WIM System Field Calibration and Validation Summary Report

Colorado SPS-2
SHRP ID – 080200

Validation Date: July 23, 2013
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1 Executive Summary

A WIM validation was performed on July 23, 2013 at the Colorado SPS-2 site located on route I-76, milepost 39.7, .75 miles east of Market Street interchange.

This site was installed on April 27, 2006. The in-road sensors are installed in the eastbound, righthand driving lane. The site is equipped with bending plate WIM sensors and an 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 February 21, 2012 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 the WIM components determined that the the equipment is operating within the manufacturer's tolerances. None of the in-road sensors show signs of damage or excessive wear and appear to be fully secured in the pavement. Further equipment discussion is provided in Section 3.

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

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

Table 1-1 – Validation Results – 23-Jul-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.2 ± 6.3%	Pass
Tandem Axles	±15 percent	0.0 ± 4.3%	Pass
GVW	±10 percent	0.9 ± 3.2%	Pass
Vehicle Length	±3.0 percent (1.7 ft)	0.7 ± 0.8 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was 0.3 ± 2.9 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 1.1% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 2.0% from the 100 vehicle sample (Class 4 – 13) was due to the misclassification of one Class 5 and one Class 6 vehicle.

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

- The Primary truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with gravel.

- The Secondary truck was a Class 9 vehicle with air suspension on the tractor tandem, air suspension on the trailer tandem, standard tandem spacing on the tractor and trailer. The Secondary truck was loaded with gravel.

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 8). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Axle spacings were measured from the center hub of the each axle to the center hub of the subsequent axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average validation test truck weights and measurements are provided in Table 1-2.

Table 1-2 – Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	76.6	9.7	16.6	16.6	16.8	16.8	17.8	4.3	24.8	3.9	50.8	55.5
2	64.8	9.9	15.2	15.2	12.2	12.2	17.8	4.3	24.6	4.0	50.7	55.5

The posted speed limit at the site is 75 mph. During the testing, the speed of the test trucks ranged from to 61 to 73 mph, a variance of 12 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The validation pavement surface temperatures varied from 89.0 to 114.4 degrees Fahrenheit, a range of 25.4 degrees Fahrenheit. The partly cloudy weather conditions prevented the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 27 shows that there are 6 years of level “E” WIM data for this site. This site requires no additional years of data to meet the minimum of five years of research quality data.

2 WIM System Data Availability and Pre-Visit Data Analysis

To assess the quality of the current traffic data, a pre-visit analysis was conducted by comparing a two-week data sample from June 3, 2013 (Data) to the most recent Comparison Data Set (CDS) from March 18, 2011. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 27 shows that there are 6 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2006 to 2012.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2006	194	8
2007	351	12
2008	363	12
2009	365	12
2010	365	12
2011	350	12
2012	253	9

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

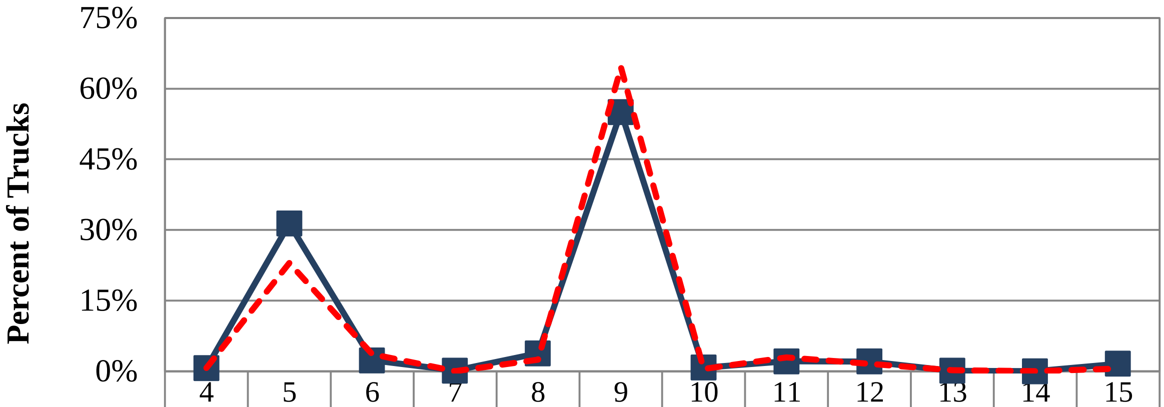
Table 2-2 provides a monthly breakdown of the available data for years 2006 through 2012.

Table 2-2 – LTPP Data Availability by Month

Year	Month												No. of Months
	1	2	3	4	5	6	7	8	9	10	11	12	
2006				3	31	30	30	10		29	30	31	8
2007	31	28	31	30	31	30	31	31	30	31	30	17	12
2008	31	29	29	30	31	30	31	30	30	31	30	31	12
2009	31	28	31	30	31	30	31	31	30	31	30	31	12
2010	31	28	31	30	31	30	31	31	30	31	30	31	12
2011	31	28	26	27	31	23	31	31	30	31	30	31	12
2012	31	29	31	30	31	30	31	31	9				9

2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site. Figure 2-1 provides a comparison of the truck type distributions between the sample dataset from June 3, 2013 (Data) and the most recent comparison Data Set (CDS) from March 18, 2011.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	0.7%	31.4%	2.3%	0.1%	3.8%	55.0%	0.8%	2.1%	2.1%	0.1%	0.0%	1.6%
CDS	0.7%	23.0%	3.6%	0.0%	2.5%	64.5%	0.5%	2.9%	1.6%	0.2%	0.0%	0.6%

Truck Classifications

Figure 2-1 – Comparison of Truck Distribution

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the two most frequent truck types crossing the WIM scale are Class 9 (55.0%) and Class 5 (31.4%) vehicles.

Table 2-3 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles. The table indicates that 1.6 percent of the vehicles at this site are unclassified.

Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	3/18/2011		6/3/2013		
4	129	0.7%	369	0.7%	0.0%
5	4201	23.0%	16675	31.4%	8.4%
6	659	3.6%	1228	2.3%	-1.3%
7	4	0.0%	67	0.1%	0.1%
8	452	2.5%	2026	3.8%	1.3%
9	11797	64.5%	29248	55.0%	-9.4%
10	92	0.5%	418	0.8%	0.3%
11	534	2.9%	1117	2.1%	-0.8%
12	293	1.6%	1111	2.1%	0.5%
13	36	0.2%	48	0.1%	-0.1%
14	0	0.0%	0	0.0%	0.0%
15	101	0.6%	844	1.6%	1.0%

From the table it can be seen that the percentage of Class 9 vehicles has decreased by 9.4 percent from March 2011 and June 2013, largely due to increase in Class 5 vehicle volume. Changes in the percentage of heavier trucks may also be attributed to natural and seasonal variations in truck distributions. During the same time period, the percentage of Class 5 trucks increased by 8.4 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, increase in local business activity, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

2.3 Speed Data Analysis

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

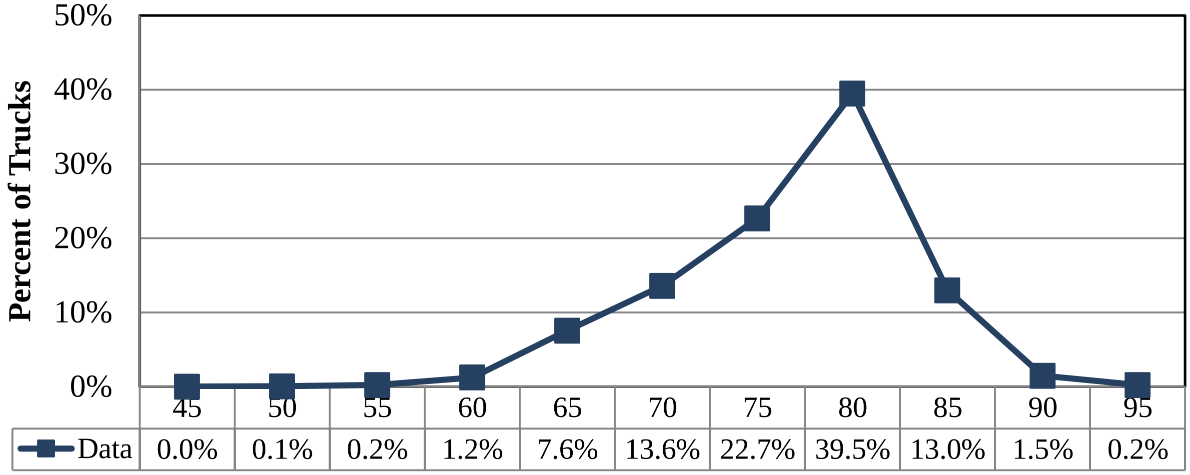


Figure 2-2 – Truck Speed Distribution – 1-Jul-13

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 70 and 85 mph. The posted speed limit at this site is 75 and the 85th percentile speed for trucks at this site is 80 mph. Based on this information, the expected range of speeds for the test trucks will be 65 to 75 mph.

