WIM System Field Calibration and Validation Summary Report

Indiana SPS-6
SHRP ID – 180600

Validation Date: March 7, 2012
Submitted: March 23, 2012

Table of Contents

List of Figures

List of Tables

1 Executive Summary

A WIM validation was performed on March 6 and 7, 2012 at the Indiana SPS-6 site located on route US-31, milepost 216.9, 8.5 miles south of US 30.

This site was installed on July 1, 2008. The in-road sensors are installed in the northbound, righthand driving lane. The site is equipped with quartz 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 November 4, 2010 and this validation visit, it appears that two of the WIM sensors have degraded beyond tolerances and were disabled from the system. No other changes have occurred during this time to the basic operating condition of the equipment. It is recommended that the two degraded sensors be replaced to improve the performance of the WIM system.

With the exception of the two disabled sensors, the equipment is in working order. Electronic and electrical checks of the remaining WIM components determined that the the equipment is operating within the manufacturer's tolerances. Two functioning in-road sensors don't 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. However, based on additional observations and trend analysis, there may be a potential for increase in weight measurement bias with speed increase.

Table 1-1 – Post-Validation Results – 7-Mar-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	0.1 ± 11.5%	Pass
Tandem Axles	±15 percent	0.8 ± 7.9%	Pass
GVW	±10 percent	0.6 ± 6.8%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.4 ± 0.7 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 -0.2 ± 5.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations

Guide for SPS WIM Sites. However, since the site is measuring axle spacing length 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 similar ranges.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 1.2% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 3.8% from the 105 vehicle sample (Class 4 – 13) was due to the 26 cross-classifications of Class 3, 4, 5, and 8 vehicles.

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

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

- 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 standard tandem on the trailer. The Secondary truck was loaded with a forklift and steel products

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 7). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Axle spacings were measured from the center hub of the each axle to the center hub of the subsequent axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average post-validation test truck weights and measurements are provided in Table 1-2.

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.4	10.4	14.9	14.9	18.6	18.6	18.0	4.3	31.2	4.3	57.8	62.4
2	65.7	10.5	13.7	13.7	13.9	13.9	18.8	4.4	30.9	4.0	58.1	69.6

The posted speed limit at the site is 60 mph. During the testing, the speed of the test trucks ranged from to 49 to 60 mph, a variance of 11 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 68.0 to 77.3 degrees Fahrenheit, a range of 9.3 degrees Fahrenheit. The mild weather conditions on the second day prevented the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 25 shows that there are 3 years of level "E" WIM data for this site. This site requires 2 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 January 30, 2012 (Data) to the most recent Comparison Data Set (CDS) from December 6, 2010. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 25 shows that there are 3 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2008 to 2011.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2008	163	6
2009	364	12
2010	354	12
2011	270	10

As shown in the table, this site requires 2 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 2008.

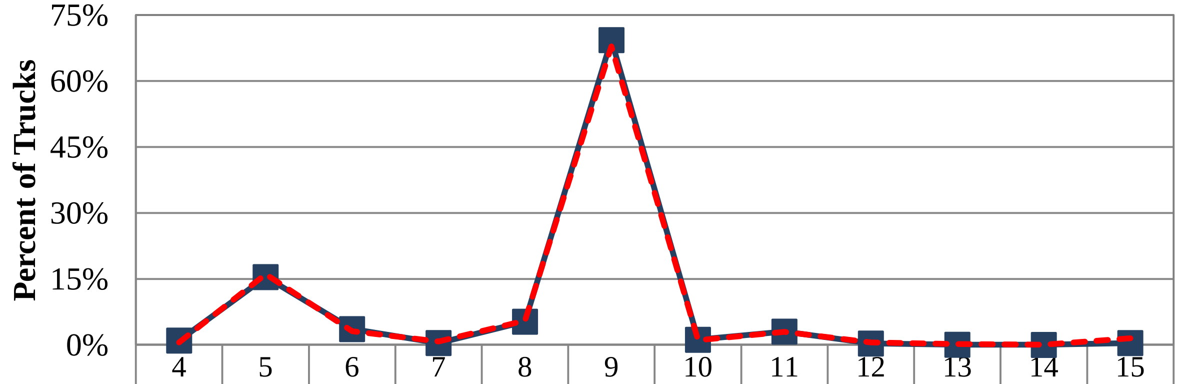
Table 2-2 provides a monthly breakdown of the available data for years 2008 through 2011.

Table 2-2 – LTPP Data Availability by Month

Year	Month												No. of Months
	1	2	3	4	5	6	7	8	9	10	11	12	
2008							14	31	28	29	30	31	6
2009	31	28	31	30	31	30	30	31	30	31	30	31	12
2010	31	28	31	29	31	24	31	30	29	31	28	31	12
2011	29	26	31	30	31	30	31	31	29	2			10

2.2 Classification Data Analysis

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



	4	5	6	7	8	9	10	11	12	13	14	15
Data	1.0%	15.4%	3.6%	0.4%	5.3%	69.3%	1.2%	3.0%	0.3%	0.0%	0.0%	0.4%
CDS	0.5%	16.1%	3.1%	0.8%	5.5%	67.8%	1.0%	2.9%	0.6%	0.2%	0.0%	1.5%

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 most frequent truck types crossing the WIM scale are Class 9 (69.3%) and Class 5 (15.4%). 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.

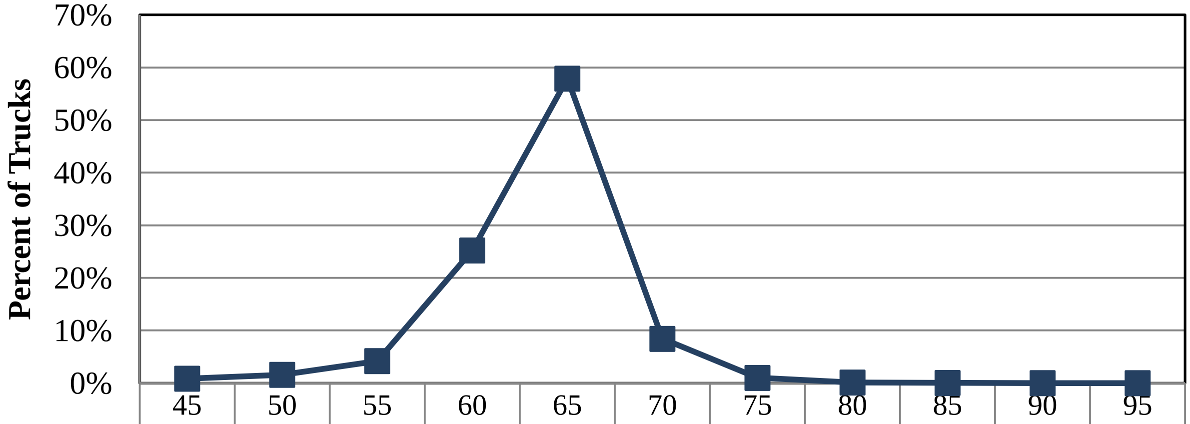
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	12/6/2010		1/30/2012		
4	82	0.5%	154	1.0%	0.5%
5	2505	16.1%	2404	15.4%	-0.7%
6	481	3.1%	560	3.6%	0.5%
7	117	0.8%	67	0.4%	-0.3%
8	859	5.5%	823	5.3%	-0.2%
9	10558	67.8%	10803	69.3%	1.5%
10	158	1.0%	182	1.2%	0.2%
11	455	2.9%	471	3.0%	0.1%
12	89	0.6%	49	0.3%	-0.3%
13	26	0.2%	6	0.0%	-0.1%
14	0	0.0%	0	0.0%	0.0%
15	233	1.5%	66	0.4%	-1.1%

From the table it can be seen that the number of Class 9 vehicles has increased by 1.5 percent from December 2010 to January 2012. Changes in the number of heavier trucks may be attributed to natural and seasonal variations in truck distributions and an increase in goods movement during current economic cycle. During the same time period, the number of Class 5 trucks increased by 0.7 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, 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 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	0.9%	1.6%	4.2%	25.2%	57.9%	8.4%	1.0%	0.1%	0.0%	0.0%	0.0%

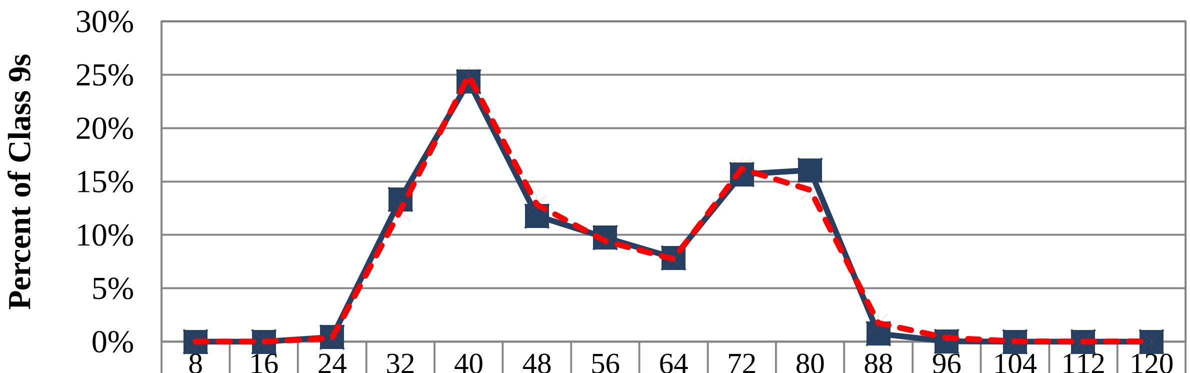
Figure 2-2 – Truck Speed Distribution – 17-Jan-12

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.

2.4 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 January 2012 and the Comparison Data Set from December 2010.

As shown in Figure 2-3, the December 2010 Comparison Data Set (CDS) and the January 2012 two-week sample W-card dataset (Data) are nearly identical.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.4%	13.3	24.4	11.8	9.8%	7.9%	15.7	16.1	0.8%	0.0%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.3%	12.3	24.9	12.8	9.4%	7.7%	16.2	14.2	1.7%	0.4%	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

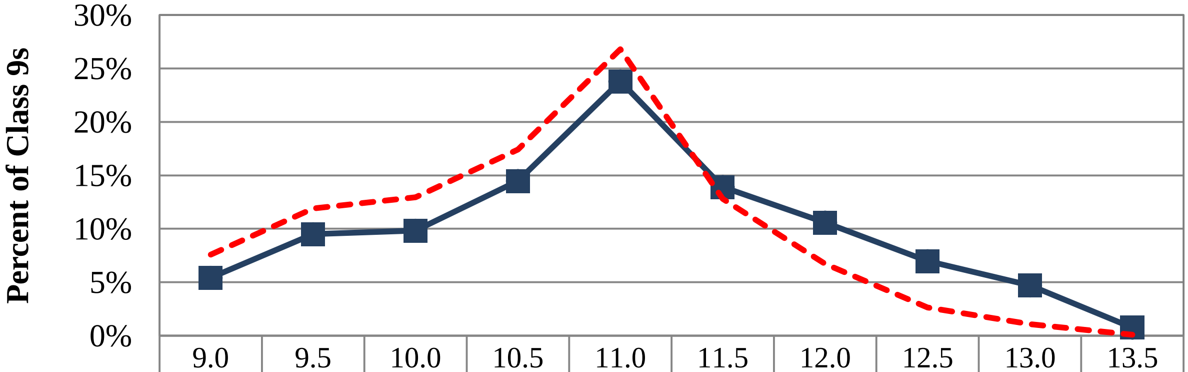
GVW weight bins (kips)	CDS		Data		Change
	Date				
	12/6/2010		1/30/2012		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	34	0.3%	46	0.4%	0.1%
32	1294	12.3%	1438	13.3%	1.1%
40	2626	24.9%	2627	24.4%	-0.5%
48	1354	12.8%	1269	11.8%	-1.1%
56	991	9.4%	1052	9.8%	0.4%
64	815	7.7%	847	7.9%	0.1%
72	1708	16.2%	1690	15.7%	-0.5%
80	1497	14.2%	1732	16.1%	1.9%
88	182	1.7%	82	0.8%	-1.0%
96	38	0.4%	3	0.0%	-0.3%
104	2	0.0%	0	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	3	0.0%	0	0.0%	0.0%
Average =	51.3 kips		51.0 kips		-0.3 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 0.5 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range increased by 1.9 percent. During this time period the number of overweight trucks decreased by 1.3 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site decreased by 0.6 percent, from 51.3 to 51.0 kips.

2.5 Class 9 Front Axle Weight Data Analysis

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

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from January 2012 and the Comparison Data Set from December 2010. The percentage of light axles (9.5 to 10.5 kips) decreased by approximately 3.2 percent and the percentage of heavy axles (12.0 to 12.5 kips) increased by approximately 4.3 percent, 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	5.4%	9.5%	9.8%	14.5%	23.8%	13.9%	10.6%	7.0%	4.7%	0.8%
CDS	7.6%	11.9%	13.0%	17.4%	26.8%	12.8%	6.7%	2.6%	1.1%	0.1%

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

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 10.5 and 11.5 kips. The percentage of trucks in this range has decreased between the December 2010 Comparison Data Set (CDS) and the January 2012 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the December 2010 Comparison Data Set (CDS) and the January 2012 dataset (Data).

