WIM System Field Calibration and Validation Summary Report

Tennessee SPS-6
SHRP ID – 470600

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1 Executive Summary

A WIM validation was performed on February 15 and 16, 2011 at the Tennessee SPS-6 site located on route I-40 at milepost 91.7, 1.75 miles west of exit 93 (SR 152).

This site was installed on May 10, 2007. The in-road sensors are installed in the westbound lane. The site is equipped with quartz WIM sensors and IRD iSINC WIM controller. The LTPP lane is identified as lane 4 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on October 01, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

The equipment is in working order. Electronic and electrical checks of the WIM components determined that the the equipment is operating within the manufacturer's tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, there were no pavement deficiencies noted that appear to 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 truck dynamics within the WIM scale area. 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 – Post-Validation Results – 16-Feb-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-2.9 ± 8.9%	Pass
Tandem Axles	±15 percent	-1.1 ± 4.2%	Pass
Tridem Axles	±15 percent	-1.0 ± 7.8%	Pass
Axle Groups	±15 percent	-1.1 ± 5.1%	Pass
GVW	±10 percent	-1.3 ± 3.7%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.8 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.0 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 0.1 ± 2.0 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and 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 0.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 1.0% from the 99 truck sample (Class 4 – 13) was due one misclassification of a Class 5 vehicle as a Class 8 vehicle.

Based on these findings, it is recommended that an expanded investigation, focusing on vehicle classification issues indicated in this report, be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

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 crane weights.

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

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

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)							Spacings (feet)						
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	Ax6	1-2	2-3	3-4	4-5	5-6	AL	OL
1	76.0	9.4	17.0	17.0	16.3	16.3		15.0	4.4	32.6	4.0		56.0	66.0
2	67.7	10.1	12.3	12.3	11.0	11.0	11.0	15.3	4.3	27.5	4.2	4.2	55.5	60.6

The posted speed limit at the site is 70 mph. During the testing, the speed of the test trucks ranged from to 58 to 70 mph, a variance of 12 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 63.9 to 79.6 degrees Fahrenheit, a range of 15.7 degrees Fahrenheit. The cloudy weather conditions prevented the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 24 shows that there are 25 consecutive months of level "E" WIM data for this site. This site requires at least 3 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 December 13, 2010 (Data) to the most recent Comparison Data Set (CDS) from June 01, 2007. The assessments performed prior to the site visits are used to develop reasonable expectations for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 24 shows that there are 2 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2007 through 2009.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2007	214	7
2008	312	12
2009	169	6

As shown in the table, this site requires 3 additional years of data to meet the minimum of five years of research quality data. The 2009 data does not meet the 210-day minimum requirement for a calendar year.

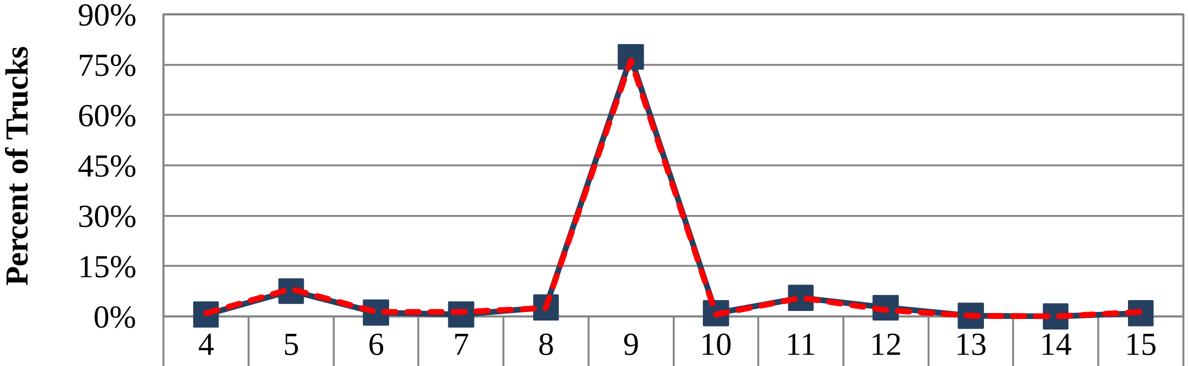
Table 2-2 provides a monthly breakdown of the available data for years 2007 through 2009.

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	
2007						30	31	31	30	31	30	31	7
2008	23	29	28	29	31	23	23	24	30	18	23	31	12
2009	31	28	31	27	31	21							6

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	0.6%	7.6%	1.1%	0.6%	2.7%	77.3%	1.0%	5.5%	2.6%	0.2%	0.0%	0.9%
CDS	1.0%	8.2%	1.3%	1.4%	2.4%	76.2%	0.6%	5.5%	1.9%	0.2%	0.0%	1.3%

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 (77.3%) and Class 5 (7.6%). 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 0.9 percent of the vehicles at this site are unclassified.

Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	6/1/2007		12/13/2010		
4	659	0.9%	449	0.6%	-0.3%
5	5805	7.7%	5669	7.6%	-0.2%
6	1003	1.3%	840	1.1%	-0.2%
7	1185	1.6%	422	0.6%	-1.0%
8	1816	2.4%	1995	2.7%	0.2%
9	57441	76.6%	57982	77.3%	0.7%
10	401	0.5%	736	1.0%	0.4%
11	4178	5.6%	4151	5.5%	0.0%
12	1394	1.9%	1933	2.6%	0.7%
13	127	0.2%	124	0.2%	0.0%
14	0	0.0%	0	0.0%	0.0%
15	991	1.3%	699	0.9%	-0.4%

From the table it can be seen that the number of Class 9 vehicles has increased by 0.7 percent from June 2007 and December 2010. Changes in the number of heavier trucks may be attributed to seasonal variations in truck distributions. During the same time period, the number of Class 5 trucks decreased by 0.2 percent. These differences may be attributed to small sample size used to develop vehicle class distributions, 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.

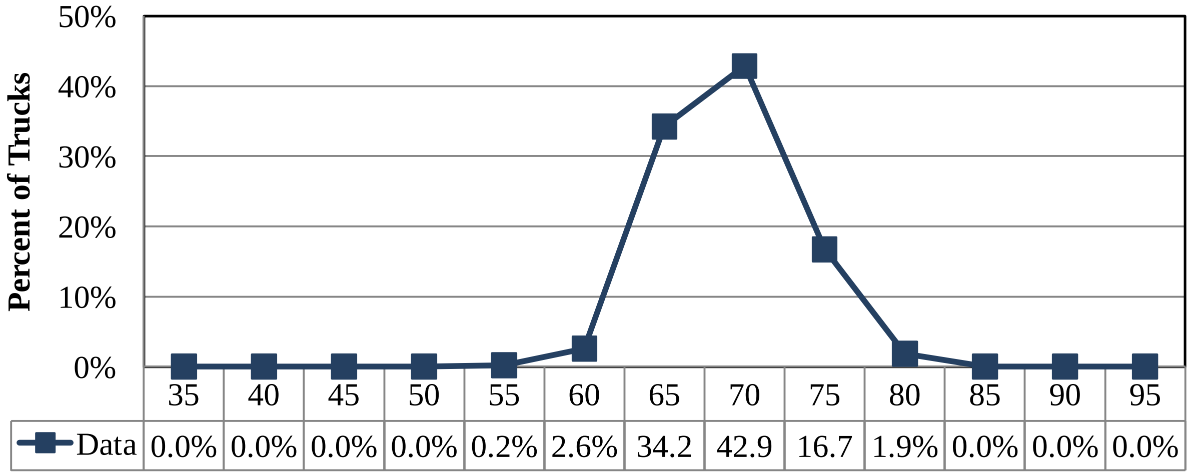


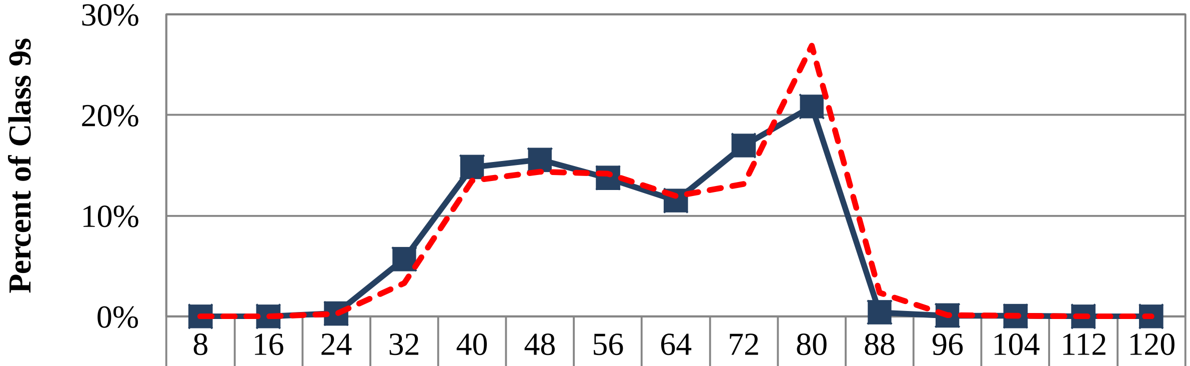
Figure 2-2 – Truck Speed Distribution – 28-Jan-11

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 65 and 75 mph. The posted speed limit at this site is 70 and the 85th percentile speed for trucks at this site is 71 mph. The range of truck speeds for the validation will be between 60 and 70 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 December 2010 and the Comparison Data Set from June 2007.

As shown in Figure 2-3, there is a downward shift for the loaded peak between the June 2007 Comparison Data Set (CDS) and the December 2010 two-week sample W-card dataset (Data). The results indicate that there may have been a change in the distribution of GVW of Class 9 vehicles on this route.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.3%	5.7%	14.8	15.6	13.8	11.5	17.0	20.9	0.4%	0.1%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.2%	3.3%	13.5	14.4	14.2	12.0	13.1	26.9	2.3%	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 December Data.

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

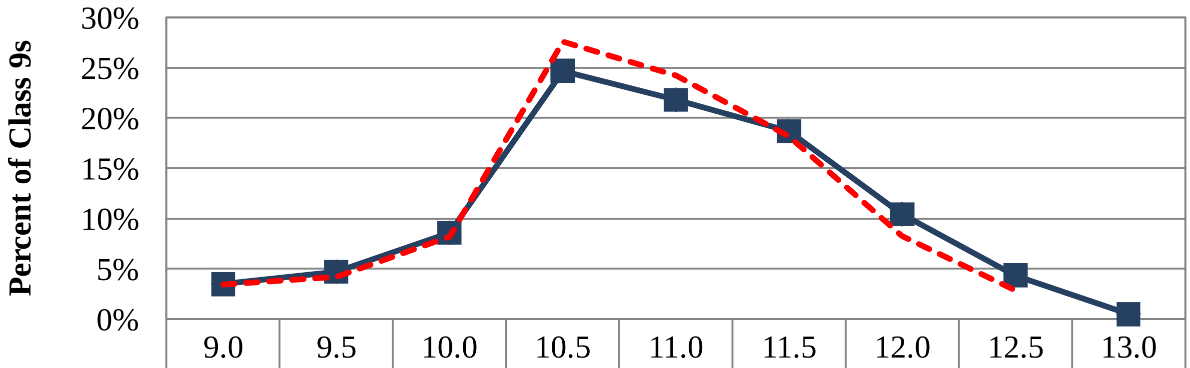
GVW weight bins (kips)	CDS		Data		Change
	Date				
	6/1/2007		12/13/2010		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	139	0.2%	174	0.3%	0.1%
32	1968	3.4%	3300	5.7%	2.3%
40	7664	13.4%	8587	14.8%	1.4%
48	8106	14.2%	9004	15.6%	1.4%
56	7980	13.9%	7963	13.8%	-0.2%
64	6751	11.8%	6653	11.5%	-0.3%
72	7429	13.0%	9832	17.0%	4.0%
80	15683	27.4%	12081	20.9%	-6.5%
88	1467	2.6%	232	0.4%	-2.2%
96	68	0.1%	51	0.1%	0.0%
104	7	0.0%	20	0.0%	0.0%
112	1	0.0%	1	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	58.0		55.8		-2.2

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range increased by 1.4 percent while the number of loaded class 9 trucks in the 72 to 80 kips range decreased by 6.5 percent. The number of overweight trucks decreased during this time period by 2.2 percent and the overall GVW average for this site decreased from 58.0 kips to 55.8 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 Data set with the expected average front axle weight average from the Comparison Data Set.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from December 2010 and the Comparison Data Set from June 2007.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Data	3.5%	4.7%	8.6%	24.7%	21.8%	18.7%	10.4%	4.3%	0.5%
CDS	3.4%	4.2%	8.2%	27.6%	24.2%	18.2%	8.3%	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 10.5 and 11.0 kips. The percentage of trucks in this range has decreased between the June 2007 Comparison Data Set (CDS) and the December 2010 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the June 2007 Comparison Data Set (CDS) and the December 2010 dataset (Data). The table shows that the average front axle weight for Class 9 trucks has remained at 11.1 kips.

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

F/A weight bins (kips)	CDS		Data		Change
	Date				
	6/1/2007		12/13/2010		
9.0	7432	2.6%	1643	2.8%	0.2%
9.5	9781	3.5%	2001	3.5%	0.0%
10.0	11935	4.2%	2710	4.7%	0.5%
10.5	23399	8.3%	4947	8.6%	0.3%
11.0	78268	27.7%	14258	24.7%	-3.1%
11.5	68183	24.2%	12599	21.8%	-2.4%
12.0	51156	18.1%	10786	18.7%	0.5%
12.5	23035	8.2%	6017	10.4%	2.3%
13.0	7861	2.8%	2508	4.3%	1.6%
13.5	1058	0.4%	279	0.5%	0.1%
Average =	11.1		11.1		0.0

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 (Data) with the expected average tractor tandem spacing from the comparison data set (CDS).

