WIM System Field Calibration and Validation Summary Report - Amended

Maryland SPS-5
SHRP ID – 240500

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1 Executive Summary

A WIM validation was performed on August 24 and 25, 2010 at the Maryland SPS-5 site located on route US-15 at milepost 4.6, .53 miles south of Mountville Road.

This site was installed on October 26, 2005. The in-road sensors are installed in the northbound lane. The site is equipped with bending plate 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 05, 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 equipment was operating within tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, no distresses that would affect the performance of the WIM scales were noted. Observations of trucks passing over the site did not detect any motions by the trucks that would affect WIM system accuracies. 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 – 25-Aug-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.1 ± 6.9%	Pass
Single Axles	±20 percent	-1.4 ± 8.1%	Pass
Tandem Axles	±15 percent	1.5 ± 3.3%	Pass
GVW	±10 percent	-0.1 ± 2.6%	Pass
Vehicle Length	±3 percent (1.8 ft)	2.2 ± 2.0 ft	FAIL
Axle Spacing 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 -0.6 ± 1.0 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 0.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 8.0% from the 100 truck sample (Class 4 – 13) was due to the 11 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 vehicle with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with concrete blocks loaded on the trailer.

- The *Secondary* truck was a Class 9 vehicle, with air suspension on the tractor tandem, air on the trailer tandem, standard tandem spacing on the tractor and split tandem on the trailer. The Secondary truck was loaded with concrete blocks loaded on the 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 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. 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	75.3	10.0	15.8	15.8	16.8	16.8	12.3	4.2	37.5	4.1	58.1	62.8
2	64.8	9.2	14.4	14.4	13.4	13.4	12.9	4.2	26.9	10.2	54.2	60.0

The posted speed limit at the site is 55 mph. During the testing, the speed of the test trucks ranged from to 44 to 56 mph, a range of 12 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 71.1 to 104.1 degrees Fahrenheit, a range of 33.0 degrees Fahrenheit. The sunny afternoon weather conditions provided the desired 30 degree range in temperatures.

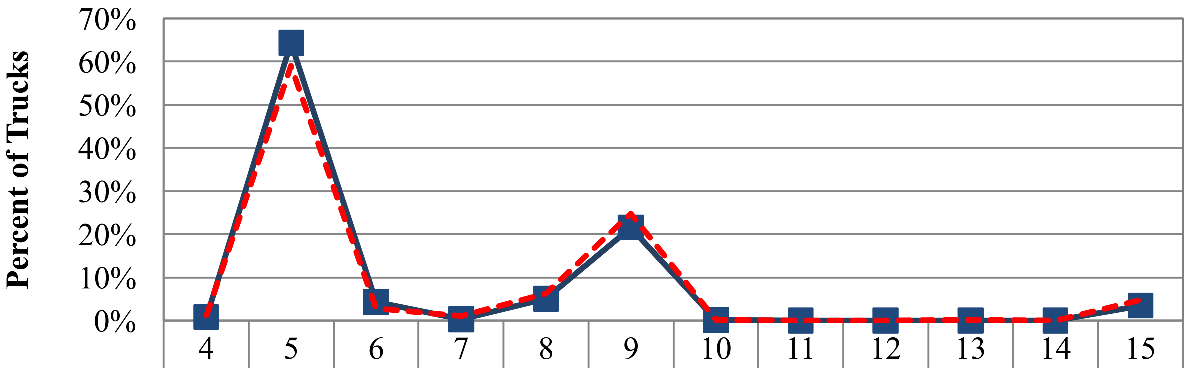
A review of the LTPP Standard Release Database 24 shows that there are 39 consecutive months of level "E" WIM data for this site. This site requires at least 2 additional years of data to meet the minimum of five years of research quality data.

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 from July 05, 2010 (Data) to the most recent Comparison Data Set (CDS) from May 15, 2008. The assessments performed prior to the site visits are used to develop reasonable expectations for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 Classification Data Analysis

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



	4	5	6	7	8	9	10	11	12	13	14	15
Data	0.8%	64.4%	4.3%	0.3%	5.0%	21.6%	0.1%	0.0%	0.0%	0.0%	0.0%	3.5%
CDS	1.2%	59.0%	2.9%	1.0%	6.2%	24.7%	0.1%	0.0%	0.0%	0.2%	0.0%	4.8%

Figure 2-1 – Comparison of Truck Distribution

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 most frequent truck types crossing the WIM scale are Class 5 (64.4%) and Class 9 (21.6%). It also indicates that 3.5 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. Table 2-1 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.

Table 2-1 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	5/15/2008		7/5/2010		
4	118	1.2%	48	0.8%	-0.4%
5	5862	59.0%	3902	64.4%	5.4%
6	286	2.9%	261	4.3%	1.4%
7	100	1.0%	16	0.3%	-0.7%
8	615	6.2%	306	5.0%	-1.1%
9	2458	24.7%	1307	21.6%	-3.2%
10	11	0.1%	9	0.1%	0.0%
11	0	0.0%	0	0.0%	0.0%
12	2	0.0%	1	0.0%	0.0%
13	16	0.2%	0	0.0%	-0.2%
14	0	0.0%	0	0.0%	0.0%
15	474	4.8%	211	3.5%	-1.3%

The table shows that the number of Class 5 vehicles has increased by 5.4 percent from May 2008 and July 2010. This increase may be attributed to small sample size used to develop vehicle class distributions, increased 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, the number of Class 9 trucks decreased by -3.2 percent. Small changes 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 during validation testing. The CDS distribution of truck speeds is presented in Figure 2-2.

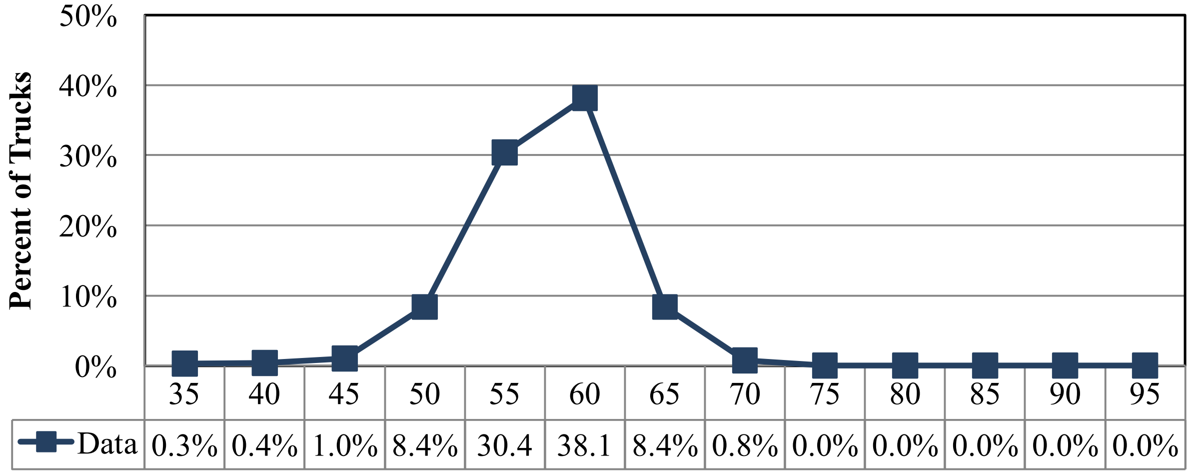


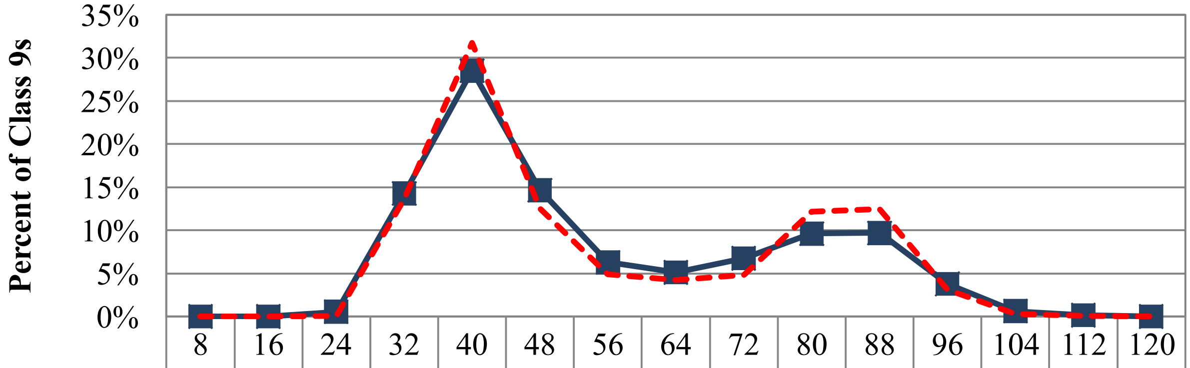
Figure 2-2 – Truck Speed Distribution from ASCII File

Figure 2-2 shows the speed distribution for trucks (Class 4 – 13) for this site. As shown in the figure, the majority of the trucks at this site are traveling between 55 and 60 mph. The posted speed limit at this site is 55 and the 85th percentile speed for trucks at this site is 60 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 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 July 2010 and the Comparison Data Set from May 2008.

As shown in Figure 2-3, there is a decrease in the percentage of trucks for the unloaded and loaded peaks between the May 2008 Comparison Data Set (CDS) and the July 2010 two-week sample W-card dataset (Data). This may indicate a change in the pavement condition or sensor deterioration.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.5%	14.3	28.5	14.7	6.3%	5.1%	6.7%	9.6%	9.7%	3.8%	0.6%	0.2%	0.0%
CDS	0.0%	0.0%	0.1%	13.7	31.8	12.6	4.9%	4.3%	4.8%	12.1	12.4	3.1%	0.3%	0.0%	0.0%

Figure 2-3 – Comparison of Class 9 GVW Distribution

Table 2-2 is provided to show the statistical comparison between the Comparison Data Set and the current dataset.

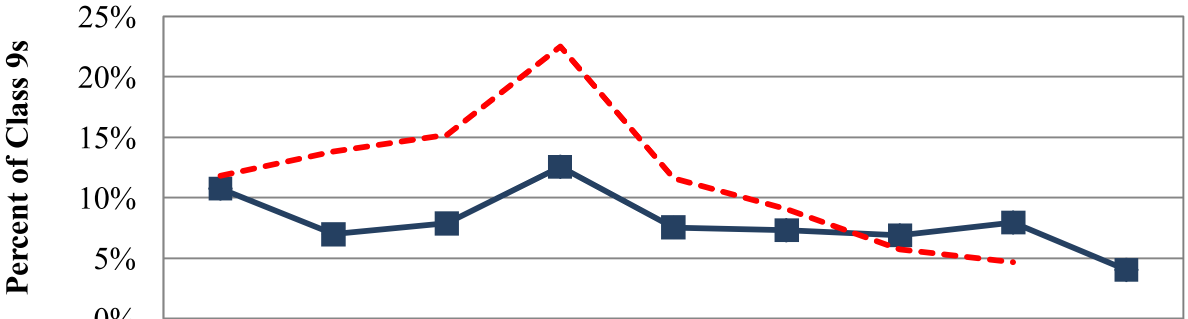
Table 2-2 – Class 9 GVW Distribution from W-Card

GVW weight bins (kips)	CDS		Data		Change
	Date				
	5/15/2008		7/5/2010		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	2	0.1%	7	0.5%	0.5%
32	331	13.7%	184	14.3%	0.6%
40	769	31.8%	368	28.5%	-3.2%
48	304	12.6%	189	14.7%	2.1%
56	118	4.9%	81	6.3%	1.4%
64	103	4.3%	66	5.1%	0.9%
72	116	4.8%	87	6.7%	2.0%
80	294	12.1%	124	9.6%	-2.5%
88	301	12.4%	125	9.7%	-2.7%
96	76	3.1%	49	3.8%	0.7%
104	7	0.3%	8	0.6%	0.3%
112	1	0.0%	2	0.2%	0.1%
120	0	0.0%	0	0.0%	0.0%
Average =	52.1		51.5		-0.5

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range decreased by 3.2 percent and the number of loaded class 9 trucks in the 72 to 80 kips range decreased by 2.5 percent. The number of overweight trucks decreased during this time period by 1.6 percent and the overall GVW average for this site decreased from 52.1 kips to 51.5 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 the two week W-card sample from July 2010 and the Comparison Data Set from May 2008.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Data	10.7%	7.0%	7.9%	12.6%	7.5%	7.3%	6.9%	8.0%	4.0%
CDS	11.8%	13.8%	15.2%	22.5%	11.6%	9.1%	5.7%	4.6%	

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

It can be seen in the figure that although the greatest percentage of trucks have front axle weights averaging 11.0 kips, the percentage of trucks at this weight have decreased between the May 2008 Comparison Data Set (CDS) and the July 2010 dataset (Data).

Table 2-3 provides the Class 9 front axle weight distribution data for the May 2008 Comparison Data Set (CDS) and the July 2010 dataset (Data).

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

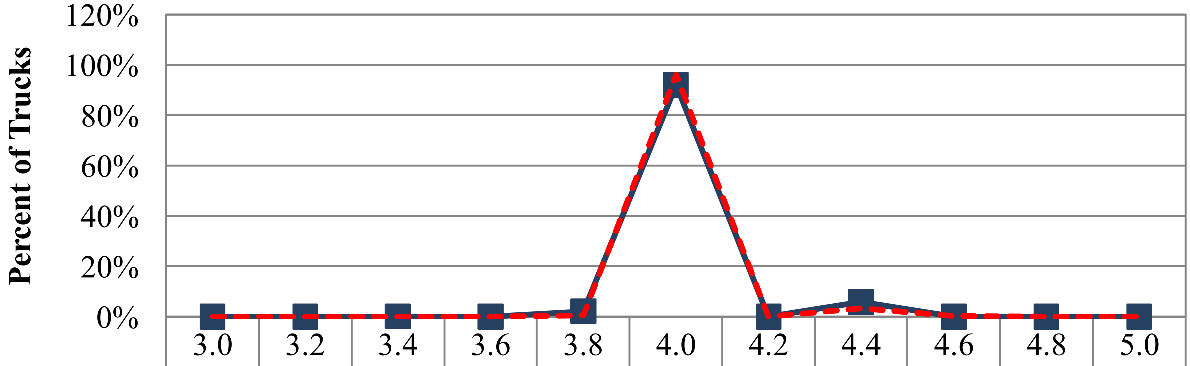
F/A weight bins (kips)	CDS		Data		Change
	Date				
	5/15/2008		7/5/2010		
8.0	10	0.4%	220	20.5%	20.1%
8.5	19	0.8%	54	5.0%	4.2%
9.0	75	3.3%	69	6.4%	3.1%
9.5	283	12.6%	131	12.2%	-0.4%
10.0	331	14.7%	85	7.9%	-6.8%
10.5	364	16.2%	96	8.9%	-7.2%
11.0	539	23.9%	153	14.3%	-9.7%
11.5	278	12.3%	92	8.6%	-3.8%
12.0	217	9.6%	89	8.3%	-1.3%
12.5	137	6.1%	84	7.8%	1.7%
Average =	10.7		10.3		0.4

The table shows that the average front axle weight for Class 9 trucks has decreased by 0.4 kips, or by 3.5 percent. 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 10.3 kips.