2.4 GVW Data Analysis

The traffic CDS data received from the Regional Support Contractor was analyzed to determine the expected Class 9 GVW distributions. Figure 2-3 shows a comparison between GVW plots generated using a two-week W-card sample from June 2013 and the Comparison Data Set from March 2011.

As shown in Figure 2-3, the unloaded and loaded peaks for the March 2011 Comparison Data Set (CDS) and the June 2013 two-week sample W-card dataset (Data) are similar.

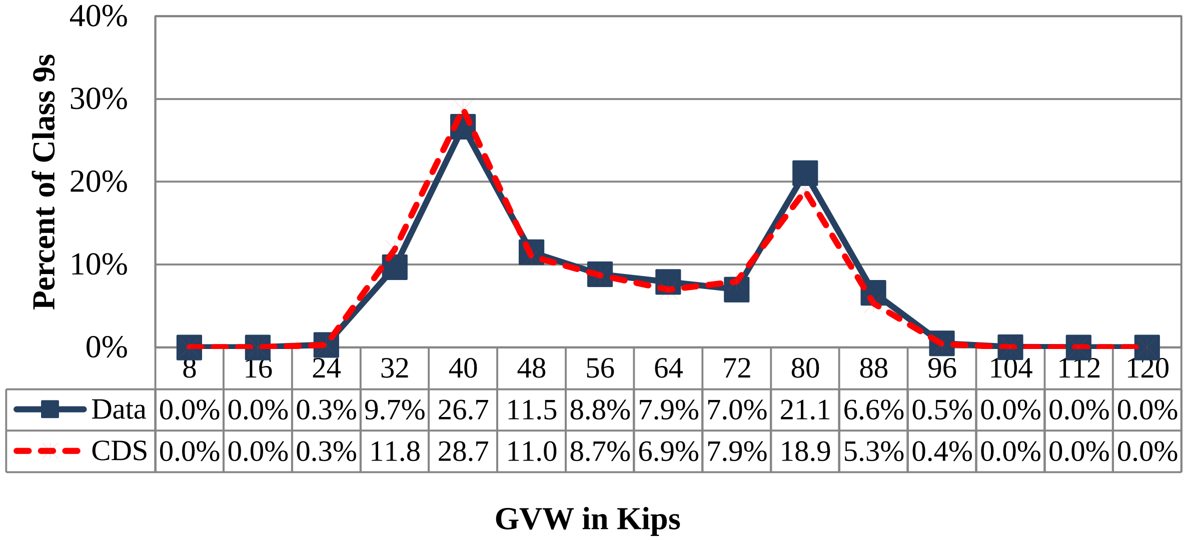


Figure 2-3 – Comparison of Class 9 GVW Distribution

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

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

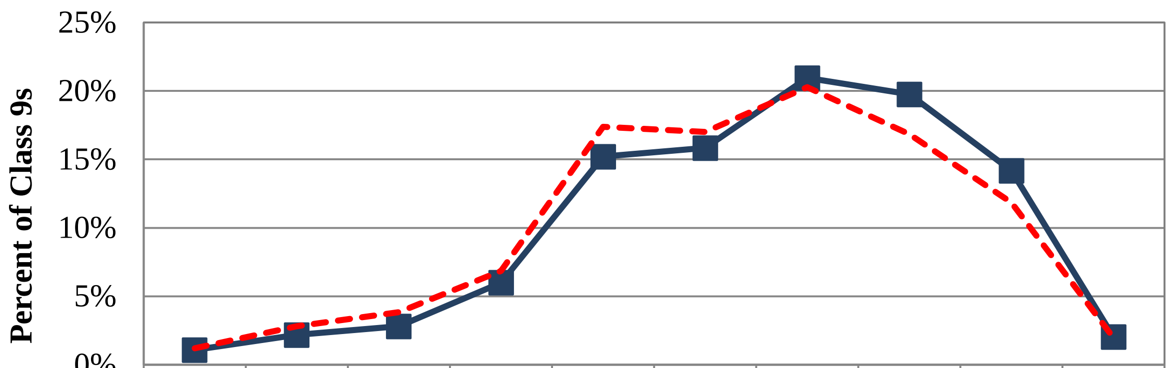
GVW weight bins (kips)	CDS		Data		Change
	Date				
	3/18/2011		6/3/2013		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	32	0.3%	88	0.3%	0.0%
32	1390	11.8%	2811	9.7%	-2.1%
40	3383	28.7%	7744	26.7%	-2.1%
48	1294	11.0%	3338	11.5%	0.5%
56	1024	8.7%	2564	8.8%	0.1%
64	817	6.9%	2294	7.9%	1.0%
72	933	7.9%	2033	7.0%	-0.9%
80	2225	18.9%	6119	21.1%	2.2%
88	624	5.3%	1918	6.6%	1.3%
96	44	0.4%	137	0.5%	0.1%
104	1	0.0%	10	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	51.8 kips		53.6 kips		1.8 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 2.1 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range increased by 2.2 percent. During this time period the percentage of overweight trucks increased by 1.4 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 3.4 percent, from 51.8 to 53.6 kips.

2.5 Class 9 Front Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from June 2013 and the Comparison Data Set from March 2011. The percentage of light axles (10.5 to 11.5 kips) decreased by approximately 3.4% and the percentage of heavy axles (12.0 to 13.0 kips) increased by approximately 5.2%, indicating possible positive bias (overestimation of loads) in front axle measurement.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	1.1%	2.2%	2.8%	6.0%	15.2%	15.8%	20.9%	19.8%	14.2%	2.0%
CDS	1.2%	2.8%	3.8%	6.9%	17.4%	17.0%	20.3%	16.8%	11.9%	2.0%

Steering Axle Weight in Kips

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

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 11.5 and 12.5 kips. The percentage of trucks in this range has increased between the March 2011 Comparison Data Set (CDS) and the June 2013 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the March 2011 Comparison Data Set (CDS) and the June 2013 dataset (Data).

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

F/A weight bins (kips)	CDS		Data		Change
	Date				
	3/18/2011		6/3/2013		
9.0	141	1.2%	310	1.1%	-0.1%
9.5	328	2.8%	623	2.2%	-0.6%
10.0	448	3.8%	804	2.8%	-1.0%
10.5	801	6.9%	1722	6.0%	-0.9%
11.0	2031	17.4%	4368	15.2%	-2.2%
11.5	1986	17.0%	4549	15.8%	-1.2%
12.0	2368	20.3%	6017	20.9%	0.7%
12.5	1968	16.8%	5673	19.8%	2.9%
13.0	1385	11.9%	4070	14.2%	2.3%
13.5	229	2.0%	585	2.0%	0.1%
Average =	11.5 kips		11.6 kips		0.1 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.1 kips, or 0.9 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.6 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

