WIM System Field Calibration and Validation Summary Report

Washington SPS-2
SHRP ID – 530200

Validation Date: June 18, 2013
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1 Executive Summary

A WIM validation was performed on June 18, 2013 at the Washington SPS-2 site located on route US-395, milepost 93.0, 3.1 miles south of Interstate 90.

This site was installed on March 1, 1998 by the Agency. The in-road sensors are installed in the northbound, righthand driving lane. The site is equipped with quartz WIM sensors and an IRD 1060 Series 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 May 2, 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 several pavement distresses noted. A visual observation of the trucks as they approach, traverse, and leave the sensor area indicated several locations within the 400-foot approach section of the WIM scales where truck bouncing occurred. The truck dynamics noted may have affected 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 – 18-Jun-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-0.7 ± 13.8%	Pass
Tandem Axles	±15 percent	1.3 ± 6.1%	Pass
Tridem Axles	±15 percent	1.6 ± 6.1%	Pass
Axle Groups	±15 percent	1.4 ± 6.1%	Pass
GVW	±10 percent	1.1 ± 4.7%	Pass
Vehicle Length	±3.0 percent (1.8 ft)	0.3 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.2 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 0.0 ± 2.5 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 7.0% from the 114 vehicle sample (Class 4 – 13) was primarily due to misclassifications of lighter vehicles in Class 3 through Class 5.

There were three 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 bagged and palletized animal feed.

- The Secondary truck was a Class 10 vehicle with air suspension on the tractor tandem, air suspension on the trailer tandem, standard tridem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with concrete blocks.

- The Third 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 truck was loaded with bagged and palletized fertilizer.

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	Ax6	1-2	2-3	3-4	4-5	5-6	AL	OL
1	76.0	10.7	15.6	15.6	17.0	17.0		12.8	4.3	28.8	4.1		50.0	57.2
2	66.7	9.6	10.0	10.0	10.0	13.6	13.6	13.8	4.3	4.3	28.8	4.2	55.4	62.0
3	62.1	12.9	12.1	12.1	12.4	12.4		18.3	4.3	27.7	4.2		54.5	61.5

The posted speed limit at the site is 60 mph. During the testing, the speed of the test trucks ranged from to 46 to 60 mph, a variance of 14 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The Validation pavement surface temperatures varied from 66.3 to 77.5 degrees Fahrenheit, a range of 11.2 degrees Fahrenheit. The mostly cloudy weather conditions prevented the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 27 shows that there are 5 years of level "E" WIM data for this site. This site requires no additional years of data to meet the minimum of five years of research quality data.

2 WIM System Data Availability and Pre-Visit Data Analysis

To assess the quality of the current traffic data, a pre-visit analysis was conducted by comparing a two-week data sample from June 1, 2013 (Data) to the most recent Comparison Data Set (CDS) from May 4, 2012. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 27 shows that there are 5 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	31	1
2007	365	12
2008	343	12
2009	363	12
2010	346	12
2011	326	12
2012	110	4

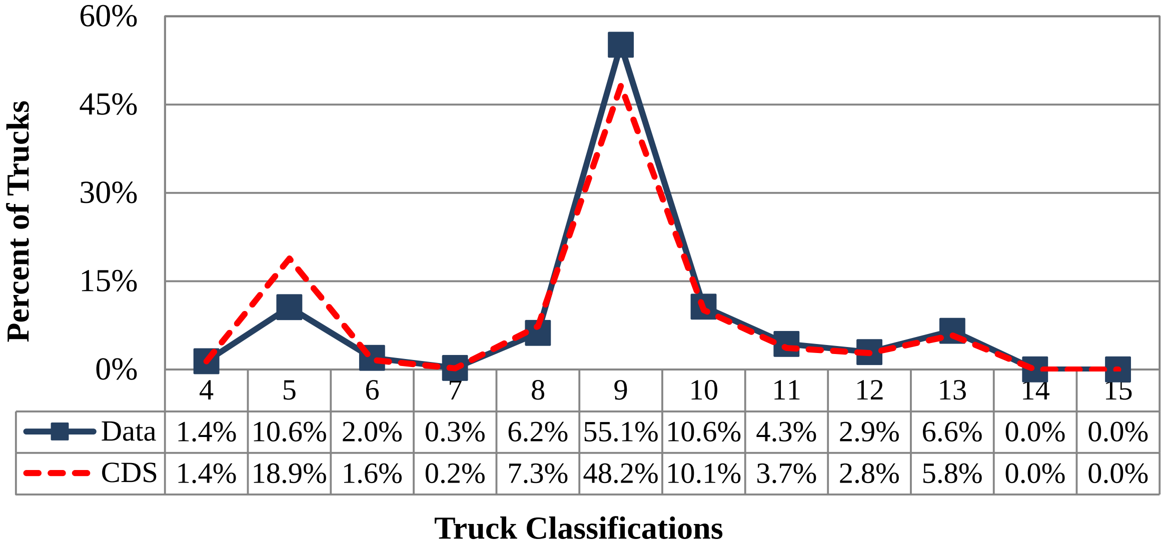
As shown in the table, this site requires no additional years of data to meet the minimum of five years of research quality data. The data does not meet the 210-day minimum requirement for calendar years 2006 and 2012.

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												31	1
2007	31	28	31	30	31	30	31	31	30	31	30	31	12
2008	31	29	31	30	31	24	24	31	30	21	30	31	12
2009	31	28	30	29	31	30	31	31	30	31	30	31	12
2010	31	28	16	30	31	30	31	31	30	30	29	29	12
2011	31	23	19	14	31	30	31	25	30	31	30	31	12
2012	31	29	21	29									4

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 1, 2013 (Data) and the most recent comparison Data Set (CDS) from May 4, 2012.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	1.4%	10.6%	2.0%	0.3%	6.2%	55.1%	10.6%	4.3%	2.9%	6.6%	0.0%	0.0%
CDS	1.4%	18.9%	1.6%	0.2%	7.3%	48.2%	10.1%	3.7%	2.8%	5.8%	0.0%	0.0%

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 (55.1%) and Class 10 (10.6%) vehicles.

Table 2-3 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles. The table indicates that 0.0 percent of the vehicles at this site are unclassified.

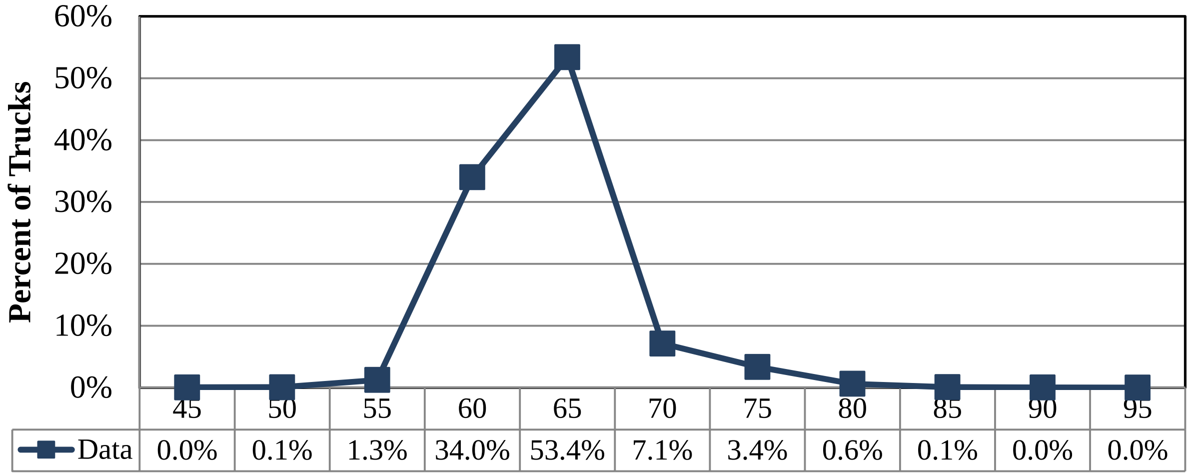
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	5/4/2012		6/1/2013		
4	203	1.4%	173	1.4%	0.0%
5	2710	18.9%	1327	10.6%	-8.3%
6	231	1.6%	247	2.0%	0.4%
7	31	0.2%	32	0.3%	0.0%
8	1056	7.3%	777	6.2%	-1.2%
9	6927	48.2%	6922	55.1%	6.9%
10	1451	10.1%	1336	10.6%	0.5%
11	527	3.7%	544	4.3%	0.7%
12	402	2.8%	370	2.9%	0.2%
13	834	5.8%	824	6.6%	0.8%
14	0	0.0%	0	0.0%	0.0%
15	0	0.0%	0	0.0%	0.0%

From the table it can be seen that the percentage of Class 9 vehicles has increased by 6.9 percent from May 2012 and June 2013. During the same time period, the percentage of Class 10 trucks increased by 0.5 percent. Changes in the percentage of heavier trucks may be attributed to natural and seasonal variations in truck distributions and an increase in goods movement during current economic cycle.