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

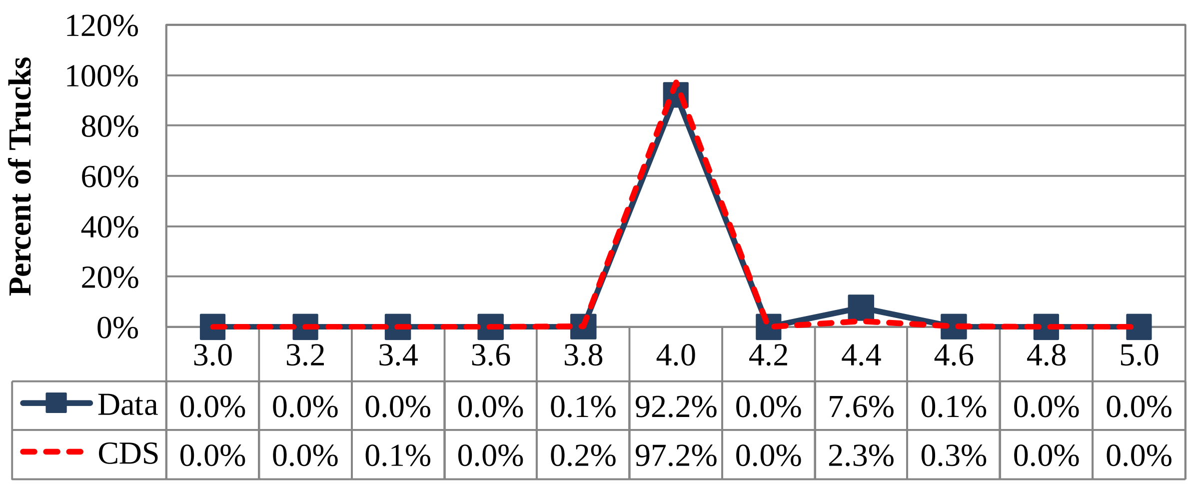


Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacing for the June 2007 Comparison Data Set and the December 2010 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 3 to 4 Spacing from W-Card

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	6/1/2007		12/13/2010		
3.0	3	0.0%	0	0.0%	0.0%
3.2	6	0.0%	0	0.0%	0.0%
3.4	13	0.0%	5	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	99	0.2%	34	0.1%	-0.1%
4.0	55658	97.2%	53391	92.2%	-5.0%
4.2	0	0.0%	0	0.0%	0.0%
4.4	1329	2.3%	4396	7.6%	5.3%
4.6	148	0.3%	68	0.1%	-0.1%
4.8	0	0.0%	0	0.0%	0.0%
5.0	7	0.0%	4	0.0%	0.0%
Average =	4.0		4.0		0.0

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. The average tractor tandem spacing from the sample data is 4.0 feet, which is identical to the expected average of 4.0 feet from the comparison data set. 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 (June 2007) based on the last calibration with the most recent two-week WIM data sample from the site (December 2010). Comparison of vehicle class distribution data indicates a 0.7 percent increased in the number of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have not changed, and average Class 9 GVW has decreased by 3.8 percent for the December 2010 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical 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 October 01, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

3.1 Description

This site was installed on May 10, 2007 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 and 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 WIM sensors and inductive loops were within tolerances. Electronic tests of the power and communication devices indicated that they were operating normally.

3.4 Equipment Troubleshooting and Diagnostics

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

3.5 Recommended Equipment Maintenance

No equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, no areas of pavement distress that may affect the accuracy of the WIM sensors were noted.

4.2 Profile and Vehicle Interaction

Profile data was collected on May 22, 2010 by the Southern 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 86 in/mi and is located approximately 663 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 93 in/mi and is located approximately 29 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)	0.518	0.560	1.015			0.698
		SRI (m/km)	*0.468*	*0.463*	**3.348**			1.426
		Peak LRI (m/km)	0.567	0.578	1.015			0.720
		Peak SRI (m/km)	0.521	0.582	**4.353**			1.819
	RWP	LRI (m/km)	0.533	*0.499*	0.508			0.513
		SRI (m/km)	*0.340*	*0.244*	*0.380*			*0.321*
		Peak LRI (m/km)	0.606	0.617	0.640			0.621
		Peak SRI (m/km)	*0.378*	*0.328*	*0.391*			*0.366*
Center	LWP	LRI (m/km)	0.659	1.077	0.576	0.624	0.665	0.734
		SRI (m/km)	1.022	0.996	*0.486*	0.597	0.895	0.775
		Peak LRI (m/km)	0.659	1.077	0.587	0.624	0.674	0.737
		Peak SRI (m/km)	1.284	1.052	*0.625*	1.007	1.059	0.992
	RWP	LRI (m/km)	0.511	0.631	0.572	0.542	*0.463*	0.564
		SRI (m/km)	*0.187*	*0.497*	*0.386*	*0.340*	*0.170*	*0.353*
		Peak LRI (m/km)	0.593	0.631	0.584	0.542	0.510	0.588
		Peak SRI (m/km)	*0.294*	0.756	*0.572*	*0.365*	*0.290*	*0.497*
Right	LWP	LRI (m/km)	0.527	0.531	0.526			0.528
		SRI (m/km)	*0.286*	*0.312*	*0.243*			*0.280*
		Peak LRI (m/km)	0.645	0.626	0.560			0.610
		Peak SRI (m/km)	*0.350*	*0.363*	*0.403*			*0.372*
	RWP	LRI (m/km)	1.065	0.652	0.585			0.767
		SRI (m/km)	**3.036**	1.059	*0.427*			1.507
		Peak LRI (m/km)	1.065	0.652	0.586			0.768
		Peak SRI (m/km)	**3.471**	1.239	*0.664*			1.791

From Table 4-2 it can be seen that most of the indices computed from the profiles are between the upper and lower threshold values, with the remaining values below the lower threshold (shown in italics). The highest values are the Peak SRI values in the left and the right wheel path (shown in bold).

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

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

5.1 Pre-Validation

The first set of 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 February 15, 2011, beginning at approximately 8:33 AM and continuing until 3:52 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with crane weights, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 10, 6-axle truck, loaded with crane weights, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tridem 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	Ax6	1-2	2-3	3-4	4-5	5-6	AL	OL
1	76.0	10.0	16.7	16.7	16.3	16.3		15.0	4.4	32.6	4.0		56.0	66.0
2	67.8	9.6	12.6	12.6	11.0	11.0	11.0	15.3	4.3	27.5	4.2	4.2	55.5	60.6

Test truck speeds varied by 12 mph, from 58 to 70 mph. The measured pre-validation pavement temperatures varied 29.2 degrees Fahrenheit, from 40.1 to 69.3. The partly cloudy weather conditions nearly provided the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

Table 5-2 – Pre-Validation Overall Results – 15-Feb-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-4.4 ± 5.6%	Pass
Tandem Axles	±15 percent	-4.3 ± 4.9%	Pass
Tridem Axles	±15 percent	-6.8 ± 5.0%	Pass
Axle Groups	±15 percent	-4.9 ± 4.9%	Pass
GVW	±10 percent	-4.6 ± 3.9%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	1.9 ± 1.7 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.0 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 ± 2.2 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 0.1 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.

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 70 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 – 15-Feb-11

Parameter	95% Confidence Limit of Error	Low	Medium	High
		58.0 to 62.0 mph	62.1 to 66.1 mph	66.2 to 70.0 mph
Steering Axles	±20 percent	-3.9 ± 5.9%	-3.8 ± 4.6%	-5.7 ± 7.3%
Tandem Axles	±15 percent	-3.6 ± 5.3%	-4.0 ± 4.4%	-5.5 ± 6.3%
Tridem Axles	±15 percent	-5.1 ± 3.7%	-6.7 ± 2.9%	-9.1 ± 7.0%
Axle Groups	±15 percent	-4.3 ± 4.5%	-5.3 ± 3.6%	-7.3 ± 6.7%
GVW	±10 percent	-3.9 ± 3.3%	-4.3 ± 3.3%	-5.9 ± 5.2%
Vehicle Length	±3.0 percent (1.9 ft)	1.8 ± 1.5 ft	2.0 ± 1.9 ft	1.9 ± 2.1 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 2.6 mph	0.4 ± 2.0 mph	0.6 ± 2.4 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.1 ft	0.1 ± 0.0 ft

From the table, it can be seen that the WIM equipment underestimates all weights at all speeds. The range of errors is greater at the higher speeds. There does not appear to be a significant relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, 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 underestimates GVW at all speeds. The range of GVW error is greater at the high speeds. Distribution of errors is shown graphically in the following figure.

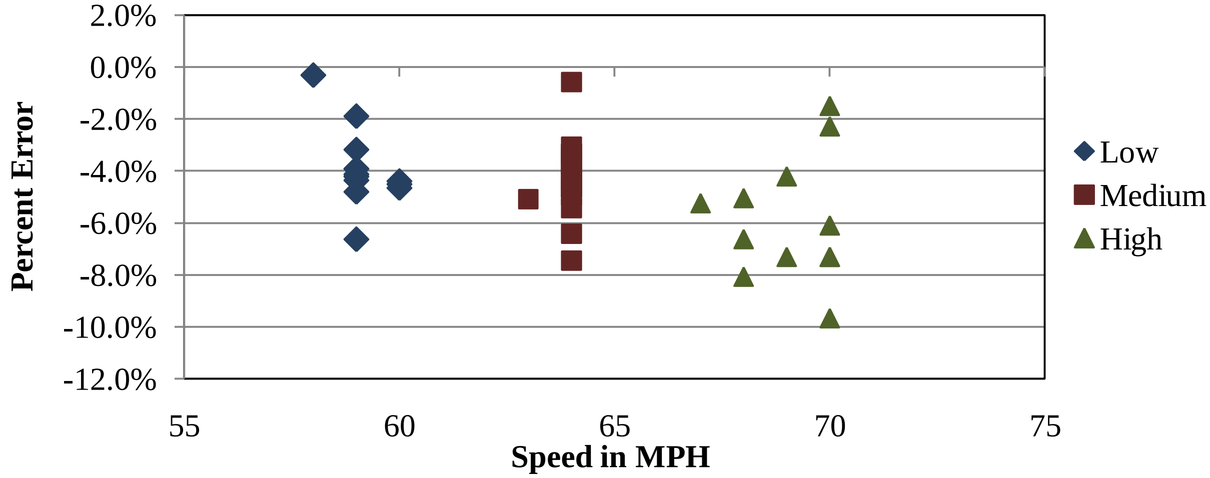


Figure 5-1 – Pre-Validation GVW Error by Speed – 15-Feb-11

5.1.1.2 Steering Axle Weight Errors by Speed

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

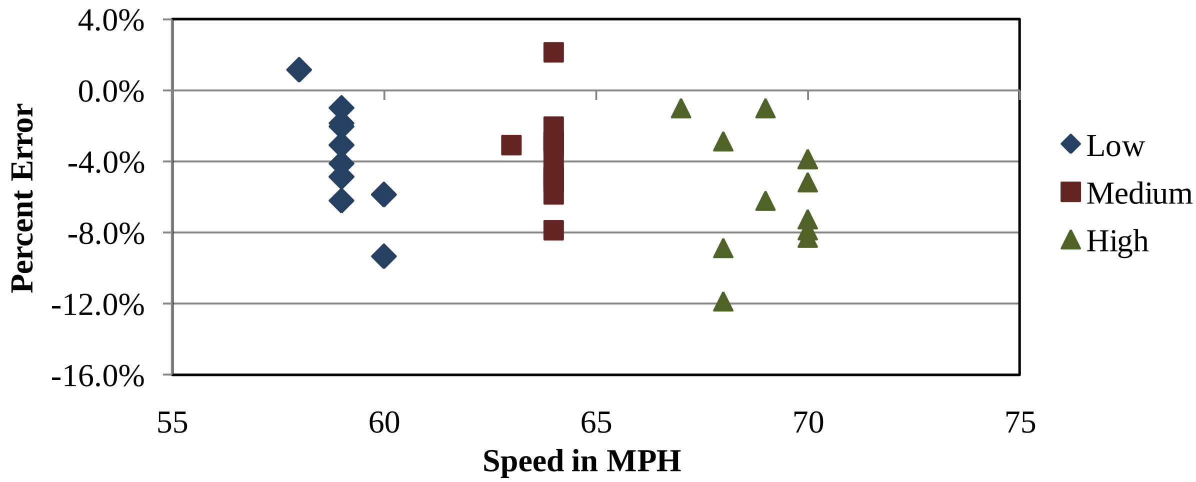


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 15-Feb-11

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment generally underestimates tandem axle weights at all speeds. The range in error is greater at the high speeds.

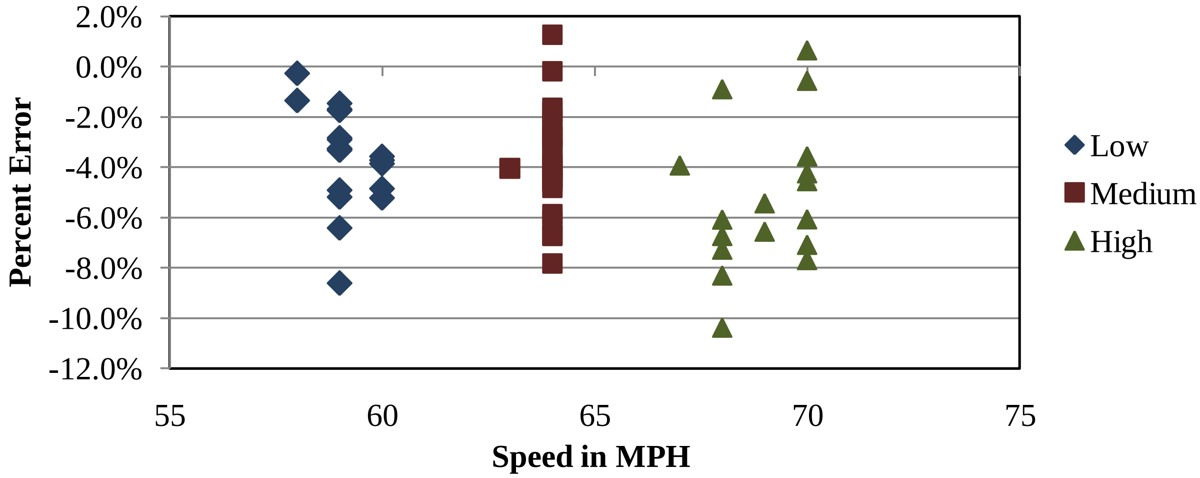


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 15-Feb-11

5.1.1.4 Tridem Axle Weight Errors by Speed

As shown in Figure 5-4, the equipment underestimates tridem axle weights at all speeds. The range in error is greater at the high speeds.

