WIM System Field Calibration and Validation Summary Report

Ohio SPS-2
SHRP ID – 390200

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1 Executive Summary

A WIM validation was performed on September 28 and 29, 2010 at the Ohio SPS-2 site located on route US-23 at milepost 19.7, 1 mile north of Radnor Road.

This site was installed on March 15, 1996. The in-road sensors are installed in the northbound lane. The site is equipped with load cell WIM sensors and a Mettler-Toledo WIM controller. The LTPP lane is identified as lane DSP-0 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on May 12, 2005 and this validation visit, it appears that the WIM Controller has been replaced. No other 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 WIM components determined that the equipment was operating within tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, no distresses that would affect the performance of the WIM scales were noted. Observations of trucks passing over the site did not detect any motions by the trucks that would affect WIM system accuracies. Further pavement condition discussion is provided in Section 4.

Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is providing research quality loading data. The summary results of the validation are provided in Table 1.1 below.

Table 1-1 – Post-Validation Results – 29-Sep-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-5.6 ± 7.0%	Pass
Tandem Axles	±15 percent	-0.1 ± 5.7%	Pass
GVW	±10 percent	-0.9 ± 3.9%	Pass
Vehicle Length	±3 percent (2 ft)	-10.8 ± 2.4 ft	FAIL
Axle Length	± 0.5 ft [150mm]	-0.3 ± 1.1 ft	FAIL

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 -0.9 ± 4.9 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of -0.3 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.

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 2.0% from the 100 truck sample (Class 4 – 13) was due to the 2 cross-classifications of Class 3, 5, and 9 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 over the front half of the trailer and crane weights over rear tandem.

- The *Secondary* truck was a Class 9 vehicle with air suspension on the tractor tandem, air on the trailer tandem, standard tandem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with crane weights over each tandem.

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

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.0	10.9	15.6	15.6	16.4	16.4	13.6	4.2	37.2	4.0	59.0	70.4
2	65.8	10.3	14.3	14.3	13.5	13.5	13.0	4.3	32.0	4.0	53.3	62.9

The posted speed limit at the site is 55 mph. During the testing, the speed of the test trucks ranged from to 42 to 57 mph, a variance of 15 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 49.3 to 86.7 degrees Fahrenheit, a range of 37.4 degrees Fahrenheit. The sunny weather conditions provided the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 24 shows that there are 26 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

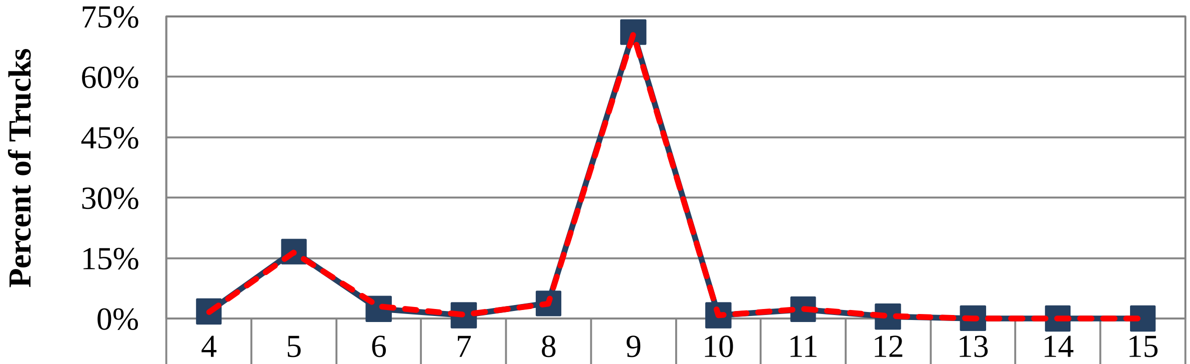
To assess the quality of the current data, a pre-visit analysis was conducted by comparing a two-week data sample from March 13, 2010 (Data) to the most recent Comparison Data Set (CDS) from October 30, 2009. The assessments performed prior to the site visits are used to develop reasonable expectations 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 Data Availability

A review of the LTPP Standard Release Database 24 shows that there are 26 consecutive months 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.

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	1.7%	16.6%	2.4%	0.8%	3.7%	71.1%	0.8%	2.3%	0.5%	0.1%	0.0%	0.0%
CDS	1.6%	16.4%	3.1%	0.9%	3.7%	70.6%	0.7%	2.4%	0.6%	0.0%	0.0%	0.0%

Figure 2-1 – Comparison of Truck Distribution

Table 2-1 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the most frequent truck types crossing the WIM scale are Class 9 (71.1%) and Class 5 (16.6%). It also indicates that 0.0 percent of the vehicles at this site are unclassified. Table 2-1 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles.

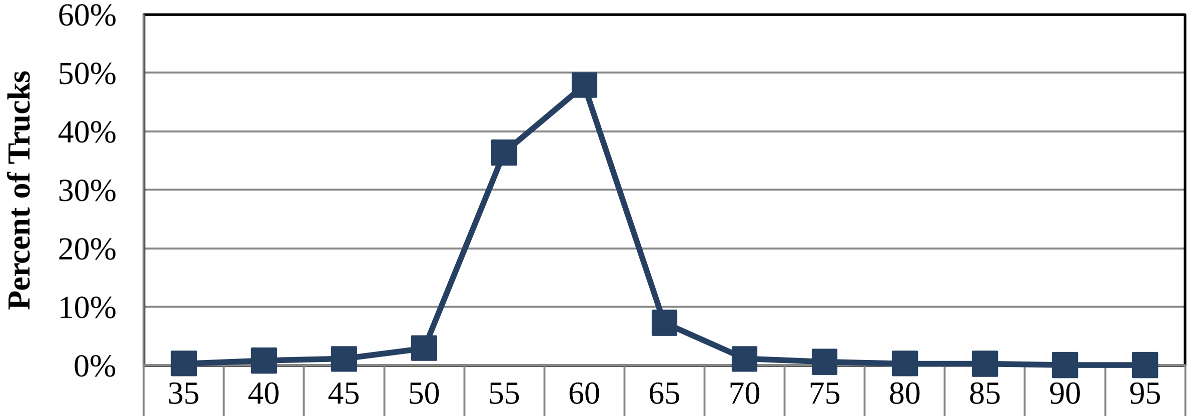
Table 2-1 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
4	946	1.6%	572	1.7%	0.2%
5	9800	16.4%	5463	16.6%	0.2%
6	1836	3.1%	795	2.4%	-0.7%
7	556	0.9%	255	0.8%	-0.2%
8	2214	3.7%	1233	3.7%	0.0%
9	42111	70.6%	23380	71.1%	0.5%
10	428	0.7%	250	0.8%	0.0%
11	1413	2.4%	746	2.3%	-0.1%
12	344	0.6%	166	0.5%	-0.1%
13	23	0.0%	18	0.1%	0.0%
14	8	0.0%	7	0.0%	0.0%
15	0	0.0%	0	0.0%	0.0%

From the table it can be seen that the number of Class 9 vehicles has increased by 0.5 percent from October 2009 and March 2010. Small increases 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 increased by 0.2 percent. These differences may be attributed to small sample size used to develop vehicle class distributions, decreased 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 the speed of the test trucks during validation testing. The CDS distribution of speeds is shown in Figure 2-2.



	35	40	45	50	55	60	65	70	75	80	85	90	95
Data	0.3%	0.8%	1.1%	2.9%	36.4	47.9	7.2%	1.1%	0.6%	0.3%	0.2%	0.0%	0.0%

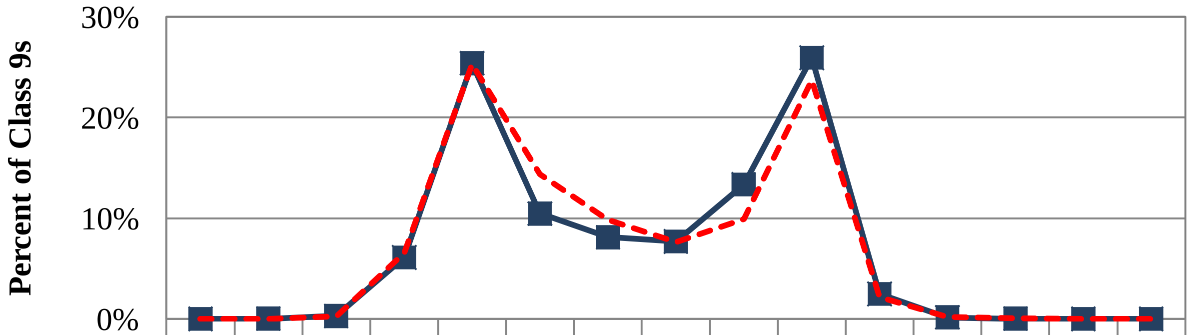
Figure 2-2 – Truck Speed Distribution – 22-Sep-10

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 55 and 60 mph. The posted speed limit at this site is 55 and the 85th percentile speed for trucks at this site is 61 mph. The coverage of truck speeds for the validation will be between 45 and 55 mph. Although the 85th percentile speeds for trucks is above the posted speed limit, the post-visit applied calibration will not be used to develop compensation factors for speed points from 55 to 65 mph due to the speed compensation factor limitations of the WIM equipment.

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 March 2010 and the Comparison Data Set from October 2009.

As shown in Figure 2-3, there is a shift to the right for trucks weighing between 40 and 80 kips. The figure also shows a decrease in the percentage of loaded trucks between the October 2009 Comparison Data Set (CDS) and the March 2010 two-week sample W-card dataset (Data).



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.3%	6.1%	25.4	10.5	8.1%	7.7%	13.3	25.9	2.5%	0.2%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.3%	6.6%	25.3	14.4	9.8%	7.6%	9.9%	23.7	2.2%	0.2%	0.0%	0.0%	0.0%

Figure 2-3 – Comparison of Class 9 GVW Distribution

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

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

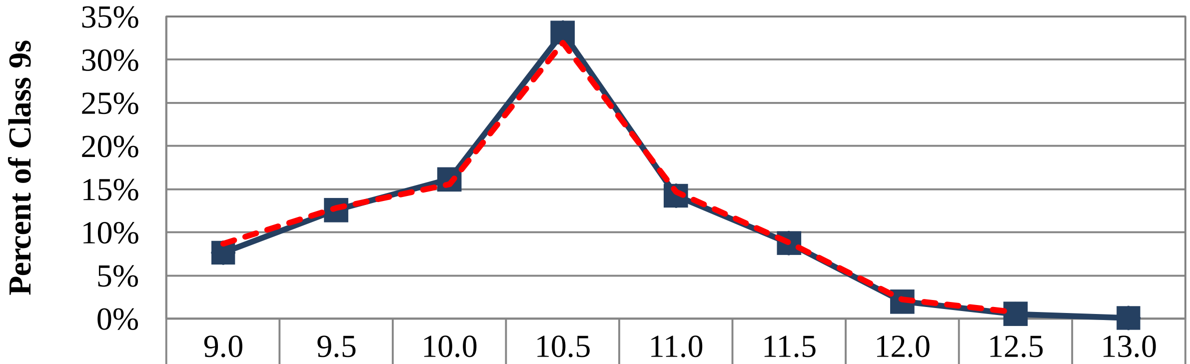
GVW weight bins (kips)	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
8	0	0.0%	0	0.0%	0.0%
16	10	0.0%	5	0.0%	0.0%
24	110	0.3%	68	0.3%	0.0%
32	2760	6.6%	1427	6.1%	-0.5%
40	10626	25.3%	5924	25.4%	0.1%
48	6041	14.4%	2441	10.5%	-3.9%
56	4140	9.8%	1894	8.1%	-1.7%
64	3207	7.6%	1792	7.7%	0.1%
72	4170	9.9%	3111	13.3%	3.4%
80	9961	23.7%	6050	25.9%	2.2%
88	913	2.2%	575	2.5%	0.3%
96	75	0.2%	35	0.2%	0.0%
104	20	0.0%	7	0.0%	0.0%
112	0	0.0%	3	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	54.1		55.5		1.4

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range increased by 0.1 percent while the number of loaded class 9 trucks in the 72 to 80 kips range decreased by 2.2 percent. The number of overweight trucks increased during this time period by 0.3 percent and the overall average GVW for this site increased from 54.1 kips to 55.5 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 observed average front axle weight with the expected average front axle weight average for Class 9 trucks of 10.3 kips.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from March 2010 and the Comparison Data Set from October 2009. The plots are nearly identical.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Data	7.6%	12.6%	16.1%	33.1%	14.2%	8.8%	2.0%	0.5%	0.1%
CDS	8.7%	12.8%	15.5%	32.0%	14.7%	8.8%	2.2%	0.8%	

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 averaging 10.5, the percentage of trucks at this weight have slightly increased between the October 2009 Comparison Data Set (CDS) and the March 2010 dataset (Data).