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

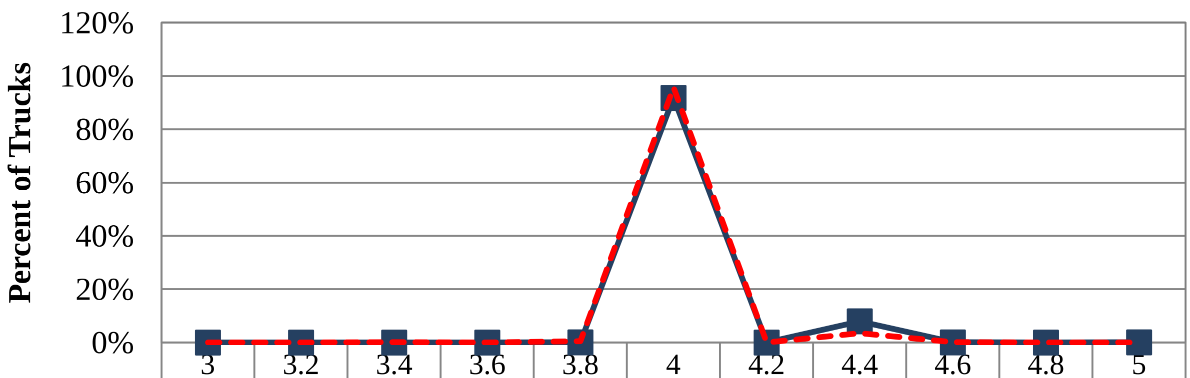
F/A weight bins (kips)	CDS		Data		Change
	Date				
	12/6/2010		1/30/2012		
9.0	798	7.6%	583	5.4%	-2.2%
9.5	1251	11.9%	1021	9.5%	-2.4%
10.0	1364	13.0%	1056	9.8%	-3.1%
10.5	1833	17.4%	1556	14.5%	-2.9%
11.0	2821	26.8%	2557	23.8%	-3.0%
11.5	1347	12.8%	1496	13.9%	1.1%
12.0	708	6.7%	1138	10.6%	3.9%
12.5	278	2.6%	750	7.0%	4.3%
13.0	113	1.1%	507	4.7%	3.6%
13.5	9	0.1%	82	0.8%	0.7%
Average =	10.4 kips		10.7 kips		0.3 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.3 kips, or 2.9 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 10.7.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

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

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



	3	3.2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5
Data	0.0%	0.0%	0.0%	0.0%	0.1%	91.8%	0.0%	8.0%	0.1%	0.0%	0.1%
CDS	0.0%	0.0%	0.1%	0.0%	0.4%	95.7%	0.0%	3.5%	0.2%	0.0%	0.0%

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

As seen in the figure, the Class 9 tractor tandem spacings for the December 2010 Comparison Data Set and the January 2012 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				
	12/6/2010		1/30/2012		
3.0	1	0.0%	0	0.0%	0.0%
3.2	1	0.0%	0	0.0%	0.0%
3.4	10	0.1%	0	0.0%	-0.1%
3.6	0	0.0%	0	0.0%	0.0%
3.8	47	0.4%	9	0.1%	-0.4%
4.0	10094	95.7%	9901	91.8%	-3.9%
4.2	0	0.0%	0	0.0%	0.0%
4.4	373	3.5%	860	8.0%	4.4%
4.6	18	0.2%	7	0.1%	-0.1%
4.8	0	0.0%	0	0.0%	0.0%
5.0	1	0.0%	9	0.1%	0.1%
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 4.6 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.0, which is identical to the expected average of 4.0 from the CDS per vehicle records. Further axle spacing analyses are performed during the validation and post-validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (December 2010) based on the last calibration with the most recent two-week WIM data sample from the site (January 2012). Comparison of vehicle class distribution data indicates a 1.5 percent increase in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 2.9 percent and average Class 9 GVW has decreased by 0.6 percent for the January 2012 data. The data indicates an average truck tandem spacing of 4.0, which is identical the expected average of 4.0.

Disclaimer - This section was compiled before the visit under the assumption that a four sensor array was being used. However, during field validation, it was discovered that only two sensors were working and the non-working sensors were disabled. Further, it was discovered that the channel assignments of the two remaining sensors was incorrect, and so weight measurements from only one sensor were being used. Consequently, the data comparison of weights performed prior to the visit, when all four sensors were being used, are not applicable based on the current WIM system setup because the results of the data comparison conducted prior to the visit were found to not be representative of the current WIM system weight measurements.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on November 4, 2010 and this validation visit, it appears that two of the WIM sensors have been disabled from the system. This was performed on December 8, 2010 and was due to the sensors degrading beyond manufacture's operating tolerances. The sensors that were disabled were the leading sensor in the left wheel path (sensor 1 for the WIM system), and the trailing sensor in the right wheel path (sensor 4 for the WIM system). No other changes have occurred during this time to the basic operating condition of the equipment.

3.1 Description

This site was installed on July 1, 2008 by International Road Dynamics. It is instrumented with quartz 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 after Section 7.

3.3 Electronic and Electrical Testing

Electronic and electrical checks of all system components were conducted prior to the pre-validation test truck runs. Dynamic and static electronic checks of the in-road sensors were performed. All values for the two working WIM sensors and the 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

It is recommended that the degraded WIM sensors be replaced to improve weight measurement accuracies. No other 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, distress was noted at a location 12 feet prior to the WIM scales. No adverse truck dynamics were noted in this area. The distress did not appear to affect the accuracy of the WIM sensors.

Photo 4-1 – Pavement Distress 12 Feet Prior to WIM

As a result of the pavement interaction study, where bouncing was detected at a location approximately 730 feet prior to the WIM scales, a specific pavement condition survey in this area was performed. As shown in the photos below, a small bump in the pavement was noted at this location. The truck dynamics caused by the bump appeared to diminish prior to the trucks crossing over the WIM scales.

Photo 4-2 – Pavement Distress 730 Feet Prior to WIM

Photo 4-3 – Pavement Distress 730 Feet Prior to WIM

4.2 Profile and Vehicle Interaction

Profile data was collected on March 28, 2011 by the North Central Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, beginning 900 feet prior to WIM scales and ending 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 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 433 in/mi and is located approximately 737 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 138 in/mi and is located approximately 12 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.

4.3 LTPP Pavement Profile Data Analysis

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

Table 4-1 – Recommended WIM Smoothness Index Thresholds

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

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

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

Table 4-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass 5**	**Avg**
Left	LWP	LRI (m/km)	0.578	0.592	0.609			0.593
		SRI (m/km)	*0.301*	*0.381*	*0.486*			*0.389*
		Peak LRI (m/km)	0.947	0.867	0.790			0.868
		Peak SRI (m/km)	*0.413*	*0.495*	*0.584*			*0.497*
	RWP	LRI (m/km)	0.773	0.786	0.801			0.787
		SRI (m/km)	1.893	1.902	**2.119**			1.971
		Peak LRI (m/km)	0.773	0.786	0.801			0.787
		Peak SRI (m/km)	2.092	2.044	2.386			2.174
Center	LWP	LRI (m/km)	0.805	0.676	0.736	0.658	0.810	0.737
		SRI (m/km)	0.558	0.620	*0.453*	0.643	0.505	0.556
		Peak LRI (m/km)	0.811	0.676	0.736	0.658	0.812	0.739
		Peak SRI (m/km)	1.083	0.978	1.080	0.939	1.467	1.109
	RWP	LRI (m/km)	0.981	1.012	0.943	0.975	0.940	0.970
		SRI (m/km)	**2.439**	**2.368**	**2.474**	**2.400**	**2.422**	**2.421**
		Peak LRI (m/km)	0.981	1.012	0.943	0.975	0.940	0.970
		Peak SRI (m/km)	2.758	2.810	2.862	2.774	**2.965**	2.834
Right	LWP	LRI (m/km)	0.674	0.680	0.673			0.676
		SRI (m/km)	0.643	0.625	0.644			0.637
		Peak LRI (m/km)	0.674	0.680	0.673			0.676
		Peak SRI (m/km)	0.818	0.849	0.828			0.832
	RWP	LRI (m/km)	0.958	1.031	0.979			0.989
		SRI (m/km)	***2.358***	***2.533***	***2.444***			***2.445***
		Peak LRI (m/km)	0.958	1.031	0.979			0.989
		Peak SRI (m/km)	2.874	**2.969**	**2.943**			**2.929**

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 upper 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 SRI values in the right wheel path of the right shift passes (shown in bold and italics).

4.4 Recommended Pavement Remediation

Pavement remediation in the area of the cracking 12 feet prior to the WIM scales is recommended.

5 Statistical Reliability of the WIM Equipment

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

On the first day of the Validation, forty truck runs were performed and changes to the system parameters to compensate for system errors were calculated. When the calibration runs were performed, the weight estimations did not reflect the changes to the system parameters. The on-site leader contacted the manufacturer. After a remote analysis was performed, it was discovered that after the sensors were disabled in December, 2010, the channel assignments were not configured properly and so weights from only one sensor were being reported. This discovery rendered the initial validation and subsequent calibration runs irrelevant.

Once the correct channel assignments were made, and associated calibration parameters were changed in the WIM system setup to reflect the change in channel assignments, the Pre-Validation test truck runs were restarted. The results of the initial Pre-Validation test truck runs performed are not described in this report.

5.1 Pre-Validation

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

The 41 pre-validation test truck runs were conducted on March 7, 2012, beginning at approximately 9:55 AM and continuing until 12:58 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with forklift and steel products, 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 forklift and steel products, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

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

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

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.7	10.5	15.0	15.0	18.6	18.6	18.0	4.3	31.2	4.3	57.8	62.4
2	65.9	10.6	13.8	13.8	13.9	13.9	18.8	4.4	30.9	4.0	58.1	69.6

Test truck speeds varied by 12 mph, from 48 to 60 mph. The measured pre-validation pavement temperatures varied 19.6 degrees Fahrenheit, from 58.3 to 77.9. The mild weather conditions prevented the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

As shown in Table 5-2, the site met LTPP requirements for loading and distance measurement as a result of the pre-validation test truck runs. However, since the steering axle error was greater than 5.0%, and a calibration would improve the measurement accuracies of the system, a calibration of the system error compensation factors was performed.

Table 5-2 – Pre-Validation Overall Results – 7-Mar-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-5.1 ± 8.4%	Pass
Tandem Axles	±15 percent	-1.2 ± 6.4%	Pass
GVW	±10 percent	-3.1 ± 5.4%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.3 ± 1.0 ft	Pass
Vehicle Speed	± 1.0 mph	-0.3 ± 3.1 mph	FAIL
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 over all speeds was -0.3 ± 3.1 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length 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 similar acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 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 – Pre-Validation Results by Speed – 7-Mar-12

Parameter	95% Confidence Limit of Error	Low	Medium	High
		48.0 to 52.0 mph	52.1 to 56.1 mph	56.2 to 60.0 mph
Steering Axles	±20 percent	-5.6 ± 9.7%	-5.3 ± 7.7%	-4.2 ± 10.3%
Tandem Axles	±15 percent	-3.2 ± 6.0%	-1.9 ± 5.6%	-3.7 ± 8.1%
GVW	±10 percent	-3.5 ± 5.5%	-2.3 ± 4.6%	-3.7 ± 7.4%
Vehicle Length	±3.0 percent (2.0 ft)	0.3 ± 1.0 ft	0.3 ± 0.9 ft	0.2 ± 1.2 ft
Vehicle Speed	± 1.0 mph	0.0 ± 0.2 mph	0.0 ± 0.2 mph	0.0 ± 0.2 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 3.6 ft	-0.5 ± 3.7 ft	-0.4 ± 2.4 ft

From the table, it can be seen that, on average, the WIM equipment underestimates all weights at all speeds. The range in error appears to be greater at the lower and upper ends of the speed range.

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

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment generally underestimated GVW with similar bias at all speeds. The range in error is higher at high speeds when compared to low and medium speeds.

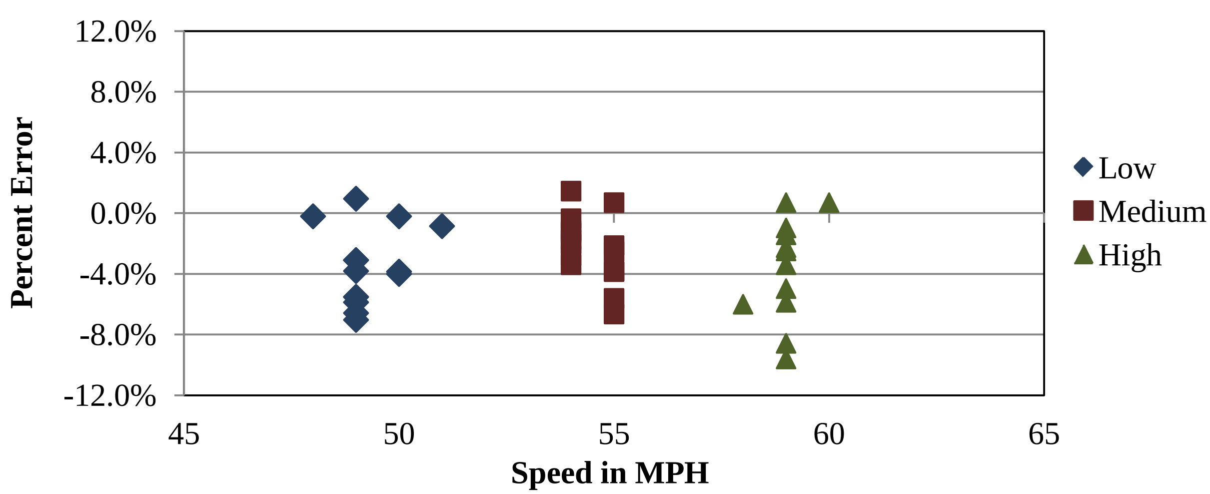


Figure 5-1 – Pre-Validation GVW Error by Speed – 7-Mar-12

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment underestimates steering axle weights with fairly similar bias at all speeds. The range in error is lower at medium speeds when compared to low and high speeds.

