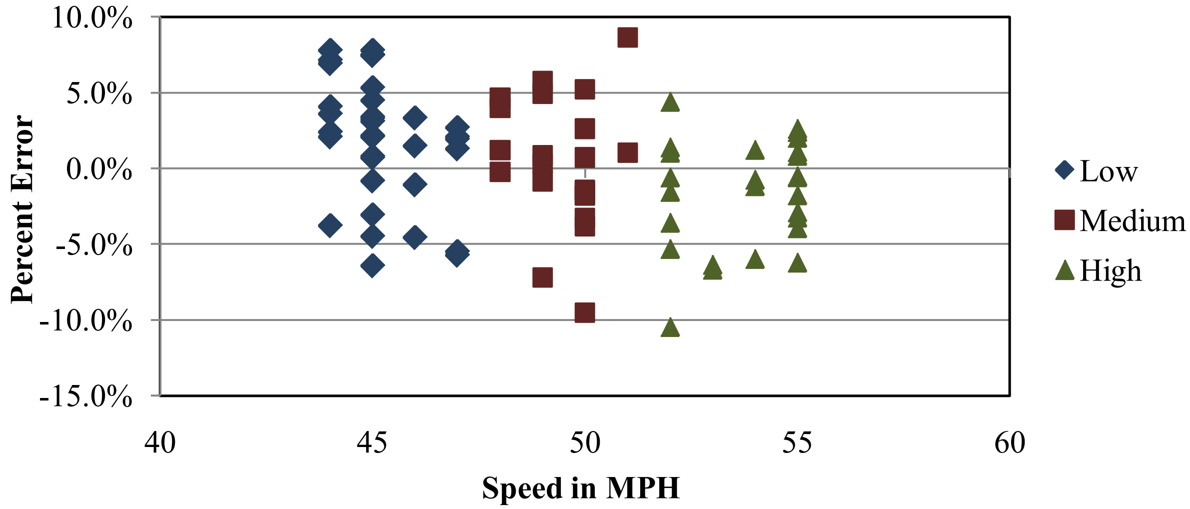


Figure 5-15 – Post-Validation Tandem Axle Error by Speed – 14-Jul-10

5.3.1.4 Individual Truck GVW Errors by Speed

When the GVW error for each truck is analyzed independently, 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 the following figure.

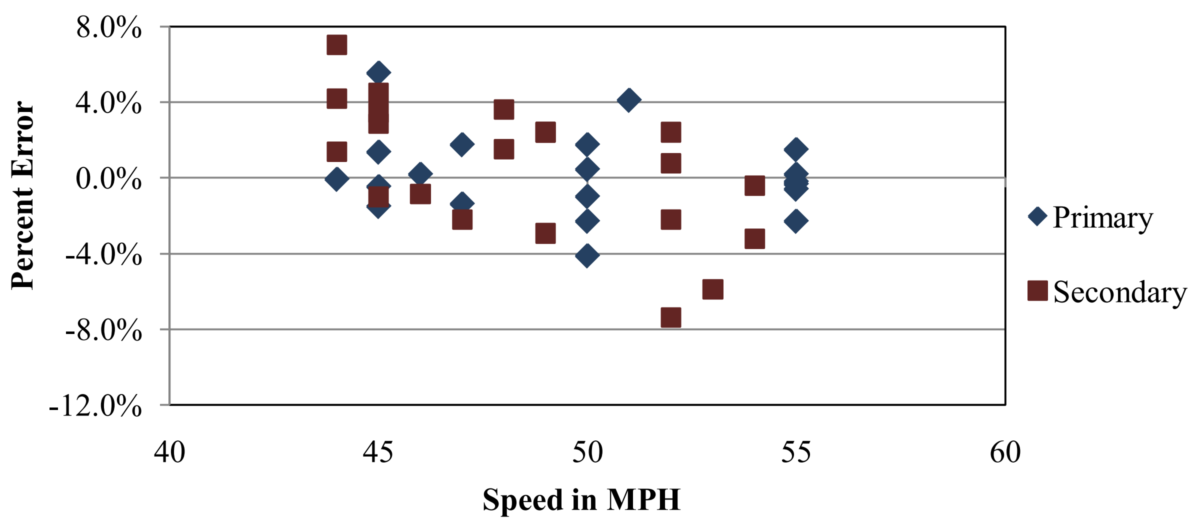


Figure 5-16 – Post-Validation GVW Error by Truck and Speed – 14-Jul-10

5.3.1.5 Axle Length GVW Errors by Speed

For this site, the range in axle length measurement error ranged from -0.5 feet to 0.1 feet. Distribution of errors is shown graphically in the following figure.

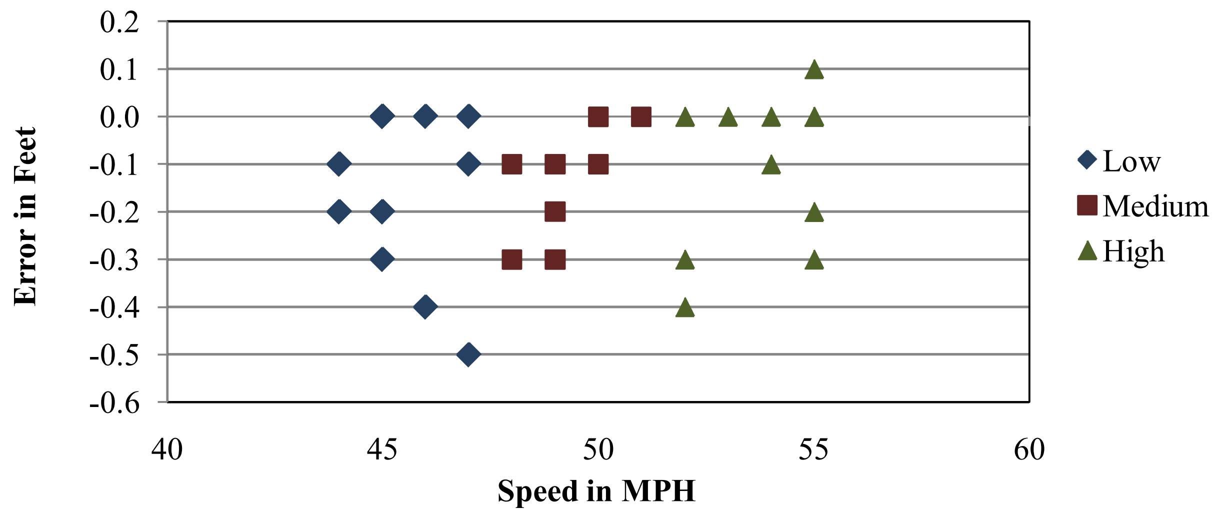


Figure 5-17 – Post-Validation Axle Length Error by Speed – 14-Jul-10

5.3.1.6 Overall Length Errors by Speed

Prior to the beginning of the test truck runs, the overall length of the truck is measured from the front bumper of the truck to the rear edge of the trailer. For this system, the WIM equipment measured consistently over the entire range of speeds, with maximum errors measuring -3.0 to 1.0 feet. Distribution of errors is shown graphically in the following figure.