Table 2-3 provides the Class 9 front axle weight distribution data for the October 2009 Comparison Data Set (CDS) and the March 2010 dataset (Data).

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

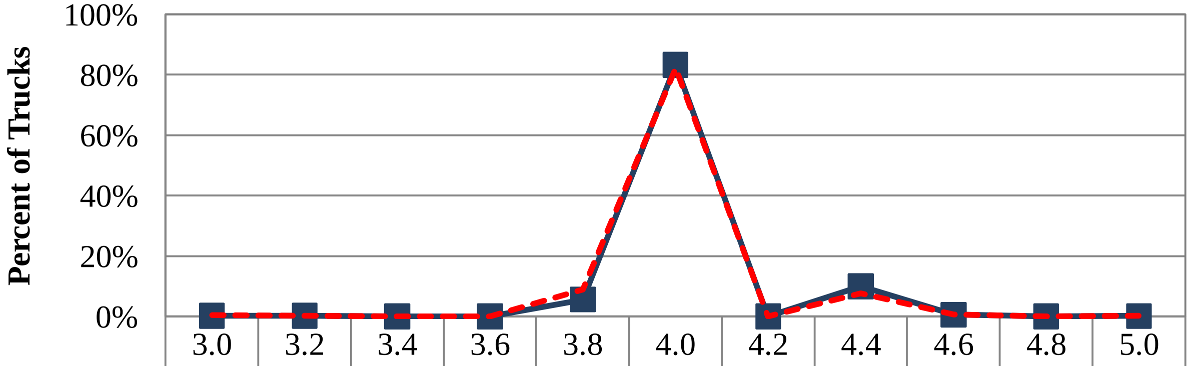
F/A weight bins (kips)	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
9.0	1837	4.4%	1145	4.9%	0.5%
9.5	3636	8.7%	1780	7.6%	-1.0%
10.0	5384	12.8%	2933	12.6%	-0.2%
10.5	6526	15.5%	3765	16.1%	0.6%
11.0	13416	32.0%	7729	33.1%	1.2%
11.5	6164	14.7%	3322	14.2%	-0.4%
12.0	3709	8.8%	2041	8.8%	-0.1%
12.5	940	2.2%	459	2.0%	-0.3%
13.0	317	0.8%	126	0.5%	-0.2%
13.5	51	0.1%	19	0.1%	0.0%
Average =	10.6		10.5		0.1

The table shows that the average front axle weight for Class 9 trucks has decreased by 0.1 kips, or -0.4 percent. According to the current data, the majority of the Class 9 front axle weights are between 10.5 and 11.0 kips and the average front axle weight for Class 9 trucks is 10.5 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average tractor tandem spacing. This will provide a basis for the evaluation of the accuracy of the equipment distance and speed measurements by comparing the observed average tractor tandem spacing with the expected average tractor tandem spacing of 4.25 feet.

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



	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Data	0.2%	0.2%	0.0%	0.0%	5.6%	83.3%	0.0%	10.0%	0.5%	0.0%	0.1%
CDS	0.4%	0.2%	0.0%	0.0%	8.8%	82.2%	0.0%	7.7%	0.6%	0.0%	0.1%

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

As seen in the figure, the Class 9 tractor tandem spacing for the October 2009 Comparison Data Set and the March 2010 Data are nearly identical.

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

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

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	10/30/2009		3/13/2010		
3.0	159	0.4%	49	0.2%	-0.2%
3.2	74	0.2%	48	0.2%	0.0%
3.4	19	0.0%	9	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	3703	8.8%	1303	5.6%	-3.2%
4.0	34542	82.2%	19441	83.3%	1.1%
4.2	0	0.0%	0	0.0%	0.0%
4.4	3247	7.7%	2324	10.0%	2.2%
4.6	239	0.6%	127	0.5%	0.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	50	0.1%	31	0.1%	0.0%
Average =	4.0		4.0		0.0

From the table it can be seen that the spacing of the tractor tandems for Class 9 trucks at this site is between 3.8 and 4.2 feet. The average tractor tandem spacing is 4.0 feet, which is below the expected average of 4.25 feet. Further analyses are performed during the validation and post-validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (October 2009) based on the last calibration with the most recent two-week WIM data sample from the site (March 2010). Comparison of vehicle class distribution data indicates a 0.5 percent increased in the number of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have decreased by 0.1 percent and average Class 9 GVW has increased by 2.6 percent for the March 2010 data. The data indicates an average truck tandem spacing of 4.0 feet, which is below the expected average of 4.25 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on May 12, 2005 and this validation visit, it appears that the WIM controller has been replaced. No changes have occurred during this time to the basic operating condition of the equipment.

3.1 Description

This site was installed on March 15, 1996 by Mettler-Toledo. It is instrumented with load cell weighing sensors and a Mettler-Toledo WIM Controller. As the installation contractor, also performs routine equipment maintenance and data quality checks of the WIM data.

3.2 Physical Inspection

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented in Section 7.

3.3 Electronic and Electrical Testing

Electronic and electrical checks of system components were conducted prior to the pre-validation test truck runs. All values for 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 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 October 21, 2009 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, 900 feet prior to WIM scales and 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 1000-foot WIM section and the 400-foot approach section is 147 in/mi and is located approximately 172 feet prior to the WIM scale. This area of pavement was closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed that would influence truck dynamics in the WIM scale area.

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)	0.809	0.881	0.746			0.812
		SRI (m/km)	0.928	0.993	0.901			0.941
		Peak LRI (m/km)	0.949	1.028	0.969			0.982
		Peak SRI (m/km)	1.313	1.502	1.155			1.323
	RWP	LRI (m/km)	1.103	1.185	1.173			1.154
		SRI (m/km)	0.594	0.834	0.595			0.674
		Peak LRI (m/km)	1.117	1.185	1.198			1.167
		Peak SRI (m/km)	0.926	1.037	0.951			0.971
Center	LWP	LRI (m/km)	1.154	1.245	1.133	1.237	1.225	1.192
		SRI (m/km)	0.975	0.984	0.694	1.242	0.944	0.974
		Peak LRI (m/km)	1.154	1.245	1.133	1.237	1.225	1.192
		Peak SRI (m/km)	1.277	1.206	1.023	1.242	1.407	1.187
	RWP	LRI (m/km)	1.091	1.081	1.088	1.058	0.983	1.080
		SRI (m/km)	0.762	0.796	0.760	1.088	0.658	0.852
		Peak LRI (m/km)	1.124	1.095	1.117	1.080	0.987	1.104
		Peak SRI (m/km)	1.157	1.254	1.474	1.395	1.062	1.320
Right	LWP	LRI (m/km)	1.100	1.053	1.018			1.057
		SRI (m/km)	0.539	*0.355*	0.711			0.535
		Peak LRI (m/km)	1.100	1.069	1.023			1.064
		Peak SRI (m/km)	1.261	1.094	1.092			1.149
	RWP	LRI (m/km)	0.875	0.851	0.764			0.830
		SRI (m/km)	0.823	0.912	0.543			0.759
		Peak LRI (m/km)	1.034	1.001	0.977			1.004
		Peak SRI (m/km)	0.823	0.987	0.758			0.856

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

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 September 27, 2010, beginning at approximately 1:05 AM and continuing until 12:53 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with a forklift over the front half of trailer and crane weight over the rear tandem, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9, 5-axle truck, loaded with crane weights over each tandem, 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	75.0	11.0	15.6	15.6	16.5	16.5	13.6	4.2	37.2	4.0	59.0	70.4
2	65.9	10.3	14.3	14.3	13.5	13.5	13.0	4.3	32.0	4.0	53.3	62.9

Test truck speeds varied by 15 mph, from 42 to 57 mph. The measured pre-validation pavement temperatures varied 5.3 degrees Fahrenheit, from 53.2 to 58.5. The rainy weather conditions prevented for reaching the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

Table 5-2 – Pre-Validation Overall Results – 28-Sep-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-5.7 ± 5.6%	Pass
Tandem Axles	±15 percent	0.8 ± 4.6%	Pass
GVW	±10 percent	-0.2 ± 3.0%	Pass
Vehicle Length	±3 percent (2 ft)	-11.2 ± 2.5 ft	FAIL
Axle Length	± 0.5 ft [150mm]	-0.7 ± 0.9 ft	FAIL

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was -0.1 ± 1.3 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 -0.7, 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 55 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3 below.

Table 5-3 – Pre-Validation Results by Speed – 28-Sep-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		42.0 to 47.0 mph	47.1 to 52.1 mph	52.2 to 57.0 mph
Steering Axles	±20 percent	-3.4 ± 4.3%	-5.6 ± 4.8%	-8.5 ± 2.5%
Tandem Axles	±15 percent	0.1 ± 5.8%	0.6 ± 3.8%	1.8 ± 3.8%
GVW	±10 percent	-0.4 ± 4.1%	-0.4 ± 2.7%	0.1 ± 2.5%
Vehicle Length	±3 percent (2 ft)	-11.6 ± 2.5 ft	-11.6 ± 2.3 ft	-10.2 ± 2.1 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 1.0 mph	-0.2 ± 1.5 mph	0.0 ± 1.6 mph
Axle Length	± 0.5 ft [150mm]	-1.0 ± 0.7 ft	-0.7 ± 0.7 ft	-0.3 ± 0.8 ft

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

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, 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 estimated GVW with reasonable accuracy at 55 mph, the speed at which the single calibration factor speed point is provided. The range in error is greater at the lower speeds when compared with the medium and high speeds.

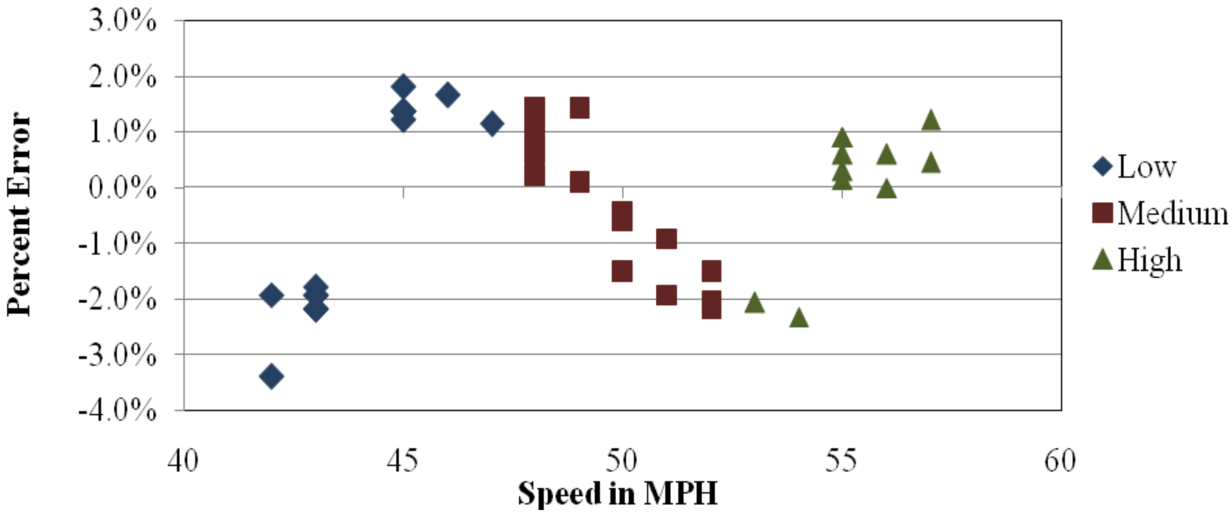


Figure 5-1 – Pre-Validation GVW Error by Speed – 28-Sep-10

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment exhibited a trend to increasingly underestimate steering axle weight as speed increased. The range in error appears to be consistent throughout the entire speed range. Distribution of errors is shown graphically in the following figure.