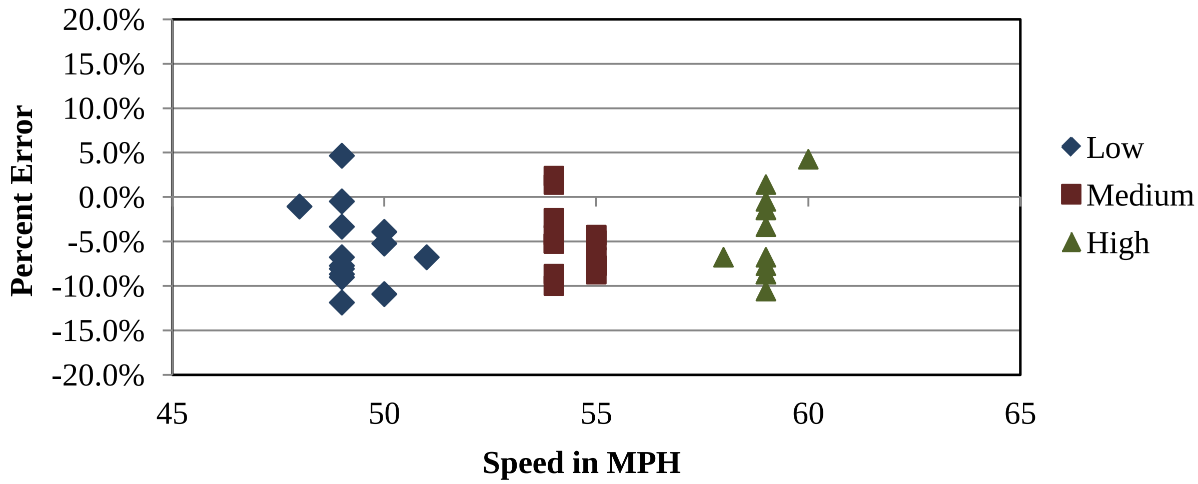


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 7-Mar-12

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment underestimates tandem axle weights with similar bias at all speeds. The range in error is higher at high speeds when compared to low and medium speeds.

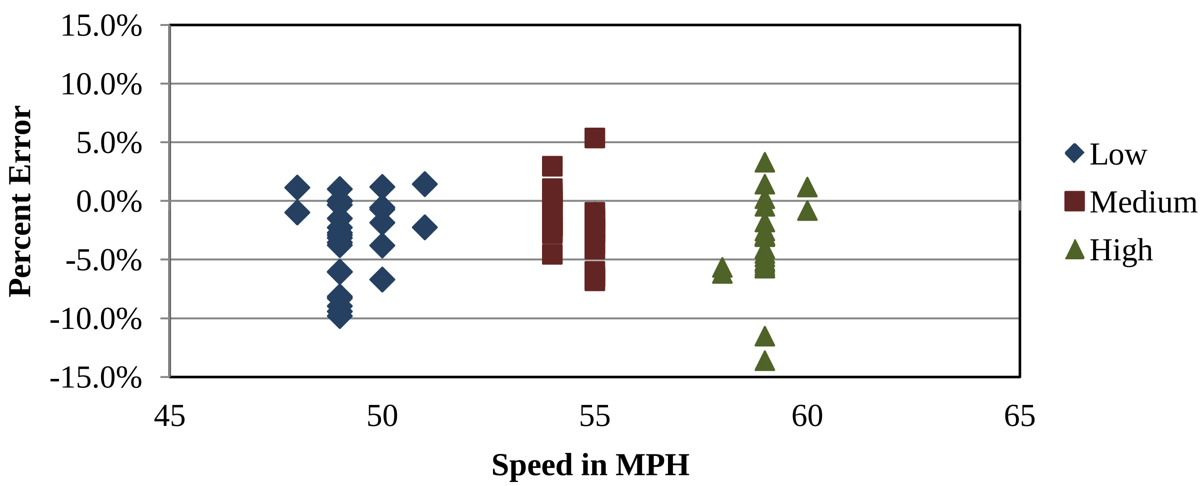


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 7-Mar-12

5.1.1.4 GVW Errors by Speed and Truck Type

When the GVW error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment bias for the heavily loaded (Primary) truck is increasing with speed. For the partially loaded (Secondary) truck, the bias appears to decrease with speed. The range in error for the Secondary truck and the Primary truck is similar at all speeds. Distribution of errors is shown graphically in Figure 5-4.

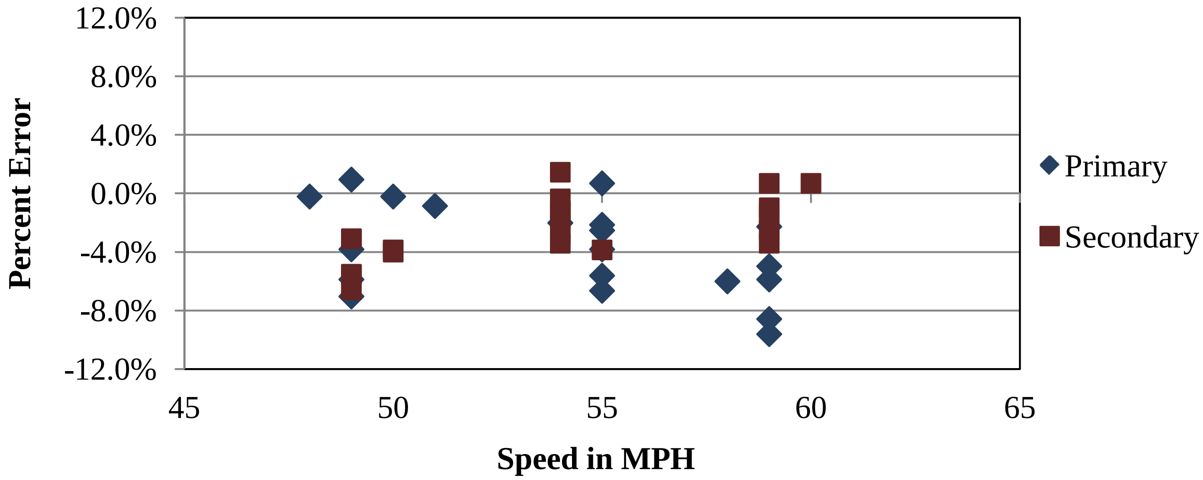


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 7-Mar-12

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from -0.1 feet to 0.2 feet. Distribution of errors is shown graphically in Figure 5-5.

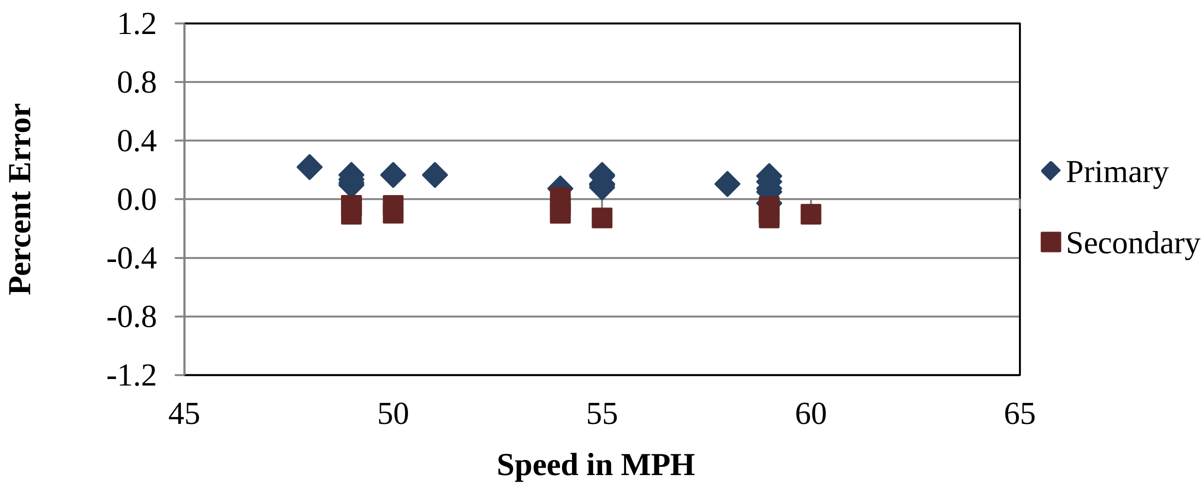


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 7-Mar-12

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment estimated overall vehicle length consistently over the entire range of speeds, with an error range of -0.6 to 0.6 feet. Distribution of errors is shown graphically in Figure 5-6.

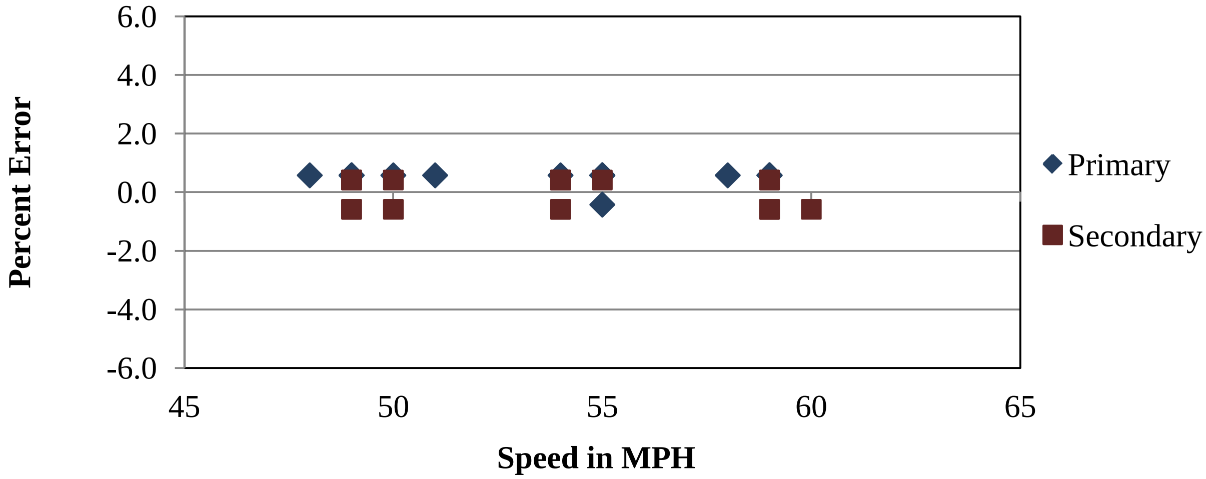


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 7-Mar-12

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 19.6 degrees, from 58.3 to 77.9 degrees Fahrenheit. Since the desired 30 degree temperature range was not met, the pre-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 7-Mar-12

Parameter	95% Confidence Limit of Error	Low	High
		58.3 to 68.1 degF	68.2 to 77.9 degF
Steering Axles	±20 percent	-5.2 ± 9.0%	-4.9 ± 9.1%
Tandem Axles	±15 percent	-2.9 ± 6.5%	-3.0 ± 7.1%
GVW	±10 percent	-3.0 ± 5.4%	-3.3 ± 6.1%
Vehicle Length	±3.0 percent (2.0 ft)	0.2 ± 1.1 ft	0.3 ± 0.9 ft
Vehicle Speed	± 1.0 mph	0.0 ± 0.2 mph	0.0 ± 0.2 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 2.7 ft	-0.4 ± 3.6 ft

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

5.1.2.1 GVW Errors by Temperature

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

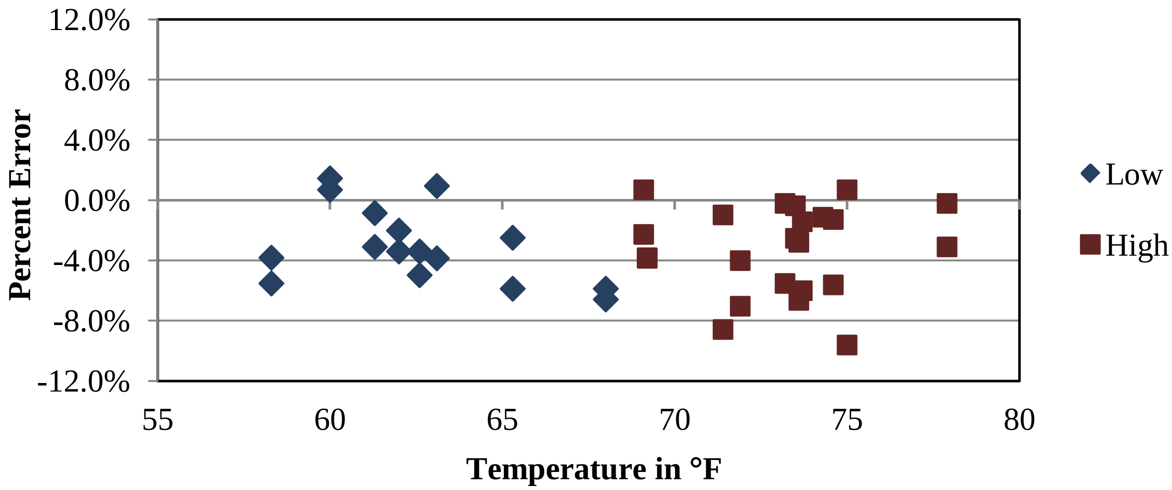


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 7-Mar-12

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 illustrates that for steering axles, the WIM equipment generally underestimates steering axle weights across the range of temperatures observed in the field. The range in error and bias is similar for the two temperature groups.