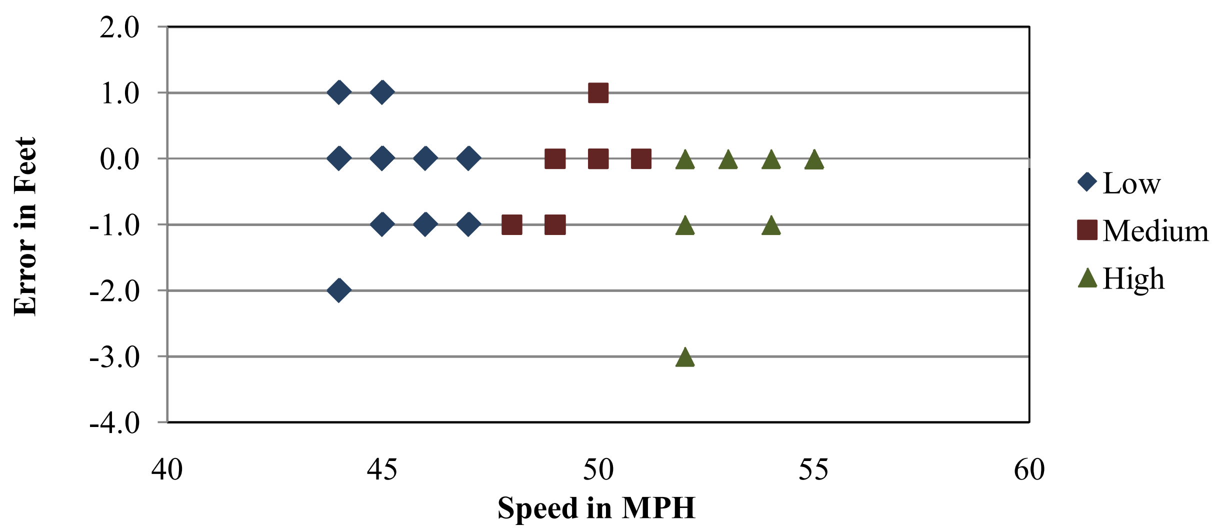


Figure 5-18 – Post-Validation Overall Length Error by Speed – 14-Jul-10

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 12.6 degrees, from 86.8 to 99.4 degrees Fahrenheit. Due to the small range of temperatures, the post-validation test runs are being reported under one temperature group as shown in the table below.

Table 5-17 – Post-Validation Results by Temperature – 14-Jul-10

Parameter	95% Confidence Limit of Error	Medium
		86.8 to 99.4 degF
Steering Axles	±20 percent	1.0 ± 9.1%
Tandem Axles	±15 percent	0.3 ± 7.6%
GVW	±10 percent	0.3 ± 6.0%
Vehicle Length	±3 percent (1.8 ft)	-0.3 ± 1.5 ft
Vehicle Speed	± 1.0 mph	-0.3 ± 2.4 mph
Axle Spacing Length	± 0.5 ft [150mm]	-0.1 ± 0.3 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.

5.3.2.1 GVW Errors by Temperature

From Figure 5-19, it can be seen that the equipment appears to estimate GVW with acceptable accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates.

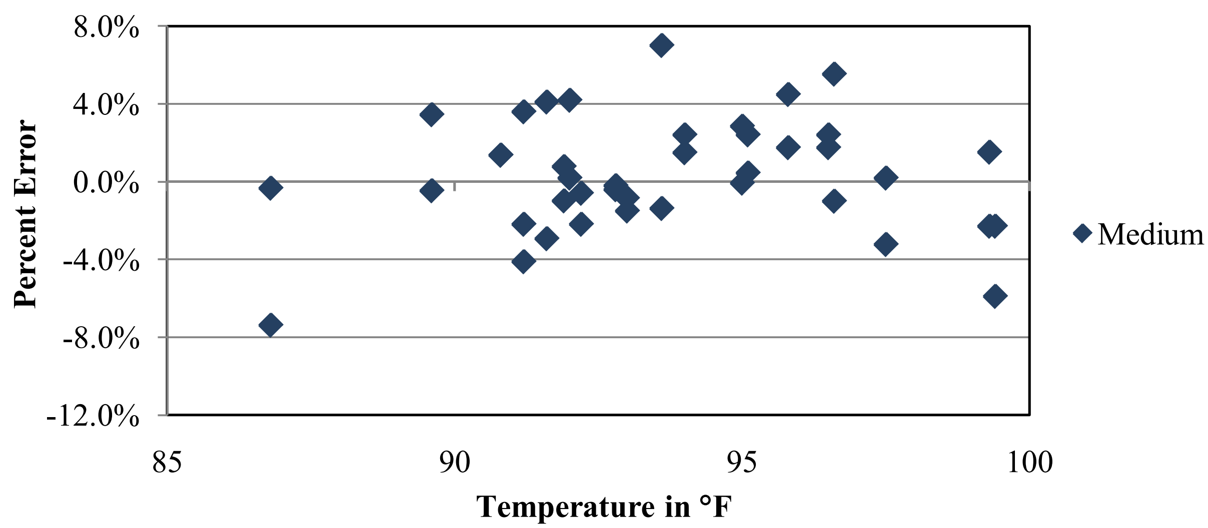


Figure 5-19 – Post-Validation GVW Error by Temperature – 14-Jul-10

5.3.2.2 Steering Axle Errors by Temperature

Figure 5-20 demonstrates that for loaded steering axles, the WIM equipment appears to measure GVW with reasonable accuracy at all temperatures. The range in error is consistent at all temperatures.