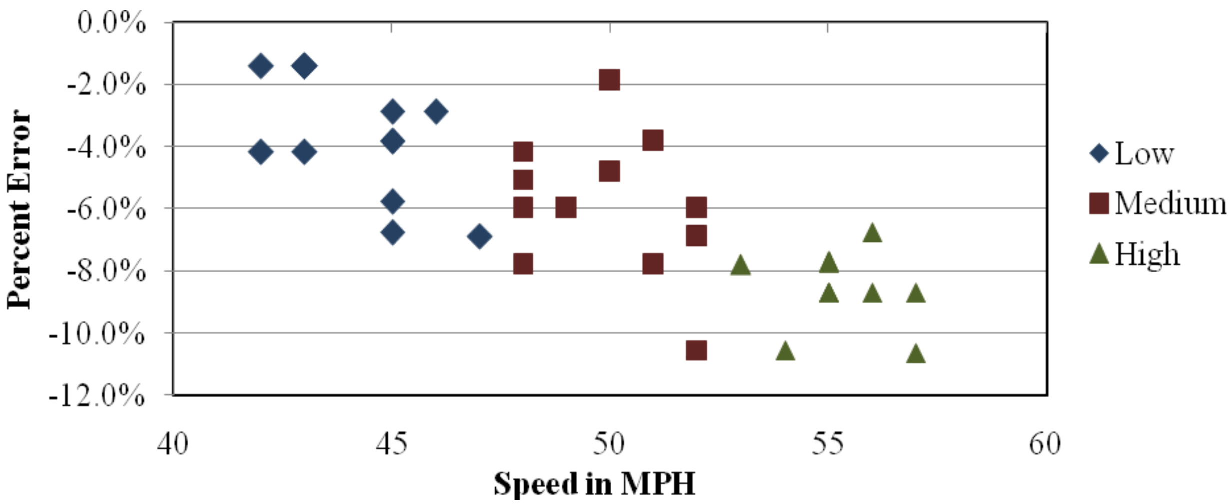


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 28-Sep-10

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment estimates tandem axle weights with reasonable accuracy at all speeds. The range in error is higher for the lowest speed range. Distribution of errors is shown graphically in the following figure.

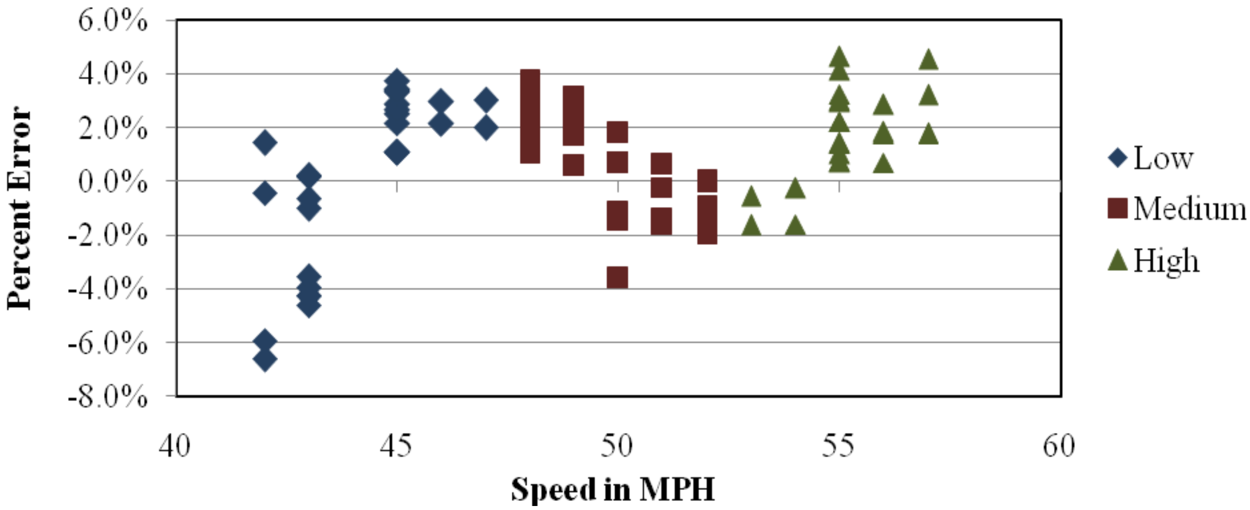


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 28-Sep-10

5.1.1.4 GVW Errors by Speed and Truck Type

When the GVW error for each truck type is analyzed as a function of speed, it can be seen that the WIM equipment precision and bias appears to be similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck (Figure 5-4). However, the measurements for the two truck types were not done throughout the entire speed range.

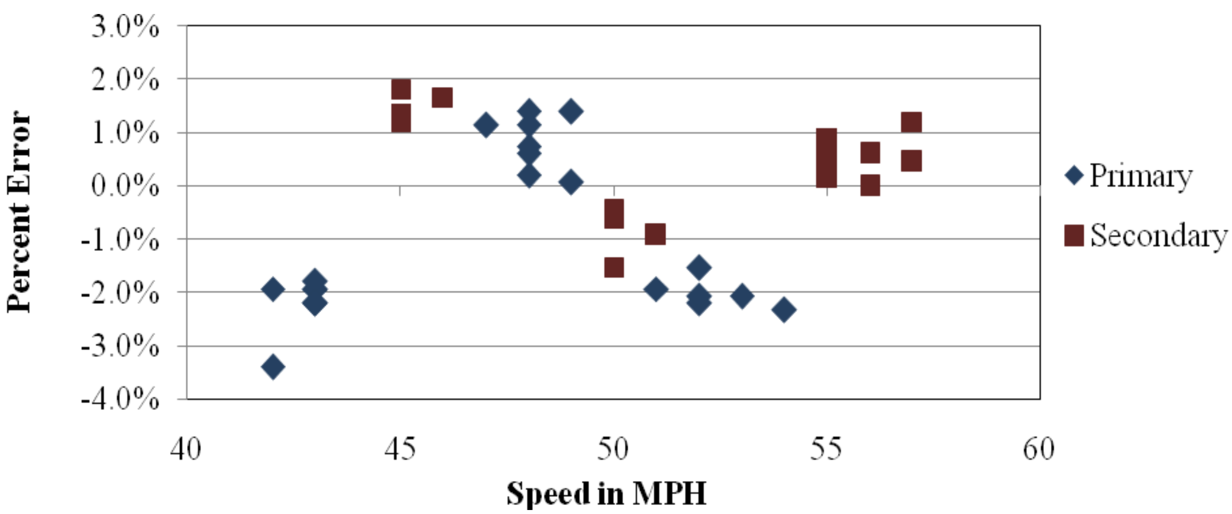


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 28-Sep-10

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was greatest at the lower speeds, moving toward more accurate estimates as speed increased. The range in axle length measurement error ranged from -1.6 feet to 0.4 feet. Distribution of errors is shown graphically in Figure 5-5.

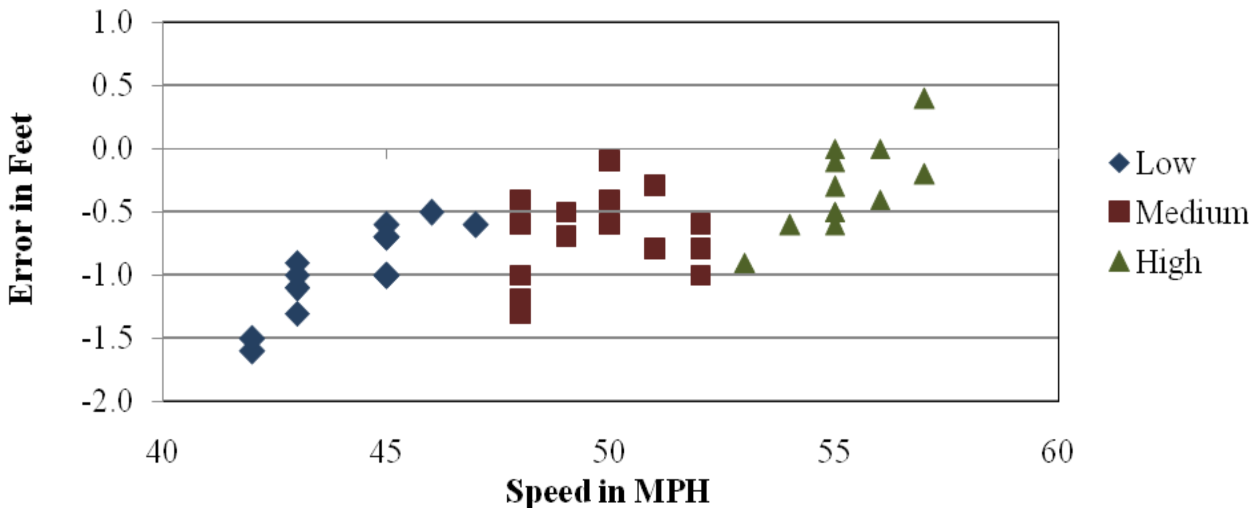


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 28-Sep-10

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment underestimated overall vehicle length consistently over the entire range of speeds, with an error range of -13.0 to -9.1 feet. Distribution of errors is shown graphically in Figure 5-6.

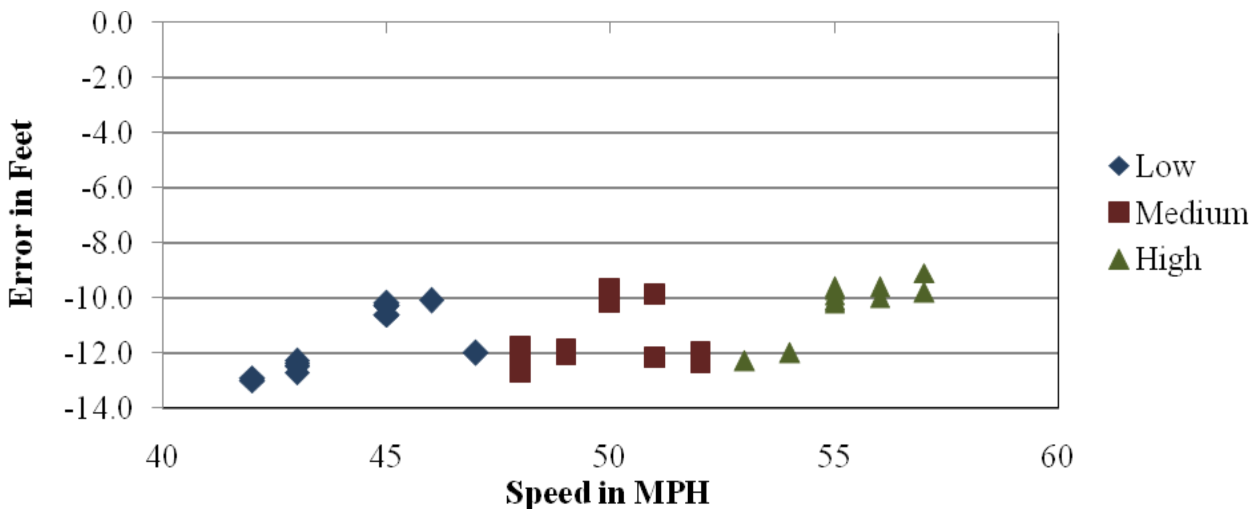


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 28-Sep-10

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 5.3 degrees, from 53.2 to 58.5 degrees Fahrenheit. The pre-validation test runs are being reported under one temperature groups as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 28-Sep-10

Parameter	**95% Confidence Limit of Error**	**Medium**
		53.2 to 58.5 degF
Steering Axles	±20 percent	-5.7 ± 5.6%
Tandem Axles	±15 percent	0.8 ± 4.6%
GVW	±10 percent	-0.2 ± 3.0%
Vehicle Length	±3 percent (2 ft)	-11.2 ± 2.5 ft
Vehicle Speed	± 1.0 mph	-0.1 ± 1.3 mph
Axle Length	± 0.5 ft [150mm]	-0.7 ± 0.9 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 appears to estimate GVW with reasonable accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and weight estimates.