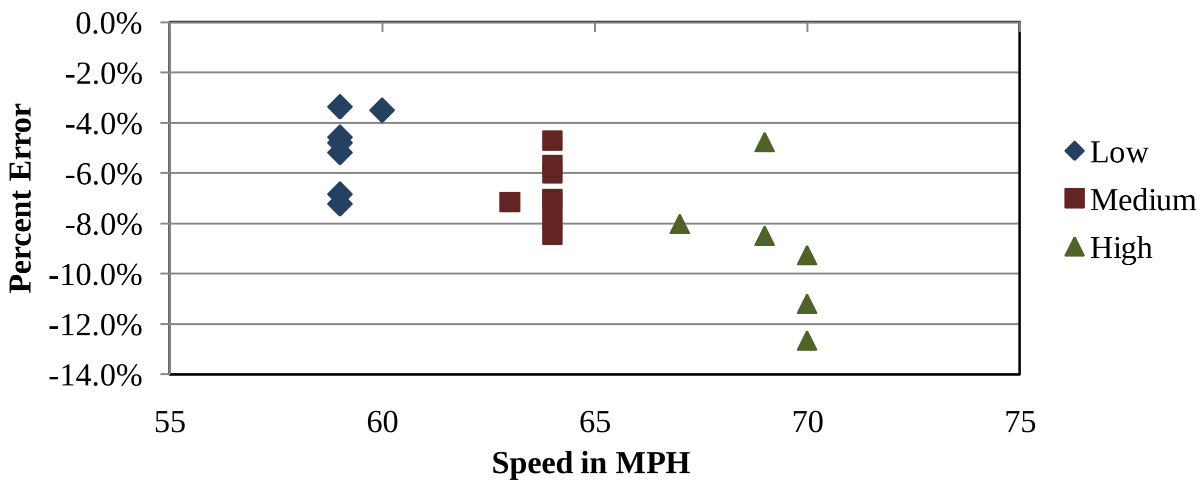


Figure 5-4 – Pre-Validation Tridem Axle Weight Errors by Speed – 15-Feb-11

5.1.1.5 GVW Errors by Speed and Truck Type

As shown in Figure 5-5, when analyzed for each test truck, the WIM equipment underestimates GVW for the partially loaded (Secondary) truck to a greater degree than for the heavily loaded (Primary) truck at medium and high speeds. The range in error is reasonably similar for each test truck.

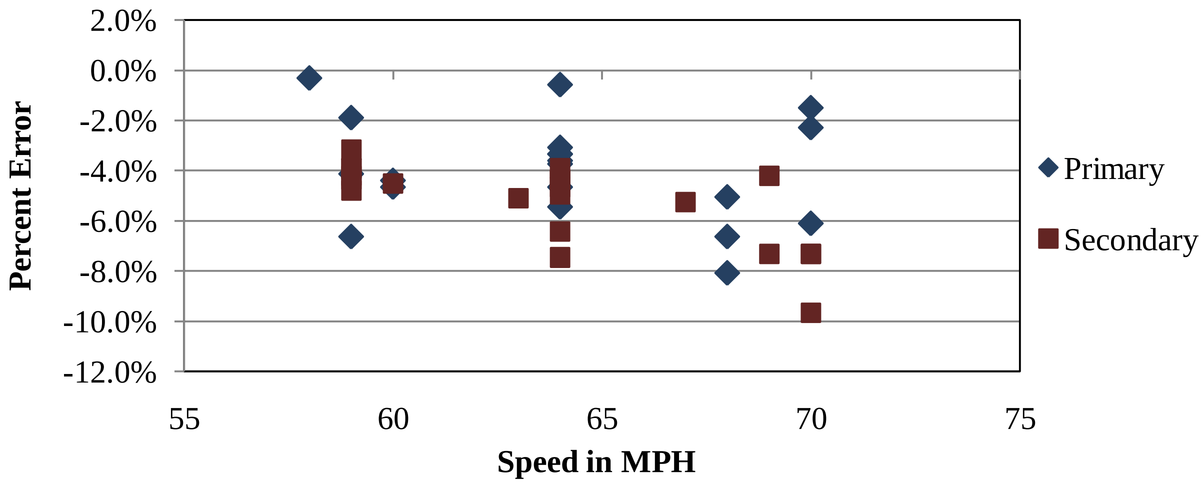


Figure 5-5 – Pre-Validation GVW Errors by Truck and Speed – 15-Feb-11

5.1.1.6 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from 0.0 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-6.

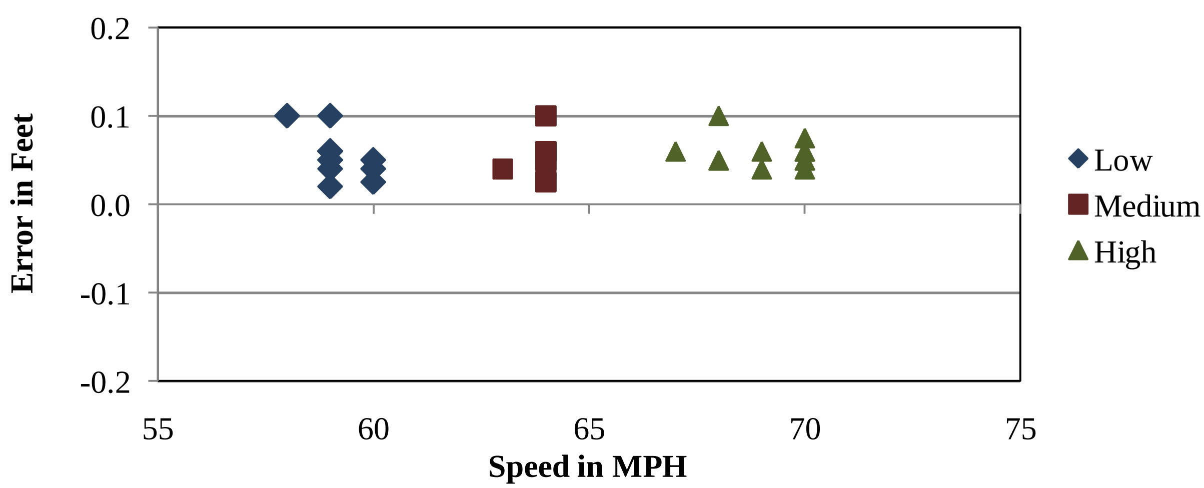


Figure 5-6 – Pre-Validation Axle Length Errors by Speed – 15-Feb-11

5.1.1.7 Overall Length Errors by Speed

For this system, the WIM equipment overestimated overall vehicle length over the entire speed range, with an error range of 1.0 to 3.4 feet. Distribution of errors is shown graphically in Figure 5-7.

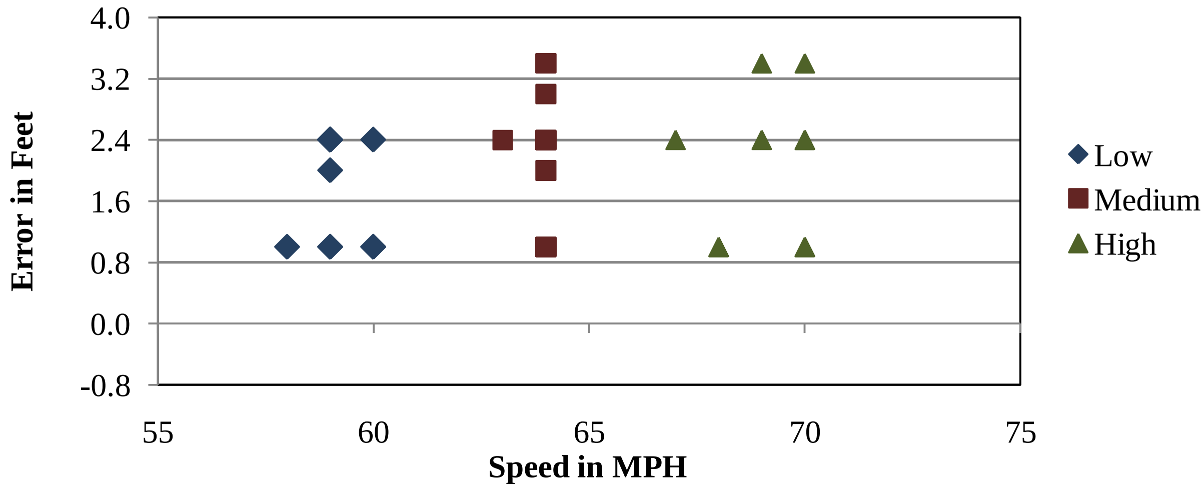


Figure 5-7 – Pre-Validation Overall Length Error by Speed – 15-Feb-11

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 29.2 degrees, from 40.1 to 69.3 degrees Fahrenheit. The pre-validation test runs are being reported under three temperature groups - low, medium, and high, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 15-Feb-11

Parameter	95% Confidence Limit of Error	Low	Medium	High
		40.1 to 49.8 degF	49.9 to 63.0 degF	63.1 to 69.3 degF
Steering Axles	±20 percent	-2.3 ± 5.6%	-3.1 ± 3.2%	-6.0 ± 5.2%
Tandem Axles	±15 percent	-2.4 ± 4.1%	-5.1 ± 6.9%	-4.9 ± 4.1%
Tridem Axles	±15 percent	-6.4 ± 2.5%	-7.3 ± 7.4%	-6.8 ± 6.3%
Axle Groups	±15 percent	-3.4 ± 3.7%	-5.6 ± 7.0%	-5.4 ± 4.7%
GVW	±10 percent	-3.1 ± 3.8%	-4.8 ± 4.2%	-5.3 ± 3.7%
Vehicle Length	±3.0 percent (1.9 ft)	2.0 ± 2.1 ft	1.9 ± 1.9 ft	1.9 ± 1.7 ft
Vehicle Speed	± 1.0 mph	-0.2 ± 2.1 mph	0.3 ± 3.5 mph	0.5 ± 1.7 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.0 ft	0.0 ± 0.0 ft

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

5.1.2.1 GVW Errors by Temperature

From Figure 5-8, it can be seen that the equipment underestimates GVW across the range of temperatures observed in the field. There appears to be a correlation between temperature and weight estimates where an increase in temperature causes a decrease in GVW estimates.

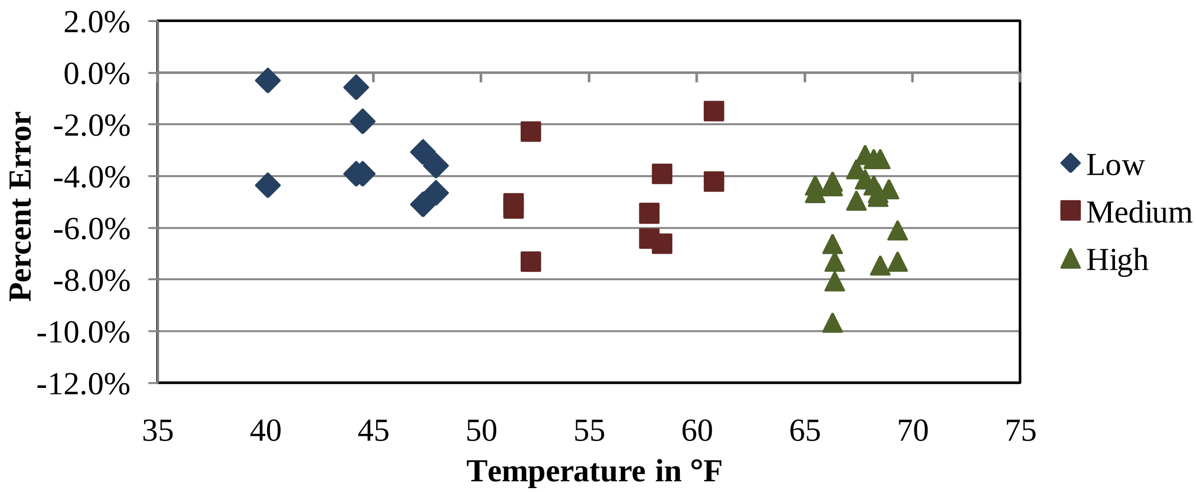


Figure 5-8 – Pre-Validation GVW Errors by Temperature – 15-Feb-11

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-9 illustrates that for steering axles, the WIM equipment demonstrates a similar trend as with GVW estimates, where as the temperature rises, the estimation of steering axle weight decreases.