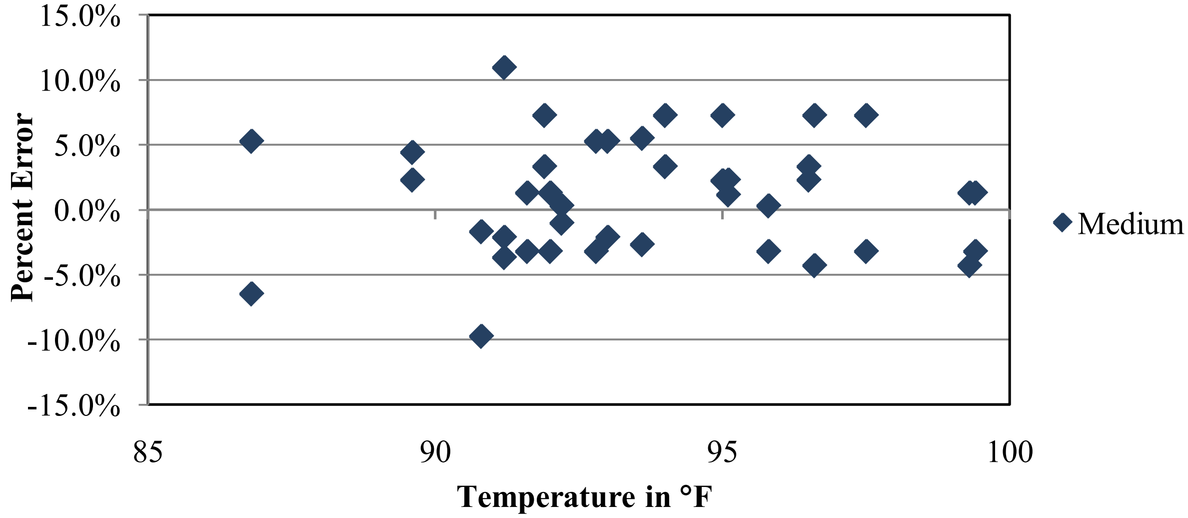


Figure 5-20 – Post-Validation Steering Axle Error by Temperature – 14-Jul-10

5.3.2.3 Tandem Axle Errors by Temperature

As shown in the following figure, tandem axle measurement error appears to be consistent over the entire range of pavement temperatures in relation to precision and bias.

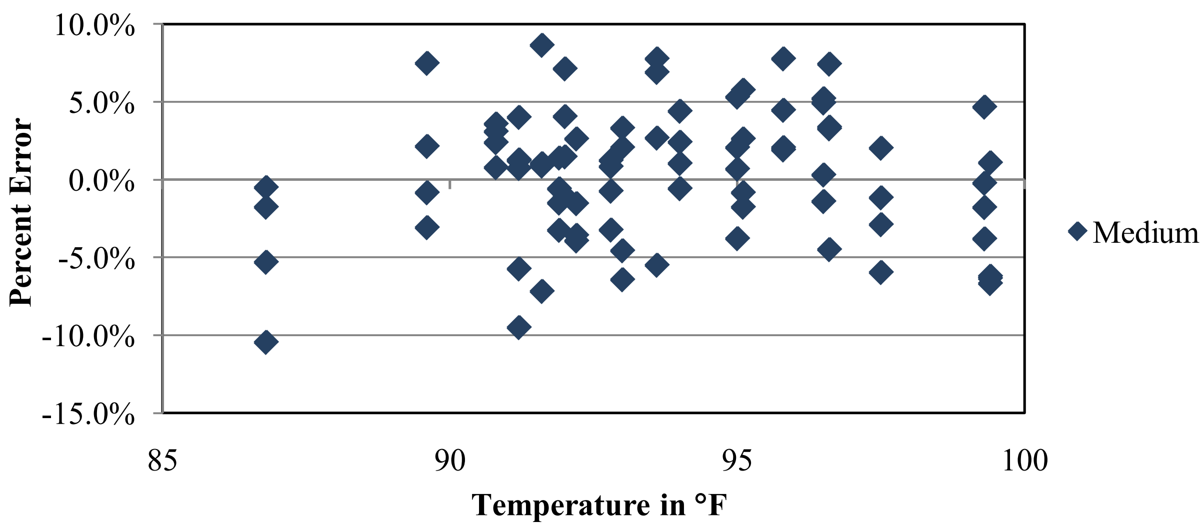


Figure 5-21 – Post-Validation Tandem Axle Error by Temperature – 14-Jul-10

5.3.2.4 Individual Truck GVW Errors by Speed

When analyzed for each test truck, GVW measurement error was found independent of temperature for both trucks. Distribution of errors is shown graphically in the following figure.

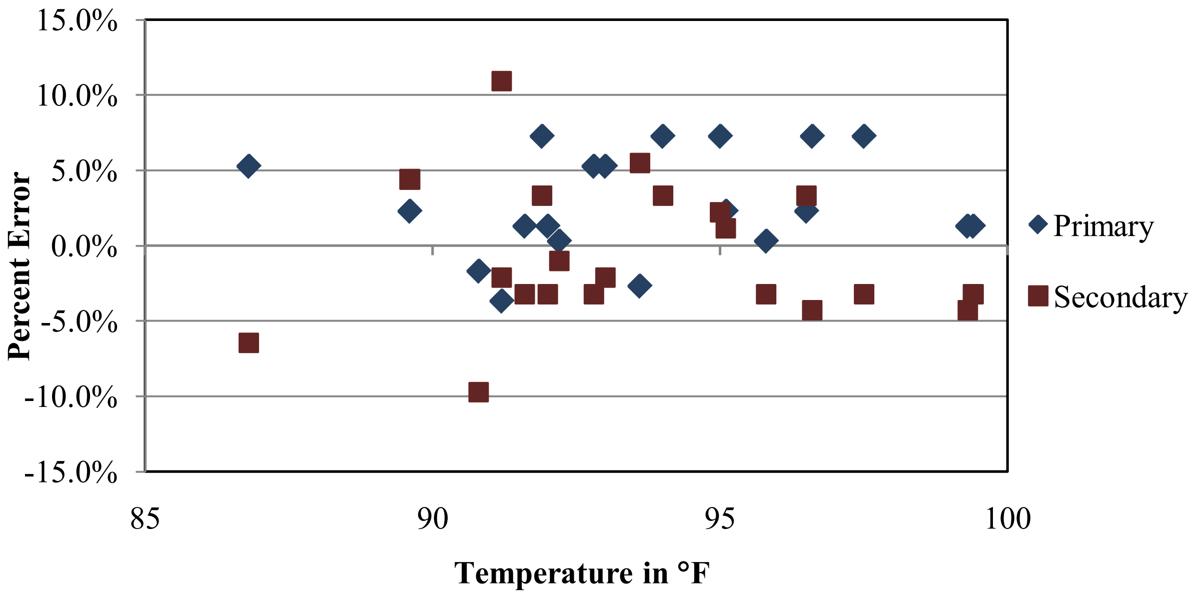


Figure 5-22 – Post-Validation GVW Error by Truck and Temperature – 14-Jul-10

5.3.3 Multivariable Analysis

This section provides additional analysis of post-validation results using a multivariable statistical technique of multiple linear regression. The same calibration data analyzed and discussed previously are analyzed again, but this time using a more sophisticated statistical methodology. 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 analyses provide additional insight on how speed, temperature, and truck type affect weight measurement errors for a specific site. It is expected that multivariable analyses done systematically for many sites will reveal overall trends.

5.3.3.1 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. Compared to analysis described previously, the weight of "loaded axle group" was evaluated separately for tandem axles on tractors and trailers. The separate evaluation was carried out because the tandem axle on the secondary tractor had a different suspension compared to all other tandem axles.