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

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

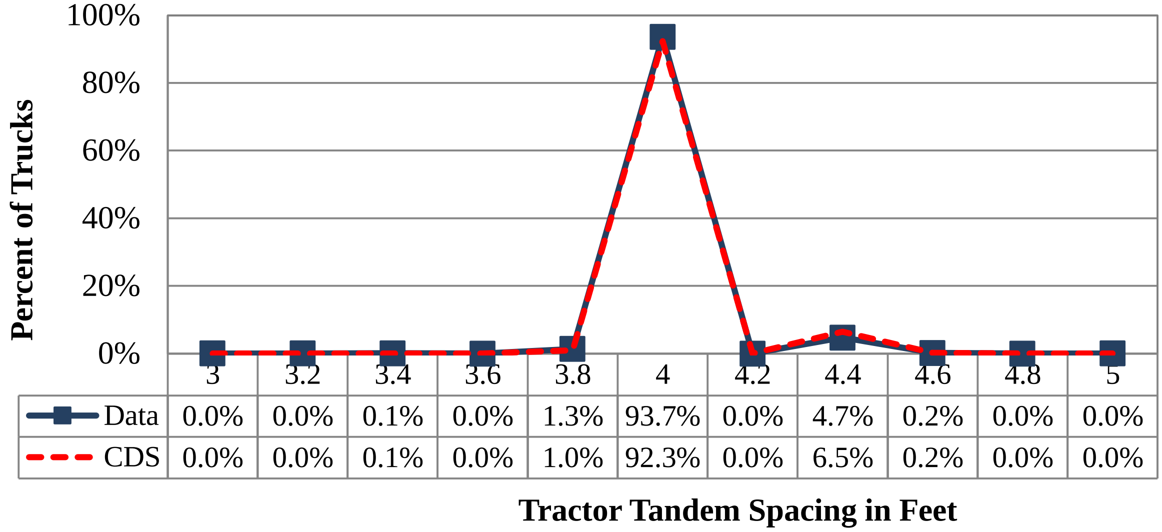


Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacings for the March 2011 Comparison Data Set and the June 2013 Data are nearly identical.

Table 2-6 shows the Class 9 axle spacings between the second and third axles.   .

Table 2-6 – Class 9 Axle 2 to 3 Spacing from W-Card

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	3/18/2011		6/3/2013		
3.0	0	0.0%	2	0.0%	0.0%
3.2	0	0.0%	2	0.0%	0.0%
3.4	6	0.1%	20	0.1%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	112	1.0%	392	1.3%	0.4%
4.0	10866	92.3%	27212	93.7%	1.3%
4.2	0	0.0%	0	0.0%	0.0%
4.4	759	6.5%	1376	4.7%	-1.7%
4.6	24	0.2%	47	0.2%	0.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	0	0.0%	5	0.0%	0.0%
Average =	4.0 feet		4.0 feet		0.0 feet

From the table it can be seen that the drive tandem spacing of Class 9 trucks at this site is between 3.8 and 4.4 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.0 feet, which is identical to the expected average of 4.0 feet from the CDS per vehicle records. Further axle spacing analyses are performed during the validation and validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (March 2011) based on the last calibration with the most recent two-week WIM data sample from the site (June 2013). Comparison of vehicle class distribution data indicates a 9.4 percent decrease in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 0.9 percent and average Class 9 GVW has increased 3.4 percent for the June 2013 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical to the expected average of 4.0 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on February 21, 2012 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 April 27, 2006 by International Road Dynamics. It is instrumented with bending plate weighing sensors and an IRD iSINC WIM Controller. As the installation contractor, IRD also performs routine equipment maintenance and data quality checks of the WIM data.

3.2 Physical Inspection

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented in Section 8.

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 unscheduled equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, there were no pavement distresses noted that may affect the accuracies of the WIM system.

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 4 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)	0.914	0.949	0.967			0.943
		SRI (m/km)	1.258	1.149	1.595			1.334
		Peak LRI (m/km)	1.186	1.122	1.240			1.183
		Peak SRI (m/km)	**1.395**	**1.216**	**1.785**			**1.465**
	RWP	LRI (m/km)	0.764	0.685	0.729			0.726
		SRI (m/km)	1.237	0.948	1.068			1.084
		Peak LRI (m/km)	0.775	0.787	0.734			0.765
		Peak SRI (m/km)	1.355	1.102	1.103			1.187
Center	LWP	LRI (m/km)	0.825	0.849	0.866	0.786		0.832
		SRI (m/km)	0.712	1.167	1.102	1.042		1.006
		Peak LRI (m/km)	1.068	1.120	0.995	1.140		1.081
		Peak SRI (m/km)	0.979	1.292	1.160	1.065		1.124
	RWP	LRI (m/km)	0.757	0.732	0.734	0.697		0.730
		SRI (m/km)	1.018	0.963	1.096	0.867		0.986
		Peak LRI (m/km)	0.877	0.928	0.873	0.742		0.855
		Peak SRI (m/km)	1.161	1.176	1.218	0.912		1.117
Right	LWP	LRI (m/km)	0.799	0.700	0.818			0.772
		SRI (m/km)	0.844	0.836	0.898			0.859
		Peak LRI (m/km)	0.997	0.828	0.992			0.939
		Peak SRI (m/km)	0.942	0.851	0.961			0.918
	RWP	LRI (m/km)	0.728	0.717	0.826			0.757
		SRI (m/km)	0.824	0.885	0.831			0.847
		Peak LRI (m/km)	0.801	0.820	1.020			0.880
		Peak SRI (m/km)	0.825	0.960	0.853			0.879

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

4.3 Profile and Vehicle Interaction

Profile data was collected on November 5, 2012 by the Western Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, beginning 900 feet prior to WIM scales and ending 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 10 profile passes were made, 4 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 1000 foot WIM section is 127 in/mi and is located approximately 469 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 129 in/mi and is located approximately 393 feet prior to the WIM scale. These areas of the pavement were closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed at these locations that would influence truck dynamics in the WIM scale area.

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

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

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

5.3 Validation

The 40 validation test truck runs were conducted on July 23, 2013, beginning at approximately 8:20 AM and continuing until 4:43 PM.

The two test trucks consisted of:

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

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

Table 5-1 - Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	76.6	9.7	16.6	16.6	16.8	16.8	17.8	4.3	24.8	3.9	50.8	55.5
2	64.8	9.9	15.2	15.2	12.2	12.2	17.8	4.3	24.6	4.0	50.7	55.5

Test truck speeds varied by 12 mph, from 61 to 73 mph. The measured validation pavement temperatures varied 25.4 degrees Fahrenheit, from 89.0 to 114.4. The partly cloudy weather conditions prevented the desired 30 degree temperature range. Table 5-2 is a summary of post validation results.

Table 5-2 – Validation Overall Results – 23-Jul-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.2 ± 6.3%	Pass
Tandem Axles	±15 percent	0.0 ± 4.3%	Pass
GVW	±10 percent	0.9 ± 3.2%	Pass
Vehicle Length	±3.0 percent (1.7 ft)	0.7 ± 0.8 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was 0.3 ± 2.9 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within similar acceptable ranges.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 75 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3.

Table 5-3 – Validation Results by Speed – 23-Jul-13

Parameter	**95% Confidence Limit of Error**	**Low**	**Medium**	**High**
		61.0 to 65.0 mph	**65.1 to 69.1 mph**	**69.2 to 73.0 mph**
Steering Axles	±20 percent	2.0 ± 6.8%	1.5 ± 6.1%	-0.2 ± 7.2%
Tandem Axles	±15 percent	0.9 ± 4.1%	0.8 ± 3.9%	0.8 ± 4.8%
GVW	±10 percent	1.2 ± 3.7%	0.9 ± 3.0%	0.6 ± 3.6%
Vehicle Length	±3.0 percent (1.7 ft)	0.6 ± 0.8 ft	0.6 ± 0.8 ft	0.9 ± 1.1 ft
Vehicle Speed	± 1.0 mph	0.0 ± 1.8 mph	0.4 ± 4.8 mph	0.4 ± 1.5 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.1 ft

From the table, it can be seen that the WIM equipment estimates all weights with similar accuracy at all speeds, except for front axles where minor dependency of measurement accuracy on speed is observed (about 2 percent over speed range tested).

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

5.3.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment estimated GVW with similar accuracy at all speeds. The range in error and bias is similar for each of the speed groups.