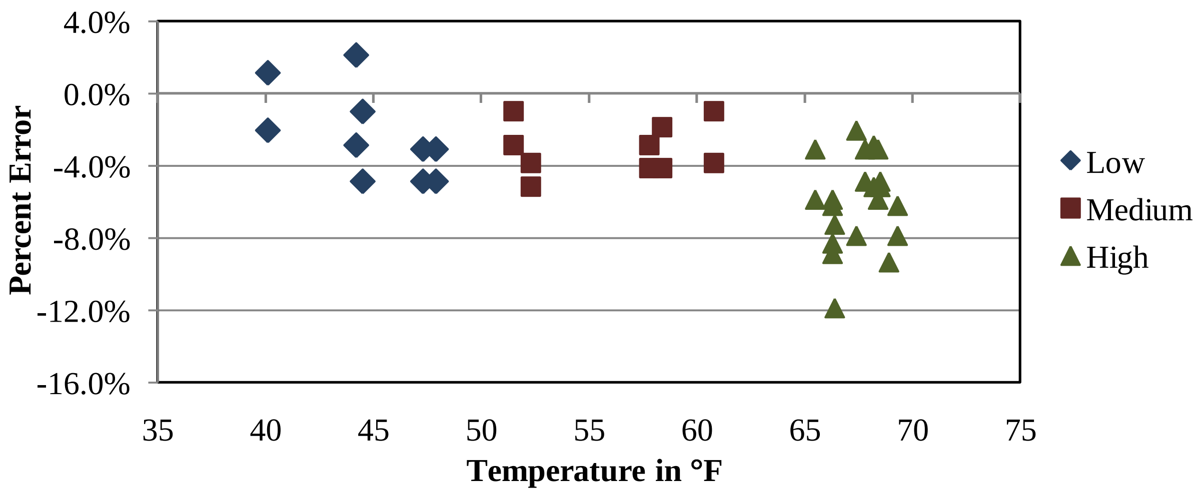


Figure 5-9 – Pre-Validation Steering Axle Weight Errors by Temperature – 15-Feb-11

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-10, the WIM equipment generally underestimates tandem axle weights across the range of temperatures observed in the field. The range in tandem axle errors is highest at medium temperatures and lowest at low temperatures.

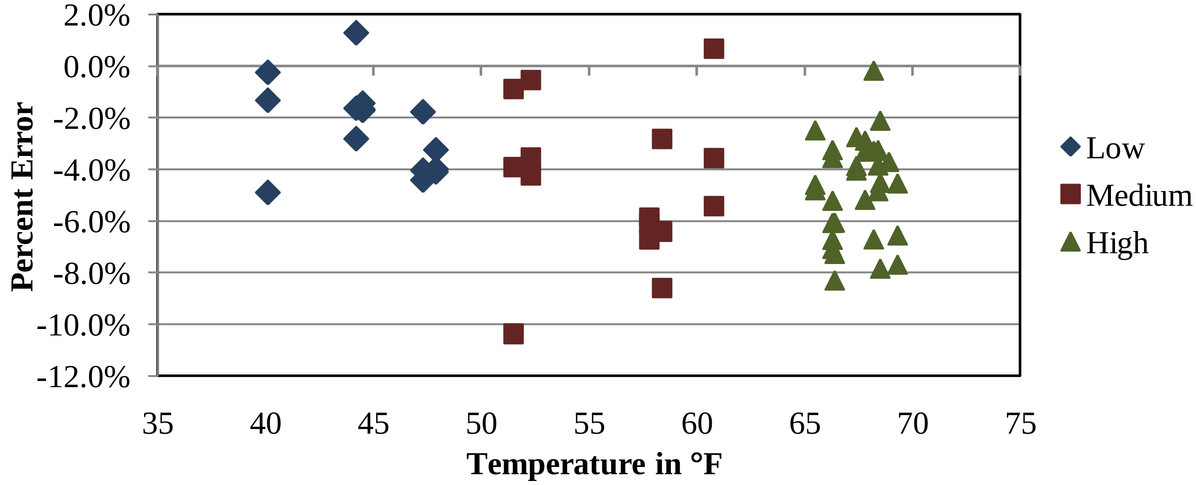


Figure 5-10 – Pre-Validation Tandem Axle Weight Errors by Temperature – 15-Feb-11

5.1.2.4 Tridem Axle Weight Errors by Temperature

As shown in Figure 5-11, the WIM equipment generally underestimates tridem axle weights across the range of temperatures observed in the field. The range in tridem axle errors increases as temperatures increase.

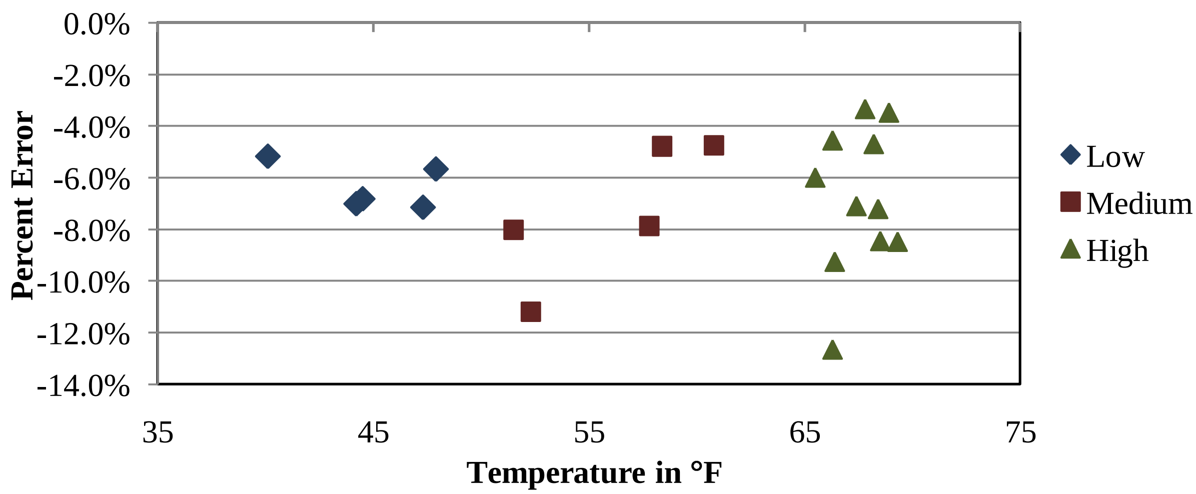


Figure 5-11 – Pre-Validation Tandem Axle Weight Errors by Temperature – 15-Feb-11

5.1.2.5 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, the WIM equipment underestimates GVW for the partially loaded (Secondary) truck to a greater degree than the heavily loaded (Primary) truck at low and medium temperatures. Distribution of errors is shown graphically in Figure 5-12.

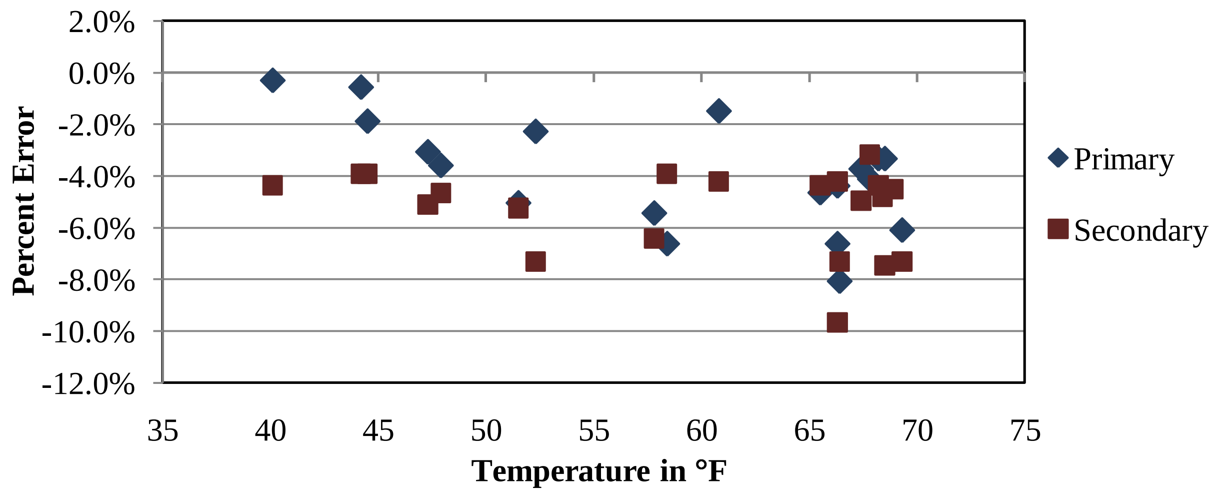


Figure 5-12 – Pre-Validation GVW Error by Truck and Temperature – 15-Feb-11

5.1.3 Classification and Speed Evaluation

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

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

Table 5-5 – Pre-Validation Classification Study Results – 15-Feb-11

Class	4	5	6	7	8	9	10	11	12	13
Observed Count	0	4	3	2	2	81	2	3	3	0
WIM Count	0	3	2	3	3	81	2	3	3	0
Observed Percent	0.0	4.0	3.0	2.0	2.0	81.0	2.0	3.0	3.0	0.0
WIM Percent	0.0	3.0	2.0	3.0	3.0	81.0	2.0	3.0	3.0	0.0
Misclassified Count	0	1	1	0	0	0	0	0	0	0
Misclassified Percent	0.0	25.0	33.3	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
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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 misclassified percentage represents the percentage of the misclassified vehicles in the manual sample. The misclassifications by pair are provided in Table 5-6.

Table 5-6 – Pre-Validation Misclassifications by Pair – 15-Feb-11

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

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

As shown in the table, a total of 2 vehicles, including 1 heavy truck (6 – 13) were misclassified by the equipment. The misclassifications were a Class 5 truck identified by the WIM equipment as Class 8 and a Class 6 truck that was identified as Class 7 by the WIM equipment.

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

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 15-Feb-11

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

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 -0.2 mph; the range of errors was 1.4 mph.

Based on these findings, it is recommended that an expanded investigation, focusing on vehicle classification issues indicated in this report, be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

5.2 Calibration

The WIM equipment required two calibration iterations 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 – 16-Feb-11

Speed Point	MPH	Left		Right	
		1	3	2	4
88	55	2899	2899	3077	3077
96	60	2899	2899	3077	3077
104	65	2923	2923	3102	3102
112	70	2910	2910	3089	3089
120	75	2910	2910	3089	3089
Axle Distance (cm)		306			
Dynamic Comp (%)		107			
Loop Width (cm)		200			

5.2.1 Calibration Iteration 1

5.2.1.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of -4.6%, and errors of -3.9%, -4.3%, and -5.9% at the 60, 65 and 70 mph speed points, respectively. The errors for the 60 mph and 70 mph speed points were extrapolated to derive new compensation factors for the 55 mph and 75 mph speed points. To compensate for these errors, the changes shown in Table 5-9 were made to the compensation factors.

Table 5-9 – Calibration 1 Equipment Factor Changes – 16-Feb-11

Speed Points	Old Factors				Error	New Factors			
	Left		Right			Left		Right	
	1	3	2	4		1	3	2	4
88	2899	2899	3077	3077	-4.43%	3034	3034	3220	3220
96	2899	2899	3077	3077	-4.21%	3026	3026	3212	3212
104	2923	2923	3102	3102	-4.66%	3066	3066	3254	3254
112	2910	2910	3089	3089	-6.24%	3104	3104	3295	3295
120	2910	2910	3089	3089	-6.24%	3104	3104	3295	3295
Axle Distance (cm)	306				-0.28%	305			
Dynamic Comp (%)	107				-4.39%	107			
Loop Width (cm)	200				1.91 ft	258			

5.2.1.2 Calibration 1 Results

The results of the 12 first calibration verification runs are provided in Table 5-10 and Figure 5-13. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the first calibration iteration.

Table 5-10 – Calibration 1 Results – 16-Feb-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	3.1 ± 7.6%	Pass
Tandem Axles	±15 percent	1.6 ± 2.8%	Pass
Tridem Axles	±15 percent	2.0 ± 10.2%	Pass
Axle Groups	±15 percent	1.7 ± 4.6%	Pass
GVW	±10 percent	2.0 ± 2.8%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	-0.4 ± 2.4 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.0 ft	Pass

Figure 5-13 shows that as a result of the first calibration iteration, the WIM equipment is overestimating GVW at all speeds.

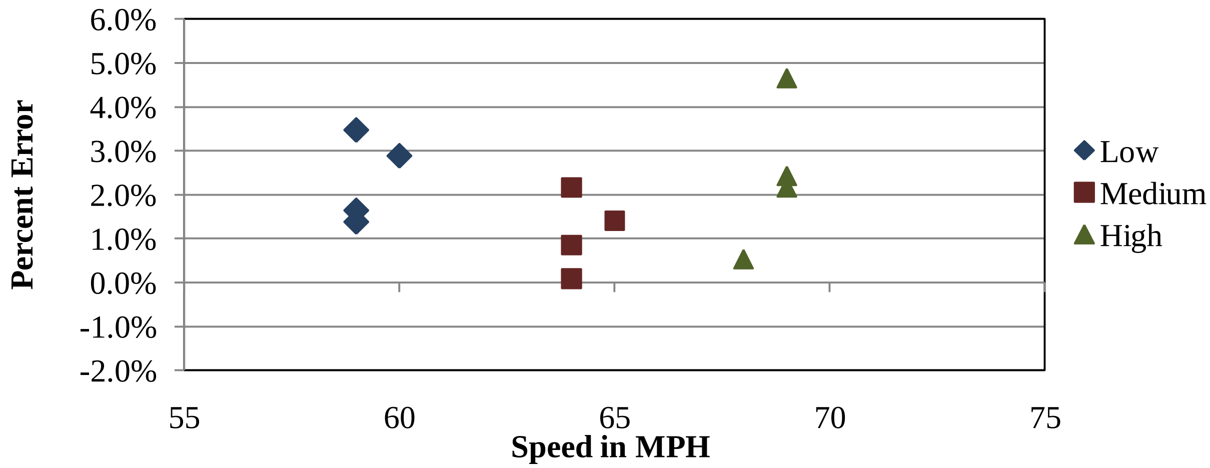


Figure 5-13 – Calibration 1 GVW Error by Speed – 16-Feb-11

Based on the results of the first calibration, where weight estimate bias was 2.0 percent, a second calibration was considered to be necessary.

5.2.2 Calibration Iteration 2

5.2.2.1 Equipment Adjustments

The first calibration test truck run set produced an overall error of 2.0%, and errors of 2.3%, 1.1%, and 2.4% at the 60, 65 and 70 mph speed points, respectively. The errors for the 60 mph and 70 mph speed points were extrapolated to derive new compensation factors for the 55 mph and 75 mph speed points. To compensate for these errors, the changes to the compensation factors given in Table 5-11 were made.