2.5 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 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%	0.1%	0.0%	2.1%	92.0%	0.0%	5.8%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.0%	0.0%	0.4%	96.0%	0.0%	3.3%	0.2%	0.0%	0.0%

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

As seen in the figure, the Class 9 tractor tandem spacing for the May 2008 Comparison Data Set and the July 2010 dataset are nearly identical.

Table 2-4 shows the Class 9 axle spacings between the second and third axles for the power unit.

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

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	5/15/2008		7/5/2010		
3.0	0	0.0%	0	0.0%	0.0%
3.2	1	0.0%	0	0.0%	0.0%
3.4	0	0.0%	1	0.1%	0.1%
3.6	0	0.0%	0	0.0%	0.0%
3.8	10	0.4%	27	2.1%	1.7%
4.0	2326	96.0%	1187	92.0%	-4.0%
4.2	0	0.0%	0	0.0%	0.0%
4.4	81	3.3%	75	5.8%	2.5%
4.6	4	0.2%	0	0.0%	-0.2%
4.8	0	0.0%	0	0.0%	0.0%
5.0	0	0.0%	0	0.0%	0.0%
Average =	4.0		4.0		0.0

From the table it can be seen that the spacing of the tractor tandems for Class 9 trucks at this site is between 3.8 and 4.6 feet. The average tractor tandem spacing is 4.0 feet, which is below the expected average of 4.25 feet. Further analyses are performed during the validation and post-validation analysis.

2.6 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (May 2008) based on the last calibration with the most recent two-week WIM data sample from the site (July 2010). Comparison of vehicle class distribution indicated that the number of Class 5 vehicles has increased. Analysis of Class 9 weight data indicated that average Class 9 GVW has decreased and Class 9 front axle weights have decreased in the July 2010 data. The Class 9 truck tandem spacing indicated that the average Class 9 truck tandem spacing is below the expected average of 4.25 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on March 05, 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 October 26, 2005 by International Road Dynamics. It is instrumented with bending plate 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 deficiencies 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 values for the WIM sensors and inductive loops were within tolerances. Electronic tests of the power and communication devices indicated that they were operating normally.

3.4 Equipment Troubleshooting and Diagnostics

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

3.5 Recommended Equipment Maintenance

No equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, no significant pavement distress was noted and no adverse truck movements prior to, or as they traversed the WIM scale area, were noted. Profile and Vehicle Interaction

Profile data collected on June 24, 2009 by the Southern Regional Support Contractor was obtained using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long 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 and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 1000-foot WIM section was 217 in/mi and is located approximately 650 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 208 in/mi and is located approximately 356 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.

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

4.2 LTPP Pavement Profile Data Analysis

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

Table 4-1 – Recommended WIM Smoothness Index Thresholds

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

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

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

Table 4-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass5**	**Avg**
Left	LWP	LRI (m/km)	0.959	1.041	0.894			0.965
		SRI (m/km)	*0.443*	*0.409*	0.502			*0.451*
		Peak LRI (m/km)	1.122	1.217	1.096			1.145
		Peak SRI (m/km)	0.748	0.706	0.835			0.763
	RWP	LRI (m/km)	0.718	0.694	0.739			0.717
		SRI (m/km)	*0.316*	*0.325*	*0.393*			*0.345*
		Peak LRI (m/km)	0.908	0.878	0.898			0.895
		Peak SRI (m/km)	*0.491*	*0.543*	*0.454*			*0.496*
Center	LWP	LRI (m/km)	0.750	0.701	0.907	0.686	0.858	0.761
		SRI (m/km)	0.598	*0.282*	*0.446*	0.566	*0.490*	*0.473*
		Peak LRI (m/km)	0.830	0.943	1.161	0.880	1.150	0.954
		Peak SRI (m/km)	0.970	*0.482*	*0.578*	*0.628*	*0.590*	*0.665*
	RWP	LRI (m/km)	0.935	0.840	0.957	0.955	0.982	0.922
		SRI (m/km)	0.654	0.629	0.525	0.799	*0.417*	0.652
		Peak LRI (m/km)	0.999	1.017	1.048	1.028	1.168	1.023
		Peak SRI (m/km)	0.816	*0.646*	*0.669*	0.843	*0.576*	*0.744*
Right	LWP	LRI (m/km)	0.694	0.929	0.686			0.770
		SRI (m/km)	0.592	0.741	*0.366*			0.566
		Peak LRI (m/km)	0.835	0.943	0.907			0.895
		Peak SRI (m/km)	0.798	0.836	*0.521*			*0.718*
	RWP	LRI (m/km)	0.758	0.818	0.783			0.786
		SRI (m/km)	0.657	0.657	0.531			0.615
		Peak LRI (m/km)	0.831	0.908	0.899			0.879
		Peak SRI (m/km)	0.862	0.842	0.902			0.869

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 below the lower threshold, shown in italics. The highest values, on average, are the Peak LRI values in the left wheel path of the left shift passes.

4.3 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

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

5.1 Pre-Validation

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

The 40 pre-validation test truck runs were conducted on August 24, 2010, beginning at approximately 8:24 AM and continuing until 3:42 PM.

The two test trucks consisted of:

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

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

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

Test Truck	Weights (kips)						Spacings (feet and tenths)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.0	9.8	15.8	15.8	16.8	16.8	12.3	4.2	37.5	4.1	58.1	62.8
2	64.6	9.1	14.4	14.4	13.4	13.4	12.9	4.2	26.9	10.2	54.2	60.0

Test truck speeds varied by 12 mph, from 44 to 56 mph. The measured pre-validation pavement temperatures varied 24.7 degrees Fahrenheit, from 72.3 to 97.0. The cloudy weather conditions prevented reaching the desired 30 degree temperature range. Table 5-12 is a summary of pre-validation results.

Table 5-2 – Pre-Validation Overall Results – 24-Aug-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-4.7 ± 5.4%	Pass
Single Axles	±20 percent	-2.8 ± 7.2%	Pass
Tandem Axles	±15 percent	1.3 ± 4.5%	Pass
GVW	±10 percent	-0.9 ± 3.1%	Pass
Vehicle Length	±3 percent (1.8 ft)	2.3 ± 2.0 ft	FAIL
Axle Spacing Length	± 0.5 ft [150mm]	-0.3 ± 0.3 ft	FAIL

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 -0.9 ± 1.2 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. Since the site is measuring axle spacing length with a mean error of -0.3 feet, 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 Table 5-3 below.

Table 5-3 – Pre-Validation Results by Speed – 24-Aug-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		44.0 to 48.0 mph	48.1 to 52.1 mph	52.2 to 56.0 mph
Steering Axles	±20 percent	-5.4 ± 6.3%	-5.0 ± 5.8%	-3.5 ± 4.9%
Single Axles	±20 percent	-2.8 ± 7.6%	-3.7 ± 8.1%	-1.7 ± 6.3%
Tandem Axles	±15 percent	-1.0 ± 3.7%	1.4 ± 2.7%	2.0 ± 2.8%
GVW	±10 percent	-2.1 ± 2.1%	-1.2 ± 3.0%	0.5 ± 2.4%
Vehicle Length	±3 percent (1.8 ft)	2.4 ± 2.1 ft	2.2 ± 2.1 ft	2.3 ± 2.5 ft
Vehicle Speed	± 1.0 mph	-1.0 ± 0.9 mph	-0.8 ± 1.2 mph	-1.1 ± 1.5 mph
Axle Spacing Length	± 0.5 ft [150mm]	-0.3 ± 0.3 ft	-0.3 ± 0.2 ft	-0.4 ± 0.3 ft

From the table, it can be seen that the WIM equipment underestimates steering and single axle weights at all speeds. The equipment underestimates tandem axles and GVW at the lower speeds and progresses toward an overestimation at the high speeds. The range of errors for each of the weights is consistent at all speeds. There appears to be a relationship between tandem axle weight and GVW weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on measured weights, as discussed in the following paragraphs.

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment underestimates GVW at the low and medium speeds and estimates with reasonable accuracy at the high speeds. The range in error and bias is greater at the medium speeds when compared with low and high speeds.

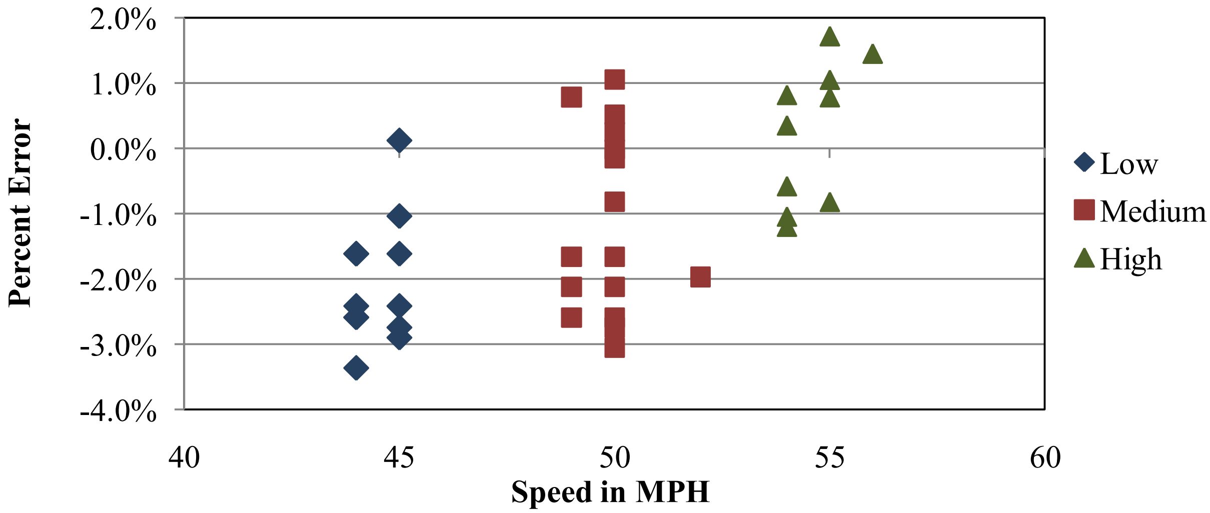


Figure 5-1 – Pre-Validation GVW Error by Speed – 24-Aug-10

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment underestimates steering axle weights at all speeds. The range in error appears to be greater at the low and medium speeds.

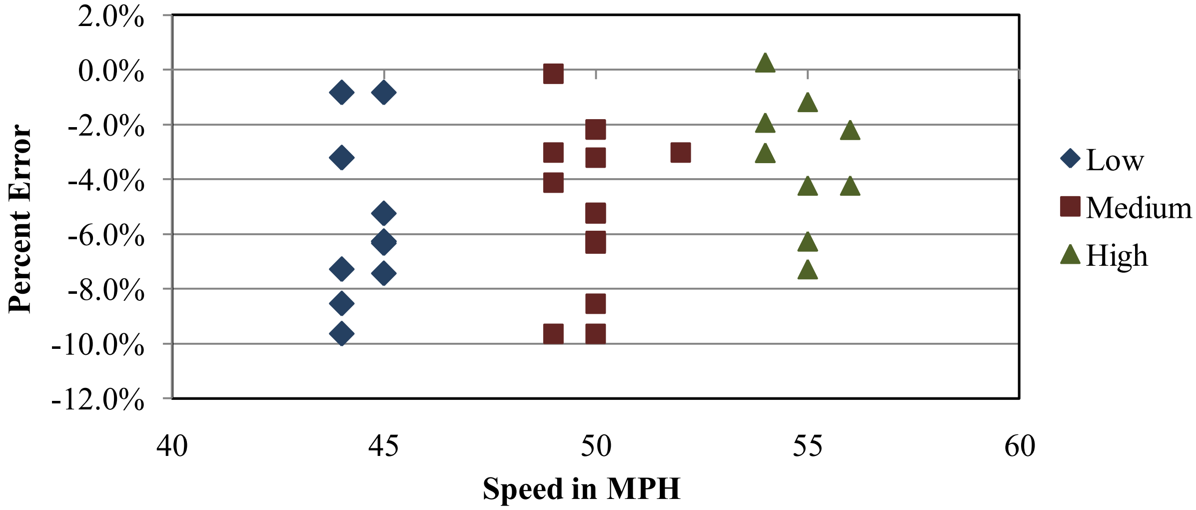


Figure 5-2 – Pre-Validation Steering Axle Weight Error by Speed – 24-Aug-10

5.1.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment underestimates single axle weights with similar bias at all speeds. The range in error appears to be grater at the low and medium speeds. Distribution of errors is shown graphically in the following figure.

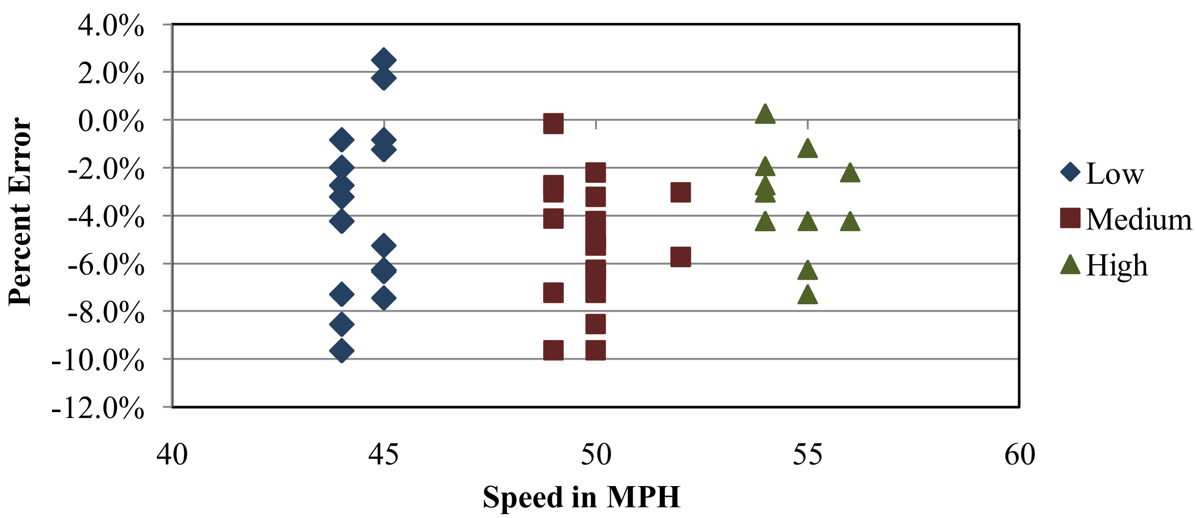


Figure 5-3 – Pre-Validation Single Axle Weight Error by Speed – 24-Aug-10

5.1.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment underestimates tandem axle weights at the low speeds and overestimates these weights at the medium and high speeds. The range in error is similar throughout the entire speed range. Distribution of errors is shown graphically in the following figure.