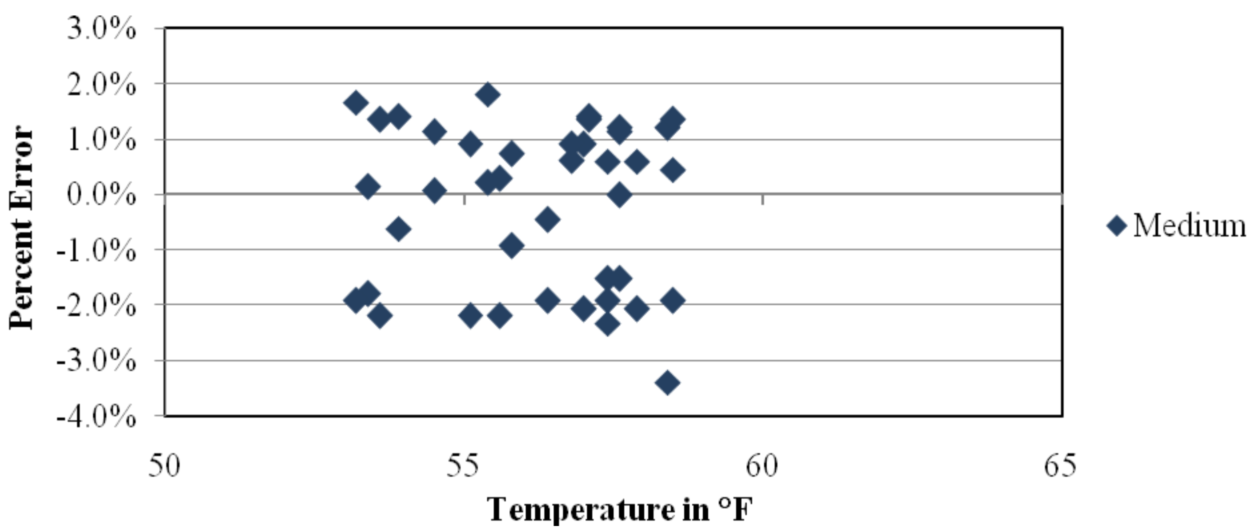


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 28-Sep-10

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 demonstrates that for steering axles, the WIM equipment appears to underestimate at all temperatures. Range in error is similar at all temperatures. Distribution of errors is shown graphically in the following figure.

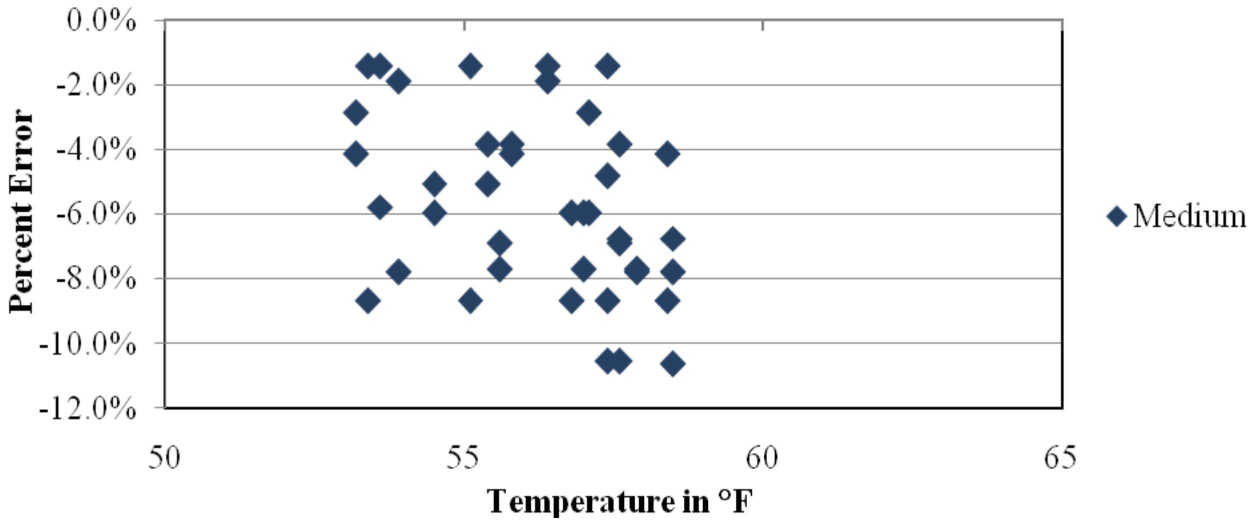


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 28-Sep-10

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment appears to estimate loaded tandem axle weights with reasonable accuracy at all temperatures. Range in error is similar at all temperatures. Distribution of errors is shown graphically in the following figure.

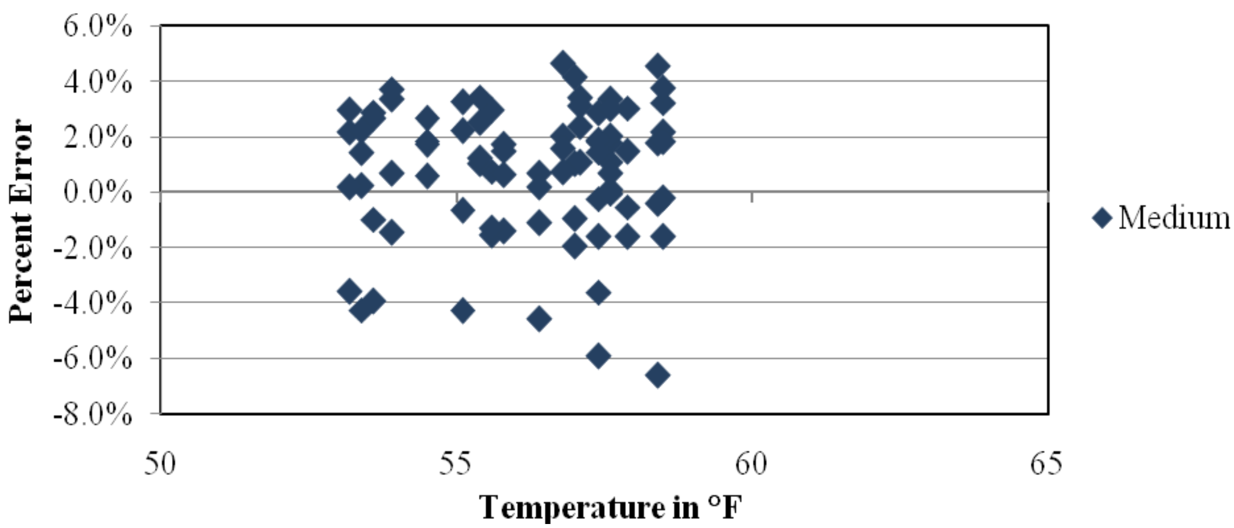


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 28-Sep-10

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, GVW measurement errors for both trucks follow similar patterns; however GVW for the Secondary truck is estimated more accurately and with greater precision than GVW for the Primary truck. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures. Distribution of errors is shown graphically in Figure 5-10.

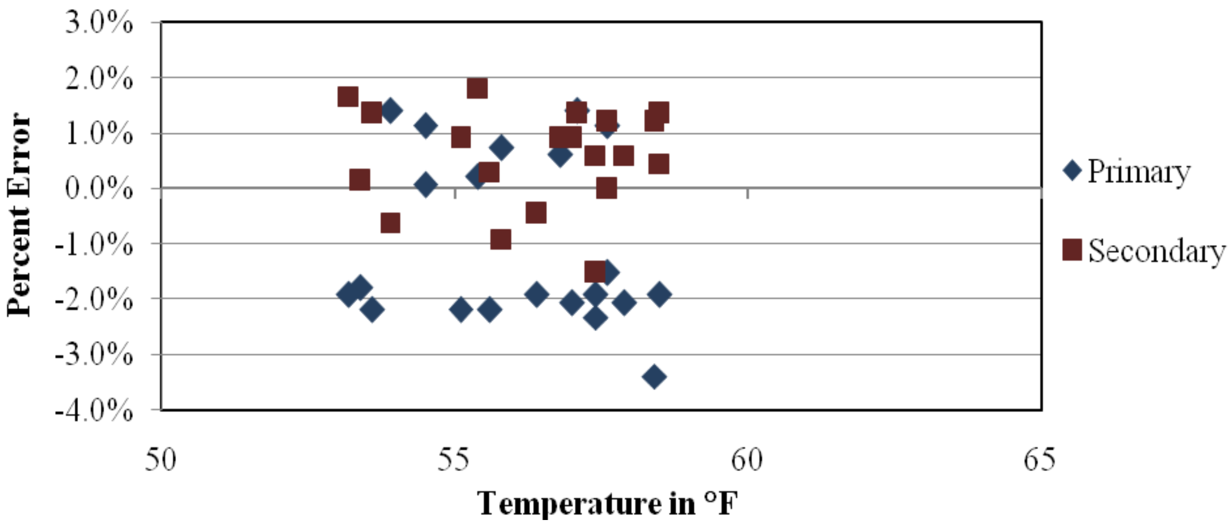


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 28-Sep-10

5.1.3 Classification and Speed Evaluation

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

For the pre-validation classification study at this site, a manual sample of 100 vehicles including 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 – 28-Sep-10

Class	4	5	6	7	8	9	10	11	12	13
Observed Count	0	9	5	0	3	81	1	1	0	0
WIM Count	0	7	4	0	3	83	1	1	0	0
Observed Percentage	0	9	5	0	3	81	1	1	0	0
WIM Percentage	0	7	4	0	3	83	1	1	0	0
Misclassified Count	0	2	1	0	0	0	0	0	0	0
Misclassified Percent	N/A	22	20	N/A	0	0	0	0	N/A	N/A
Unclassified Count	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	N/A	0	0	N/A	0	0	0	0	N/A	N/A

As shown in Table 5-5, there were three misclassifications, including one Class 5 and one Class 6 identified as Class 9s, which resulted in an over count of two Class 9s by the WIM equipment and an under count of one Class 5 and one Class 6. Also, one Class 5 was identified as a Class 3 by the equipment, resulting in an additional under count of one Class 5 vehicle.

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 – 28-Sep-10

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

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 1.1% 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 two vehicles, including one heavy truck (6 – 13) were misclassified by the equipment. The misclassifications were one class 5 identified as a Class 3 by the equipment, and one Class 9 identified as a Class 5 by the WIM equipment. The cause of the misclassifications was not investigated in the field.

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 – 28-Sep-10

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	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 -2.0 mph; the range of errors was 5.1 mph.

5.2 Calibration

The WIM equipment required no calibration iterations for weight between the pre- and post-validations. A calibration for the distance was performed. The bias in overall length measurement or steering axle weight could not be compensated for by this equipment, as no system factors for calibrating these elements exist. From the information made available to the validation team by the Agency and Mettler-Toledo representatives on site, only one speed factor (55) was available for calibration. Since the estimated weights at this speed are acceptable, no adjustments to this factor were made.

5.3 Post-Validation

The 40 post-validation test truck runs were conducted on September 29, 2010, beginning at approximately 1:08 AM and continuing until 12:57 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with forklifts over front half of trailer and crane weight over rear tandem, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 9, 5-axle truck, loaded with crane weights over each tandem, 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 5-8.