Table 5-11 – Calibration 2 Equipment Factor Changes – 16-Feb-11

Speed Points	Old Factors				Error	New Factors			
	Left		Right			Left		Right	
	1	3	2	4		1	3	2	4
88	3034	3034	3220	3220	1.60%	2986	2986	3169	3169
96	3026	3026	3212	3212	2.20%	2961	2961	3143	3143
104	3066	3066	3254	3254	0.99%	3036	3036	3222	3222
112	3104	3104	3295	3295	2.30%	3034	3034	3220	3220
120	3104	3104	3295	3295	2.30%	3034	3034	3220	3220
Axle Distance (cm)	305				0.02%	305			
Dynamic Comp (%)	107				3.12%	106			
Loop Width (cm)	258				-0.383 ft	246			

5.2.2.2 Calibration 2 Results

The results of the 12 second calibration verification runs are provided in Table 5-12 and Figure 5-14. As can be seen in the table, the mean error of all weight estimates was reduced to an acceptable level as a result of the second calibration iteration.

Table 5-12 – Calibration 2 Results – 16-Feb-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-0.3 ± 5.5%	Pass
Tandem Axles	±15 percent	-1.6 ± 3.8%	Pass
Tridem Axles	±15 percent	0.4 ± 6.3%	Pass
Axle Groups	±15 percent	-1.1 ± 4.4%	Pass
GVW	±10 percent	-0.8 ± 3.8%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.5 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.0 ft	Pass

Figure 5-14 shows that the WIM equipment is estimating GVW with reasonable accuracy at all speeds.

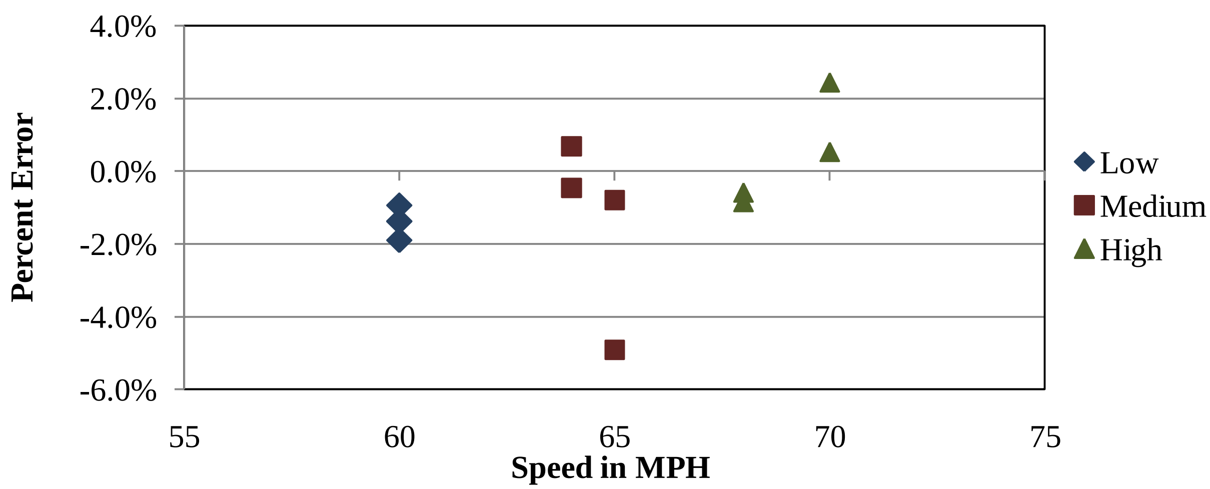


Figure 5-14 – Calibration 2 GVW Error by Speed – 16-Feb-11

Based on the results of the second calibration, where weight estimate bias decreased to -0.8 percent, a third calibration was not considered to be necessary. The 12 calibration runs from the second calibration were combined with 28 additional post-validation runs to complete the WIM system validation.

5.3 Post-Validation

The 40 post-validation test truck runs were conducted on February 16, 2011, beginning at approximately 10:02 AM and continuing until 3:55 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with crane weights, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 10, 6-axle truck, loaded with crane weights, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tridem 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 5-13.

Table 5-13 - Post-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	9.4	17.0	17.0	16.3	16.3		15.0	4.4	32.6	4.0		56.0	66.0
2	67.7	10.1	12.3	12.3	11.0	11.0	11.0	15.3	4.3	27.5	4.2	4.2	55.5	60.6

Test truck speeds varied by 12 mph, from 58 to 70 mph. The measured post-validation pavement temperatures varied 15.7 degrees Fahrenheit, from 63.9 to 79.6. The cloudy weather conditions prevented attaining the desired 30 degree temperature range. Table 5-14 is a summary of post validation results.

Table 5-14 – Post-Validation Overall Results – 16-Feb-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-2.9 ± 8.9%	Pass
Tandem Axles	±15 percent	-1.1 ± 4.2%	Pass
Tridem Axles	±15 percent	-1.0 ± 7.8%	Pass
Axle Groups	±15 percent	-1.1 ± 5.1%	Pass
GVW	±10 percent	-1.3 ± 3.7%	Pass
Vehicle Length	±3.0 percent (1.9 ft)	0.0 ± 1.8 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.0 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 0.1 ± 2.0 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, 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 acceptable ranges.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relation exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 70 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-15 below.

Table 5-15 – Post-Validation Results by Speed – 16-Feb-11

Parameter	95% Confidence Limit of Error	Low	Medium	High
		58.0 to 62.0 mph	62.1 to 66.1 mph	66.2 to 70.0 mph
Steering Axles	±20 percent	-3.2 ± 10.9%	-2.8 ± 7.5%	-2.7 ± 10.3%
Tandem Axles	±15 percent	-1.4 ± 4.4%	-1.2 ± 5.2%	-0.8 ± 4.4%
Tridem Axles	±15 percent	-2.3 ± 3.6%	-1.2 ± 8.8%	0.5 ± 12.8%
Axle Groups	±15 percent	-1.9 ± 4.0%	-1.2 ± 7.0%	-0.2 ± 8.6%
GVW	±10 percent	-2.0 ± 2.1%	-1.3 ± 4.2%	-0.5 ± 4.9%
Vehicle Length	±3.0 percent (1.9 ft)	0.3 ± 2.3 ft	-0.2 ± 1.4 ft	0.1 ± 2.0 ft
Vehicle Speed	± 1.0 mph	-0.3 ± 2.7 mph	0.2 ± 1.8 mph	0.3 ± 1.6 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.0 ft	0.0 ± 0.0 ft	0.0 ± 0.0 ft

From the table, it can be seen that the WIM equipment estimates all weights with reasonable accuracy. The range of errors generally increases as speed increases. Consequently, there does appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, 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 5-15, the equipment estimated GVW with reasonable accuracy at all speeds. The range in error, as well as percent error, increases as speed increases.

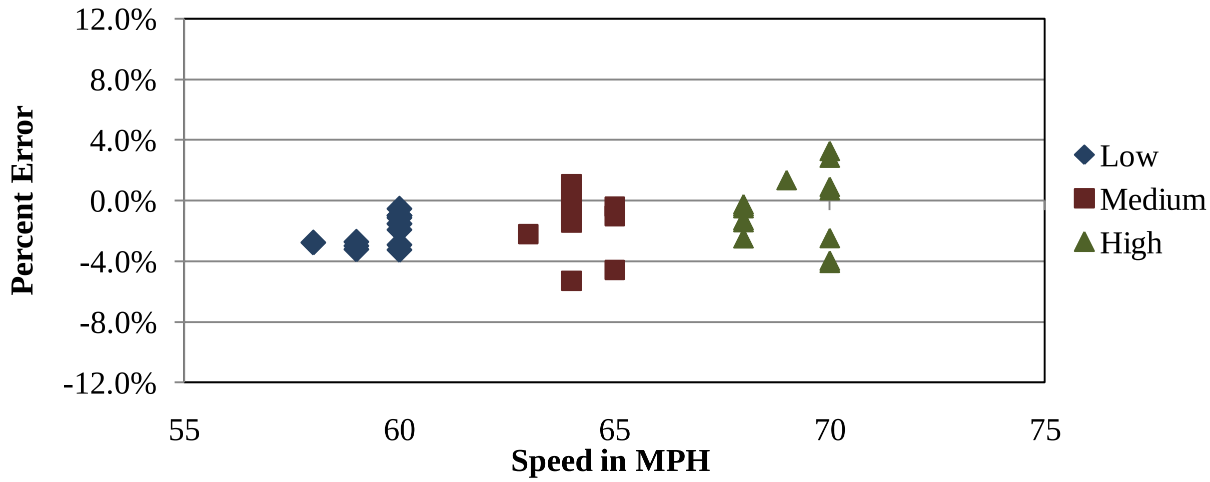


Figure 5-15 – Post-Validation GVW Errors by Speed – 16-Feb-11

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-16, the equipment estimated steering axle weights with reasonable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range. There does not appear to be a correlation between speed and steering axle weight estimates at this site.

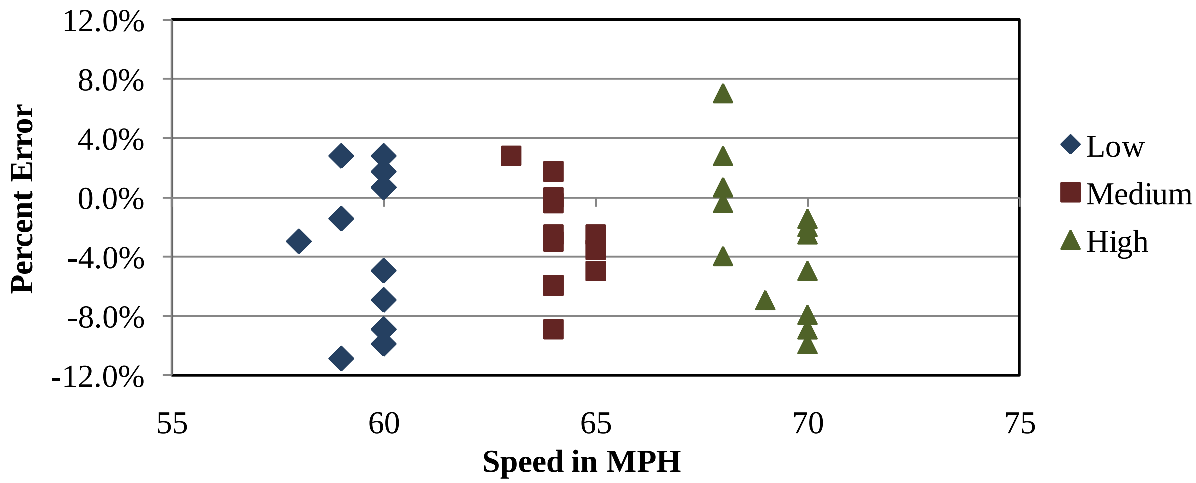


Figure 5-16 – Post-Validation Steering Axle Weight Errors by Speed – 16-Feb-11

5.3.1.3 Tandem Axle Weight Errors by Speed

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

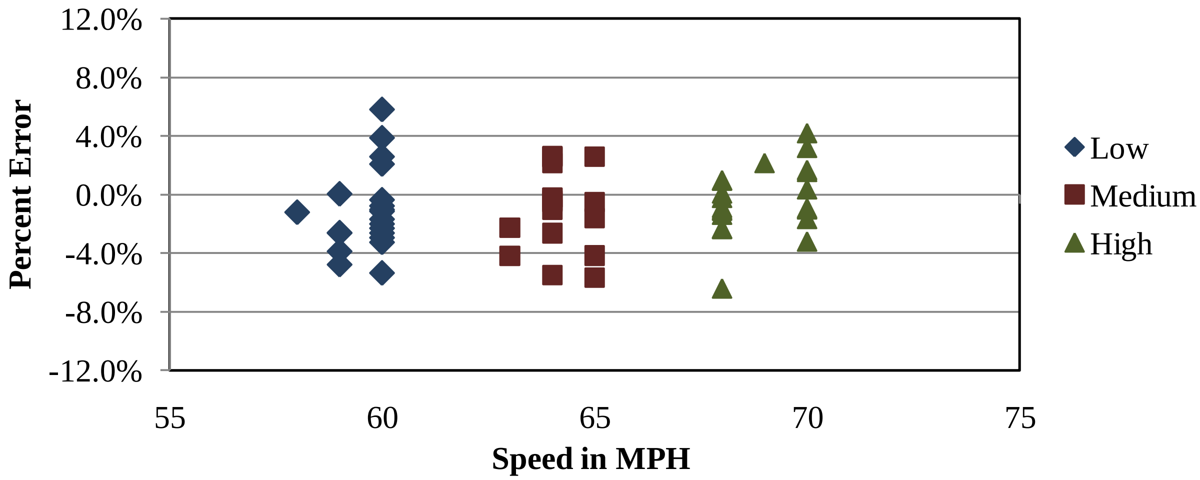


Figure 5-17 – Post-Validation Tandem Axle Weight Errors by Speed – 16-Feb-11

5.3.1.4 Tridem Axle Weight Errors by Speed

As shown in Figure 5-18, the equipment underestimated tridem axle weights at the low and medium speeds and estimated with reasonable accuracy at high speeds. The range in error and bias is similar throughout the entire speed range.