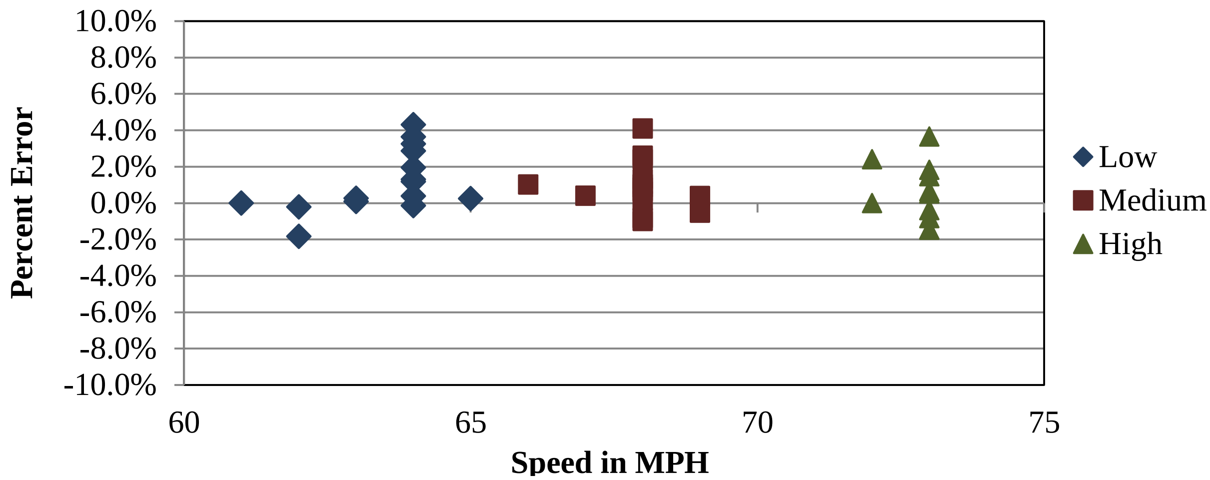


Figure 5-1 – Validation GVW Errors by Speed – 23-Jul-13

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment estimated steering axle weights with similar accuracy at low and medium speeds and slightly underestimated at high speeds. The range in error is similar throughout the entire speed range.

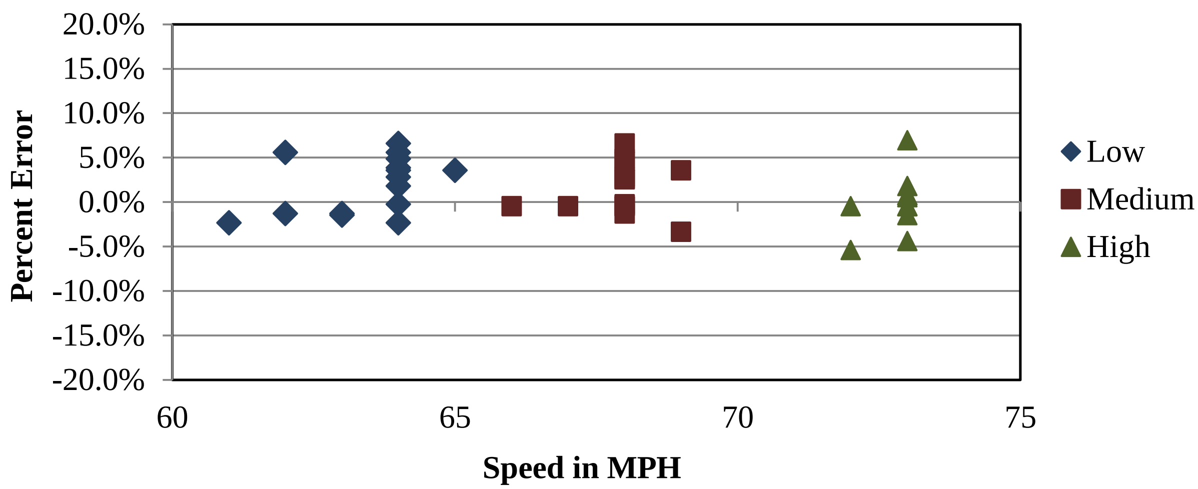


Figure 5-2 – Validation Steering Axle Weight Errors by Speed – 23-Jul-13

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment estimated tandem axle weights with similar accuracy at all speeds. The range in error and bias is similar for each of the speed groups.

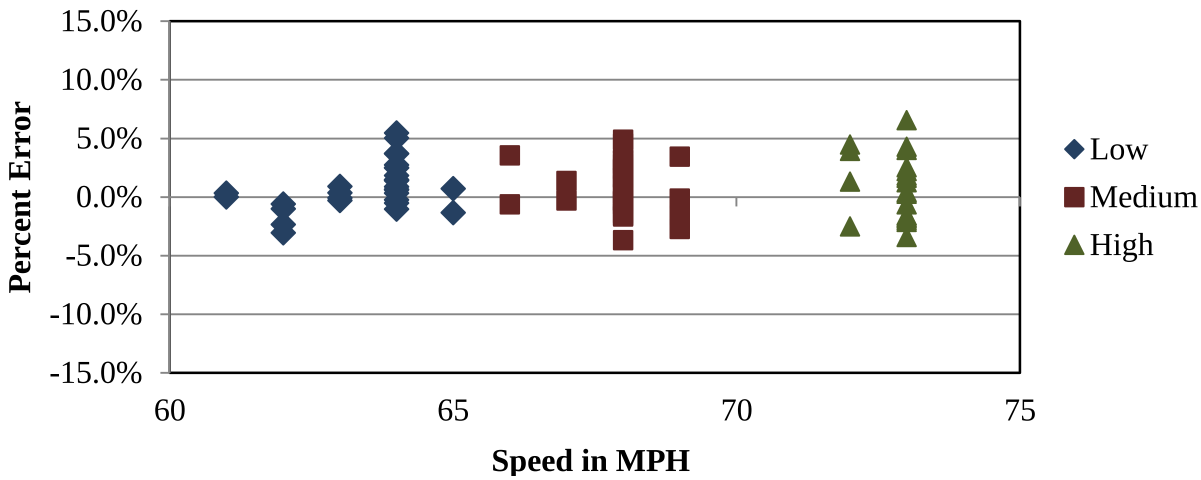


Figure 5-3 – Validation Tandem Axle Weight Errors by Speed – 23-Jul-13

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-4 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck.