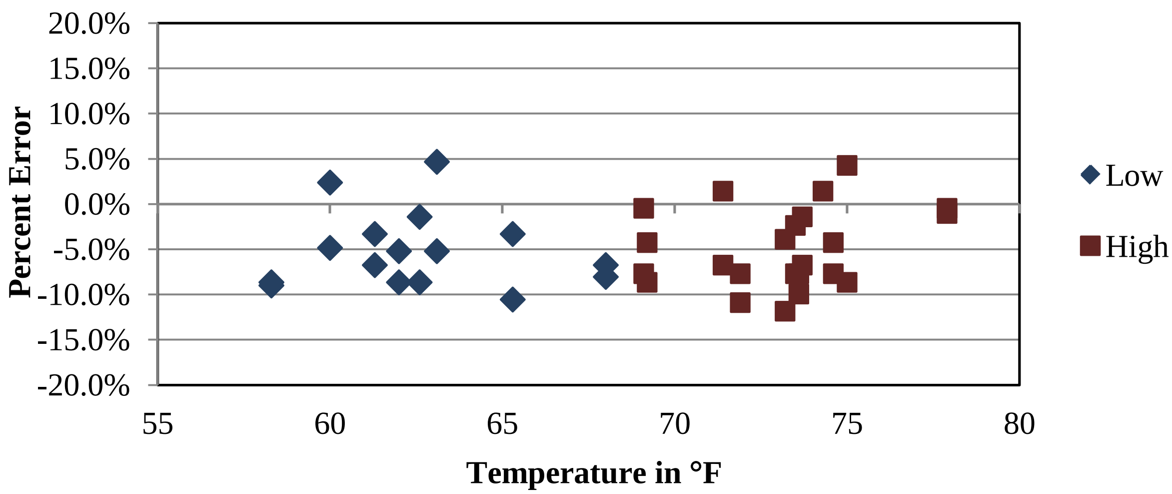


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 7-Mar-12

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment generally underestimates tandem axle weights across the range of temperatures observed in the field. The range in tandem axle errors is slightly greater at high temperatures.

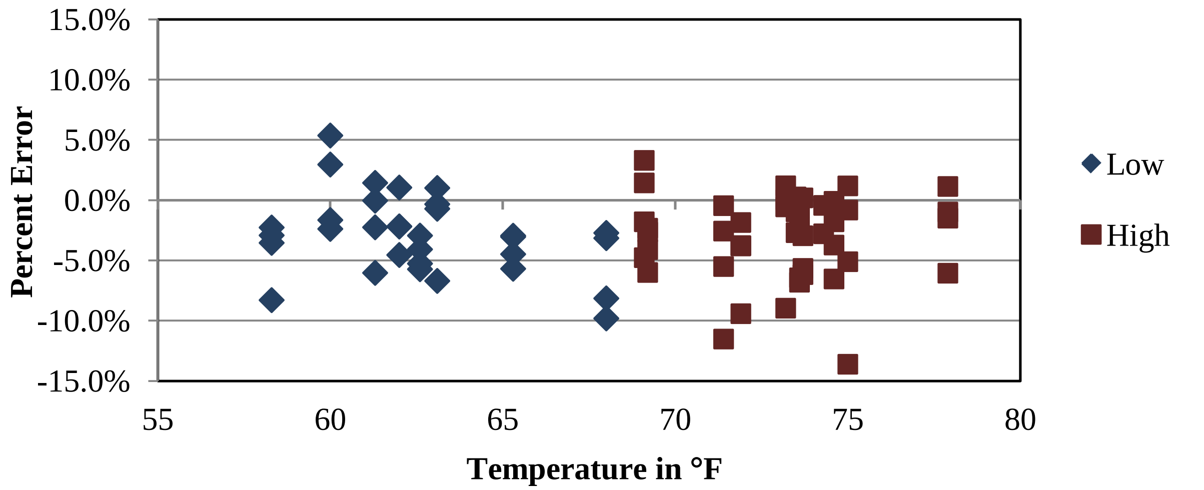


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 7-Mar-12

5.1.2.4 GVW Errors by Temperature and Truck Type

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

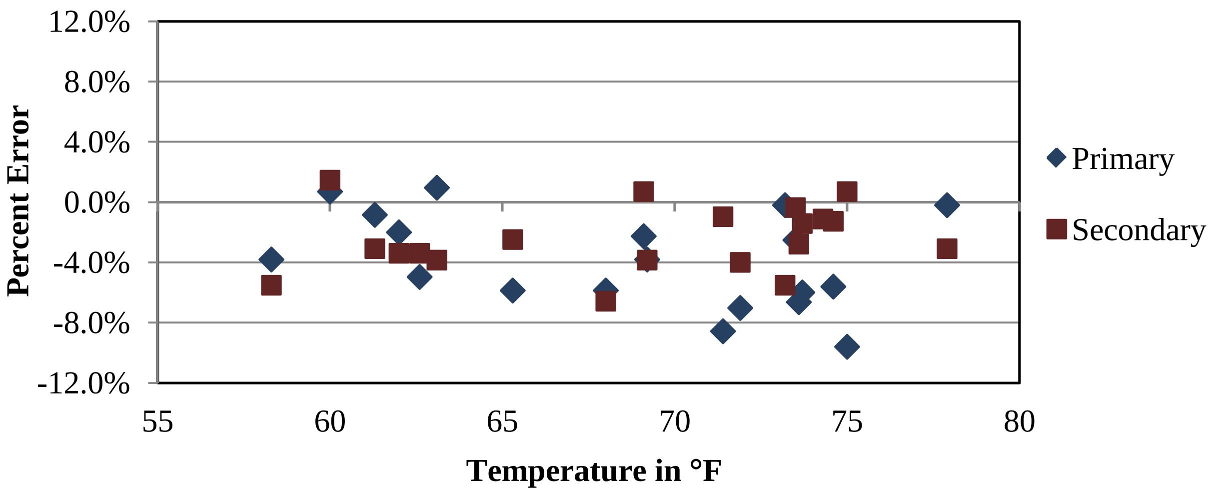


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 7-Mar-12

5.1.3 Classification and Speed Evaluation

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

For the pre-validation classification study at this site, a manual sample of 112 vehicles including 99 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one class of vehicle but identified by the WIM equipment as another class of vehicle. 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 3 vehicle was misclassified as a Class 5 vehicle, two Class 5 vehicles were misclassified as Class 3 vehicles, three Class 5 vehicles were misclassified as Class 4 vehicles, and two more Class 5 vehicles were misclassified as Class 8 vehicles by the equipment.

Table 5-5 – Pre-Validation Misclassifications by Pair – 7-Mar-12

	WIM												
Observed		3	4	5	6	7	8	9	10	11	12	13	14
	3	-		1									
	4		-										
	5	2	3	-			2						
	6				-								
	7					-							
	8						-						
	9							-					
	10								-				
	11									-			
	12										-		
	13											-	-

As shown in the table, a total of 8 vehicles, including 0 heavy trucks (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the pre-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 7.1%. The causes for the misclassifications were not investigated in the field.

The combined results produced an undercount of six Class 5 vehicles and an overcount of one Class 3, three Class 4, and two Class 8 vehicles, as shown in Table 5-6. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-6 – Pre-Validation Classification Study Results – 7-Mar-12

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	13	1	17	6	2	4	64	5	0	0	0
WIM Count	14	4	11	6	2	6	64	5	0	0	0
Observed Percent	11.6	0.9	15.2	5.4	1.8	3.6	57.1	4.5	0.0	0.0	0.0
WIM Percent	13.4	3.6	9.8	5.4	1.8	5.4	57.1	4.5	0.0	0.0	0.0
Misclassified Count	1	0	7	0	0	0	0	0	0	0	0
Misclassified Percent	7.1	0.0	41.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 7-Mar-12

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 99 trucks (Class 4 - 15), 0.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 0.8 mph; the range of errors was 5.8 mph.

5.2 Calibration

The WIM equipment required one calibration iteration between the pre- and post-validations. Information regarding the basis for changing equipment compensation factors, supporting data for the changes, and the resulting WIM accuracies from the calibrations are provided in this section.

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

Table 5-8 – Initial System Parameters – 7-Mar-12

Speed Point	MPH	Left		Right	
		1	3	2	4
80	50	3314	3439	3439	3314
88	55	3257	3380	3380	3257
96	60	3212	3332	3332	3212
104	65	3129	3247	3247	3129
112	70	3133	3281	3281	3133
Axle Distance (cm)		304			
Dynamic Comp (%)		102			
Loop Width (cm)		291			

5.2.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of -3.1% and errors of -3.5%, -2.3%, and -3.7% at the 50, 55 and 60 mph speed points respectively. To compensate for these errors, the changes in Table 5-9 were made to the compensation factors.

Table 5-9 – Calibration Equipment Factor Changes – 7-Mar-12

Speed Points	Old Factors				New Factors			
	Left		Right		Left		Right	
	1	3	2	4	1	3	2	4
80	3314	3439	3439	3314	3424	3439	3553	3314
88	3257	3380	3380	3257	3326	3380	3451	3257
96	3212	3332	3332	3212	3325	3332	3449	3212
104	3129	3247	3247	3129	3239	3247	3361	3129
112	3133	3281	3281	3133	3243	3281	3397	3133
Axle Distance (cm)	304				304			
Dynamic Comp (%)	102				102			
Loop Width (cm)	291				291			

5.2.2 Calibration Results

The results of the 12 calibration verification runs are provided in Table 5-10 and Figure 5-11. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the calibration. Although all weight measurements passed WIM system requirement with respect to accuracy, the range of errors observed is higher than other SPS sites. This may be attributed to the fact that two WIM sensors are disabled and the full capabilities of the WIM system are not being utilized.

Table 5-10 – Calibration Results – 7-Mar-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-0.4 ± 12.7%	Pass
Tandem Axles	±15 percent	0.8 ± 9.0%	Pass
GVW	±10 percent	0.4 ± 8.3%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.2 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.2 ft	Pass

Figure 5-11 shows that the WIM equipment is estimating GVW with similar accuracy at all speeds.

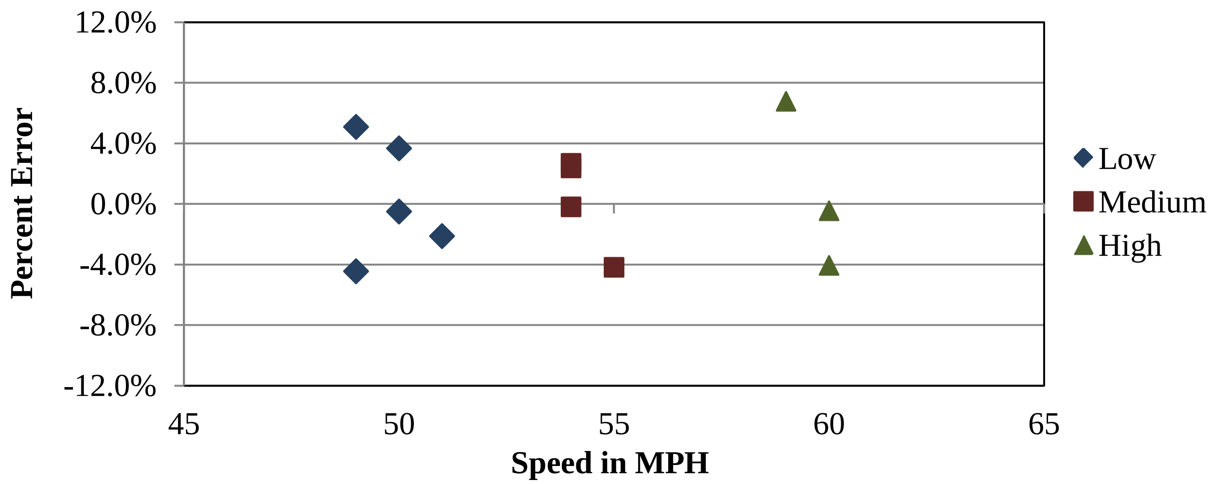


Figure 5-11 – Calibration GVW Error by Speed – 7-Mar-12

Based on the results of the first calibration, where GVW estimate bias decreased to 0.4 percent, a second calibration was not considered to be necessary. The 12 calibration runs were combined with 29 additional post-validation runs to complete the WIM system validation.

5.3 Post-Validation

The 41 post-validation test truck runs were conducted on March 7, 2012, beginning at approximately 1:22 PM and continuing until 3:14 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with forklift and steel products, 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 forklift and steel products, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

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

Table 5-11 - Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.4	10.4	14.9	14.9	18.6	18.6	18.0	4.3	31.2	4.3	57.8	62.4
2	65.7	10.5	13.7	13.7	13.9	13.9	18.8	4.4	30.9	4.0	58.1	69.6

Test truck speeds varied by 11 mph, from 49 to 60 mph. The measured post-validation pavement temperatures varied 9.3 degrees Fahrenheit, from 68.0 to 77.3. The mild weather conditions prevented the desired minimum 30 degree temperature range. Table 5-12 is a summary of post validation results.

Table 5-12 – Post-Validation Overall Results – 7-Mar-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	0.1 ± 11.5%	Pass
Tandem Axles	±15 percent	0.8 ± 7.9%	Pass
GVW	±10 percent	0.6 ± 6.8%	Pass
Vehicle Length	±3.0 percent (2.0 ft)	0.4 ± 0.7 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 -0.2 ± 5.4 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length 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 5-13.

Table 5-13 – Post-Validation Results by Speed – 7-Mar-12

Parameter	95% Confidence Limit of Error	Low 49.0 to 52.7 mph	Medium 52.8 to 56.4 mph	High 56.5 to 60.0 mph
Steering Axles	±20 percent	-1.7 ± 10.0%	-0.4 ± 11.8%	3.3 ± 14.2%
Tandem Axles	±15 percent	0.7 ± 7.0%	0.6 ± 8.0%	1.1 ± 11.0%
GVW	±10 percent	0.3 ± 5.1%	0.4 ± 7.1%	1.3 ± 10.5%
Vehicle Length	±3.0 percent (2.0 ft)	0.4 ± 0.6 ft	0.4 ± 0.7 ft	0.2 ± 1.0 ft
Vehicle Speed	± 1.0 mph	0.1 ± 0.2 mph	0.0 ± 0.1 mph	0.0 ± 0.2 mph
Axle Length	± 0.5 ft [150mm]	-0.3 ± 7.4 ft	-0.1 ± 3.9 ft	-0.3 ± 5.5 ft

From the table, it can be seen that the WIM equipment precision and bias for all weights increases with increase in speed. Vehicle length and axle length errors are consistent at all 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 5-12, the equipment estimated GVW with similar accuracy at low and medium speeds. The range in error is greater at the high speeds.