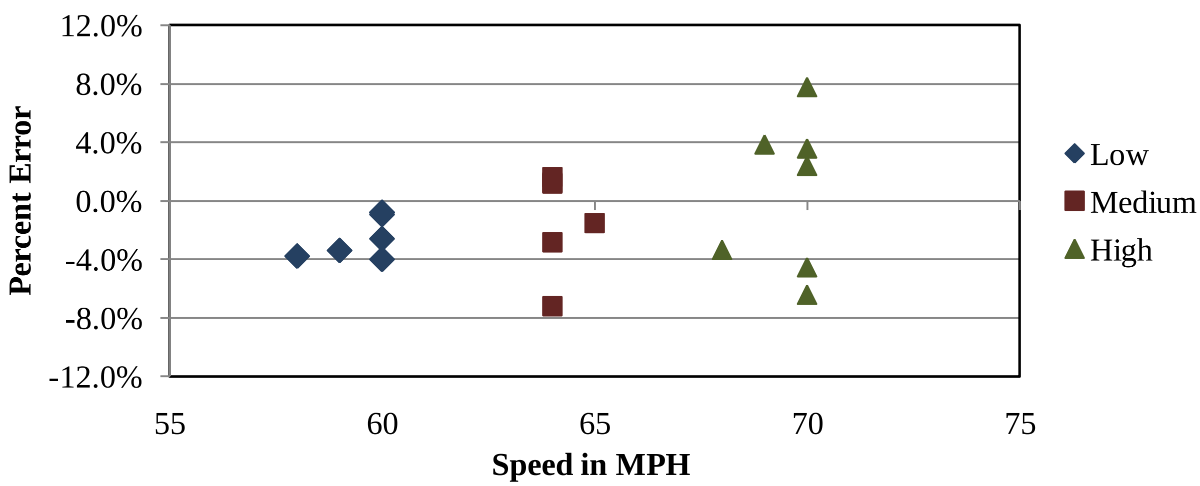


Figure 5-18 – Post-Validation Tridem Axle Weight Errors by Speed – 16-Feb-11

5.3.1.5 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-19 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck.

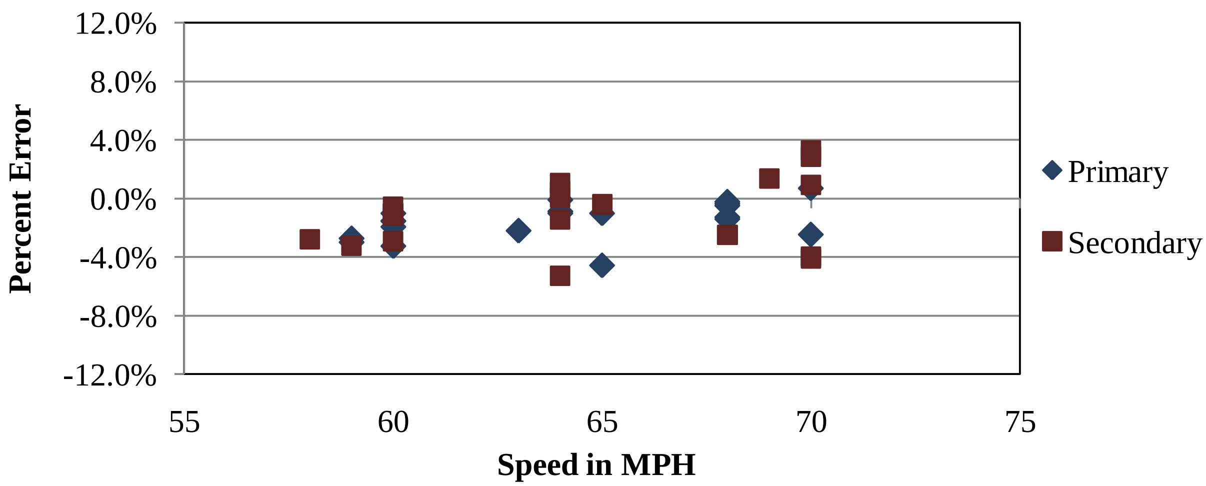


Figure 5-19 – Post-Validation GVW Error by Truck and Speed – 16-Feb-11

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 negligible. Distribution of errors is shown graphically in Figure 5-20.

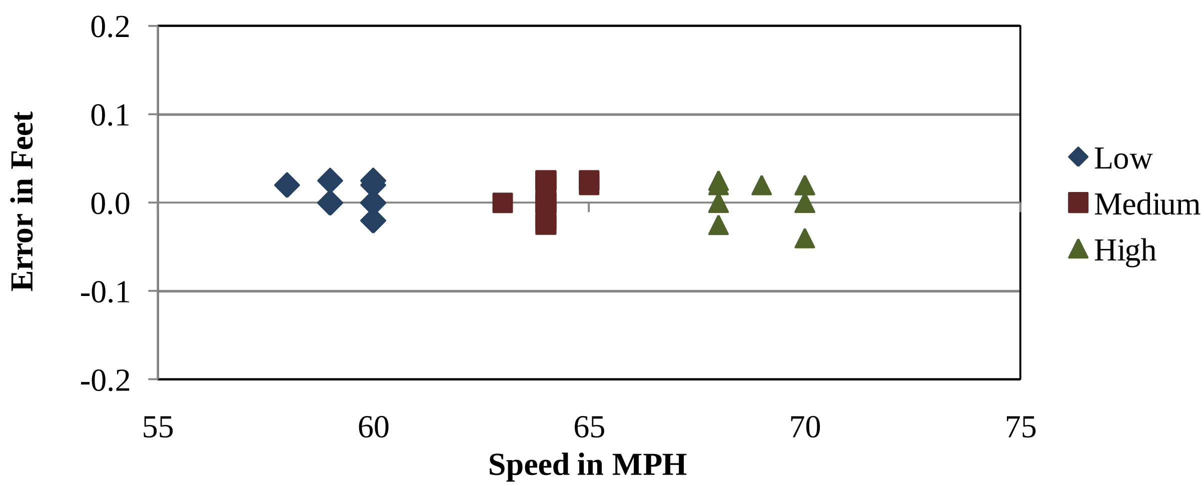


Figure 5-20 – Post-Validation Axle Length Error by Speed – 16-Feb-11

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 2.4 feet. Distribution of errors is shown graphically in Figure 5-21.

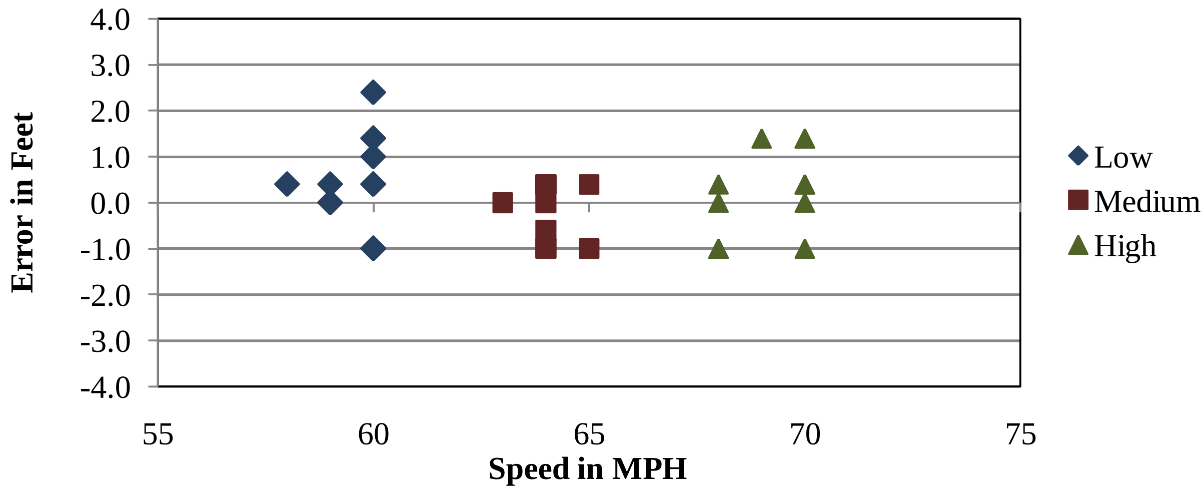


Figure 5-21 – Post-Validation Overall Length Error by Speed – 16-Feb-11

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 varied 15.7 degrees, from 63.9 to 79.6 degrees Fahrenheit. The post-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-16 below.

Table 5-16 – Post-Validation Results by Temperature – 16-Feb-11

Parameter	95% Confidence Limit of Error	Low 63.9 to 71.8 degF	High 71.9 to 79.7 degF
Steering Axles	±20 percent	-2.4 ± 9.2%	-3.2 ± 9.4%
Tandem Axles	±15 percent	-0.8 ± 4.4%	-1.3 ± 4.5%
Tridem Axles	±15 percent	-0.3 ± 7.1%	-1.4 ± 9.0%
Axle Groups	±15 percent	-0.7 ± 5.1%	-1.3 ± 5.6%
GVW	±10 percent	-0.7 ± 4.1%	-1.5 ± 3.7%
Vehicle Length	±3.0 percent (1.9 ft)	0.1 ± 1.7 ft	0.0 ± 2.0 ft
Vehicle Speed	± 1.0 mph	0.1 ± 1.4 mph	0.0 ± 2.3 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.0 ft	0.0 ± 0.0 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 5-22, it can be seen that the equipment appears to estimate GVW with acceptable accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates at this site.

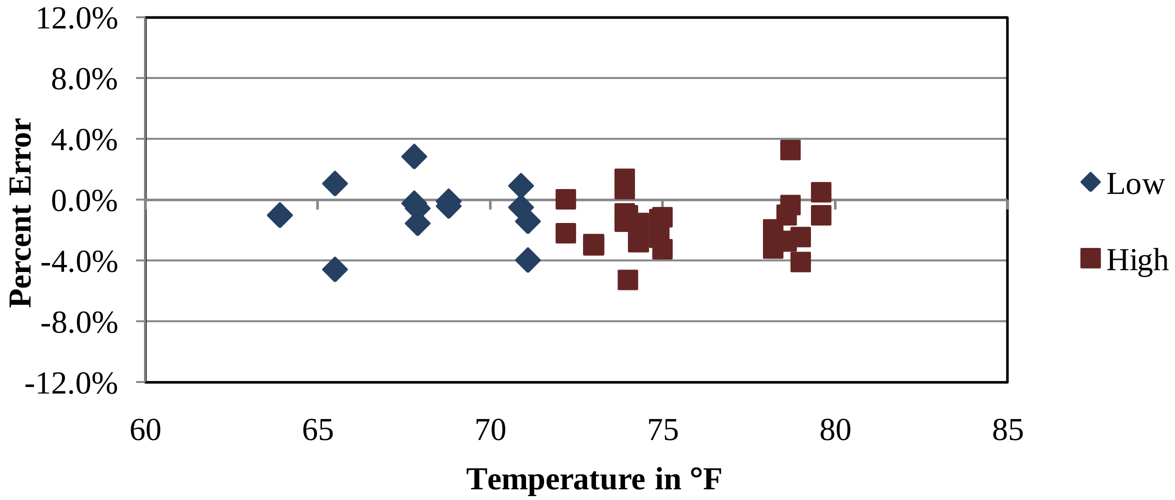


Figure 5-22 – Post-Validation GVW Errors by Temperature – 16-Feb-11

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-23 demonstrates that for steering axles, the WIM equipment appears to estimate weights with acceptable 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 the two temperature groups.

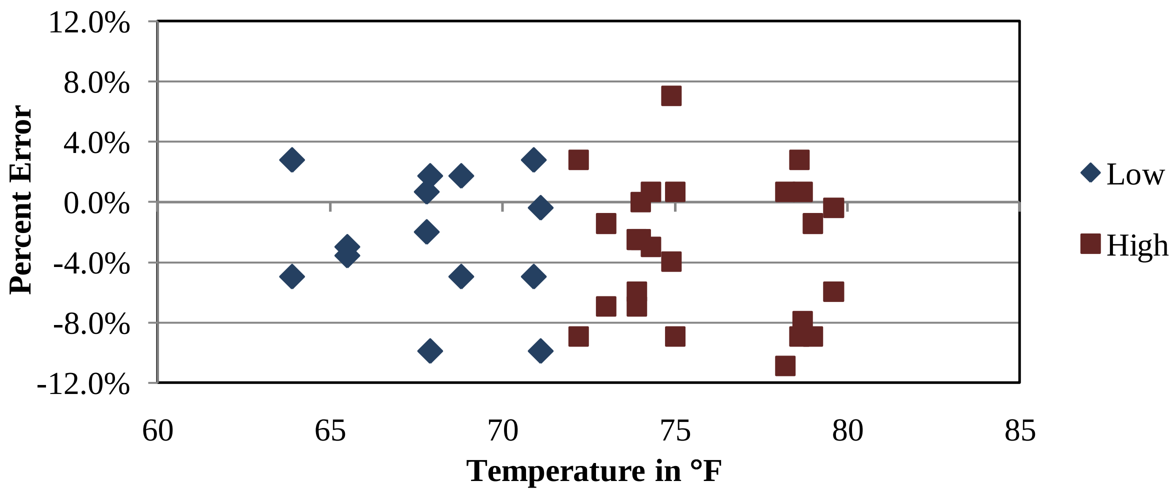


Figure 5-23 – Post-Validation Steering Axle Weight Errors by Temperature – 16-Feb-11

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-24, the WIM equipment appears to estimate tandem axle weights with acceptable 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 two temperature groups.

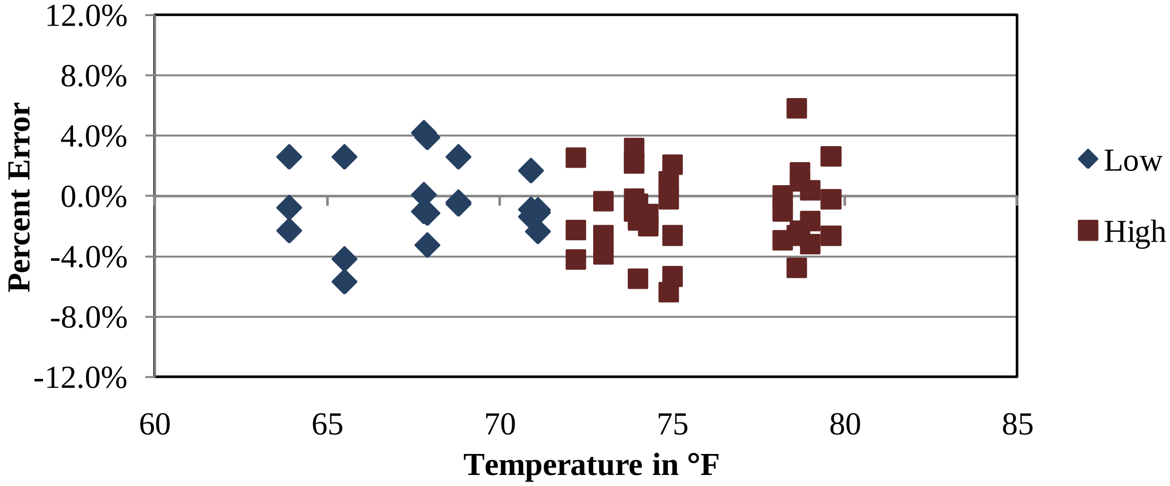


Figure 5-24 – Post-Validation Tandem Axle Weight Errors by Temperature – 16-Feb-11

5.3.2.4 Tridem Axle Weight Errors by Temperature

As shown in Figure 5-25, the WIM equipment appears to estimate tridem axle weights with acceptable 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. The range in tridem axle errors is consistent for the two temperature groups.