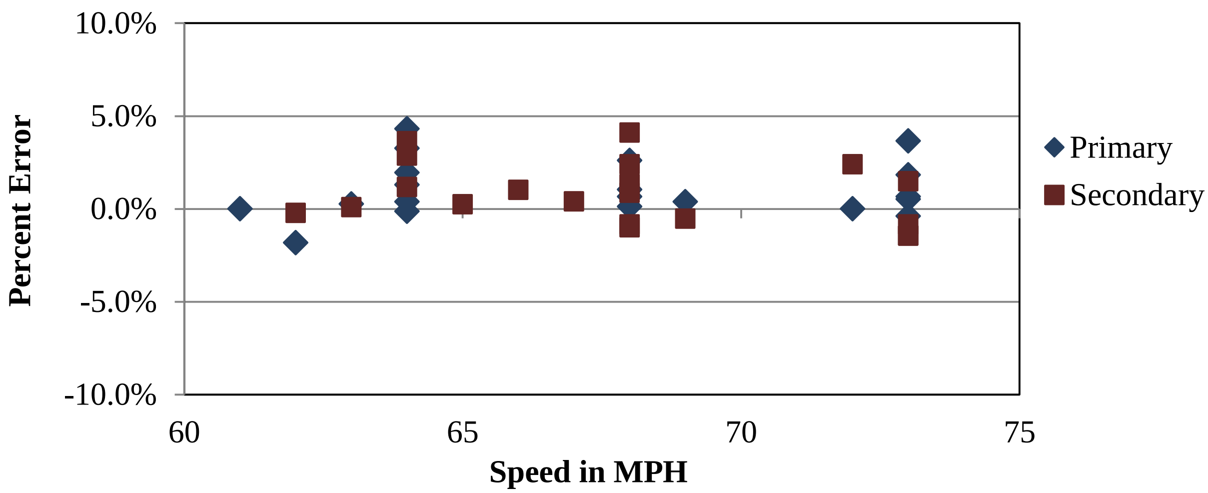


Figure 5-4 – Validation GVW Error by Truck and Speed – 23-Jul-13

5.3.1.5 Axle Length Errors by Speed

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

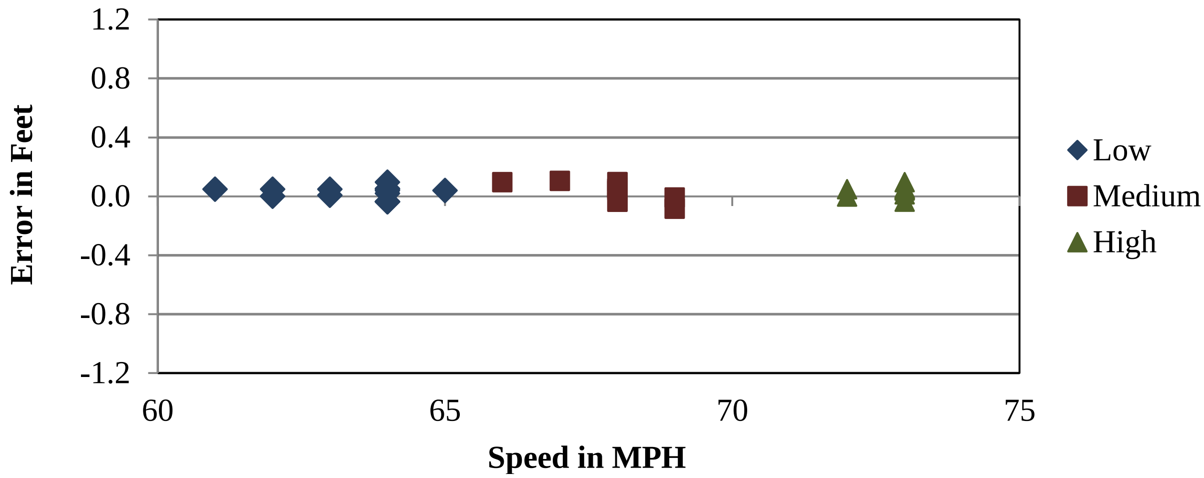


Figure 5-5 – Validation Axle Length Error by Speed – 23-Jul-13

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length consistently over the entire range of speeds, with errors ranging from 0.5 to 1.5 feet. Distribution of errors is shown graphically in Figure 5-6.

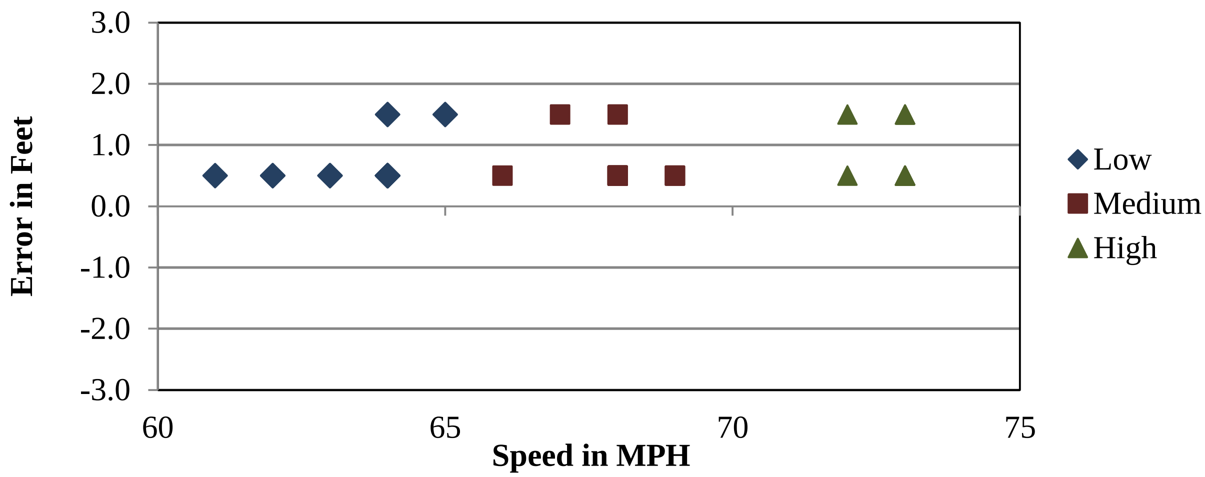


Figure 5-6 – Validation Overall Length Error by Speed – 23-Jul-13

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 25.4 degrees, from 89.0 to 114.4 degrees Fahrenheit. The Validation test runs are being reported under three temperature groups – low, medium and high, as shown in Table 5-4 below.

Table 5-4 – Validation Results by Temperature – 23-Jul-13

Parameter	**95% Confidence Limit of Error**	**Low**	**Medium**	**High**
		89.0 to 100 degF	**100.1 to 110.0 degF**	**110.1 to 114.4 degF**
Steering Axles	±20 percent	3.7 ± 5.5%	-0.2 ± 7.0%	0.5 ± 4.7%
Tandem Axles	±15 percent	2.1 ± 4.8%	0.2 ± 4.0%	0.4 ± 4.2%
GVW	±10 percent	2.3 ± 3.1%	0.2 ± 2.4%	0.4 ± 2.8%
Vehicle Length	±3.0 percent (1.7 ft)	0.6 ± 0.6 ft	0.8 ± 1.0 ft	0.7 ± 0.9 ft
Vehicle Speed	± 1.0 mph	0.3 ± 1.7 mph	0.6 ± 5.0 mph	-0.1 ± 0.6 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.1 ft

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

5.3.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment appears to overestimate GVW at the lower temperatures and estimate with similar accuracy at the medium and high temperatures. There does appear to be a correlation between temperature and weight estimates at this site.

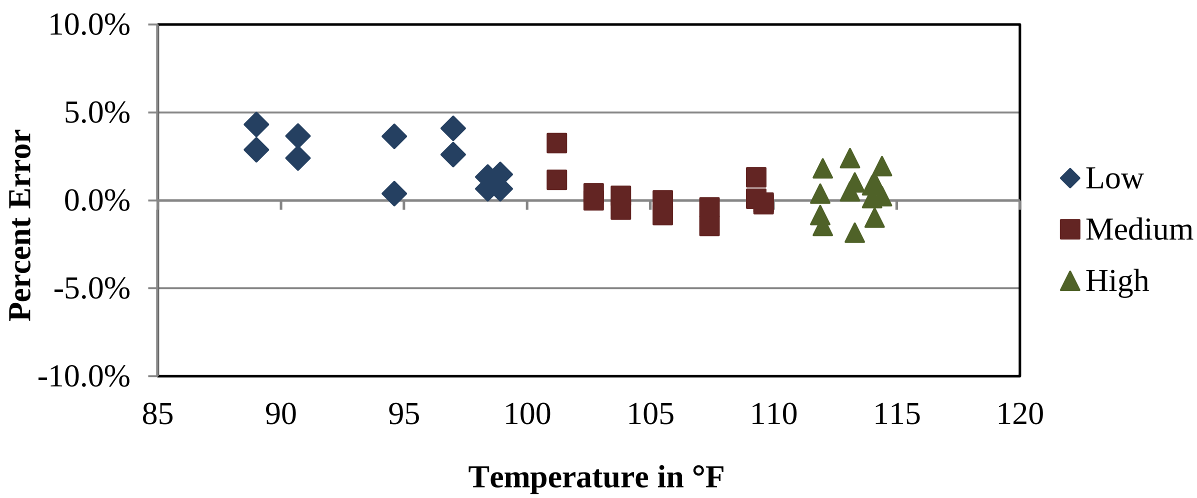


Figure 5-7 – Validation GVW Errors by Temperature – 23-Jul-13

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 demonstrates that for steering axles, the WIM equipment appears to overestimate weights at the low temperatures and estimate with similar accuracy at the medium and high temperatures. There does appear to be a correlation between temperature and steering axle weight estimates at this site. The range in error is similar for different temperature groups.