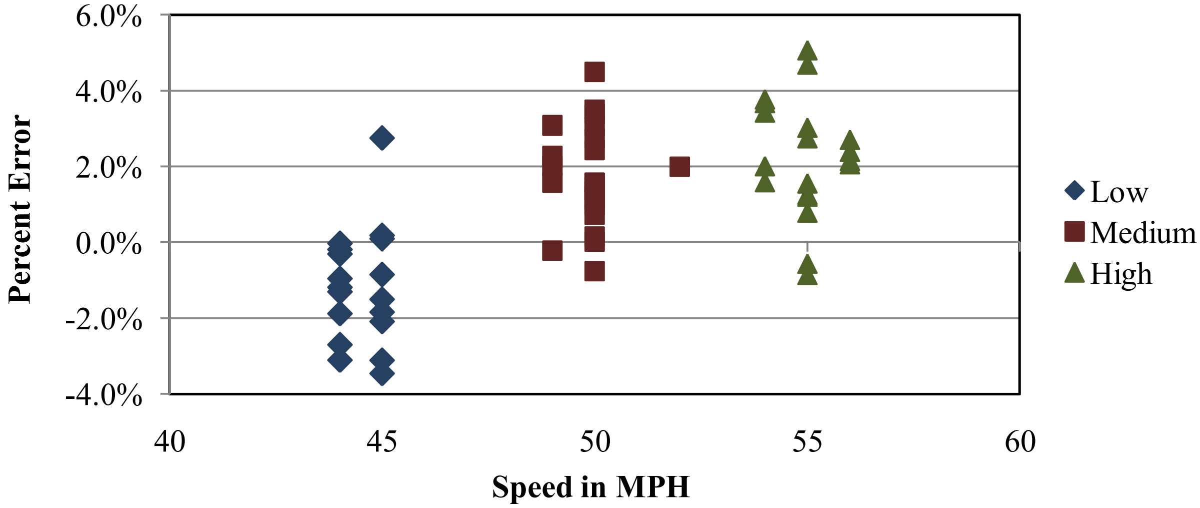


Figure 5-4 – Pre-Validation Tandem Axle Weight Error by Speed – 24-Aug-10

5.1.1.5 GVW Errors by Speed and Truck Type

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

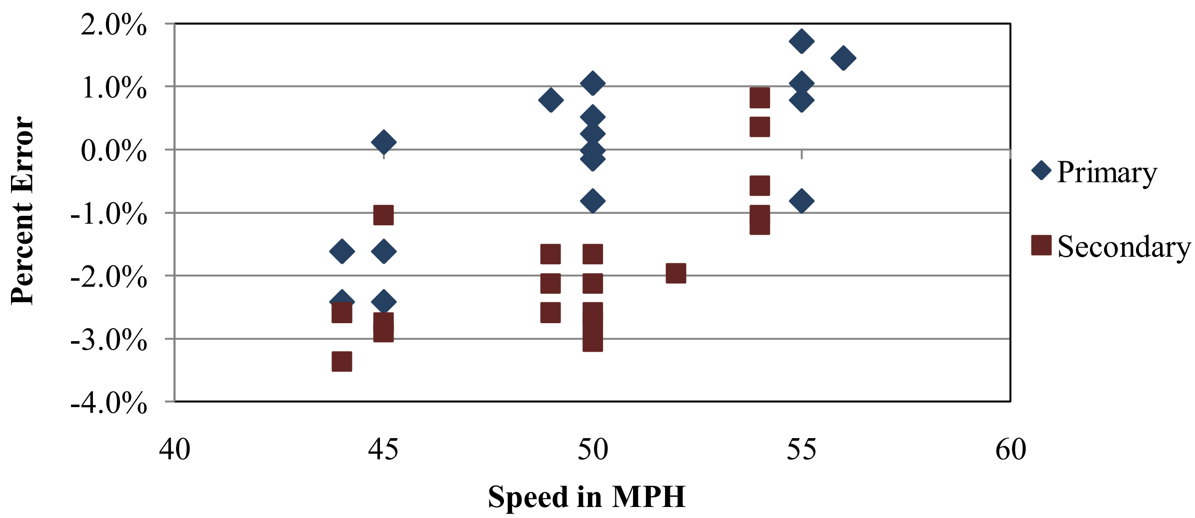


Figure 5-5 – Pre-Validation GVW Error by Truck and Speed – 24-Aug-10

5.1.1.6 Axle Length Errors by Speed

For this site, the axle length error is underestimated at all speeds. The range in axle length measurement error ranged from -0.6 feet to 0.0 feet. Distribution of errors is shown graphically in Figure 5-6.

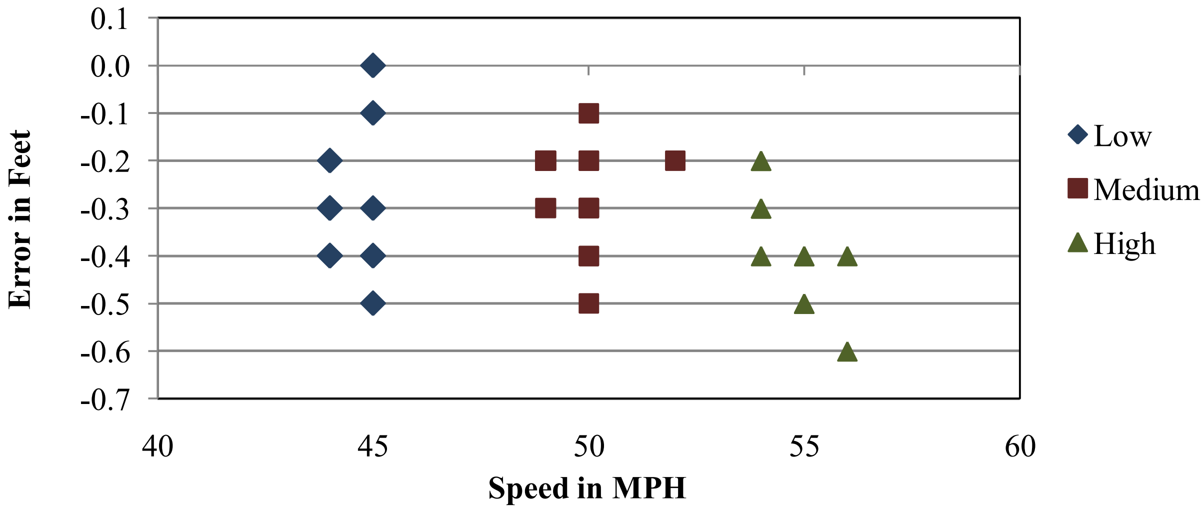


Figure 5-6 – Pre-Validation Axle Length Error by Speed – 24-Aug-10

5.1.1.7 Overall Length Errors by Speed

For this system, the WIM equipment overestimates overall vehicle length over the entire range of speeds, with errors ranging from 1.0 to 3.2 feet. Distribution of errors is shown graphically in the Figure 5-7.

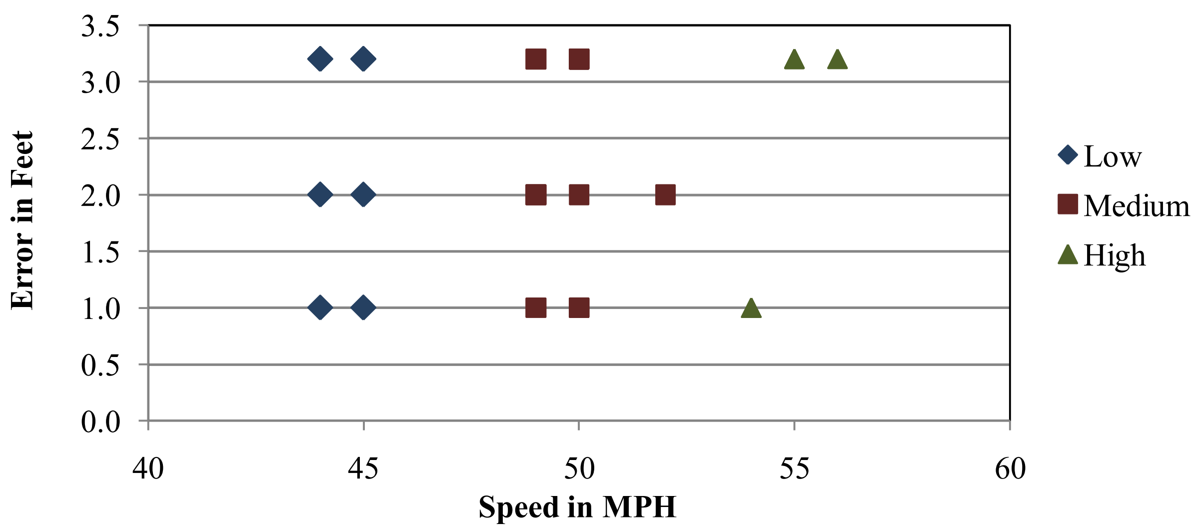


Figure 5-7 – Pre-Validation Overall Length Error by Speed – 24-Aug-10

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relationship between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 24.7 degrees, from 72.3 to 97.0 degrees Fahrenheit. The pre-validation test runs are being reported under two temperature groups as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 24-Aug-10

Parameter	**95% Confidence Limit of Error**	**Low**	**High**
		72.3 to 84.7 degF	**84.8 to 97.0 degF**
Steering Axles	±20 percent	-4.6 ± 6.3%	-4.8 ± 5.0%
Single Axles	±20 percent	-2.8 ± 7.6%	-2.8 ± 7.3%
Tandem Axles	±15 percent	1.0 ± 4.1%	0.7 ± 4.1%
GVW	±10 percent	-0.8 ± 3.6%	-1.1 ± 2.9%
Vehicle Length	±3 percent (1.8 ft)	2.4 ± 2.0 ft	2.2 ± 2.2 ft
Vehicle Speed	± 1.0 mph	-1.0 ± 1.2 mph	-0.9 ± 1.2 mph
Axle Spacing Length	± 0.5 ft [150mm]	-0.3 ± 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 5-8, 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.

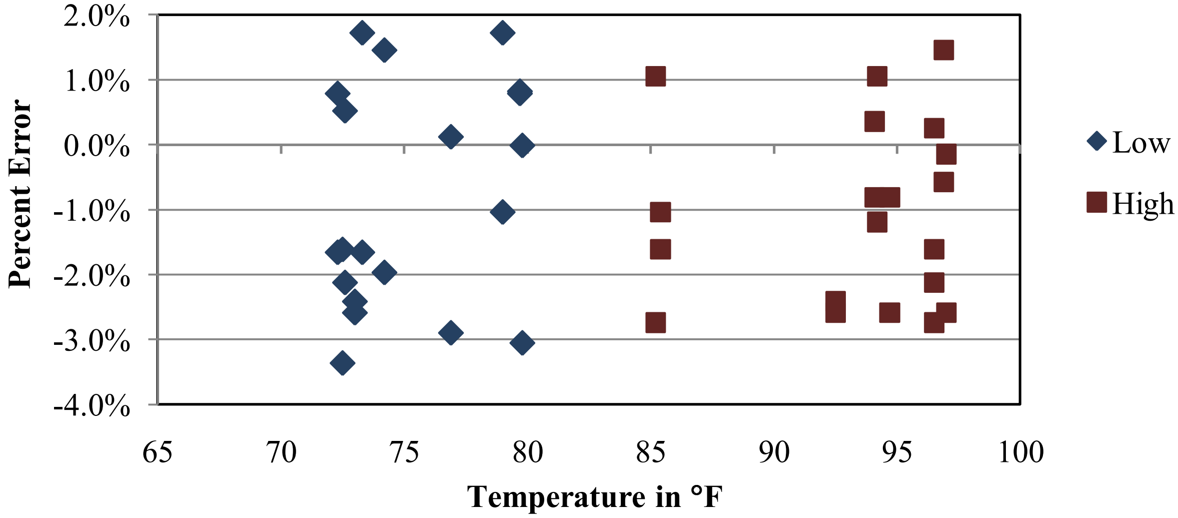


Figure 5-8 – Pre-Validation GVW Error by Temperature – 24-Aug-10

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 illustrates that the WIM equipment underestimates steering axle weights at all temperatures. The range in error is similar for each of the temperature groups. Distribution of errors is shown graphically in the following figure.

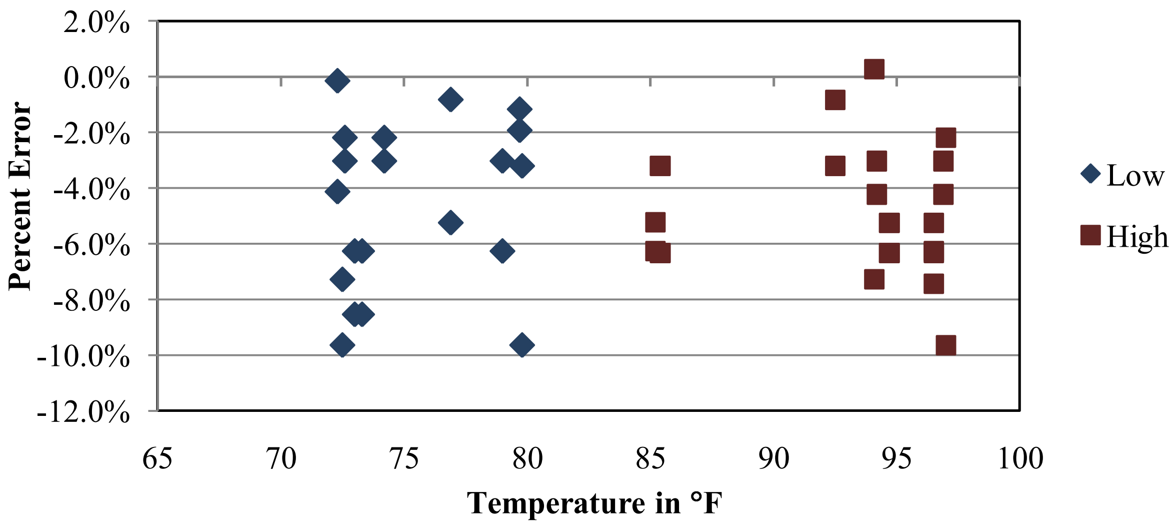


Figure 5-9 – Pre-Validation Steering Axle Weight Error by Temperature – 24-Aug-10

5.1.2.3 Single Axle Weight Errors by Temperature

Figure 5-10 illustrates that the WIM equipment underestimates single axle weights at all temperatures. The range in error is similar for each of the temperature groups. Distribution of errors is shown graphically in the following figure.