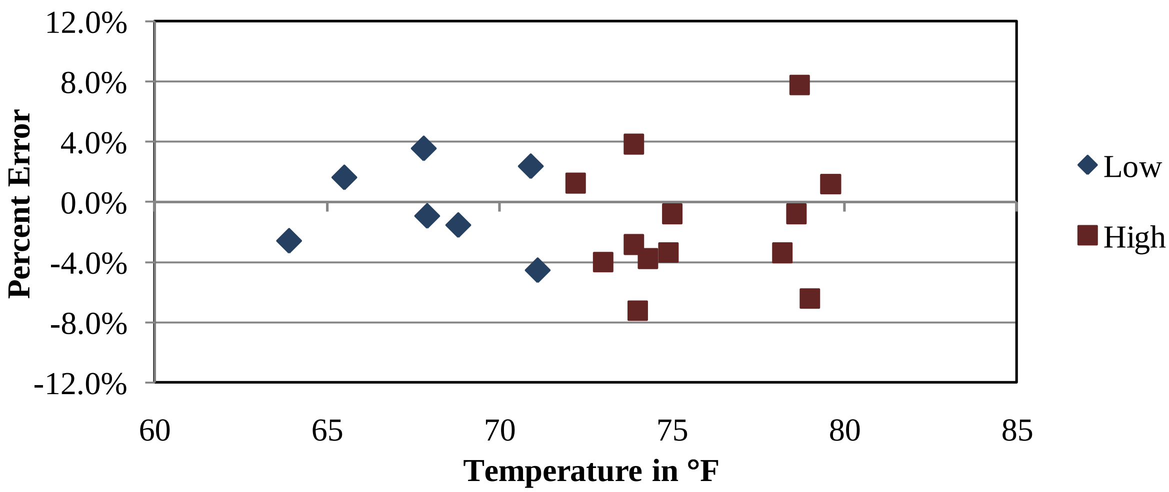


Figure 5-25 – Post-Validation Tridem Axle Weight Errors by Temperature – 16-Feb-11

5.3.2.5 GVW Errors by Temperature and Truck Type

As shown in Figure 5-26, when analyzed by truck type, GVW measurement errors for both trucks are similar at all temperatures. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures.

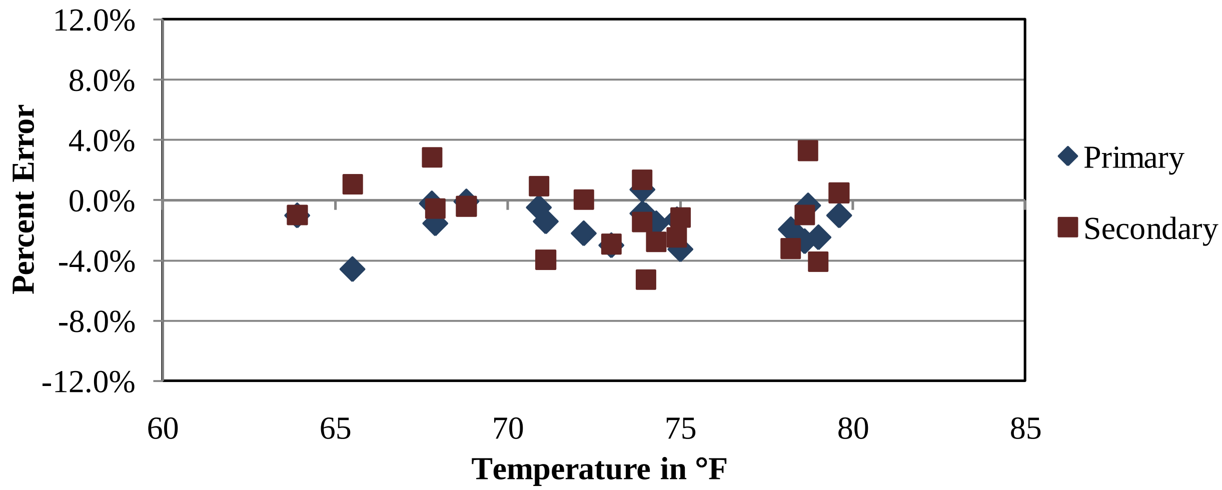


Figure 5-26 – Post-Validation GVW Error by Truck and Temperature – 16-Feb-11

5.3.3 GVW and Steering Axle Trends

Figure 5-27 is provided to illustrate the predicted GVW error with respect to the post-validation errors by speed.

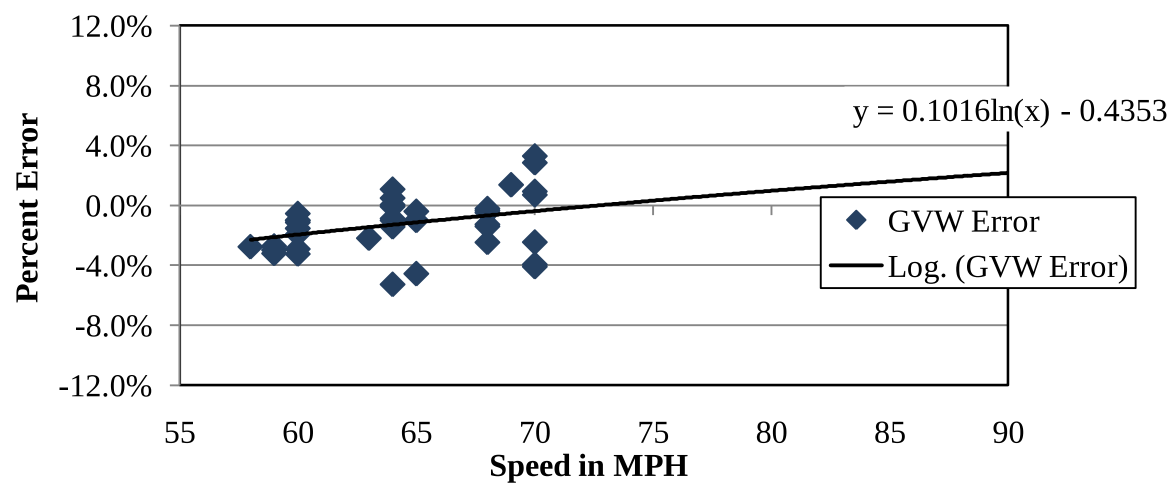


Figure 5-27 - GVW Error Trend by Speed

Figure 5-28 is provided to illustrate the predicted Steering Axle error with respect to the post-validation errors by speed.

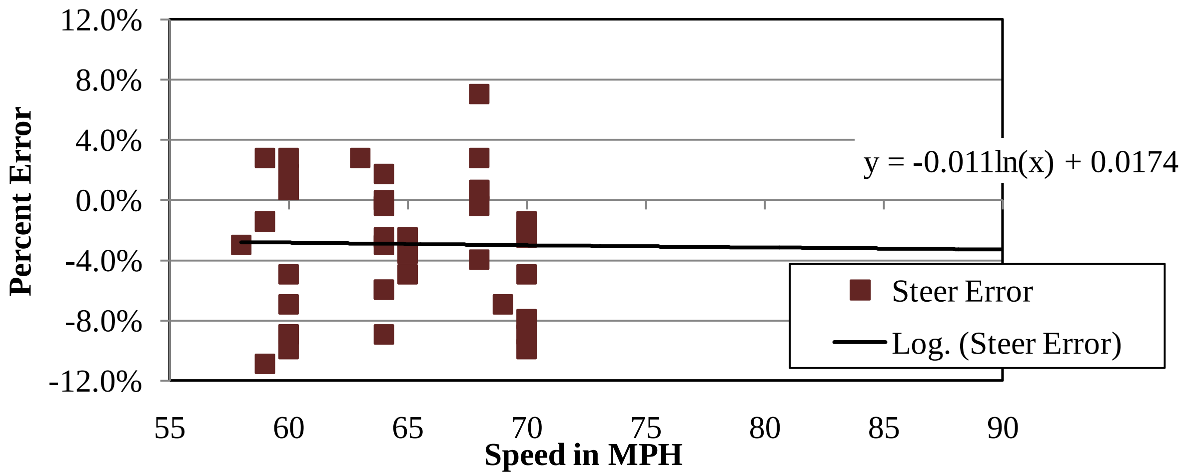


Figure 5-28 - Steering Axle Trend by Speed

5.3.4 Multivariable Analysis

This section provides additional analysis of post-validation results using a multivariable statistical technique of multiple linear regression. The same calibration data analyzed and discussed previously are analyzed again, but this time using a more sophisticated statistical methodology. The objective of the additional analysis is to investigate if the trends identified using previous analyses are statistically significant, and to quantify these trends.

Multivariable analyses provide additional insight on how speed, temperature, and truck type affect weight measurement errors for a specific site. It is expected that multivariable analyses done systematically for many sites will reveal overall trends.

5.3.4.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. Compared to analysis described previously, the weight of "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 58 to 70 mph.

- Pavement temperature. Pavement temperature ranged from 63.9 to 79.6 degrees Fahrenheit.

- Interaction between the factors such as the interaction between speed and pavement temperature.

5.3.4.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-17. 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 5-17 are for the null hypothesis that assumes that the coefficients are equal to zero. Only the effect of speed was found to be statistically significant. The probability that the effect of truck speed on the observed GVW errors occurred by chance alone was about 3 percent.

Table 5-17 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value
Intercept	-7.1415	6.2299	-1.1463	0.2592
Speed	0.1593	0.0697	2.2836	0.0284
Temp	-0.0628	0.0625	-1.0051	0.3215
Truck	0.4538	0.5591	0.8117	0.4223

The relationship between speed and GVW measurement errors is shown in Figure 5-29. The figure includes trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 5-29 provides quantification and statistical assessment of the relationship.

The quantification is provided by the value of the regression coefficient, in this case 0.1593 (in Table 5-17). This means, for example, that for a 10 mph increase in speed, the % error is increased by about 1.6 % (0.1593 x 20). The statistical assessment of the relationship is provided by the probability value of the regression coefficients.

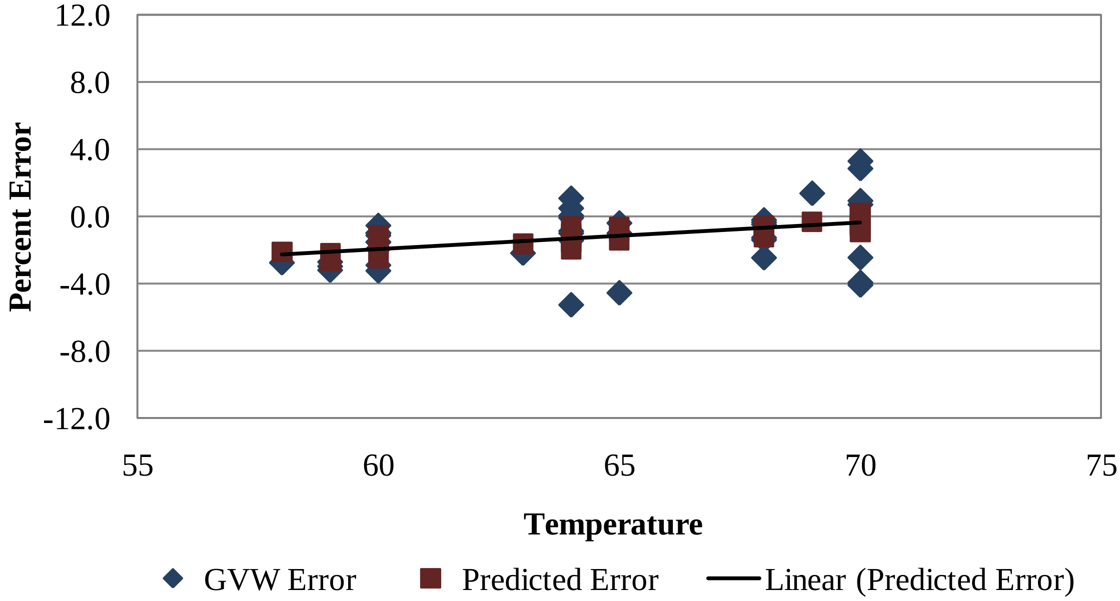


Figure 5-29 – Influence of Speed on the Measurement Error of GVW

The effect of temperature on GVW was not statistically significant. The probability that the regression coefficient for temperature (-0.0628 in Table 5-17) is not different from zero was 0.3215. In other words, there is about 32 percent chance that the value of the regression coefficient is due to the chance alone.

The interaction between speed, temperature, and truck type was investigated by adding an interactive variable (or variables) such as the product of speed and temperature. No interactive variables were statistically significant. The intercept was not statistically significant and does not have practical meaning.

5.3.4.3 Summary Results

Table 5-18 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Not listed in the table are factor interactions because the interactions were not statistically significant. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 5-18 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-18 – Summary of Regression Analysis

	Factor					
	Speed		Temperature		Truck type	
Weight, % error	Regression coefficient	Probability value	Regression coefficient	Probability value	Regression coefficient	Probability value
GVW	0.1593	0.0284	-	-	-	-
Steering axle	-	-	-	-	-6.872	0.0000
Tandem axle on tractor	0.1375	0.1485	-	-	2.998	0.0003
Tridem axle on trailer	-	-	-	-	not applicable	not applicable

5.3.4.4 Conclusions

1. Speed had statistically significant effect on measurement errors of GVW and tandem axles on tractors.

2. Temperature had no statistically significant effect on measurement errors.

3. Truck type affected steering axle and the tandem axle on tractor weight errors. The regression coefficient for truck type in Table 5-18, represent the difference between the mean errors for the primary and secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). For example, the mean error in the steering axle weight for the secondary truck was about 7 % smaller than the corresponding error for the primary truck.