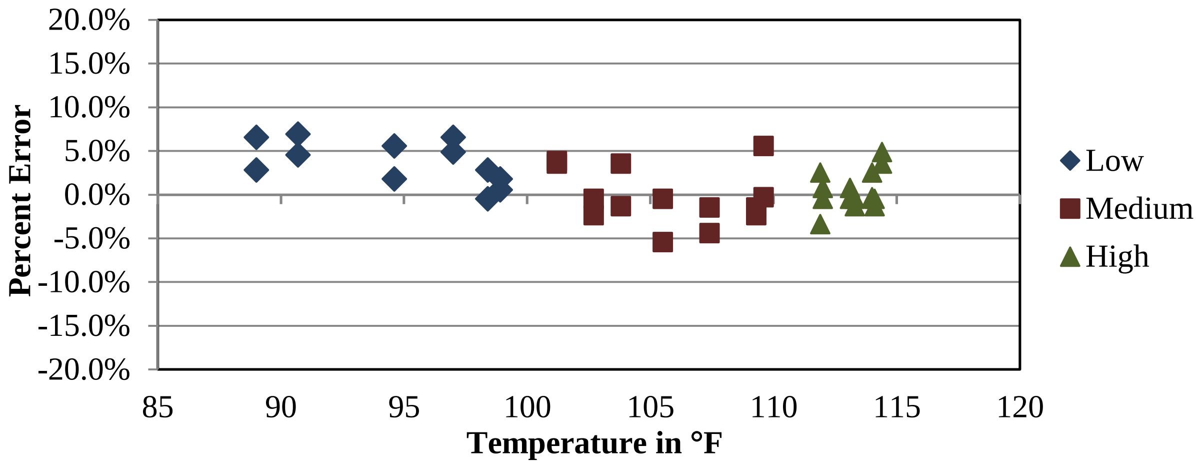


Figure 5-8 – Validation Steering Axle Weight Errors by Temperature – 23-Jul-13

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. There does appear to be a slight correlation between temperature and tandem axle weight estimates at this site. The range in tandem axle errors is consistent for the three temperature groups.

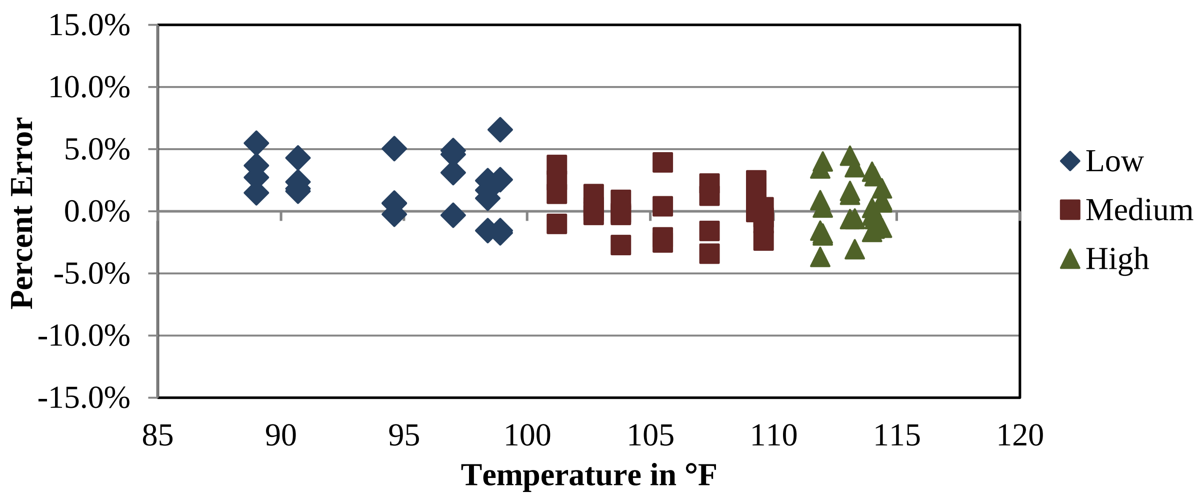


Figure 5-9 – Validation Tandem Axle Weight Errors by Temperature – 23-Jul-13

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-10, when analyzed by truck type, GVW measurement errors for both trucks are similar: the WIM equipment appears to overestimate weights at the low temperatures and estimate with similar accuracy at the medium and high temperatures. For both trucks, the range of errors is similar over the range of temperatures.

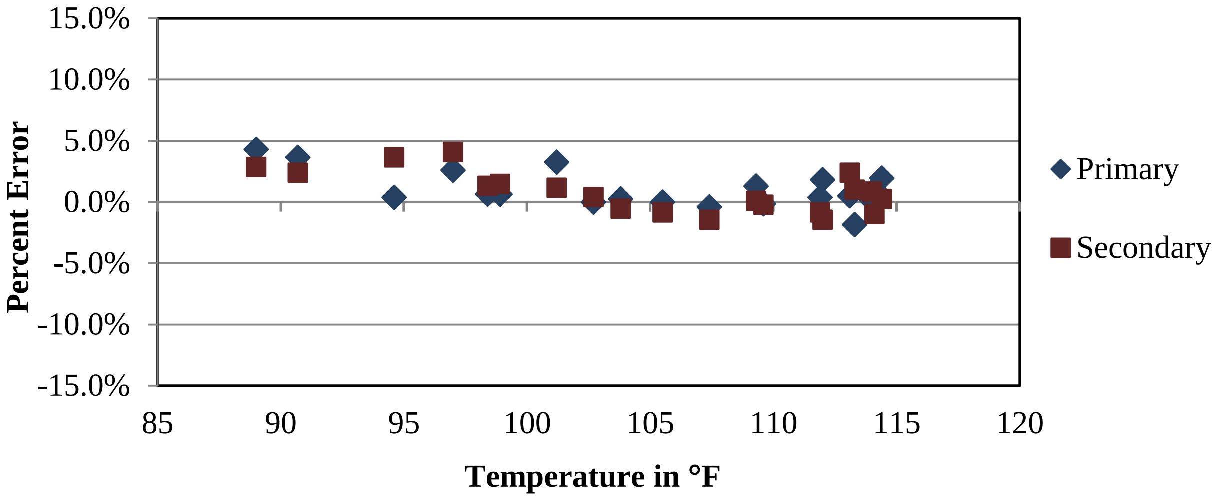


Figure 5-10 – Validation GVW Error by Truck and Temperature – 23-Jul-13

5.3.3 Classification and Speed Evaluation

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

For the validation classification study at this site, a manual sample of 102 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.

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one type of vehicle but identified by the WIM equipment as another type of vehicle. The misclassifications by pair are provided in Table 5-5. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-5, one Class 5 vehicle was misclassified as a Class 8 vehicle and one Class 6 vehicle was misclassified as a Class 9 vehicle by the equipment.

Table 5-5 – Validation Misclassifications by Pair – 23-Jul-13

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

As shown in the table, a total of 2 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the validation study, the misclassification percentage is 1.1% for heavy trucks (vehicle classes 6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 2.0 percent due to the misclassification of one Class 5 and one Class 6 vehicle.

The causes for the misclassifications were not investigated in the field. A post-visit investigation of misclassified vehicles was performed on misclassifications of heavy trucks (6 – 13) using the collected video. The analysis determined that the Class 6 that was a Recreational Vehicle towing a car.

The combined results of the misclassifications resulted in an undercount of one Class 5 and one Class 6 vehicle, and an overcount of one Class 8 vehicle and one Class 9 vehicle, as shown in Table 5-6. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-6 – Validation Classification Study Results – 23-Jul-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	0	1	9	9	0	2	74	1	1	3	0
WIM Count	0	1	8	8	0	3	75	1	1	3	0
Observed Percent	0.0	1.0	9.0	9.0	0.0	2.0	74.0	1.0	1.0	3.0	0.0
WIM Percent	0.0	1.0	8.0	8.0	0.0	3.0	75.0	1.0	1.0	3.0	0.0
Misclassified Count	0	0	1	1	0	0	0	0	0	0	0
Misclassified Percent	0.0	0.0	11.1	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. Based on the manually collected sample of the 100 vehicles, 0.0 percent of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 0.8 mph; the range of errors was 1.3 mph.

Since the equipment is measuring all weight and distance parameters within the LTPP requirements for SPS WIM sites and with a very low bias (the average measurement error for GVW is 0.9 percent), a calibration of the system was not required and therefore was not carried out.

5.3.4 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-7.

Table 5-7 – Final Factors

Speed Point	MPH	Left	Right
		2	1
88	55	3489	3658
96	60	3505	3674
104	65	3470	3635
112	70	3443	3608
120	75	3435	3599
Axle Distance (cm)		372	
Dynamic Comp (%)		105	
Loop Width (cm)		273	

6 Post-Visit Data Analysis

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

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

6.1 Regression Analysis

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

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

6.1.1 Data

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

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

- Truck type. Primary truck and Secondary truck.
- Truck test speed. Truck test speed ranged from 61 to 73 mph.
- Pavement temperature. Pavement temperature ranged from 89.0 to 114.4 degrees Fahrenheit.