2.2 Speed Data Analysis

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



	45	50	55	60	65	70	75	80	85	90	95
Data	0.0%	0.1%	1.3%	34.0%	53.4%	7.1%	3.4%	0.6%	0.1%	0.0%	0.0%

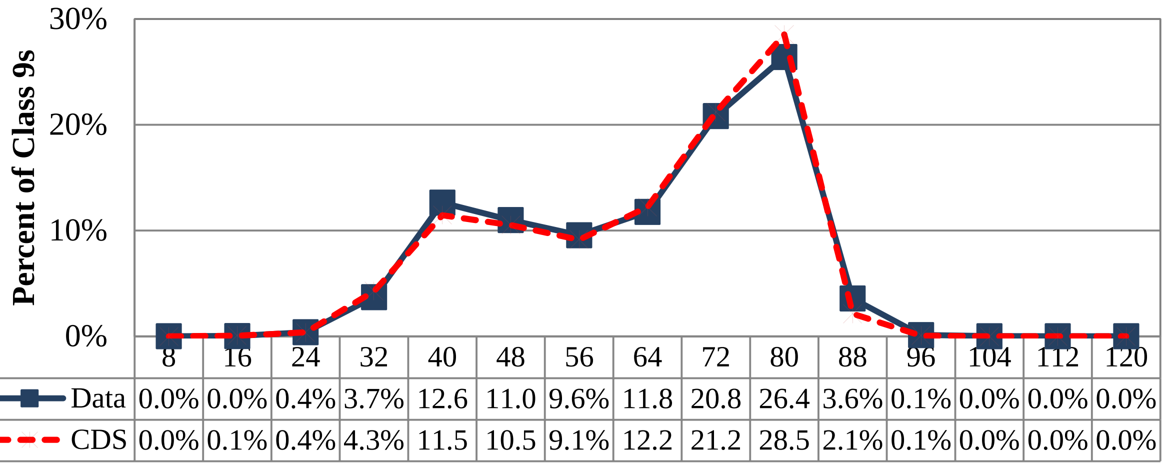
Figure 2-2 – Truck Speed Distribution – 1-Jun-13

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 60 and 70 mph. The posted speed limit at this site is 60 and the 85th percentile speed for trucks at this site is 65 mph. The range of truck speeds for the validation will be 50 to 60 mph.

2.3 GVW Data Analysis

The traffic CDS data received from the Agency 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 May 2012.

As shown in Figure 2-3, the unloaded and loaded peaks the May 2012 Comparison Data Set (CDS) and the June 2013 two-week sample W-card dataset (Data) are similar.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.4%	3.7%	12.6	11.0	9.6%	11.8	20.8	26.4	3.6%	0.1%	0.0%	0.0%	0.0%
CDS	0.0%	0.1%	0.4%	4.3%	11.5	10.5	9.1%	12.2	21.2	28.5	2.1%	0.1%	0.0%	0.0%	0.0%

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				
	5/4/2012		6/1/2013		
8	0	0.0%	0	0.0%	0.0%
16	4	0.1%	2	0.0%	0.0%
24	26	0.4%	26	0.4%	0.0%
32	293	4.3%	253	3.7%	-0.6%
40	786	11.5%	866	12.6%	1.2%
48	722	10.5%	753	11.0%	0.5%
56	627	9.1%	655	9.6%	0.4%
64	840	12.2%	806	11.8%	-0.5%
72	1455	21.2%	1427	20.8%	-0.4%
80	1959	28.5%	1809	26.4%	-2.1%
88	146	2.1%	245	3.6%	1.4%
96	4	0.1%	8	0.1%	0.1%
104	0	0.0%	1	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	60.1 kips		59.9 kips		-0.2 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range increased by 1.2 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 2.1 percent. During this time period the percentage of overweight trucks increased by 1.5 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site decreased by 0.2 percent, from 60.1 to 59.9 kips.

2.4 Class 9 Front Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from June 2013 and the Comparison Data Set from May 2012. The percentage of light axles (9.5 to 10.5 kips) decreased by approximately 3.7% and the percentage of heavy axles (12.0 to 13.0 kips) increased by approximately 2.8%.

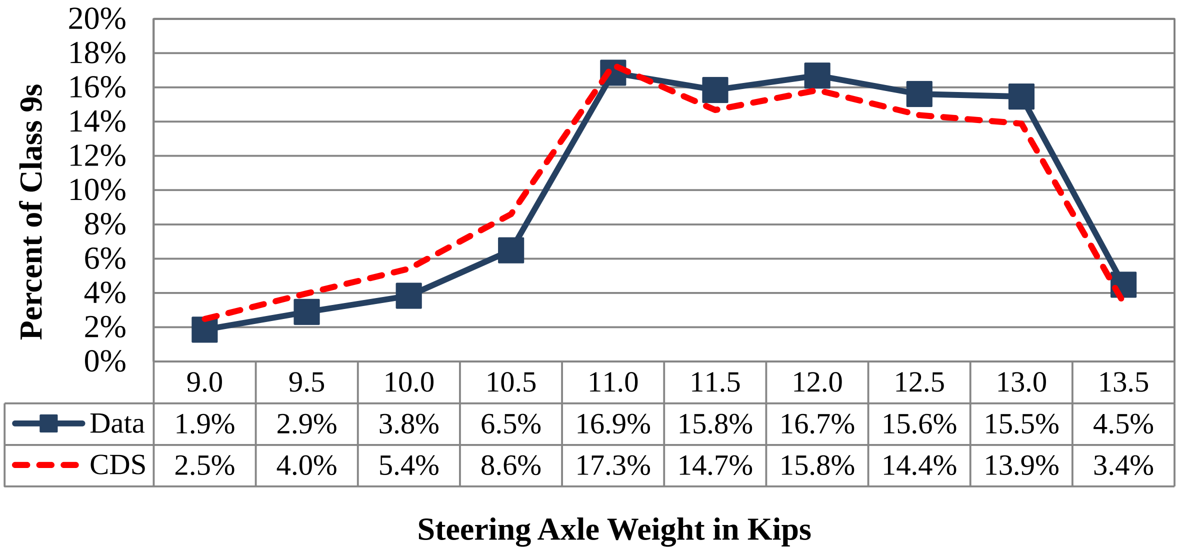


Figure 2-4 – Distribution of Class 9 Front Axle Weights

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

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

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

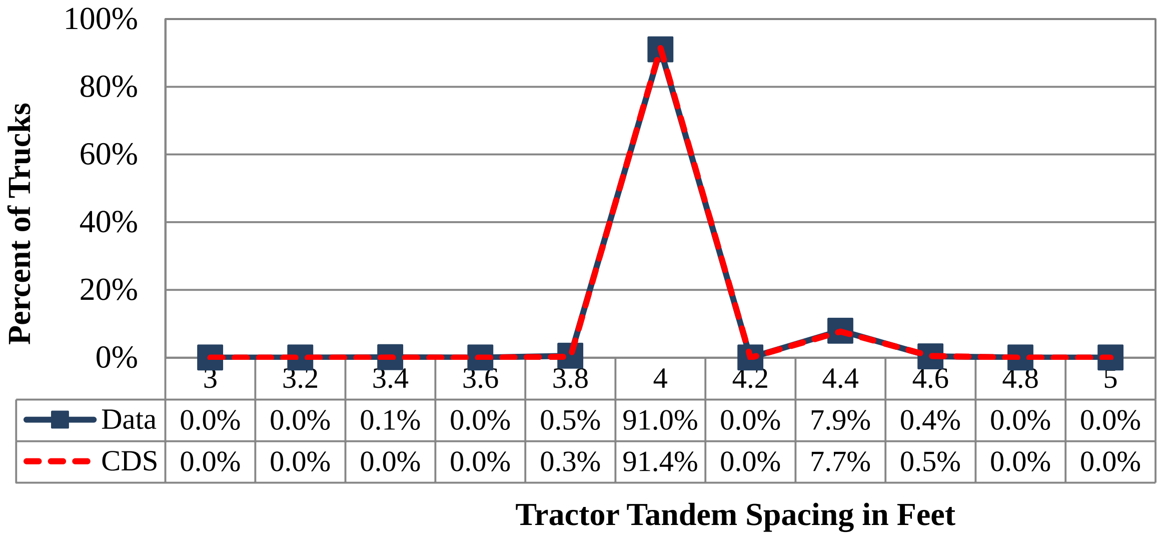
F/A weight bins (kips)	CDS		Data		Change
	Date				
	5/4/2012		6/1/2013		
9.0	167	2.5%	124	1.9%	-0.6%
9.5	267	4.0%	193	2.9%	-1.1%
10.0	364	5.4%	256	3.8%	-1.6%
10.5	578	8.6%	433	6.5%	-2.1%
11.0	1162	17.3%	1125	16.9%	-0.4%
11.5	986	14.7%	1058	15.8%	1.2%
12.0	1064	15.8%	1114	16.7%	0.8%
12.5	966	14.4%	1042	15.6%	1.2%
13.0	933	13.9%	1032	15.5%	1.6%
13.5	230	3.4%	299	4.5%	1.1%
Average =	11.4 kips		11.6 kips		0.2 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.2 kips, or 1.8 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.6 kips.