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

5.3.5 Classification and Speed Evaluation

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

For the post-validation classification study at this site, a manual sample of 100 vehicles including 99 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field. Table 5-19 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-19 – Post-Validation Classification Study Results – 16-Feb-11

Class	4	5	6	7	8	9	10	11	12	13
Observed Count	0	4	1	1	3	79	2	5	4	0
WIM Count	0	3	1	1	4	79	2	5	4	0
Observed Percent	0.0	4.0	1.0	1.0	3.0	79.0	2.0	5.0	4.0	0.0
WIM Percent	0.0	3.0	1.0	1.0	4.0	79.0	2.0	5.0	4.0	0.0
Misclassified Count	0	1	0	0	0	0	0	0	0	0
Misclassified Percent	0.0	25.0	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
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one type of vehicle but identified by the WIM equipment as another type of vehicle. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample. The misclassifications by pair are provided in Table 5-20.

Table 5-20 – Post-Validation Misclassifications by Pair – 16-Feb-11

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

Based on the vehicles observed during the post-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 1.0%.

As shown in the table, one vehicle, including no heavy trucks (6 – 13) were misclassified by the equipment. The only misclassification was a Class 5 truck identified by the WIM equipment as Class 8.

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 5-21.

Table 5-21 – Post-Validation Unclassified Trucks by Pair – 16-Feb-11

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

Based on the manually collected sample of the 99 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 -0.3 mph; the range of errors was 1.9 mph.

6 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 post-validation results.

6.1 Sheet 16s

This site has validation information from two previous visits as well as the current one as summarized in the tables below and provided on the Traffic Sheet 16. Table 6-1 data was extracted from the most recent previous validation and was updated to include the results of this validation.

Table 6-1 – Classification Validation History

Date	Misclassification Percentage by Class										Pct Unclass
	4	5	6	7	8	9	10	11	12	13	
12-Jun-07	100	75	0	0	0	0	0	0	0	N/A	0
13-Jun-07	N/A	N/A	0	0	0	0	0	0	0	0	0
30-Sep-08	0	0	0	0	0	0	0	0	0	0	0
1-Oct-08	0	0	0	0	0	0	0	0	0	0	0
15-Feb-11	0	25	33	0	0	0	0	0	0	0	0
16-Feb-11	0	25	0	0	0	0	0	0	0	0	0

Table 6-2 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, single axles and tandems for prior pre- and post-validations as reported on the LTPP Traffic Sheet 16s.

Table 6-2 – Weight Validation History

Date	Mean Error and SD		
	GVW	Single Axles	Tandem
12-Jun-07	1.4 ± 1.4	0.3 ± 3.0	1.0 ± 2.9
13-Jun-07	1.1 ± 2.1	-1.5 ± 4.4	1.4 ± 3.7
30-Sep-08	-2.9 ± 1.5	-0.1 ± 4.0	-3.3 ± 2.7
1-Oct-08	1.0 ± 1.4	3.1 ± 2.8	0.6 ± 2.4
15-Feb-11	-4.6 ± 1.9	-4.4 ± 2.8	-4.3 ± 2.4
16-Feb-11	-1.3 ± 1.9	-2.9 ± 4.4	-1.1 ± 2.1

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an underestimation of vehicle weights (GVW, and single and tandem axle weights) over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

6.2 Comparison of Past Validation Results

A comparison of the post-validation results from previous visits is provided in Table 6-3. The table provides the historical performance of the WIM system with regard to the 95% Confidence Interval tolerances.

Table 6-3 – Comparison of Post-Validation Results

Parameter	95 %Confidence Limit of Error	Site Values (Mean Error and 95% Confidence Interval)		
		13-Jun-07	1-Oct-08	16-Feb-11
Steering Axles	±20 percent	-1.5 ± 5.6	3.1 ± 5.6	-2.9 ± 8.9
Tandem Axles	±15 percent	1.4 ± 7.4	0.6 ± 5.4	-1.1 ± 4.2
GVW	±10 percent	1.1 ± 4.3	1.0 ± 2.8	-1.3 ± 3.7

From the table, it appears that the variance for steering axle weights has increased, and variance for GVW and tandem axles has decreased over time.

The final factors left in place at the conclusion of the validation are provided in Table 6-4.

Table 6-4 – Final Factors

Speed Points	Factors			
	Left		Right	
	1	3	2	4
88	2986	2986	3169	3169
96	2961	2961	3143	3143
104	3036	3036	3222	3222
112	3034	3034	3220	3220
120	3034	3034	3220	3220
Axle Distance (cm)	305			
Dynamic Comp (%)	106			
Loop Width (cm)	246			

A review of the LTPP Standard Release Database 24 shows that there are 2 years of level “E” WIM data for this site. This site requires 3 additional years of data to meet the minimum of five years of research quality data.

7 Additional Information

The following information is provided in the attached appendix:

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

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

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

WIM System Field Calibration and Validation - Photos

Tennessee, SPS-6
SHRP ID: 470600

Validation Date: February 16, 2011

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 4

Photo 27 – Truck 2 Suspension 5

Photo 28 – Truck 2 Suspension 6

Traffic Sheet 16	STATE CODE:	47
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	470600
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	2/15/2011

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 2/15/11

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
   - b. Quartz Piezo
   - c.
   - d.

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

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

Number of Trucks Compared:

Number of Test Trucks Used: 2

Passes Per Truck: 21

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air	air
Truck 2:	10	air	air
Truck 3:	0	0	0

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

Mean Difference Between -

Dynamic and Static GVW:	-4.6%	Standard Deviation:	1.9%
Dynamic and Static Single Axle:	-4.4%	Standard Deviation:	2.8%
Dynamic and Static Double Axles:	-4.3%	Standard Deviation:	2.4%

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

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

		Low		High	Runs
a.	Low	58.0	to	62.0	13
b.	Medium	62.1	to	66.1	16
c.	High	66.2	to	70.0	12
d.			to		
e.			to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	47 470600 2/15/2011

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3104 | 3295

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: ____________

13. METHOD TO DETERMINE LENGTH OF COUNT: ____________

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	0.0	FHWA Class	______	-	______
FHWA Class 8:	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: 47 SPS WIM ID: 470600 DATE (mm/dd/yyyy) 2/16/2011

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 2/16/11

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
   b. Quartz Piezo
   c.
   d.

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

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

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

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

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

Mean Difference Between -

Dynamic and Static GVW:	-1.3%	Standard Deviation:	1.9%
Dynamic and Static Single Axle:	-2.9%	Standard Deviation:	4.4%
Dynamic and Static Double Axles:	-1.1%	Standard Deviation:	2.1%

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

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

			Low		High	Runs
a.	Low	-	58.0	to	62.0	14
b.	Medium	-	62.1	to	66.1	12
c.	High	-	66.2	to	70.0	14
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: SPS WIM ID: DATE (mm/dd/yyyy)	47 470600 2/16/2011

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3044 | 3231

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		-	
FHWA Class 8:	33.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Kevin Trousdale**

Contact Information: Phone: 717-975-3550

E-mail: ktrousdale@ara.com

Traffic Sheet 20	STATE CODE:	47
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	470600
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy)	2/15/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	9	50860	62	9	67	9	51158	68	9
71	9	50893	72	9	63	5	51160	63	5
72	9	50920	72	9	69	9	51191	69	9
70	9	50927	69	9	68	9	51192	68	9
70	9	50936	67	9	62	9	51203	62	9
65	9	50944	68	9	64	9	51207	64	9
62	9	50960	63	9	65	9	51214	66	9
65	9	50977	68	9	65	9	51220	66	9
73	9	50978	74	9	65	9	51233	65	9
67	9	50984	66	9	66	9	51248	68	9
61	9	50989	61	9	72	9	51251	72	9
66	11	50995	66	11	60	9	51262	60	9
65	9	51006	65	9	67	9	51268	70	9
71	6	51014	70	6	65	9	51272	65	9
62	9	51017	66	9	72	9	51278	70	9
63	9	51025	63	9	65	9	51287	66	9
64	12	51028	64	12	67	9	51291	67	9
70	7	51045	72	7	68	9	51303	69	9
71	9	51056	70	9	62	9	51324	64	9
65	9	51069	65	9	68	9	51336	68	9
65	9	51071	65	9	65	10	51351	65	10
73	10	51081	73	10	65	9	51353	65	9
67	9	51105	65	9	72	9	51364	72	9
69	5	51142	67	5	65	9	51368	66	9
69	9	51149	68	9	68	9	51390	68	9

Sheet 1 - 0 to 50 Start: 12:10:00 Stop: 12:24:00

Recorded By: ar Verified By: kt

Validation Test Truck Run Set - Pre

Traffic Sheet 20 **LTPP MONITORED TRAFFIC DATA** **SPEED AND CLASSIFICATION STUDIES**	STATE CODE: 47 SPS WIM ID: 470600 DATE (mm/dd/yyyy) 2/15/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
61	11	51398	61	11	62	9	51713	62	9
65	9	51413	64	9	75	9	51720	75	9
64	9	51422	68	9	65	11	51738	68	11
65	9	51431	65	9	75	9	51745	72	9
68	9	51440	65	9	71	6	51755	70	6
75	7	51449	74	7	60	9	51759	60	9
60	9	51461	60	9	64	9	51760	64	9
62	9	51469	61	9	65	9	51778	65	9
70	8	51485	70	8	67	12	51782	66	12
67	9	51493	67	9	64	9	51790	66	9
69	9	51503	69	9	61	8	51793	62	8
68	9	51507	68	9	67	9	51805	66	9
67	12	51513	66	12	63	9	51806	64	9
65	9	51520	64	9	65	9	51810	64	9
65	9	51539	67	9	63	9	51819	62	9
67	9	51555	66	9	70	9	51825	70	9
62	9	51563	62	9	62	9	51830	64	9
67	**7**	**51575**	**68**	**6**	64	9	51843	67	9
64	9	51636	63	9	71	9	51858	70	9
67	9	51644	66	9	64	9	51866	67	9
65	9	51649	65	9	72	9	51876	72	9
68	9	51672	69	9	64	9	51882	64	9
68	9	51699	69	9	**70**	**8**	**51884**	**70**	**5**
64	9	51702	64	9	69	9	51891	69	9
68	5	51709	69	5	69	9	51894	68	9

Sheet 2 - 51 to 100 Start: 12:25:00 Stop: 12:45:00

Recorded By: ar Verified By: kt

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE:	47
	SPS WIM ID:	470600
	DATE (mm/dd/yyyy)	2/16/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
68	9	8536	68	9	73	8	8802	72	8
67	9	8550	66	9	72	5	8813	71	5
65	9	8551	66	9	64	9	8820	64	9
67	9	8568	66	9	59	15	8850	59	15
73	9	8572	72	9	67	9	8857	66	9
62	9	8620	64	9	65	9	8868	65	9
64	9	8627	63	9	70	9	8878	70	9
68	9	8631	68	9	70	10	8879	69	10
62	9	8635	63	9	64	9	8896	65	9
64	9	8646	65	9	70	9	8902	68	9
67	9	8657	66	9	65	9	8915	65	9
64	11	8670	64	11	77	9	8918	77	9
65	12	8676	64	12	65	9	8930	66	9
70	12	8685	69	12	65	6	8942	69	6
65	9	8700	65	9	**65**	**8**	**8943**	**65**	**5**
67	9	8705	69	9	63	10	8947	63	10
69	7	8707	70	7	64	9	8948	64	9
68	9	8735	69	9	72	9	8956	72	9
68	9	8742	70	9	69	9	8959	68	9
65	9	8746	65	9	70	9	8963	71	9
64	9	8748	64	9	67	9	8969	68	9
70	9	8758	69	9	65	9	8982	64	9
60	5	8772	72	5	68	9	8984	68	9
62	9	8786	62	9	71	9	9003	71	9
65	9	8798	67	9	62	8	9012	64	8

Sheet 1 - 0 to 50 Start: 11:35:00 Stop: 11:50:00

Recorded By: ar Verified By: kt

Validation Test Truck Run Set - Post

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 47 SPS WIM ID: 470600 DATE (mm/dd/yyyy) 2/16/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
67	9	9023	67	9	65	9	9206	65	9
63	9	9034	65	9	75	9	9215	74	9
64	9	9035	64	9	67	9	9221	66	9
63	9	9036	68	9	64	9	9235	65	9
65	9	9053	69	9	72	9	9245	70	9
67	9	9064	66	9	70	9	9259	70	9
62	11	9069	62	11	64	11	9262	62	11
64	9	9072	64	9	62	9	9267	63	9
67	9	9076	66	9	65	9	9274	64	9
69	9	9081	67	9	67	9	9277	75	9
70	9	9087	70	9	68	9	9294	68	9
65	9	9092	65	9	67	12	9310	66	12
68	11	9106	67	11	70	9	9317	70	9
64	9	9114	63	9	69	9	9326	69	9
63	9	9126	66	9	64	9	9332	64	9
63	9	9129	65	9	57	8	9338	58	8
67	9	9135	65	9	72	9	9342	72	9
64	9	9142	63	9	67	9	9346	67	9
65	9	9158	65	9	66	9	9352	65	9
62	9	9165	63	9	66	9	9356	67	9
62	9	9176	61	9	65	11	9360	65	11
65	12	9182	64	12	65	5	9393	64	5
66	9	9191	66	9	65	9	9398	65	9
65	9	9198	65	9	67	9	9429	66	9
66	9	9203	66	9	72	9	9458	71	9

Sheet 2 - 51 to 100 Start: 11:50:00 Stop: 12:03:00

Recorded By: ar Verified By: kt

Validation Test Truck Run Set - Post