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 44 to 55 mph.
- Pavement temperature. Pavement temperature ranged from 86.8 to 99.4 degrees Fahrenheit.
- Interaction between the factors such as the interaction between speed and pavement temperature.

5.3.3.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-18. The value of regression coefficients defines the slope of the relationship between the % error in GVW (y in Equation 1) and the predictor variables (x_i in Equation 1). The values of the t-distribution (for the regression coefficients) given in Table 5-18 table are for the null hypothesis that assumes that the coefficients are equal to zero. The effects of temperature and truck type were found statistically significant. The probabilities that the effect of truck type and temperature on the observed GVW errors occurred by chance alone are less than 1 percent.

Table 5-18 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value
Intercept	8.3368	13.84	0.6023	0.5506
Speed	-0.3323	0.1167	-2.847	0.0071
Temperature	0.0888	0.1395	0.6366	0.5282
Truck type	-0.0624	0.8797	-0.07093	0.9438

The relationship between truck speed and measurement errors is shown in Figure 5-23. The Figure is similar to Figure 5-1. Both figures provide a plot of % error in GVW versus speed for the same 41 test truck runs. However, the figure also includes predicted percent errors and a trend line for the predicted error.

The quantification is provided by the value of the regression coefficient, in this case -0.3323 (in Table 5-18). This means that for a 10 mph increase in speed, the % error is decreased by about 3.3 %. The statistical assessment of the relationship is provided by the probability value of the regression coefficient.

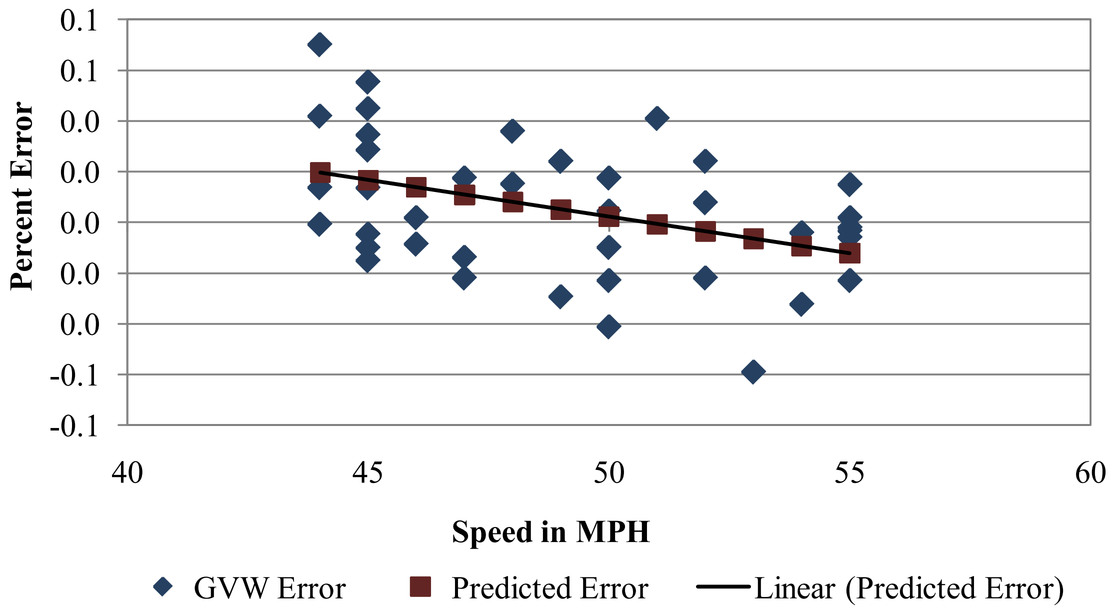


Figure 5-23 – Influence of Speed on the Measurement Error of GVW

The effect of temperature and truck type on GWV was not statistically significant. For example, the probability that the regression coefficient for temperature (0.0888 in Table 5-18) is not different from zero was 0.5282. In other words, there is about 53 percent chance that the value of the regression coefficient is due to the chance alone.

The interaction between speed, temperature, and truck type was investigated by adding an interactive variable (or variables) such as the product of speed and temperature. No interactive variables were statistically significant. The intercept was not statistically significant and does not have practical meaning because the speed and temperature are always larger than zero. Data for intercept are not included in the following summary.

5.3.3.3 Summary Results

Table 5-19 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Not listed in the table are factor interactions that were not statistically significant. Entries in the table are provided only if the probability value was smaller than 0.20. The dash indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-19 – Summary of Regression Analysis

	Factor					
	Speed		**Temperature**		**Truck type**	
Weight, % error	Regression coefficient	Probability value	Regression coefficient	Probability value	Regression coefficient	Probability value
GVW	0.3323	0.0071	–	–	–	–
Steering axle	–	–	–	–	3.483	0.014
Tandem axle tractor	0.4832	0.0003	–	–	–	–
Tandem axle trailer	0.2898	0.0785	–	–	–	–

5.3.3.4 Conclusions

1 Temperature had no effect on measurement errors. However, the variation in temperatures was relatively small for this site.

2 Speed affected GWV errors and tandem axle weight errors. The most affected by speed was tractor tandem axle. A preliminary hypothesis can be advanced that dynamic forces affect most tandem axles on the tractor. (At the same time, truck type had no effect on tandem axles, even though different tractors had different suspension systems).

3 Even though the speed had a statistically significant influence on the measurement errors, the practical significance of the influence is small and does not affect the validity of the calibration.

4 Truck type affected steering axle weight errors only. The magnitude of the effect, given by the regression coefficient for truck type (3.483 in Table 2), means that the difference between the mean errors for the primary and secondary trucks is 3.483 percent. (Truck type is an indicator variable with values of 0 or 1.)

5 Truck type had statistically significant influence on steering axle error only. However, the effect was small (about 3.5 percent overall). Consequently, based on the results of Delaware validation and calibration effort, very similar results would have been obtained by using only one test truck of either type.

5.3.4 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 102 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field. Table 5-5 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-20 – Post-Validation Classification Study Results – 14-Jul-10

Class	4	5	6	7	8	9	10	11	12	13
Obs. Distribution (%)	2.0	36.3	14.7	2.0	5.9	36.3	1.0	0.0	0.0	0.0
WIM Distribution (%)	0.0	33.3	14.7	2.0	6.9	36.3	0.0	0.0	0.0	1.0
WIM Count	0	34	15	2	7	37	0	0	0	1
Observed Count	2	37	15	2	6	37	1	0	0	0
Misclassified	2	7	0	0	0	0	1	0	0	0
Misclassified (%)	100	18.9	0.0	0.0	0.0%	0.0	100	N/A	N/A	N/A

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 misclassified percentage represents the percent of the observed vehicles that were identified as another vehicle class by the WIM equipment. Based on the vehicles observed during the post-validation study, the misclassification percentage is 1.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 10.8%. The misclassifications by pair are provided in Table 5-6.