2.5 Class 9 Tractor Tandem Spacing Data Analysis

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

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



	3	3.2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5
Data	0.0%	0.0%	0.1%	0.0%	0.5%	91.0%	0.0%	7.9%	0.4%	0.0%	0.0%
CDS	0.0%	0.0%	0.0%	0.0%	0.3%	91.4%	0.0%	7.7%	0.5%	0.0%	0.0%

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

As seen in the figure, the Class 9 tractor tandem spacings for the May 2012 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				
	5/4/2012		6/1/2013		
3.0	0	0.0%	0	0.0%	0.0%
3.2	1	0.0%	1	0.0%	0.0%
3.4	3	0.0%	7	0.1%	0.1%
3.6	0	0.0%	0	0.0%	0.0%
3.8	18	0.3%	36	0.5%	0.3%
4.0	6275	91.4%	6237	91.0%	-0.4%
4.2	0	0.0%	0	0.0%	0.0%
4.4	529	7.7%	544	7.9%	0.2%
4.6	36	0.5%	25	0.4%	-0.2%
4.8	0	0.0%	0	0.0%	0.0%
5.0	0	0.0%	1	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, which is identical to the expected average of 4.0 from the CDS per vehicle records. Further axle spacing analyses are performed during the validation and post-validation analysis.

2.6 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (May 2012) 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 6.9 percent increase in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 1.8 percent and average Class 9 GVW has decreased by 0.2 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 May 2, 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 March 1, 1998 by the Agency. It is instrumented with quartz weighing sensors and an IRD 1060 Series WIM Controller. The Agency 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. From an inspection from the shoulder it appeared that the sensors were not flush with the pavement surface. 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

The sensors should be checked to determine if they are flush with the pavement surface and if not, they should be re-ground.

4 Pavement Discussion

4.1 Pavement Condition Survey

During the pavement condition survey conducted from the shoulder, the distresses shown in Photo 4-1 through Photo 4-5 were noted at various locations within the 400 WIM section.

Photo 4-1 – Pavement Distress 60 Feet Prior to WIM

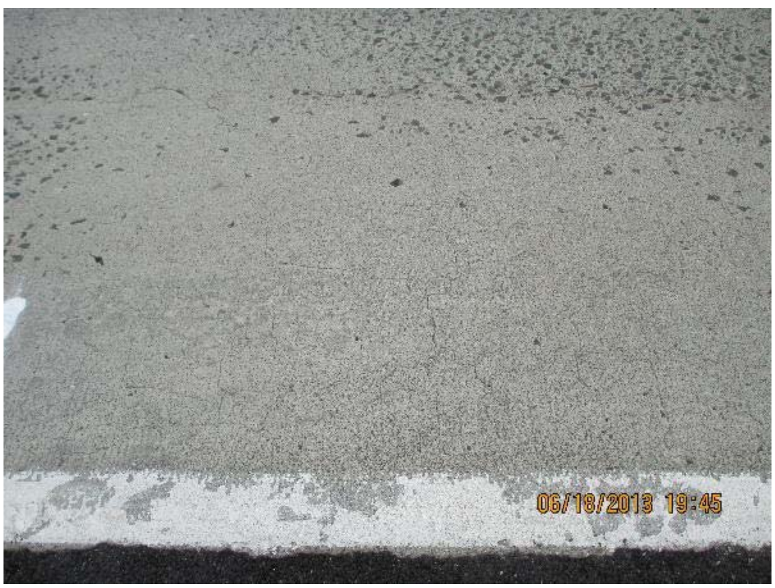


Photo 4-2 – Pavement Distress 72 Feet Prior to WIM

Photo 4-3 – Pavement Distress 176 Feet Prior to WIM

Photo 4-4 – Pavement Distress 250 Feet Prior to WIM

Photo 4-5 – Pavement Distress 266 Feet Prior to WIM

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)	1.029	0.903	0.999			0.977
		SRI (m/km)	0.508	*0.348*	*0.360*			*0.405*
		Peak LRI (m/km)	1.100	1.010	1.100			1.070
		Peak SRI (m/km)	1.185	0.966	0.856			1.002
	RWP	LRI (m/km)	0.962	1.018	0.986			0.989
		SRI (m/km)	*0.408*	*0.454*	0.740			0.534
		Peak LRI (m/km)	1.173	1.078	1.036			1.096
		Peak SRI (m/km)	0.757	1.093	1.001			0.950
Center	LWP	LRI (m/km)	1.140	1.215	1.243	1.182		1.195
		SRI (m/km)	0.997	1.042	1.401	0.691		1.033
		Peak LRI (m/km)	1.208	1.257	1.297	1.248		1.253
		Peak SRI (m/km)	1.164	1.188	1.498	0.963		1.203
	RWP	LRI (m/km)	1.081	1.069	1.198	1.071		1.105
		SRI (m/km)	*0.499*	0.532	0.862	0.595		0.622
		Peak LRI (m/km)	1.413	1.334	1.360	1.352		1.365
		Peak SRI (m/km)	*0.689*	*0.547*	1.012	0.835		0.771
Right	LWP	LRI (m/km)	0.862	0.905	0.930			0.899
		SRI (m/km)	0.500	0.612	0.518			0.543
		Peak LRI (m/km)	0.993	0.930	1.020			0.981
		Peak SRI (m/km)	*0.516*	*0.615*	*0.639*			*0.590*
	RWP	LRI (m/km)	1.022	0.816	1.062			0.967
		SRI (m/km)	*0.478*	0.678	0.676			0.611
		Peak LRI (m/km)	**1.407**	**2.704**	**1.161**			**1.757**
		Peak SRI (m/km)	*0.585*	0.785	0.758			*0.709*

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

4.3 Profile and Vehicle Interaction

Profile data was collected on May 15, 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 160 in/mi and is located approximately 548 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 128 in/mi and is located approximately 74 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.

A visual observation of the trucks as they approach, traverse, and leave the sensor area indicated several locations within the 400-foot approach section of the WIM scales where truck bouncing occurred. The truck dynamics noted may have affected the accuracy of the WIM system. The trucks appear to track down the center of the lane.

4.4 Recommended Pavement Remediation

Pavement rehabilitation within the 400-foot WIM approach section would most likely improve the accuracy of the WIM system.

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 42 validation test truck runs were conducted on June 18, 2013, beginning at approximately 10:14 AM and continuing until 3:35 PM.

The three test trucks consisted of:

- A Class 9 truck, loaded with bagged and palletized animal feed, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 10 truck, loaded with concrete blocks, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tridem spacing on the tractor and standard tandem spacing on the trailer.
- A Class 9 truck, loaded with bagged and palletized fertilizer, and equipped with air suspension on the tractor, air suspension on the trailer, with tridem tandem spacing on the tractor and standard tandem spacing on the 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	Ax6	1-2	2-3	3-4	4-5	5-6	AL	OL
1	76.0	10.7	15.6	15.6	17.0	17.0		12.8	4.3	28.8	4.1		50.0	57.2
2	66.7	9.6	10.0	10.0	10.0	13.6	13.6	13.8	4.3	4.3	28.8	4.2	55.4	62.0
3	62.1	12.9	12.1	12.1	12.4	12.4		18.3	4.3	27.7	4.2		54.5	61.5

Test truck speeds varied by 14 mph, from 46 to 60 mph. The measured validation pavement temperatures varied 11.2 degrees Fahrenheit, from 66.3 to 77.5. The mostly cloudy weather conditions prevented the desired minimum 30 degree temperature range. Table 5-2 is a summary of post validation results.

Table 5-2 – Validation Overall Results – 18-Jun-13

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-0.7 ± 13.8%	Pass
Tandem Axles	±15 percent	1.3 ± 6.1%	Pass
Tridem Axles	±15 percent	1.6 ± 6.1%	Pass
Axle Groups	±15 percent	1.4 ± 6.1%	Pass
GVW	±10 percent	1.1 ± 4.7%	Pass
Vehicle Length	±3.0 percent (1.8 ft)	0.3 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.2 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 0.0 ± 2.5 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 60 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 – 18-Jun-13

Parameter	95% Confidence Limit of Error	Low	Medium	High
		46.0 to 50.7 mph	50.8 to 55.4 mph	55.5 to 60.0 mph
Steering Axles	±20 percent	1.0 ± 15.2%	1.2 ± 12.3%	-5.2 ± 14.3%
Tandem Axles	±15 percent	0.7 ± 7.5%	1.4 ± 6.4%	2.0 ± 6.3%
Tridem Axles	±15 percent	1.5 ± 11.5%	2.3 ± 3.1%	1.0 ± 10.2%
Axle Groups	±15 percent	1.0 ± 8.8%	1.6 ± 5.6%	1.8 ± 7.2%
GVW	±10 percent	0.8 ± 5.9%	1.6 ± 4.7%	0.6 ± 4.7%
Vehicle Length	±3.0 percent (1.8 ft)	0.4 ± 1.5 ft	0.4 ± 0.9 ft	0.2 ± 1.2 ft
Vehicle Speed	± 1.0 mph	-0.6 ± 2.3 mph	0.5 ± 1.9 mph	-0.1 ± 3.6 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.2 ft	0.0 ± 0.2 ft	0.0 ± 0.2 ft

From the table, it can be seen that the WIM equipment estimates all weights with similar accuracy at all speeds. The range in error for each parameter is generally greater at the low and high speeds when compared with medium speeds.

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 throughout the entire speed range.