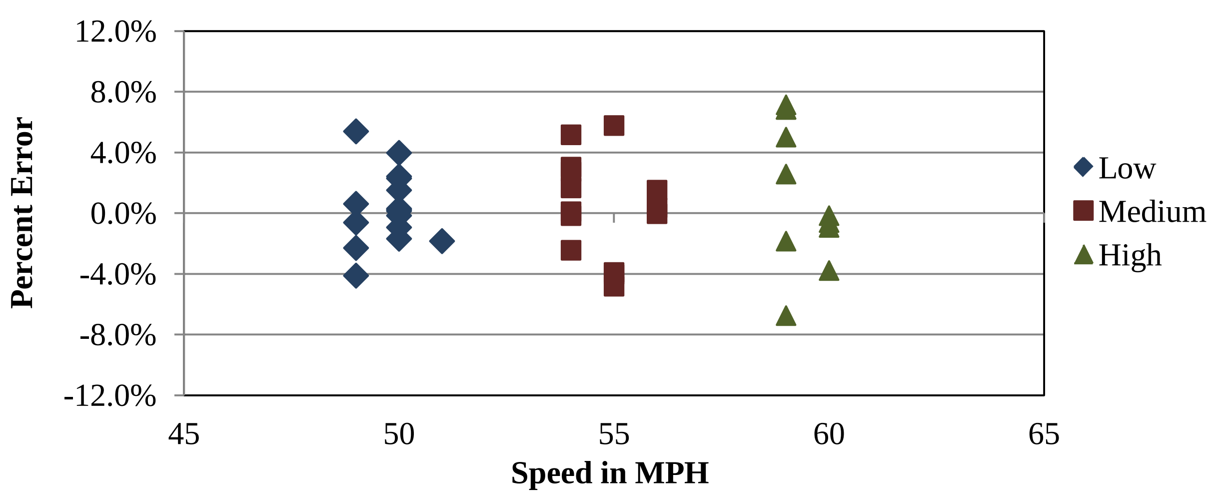


Figure 5-12 – Post-Validation GVW Errors by Speed – 7-Mar-12

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-13, the equipment estimated steering axle weights with similar accuracy at low and medium speeds. The range in error and bias is similar at all speeds.

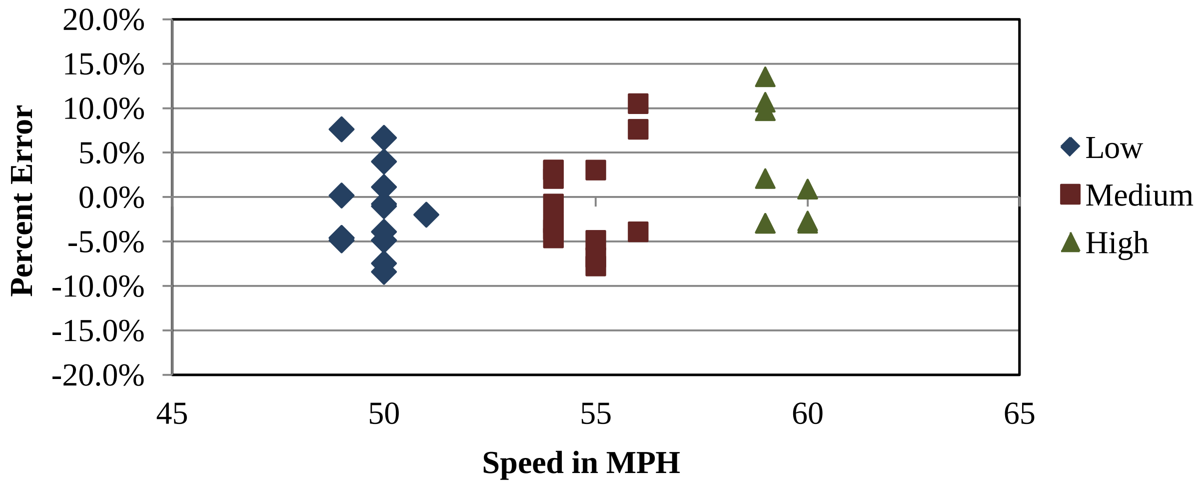


Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 7-Mar-12

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-14, the equipment estimated tandem axle weights with similar accuracy at low and medium speeds. The range in error is greater at the high speeds.

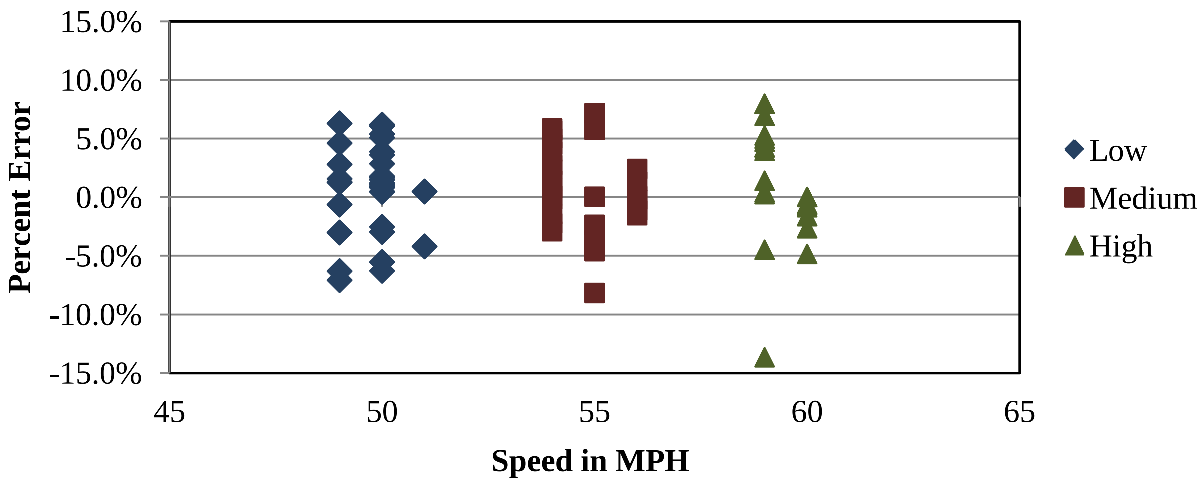


Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 7-Mar-12

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-15 that when the GVW errors are analyzed by truck type, the WIM equipment bias for the heavily loaded (Primary) truck changes from positive to negative with increase in speed while the bias for the partially loaded (Secondary) truck changes from negative to positive with increase in speed. The bias appears to be the greatest at 60 mph. For both trucks, the range of errors is consistent at all speeds.

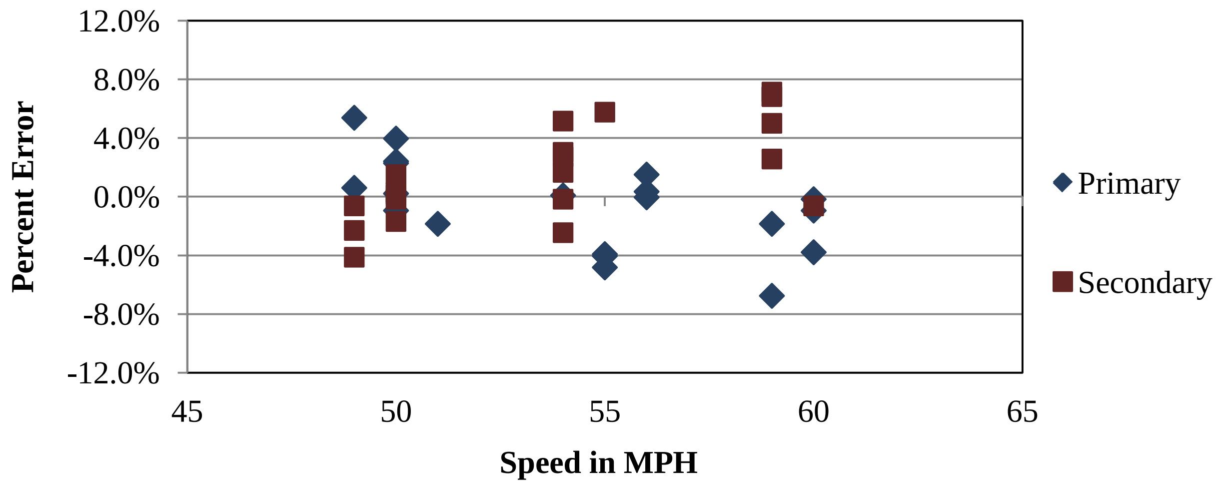


Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 7-Mar-12

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 0.3 feet. Distribution of errors is shown graphically in Figure 5-16.

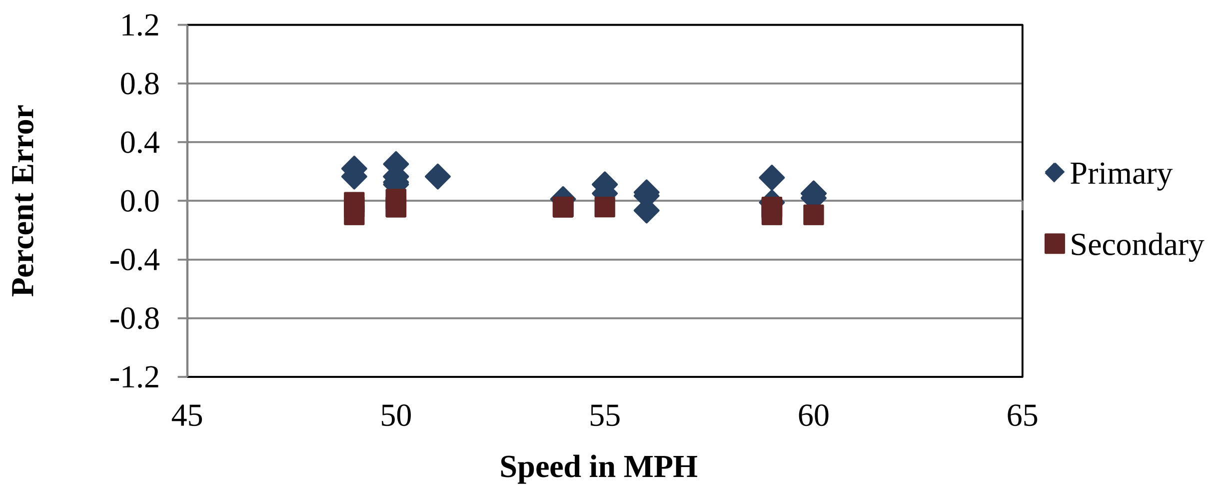


Figure 5-16 – Post-Validation Axle Length Error by Speed – 7-Mar-12

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 -0.6 to 0.6 feet. Distribution of errors is shown graphically in Figure 5-17.

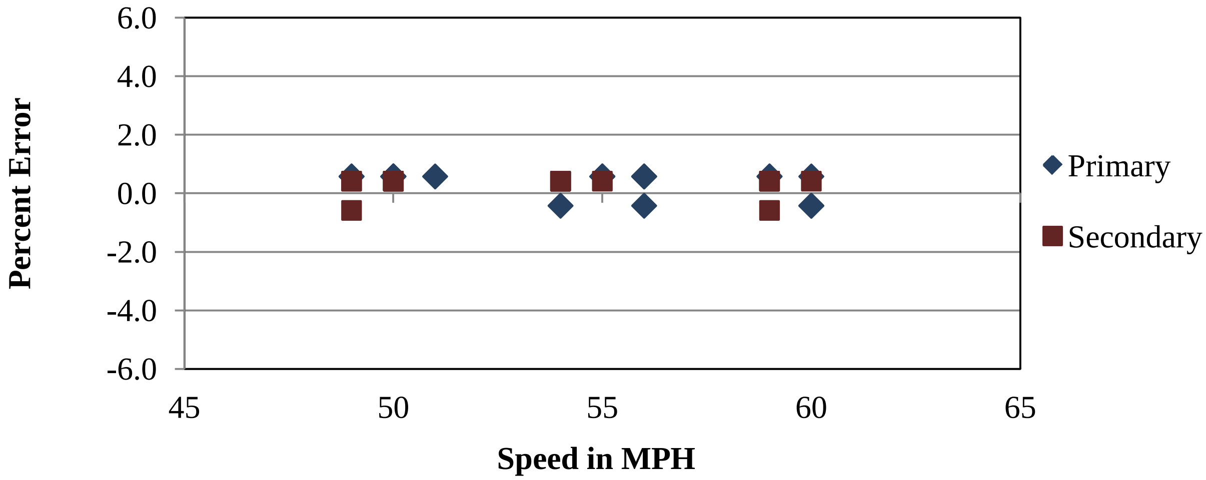


Figure 5-17 – Post-Validation Overall Length Error by Speed – 7-Mar-12

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 9.3 degrees, from 68.0 to 77.3 degrees Fahrenheit. The post-validation test runs are reported under two temperature groups – low and high, as shown in Table 5-14 below.