6.1.2 Results

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

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

Parameter	**Regression coefficients**	**Standard error**	**Value of t-distribution**	**Probability value (p-value)**
Intercept	11.4130	3.9515	2.8882	0.0065
Speed	-0.0057	0.0535	-0.1070	0.9154
Temp	-0.0958	0.0206	-4.6525	$4.3\ 10^{-5}$
Truck	-0.2413	0.4043	-0.5968	0.5544

The lowest probability value given in Table 6-1 was $4.3\ 10^{-5}$ for temperature. This means that there is about 0.004 percent chance that the value of the regression coefficient for temperature (-0.0958) can occur by chance alone. Overall, only the pavement temperature had statistically significant effect on the GVW measurement errors, assuming that p-values equal or less than 0.05 indicate statistical significance in this case.

As an example, the relationship between temperature and measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Figure 6-1 provides a visual assessment of the relationship. The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.0958 (in Table 6-1). This means, for example, that for a 10 degree change in temperature may lead to up to a 0.9 percent (-0.0958 x 10) change in weight measurement. The statistical assessment of the relationship is provided by the probability value of the regression coefficient ($4.3\ 10^{-5}$) and is statistically significant.

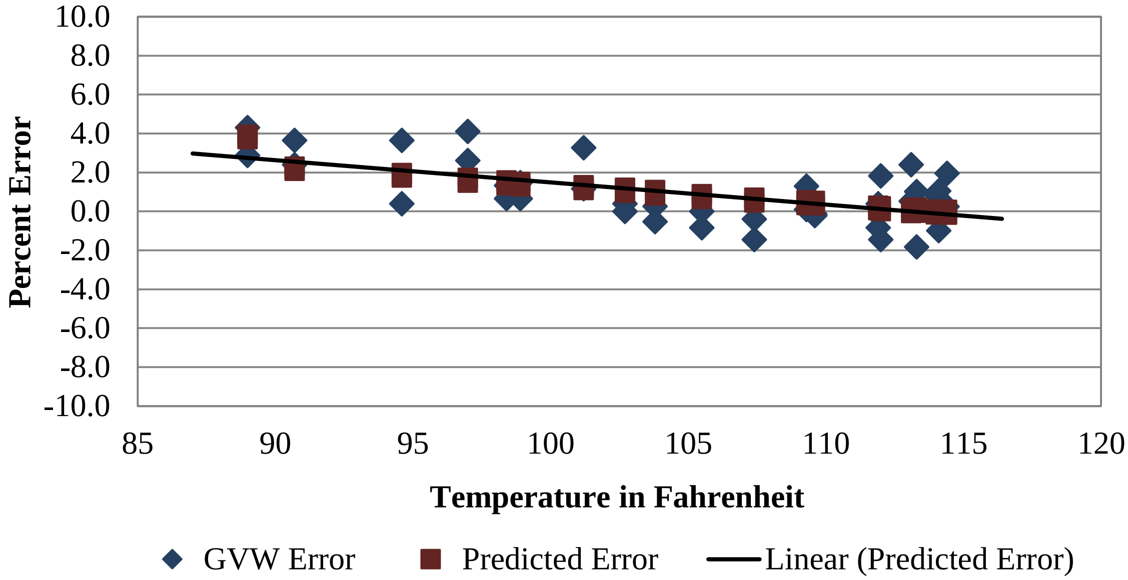


Figure 6-1 – Influence of Temperature on the Measurement Error of GVW

6.1.3 Summary Results

Table 6-2 lists regression coefficients and their probability values for all combinations of factors and percent errors evaluated. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 6-2 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 6-2 – Summary of Regression Analysis

Parameter	**Factor**					
	Speed		**Temperature**		**Truck type**	
	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)
GVW	-	-	-0.0958	$4.3\ 10^{-5}$	-	-
Steering axle	-	-	-0.1429	0.0022	1.5475	0.0772
Tandem axle tractor	-0.1819	0.0100	-0.0885	0.0015	-	-
Tandem axle trailer	0.2600	0.0033	-0.0881	0.0087	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on the measurement errors of tractor and trailer tandem axles. However, because the correlations between speed and error are in opposite directions (one underestimates and the other overestimates), those effects cancel each other out.

2. Temperature affected measurement error of all axle groups and thus also the measurement error of the GVW. It should be noted that the relationship applies only to the range of pavement temperatures encountered, and that it is assumed that the relationship is linear.

3. Truck type had statistically significant effect on the measurement errors of steering axles only, and at 0.077 probability value. The regression coefficients for truck type in Table 6-2 represent the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). Thus, the mean measurement error for steering axles for the Primary truck was about 1.5 % larger than the corresponding error for the Secondary truck. Truck type is further investigated in Section 6.1.5.

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

6.1.5 Contribution of Two Trucks to Calibration

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

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

Figure 6-2 and associated statistical analysis show that speed had no effect on weight measurement errors for the primary truck and very small negative correlation for the secondary truck. However from practical perspective, it could be concluded that speed had similar influences on the GVW measurement for each truck. Overall GVW error dependency on speed was very low for both trucks.

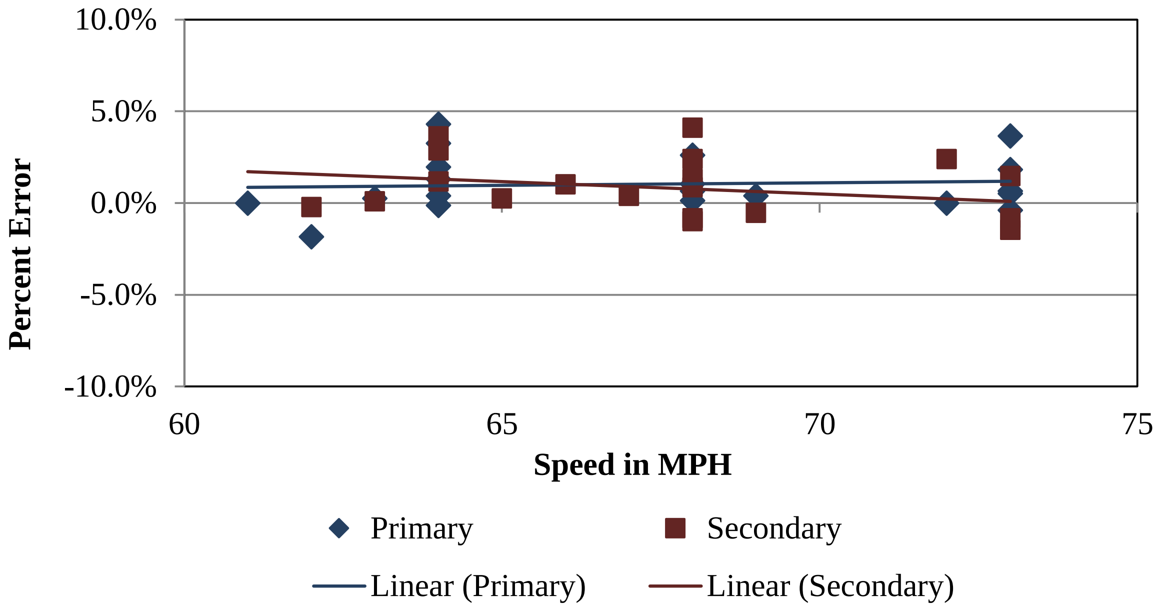


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

The use of two calibration trucks provided verification of the trends and speeded up the time required to obtain 40 pre-validation runs. However for this site, the use of only one of the trucks (Primary or Secondary) with 20 calibration runs would have resulted in similar verification and calibration results, based on similarities in observed errors for both trucks.

6.2 Misclassification Analysis

A post-visit analysis was conducted on the truck misclassification identified during the validation conducted in the field. For this site, a total of 2 vehicles, including 1 heavy truck (6 – 13) was misclassified by the equipment. The single truck misclassification was a Class 6 which was identified by the WIM system as a Class 9 vehicle. According to the Sheet 20, this vehicle was vehicle number 511. The capture of the real-time record for vehicle 511 is provided in Figure 6-3.