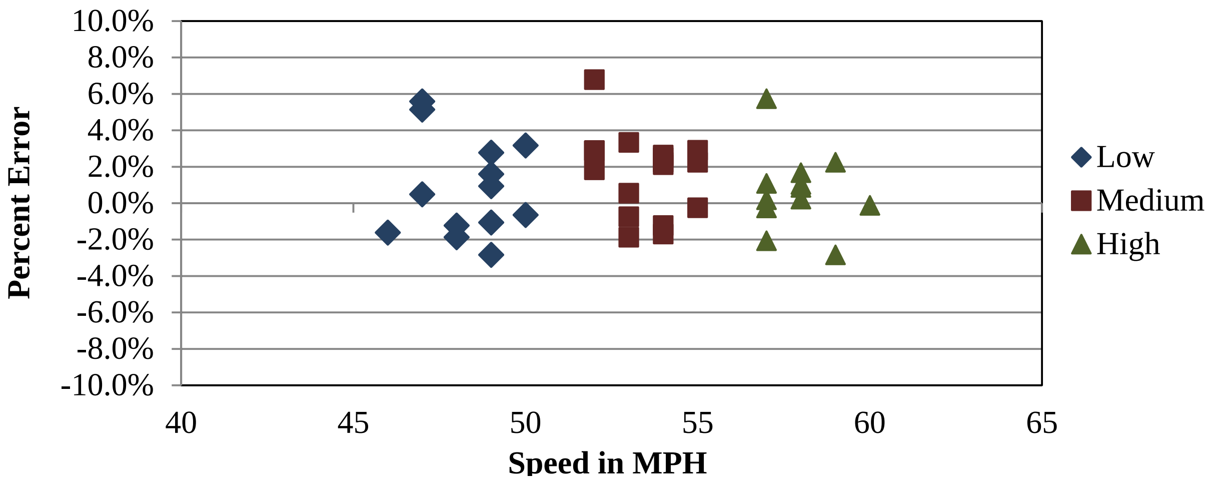


Figure 5-1 – Validation GVW Errors by Speed – 18-Jun-13

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 the low and medium speeds. The system underestimates steering axle weights at the high speeds, indicating a correlation between steering axle weights and speed for this site.

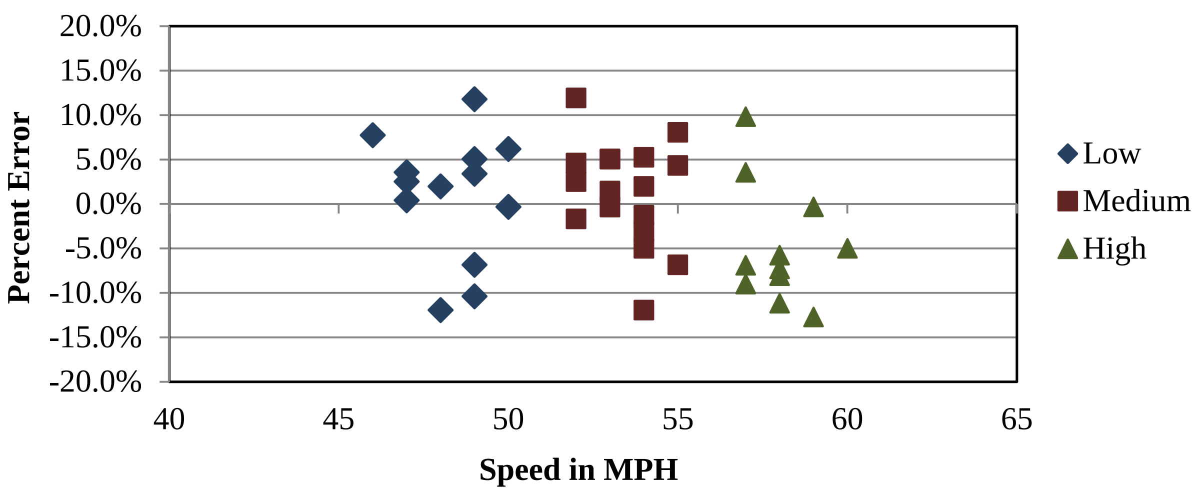


Figure 5-2 – Validation Steering Axle Weight Errors by Speed – 18-Jun-13

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 throughout the entire speed range.

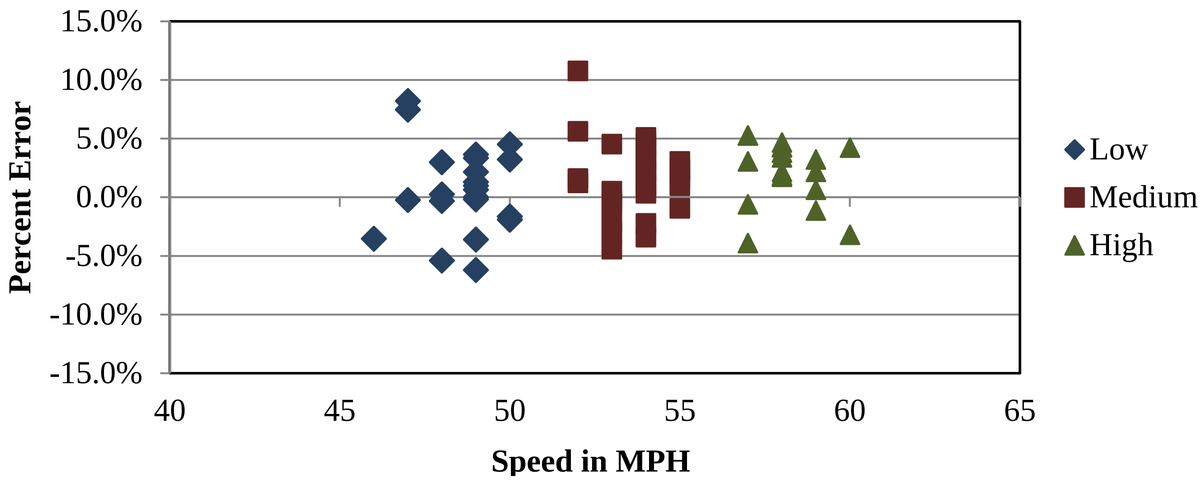


Figure 5-3 – Validation Tandem Axle Weight Errors by Speed – 18-Jun-13

5.3.1.4 Tridem Axle Weight Errors by Speed

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

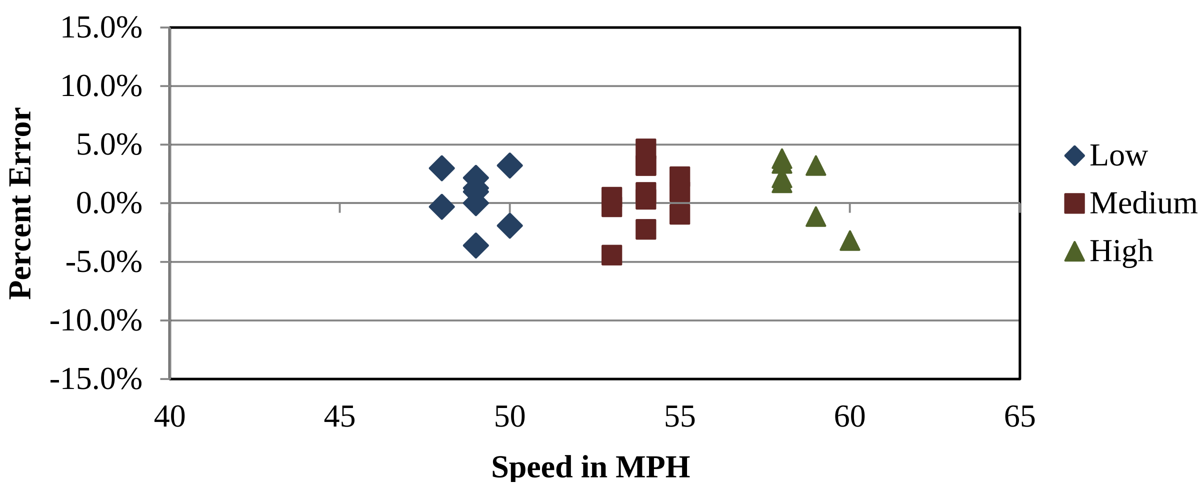


Figure 5-4 – Validation Tridem Axle Weight Errors by Speed – 18-Jun-13

5.3.1.5 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-5 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for all three trucks.