Table 5-8 - Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.0	10.9	15.6	15.6	16.4	16.4	13.6	4.2	37.2	4.0	59.0	70.4
2	65.8	10.3	14.3	14.3	13.5	13.5	13.0	4.3	32.0	4.0	53.3	62.9

Test truck speeds varied by 15 mph, from 42 to 57 mph. The measured post-validation pavement temperatures varied 37.4 degrees Fahrenheit, from 49.3 to 86.7. The sunny weather conditions provided for reaching the desired 30 degree temperature range. Table 5-9 is a summary of post validation results.

Table 5-9 – Post-Validation Overall Results – 29-Sep-10

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-5.6 ± 7.0%	Pass
Tandem Axles	±15 percent	-0.1 ± 5.7%	Pass
GVW	±10 percent	-0.9 ± 3.9%	Pass
Vehicle Length	±3 percent (2 ft)	-10.8 ± 2.4 ft	FAIL
Axle Length	± 0.5 ft [150mm]	-0.3 ± 1.1 ft	FAIL

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was -0.9 ± 4.9 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of -0.3, 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 55 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-10 below.

Table 5-10 – Post-Validation Results by Speed – 29-Sep-10

Parameter	95% Confidence Limit of Error	Low 42.0 to 47.0 mph	Medium 47.1 to 52.0 mph	High 52.1 to 57.0 mph
Steering Axles	±20 percent	-3.7 ± 6.0%	-5.9 ± 7.6%	-8.7 ± 3.9%
Tandem Axles	±15 percent	-0.3 ± 5.1%	-0.3 ± 7.1%	0.7 ± 3.4%
GVW	±10 percent	-0.8 ± 3.5%	-1.1 ± 5.6%	-0.7 ± 2.5%
Vehicle Length	±3 percent (2 ft)	-11.2 ± 2.5 ft	-10.8 ± 2.5 ft	-10.0 ± 2.1 ft
Vehicle Speed	± 1.0 mph	-1.6 ± 4.9 mph	-0.9 ± 5.8 mph	0.7 ± 3.3 mph
Axle Length	± 0.5 ft [150mm]	-0.5 ± 1.0 ft	-0.3 ± 1.0 ft	0.2 ± 1.1 ft

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

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, 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 5-11, the equipment estimated GVW with reasonable accuracy at all speeds, on average. The range in error and bias is greater at the medium speeds when compared with the low and high speeds. Distribution of errors is shown graphically in the figure.

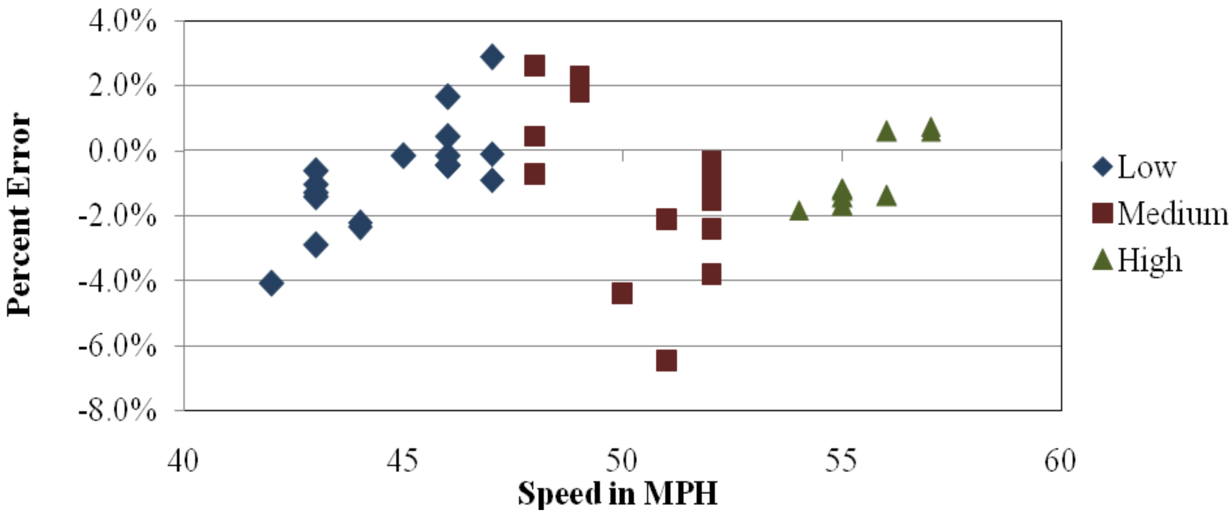


Figure 5-11 – Post-Validation GVW Errors by Speed – 29-Sep-10

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-12, the equipment increasingly underestimated steering axle weights as speed increased. The range in error appears to greater at the low and medium speeds when compared with the higher speeds. Distribution of errors is shown graphically in the figure.

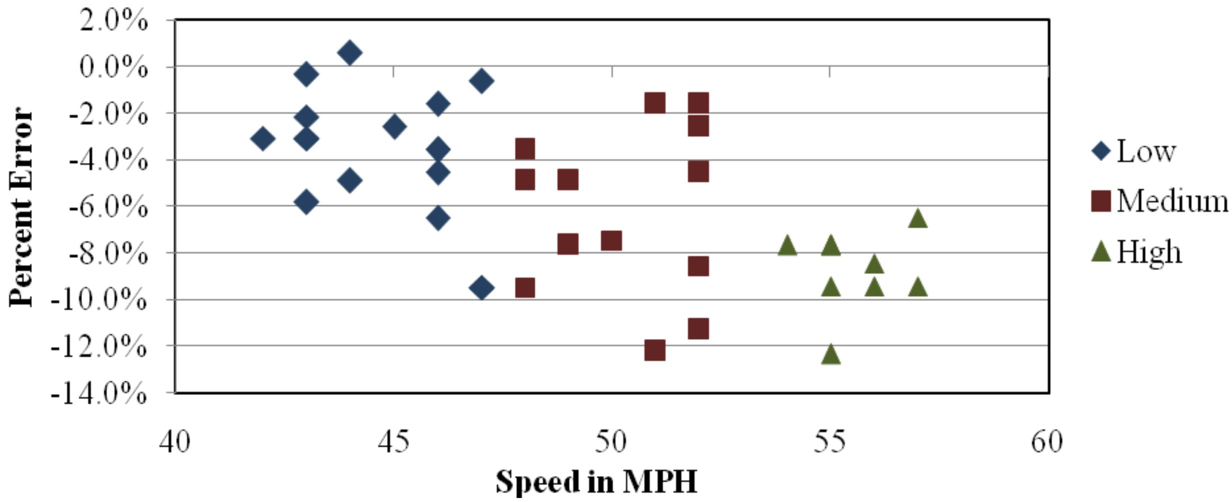


Figure 5-12 – Post-Validation Steering Axle Weight Errors by Speed – 29-Sep-10

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-13, the equipment estimated tandem axle weights with reasonable accuracy at all speeds. The range in error appears to be greater at the low and medium speeds when compared with the higher speeds. Distribution of errors is shown graphically in the figure.

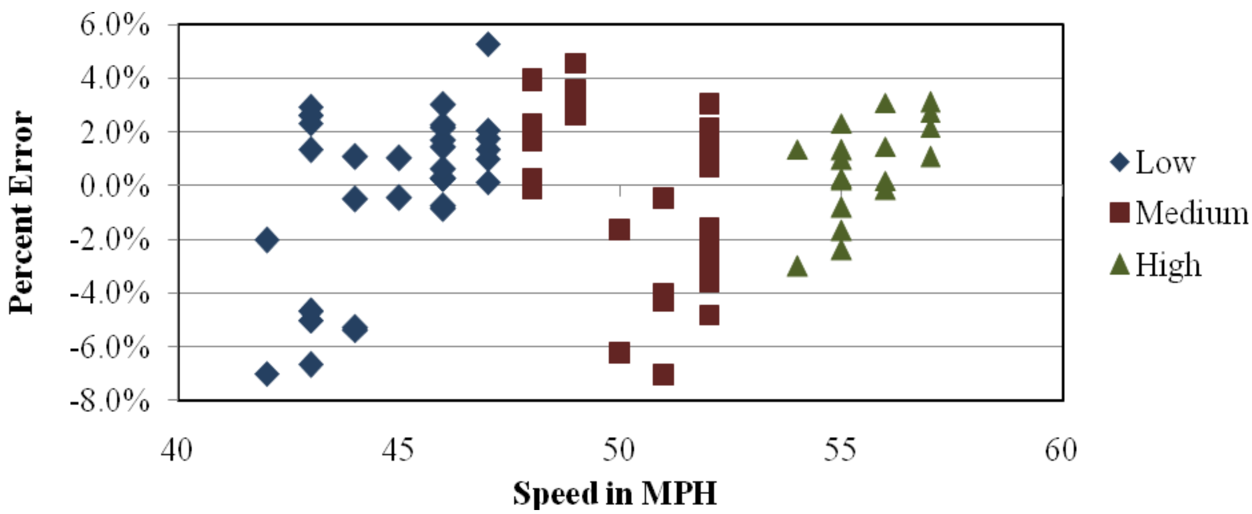


Figure 5-13 – Post-Validation Tandem Axle Weight Errors by Speed – 29-Sep-10

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-14 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. Distribution of errors is shown graphically in the figure.

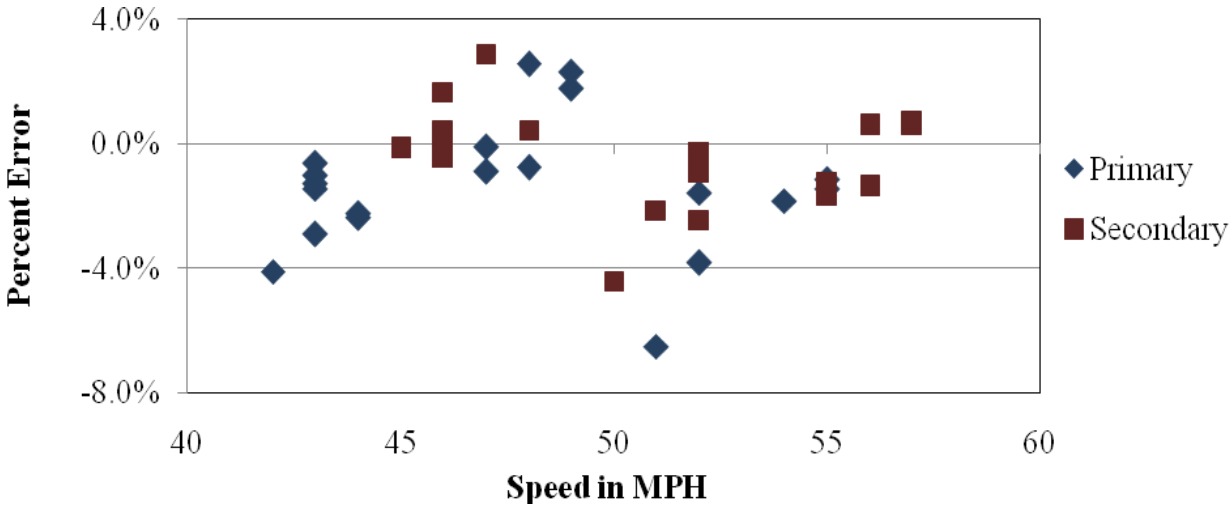


Figure 5-14 – Post-Validation GVW Error by Truck and Speed – 29-Sep-10

5.3.1.5 Axle Length Errors by Speed

For this site, there appears to be a relation between axle length measurement and speed where the axle length measurement increased as speed increased. The range in axle length measurement error ranged from -1.5 feet to 0.8 feet. Distribution of errors is shown graphically in Figure 5-15.