Table 5-14 – Post-Validation Results by Temperature – 7-Mar-12

Parameter	**95% Confidence Limit of Error**	**Low**	**High**
		68.0 to 72 degF	**72.1 to 77.3 degF**
Steering Axles	±20 percent	-0.1 ± 11.5%	0.7 ± 13.5%
Tandem Axles	±15 percent	0.6 ± 7.7%	1.1 ± 9.4%
GVW	±10 percent	0.5 ± 6.6%	0.9 ± 8.6%
Vehicle Length	±3.0 percent (2.0 ft)	0.4 ± 0.5 ft	0.1 ± 1.2 ft
Vehicle Speed	± 1.0 mph	0.0 ± 0.2 mph	0.0 ± 0.2 mph
Axle Length	± 0.5 ft [150mm]	-0.5 ± 5.9 ft	0.7 ± 3.9 ft

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

5.3.2.1 GVW Errors by Temperature

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

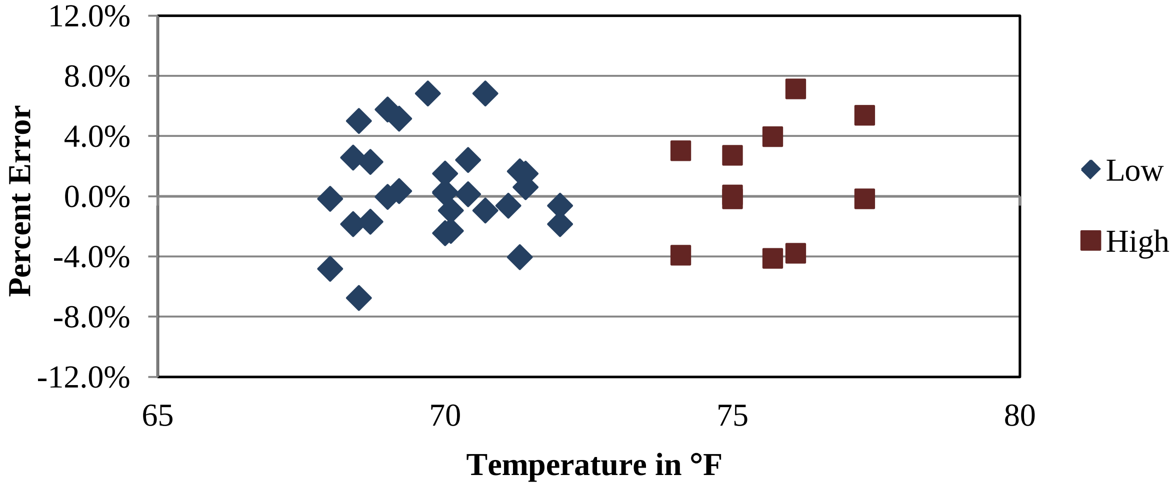


Figure 5-18 – Post-Validation GVW Errors by Temperature – 7-Mar-12

5.3.2.2 Steering Axle Weight Errors by Temperature

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

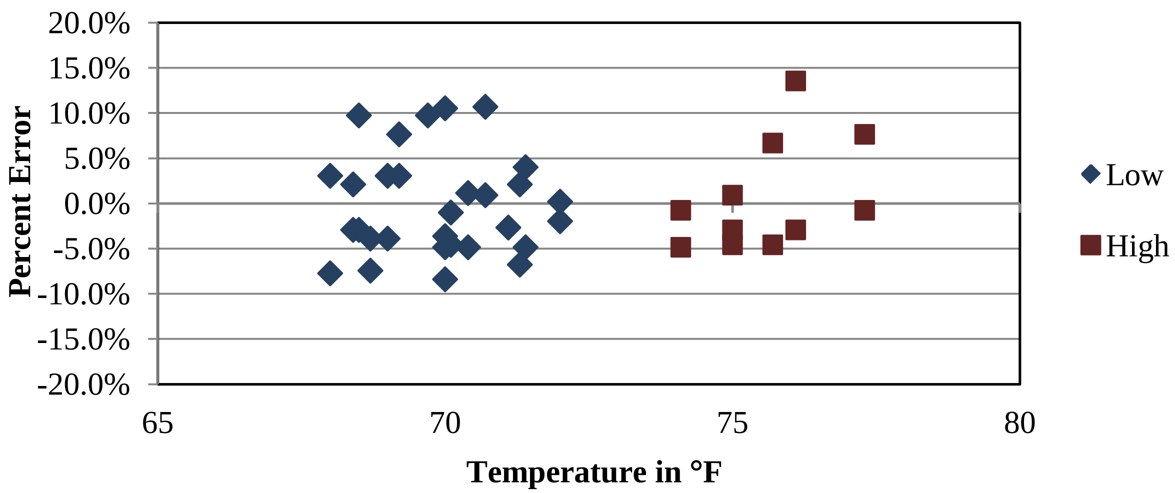


Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 7-Mar-12

5.3.2.3 Tandem Axle Weight Errors by Temperature

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

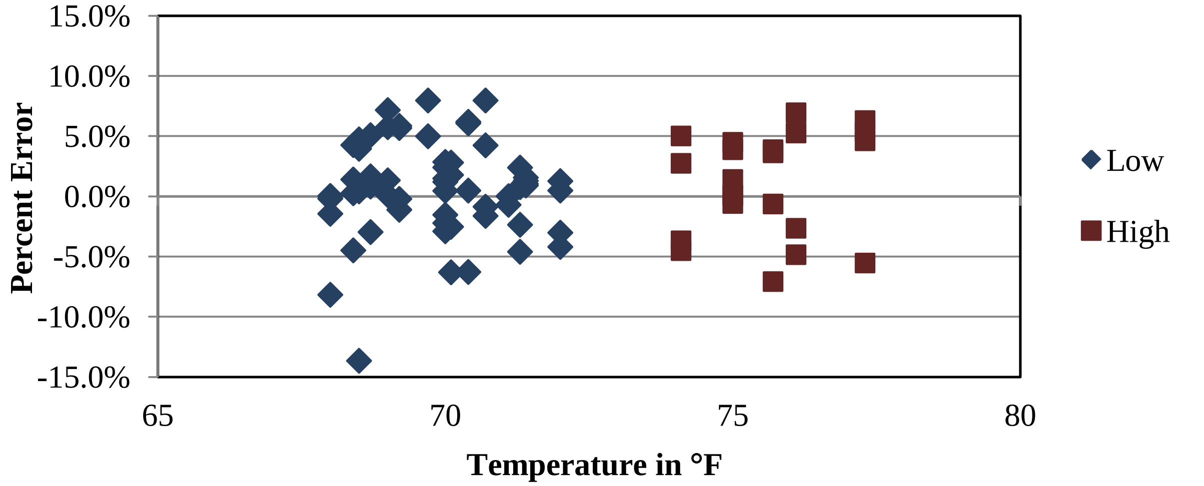


Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 7-Mar-12

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, when analyzed by truck type, the WIM equipment bias for the partially loaded (Secondary) truck is higher at low temperatures when compared to the heavily loaded (Primary) truck. For both trucks, the range of errors is consistent over the range of temperatures.

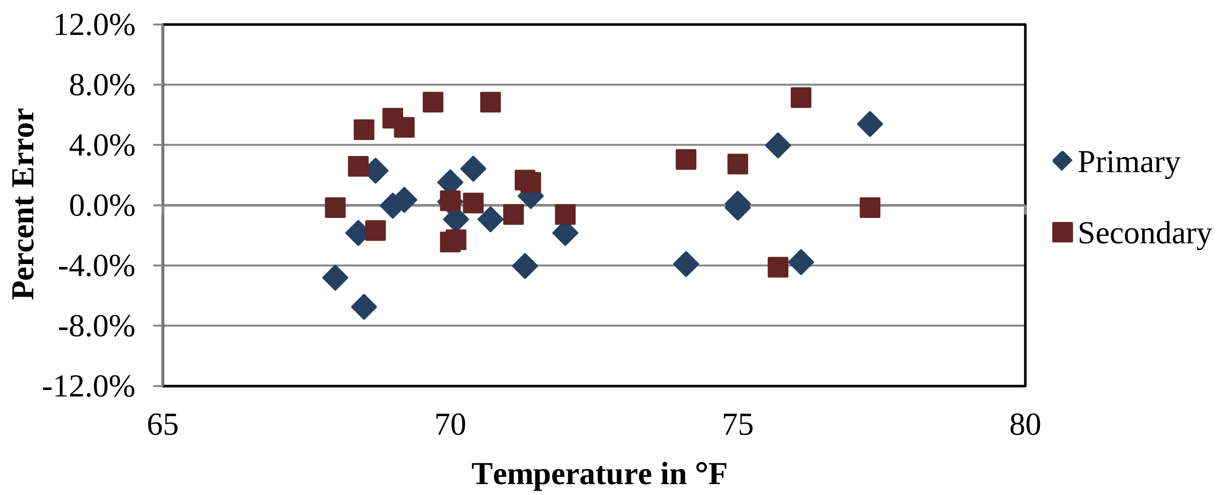


Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 7-Mar-12

5.3.3 Classification and Speed Evaluation

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

For the post-validation classification study at this site, a manual sample of 105 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

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 5-15. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-15, two Class 3 and one Class 5 vehicles were misclassified as Class 8 vehicles and one Class 6 vehicle was misclassified as a Class 9 vehicle.

Table 5-15 – Post-Validation Misclassifications by Pair – 7-Mar-12

	WIM												
		3	4	5	6	7	8	9	10	11	12	13	14
Observed	3	-					2						
	4		-										
	5			-			1						
	6				-			1					
	7					-							
	8						-						
	9							-					
	10								-				
	11									-			
	12										-		
	13											-	-

As shown in the table, a total of 4 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the post-validation study, the misclassification percentage is 1.2% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 3.8percent. The causes for the misclassifications were not investigated in the field.

The combined results of the misclassifications resulted in an undercount of two Class 3, one Class 5, and one Class 6 vehicle, and an overcount of three Class 8 vehicles and one Class 9 vehicle, as shown in Table 5-16. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-16 – Post-Validation Classification Study Results – 7-Mar-12

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	5	1	16	4	1	4	71	3	0	0	0
WIM Count	3	1	15	3	1	7	72	3	0	0	0
Observed Percent	4.8	1.0	15.2	3.8	1.0	3.8	67.6	2.9	0.0	0.0	0.0
WIM Percent	2.9	1.0	14.3	2.9	1.0	6.7	68.6	2.9	0.0	0.0	0.0
Misclassified Count	2	0	1	1	0	0	0	0	0	0	0
Misclassified Percent	40.0	0.0	6.3	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-17.

Table 5-17 – Post-Validation Unclassified Trucks by Pair – 7-Mar-12

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 100 trucks, 0.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 0.5 mph; the range of errors was 1.5 mph.

5.3.4 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-18.

Table 5-18 – Final Factors

Speed Point	**MPH**	**Left**		**Right**	
		1	**3**	**2**	**4**
80	50	3424	3439	3553	3314
88	55	3326	3380	3451	3257
96	60	3325	3332	3449	3212
104	65	3239	3247	3361	3129
112	70	3243	3281	3397	3133
Axle Distance (cm)		304			
Dynamic Comp (%)		102			
Loop Width (cm)		291			

6 Post-Visit Data Analysis

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

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

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 49 to 60 mph.
- Pavement temperature. Pavement temperature ranged from 68.0 to 77.3 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	-15.4281	16.1965	-0.9526	0.3472
Speed	0.0925	0.1346	0.6868	0.4966
Temp	0.1371	0.1876	0.7307	0.4697
Truck	2.4172	1.0439	2.3154	0.0264

Only the truck type had a statistically significant effect on the GVW measurement errors. The probability value given in Table 6-1 for truck type was 0.0264. This means that there is only about 3 percent chance that the value of regression coefficient for truck (2.4172) is equal to zero. In addition, as shown in Figure 5-23, the effect of speed on GVW measurement errors depends on truck type. It is positive for the Secondary truck and negative for the Primary truck. However, considering both trucks combined, the effect is not statistically significant. Additional multiple regression analysis were carried out to investigate statistical significance of the interaction between speed and truck type. The interaction was found to be highly statistically significant.

The relationship between truck type and measurement errors is shown in Figure 6-4. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 6-4 provides quantification and statistical assessment of the relationship.

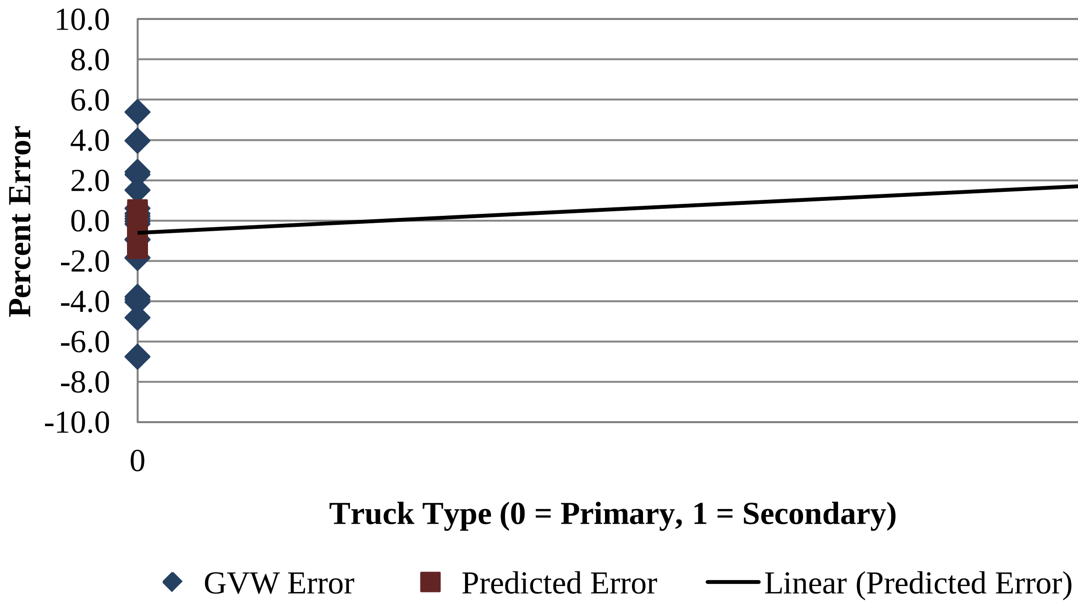


Figure 6-1 – Influence of Truck Type on the Measurement Error of GVW

The quantification of the relationship is provided by the value of the regression coefficient, in this case 2.4172 (in Table 6-1). The regression coefficient represents the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). The difference in the mean errors was statistically significant.