Table 5-21 – Post-Validation Misclassifications by Pair – 14-Jul-10

Observed/WIM	Number of Pairs	Observed/WIM	Number of Pairs
3/5	2	8/9	0
3/8	0	9/5	0
4/5	2	9/8	0
4/6	0	9/10	0
5/3	5	10/9	0
5/4	0	10/13	1
5/8	1	11/12	0
6/4	0	12/11	0
7/6	0	13/10	0
8/3	0	13/11	0
8/5	0		

As shown in the table, a total of 10 vehicles, including 8 trucks were misclassified by the equipment. For all vehicles, the majority (5) of the misclassifications were Class 5s identified by the WIM equipment as Class 3. For trucks, both of the Class 4s observed were identified by the

WIM equipment as Class 5 and one of the Class 5s was identified as a Class 8. For heavy trucks, one Class 10 was identified as a Class 13.

The misclassified percentage represents the percent of the observed vehicles that were identified as another vehicle class by the WIM equipment. Based on the vehicles observed during the study, the misclassification percentage is 9.8% for all vehicles and 8.0% for trucks. The misclassification rate for heavy trucks is 0.9% for this site, which is below the 2.0% acceptability criteria for LTPP SPS WIM sites.

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 5-22 – Post-Validation Unclassified Trucks by Pair – 14-Jul-10

Observed/WIM	Number of Pairs	Observed/WIM	Number of Pairs
3/15	0	9/15	0
4/15	0	10/15	0
5/15	1	11/15	0
6/15	0	12/15	0
7/15	0	13/15	0
8/15	0		

Based on the manually collected sample of the 100 trucks, 1.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTPP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was -1.0 mph. The range of errors for this study was 1.7 mph.

5.4 Post Visit Applied Calibration

As shown in, the 85th percentile speed for trucks is 63 mph, 8 mph above the posted speed limit of 55 mph and the highest test truck speed. Consequently, applied calibration will be utilized and recommendations for changes to the 55, 60 and 65 mph speed point compensation factors will be made. The final calibration factors that were in place at the conclusion of the post-validation conducted on July 14, 2010 are provided in Table 5-23.

Table 5-23 – Final System Parameters

Speed Point	MPH	Right
64	40	3597
72	45	3631
80	50	3426
88	55	3468
105	65	3503
		Left
64	40	3863
72	45	3900
80	50	3680
88	55	3727
105	65	3764
Axle Distance (cm)	-	276
Dynamic Comp (%)	-	105

For the applied calibration, post-validation, and post-visit front axle and GVW averages for Class 9 trucks were compared with the most recent data comparison set and the errors were plotted, as shown in the following figure.

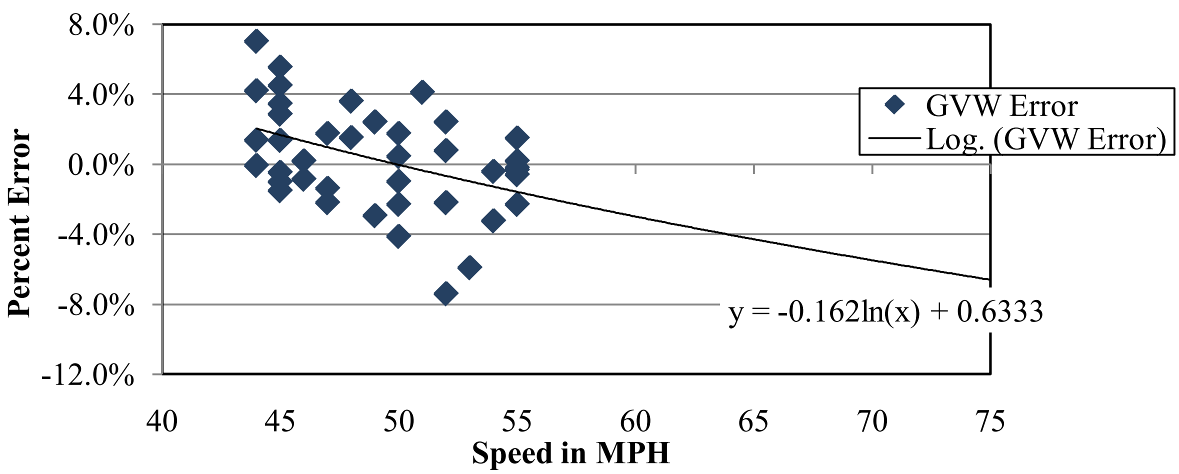


Figure 5-24 – GVW Error Trend

Based on these errors and the GVW error trend developed from the post-validation test truck runs and shown in, applied errors were calculated and plotted in Figure 5-25.