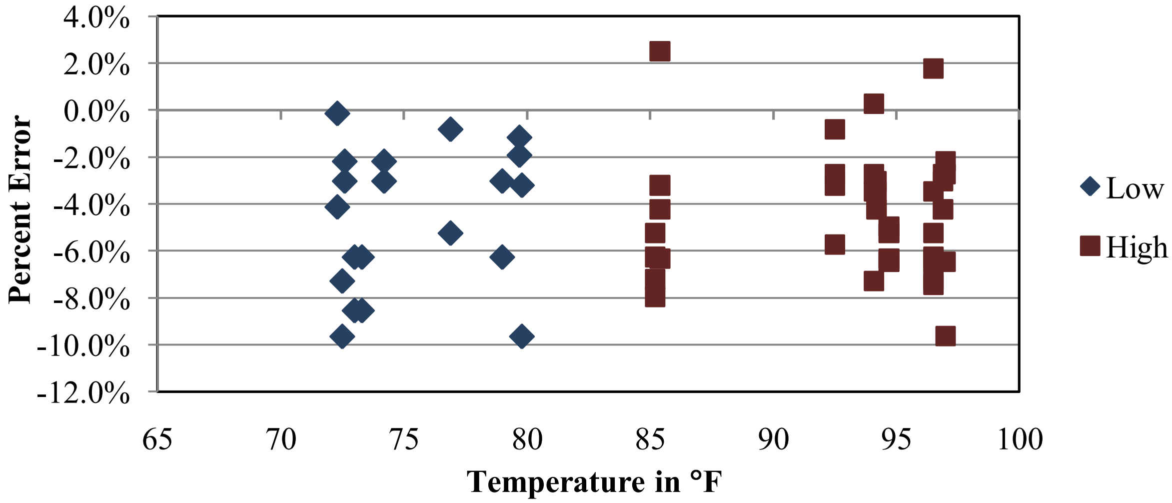


Figure 5-10 – Pre-Validation Single Axle Weight Error by Temperature – 24-Aug-10

5.1.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-11, it can be seen that the equipment generally overestimates tandem axle weights across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates.

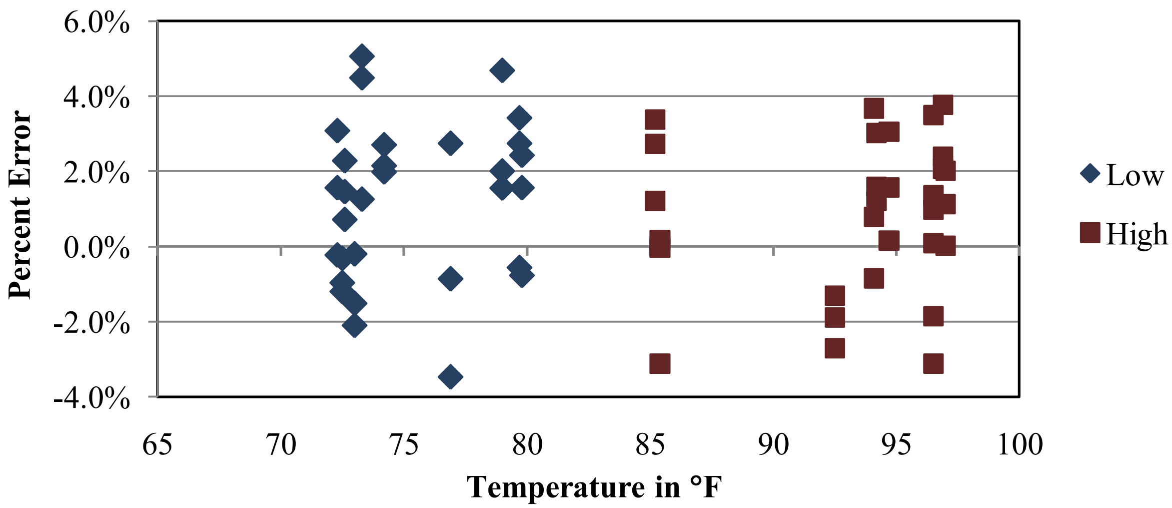


Figure 5-11 – Pre-Validation Tandem Axle Weight Error by Temperature – 24-Aug-10

5.1.2.5 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, the WIM equipment overestimates GVW for each truck at all temperatures, on average. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures. Distribution of errors is shown graphically in Figure 5-12.

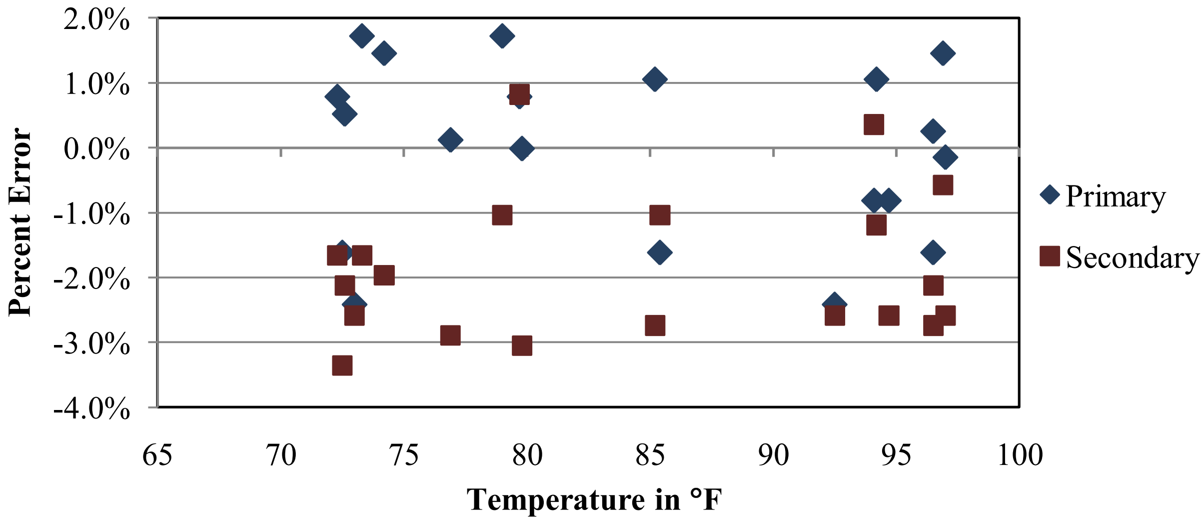


Figure 5-12 – Pre-Validation GVW Error by Truck and Temperature – 24-Aug-10

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 100 vehicles including 99 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 – 24-Aug-10

Class	4	5	6	7	8	9	10	11	12	13
WIM Count	1	45	4	0	5	42	0	0	0	0
Observed Count	5	42	4	1	5	42	0	0	0	0
Obs. Distribution (%)	5%	42%	4%	1%	5%	42%	0%	0%	0%	0%
WIM Distribution (%)	1%	45%	4%	0%	5%	42%	0%	0%	0%	0%
Misclassified	4	2	0	0	0	0	0	0	0	0
Misclassified (%)	80%	5%	0%	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 percentage of the misclassified vehicles in the manual sample. The overall misclassification rate for all vehicles (3 – 15) is 7.0%. The misclassifications by pair are provided in Table 5-6.

Table 5-6 – Pre-Validation Misclassifications by Pair – 24-Aug-10

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

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all trucks (3 – 15) is 7.0%. As shown in the table, a total of 7 vehicles, including zero heavy trucks (6 – 13) were misclassified by the equipment. All of the misclassifications were cross-classifications of Class 3, 4, 5 and 8 vehicles.

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 – 24-Aug-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	1	13/15	0
8/15	0		

Based on the manually collected sample of the 99 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 LTTP SPS WIM sites. The single unclassified vehicle was a Class 7. The cause of the unclassification could not be determined in the field.

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

The operating system weight compensation parameters that were in place prior to the pre-validation are shown in Table 5-8.

Table 5-8 – Initial System Parameters – 25-Aug-10

Speed Point	MPH	Right	Left
72	45	3271	3635
80	50	3336	3707
88	55	3380	3755
96	60	3380	3755
105	65	3380	3755
Axle Distance (cm)	364		
Dynamic Comp (%)	100		

5.2.1 Calibration Iteration 1

5.2.1.1 Equipment Adjustments

For the GVW, the pre-validation test truck runs produced an overall error of -0.9% and errors of -2.1%, -1.2%, and 0.5% at the 40, 50 and 55 mph speed points respectively. The error for 55 mph was extrapolated to derive new compensation factors for the 60 and 65 mph speed points. To compensate for these errors, the changes in Table 5-9 were made to the compensation factors.

Table 5-9 – Calibration 1 Equipment Factor Changes – 25-Aug-10

Speed Points	Speed	% Error	Old Factors		New Factors	
			Right	Left	Right	Left
72	45	-1.58%	3271	3635	3318	3688
80	50	-0.69%	3336	3707	3354	3727
88	55	0.96%	3380	3714	3343	3714
96	60	0.96%	3380	3714	3343	3714
105	65	0.96%	3380	3714	3343	3714
Axle Distance (cm)		0.6%	364		366	
Dynamic Comp (%)		-4.69%	100		104	

5.2.1.2 Calibration 1 Results

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

Table 5-10 – Calibration 1 Results – 25-Aug-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.6 ± 8.4%	Pass
Single Axles	±20 percent	-1.4 ± 8.4%	Pass
Tandem Axles	±15 percent	0.9 ± 3.9%	Pass
GVW	±10 percent	-0.4 ± 2.1%	Pass
Vehicle Length	±3 percent (1.8 ft)	2.2 ± 2.3 ft	FAIL
Axle Spacing Length	± 0.5 ft [150mm]	0.0 ± 0.2 ft	Pass

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

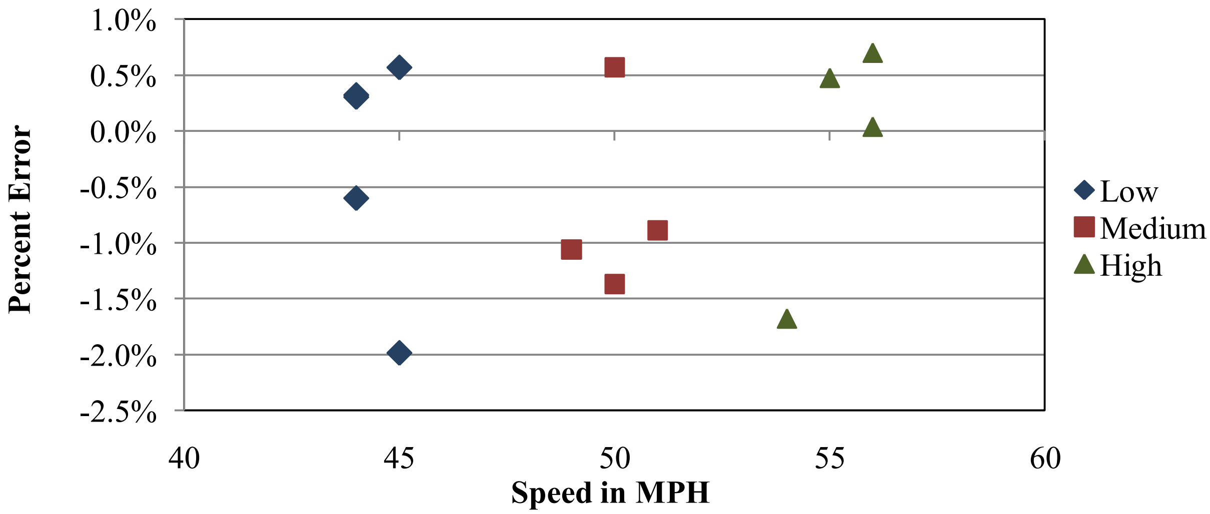


Figure 5-13 – Calibration 1 GVW Error by Speed – 25-Aug-10

The results of the first calibration show that GVW is being estimated with reasonable accuracy by the WIM equipment at all speeds. Based on the results of the first calibration, where weight estimate bias decreased to less than 1.0 percent, a second calibration was not considered to be necessary. The 12 calibration runs were combined with 28 additional post-validation runs to complete the WIM system validation.

5.3 Post-Validation

The 40 post-validation test truck runs were conducted on August 25, 2010, beginning at approximately 7:45 AM and continuing until 3:01 PM.

The two test trucks consisted of:

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

The test trucks were weighed prior to the post-validation and re-weighed at the conclusion of the post-validation. The average test truck weights and measurements are provided in Table 5-11.

Table 5-11 - Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.3	10.0	15.8	15.8	16.8	16.8	12.3	4.2	37.5	4.1	58.1	62.8
2	64.8	9.2	14.4	14.4	13.4	13.4	12.9	4.2	26.9	10.2	54.2	60.0

Test truck speeds varied by 12 mph, from 44 to 56 mph. The measured post-validation pavement temperatures varied 33.0 degrees Fahrenheit, from 71.1 to 104.1. The sunny weather conditions provided for achieving the desired 30 degree temperature range. Table 5-12 is a summary of post validation results.

Table 5-12 – Post-Validation Overall Results – 25-Aug-10

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	-1.1 ± 6.9%	Pass
Single Axles	±20 percent	-1.4 ± 8.1%	Pass
Tandem Axles	±15 percent	1.5 ± 3.3%	Pass
GVW	±10 percent	-0.1 ± 2.6%	Pass
Vehicle Length	±3 percent (1.8 ft)	2.2 ± 2 ft	FAIL
Axle Spacing 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 -0.6 ± 1 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 speed and spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

5.3.1 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 Table 5-13 below.