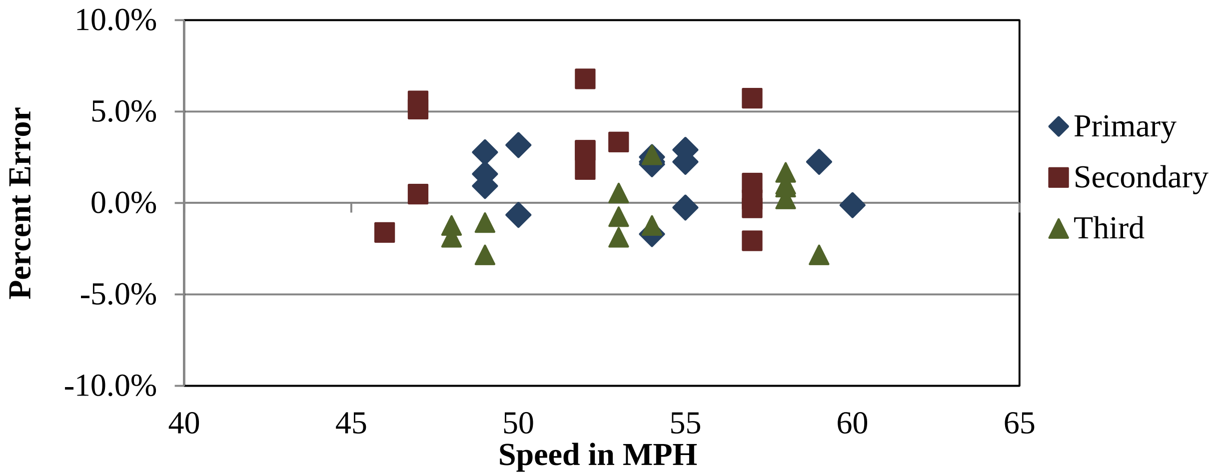


Figure 5-5 – Validation GVW Error by Truck and Speed – 18-Jun-13

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 was from -0.1 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-6.

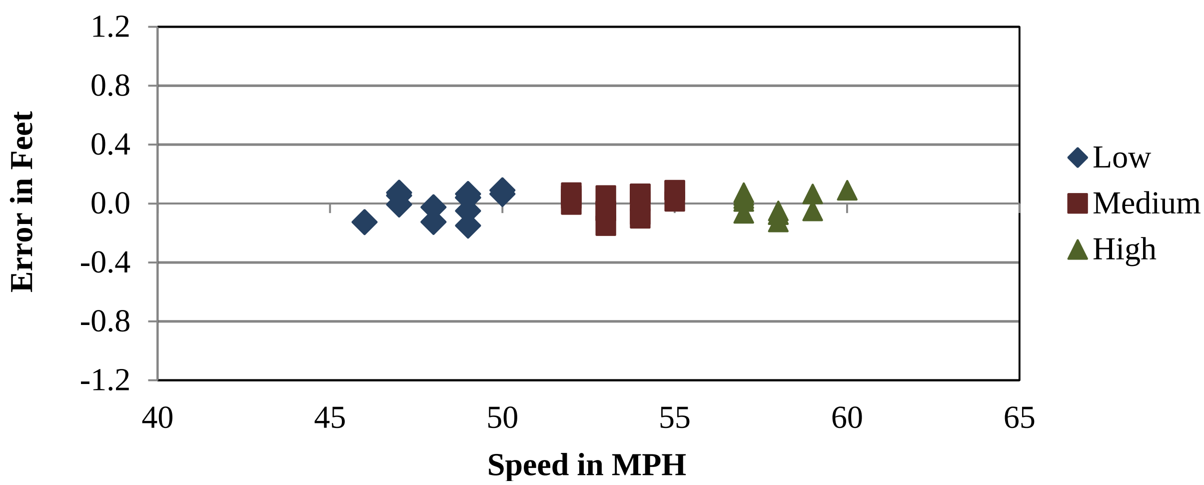


Figure 5-6 – Validation Axle Length Error by Speed – 18-Jun-13

5.3.1.7 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length consistently over the entire range of speeds, with errors ranging from -1.0 to 1.8 feet. Distribution of errors is shown graphically in Figure 5-7.

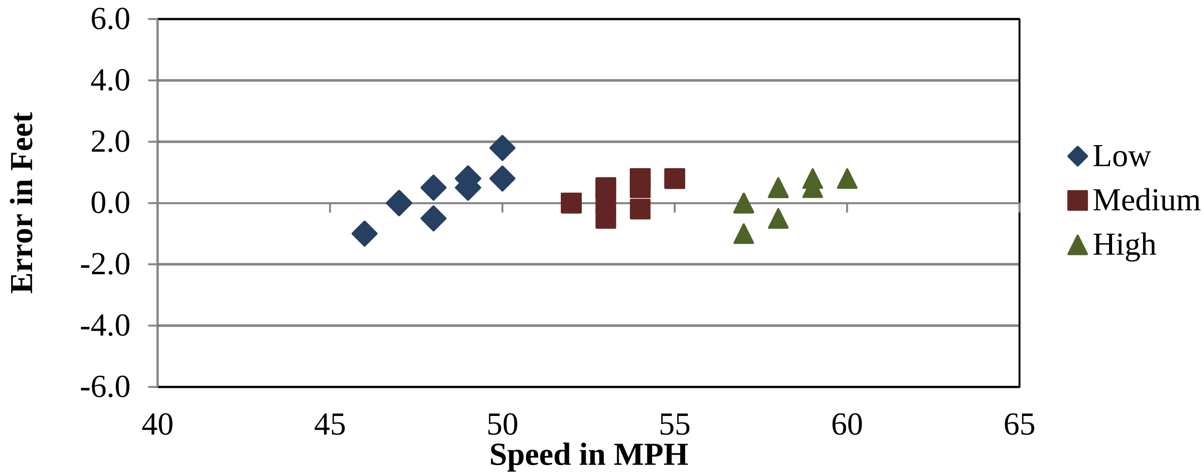


Figure 5-7 – Validation Overall Length Error by Speed – 18-Jun-13

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 11.2 degrees, from 66.3 to 77.5 degrees Fahrenheit. The validation test runs are reported under one temperature group – medium, as shown in Table 5-4 below.

Table 5-4 – Validation Results by Temperature – 18-Jun-13

Parameter	95% Confidence Limit of Error	Medium 66.3 to 77.5 degF
Steering Axles	±20 percent	-0.7 ± 13.8%
Single Axles	±20 percent	-0.7 ± 13.8%
Tandem Axles	±15 percent	1.3 ± 6.1%
Tridem Axles	±15 percent	1.6 ± 6.1%
Axle Groups	±15 percent	1.4 ± 6.1%
GVW	±10 percent	1.1 ± 4.7%
Vehicle Length	±3.0 percent (1.8 ft)	0.3 ± 1.1 ft
Vehicle Speed	± 1.0 mph	0.0 ± 2.5 mph
Axle Length	± 0.5 ft [150mm]	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 5-8, it can be seen that the equipment appears to estimate GVW with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

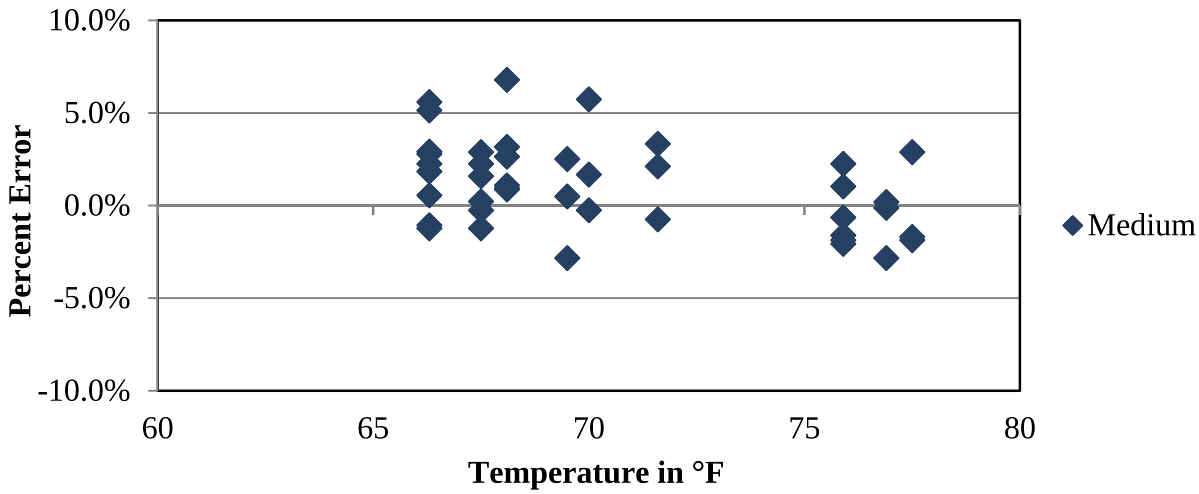


Figure 5-8 – Validation GVW Errors by Temperature – 18-Jun-13

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 demonstrates that for steering axles, the WIM equipment appears to estimate weights with similar accuracy across the range of temperatures observed in the field.