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	-	-	-	-	2.4172	0.0264
Steering axle	0.5624	0.0142	-	-	2.3330	0.1765
Tandem axle tractor	-	-	-	-	3.0027	0.0007
Tandem axle trailer	-	-	-	-	-	-

6.1.4 GVW and Steering Axle Trends

This section provides additional discussion regarding the effect of speed on measurement errors. This section is included because there was some evidence of measurement error dependency on speed when data for each of calibration trucks was analyzed independently. Figure 6-2 and Figure 6-3 are provided to illustrate the trend in post-validation GVW errors with respect to speed. Figure 6-2 shows combined data for both trucks; Figure 6-3 shows separate trends for the Primary and Secondary trucks.

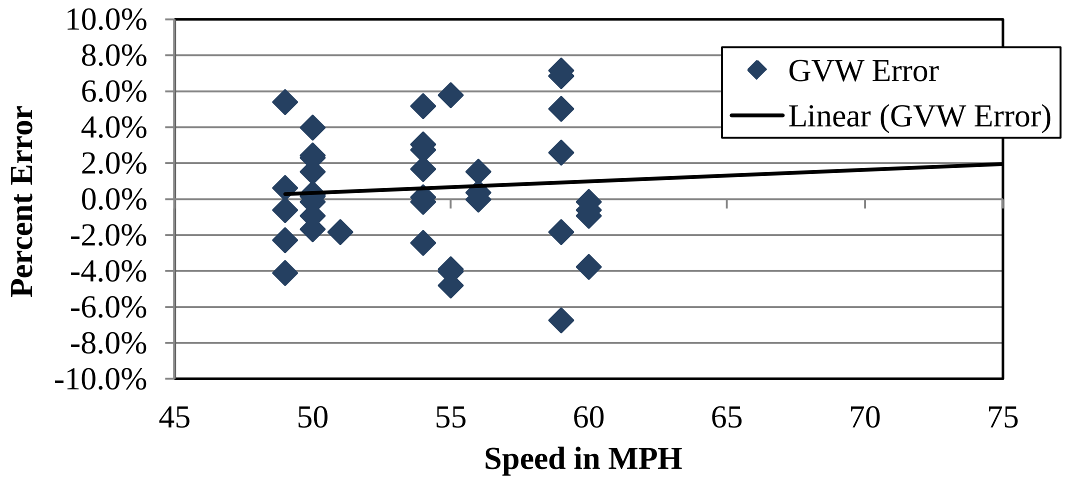


Figure 6-2 – GVW Error Trend by Speed

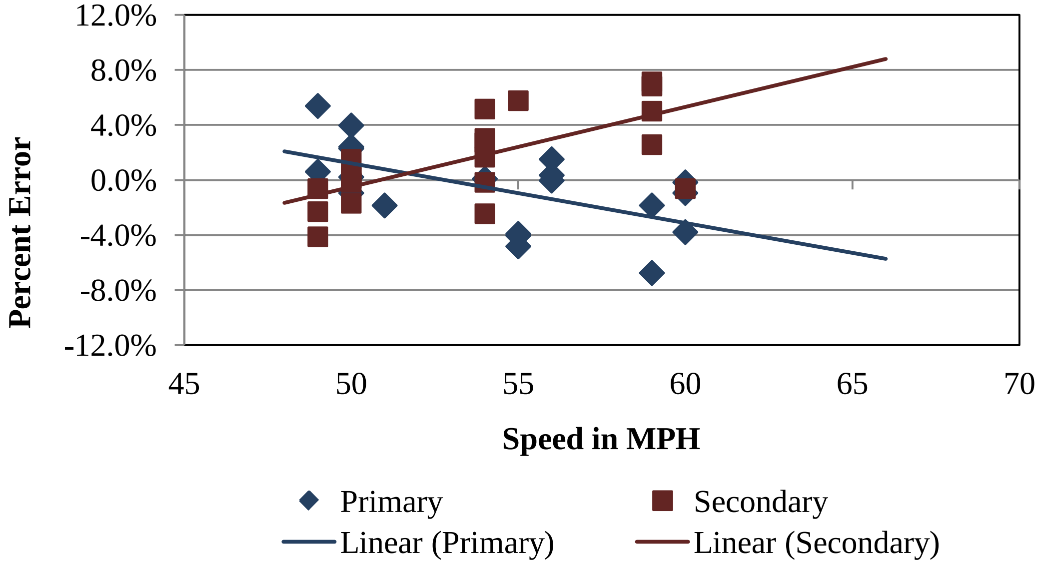


Figure 6-3 – GVW Trend by Truck and Speed

The trend line shown in Figure 5-22 has the slope of 0.072 and has no statistical significance. The probability that the slope is zero, rather than 0.072 is about 60%. Therefore, measurement error dependency on speed is not evident when data from both calibration trucks are combined. On the other hand, the two trend lines shown in Figure 6-3, for the Primary and Secondary trucks, have high statistical significance. The trend line for the Primary truck has the slope of -0.43 and the probability that the slope is zero is less than one percent. The slope for the Secondary truck is +0.609 and the probability that the slope is zero is less than 0.1 percent.

When considering the effect of speed on tandem axles on tractors and tandem axles on trailers separately for the Primary and the Secondary trucks, the effect of speed becomes statistically significant: the measurement errors for the Secondary truck increase with speed whereas for the Primary truck decrease with speed.

The opposite results regarding the influence of speed on the measurement errors for the Primary and Secondary trucks are unexpected considering that both trucks have similar suspension systems and axle spacing. Observations of this sort should be further investigated as part of a comprehensive effort summarizing lessons learned during verification activities.

Figure 6-4 is provided to illustrate the trend in post-validation errors for steering axles with respect to speed for both trucks combined.

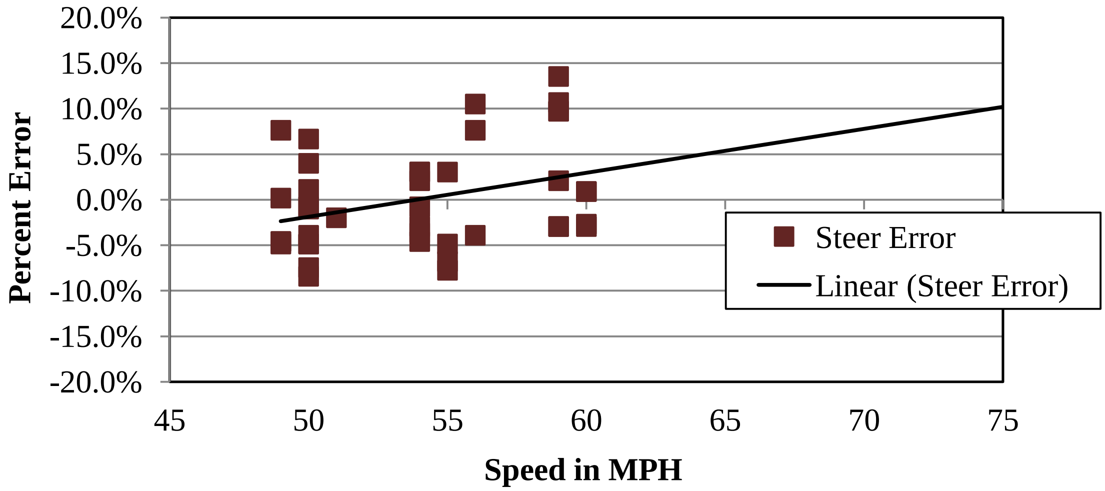


Figure 6-4 – Steering Axle Trend by Speed

The slope of the trend line in Figure 6-4 is 0.52 and is statistically significant (the probability the slope is zero is about 2 percent).

The relationship between speed and steering axle weight measuring errors, given in Figure 6-5, shows separately the results for the Primary and Secondary trucks. The slope of the trend line for the Secondary truck is 1.06, and the probability that the slope is zero is less than 0.1 percent. The trend line for the Primary truck is not statistically significant.

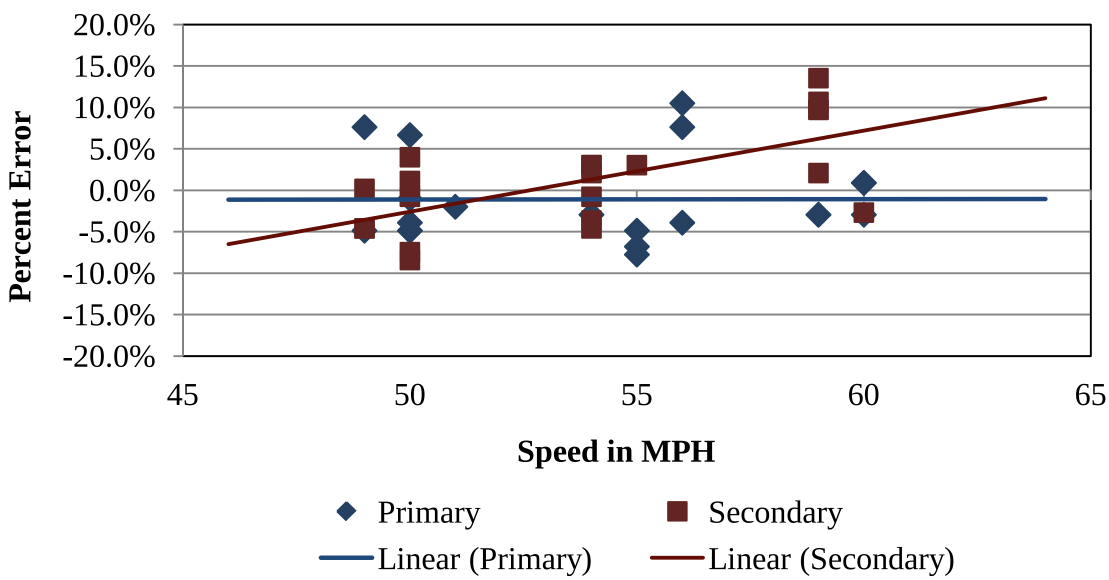


Figure 6-5 – Influence of Speed on the Measurement Error of Steering Axles Weight

For simplicity, the trend lines used in the previous four figures were linear. The relationship between measurement errors and speed may not be linear, particularly for speeds above 60 mph. It is recalled that about 68% of all speed observations for trucks at this site had speed over 60 mph.

6.1.5 Conclusions

1. According to Table 6-2, speed had statistically significant effect on measurement errors of steering axles only. The value of the regression coefficient, 0.5624 in Table 6-2, indicates that, for example, for a 10 mph increase in speed, the measurement error increases by about 5.6 % (10 x 0.5624). In addition, speed was found to have statistically significant effect on GVW measurement errors when two calibration trucks were analyzed separately.

2. The effect of temperature on the measurement error of axle weights was not statistically significant. However, the range of pavement temperatures during post-validation testing was only 9.3 °F.

3. Overall, truck type had statistically significant effect on measurement errors of the GVW, and the weights of tandem axles on tractors. However, when the effect of the truck type is investigated separately for the Primary and Secondary trucks, the effect of truck type is also statistically significant for the measurement errors of steering axles and tandem axles.

4. Even though speed and truck type had statistically significant effects 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 for the speed range tested. This assurance is the one of the reasons why the multivariable statistical analysis are carried out. The other reason is obtain in-depth understanding of all major factors influencing calibration of SPS sites with the objective to improve future validation and calibration activities.

6.2 Misclassification Analysis

A post-visit analysis was conducted on the truck misclassifications identified during the post-validation conducted in the field. For this site, a total of 4 vehicles, including 1 heavy truck (6 – 13) were 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 46286. The capture of the real-time record for vehicle 46286 is provided in Figure 6-6.

(46286) LANE 1 NB Dr CLASS 9 GVW 53.2 kips LENGTH 66 ft
SPEED 68 mph MAX GVW 80.0 kips Wed Mar 7 2012 16:16:35 (2643)

AXLE	SEPARATION (ft)	LEFT WT (kips)	RIGHT WT (kips)	TOTAL WT (kips)	ALLOWABLE (kips)
1		9.5	8.6	18.2	20.0
2	24.9	9.4	10.3	19.7	17.0
3	4.1	4.4	4.8	9.2	17.0
4	15.6	1.6	1.5	3.1	20.0
5	10.9	1.6	1.4	3.0	20.0

Figure 6-6 – Vehicle Record 46286

The video capture of vehicle 46286 is provided in Photo 6-1. As the photo illustrates, the misclassification involved an RV camper that was towing a car. As would be expected, due to the short gap between the vehicles, the WIM system combined the two vehicles into one Class 9 vehicle. Setting minimum weight limit on trailer axles could prevent this misclassification in the future.

Photo 6-1 – Video Capture of Vehicle 46286

6.3 Traffic Data Analysis

Due to the circumstances created by the WIM sensor channel assignments, the results of the pre-visit data analysis for determining the presence of imbalanced weights could not be used for the validation. Additionally, left-to-right imbalance percentage cannot be developed from test trucks runs due to the limited sample. Consequently, free flow truck traffic must be used.

A post-visit data analysis was conducted using the data immediately following the date of the validation. The results of the post-visit imbalance analysis are presented in Table 6-3.

Table 6-3 - Front Axle Weight Imbalance

Imbalance		
AVG Front axle left wheel weights	5.92	
AVG Front axle right wheel weights	5.33	-10.0%

As shown in the table, the left weights are 10.0 percent greater than the right side weights. A reduction of left side compensation factors that is nearly equal to the increase in right side compensation factors "shifts" the weight from one side to the other and does not change any of the overall axle weight estimations of the system. Therefore, it is recommended that the calibration factors be adjusted as presented in Table 6-4. Since only sensors 2 and 3 are currently enabled in the system, changes to compensation factors for sensors 1 and 4 are not provided.

Table 6-4 – Recommended Adjustments to Compensation Factors

	Current		**Recommended Changes**			
Speed Point	**Left**	**Right**	**Left**		**Right**	
	3	**2**	**3**	**Change**	**2**	**Change**
80	3439	3553	3268	-4.98%	3750	+5.53%
88	3380	3451	3212	-4.98%	3642	+5.53%
96	3332	3449	3166	-4.98%	3640	+5.53%
104	3247	3361	3085	-4.98%	3547	+5.53%
112	3281	3397	3118	-4.98%	3585	+5.53%

The change in compensation factors would split the difference in the imbalance percentage, bringing the left and right wheel weight estimations in line with each other, greatly reducing the number of flagged data due to imbalance issues and increasing the quantity of research quality data collected from the site.