Table 5-13 – Post-Validation Results by Speed – 25-Aug-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		44.0 to 48.0 mph	48.1 to 52.1 mph	52.2 to 56.0 mph
Steering Axles	±20 percent	-0.8 ± 10.3%	-0.3 ± 6.4%	-2.1 ± 4.5%
Single Axles	±20 percent	-0.1 ± 8.8%	-2.1 ± 8.9%	-1.9 ± 6.7%
Tandem Axles	±15 percent	1.2 ± 3.2%	1.0 ± 2.8%	1.1 ± 3.3%
GVW	±10 percent	0.0 ± 2.9%	-0.5 ± 3.1%	0.1 ± 2.3%
Vehicle Length	±3 percent (1.8 ft)	2.2 ± 2.2 ft	2.2 ± 2.2 ft	2.2 ± 2.3 ft
Vehicle Speed	± 1.0 mph	-0.6 ± 1.1 mph	-0.8 ± 1.0 mph	-0.5 ± 1.1 mph
Axle Spacing Length	± 0.5 ft [150mm]	0.0 ± 0.2 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 reasonable accuracy and the range of errors is consistent at all speeds. There does not appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, 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. Distribution of errors is shown graphically in Figure 5-14.

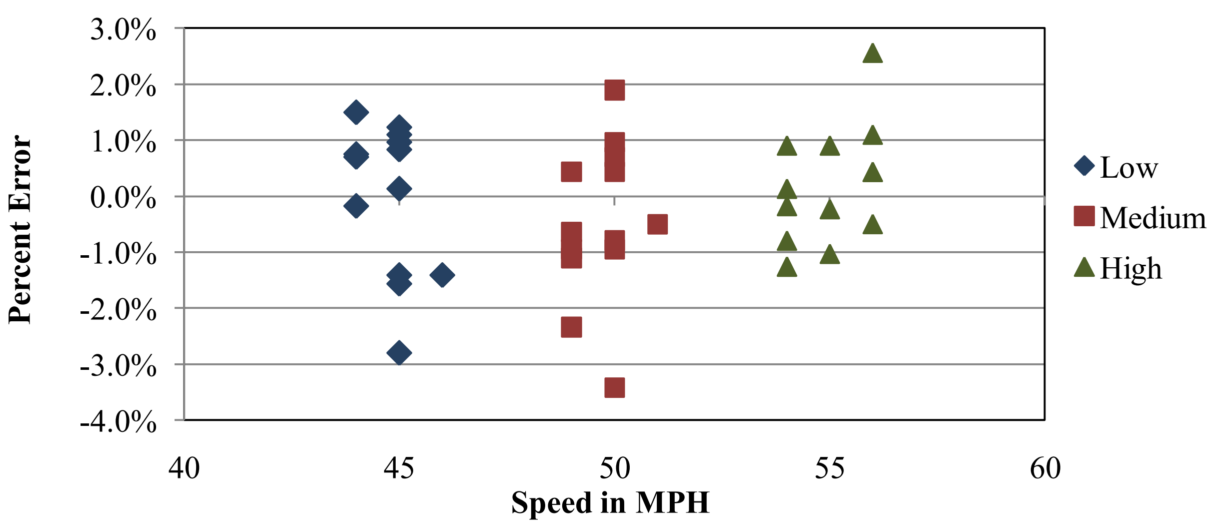


Figure 5-14 – Post-Validation GVW Error by Speed – 25-Aug-10

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-15, the equipment estimated steering axle weights with reasonable accuracy at all speeds. The range in error appears to decrease as speeds increase. Distribution of errors is shown graphically in the figure.

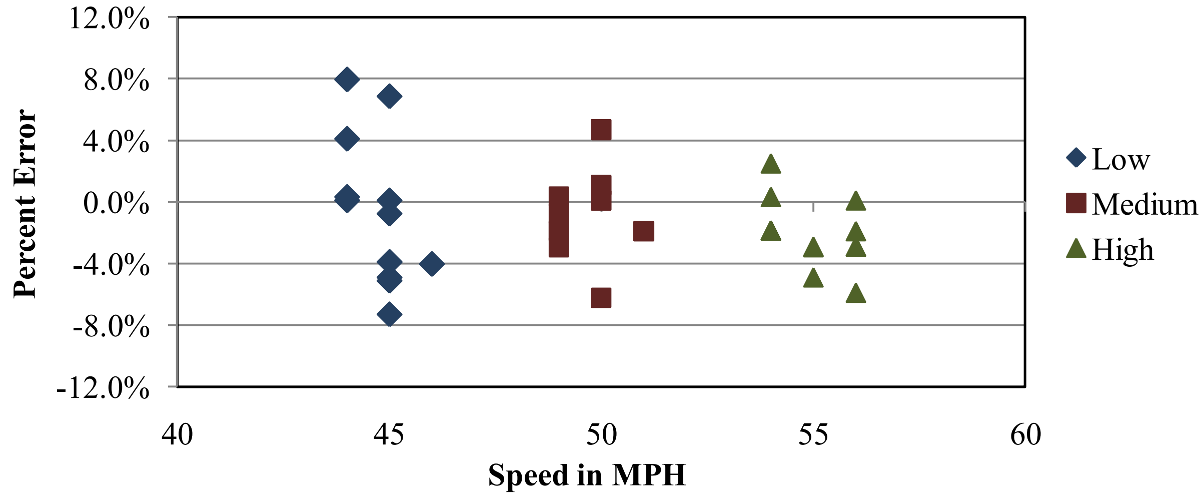


Figure 5-15 – Post-Validation Steering Axle Weight Error by Speed – 25-Aug-10

5.3.1.3 Single Axle Weight Errors by Speed

As shown in Figure 5-16, the equipment estimated single axle weights with reasonable accuracy at all speeds. The range in error appears to decrease as speed increases. Distribution of errors is shown graphically in the figure.

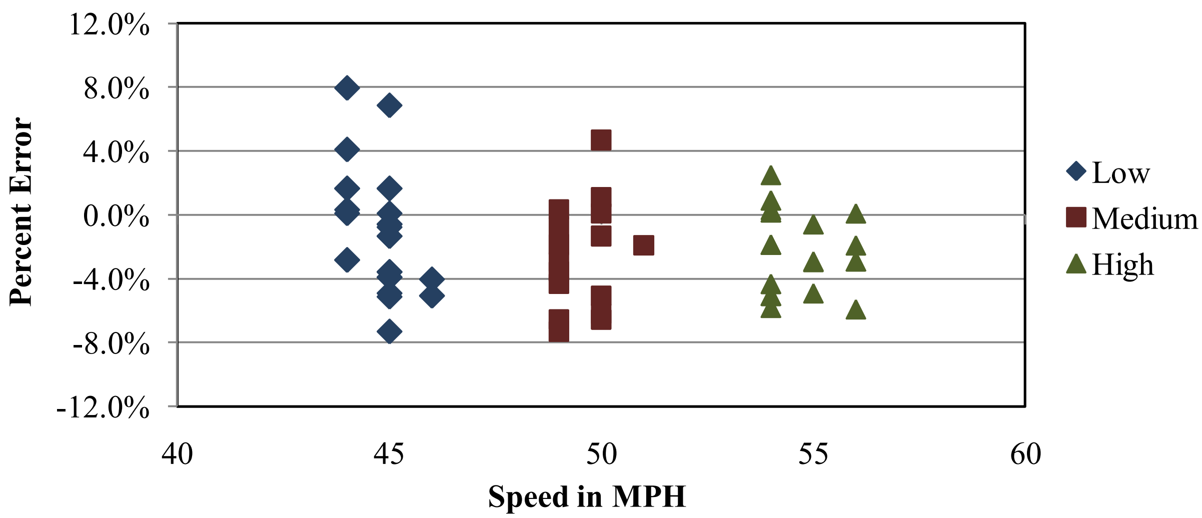


Figure 5-16 – Post-Validation Single Axle Weight Error by Speed – 25-Aug-10

5.3.1.4 Tandem Axle Weight Errors by Speed

As shown in Figure 5-17, the equipment estimates tandem axle weights with reasonable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range. Distribution of errors is shown graphically in the figure.

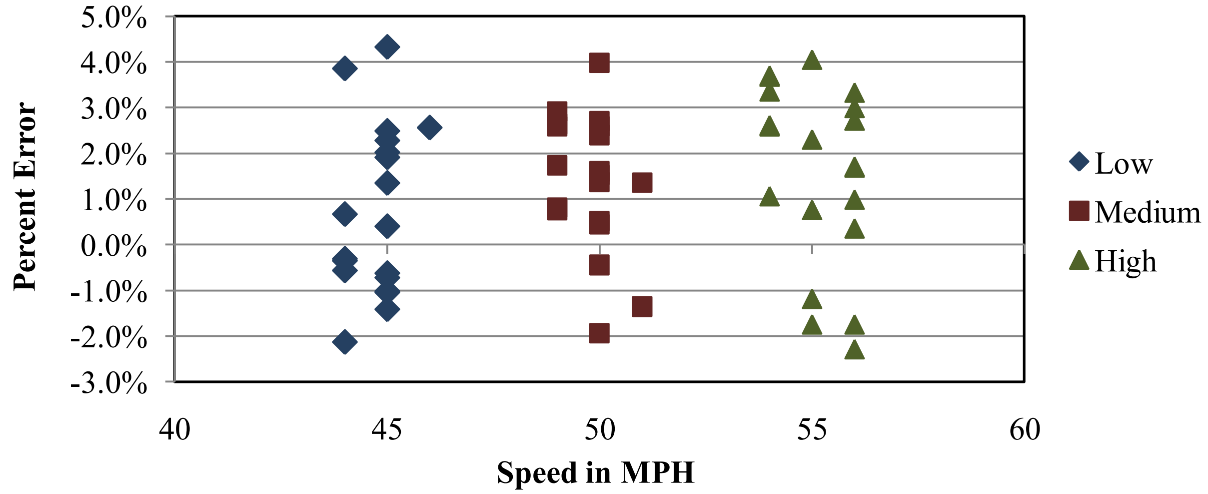


Figure 5-17 – Post-Validation Tandem Axle Weight Error by Speed – 25-Aug-10

5.3.1.5 GVW Errors by Speed and Truck

When the GVW error is analyzed by truck type, it can be seen in Figure 5-18 that the WIM equipment precision and bias is similar for both trucks at the higher speeds. At the low and medium speeds, the equipment overestimates GVW for the Primary truck and underestimates GVW for the Secondary truck.

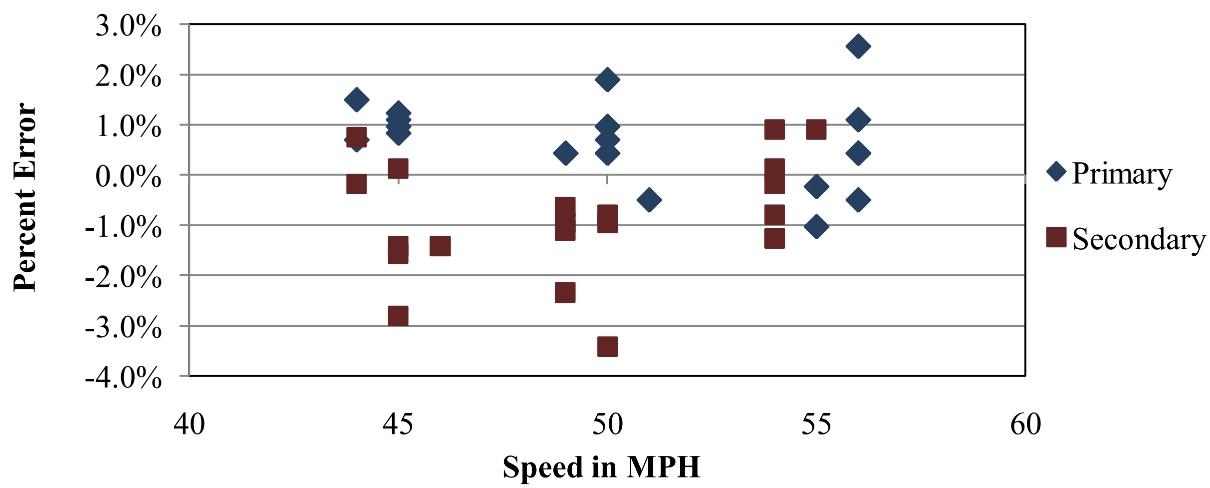


Figure 5-18 – Post-Validation GVW Error by Truck Type and Speed – 25-Aug-10

5.3.1.6 Axle Length Errors by Speed

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

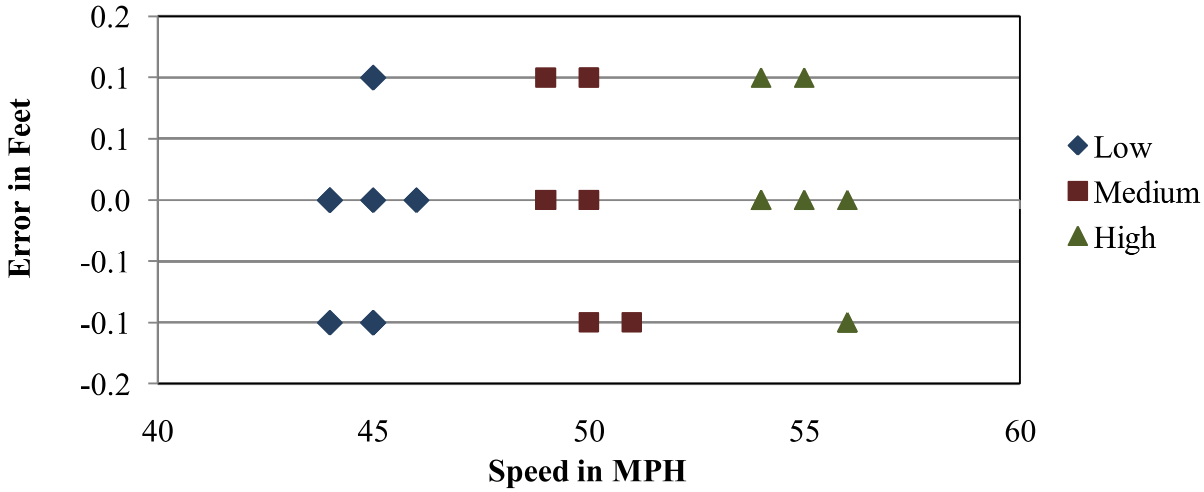


Figure 5-19 – Post-Validation Axle Length Error by Speed – 25-Aug-10

5.3.1.7 Overall Length Errors by Speed

For this system, the WIM equipment overestimates overall length consistently over the entire range of speeds, with errors ranging from 1.0 to 3.2 feet. Distribution of errors is shown graphically in Figure 5-20.