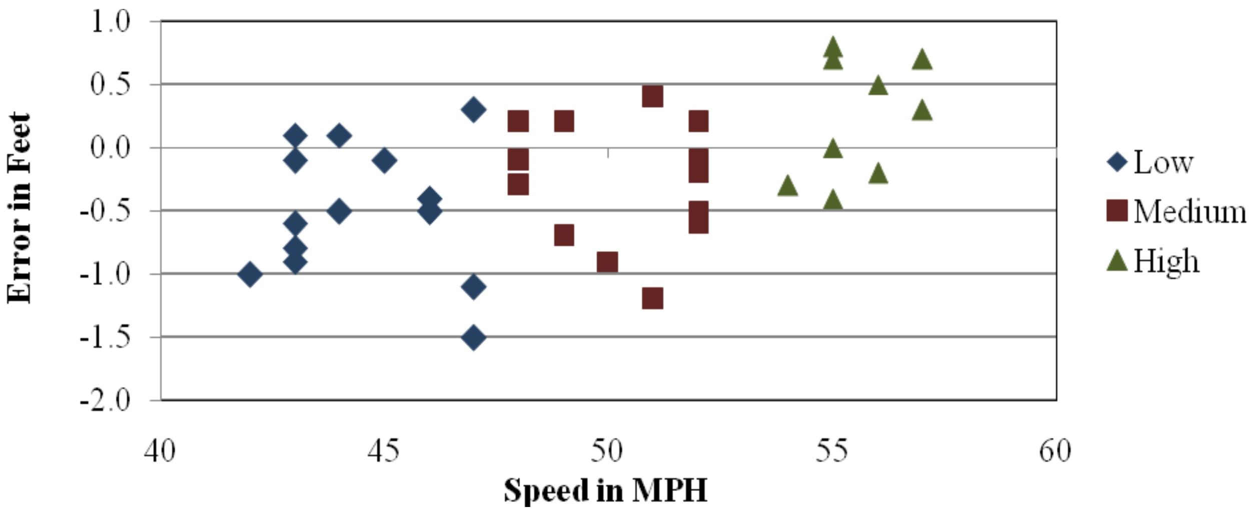


Figure 5-15 – Post-Validation Axle Length Error by Speed – 29-Sep-10

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment underestimates overall length consistently over the entire range of speeds, with errors ranging from -12.9 to -8.9 feet. Distribution of errors is shown graphically in Figure 5-16.

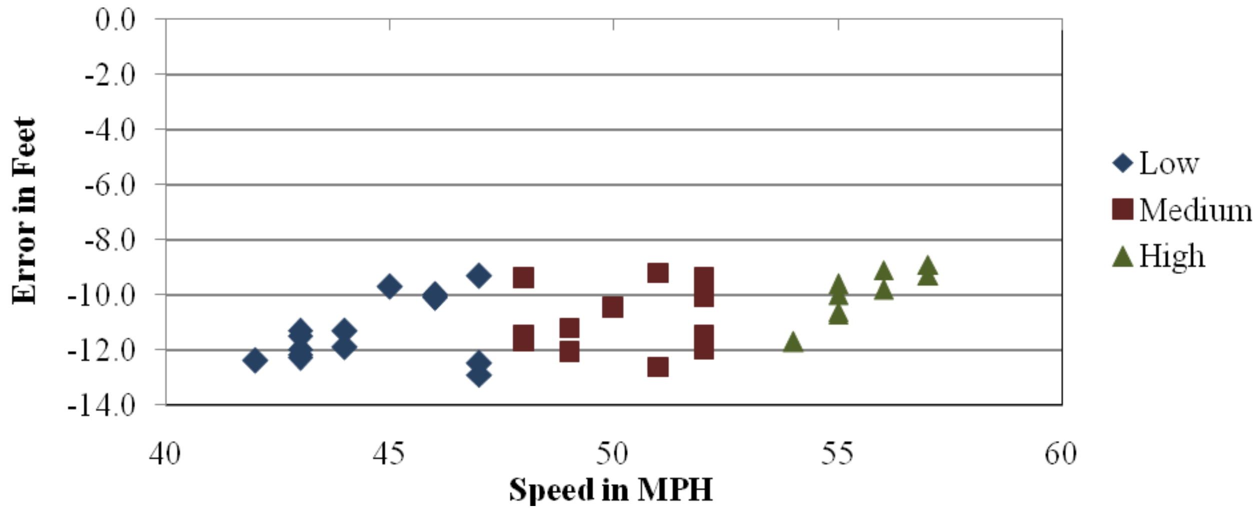


Figure 5-16 – Post-Validation Overall Length Error by Speed – 29-Sep-10

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether there is a relation between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 37.4 degrees, from 49.3 to 86.7 degrees Fahrenheit. The post-validation test runs are being reported under three temperature groups as shown in Table 5-11 below.

Table 5-11 – Post-Validation Results by Temperature – 29-Sep-10

Parameter	95% Confidence Limit of Error	Low	Medium	High
		49.3 to 61.8 degF	61.9 to 75.0 degF	75.1 to 86.7 degF
Steering Axles	±20 percent	-3.2 ± 6.9%	-7.4 ± 8.6%	-5.6 ± 5.9%
Tandem Axles	±15 percent	0.3 ± 6.4%	-1.3 ± 6.7%	0.5 ± 5.6%
GVW	±10 percent	-0.2 ± 3.5%	-2.1 ± 4.8%	-0.4 ± 3.3%
Vehicle Length	±3 percent (2 ft)	-10.9 ± 2.8 ft	-11.2 ± 3.0 ft	-10.5 ± 2.1 ft
Vehicle Speed	± 1.0 mph	-1.1 ± 4.6 mph	-1.3 ± 4.7 mph	-0.6 ± 5.8 mph
Axle Length	± 0.5 ft [150mm]	-0.4 ± 0.8 ft	-0.7 ± 1.2 ft	0.1 ± 0.9 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 5-17, it can be seen that the equipment appears to estimate GVW with reasonable accuracy across the range of temperatures observed in the field. There does not appear to be a significant correlation between temperature and weight estimates.

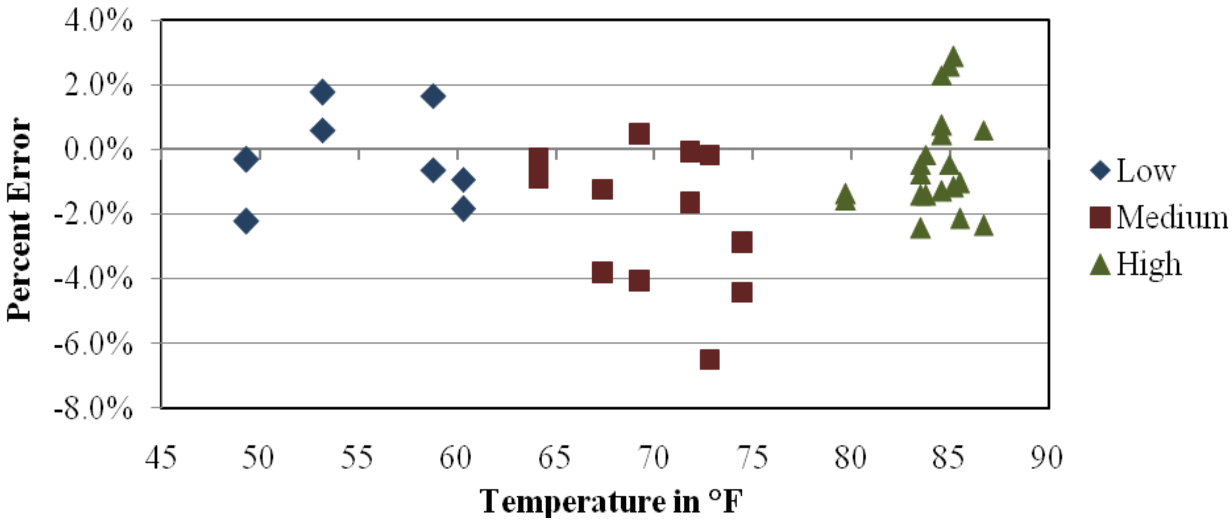


Figure 5-17 – Post-Validation GVW Errors by Temperature – 29-Sep-10

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-18 demonstrates that for steering axles, the WIM equipment underestimates steering axle weight at all temperatures. The range in error is similar for the two higher temperature groups, and lower for the lowest temperature group.

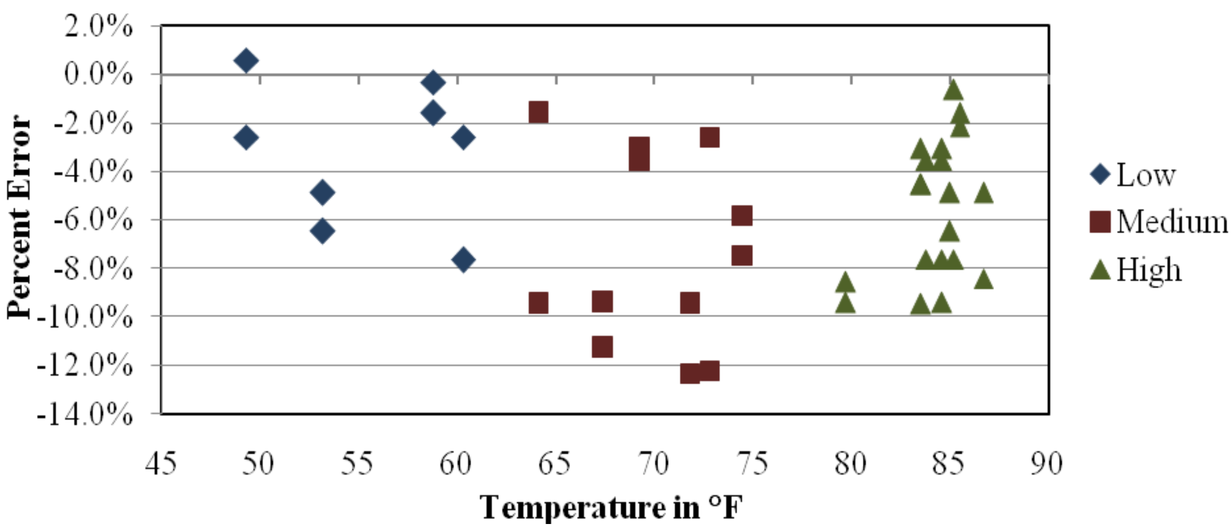


Figure 5-18 – Post-Validation Steering Axle Weight Errors by Temperature – 29-Sep-10

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-19, the equipment appears to estimate loaded tandem axle weights with reasonable accuracy at all temperatures. The range in tandem axle errors is consistent for the three temperature groups. Distribution of errors is shown graphically in the figure.

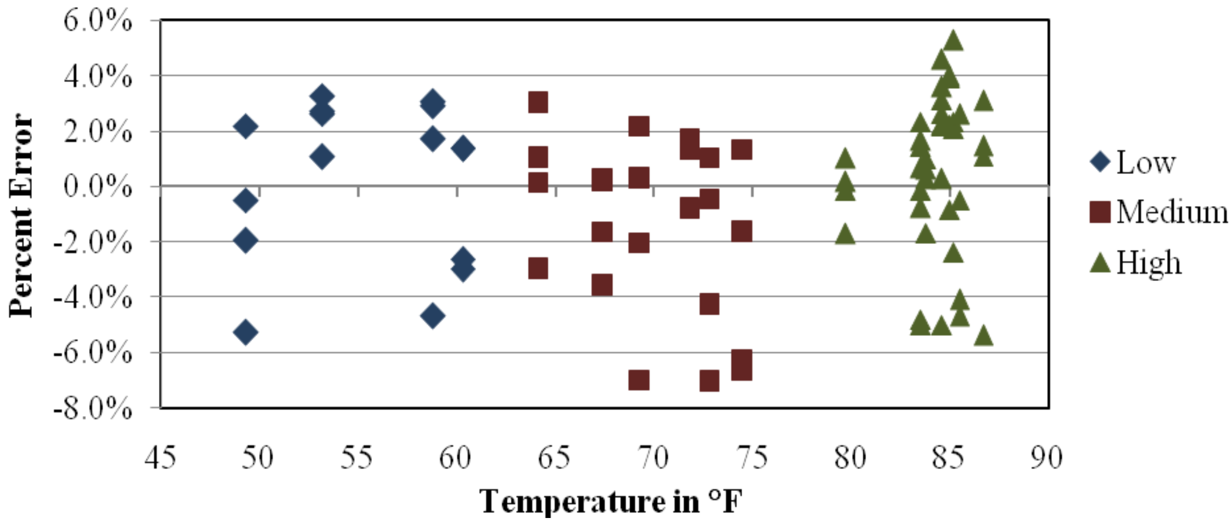


Figure 5-19 – Post-Validation Tandem Axle Weight Errors by Temperature – 29-Sep-10

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-20, when analyzed by truck type, GVW measurement errors for both trucks follow similar patterns: GVW for both trucks is measured with reasonable accuracy at all temperatures. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures. Distribution of errors is shown graphically in the following figure.