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. This site has validation information from five previous visits as well as the current one as summarized in the tables below. The information includes historical data on classification and weight accuracies.

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	
3-Sep-08	-	100	8	0	0	0	0	0	0	-	0	0
4-Sep-08	-	-	6	0	0	25	0	0	0	-	-	0
4-Nov-10	-	-	6	0	0	0	0	-	-	-	-	0
6-Mar-12	7	0	41	0	0	0	0	0	0	0	0	0
7-Mar-12	40	0	63	25	0	0	0	0	0	0	0	0

7.2 Weight

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

Table 7-2 – Weight Validation History

Date	Site Values (Mean Error and 95% Confidence Interval)			
	GVW	Steering Axles	Single Axles	Tandem
3-Sep-08	3.7 ± 3.2	1.8 ± 5.3	1.8 ± 5.3	4.2 ± 5.1
4-Sep-08	-1.7 ± 1.6	-0.8 ± 6.9	-0.8 ± 6.9	-1.7 ± 4.0
4-Nov-10	0.0 ± 3.2	0.6 ± 5.3	0.6 ± 5.3	0.0 ± 2.5
6-Mar-12	-3.1 ± 5.4	-5.1 ± 8.4	-5.1 ± 8.4	-2.9 ± 6.4
7-Mar-12	0.6 ± 6.8	0.1 ± 11.5	0.1 ± 11.5	0.8 ± 7.9

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, and for the Mar 7, 2012 validation, from two sensors being disabled. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an underestimation of GVW over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

8 Additional Information

The following information is provided in the attached appendix:

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

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

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

WIM System Field Calibration and Validation - Photos

Indiana, SPS-6
SHRP ID: 180600

Validation Date: March 6 and 7, 2012

APPLIED RESEARCH ASSOCIATES, INC.

Photo 1 – Cabinet Exterior

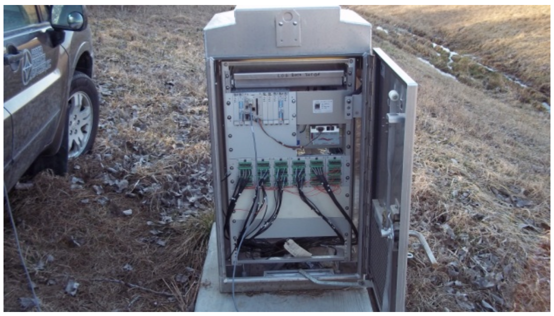


Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior (Back)

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

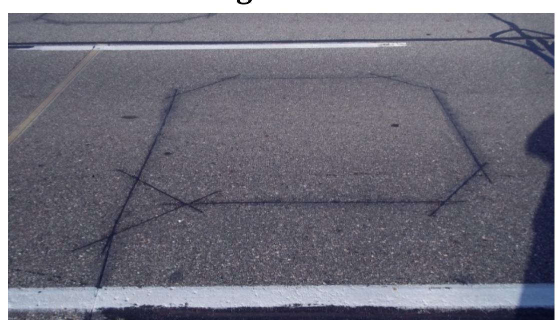


Photo 7 – Trailing Loop Sensor

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

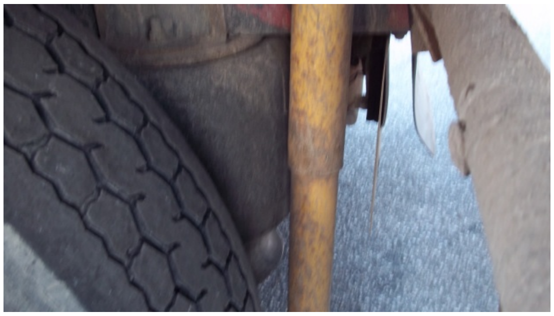


Photo 25 – Truck 2 Suspension 3

Photo 26 – Truck 2 Suspension 5

Photo 27 – Truck 2 Suspension 4

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	18 180600 3/6/2012

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 3/6/12

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. ______ c. ______
   b. ______ d. ______

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

6. **CALIBRATION TECHNIQUE USED:** ______
   Number of Trucks Compared: ______
   Number of Test Trucks Used: 2
   Passes Per Truck: 22

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

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

Mean Difference Between -

Dynamic and Static GVW:	-2.3%	Standard Deviation:	2.3%
Dynamic and Static Single Axle:	-1.0%	Standard Deviation:	4.2%
Dynamic and Static Double Axles:	-0.8%	Standard Deviation:	2.9%

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

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

			Low		High	Runs
a.	Low	-	49.0	to	52.7	15
b.	Medium	-	52.8	to	56.4	17
c.	High	-	56.5	to	60.0	11
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	18
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	180600
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	3/6/2012

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3161 | 3046

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	-	-35.0
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: **Kevin Trousdale**

Contact Information: Phone: 717-975-3550

E-mail: ktrousdale@ara.com

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 18 SPS WIM ID: 180600 DATE (mm/dd/yyyy) 3/7/2012

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 3/7/12

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. ______ c. ______

b. ______ d. ______

5. EQUIPMENT MANUFACTURER: IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: ______

Number of Trucks Compared: ______

Number of Test Trucks Used: 2

Passes Per Truck: 21

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

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

Mean Difference Between -

Dynamic and Static GVW:	0.6%	Standard Deviation:	3.4%
Dynamic and Static Single Axle:	0.1%	Standard Deviation:	5.7%
Dynamic and Static Double Axles:	0.8%	Standard Deviation:	3.9%

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

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	49.0	to	52.7	16
b.	Medium	-	52.8	to	56.4	14
c.	High	-	56.5	to	60.0	11
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	18
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	180600
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	3/7/2012

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3239 | 3361

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	5	-	-6.0
FHWA Class 8:	75.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 18 SPS WIM ID: 180600 DATE (mm/dd/yyyy) 3/6/2012

Count - 113 Time = 2:46:31 Trucks (4-15) - 99 Class 3s - 14

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	6	30558	60	6	62	9	30752	60	9
70	9	30580	71	9	**62**	**8**	**30753**	**61**	**5**
59	9	30585	60	9	64	5	30756	65	5
64	9	30598	64	9	61	5	30758	63	5
62	9	30592	63	9	63	9	30759	63	9
62	9	30598	63	9	62	3	30770	60	3
65	5	30610	64	5	62	10	30772	60	10
60	**4**	**30622**	**61**	**5**	73	3	30776	72	3
62	9	30625	59	9	65	9	30779	65	9
66	9	30636	66	9	60	9	30787	59	9
62	9	30647	61	9	70	3	30793	67	3
61	9	30656	67	9	**61**	**4**	**30810**	**62**	**5**
60	9	30658	66	9	64	9	30813	63	9
63	9	30665	62	9	62	9	30814	64	9
60	9	30668	61	9	52	9	30820	57	9
63	8	30670	63	8	63	3	30826	58	3
61	9	30680	61	9	62	9	30830	62	9
61	5	30684	61	5	60	9	30838	60	9
67	6	30691	63	6	66	9	30845	66	9
61	9	30710	61	9	63	8	30856	63	8
63	9	30723	62	9	65	9	30858	66	9
61	**4**	**30729**	**60**	**5**	**65**	**3**	**30860**	**64**	**5**
57	9	30734	58	9	60	3	30870	60	3
65	9	30743	64	9	70	3	30874	70	3
60	9	30744	60	9	**63**	**5**	**30884**	**62**	**3**

Validation Test Truck Run Set - Pre

Sheet 1 - 0 to 50 Start: 9:50:01 Stop: 10:19:17

Recorded By: ar Verified By: djw

Traffic Sheet 20	STATE CODE:	18
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	180600
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy)	3/6/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	7	30886	65	7	60	9	32130	59	9
65	9	30894	64	9	64	9	32134	59	9
60	8	30902	60	8	62	9	32147	62	9
62	9	30906	61	9	60	8	32155	60	8
61	9	30912	62	9	60	10	32162	63	10
60	9	30913	60	9	62	9	32179	62	9
62	5	30914	58	5	62	9	32192	61	9
63	9	30916	60	9	60	9	32199	60	9
63	6	30920	63	6	64	4	32201	61	4
64	3	30922	64	3	62	9	32206	59	9
64	9	30923	64	9	59	10	32213	59	10
60	6	30925	64	6	64	5	32216	64	5
61	5	30930	60	5	60	9	32221	60	9
68	3	30935	68	3	62	9	32223	61	9
63	10	30944	63	10	**62**	**8**	**32225**	**62**	**5**
63	**3**	**30947**	**62**	**5**	65	5	32226	66	5
70	3	30953	69	3	65	9	32229	64	9
71	3	30968	70	3	60	9	32235	60	9
63	9	30972	63	9	64	10	32240	62	10
61	3	30979	59	3	60	9	32249	57	9
61	9	30984	60	9	63	5	32255	63	5
62	9	32111	64	9	61	9	32256	61	9
67	3	32112	64	3	55	9	32258	54	9
59	9	32123	60	9	66	9	32262	65	9
60	6	32124	59	6	62	9	32267	61	9

Validation Test Truck Run Set - Pre

Sheet 2 - 51 to 100   Start: 10:19:37   Stop: 12:26:34

Recorded By: ar   Verified By: djw

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 18 SPS WIM ID: 180600 DATE (mm/dd/yyyy) 3/6/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
61	9	32279	60	9					
62	9	32290	60	9					
60	9	32292	60	9					
62	9	32297	62	9					
59	9	32299	61	9					
58	3	32300	62	3					
62	9	32305	61	9					
64	7	32318	62	7					
57	9	32327	58	9					
65	6	32331	65	6					
60	5	32336	59	5					
55	9	32341	55	9					
59	9	32361	60	9					

Validation Test Truck Run Set - Pre

Sheet 3 - 101 - 150 Start: 12:27:19 Stop: 12:36:32

Recorded By: ar Verified By: djw

Traffic Sheet 20	STATE CODE:	18
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	180600
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy)	3/7/2012

Count - 105 Time = 1:19:47 Trucks (4-15) - 100 Class 3s - 5

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
60	5	46238	52	5	59	9	46499	59	9
60	9	46264	62	9	60	9	46502	59	9
62	6	46285	68	6	62	9	46527	62	9
68	**9**	**46286**	**67**	**6**	60	9	46538	61	9
62	9	46291	61	9	58	9	46550	58	9
61	9	46292	61	9	68	5	46556	68	5
64	**8**	**46311**	**64**	**5**	64	5	46573	64	5
59	9	46352	60	9	64	9	46585	64	9
63	9	46355	64	9	65	9	46586	65	9
55	9	46360	54	9	64	5	46609	61	5
57	9	46363	57	9	60	9	46618	58	9
65	**8**	**46372**	**64**	**3**	65	9	46623	63	9
60	5	46383	61	5	64	9	46633	64	9
57	5	46412	59	5	60	9	46653	62	9
66	9	46417	65	9	65	10	46658	64	10
63	9	46419	63	9	64	10	46659	64	10
65	9	46426	64	9	60	9	46674	63	9
60	8	46440	60	8	61	9	46705	61	9
60	6	46441	60	6	60	9	46707	59	9
65	3	46445	65	3	62	9	46720	61	9
66	3	46453	66	3	62	9	46723	61	9
65	9	46458	65	9	60	5	46762	60	5
61	9	46460	62	9	60	9	46770	59	9
61	9	46481	60	9	61	9	46791	60	9
62	9	46493	62	9	63	9	46818	62	9

Validation Test Truck Run Set - Post

Sheet 1 - 0 to 50 Start: 16:13:23 Stop: 16:53:09

Recorded By: ar Verified By: djw

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 18 SPS WIM ID: 180600 DATE (mm/dd/yyyy) 3/7/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
63	4	46821	66	4	60	9	47071	60	9
67	5	46824	65	5	59	10	47074	58	10
59	9	46831	56	9	67	9	47081	67	9
63	9	46858	62	9	64	5	47083	61	5
60	9	46864	60	9	64	9	47103	63	9
58	9	46892	59	9	63	9	47109	62	9
56	9	46896	54	9	63	9	47140	62	9
60	9	46907	62	9	61	5	47144	60	5
63	9	46914	59	9	61	9	47149	59	9
55	8	46922	53	8	63	9	47155	63	9
56	5	46949	58	5	62	9	47156	61	9
47	9	46950	47	9	60	9	47160	59	9
60	9	46954	60	9	61	9	47169	62	9
68	9	46983	67	9	63	8	47182	62	8
64	9	46985	63	9	61	9	47223	60	9
62	9	46995	61	9	64	5	47230	64	5
64	9	47010	62	9	61	5	47239	60	5
61	9	47011	61	9	63	9	47241	63	9
60	9	47015	61	9	66	7	47252	64	7
63	9	47026	63	9	64	5	47258	63	5
67	**8**	**47033**	**66**	**3**	61	6	47267	61	6
60	9	47041	58	9	62	8	47285	62	8
60	9	47048	59	9	62	9	47297	60	9
66	9	47056	66	9	65	9	47315	64	9
73	3	47057	73	3	60	9	47330	60	9

Validation Test Truck Run Set - Post

Sheet 2 - 51 to 100 Start: 16:53:32 Stop: 17:31:23

Recorded By: ar Verified By: djw

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 18 SPS WIM ID: 180600 DATE (mm/dd/yyyy) 3/7/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	5	47342	62	5					
65	9	47346	64	9					
65	9	47347	64	9					
60	9	47349	59	9					
62	9	47353	60	9					

Validation Test Truck Run Set - Post

Sheet 3 - 101 - 150 Start: 17:32:26 Stop: 17:33:10

Recorded By: ar Verified By: djw