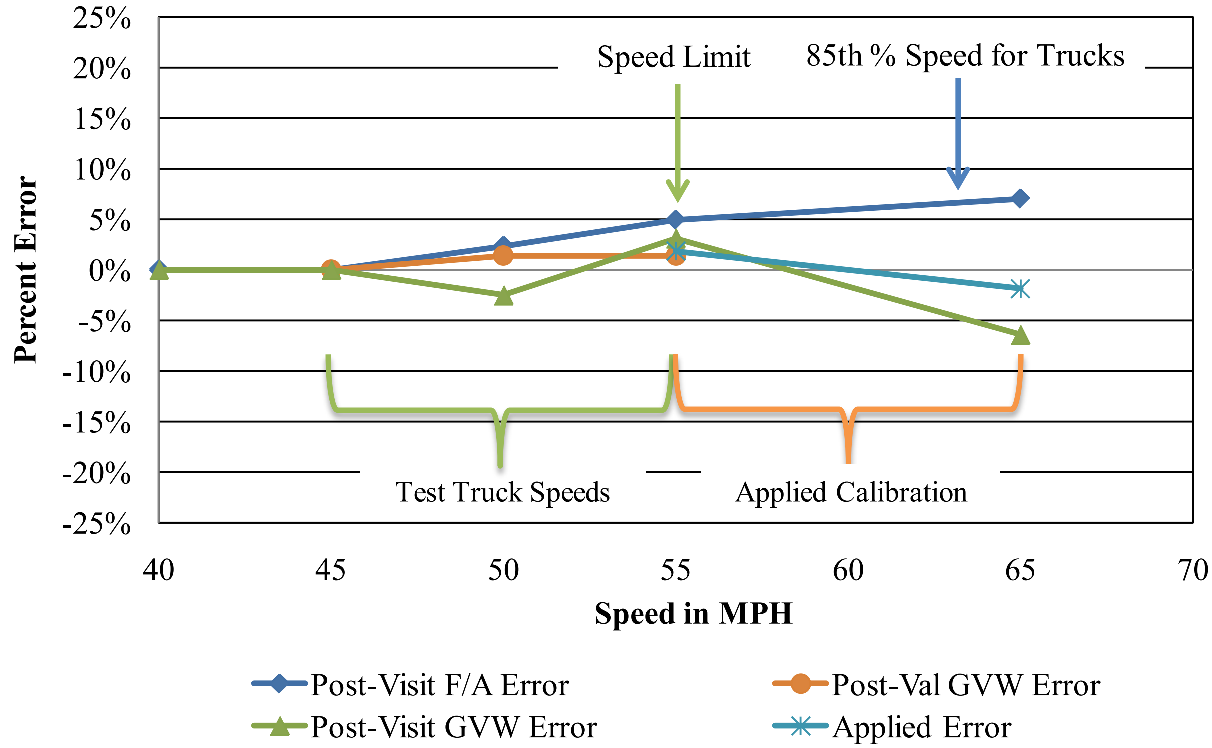


Figure 5-25 – Applied Calibration

The applied errors were compared with existing compensation factors to develop recommendations for new factors. These recommendations are provide in Table 5-24.

Table 5-24 – Recommended Factor Changes from Applied Error

Speed Point	MPH	Old Factors	Applied Error	New Factors
Right				
88	55	3468	1.9%	3401
105	65	3503	-1.9%	3573
Left				
88	55	3727	1.9%	3656
105	65	3764	-1.9%	3839

6 Previous WIM Site Validation Information

As of March 21, 2008, the date of the most recent validation, this site required 5 more years of research quality data. Research quality data is defined to be at least 210 days in a year of data of known calibration meeting LTPP's precision requirements. A review of the LTPP Standard Release Database 24 shows that there are 35 consecutive months of level "E" WIM data for this site. This site requires 2 additional years of data to meet the minimum of five years of research quality data.

6.1 Sheet 16s

This site has validation information from four previous visits as well as the current one in the tables below. Table 6-1 was extracted from past validation reports and was updated to include the results of this validation. This table shows misclassification history at this site.

Table 6-1 – Classification Validation History

Date	Method	Misclassification Percent by Class										Pct Unclass
		4	5	6	7	8	9	10	11	12	13	
14-Jul-10	Manual	100	19	0	0	0	0	100				1.0
13-Jul-10	Manual	100	6	0	100	10	0					1.0
19-Mar-08	Manual	100	5	0	0	0	0					0.0
18-Mar-08	Manual	100	4	8	8	0	2	50				3.7
8-Aug-07	Manual	100	8	10	0	0	3					0.0
7-Aug-07	Manual	100	5	22	0	0	0	0				0.0

Table 6-2 was extracted from the most recent validation and was updated to include the results of this validation.

Table 6-2 – Weight Validation History

Date	Method	Mean Error and (SD)		
		GVW	Single Axles	Tandem
14-Jul-10	Test Trucks	0.3 (2.9)	1.1 (3.7)	0.3 (3.7)
13-Jul-10	Test Trucks	-2.4 (2.3)	-2.9 (3.1)	-2.4 (3.1)
21-Mar-08	Test Trucks	-0.5 (2.9)	1.8 (2.9)	-0.8 (3.6)
20-Mar-08	Test Trucks	-4.1 (5.6)	-3.4 (8.9)	-3.9 (4.7)
8-Aug-07	Test Trucks	0.6 (3.1)	2.1 (3.5)	0.3 (4.0)
7-Aug-07	Test Trucks	1.1 (2.9)	2.3 (3.3)	0.5 (5.0)

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.

6.2 Comparison of Post-Validation Results

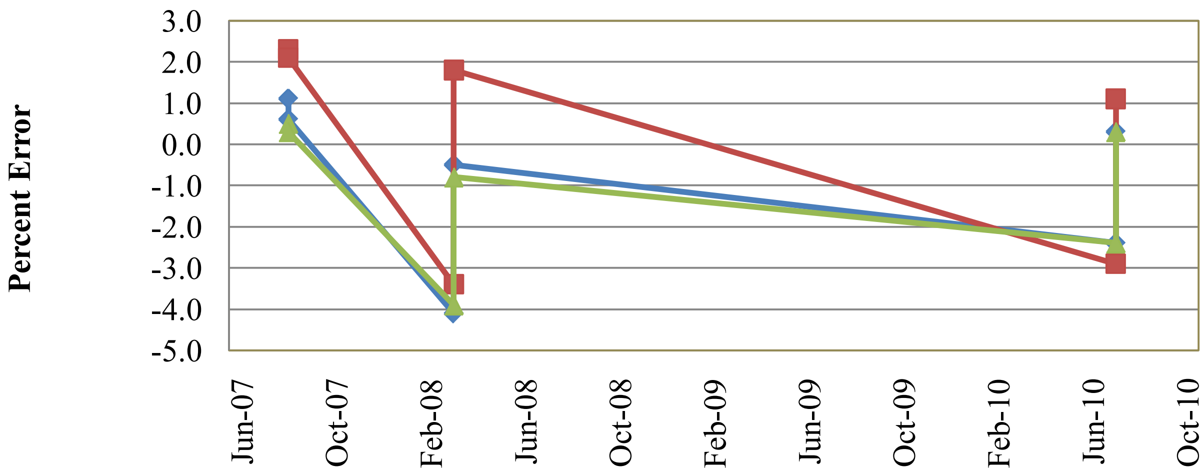
A comparison of the post-validation results from previous visits is provided in Table 6-3.

Table 6-3 – Comparison of Post-Validation Results

Parameter	95 %Confidence Limit of Error	Site Values		
		08-Aug-07	21-Mar-08	14-Jul-10
Single Axles	±20 percent	2.1 (7.0)	1.8 (5.9)	1.0 (9.1)
Tandem Axles	±15 percent	0.3 (8.0)	-0.8 (7.2)	0.3 (7.6)
GVW	±10 percent	0.6 (6.2)	-0.5 (5.9)	0.3 (6.0)
Axle Spacing	±1.5 feet	-0.2 (0.1)	0.0 (0.0)	n/a
Vehicle Speed	± 1.0 mph	-0.2 (1.6)	n/a	-0.3 (2.4)
Axle Length	± 0.5 ft	n/a	n/a	-0.1 (0.3)

From the table, it appears that the variance for all weights has remained reasonably consistent since the equipment was installed.

Figure 6-1 has been provided to present a graphical depiction of the WIM system performance with regard to time. The table below the graph provides the percent error for each of the pre- and post-validations for each visit.