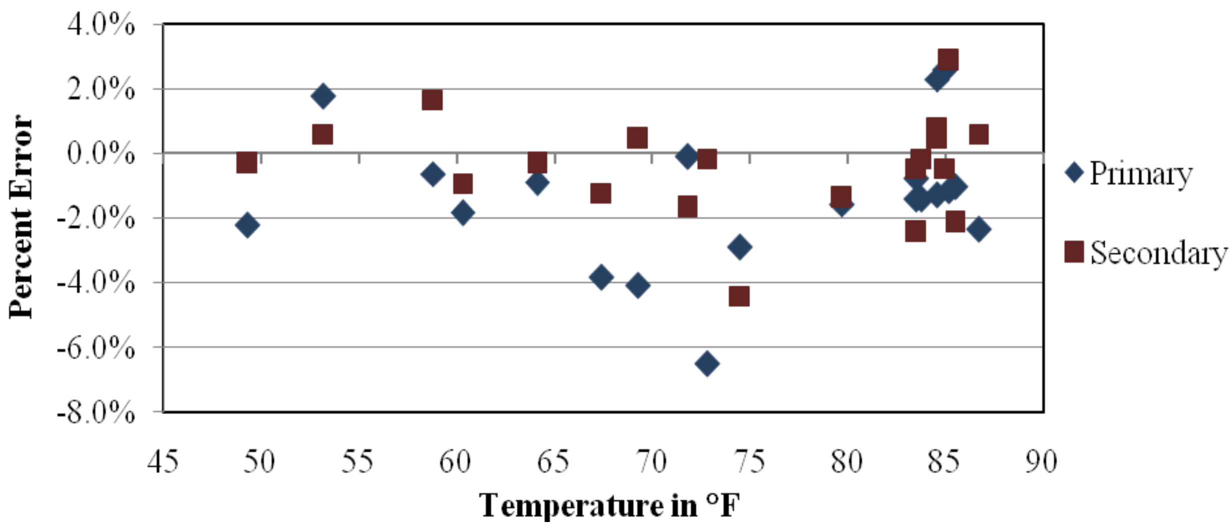


Figure 5-20 – Post-Validation GVW Error by Truck and Temperature – 29-Sep-10

5.3.3 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.

5.3.3.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. Compared to analysis described previously, the weight of "axle group" was evaluated separately for tandem axles on tractors and trailers. The separate evaluation was carried out because the tandem axle 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 42 to 57 mph.
- Pavement temperature. Pavement temperature ranged from 49.3 to 86.7 degrees Fahrenheit.
- Interaction between the factors such as the interaction between speed and pavement temperature.

5.3.3.2 Results

For analysis of steering axle weights, the value of regression coefficients and their statistical properties are summarized in Table 5-12. The value of the regression coefficients defines the slope of the relationship between the % error in steering axle weight and the predictor variables. The values of the t-distribution (for the regression coefficients) given in Table 5-12 are for the null hypothesis that assumes that the coefficients are equal to zero. The effects of speed and truck type were found statistically significant. The probabilities that the effect of truck type and temperature on the observed steering axle errors occurred by chance alone are less than 1 percent.

Table 5-12 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value
Intercept	26.7013	5.6263	4.7458	3.26E-05
Speed	-0.5388	0.0952	-5.6578	1.99E-06
Temp	-0.0603	0.0346	-1.7453	0.0895
Truck	-2.7097	0.8567	-3.1629	0.0032

The relationship between speed and measurement errors for steering axle weights is shown in Figure 5-21. The figure includes trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 5-21 provides quantification and statistical assessment of the relationship. The quantification is provided by the value of the regression coefficient, in this case -0.5388 (in Table 5-12). This means, for example, that for a 10 MPH increase in speed, the % error is decreased by about 5.4 % (0.5388 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient.

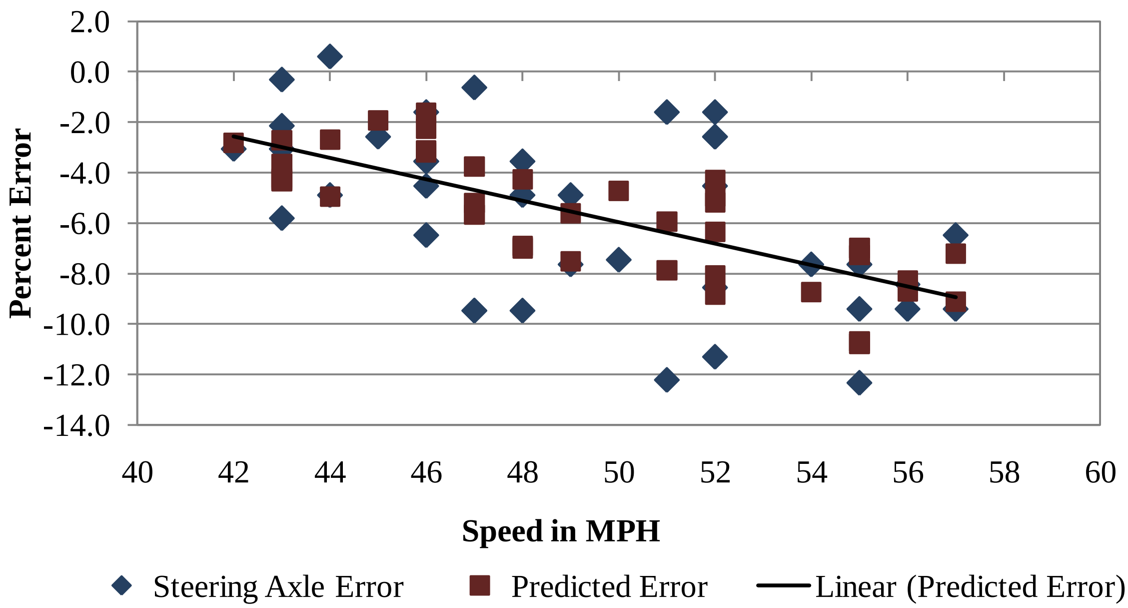


Figure 5-21 – Influence of Speed on the Measurement Error of Steering Axle Weights

5.3.3.3 Summary Results

Table 5-13 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 5-13 the table indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-13 – Summary of Regression Analysis

	Factor					
	Speed		**Temperature**		**Truck type**	
Weight, % error	Regression coefficient	Probability value	Regression coefficient	Probability value	Regression coefficient	Probability value
GVW	-	-	-	-	-	-
Steering axle	-0.5387	2.0E-06	-0.0603	0.0895	-2.7097	0.0032
Tandem axle tractor	0.3748	0.0019	-	-	-	-
Tandem axle trailer	-0.2436	0.0039	-	-	-1.9850	0.0082

5.3.3.4 Conclusions

1. No parameter had statistically significant effect on the measurement errors of GVW.

2. Speed had statistically significant effect on the measurement errors of all axle types. While the increase in speed increased the measurement errors of tandem axle tractor, it decreased the errors of steering axle and tandem trailer. As such, speed did not significantly affected the GVW.

3. Temperature had statistically significant effect on the measurement error of steering axles only. A 10 degree increase in temperature though would only decrease the measurement errors by 0.6 percent (10x0.0603).

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

5.4 Post Visit Applied Calibration

The 85th percentile speed for trucks, based on the CDS data, is 61 mph, 6 mph above the posted speed limit of 55 mph and 6 mph above the highest test truck speed. Consequently, applied calibration should be utilized for the speeds above 55 mph; however, this system provides one speed-based compensation at 55 mph. Consequently, changes to relative compensation factors using applied calibration cannot be recommended.

Figure 5-22 is provided to illustrate the predicted GVW error with respect to the post-validation errors by speed. This provides a reasonable expectation for the applied errors.

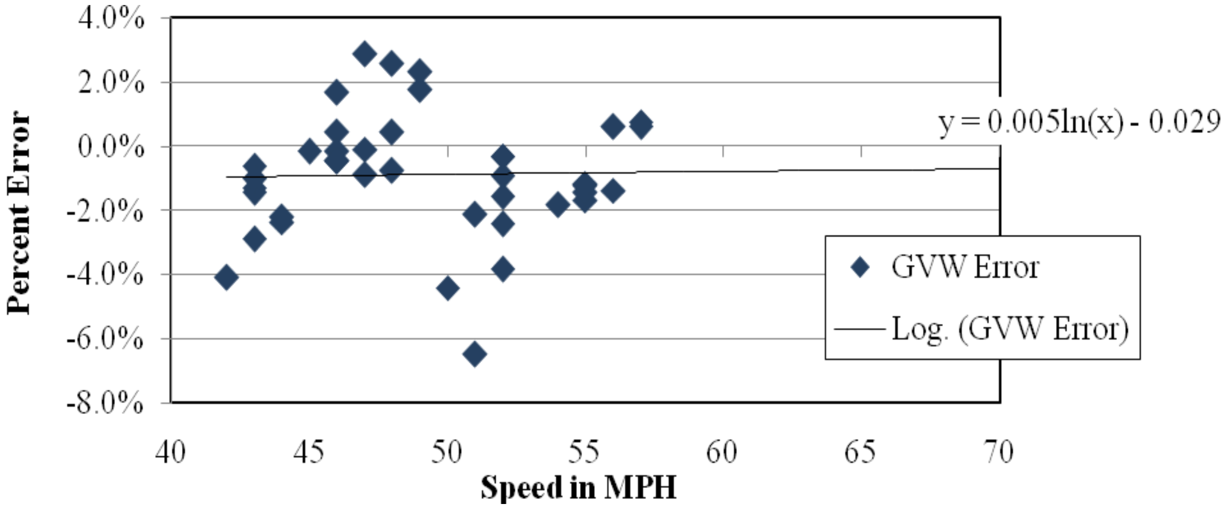


Figure 5-22 – GVW Error Trend

The final calibration factor for the 55 mph speed point that was left in place at the conclusion of the post-validation was 1000. The final distance factor was .8943.

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. 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	
14-Apr-04	25	17	67	67	33	6	100	0	0	100	0
15-Apr-04	N/A	33	20	100	17	5	0	0	N/A	100	0
11-May-05	100	50	0	0	0	0	0	N/A	N/A	N/A	0
12-May-05	75	54	100	N/A	0	3	0	0	N/A	N/A	0
28-Sep-10	N/A	22	0	N/A	0	0	0	0	N/A	N/A	0

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

Table 6-2 – Weight Validation History

Date	Mean Error and (SD)		
	GVW	Single Axles	Tandem
14-Apr-04	-2.7 (3.6)	-6.6 (3.7)	0.0 (5.4)
15-Apr-04	-0.8 (3.6)	-4.6 (4.1)	-1.5 (5.0)
11-May-05	2.9 (6.2)	-1.6 (4.9)	3.8 (7.5)
12-May-05	0.3 (3.1)	-5.1 (3.6)	1.5 (4.6)
28-Sep-10	-0.2 (1.5)	-5.7 (2.8)	0.8 (2.3)
29-Sep-10	-0.9 (1.9)	-5.6 (3.4)	-0.1 (2.8)

The variability (the standard deviation) of the weight errors appears to have decreased since the site was first validated. Based on information provided in Table 6.2, it appears that the system is stable and does not exhibit any tendency to under-estimate or over-estimate axle weights or GVW over time. Even though no calibration action was required at this time, the field verification provides reassurance that the system continues to yield research quality traffic load data.