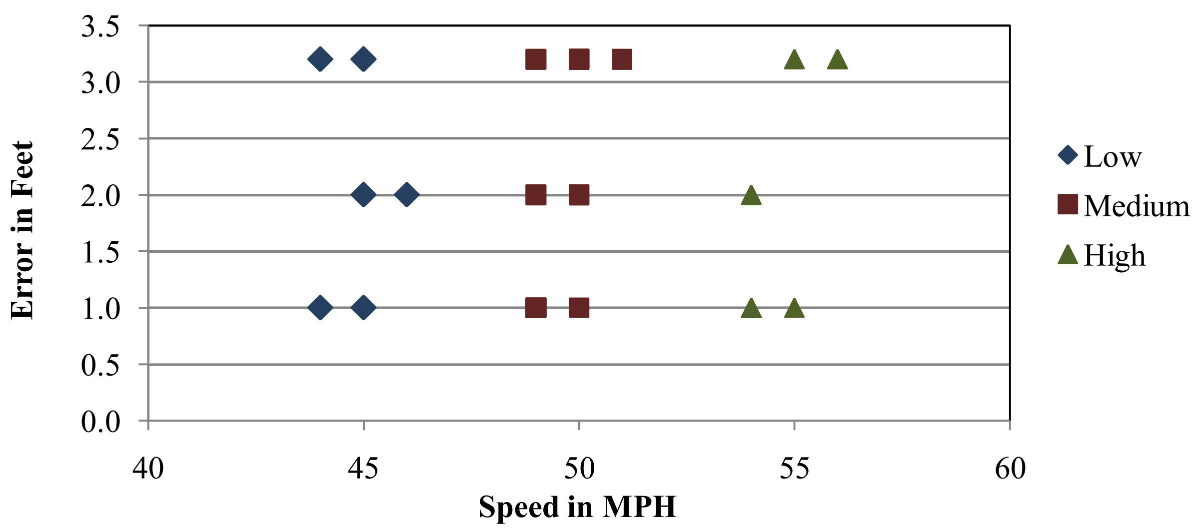


Figure 5-20 – Post-Validation Overall Length Error by Speed – 25-Aug-10

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 33.0 degrees, from 71.1 to 104.1 degrees Fahrenheit. The post-validation test runs are being reported under three temperature groups as shown in Table 5-14 below.

Table 5-14 – Post-Validation Results by Temperature – 25-Aug-10

Parameter	**95% Confidence Limit of Error**	**Low**	**Medium**	**High**
		71.1 to 82.1 degF	**82.2 to 93.2 degF**	**93.3 to 104.1 degF**
Steering Axles	±20 percent	-0.6 ± 8.0%	-0.4 ± 8.8%	-1.9 ± 6.0%
Single Axles	±20 percent	-1.2 ± 8.2%	-0.9 ± 10.2%	-1.9 ± 8.3%
Tandem Axles	±15 percent	0.8 ± 3.8%	1.4 ± 6.5%	1.2 ± 3.5%
GVW	±10 percent	0.0 ± 2.0%	0.2 ± 2.6%	-0.5 ± 3.5%
Vehicle Length	±3 percent (1.8 ft)	2.2 ± 2.3 ft	2.3 ± 2.3 ft	2.3 ± 2.0 ft
Vehicle Speed	± 1.0 mph	-0.4 ± 1.1 mph	-0.6 ± 1.2 mph	-0.9 ± 0.8 mph
Axle Spacing Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.2 ft	0.0 ± 0.2 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 5-21, it can be seen that the equipment appears to estimate GVW with acceptable accuracy across the range of temperatures.

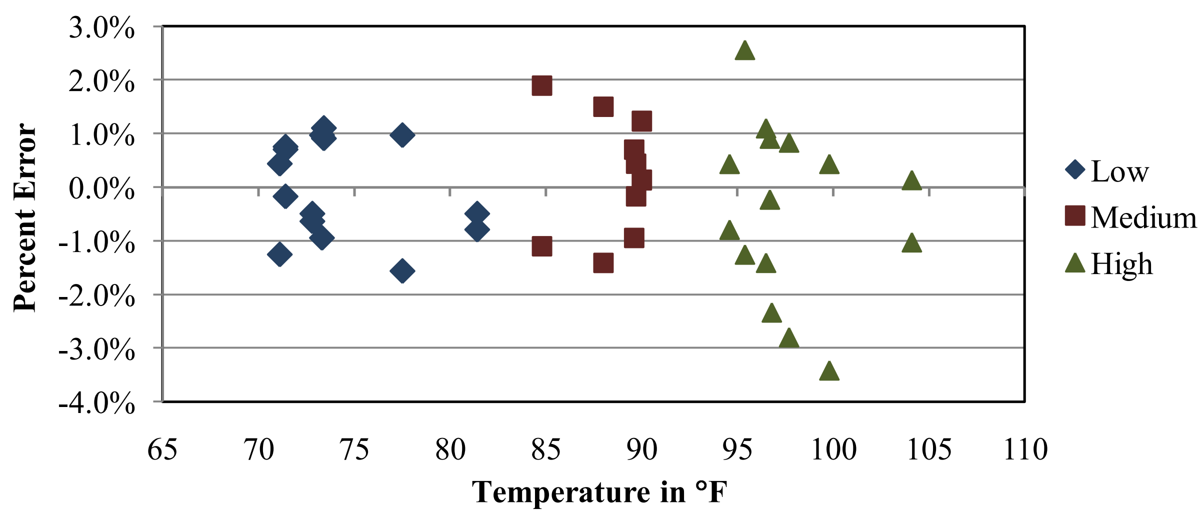


Figure 5-21 – Post-Validation GVW Error by Temperature – 25-Aug-10

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-22 demonstrates that for loaded steering axles, the WIM equipment appears to estimate with acceptable accuracy across the range of temperatures. Distribution of errors is shown graphically in the following figure.

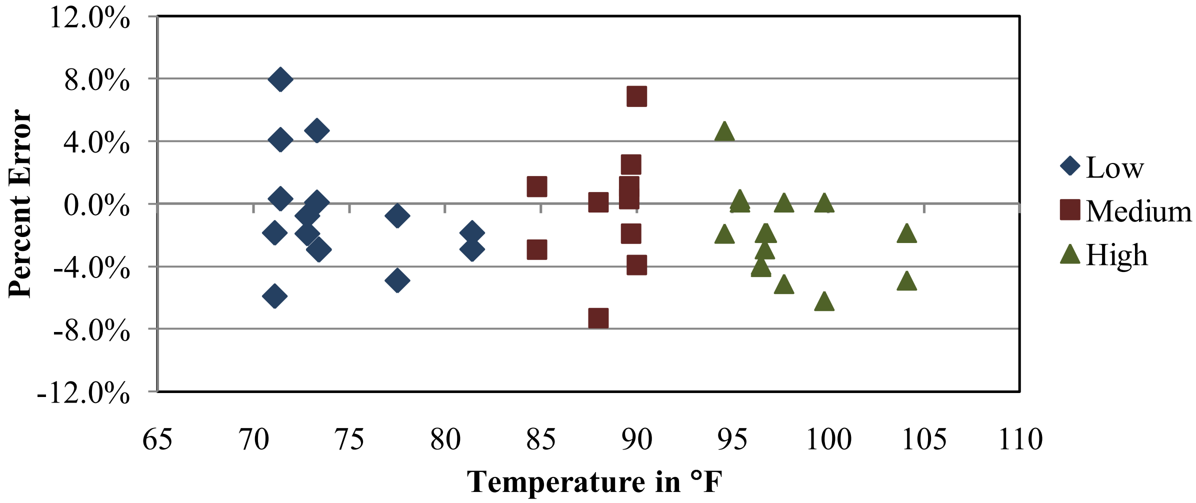


Figure 5-22 – Post-Validation Steering Axle Weight Error by Temperature – 25-Aug-10

5.3.2.3 Single Axle Weight Errors by Temperature

Figure 5-23 demonstrates that the WIM equipment appears to underestimate single axle weight with similar bias across the range of temperatures. The range in error is similar for different temperature groups. Distribution of errors is shown graphically in the following figure.

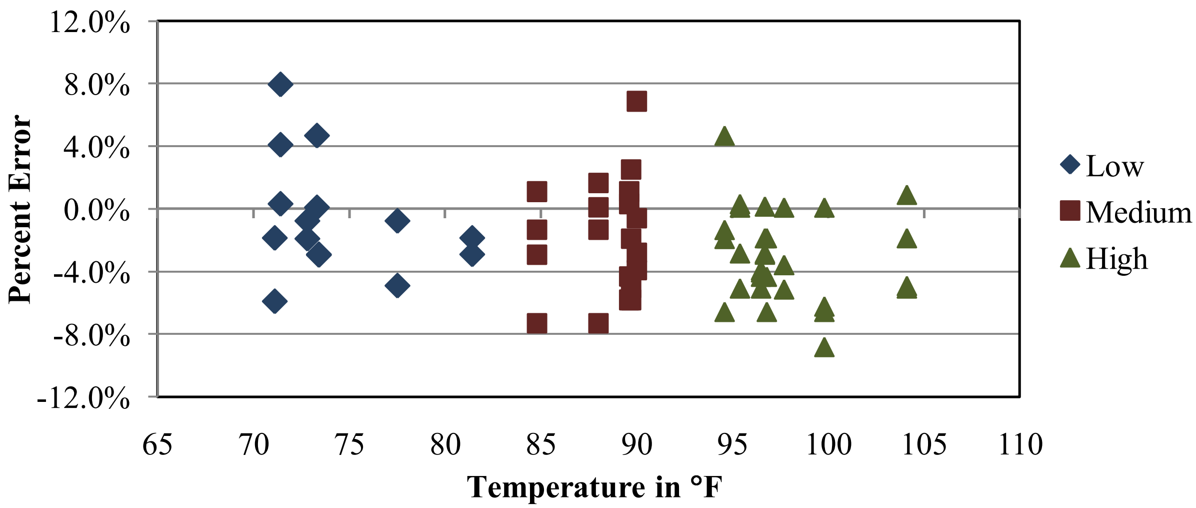


Figure 5-23 – Post-Validation Single Axle Weight Error by Temperature – 25-Aug-10

5.3.2.4 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-24, the equipment appears to overestimate tandem axle weights with similar bias across the range of temperatures. The range in error is similar for different temperature groups. Distribution of errors is shown graphically in the figure.

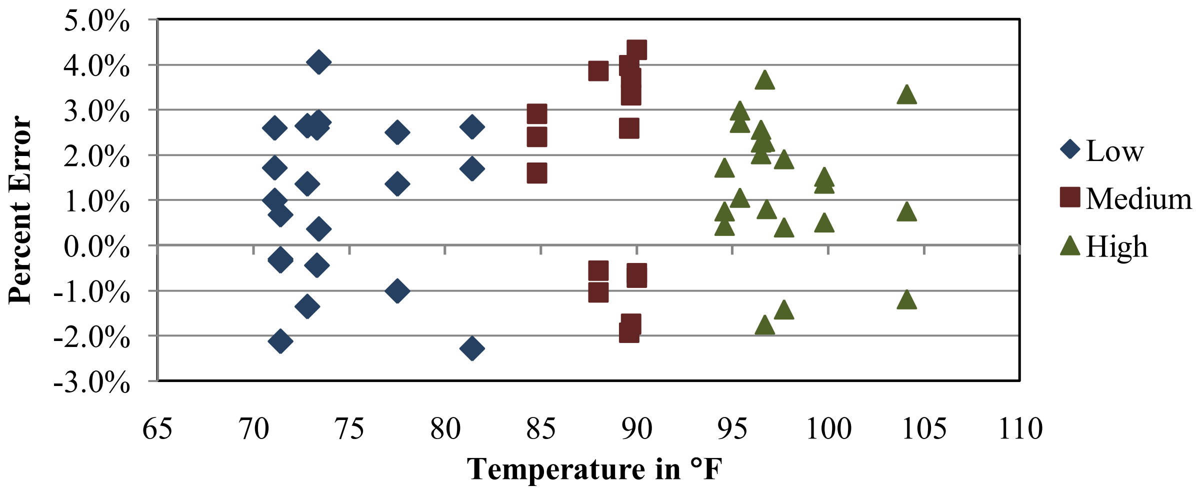


Figure 5-24 – Post-Validation Tandem Axle Weight Error by Temperature – 25-Aug-10

5.3.2.5 GVW Errors by Temperature and Truck

When analyzed for each test truck, GVW measurement errors for both trucks follow similar patterns: GVW for both trucks is estimated accurately at all temperatures. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures. Distribution of errors is shown graphically in Figure 5-25.

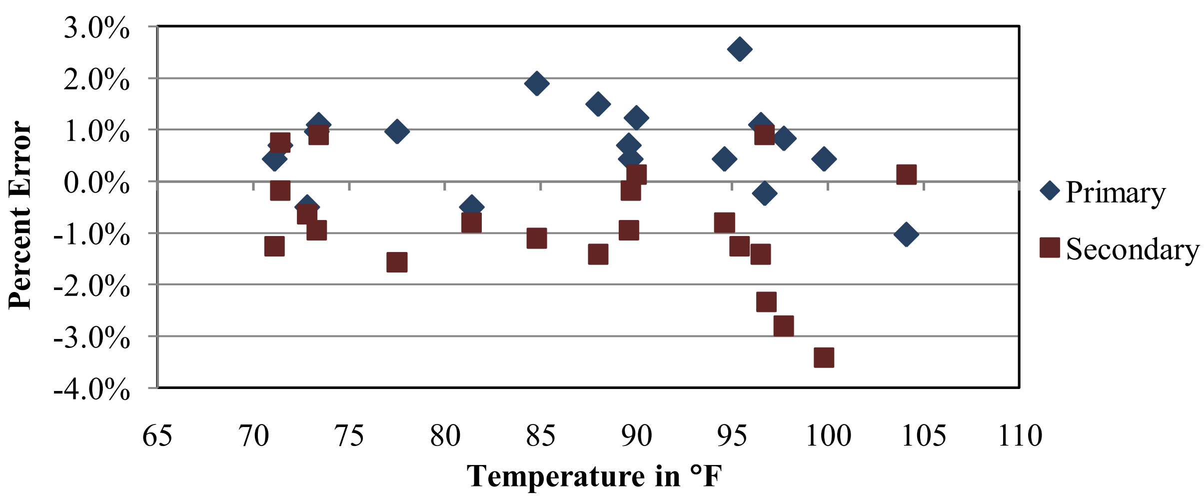


Figure 5-25 – Post-Validation GVW Error by Truck Type and Temperature – 25-Aug-10

5.3.3 Multivariable Analysis

This section provides additional analysis of post-validation results using a multivariable statistical technique of multiple linear regressions. 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.