	7-Aug-07	8-Aug-07	20-Mar-08	21-Mar-08	13-Jul-10	14-Jul-10
GVW	1.1	0.6	-4.1	-0.5	-2.4	0.3
Single Axles	2.3	2.1	-3.4	1.8	-2.9	1.1
Tandem	0.5	0.3	-3.9	-0.8	-2.4	0.3

Figure 6-1 – Weight Estimations Over Time

The graph illustrates the tendency of the equipment to increasingly underestimate all weights. As shown in the figure above, the WIM equipment has demonstrated a negative drift of approximately 2.3 percent per year, on average. The graph demonstrates the effectiveness of the validations in bringing the weight estimations back to within LTPP SPS WIM equipment tolerances.

7 Additional Information

The following information is provided in the attached appendix:

- Pre-validation Sheet 16 – Site Calibration Summary
- Post-validation Sheet 16 – Site Calibration Summary
- Site Photographs
  - Equipment
  - Test Trucks
  - Pavement Condition
- 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 – Calibration Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 23 – WIM Troubleshooting Outline
- Sheet 24A/B/C – Site Photograph Logs
- Updated Handout Guide

WIM System Field Calibration and Validation - Photos

Delaware, SPS-1
SHRP ID: 100100

Validation Date: July 14, 2010
Submitted: 08/12/2010

1 Equipment

Photo 1 - 100100 - Cabinet Exterior - 13-Jul-10

Photo 2 - 100100 - Cabinet Interior (Back) - 13-Jul-10

Photo 3 - 100100 - Cabinet Interior (Front) - 13-Jul-10

Photo 4 - 100100 - Leading Loop - 13-Jul-10

Photo 5 - 100100 - Leading WIM Sensor - 13-Jul-10

Photo 6 – 100100 – Trailing WIM Sensor – 13-Jul-10

Photo 7 - 100100 - Trailing Loop Sensor - 13-Jul-10

Photo 8 - 100100 - Power Service Box - 13-Jul-10

Photo 9 - 100100 - Telephone Pedestal - 13-Jul-10

2 Pavement

Photo 10 - 100100 - Downstream - 13-Jul-10

Photo 11 - 100100 - Upstream - 13-Jul-10

Photo 12 - 100100 – Sensor Patch - 13-Jul-10

Photo 13 - 100100 - Popout - 13-Jul-10

Photo 14 - 100100 – Asphalt to PCC Transition - 13-Jul-10

3 Test Trucks

Photo 15 - 100100 – Truck 1 - 13-Jul-10

Photo 16 - 100100 – Truck 1 Tractor - 13-Jul-10

Photo 17 - 100100 – Truck 1 Trailer - 13-Jul-10

Photo 18 - 100100 – Truck 1 Load - 13-Jul-10

Photo 19 - 100100 – Truck 1 Suspension 1 - 13-Jul-10

Photo 20 - 100100 - Truck 1 Suspension 2 - 13-Jul-10

Photo 21 - 100100 - Truck 1 Suspension 3 - 13-Jul-10

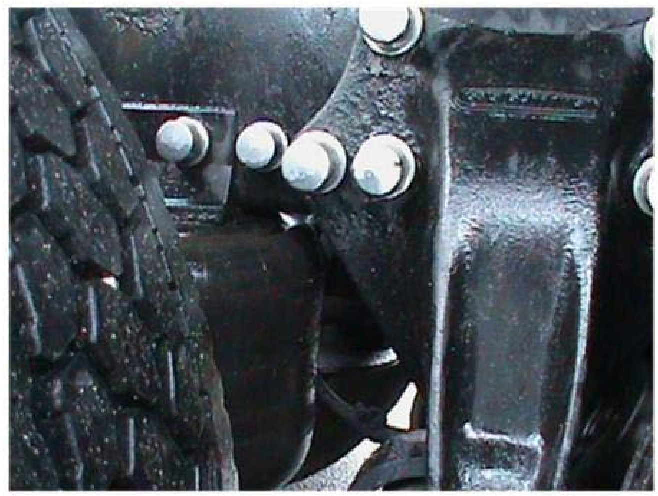


Photo 22 - 100100 - Truck 1 Suspension 4 - 13-Jul-10

Photo 23 - 100100 – Truck 1 Suspension 5 - 13-Jul-10

Photo 24 - 100100 – Truck 2 - 13-Jul-10

Photo 25 - 100100 – Truck 2 Tractor - 13-Jul-10

Photo 26 - 100100 – Truck 2 Trailer - 13-Jul-10

Photo 27 - 100100 – Truck 2 Load - 13-Jul-10

Photo 28 - 100100 – Truck 2 Suspension 1 - 13-Jul-10

Photo 29 - 100100 - Truck 2 Suspension 2 - 13-Jul-10

Photo 30 - 100100 - Truck 2 Suspension 3 - 13-Jul-10

Photo 31 - 100100 - Truck 2 Suspension 4 - 13-Jul-10

Photo 32 - 100100 - Truck 2 Suspension 5 - 13-Jul-10

Traffic Sheet 16	STATE CODE:	10
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	100100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	7/13/2010

SITE CALIBRATION INFORMATION

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

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

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

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

   Number of Trucks Compared: ______
   Number of Test Trucks Used: 2
   Passes Per Truck: 20

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air spring	air spring
Truck 2:	9	air spring	steel spring
Truck 3:	0	0	0

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

   Mean Difference Between -

Dynamic and Static GVW:	-2.4%	Standard Deviation:	2.3%
Dynamic and Static Single Axle:	-2.9%	Standard Deviation:	3.1%
Dynamic and Static Double Axles:	-2.3%	Standard Deviation:	3.1%

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

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

			Low		High	Runs
a.	Low	-	42.0	to	46.3	12
b.	Medium	-	46.4	to	50.8	13
c.	High	-	50.9	to	55.2	15
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/13/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) R-3409 | L-3663

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

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

The Auto-cal feature is using a linear progression of numerical values, starting at 1000 for 0 degrees, with a value incremented by 4 for every degree up to 100 degrees.

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

Percent of "Unclassified" Vehicles: 0.9%

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

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/14/2010

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 7/14/10

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. Quartz Piezo
   b. Inductance Loops
   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	air spring	air spring
Truck 2:	9	air spring	steel spring
Truck 3:	0	0	0

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

Mean Difference Between -

	Mean Difference		Standard Deviation
Dynamic and Static GVW:	0.3%	Standard Deviation:	2.9%
Dynamic and Static Single Axle:	1.1%	Standard Deviation:	3.9%
Dynamic and Static Double Axles:	0.2%	Standard Deviation:	3.9%

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

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

			Low		High	Runs
a.	Low	-	44.0	to	47.7	17
b.	Medium	-	47.8	to	51.4	11
c.	High	-	51.5	to	55.2	13
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/14/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3430 | 3685

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

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

The Auto-cal feature is using a linear progression of numerical values, starting at 1000 for 0 degrees, with a value incremented by 4 for every degree up to 100 degrees.