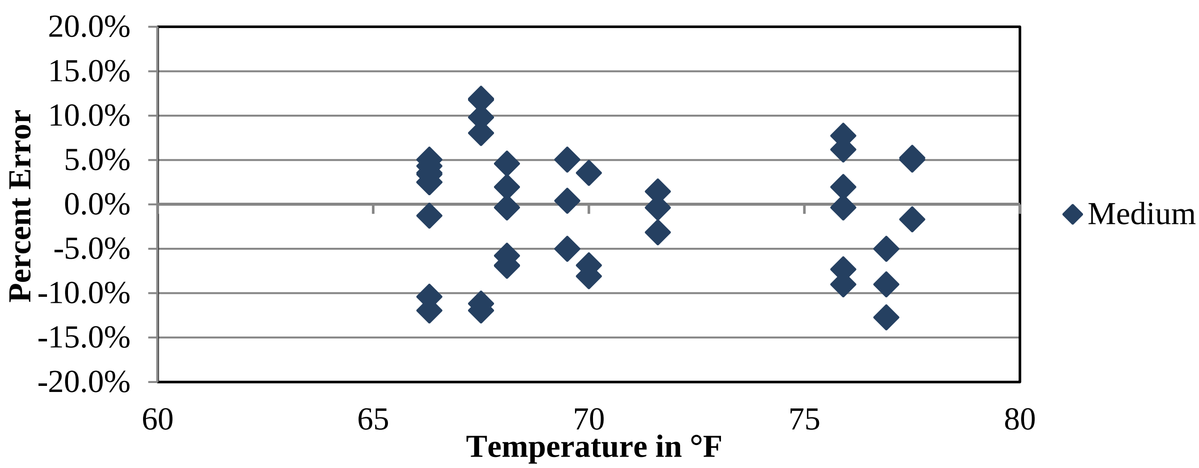


Figure 5-9 – Validation Steering Axle Weight Errors by Temperature – 18-Jun-13

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-10, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and tandem axle weight estimates at this site. The range in tandem axle errors is consistent for the range of temperatures observed.

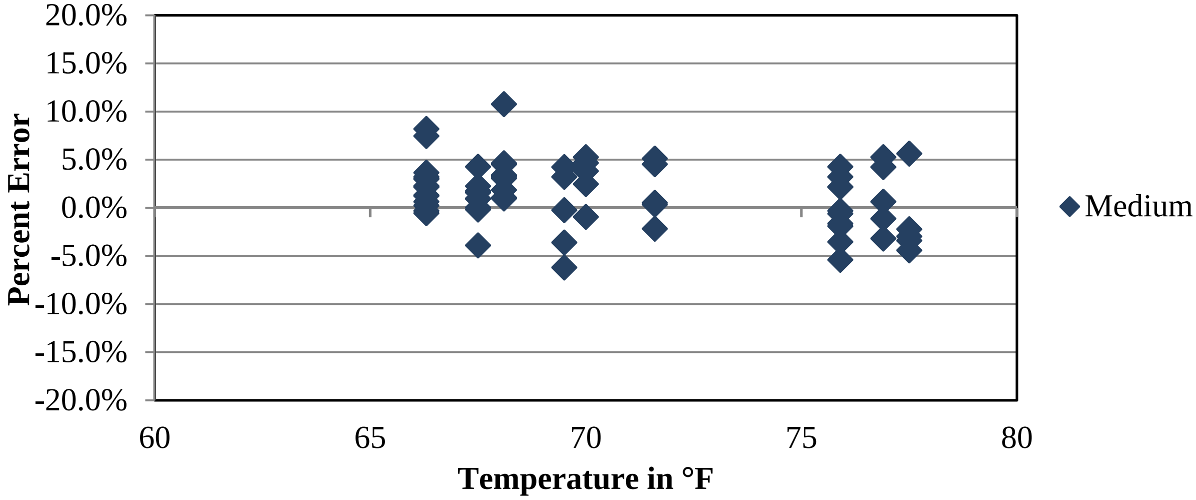


Figure 5-10 – Validation Tandem Axle Weight Errors by Temperature – 18-Jun-13

5.3.2.4 Tridem Axle Weight Errors by Temperature

As shown in Figure 5-11, the WIM equipment appears to estimate tridem axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and tridem axle weight estimates at this site.

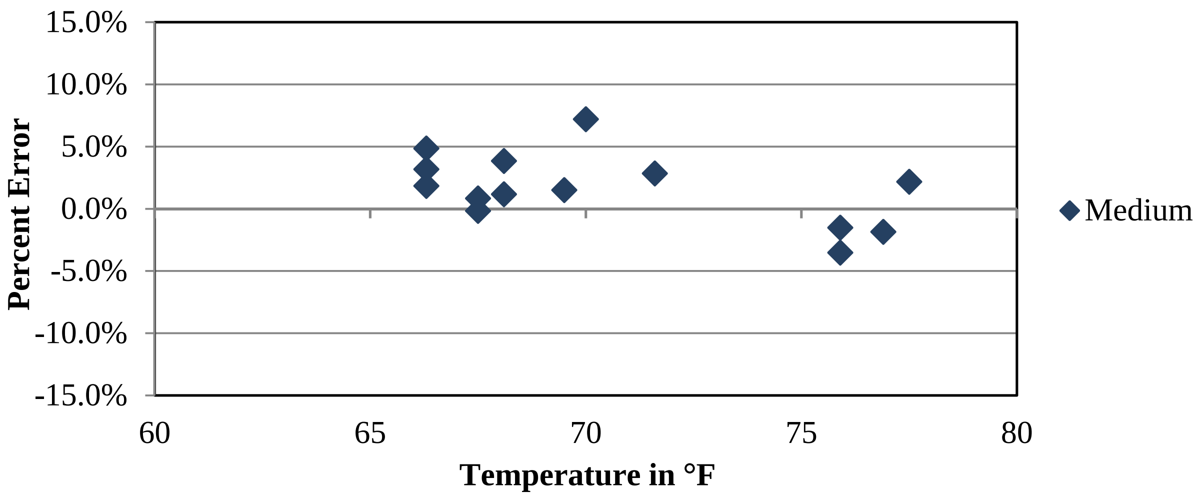


Figure 5-11 – Validation Tridem Axle Weight Errors by Temperature – 18-Jun-13

5.3.2.5 GVW Errors by Temperature and Truck Type

As shown in Figure 5-12, when analyzed by truck type, GVW measurement errors for all trucks are similar at all temperatures. For all trucks, the range of errors and bias are reasonably consistent over the range of temperatures.

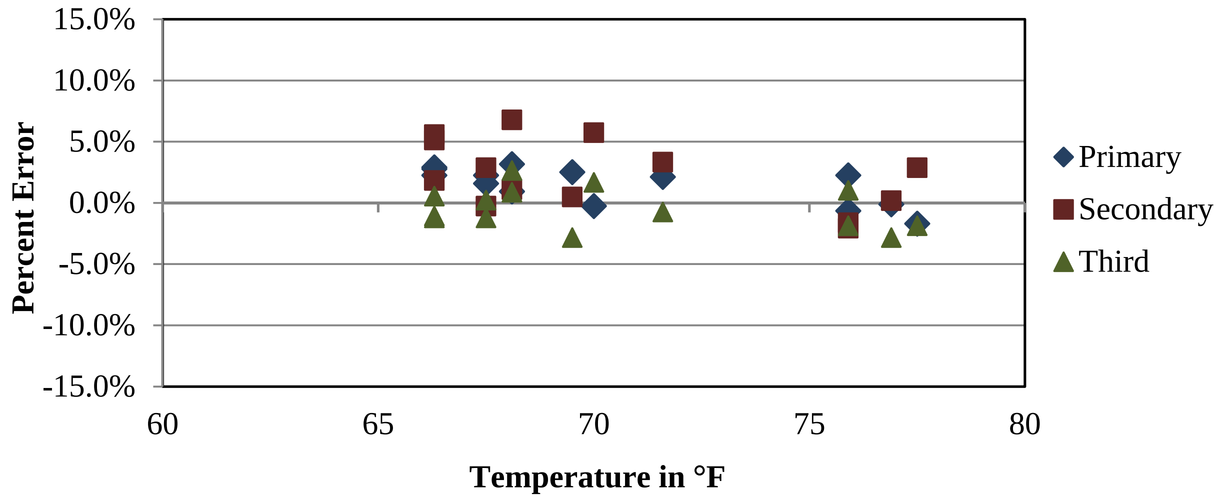


Figure 5-12 – Validation GVW Error by Truck and Temperature – 18-Jun-13

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 114 vehicles including 114 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 4 vehicle was misclassified as a Class 5 vehicle, one Class 5 vehicle was misclassified as a Class 4 vehicle, and five Class 5 vehicles were identified by the system as Class 8 vehicles. For heavy trucks, one Class 9 was misclassified as a Class 11.

Table 5-5 – Validation Misclassifications by Pair – 18-Jun-13

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

As shown in the table, a total of 8 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 7.0 percent, primarily due to the misclassification of lightweight vehicles in Class 3 through Class 5.

The causes for the misclassifications were not investigated in the field. A post-visit investigation of misclassified vehicles was performed using the collected video. The analysis is discussed in Section 6.2.

The combined results of the misclassifications resulted in an undercount of five Class 5 and one Class 9 vehicle, and an overcount of five Class 8 and one Class 11 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 – 18-Jun-13

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	0	1	19	1	0	3	60	20	0	3	7
WIM Count	0	1	14	1	0	8	59	20	1	3	7
Observed Percent	0.0	0.9	16.7	0.9	0.0	2.6	52.6	17.5	0.0	2.6	6.1
WIM Percent	0.0	0.9	12.3	0.9	0.0	7.0	51.8	17.5	0.9	2.6	6.1
Misclassified Count	0	1	6	0	0	0	1	0	0	0	0
Misclassified Percent	0.0	100	31.6	0.0	0.0	0.0	1.7	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. The unclassified vehicles by pair are provided in Table 5-7.

Table 5-7 – Validation Unclassified Trucks by Pair – 18-Jun-13

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

Based on the manually collected sample of the 114 trucks, 0.0 percent of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was -0.8 mph; the range of errors was 2.8 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 1.1 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 5-8.