(511) LANE #1 CLASS 9 GVW 41.6 kips LENGTH 59 ft
SPEED 63 mph MAX GVW 0.0 kips Tue Jul 23 2013 04:06:05 (1095)

AXLE		SEPARATION (ft)	LEFT WT (kips)	RIGHT WT (kips)	TOTAL WT (kips)	ALLOWABLE (kips)
1	S		6.2	6.6	12.9	
2	D	20.1	8.0	9.3	17.3	
3	D	3.8	3.3	3.4	6.7	
4	S	16.6	1.4	1.3	2.6	
5	S	8.9	1.1	1.0	2.1	

Figure 6-3 **– Vehicle Record 511**

The video capture of vehicle 511 is provided in Photo 6-1. As the photo illustrates, the misclassification involved a 3-axle power unit (RV) that was towing a car.

6.3 Photo 6-1 – Video Capture of Vehicle 511

6.4 Traffic Data Analysis

Since there was no calibration of the WIM system operating parameters performed during this validation, the post-visit data analysis was not performed.

7 Previous WIM Site Validation Information

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

7.1 Classification

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

Table 7-1 – Classification Validation History

Date	Misclassification Percentage by Class											Pct Unclass
	3	4	5	6	7	8	9	10	11	12	13	
27-Jun-06	-	0	30	0	-	0	0	-	0	0	-	0.0
28-Jun-06	-	-	38	0	-	0	0	0	0	-	-	1.0
16-Oct-07	-	-	0	0	-	0	0	-	0	-	-	0.0
17-Oct-07	-	100	11	-	-	0	0	-	0	0	-	0.0
29-Apr-08	-	100	29	25	-	75	3	-	0	-	0	0.0
30-Apr-08	-	-	22	0	100	100	4	0	0	0	-	5.0
16-Mar-11	-	0	13	0	0	0	0	0	0	0	0	0.0
17-Mar-11	-	0	0	0	0	0	0	0	0	0	0	0.0
21-Feb-12	63	0	10	17	0	0	0	0	0	0	0	0.0
17-Jul-13	0	0	11	11	0	0	1	0	0	0	0	0.0

7.2 Weight

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

Table 7-2 – Weight Validation History

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
27-Jun-06	3.3 ± 4.8	3.1 ± 5.7	3.3 ± 6.5
28-Jun-06	-0.6 ± 3.6	-1.2 ± 6.6	-0.5 ± 6.2
16-Oct-07	-3.5 ± 6.6	-7.5 ± 9.5	-2.8 ± 9.0
17-Oct-07	0.9 ± 5.2	-2.3 ± 9.2	1.5 ± 7.8
29-Apr-08	3.5 ± 3.4	-0.1 ± 3.2	4.2 ± 4.9
30-Apr-08	-0.9 ± 3.3	-5.0 ± 5.8	-0.1 ± 4.0
16-Mar-11	-3.0 ± 2.9	-7.2 ± 5.1	-2.7 ± 7.8
17-Mar-11	-0.1 ± 3.2	-1.1 ± 5.7	0.1 ± 4.6
21-Feb-12	0.4 ± 2.9	1.2 ± 5.3	0.2 ± 4.5
17-Jul-13	0.9 ± 3.2	1.2 ± 6.3	0.0 ± 4.3

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. With the exception of the period between the 2007 and 2008 validations, it appears that the system demonstrates a tendency for the equipment to move toward an underestimation of GVW over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

8 Additional Information

The following information is provided in the attached appendix:

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

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

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

WIM System Field Calibration and Validation - Photos

Colorado, SPS-2
SHRP ID: 080200

Validation Date: July 23, 2013

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior (Back)

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Power Service Box

Photo 9 – Telephone Service Box

Photo 10 – Downstream

Photo 11 – Upstream

Photo 12 – Truck 1

Photo 13 – Truck 1 Tractor

Photo 14 – Truck 1 Trailer and Load

Photo 15 – Truck 1 Suspension 1

Photo 16 – Truck 1 Suspension 2

Photo 17 – Truck 1 Suspension 3

Photo 18 – Truck 1 Suspension 4

Photo 19 – Truck 1 Suspension 5

Photo 20 – Truck 2

Photo 21 – Truck 2 Tractor

Photo 22 – Truck 2 Trailer and Load

Photo 23 – Truck 2 Suspension 1

Photo 24 – Truck 2 Suspension 2

Photo 25 – Truck 2 Suspension 3

Photo 26 – Truck 2 Suspension 5

Photo 27 – Truck 2 Suspension 4

Traffic Sheet 16	STATE CODE:	08
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	080200
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	7/23/2013

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 7/23/13

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

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

a. Inductance Loops c.

b. Bending Plates d.

5. EQUIPMENT MANUFACTURER: IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks

Number of Trucks Compared:

Number of Test Trucks Used: 2

Passes Per Truck: 20

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

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

Mean Difference Between -

Dynamic and Static GVW:	0.9%	Standard Deviation:	1.6%
Dynamic and Static Single Axle:	1.2%	Standard Deviation:	3.1%
Dynamic and Static Double Axles:	0.0%	Standard Deviation:	2.1%

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

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	61.0	to	65.0	15
b.	Medium	-	65.1	to	69.1	14
c.	High	-	69.2	to	73.0	11
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	08 080200 7/23/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3435 | 3599

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

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

CLASSIFIER TEST SPECIFICS

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: Number of Trucks

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	1.0	FHWA Class		-	
FHWA Class 8:	50.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 08 SPS WIM ID: 080200 DATE (mm/dd/yyyy) 7/23/2013

Count - 100 Time = 1:22:22 Trucks (4-15) - 100 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	8	225	65	8	60	12	387	59	12
75	9	230	75	9	65	9	392	66	9
68	9	240	67	9	69	9	469	69	9
65	9	241	62	9	73	4	472	73	4
61	9	243	59	9	73	5	484	72	5
78	**8**	**251**	**77**	**5**	75	5	487	75	5
78	9	252	77	9	65	9	490	65	9
68	12	284	67	12	66	5	493	66	5
60	6	296	62	6	65	9	495	64	9
66	9	301	64	9	71	5	498	69	5
65	9	307	63	9	62	6	506	61	6
59	9	308	59	9	**63**	**9**	**511**	**63**	**6**
61	9	310	59	9	78	9	519	77	9
75	9	318	76	9	66	9	604	66	9
66	12	320	68	12	74	5	605	72	5
70	9	325	68	9	74	9	611	75	9
73	9	331	73	9	64	9	612	65	9
72	9	345	71	9	76	9	620	75	9
68	9	346	69	9	70	9	630	69	9
75	9	349	75	9	73	6	636	70	6
73	9	354	73	9	67	9	637	67	9
71	9	357	70	9	75	9	641	74	9
66	5	359	65	5	78	5	645	76	5
69	9	380	69	9	68	9	655	68	9
67	9	386	66	9	75	9	658	74	9

Sheet 1 - 0 to 50 Start: 3:13:44 Stop: 4:34:27

Recorded By: gh Verified By: kt

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 08 SPS WIM ID: 080200 DATE (mm/dd/yyyy) 7/23/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
68	9	659	69	9	70	9	894	68	9
67	9	674	67	9	72	9	900	72	9
74	9	677	73	9	70	9	915	69	9
65	9	679	65	9	65	9	919	62	9
71	6	680	71	6	65	9	924	65	9
71	8	683	65	8	64	9	930	60	9
62	9	684	63	9	65	9	936	65	9
70	10	691	70	10	64	9	940	63	9
72	9	693	71	9	73	5	941	73	5
71	9	777	67	9	65	9	967	64	9
69	9	781	69	9	65	9	982	64	9
65	9	790	64	9	59	9	983	59	9
63	9	795	61	9	68	9	1016	68	9
70	9	800	70	9	61	9	1019	62	9
61	9	803	60	9	59	9	1022	58	9
64	6	809	63	6	65	9	1035	65	9
75	9	817	74	9	72	9	1037	72	9
77	9	818	77	9	73	9	1046	71	9
75	9	823	74	9	64	11	1047	62	11
67	6	830	66	6	65	9	1061	64	9
73	6	831	73	6	72	9	1062	71	9
72	6	841	71	6	75	9	1065	72	9
69	9	843	67	9	69	9	1066	69	9
75	9	850	73	9	70	9	1075	70	9
75	9	851	73	9	61	9	1077	58	9

Sheet 2 - 51 to 100 Start: 4:35:02 Stop: 5:57:24

Recorded By: ____________________

Validation Test Truck Run Set - Pre