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		-	
FHWA Class 8:	17.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 1.0%

Person Leading Calibration Effort: **Dean J. 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: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/13/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
58	9	56126	59	9	54	5	56489	51	5
68	5	56133	69	5	55	6	58845	53	6
62	5	56158	62	5	52	5	58846	51	5
54	5	56171	54	5	61	6	58848	60	6
56	5	56177	58	5	55	8	58872	53	8
57	8	56188	60	8	56	9	58876	56	9
58	9	56191	60	9	56	8	58877	56	8
60	9	56244	60	9	57	5	58883	57	5
59	9	56249	60	9	56	9	58886	57	9
50	9	56301	50	9	57	5	58890	57	3
49	9	56302	50	9	51	8	58905	54	5
67	9	56304	69	9	59	5	58919	62	5
60	6	56322	59	6	63	5	58923	63	3
54	5	56334	52	5	57	9	58930	58	9
57	9	56335	55	9	59	9	58931	60	9
60	5	56353	60	3	49	5	58938	51	5
60	3	56358	61	5	62	5	58944	64	5
57	8	56364	58	8	54	5	58948	54	5
57	6	56365	55	6	57	9	58950	58	9
59	9	56371	61	9	49	5	58953	51	5
58	9	56372	59	9	57	9	58962	61	9
60	9	56409	59	9	62	5	58970	62	5
58	9	56414	59	9	58	9	59000	59	9
60	9	56437	60	9	57	9	59002	58	9
62	9	56438	63	9	60	9	59005	62	9

Sheet 1 - 0 to 50

Recorded By: ______________________ Verified By: ______________________

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/13/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
54	5	59017	54	3	58	9	59149	58	9
49	9	59020	51	9	56	5	59153	57	5
54	5	59021	54	3	50	5	59181	53	5
54	5	59022	54	3	64	6	59197	62	6
59	5	59032	63	5	56	9	59198	55	9
42	5	59034	42	4	54	5	59200	54	3
48	5	59039	49	4	62	5	59212	62	5
59	9	59045	61	9	65	15	59218	65	8
58	9	59048	58	9	55	8	59223	54	8
62	9	59049	62	9	60	9	59230	64	9
60	6	59065	60	6	57	5	59232	55	5
54	9	59067	52	9	60	9	59240	60	9
61	9	59075	62	9	59	8	59242	59	8
56	9	59081	58	9	62	5	59249	67	5
56	8	59084	56	8	58	5	59255	59	5
53	9	59085	53	9	45	6	59257	45	6
55	5	59087	55	5	60	5	59259	60	5
60	5	59096	60	5	60	9	59260	60	9
58	9	59102	59	9	57	9	59274	57	9
50	5	59109	50	5	57	6	59276	56	7
59	9	59114	60	9	57	6	59277	57	6
57	9	59121	57	9	57	9	59290	58	9
55	5	59124	54	5	57	9	59293	58	9
55	9	59130	56	9	60	5	59301	64	5
55	6	59142	54	6	55	5	59306	56	5

Sheet 2 - 51 to 100

Recorded By: ______________________ Verified By: ______________________

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/13/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
59	5	59307	61	5					
59	6	59318	60	6					
58	8	59328	60	8					
57	8	59329	52	8					
60	5	59332	61	5					
56	9	59333	52	9					
58	9	59334	58	9					
58	5	59356	60	5					
55	6	59357	56	6					

Sheet 101 - 150

Recorded By: ______________________ Verified By: ______________________

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 10 SPS WIM ID: 100100 DATE (mm/dd/yyyy) 7/14/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
55	6	61007	57	6	62	3	61224	64	5
60	9	61015	63	9	59	3	61227	60	5
59	9	61017	62	9	66	9	61236	66	9
65	8	61021	67	8	61	5	61244	64	5
50	8	61028	51	8	57	5	61248	57	5
59	5	61033	61	5	54	9	61262	55	9
59	9	61036	60	9	53	5	61263	53	3
60	6	61038	62	6	55	5	61270	58	5
61	9	61042	62	9	52	9	61278	53	9
58	9	61060	58	9	55	9	61323	56	9
61	13	61122	63	10	63	3	61327	64	5
60	9	61123	59	9	59	9	61329	69	9
57	7	61125	57	7	57	3	61333	58	5
56	9	61132	59	9	57	9	61343	58	9
55	9	61134	56	9	63	5	61366	66	5
67	9	61144	68	9	57	8	61386	57	8
60	5	61145	61	5	56	9	61456	58	9
55	5	61159	57	5	61	5	61459	63	4
50	5	61161	50	3	58	5	61461	59	5
49	6	61162	51	6	46	5	61467	50	5
57	9	61171	58	9	65	5	61471	67	5
62	5	61172	64	5	55	6	61478	56	6
58	9	61173	58	9	60	5	61480	61	5
62	9	61178	62	9	58	9	61503	62	9
57	9	61182	57	9	54	6	61512	54	6

Sheet 1 - 0 to 50

Recorded By: ____________________ Verified By: ____________________

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE:	10
	SPS WIM ID:	100100
	DATE (mm/dd/yyyy)	7/14/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
61	9	61549	61	9	62	9	61778	60	9
57	6	61559	56	6	58	6	61779	57	6
47	5	61560	47	5	50	5	61782	50	5
58	8	61568	58	8	54	8	61795	54	8
59	5	61572	58	5	60	5	61797	60	5
59	5	61576	59	5	57	5	61803	57	5
54	9	61580	54	9	55	5	61804	55	5
64	9	61589	64	9	64	9	61810	63	9
61	9	61590	63	9	60	5	61811	60	5
59	9	61603	59	9	61	8	61812	62	8
55	5	61604	57	4	65	5	61826	65	5
65	6	61609	66	6	55	6	61853	54	6
62	5	61613	62	5	59	5	61861	58	5
64	9	61660	65	9	57	7	61876	59	7
60	5	61662	63	5	59	5	61878	62	5
63	9	61665	64	9	61	5	61881	62	5
62	9	61666	64	9	55	6	61887	56	6
63	5	61681	63	5	59	3	61892	61	5
59	15	61695	59	5	59	6	61908	61	6
64	9	61697	63	9	60	6	61947	58	6
60	5	61708	63	5	54	5	61951	59	5
61	9	61714	62	9	68	8	61952	65	5
53	6	61718	59	6	57	9	61958	58	9
63	9	61728	64	9	62	9	61960	63	9
59	5	61578	59	5	62	6	61965	63	6

Sheet 2 - 51 to 100

Recorded By: ______________________ Verified By: ______________________

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	10 100100 7/14/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
55	9	61980	57	9					
55	6	61981	55	6					

Sheet 101 - 150

Recorded By: ______________________ Verified By: ______________________