Table 5-8 – Final Factors

Speed Point	MPH	Left	Right
		1	2
80	50	6.188480	6.188480
100	62	6.210766	6.210766
120	75	6.539214	6.539214
Axle Distance (cm)		119	
Dynamic Comp (%)		107	
Loop Width (cm)		102	

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 46 to 60 mph.
- Pavement temperature. Pavement temperature ranged from 66.3 to 77.5 degrees Fahrenheit.

6.1.2 Results

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

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

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value (p-value)
Intercept	17.2761	6.9237	2.4952	0.0173
Speed	0.0497	0.0900	0.5528	0.5838
Temp	-0.2528	0.0858	-2.9471	0.0056
Truck	-0.9968	0.4038	-2.4687	0.0184

The lowest probability value given in Table 6-1 was 0.0184 for truck type. This means that there is about a 2 percent chance that the value of regression coefficient for truck (-0.9968) can occur by chance alone. This relationship is further investigated in Section 6.1.5. Changes in temperature also showed statistically significant effect on changes in GVW measurement error.

The relationship between pavement temperature and measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 6-1 provides quantification and statistical assessment of the relationship. The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.2528 (in Table 6-1). This means, for example, that for a 10-degree increase in temperature, the error is decreased by about 2.5 percent (-0.2528 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0056) and is statistically significant (values equal or less than 0.05 indicate statistical significance in this case).

Changes in speed did not showed statistically significant effect on changes in GVW measurement error.

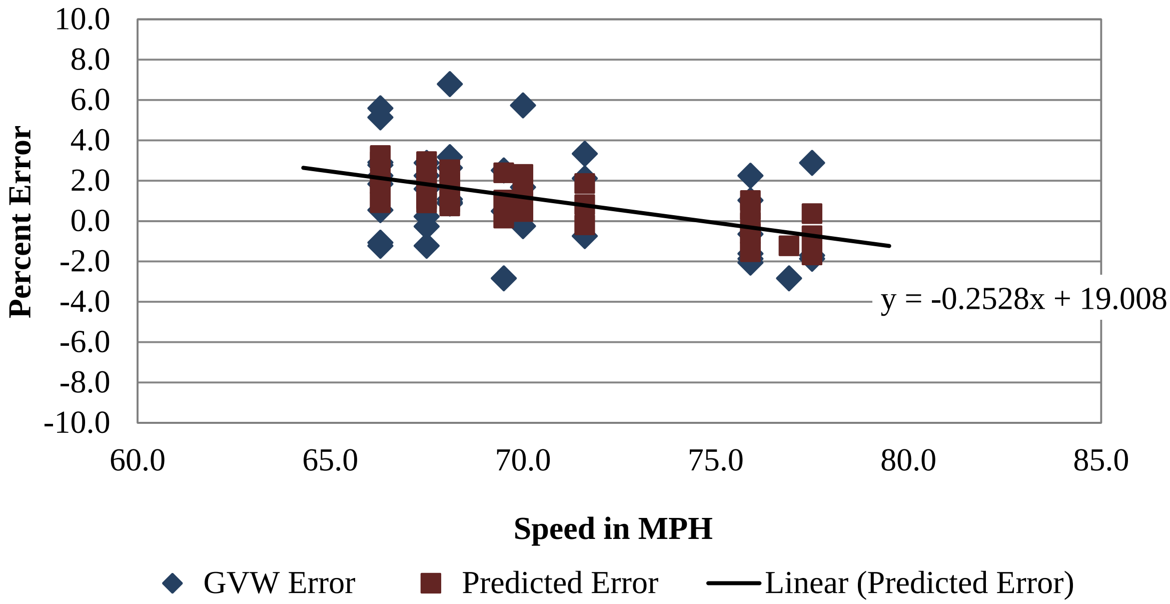


Figure 6-1 – Influence of Temperature on the Measurement Error of GVW

6.1.3 Summary Results

Table 6-2 lists regression coefficients and their probability values for all combinations of factors and % 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	-	-	-0.2528	0.0056	-0.9968	0.0184
Steering axle	-0.5713	0.0437	-	-	-2.5566	0.0442
Tandem axle tractor	0.2639	0.0222	-0.3424	0.0015	-	-
Tandem axle trailer	0.2065	0.1694	-0.3330	0.0232	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on the measurement errors of steering axles and on tractor tandem axles. However, while the effect of speed was statistically significant, the size of the effect was small as indicated by low values of regression coefficients.

2. Temperature affected measurement error of all axles except the steering axles. The regression coefficients ranged from for -0.3423 for tandem axles on trailers to -0.2528 for GVW. However, the regression coefficients were small and the range of temperature was only 11.2 degrees Fahrenheit.

3. Truck type had statistically significant effect on measurement errors of GVW and steering axles. Truck type was modeled with an indicator variable with values of 0, 1 or 2 (for Primary, Secondary and Third truck types respectively).

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 Three 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 three 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, Secondary or Third) was used?

The contribution of using Primary, Secondary and Third 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 is not considered in this analysis.

Figure 6-2 shows that speed had a similar influence on the GVW measurement errors for the two Class 9 trucks, Primary and Secondary (decreasing error with the increasing speed). The Third truck showed increasing errors with speed. However, none of the three trends shown in Figure 6.2 was statistically significant as indicated by the low R-square values. The system compensation factors (used for calibration) are based on the combined and averaged GVW measurements obtained for the Primary, Secondary and Third trucks. Thus, the figure illustrates that use of the Third truck resulted in a slight reduction of the average measurement error (1.4 percent in Table 1-1).

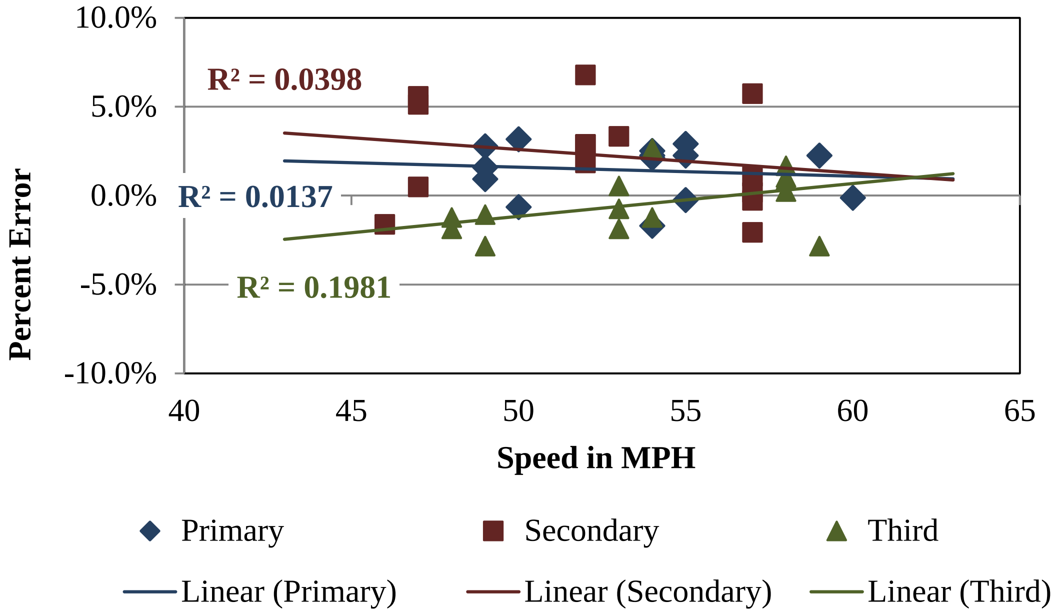


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary, Secondary and Third Trucks

The use of three 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 about 20 calibration runs would have been sufficient to verify the WIM operation.

More detailed analysis of the influence of calibration trucks on the verification/calibration results would be beneficial. In this case, the Secondary Truck's axle configuration and suspension was different from the Primary and Third Truck's axle and suspension systems.

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 8 vehicles, including 1 heavy truck (6 – 13) was misclassified by the equipment. The single truck misclassification was a Class 9 which was identified by the WIM system as a Class 11 vehicle. According to the Sheet 20, this vehicle was vehicle number 4518. The capture of the real-time record for vehicle 4518 is provided in Figure 6-3.

```
(4518) LANE NB_DRIVE  TYPE 11  GVW 40.6 kips  LENGTH 70 ft
18-K ESAL 0.634  SPEED 64 mph  MAX GVW 88.5 kips  Tue Jun 18 14:56:27.38 2013
      19.4        21.1      4.5      20.3
  o----------o-----------o----o------------*
 1.9       3.0          12.0  9.5         14.3
```

Figure 6-3 – Vehicle Record 4518

The video capture of vehicle 4518 is provided in Photo 6-1. As the photo illustrates, the misclassification involved a 3-axle power unit that was towing a 2-axle trailer.