The interpretation of statistical analysis must distinguish between statistical significance of a relationship and its practical significance. Statistical significance is related to the evidence that a relationship (e.g., between speed and a weight measurement error) does not occur by chance alone. However, it does not automatically mean that relationship has any practical impact or importance. For example, the change in speed form 40 to 55 mph, may, on the average, increase the measurement error by 2 percent, and this relationship may be statistically significant. However, if the allowable error is ±20 percent and all measurement errors are in ±10 percent range, the effect of speed has no practical impact on the results.

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 56 mph.
- Pavement temperature. Pavement temperature ranged from 71.1 to 104.1 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 5-15. The value of regression coefficients defines the slope of the relationship between the % error in GVW and the predictor variables. The values of the t-distribution (for the regression coefficients) given in the table are for the null hypothesis that assumes that the coefficients are equal to zero. The effects of temperature and truck type were not found statistically significant. Based on the table, the probabilities that the effect of truck type on the observed GVW errors occurred by chance alone is about 6 percent.

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

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value
Intercept	4.15	10.03	0.41	0.69
Speed	-0.01	0.06	-0.18	0.86
Temperature	-0.06	0.12	-0.50	0.63
Truck type	1.09	0.50	2.17	0.06

The relationship between truck and measurement errors is shown in Figure 5-26. The figure includes predicted percent errors and a trend line for the predicted error. Besides the visual assessment of the relationship, Figure 5-26 provides quantification and statistical assessment of the relationship.

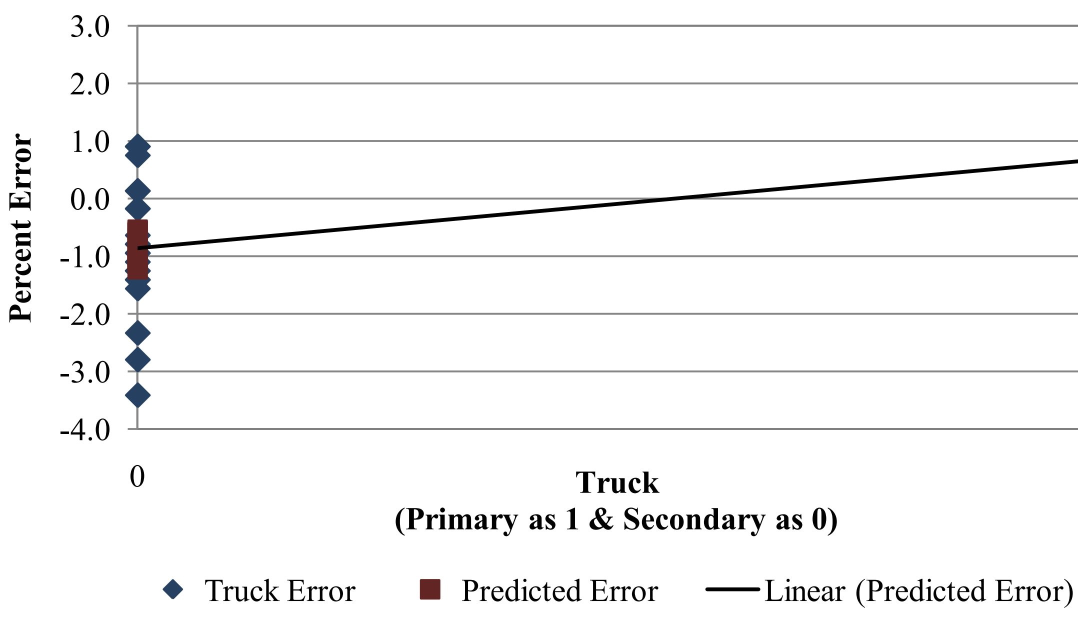


Figure 5-26 – Influence of Truck Type on the Measurement Error of GVW

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.

5.3.3.3 Summary Results

Table 5-16 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Not listed in the table are factor interactions because the interactions were not statistically significant. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 5-16 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-16 – Summary of Regression Analysis

	Factor					
	Speed		Temperature		Truck type	
Weight, % error	Regression coefficient	Probability value	Regression coefficient	Probability value	Regression coefficient	Probability value
GVW	-	-	-	-	1.09	0.058
Steering axle	-	-	-0.78	0.086	-	-
Tandem axle tractor	0.32	0.003	-	-	-	-
Tandem axle trailer	-	-	-	-	-	-

5.3.3.4 Conclusions

1. Speed had statistically significant effect on measurement errors of only tandem axle tractor weights. Based on the regression results, the probability that this could have happened only by chance is less than 1%.

2. Temperature affected measurement error of only steering axle.

3. Truck type affected the GVW weight errors. The regression coefficient for truck type in Table 5-16, represent the difference between the mean errors for the primary and secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). For example, the mean error in GVW for the secondary truck was about 1.1 % larger than the error for the primary truck.

4. Even though speed, temperature and truck type had statistically significant effect on measurement errors, the practical significance of these factors is small and does not affect the validity of the calibration.

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 100 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 5-17 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-17 – Post-Validation Classification Study Results – 25-Aug-10

Class	4	5	6	7	8	9	10	11	12	13
WIM Count	3	27	11	2	7	44	1	0	0	0
Observed Count	1	36	11	3	6	42	1	0	0	0
Obs. Distribution (%)	1%	36%	11%	3%	6%	42%	1%	0%	0%	0%
WIM Distribution (%)	3%	27%	11%	2%	7%	44%	1%	0%	0%	0%
Misclass/Unclass	1	10	0	2	0	0	0	0	0	0
Misclassified (%)	100%	28%	0%	67%	0%	0%	0%	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 overall misclassification rate for all vehicles (3 – 15) is 8.0%. The misclassifications by pair are provided in Table 5-18.

Table 5-18 – Post-Validation Misclassifications by Pair – 25-Aug-10

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

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

As shown in the table, a total of 8 vehicles, including no heavy trucks (6 – 13) were misclassified by the equipment. All of the misclassifications were cross-classifications of Class 3, 4, 5 and 8 vehicles. Two Class 5 vehicles were identified as Class 9 trucks by the equipment.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-19.

Table 5-19 – Post-Validation Unclassified Trucks by Pair – 25-Aug-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	2	13/15	0
8/15	0		

Based on the manually collected sample of the 100 trucks, 2.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites. Both misclassifications were class 7 vehicles. The reason for the unclassification could not be determined in the field.

For speed, the mean error for WIM equipment speed measurement was -1.1 mph; the corresponding range of errors was 1.5 mph.

5.4 Post Visit Applied Calibration

The 85th percentile speed for trucks, based on the CDS data is 60 mph, 5 mph above the posted speed limit of 55 mph and 5 mph above the highest test truck speed. Consequently, applied calibration will be utilized and recommendations for changes to the 55 to 65 mph speed point compensation factors will be made.

The predicted error for GVW is presented in Figure 5-27. This is used to assist in determining applied calibration factors.

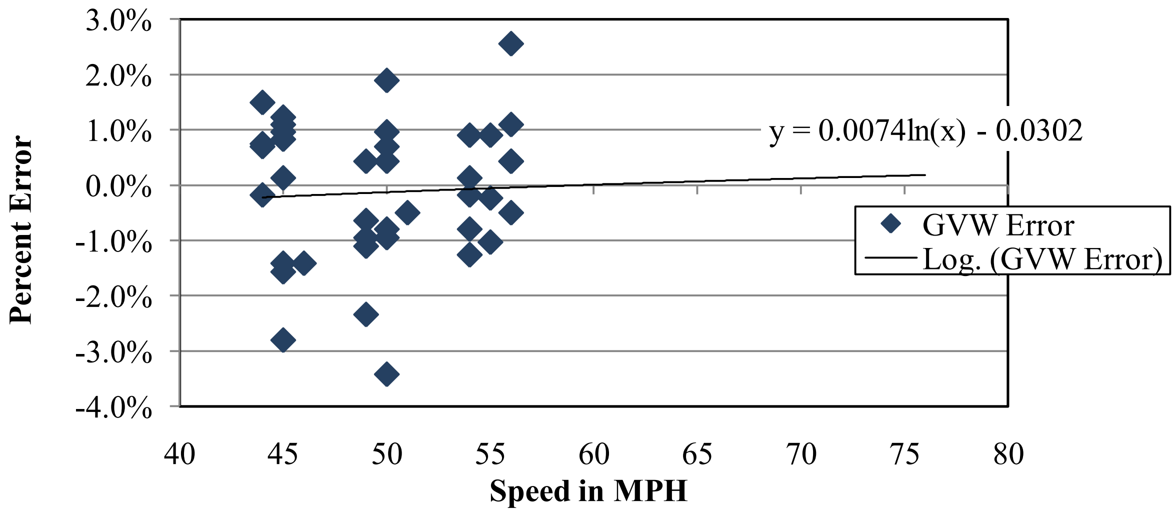


Figure 5-27 – GVW Error Trend

For the applied calibration, post-validation, and post-visit front axle and GVW averages for Class 9 trucks were compared with the most recent Comparison Data Set and the errors were plotted, as shown in Figure 5-28.

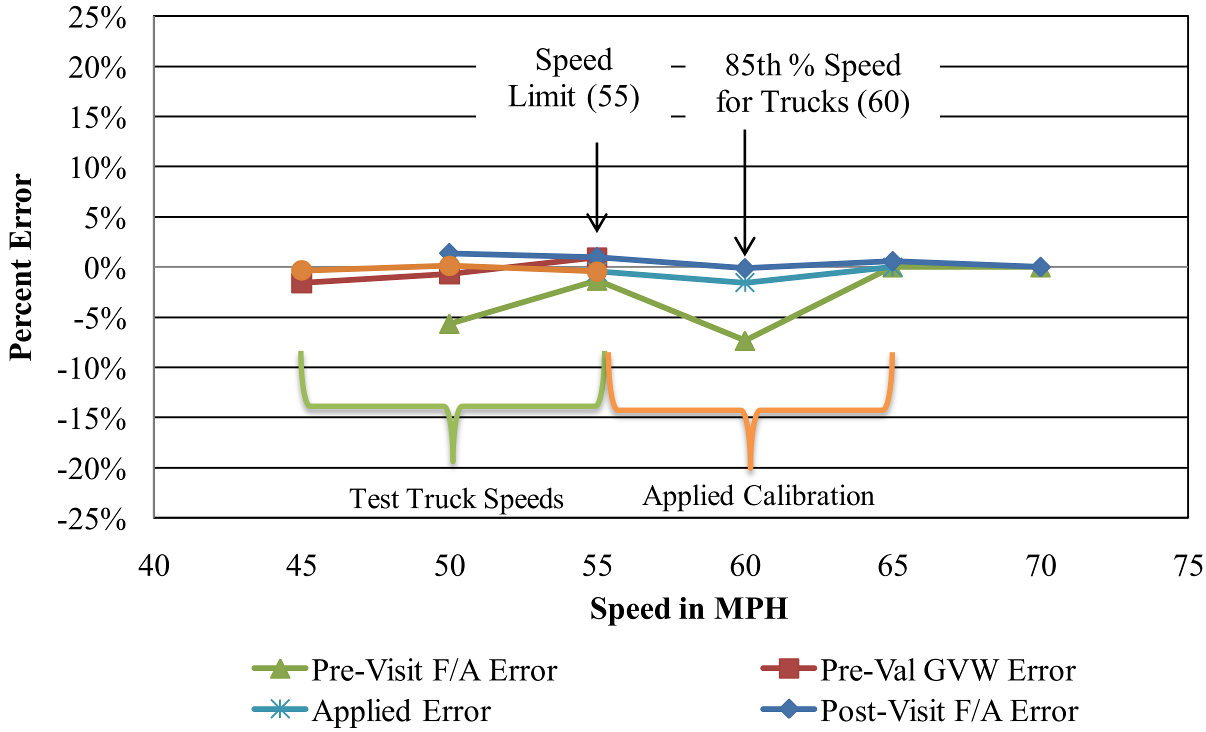


Figure 5-28 – Applied Calibration

Based on these errors and the GVW error trend developed from the post-validation test truck runs and shown in Figure 5-27, applied errors were calculated and are provided in Table 5-20.

Table 5-20 – Recommended Factor Changes from Applied Error

Speed Point	Speed	Old Factors		Applied Error	New Factors	
	mph	Right	Left		Right	Left
88	55	3343	3714	0.2%	3341	3711
96	60	3343	3714	-0.9%	3378	3752
105	65					

The empty boxes in the table above indicate that the truck sample for the 105 speed point was not sufficient and so changes cannot be recommended. Final speed factor settings are provided in Table 5-21.

Table 5-21 – Final Recommended Factor Settings

Speed Point	Speed	Old Factors		Applied Error	New Factors	
		Right	Left		Right	Left
72	45	3318	3688	0.0%	3318	3688
80	50	3354	3727	0.0%	3354	3727
88	55	3343	3714	0.2%	3336	3707
96	60	3343	3714	-0.9%	3373	3748
105	65	3343	3714	0.0%	3343	3714

6 Previous WIM Site Validation Information

As of March 22, 2006, 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 39 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 three previous visits as well as the current one as summarized in the tables below. Table 6-1 data was extracted from the most previous validation and was updated to include the results of this validation.

Table 6-1 – Classification Validation History

Date	Misclassification Percentage by Class										Pct Unclass
	4	5	6	7	8	9	10	11	12	13	
21-Mar-06	100	20	0	N/A	0	0	N/A	N/A	N/A	N/A	0.0
22-Mar-06	100	20	0	N/A	0	0	N/A	N/A	N/A	N/A	0.0
4-Sep-07	N/A	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	0.0
5-Sep-07	N/A	0	0	0	0	0	0	N/A	N/A	N/A	0.0
13-May-08	N/A	7	14	N/A	25	9	N/A	N/A	N/A	N/A	0.0
14-May-08	N/A	0	0	0	0	0	100	N/A	N/A	100	0.0
24-Aug-10	80	5	0	1	0	0	N/A	N/A	N/A	N/A	0.0
25-Aug-10	100	28	0	67	0	0	0	N/A	N/A	N/A	2.0

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

Table 6-2 – Weight Validation History

Date	Mean Error and (SD)		
	GVW	Single Axles	Tandem
21-Mar-06	1.0 (2.6)	1.1 (4.2)	0.9 (2.8)
22-Mar-06	2.8 (3.1)	2.5 (3.7)	2.9 (3.3)
4-Sep-07	0.5 (2.8)	0.3 (4.7)	0.6 (3.4)
5-Sep-07	1.1 (3.4)	0.5 (5.5)	1.3 (4.1)
13-May-08	1.7 (5.1)	1.1 (6.0)	1.8 (5.3)
14-May-08	2.2 (3.4)	1.5 (5.0)	2.3 (3.7)
24-Aug-10	-0.9 (1.5)	-2.8 (3.5)	1.3 (2.2)
25-Aug-10	-0.1 (1.3)	-1.4 (4.0)	1.5 (1.6)

As shown in the table, the WIM equipment has demonstrated a negative drift in GVW of approximately 1.2 percent since the installation. The graph also demonstrates the effectiveness of the validations in bringing the weight estimations back to within LTPP SPS WIM equipment tolerances. From the table, it can be seen that single axle error ranges have remained reasonably consistent since the site was first validated. From this information, it appears that the system demonstrates an ability to maintain accuracy in weight measurement over time.