6.2 Comparison of Past Validation Results

A comparison of the post-validation results from previous visits is provided in Table 6-3.

Table 6-3 – Comparison of Post-Validation Results

Parameter	95 %Confidence Limit of Error	Site Values (Mean Error and SD)		
		15-Apr-04	12-May-05	29-Sep-10
Single Axles	±20 percent	-4.6 ± 4.1	-5.1 ± 3.6	-5.6 ± 3.4
Tandem Axles	±15 percent	-1.5 ± 5.0	1.5 ± 4.6	-0.1 ± 2.8
GVW	±10 percent	-0.8 ± 3.6	0.3 ± 3.1	-0.9 ± 1.9

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

7 Additional Information

The following information is provided in the attached appendix:

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

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

- Sheet 17 – WIM Site Inventory
- Sheet 18 – WIM Site Coordination
- Sheet 19 – Calibration Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 23 – WIM Troubleshooting Outline
- Sheet 24A/B/C – Site Photograph Logs
- Updated Handout Guide

WIM System Field Calibration and Validation - Photos

Ohio, SPS-2
SHRP ID: 390200

Validation Date: September 29, 2010

Photo 1 - Cabinet Exterior

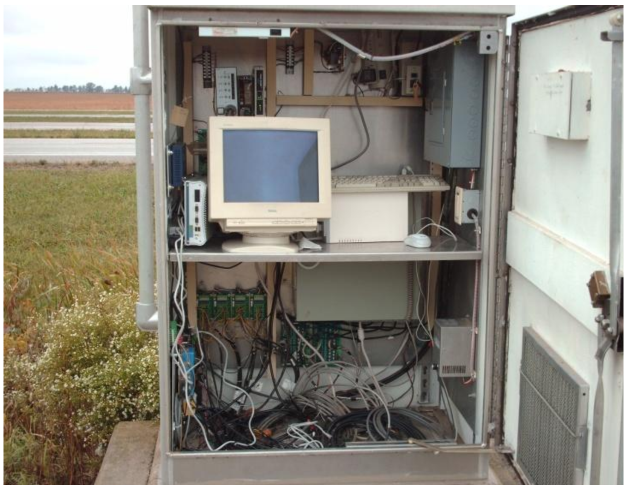


Photo 2 - Cabinet Interior (Back)

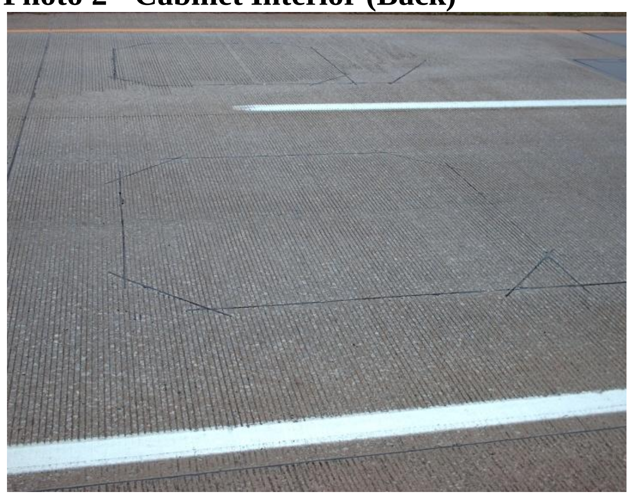


Photo 3 -Leading Loop

Photo 4 - Leading WIM Sensor

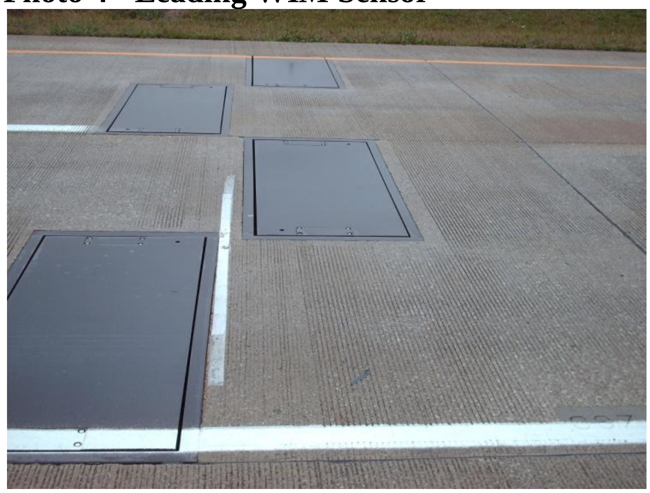


Photo 5 – Trailing WIM Sensor

Photo 6 - Power Service Box

Photo 7 - Telephone Pedestal

Photo 8 -Downstream

Photo 9 -Upstream

Photo 10 - 390200 – Truck 1

Photo 11 - 390200 – Truck 1 Tractor

Photo 12 - Truck 1 Trailer

Photo 13 - Truck 1 Load

Photo 14 - 390200 – Truck 1 Suspension 1

Photo 15 - Truck 1 Suspension 2

Photo 16 - Truck 1 Suspension 3

Photo 17 - Truck 1 Suspension 4

Photo 18 - 390200 – Truck 1 Suspension 5

Photo 19 - 390200 – Truck 2

Photo 20 - 390200 – Truck 2 Tractor

Photo 21 - 390200 – Truck 2 Trailer

Photo 22 - 390200 – Truck 2 Load

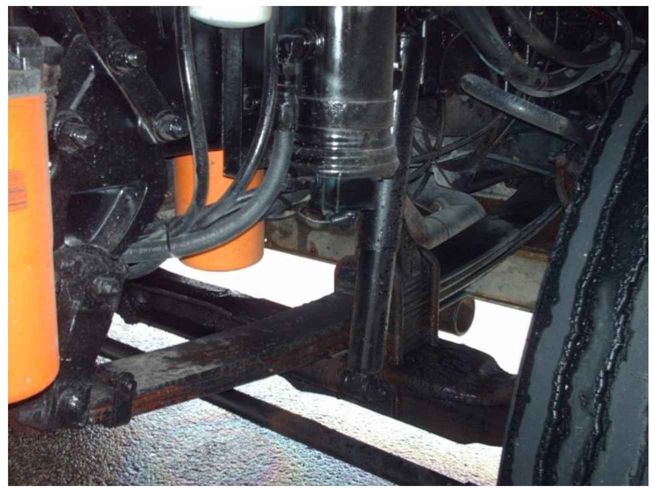


Photo 23 - 390200 – Truck 2 Suspension 1

Photo 24 - Truck 2 Suspension 2


Photo 25 - Truck 2 Suspension 3

Photo 26 - Truck 2 Suspension 4

Photo 27 - Truck 2 Suspension 5

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 39 SPS WIM ID: 390200 DATE (mm/dd/yyyy) 9/28/2010

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 9/28/10

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

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

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

5. **EQUIPMENT MANUFACTURER:** Mettler

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:	9	air	air
Truck 3:			

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

Mean Difference Between -

Dynamic and Static GVW:	-0.2%	Standard Deviation:	1.5%
Dynamic and Static Single Axle:	-5.7%	Standard Deviation:	2.8%
Dynamic and Static Double Axles:	0.8%	Standard Deviation:	2.3%

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

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

			Low		High	Runs
a.	Low	-	42.0	to	47.0	14
b.	Medium	-	47.1	to	52.1	15
c.	High	-	52.2	to	57.0	12
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 39 SPS WIM ID: 390200 DATE (mm/dd/yyyy) 9/28/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 1000

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

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-512-6638

E-mail: dwolf@ara.com

Traffic Sheet 16 **LTPP MONITORED TRAFFIC DATA** **SITE CALIBRATION SUMMARY**	STATE CODE: 39 SPS WIM ID: 390200 DATE (mm/dd/yyyy) 9/29/2010

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 9/29/10

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

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

a. Load Cells   c. ______

b. Inductance Loops   d. ______

5. EQUIPMENT MANUFACTURER: Mettler

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks

Number of Trucks Compared: ______

Number of Test Trucks Used: 2

Passes Per Truck: 20

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

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

Mean Difference Between -

Dynamic and Static GVW:	-0.9%	Standard Deviation:	1.9%
Dynamic and Static Single Axle:	-5.6%	Standard Deviation:	3.4%
Dynamic and Static Double Axles:	-0.1%	Standard Deviation:	2.8%

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

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	42.0	to	47.0	17
b.	Medium	-	47.1	to	52.0	14
c.	High	-	52.1	to	57.0	9
d.		-		to		
e.		-		to		

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 39 SPS WIM ID: 390200 DATE (mm/dd/yyyy) 9/29/2010

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 1000

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

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-512-6638

E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 39 SPS WIM ID: 390200 DATE (mm/dd/yyyy) 9/28/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
48	9	17523	50	9	56	9	19773	60	9
56	9	17561	57	9	52	9	19838	52	9
60	9	18414	63	9	58	9	19866	57	9
56	9	18679	52	9	53	9	19936	54	9
58	9	18714	56	9	55	9	19995	59	9
55	9	18810	53	9	55	9	20022	58	9
55	8	18825	53	8	53	9	20040	53	9
54	9	18889	59	9	48	9	20057	49	9
56	9	18940	56	9	59	9	20065	62	9
54	9	19284	60	9	58	11	20070	59	11
58	9	19308	62	9	51	9	20081	53	9
50	9	19322	53	9	46	9	6453	46	9
58	9	19386	59	9	55	3	7708	55	5
53	5	19407	58	5	57	9	7760	59	9
51	9	19431	58	5	52	9	7777	55	9
58	9	19451	61	9	57	9	7797	56	6
57	9	19508	55	9	54	9	8169	52	9
53	9	19585	53	9	57	9	8175	56	9
59	9	19616	62	9	57	9	8184	58	9
50	9	19654	54	9	61	9	8197	61	9
60	6	19664	60	6	57	9	8303	59	9
51	6	19675	52	6	56	9	8315	54	9
56	6	19688	56	6	61	9	8362	61	9
60	9	19700	62	9	57	9	8396	55	9
56	9	19770	61	9	57	9	8410	57	9

Validation Test Truck Run Set - Pre

Sheet 1 - 0 to 50 Start: ______ Stop: ______

Recorded By: djw Verified By: kt

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE:	39
	SPS WIM ID:	390200
	DATE (mm/dd/yyyy)	9/28/2010

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
53	5	8543	54	5	57	9	9115	58	9
49	5	8560	51	5	53	9	9167	57	9
57	9	8563	58	9	52	9	9215	55	9
56	9	8565	59	9	53	9	9218	58	9
64	9	8612	64	9	56	9	9275	57	9
62	9	8616	58	9	10	10	9285	56	10
57	9	8626	55	9	56	9	9292	55	9
61	9	8644	60	9	57	9	9298	61	9
58	9	8657	60	9	56	9	9320	57	9
58	9	8659	59	9	54	9	9322	56	9
53	5	8755	54	5	56	5	9328	59	5
55	9	8820	63	9	54	5	9329	54	5
55	9	8842	57	9	54	6	9341	58	6
57	9	8868	58	9	55	9	9346	55	9
54	9	8873	54	9	58	9	9355	60	9
56	9	8915	65	9	59	9	9357	60	9
59	9	8936	60	9	57	8	9412	59	8
57	9	8940	58	9	56	9	9460	59	9
54	9	9003	57	9	55	9	9470	58	9
56	9	9010	56	9	57	9	9478	63	9
52	9	9018	56	9	54	9	9481	57	9
56	8	9060	58	8	57	9	9494	61	9
50	5	9091	54	5	58	9	9501	55	9
54	9	9105	57	9	55	9	9505	55	9
55	9	9169	54	9	55	9	9506	57	9

Validation Test Truck Run Set - Pre

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

Recorded By: djw Verified By: kt