Photo 6-1 – Video Capture of Vehicle 4518

6.3 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	
28-Nov-06	-	-	-	0	0	50	0	0	0	0	0	0
29-Nov-06	-	-	0	0	-	50	0	0	-	0	0	0
11-Jul-07	-	-	-	0	-	-	0	0	0	-	-	0
12-Jul-07	-	-	-	0	-	0	0	0	0	-	-	0
22-Apr-08	-	0	33	0	-	50	2	4	0	-	-	0
23-Apr-08	-	100	33	100	-	25	2	11	0	-	-	0
29-Mar-11	-	0	0	38	0	0	0	0	0	0	0	0
30-Mar-11	-	0	0	50	17	0	0	0	0	0	0	0
1-May-12	64	100	48	33	0	0	0	5	0	0	0	0
2-May-12	78	0	71	0	0	0	0	7	0	0	0	0
18-Jun-13	0	100	32	0	0	0	1.7	9.1	100	50.0	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-validations.

Table 7-2 – Weight Validation History

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
28-Nov-06	-6.0 ± 8.6	-12.9 ± 7.3	-4.5 ± 11.7
29-Nov-06	0.3 ± 6.4	-3.7 ± 11.5	1.2 ± 8.4
11-Jul-07	11.7 ± 5.0	6.2 ± 13.3	12.7 ± 6.4
12-Jul-07	-1.0 ± 4.7	0.6 ± 11.2	-1.2 ± 5.7
22-Apr-08	-3.3 ± 4.7	-2.8 ± 9.3	-3.2 ± 7.1
23-Apr-08	1.2 ± 6.9	3.2 ± 9.7	1.0 ± 9.6
29-Mar-11	5.3 ± 7.9	4.8 ± 14.4	5.3 ± 10.9
30-Mar-11	1.0 ± 7.6	-0.4 ± 14.2	0.1 ± 7.9
1-May-12	5.1 ± 7.6	1.0 ± 14.5	4.3 ± 10.6
2-May-12	2.1 ± 7.7	-3.8 ± 11.9	1.7 ± 12.1
18-Jun-13	1.1 ± 4.7	-0.7 ± 13.8	1.3 ± 6.1

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. However, the 95% confidence interval has been increasing with time, possibly reflecting the increase in pavement roughness at the WIM site. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an underestimation of GVW over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

8 Additional Information

The following information is provided in the attached appendix:

- Site Photographs
  - Equipment
  - Test Trucks
  - Pavement Condition
- 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

Washington, SPS-2
SHRP ID: 530200

Validation Date: June 18, 2013

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Front)

Photo 3 – Leading Loop Sensor

Photo 4 – Leading WIM Sensor

Photo 5 – Trailing WIM Sensor

Photo 6 – Trailing Loop Sensor

Photo 7 – Power Service Box

Photo 8 – Telephone Service Box

Photo 9 – Downstream

Photo 10 – Upstream

Photo 11 – Truck 1

Photo 12 – Truck 1 Tractor

Photo 13 – Truck 1 Trailer and Load

Photo 14 – Truck 1 Suspension 1

Photo 15 – Truck 1 Suspension 2

Photo 16 – Truck 1 Suspension 3

Photo 17 – Truck 1 Suspension 4

Photo 18 – Truck 1 Suspension 5

Photo 19 – Truck 2

Photo 20 – Truck 2 Tractor

Photo 21 – Truck 2 Trailer and Load

Photo 22 – Truck 2 Suspension 1

Photo 23 – Truck 2 Suspension 2

Photo 24 – Truck 2 Suspension 3

Photo 25 – Truck 2 Suspension 4

Photo 27 – Truck 2 Suspension 6

Photo 26 – Truck 2 Suspension 5

Photo 29 – Truck 3

Photo 27 – Truck 3 Tractor

Photo 30 – Truck 3 Trailer and Load

Photo 31 – Truck 3 Suspension 1

Photo 32 – Truck 3 Suspension 2

Photo 33 – Truck 3 Suspension 3

Photo 34 – Truck 3 Suspension 4

Photo 35 – Truck 3 Suspension 5

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 53 SPS WIM ID: 530200 DATE (mm/dd/yyyy) 6/18/2013

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 6/18/13

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

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

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

5. **EQUIPMENT MANUFACTURER:** IRD 1060 Series

WIM SYSTEM CALIBRATION SPECIFICS

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

Number of Trucks Compared:
Number of Test Trucks Used: 3
Passes Per Truck: 14

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	steel spring	air
Truck 2:	10	steel spring	air
Truck 3:	9	steel spring	air

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

Mean Difference Between -

Dynamic and Static GVW:	1.1%	Standard Deviation:	2.3%
Dynamic and Static Single Axle:	-0.7%	Standard Deviation:	6.8%
Dynamic and Static Double Axles:	1.3%	Standard Deviation:	3.0%

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

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

			Low		High	Runs
a.	Low	-	46.0	to	50.7	13
b.	Medium	-	50.8	to	55.4	17
c.	High	-	55.5	to	60.0	12
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 53 SPS WIM ID: 530200 DATE (mm/dd/yyyy) 6/18/2013

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 6.539214 | 6.539214

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

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

CLASSIFIER TEST SPECIFICS

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

Manual

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

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	0.0	FHWA Class	5	-	-26.0
FHWA Class 8:	167.0	FHWA Class	10	-	-9.0
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 53 SPS WIM ID: 530200 DATE (mm/dd/yyyy) 6/18/2013

Count - 114 Time = 2:13:58 Trucks (4-15) - 114 Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	9	3315	61	9	60	9	3636	63	9
60	10	3328	63	10	61	9	3664	64	9
61	5	3325	51	5	63	9	3667	63	9
61	9	3366	63	9	62	9	3669	54	9
57	13	3368	59	13	62	9	3678	62	9
56	10	3378	54	10	60	9	3680	60	9
64	9	3386	64	9	59	9	3683	59	9
61	9	3399	61	9	50	5	3689	51	5
61	10	3440	62	10	60	9	3704	60	9
57	10	3444	61	10	62	10	3715	62	10
62	12	3446	64	12	59	10	3727	60	10
62	10	3456	61	10	58	10	3728	58	10
62	**8**	**3459**	**61**	**5**	61	9	3740	63	9
60	13	3469	61	13	**62**	**8**	**3759**	**63**	**5**
61	10	3502	53	10	61	9	3763	63	9
59	5	3513	60	5	59	9	3773	60	9
63	9	3523	69	9	58	13	3788	60	13
64	5	3529	67	5	58	9	3790	59	9
61	9	3545	65	9	59	8	3817	59	8
59	10	3560	61	10	61	9	3832	62	9
55	9	3595	59	9	62	5	3835	62	5
59	9	3603	61	9	62	10	3842	65	10
59	9	3609	64	9	60	10	3850	61	10
62	9	3625	63	9	60	9	3860	61	9
61	8	3629	61	8	63	9	3932	66	9

Sheet 1 - 0 to 50 Start: 12:44:01 Stop: 13:49:15

Recorded By: kt Verified By: djw

Validation Test Truck Run Set - Pre

Traffic Sheet 20	
LTPP MONITORED TRAFFIC DATA	STATE CODE: 53
SPEED AND CLASSIFICATION STUDIES	SPS WIM ID: 530200
	DATE (mm/dd/yyyy) 6/18/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
68	5	3954	67	5	59	10	4195	61	10
55	5	3995	55	5	60	10	4206	60	10
60	8	3999	56	8	61	13	4209	60	13
63	9	4003	66	9	59	9	4221	59	9
56	12	4012	58	12	57	13	4266	58	13
61	13	4019	60	13	**62**	**8**	**4272**	**62**	**5**
60	5	4030	70	5	64	9	7286	64	9
58	9	4042	61	9	62	9	4298	68	9
59	10	4045	62	10	60	10	4311	62	10
60	9	4046	59	9	62	9	4326	62	9
62	9	4047	59	9	61	9	4327	60	9
62	9	4054	63	9	60	10	4345	61	10
60	9	4060	61	9	**56**	**8**	**4356**	**58**	**5**
61	9	4061	62	9	60	9	4376	60	9
63	9	4065	64	9	59	9	4384	61	9
60	9	4072	61	9	**62**	**5**	**4388**	**63**	**4**
61	9	4125	63	9	61	9	4396	64	9
59	9	4129	55	9	56	9	4405	58	9
60	9	4138	63	9	73	5	4431	74	5
62	12	4141	68	12	63	9	4458	64	9
60	9	4152	61	9	54	9	4464	53	9
57	**8**	**4166**	**54**	**5**	63	9	4489	63	9
59	9	4170	60	9	62	9	4503	64	9
60	9	4174	58	9	**64**	**11**	**4518**	**69**	**9**
60	**4**	**4184**	**59**	**5**	60	9	4545	61	9

Sheet 2 - 51 to 100 Start: 13:51:26 Stop: 14:57:59

Recorded By: kt djw

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 53 SPS WIM ID: 530200 DATE (mm/dd/yyyy) 6/18/2013

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
59	13	4555	59	13					
57	6	4600	59	6					
60	10	4623	62	10					
61	5	4633	63	5					
62	5	4640	56	5					
55	10	4656	61	10					
60	9	4665	59	9					
59	9	4666	59	9					
62	5	4676	63	5					
60	9	4682	61	9					
61	5	4694	53	5					
60	9	4640	62	9					
59	9	4644	61	9					
61	10	4746	61	10					

Sheet 3 - 76 to 150 Start: ____________ Stop: ____________

Recorded By: kt djw

Validation Test Truck Run Set - Pre