6.2 Comparison of Past 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			
		22-Mar-06	5-Sep-07	14-May-08	25-Aug-10
Single Axles	±20 percent	2.5 ± 7.5	0.5 ± 11.0	1.5 ± 10.2	-1.4 ± 8.1
Tandem Axles	±15 percent	2.9 ± 6.5	1.3 ± 8.1	2.3 ± 7.3	1.5 ± 3.3
GVW	±10 percent	2.8 ± 6.2	1.1 ± 6.9	2.2 ± 6.9	0.1 ± 2.6

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

7 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 – 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

Maryland, SPS-5
SHRP ID: 240500

Validation Date: August 24, 2010
Submitted: 10/27/2010

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Back)

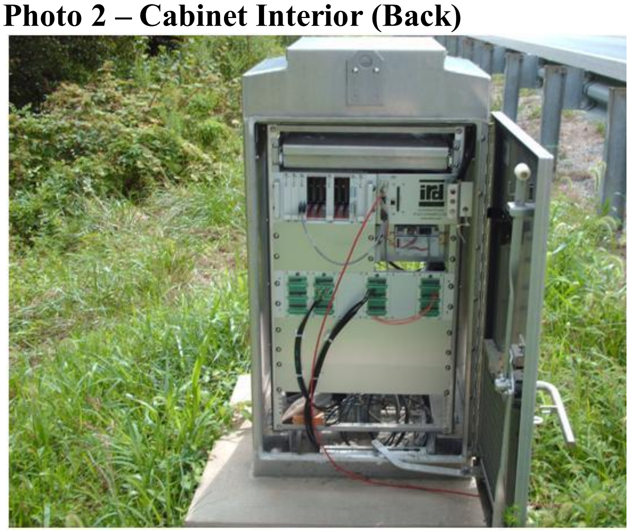


Photo 3 – Cabinet Interior (Front)

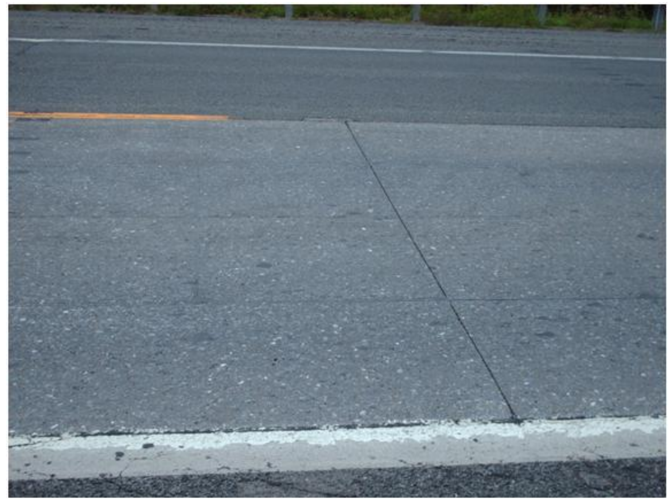


Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Power Service Box

Photo 9 – Telephone Pedestal

Photo 10 – Downstream

Photo 11 – Upstream

Photo 122 – Truck 1

Photo 133 – Truck 1 Tractor

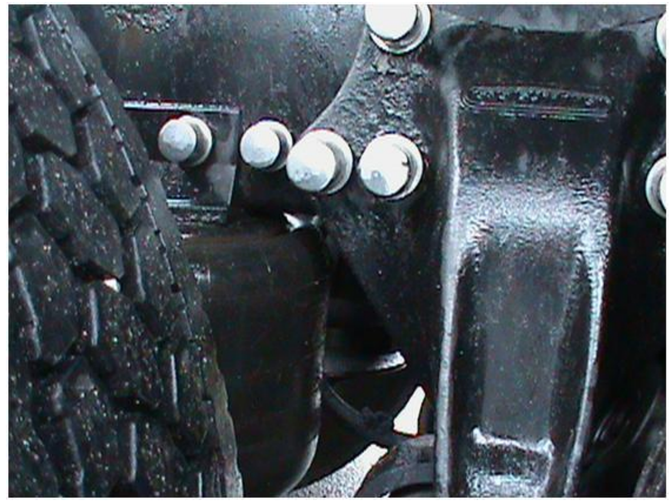


Photo 16 – Truck 1 Suspension 2/3

Photo 144 – Truck 1 Trailer and Load

Photo 17 – Truck 1 Suspension 4

Photo 155 – Truck 1 Suspension 1

Photo 18 – Truck 1 Suspension 5

Photo 19 – Truck 2

Photo 172– Truck 2 Suspension 1

Photo 20 – Truck 2 Tractor

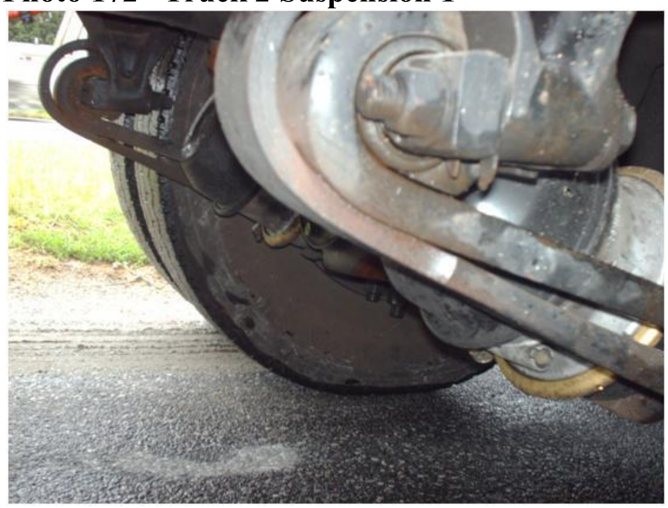


Photo 23 – Truck 2 Suspension 2/3

Photo 161 – Truck 2 Trailer and Load

Photo 24 – Truck 2 Suspension 4

Photo 25 – Truck 2 Suspension 5

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/24/2010

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 8/24/10

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. Bending Plates
   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: 20

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

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

Mean Difference Between -

Dynamic and Static GVW:	-0.9%	Standard Deviation:	1.5%
Dynamic and Static Single Axle:	-2.8%	Standard Deviation:	3.5%
Dynamic and Static Double Axles:	1.3%	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	-	44.0	to	48.0	12
b.	Medium	-	48.1	to	52.1	16
c.	High	-	52.2	to	56.0	12
d.	0	-		to		
e.	0	-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/24/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3348 | 3719

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:

____

13. METHOD TO DETERMINE LENGTH OF COUNT: ______________________

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: 1.0%

Validation Test Truck Run Set - Pre

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: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/25/2010

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 8/25/10

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. Bending Plates 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	air
Truck 2:	9	air	air
Truck 3:	0	0	0

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

Mean Difference Between -

Dynamic and Static GVW:	-0.1%	Standard Deviation:	1.3%
Dynamic and Static Single Axle:	-1.4%	Standard Deviation:	4.0%
Dynamic and Static Double Axles:	1.5%	Standard Deviation:	1.6%

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

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

			Low		High	Runs
a.	Low	-	44.0	to	48.0	13
b.	Medium	-	48.1	to	52.1	13
c.	High	-	52.2	to	56.0	14
d.	0	-		to		
e.	0	-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/25/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3336 | 3706

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: ____________

13. METHOD TO DETERMINE LENGTH OF COUNT: ____________

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	5.0	FHWA Class	____	-	____
FHWA Class 8:	17.0	FHWA Class	____	-	____
		FHWA Class	____	-	____
		FHWA Class	____	-	____

Percent of "Unclassified" Vehicles: 2.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean J. Wolf**
Contact Information: Phone: 717-975-3550
E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/24/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
55	9	41569	52	9	55	9	41801	55	9
61	9	41575	63	9	54	6	41814	54	6
62	9	41580	64	9	53	4	41815	53	4
55	9	41589	54	9	51	5	41816	52	5
47	3	41603	48	5	54	5	41848	53	5
50	9	41613	50	9	45	3	41853	51	5
52	8	41637	50	8	56	5	41857	58	5
62	5	41651	65	5	56	9	41878	55	9
55	8	41662	55	8	58	9	41885	58	9
61	5	41684	62	5	59	5	41888	60	5
44	9	41690	45	9	54	9	41902	55	9
57	9	41692	58	9	57	5	41920	58	5
57	9	41693	59	9	52	5	41926	54	5
58	5	41702	58	3	58	9	41930	59	9
57	5	41709	58	5	62	6	41944	64	6
52	5	41714	54	5	60	15	41954	62	7
64	5	41720	67	5	47	9	41967	48	9
50	5	41726	51	5	55	9	41999	56	9
54	9	41741	52	9	55	5	42029	57	5
52	5	41749	53	5	56	5	42030	57	5
47	9	41756	48	9	53	8	42041	54	8
50	9	41759	51	9	53	5	42042	49	5
49	5	41776	50	5	55	9	42043	55	9
59	9	41780	61	9	52	9	42047	53	9
58	5	41790	59	5	55	5	42091	54	5

Sheet 1 - 0 to 50   Start: 8:45:00   Stop: ____________

Recorded By: djw   Verified By: kt

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/24/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
57	9	42100	59	9	50	9	42542	51	9
60	9	42117	62	9	53	9	42706	54	9
57	9	42118	60	9	53	9	42716	55	9
54	5	42157	55	5	57	9	42717	58	9
49	9	42211	51	9	54	5	42753	56	5
54	5	42228	53	5	46	5	42754	48	5
59	5	42245	60	5	58	9	42765	59	9
51	9	42277	52	9	54	9	42771	55	9
52	5	42278	52	5	56	5	42773	52	5
60	9	42316	62	9	54	9	42795	54	9
59	5	42336	57	5	51	9	42815	50	9
55	5	42343	55	5	55	5	42831	55	5
49	5	42348	50	5	50	8	42850	52	8
50	6	42354	52	6	57	5	42876	59	5
50	8	42355	51	8	61	9	42883	62	9
47	5	42369	47	4	50	9	42890	56	9
47	5	42376	47	4	50	5	42934	52	5
55	9	42389	54	9	54	9	42944	54	9
54	9	42418	55	9	52	9	42969	54	9
53	5	42419	52	5	57	5	43005	59	5
50	5	42502	53	5	50	5	43006	50	4
51	5	42503	56	5	48	9	43023	49	9
50	6	42511	49	6	55	5	43030	57	5
51	5	42514	52	5	54	5	43031	55	5
50	5	42523	51	5	61	5	43052	62	4

Sheet 2 - 51 to 100 Start: ________ Stop: ________

Recorded By: djw Verified By: kt

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/25/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
49	5	57297	50	5	49	8	57740	50	8
41	5	57304	43	5	50	5	57746	51	5
55	8	57310	57	8	49	9	57747	49	9
49	8	57327	50	8	49	9	57751	49	9
57	5	57347	57	5	51	5	57757	52	5
53	9	57400	54	9	58	9	57761	59	9
58	5	57499	55	5	57	7	57816	59	5
53	9	57521	54	9	56	9	57817	59	9
50	5	57523	51	5	51	9	57831	52	9
54	9	57524	54	9	55	9	57837	57	9
58	9	57529	58	9	54	9	57847	55	9
49	9	57547	50	9	51	4	57848	52	5
53	3	57589	53	5	45	9	57877	46	9
55	8	57601	55	8	51	5	57886	53	5
50	6	57614	51	6	47	9	57887	48	9
60	8	57622	62	8	53	6	57888	54	6
54	9	57634	55	9	53	6	57889	54	6
56	9	57643	57	9	50	9	57907	52	9
54	10	57647	54	10	53	5	57929	58	5
56	9	57692	57	9	58	7	57940	49	7
49	5	57695	49	5	50	9	58401	49	9
54	9	57700	56	9	57	9	58403	59	9
53	5	57701	56	5	57	9	58404	58	9
56	9	57727	58	9	59	9	58408	58	5
58	8	57737	59	8	51	9	58420	52	9

Sheet 1 - 0 to 50 Start: 8:45:00 Stop: ________

Recorded By: djw Verified By: kt

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 24 SPS WIM ID: 240500 DATE (mm/dd/yyyy) 8/25/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
55	5	58429	57	5	52	5	58604	53	5
50	9	58430	52	9	51	5	58618	54	5
49	5	58432	50	5	60	9	58629	61	9
55	5	58438	56	5	51	5	58672	53	5
45	6	58447	47	6	51	5	58676	52	5
53	6	58457	54	6	57	9	58678	59	9
54	9	58460	56	9	45	9	58688	51	9
55	9	58461	58	9	55	3	58708	57	5
55	5	58468	56	5	54	9	58716	54	9
54	4	58471	55	5	57	6	58718	59	6
52	9	58531	53	9	52	6	58720	53	6
54	9	58545	55	9	60	5	58745	61	5
55	9	58550	56	9	55	8	58841	56	5
53	9	58551	55	9	60	5	58856	62	5
58	5	58553	59	5	58	15	58859	59	7
57	9	58573	58	9	52	6	58871	53	6
55	9	58576	55	9	52	6	58872	53	6
57	9	58579	57	9	51	9	58875	51	9
55	9	58580	56	5	57	9	58876	58	9
59	15	58582	60	7	50	6	58886	51	6
56	6	58586	60	6	53	4	58892	54	5
46	9	58587	48	9	48	5	58899	49	5
50	5	58595	51	5	48	9	58900	49	9
55	5	58602	56	4	57	5	58918	57	5
58	5	58603	58	5	56	3	58920	59	5

Sheet 2 - 51 to 100 Start: ____________ Stop: ____________

Recorded By: djw Verified By: kt