WIM System Field Calibration and Validation Summary Report

Tennessee SPS-6
SHRP ID – 470600

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Applied Research Associates, Inc.

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LTPP

Table of Contents

1 Executive Summary 1

2 WIM System Data Availability and Pre-Visit Data Analysis 3

2.1 LTPP WIM Data Availability 3

2.2 Classification Data Analysis 4

2.3 Speed Data Analysis 5

2.4 GVW Data Analysis 6

2.5 Class 9 Front Axle Weight Data Analysis 8

2.6 Class 9 Tractor Tandem Spacing Data Analysis 9

2.7 Data Analysis Summary 11

3 WIM Equipment Discussion 12

3.1 Description 12

3.2 Physical Inspection 12

3.3 Electronic and Electrical Testing 12

3.4 Equipment Troubleshooting and Diagnostics 12

3.5 Recommended Equipment Maintenance 12

4 Pavement Discussion 13

4.1 Pavement Condition Survey 13

4.2 LTPP Pavement Profile Data Analysis 13

4.3 Profile and Vehicle Interaction 14

4.4 Recommended Pavement Remediation 15

5 Statistical Reliability of the WIM Equipment 16

5.1 Pre-Validation 16
5.1.1 Statistical Speed Analysis 17
5.1.2 Statistical Temperature Analysis 21
5.1.3 Classification and Speed Evaluation 24
5.2 Calibration 25
5.2.1 Calibration Iteration 1 26
5.3 Post-Validation 27
5.3.1 Statistical Speed Analysis 28
5.3.2 Statistical Temperature Analysis 32
5.3.3 Classification and Speed Evaluation 35
5.3.4 Final WIM System Compensation Factors 36
6 Post-Visit Data Analysis 37
6.1 Regression Analysis 37
6.1.1 Data 37
6.1.2 Results 38
6.1.3 Summary Results 39
6.1.4 Conclusions 40
6.1.5 Contribution of Two Trucks to Calibration 40
6.2 Misclassification Analysis 42
6.3 Traffic Data Analysis 43
6.3.1 GVW and Steering Axle Weight Distributions 43
6.3.2 Imbalance 44
6.3.3 WIM System Factor Adjustments 44
7 Previous WIM Site Validation Information 44

7.1 Classification 44

7.2 Weight 45

8 Additional Information 46

List of Figures

Figure 2-1 – Comparison of Truck Distribution 4
Figure 2-2 – Truck Speed Distribution – 18-Mar-12 6
Figure 2-3 – Comparison of Class 9 GVW Distribution 7
Figure 2-4 – Distribution of Class 9 Front Axle Weights 8
Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing 10
Figure 5-1 – Pre-Validation GVW Error by Speed – 17-Apr-12 18
Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 17-Apr-12 18
Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 17-Apr-12 19
Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 17-Apr-12 20
Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 17-Apr-12 20
Figure 5-6 – Pre-Validation Overall Length Error by Speed – 17-Apr-12 21
Figure 5-7 – Pre-Validation GVW Errors by Temperature – 17-Apr-12 22
Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 17-Apr-12 22
Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 17-Apr-12 23
Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 17-Apr-12 23
Figure 5-11 – Calibration 1 GVW Error by Speed – 18-Apr-12 27
Figure 5-12 – Post-Validation GVW Errors by Speed – 18-Apr-12 29
Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 18-Apr-12 30
Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 18-Apr-12 30
Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 18-Apr-12 31
Figure 5-16 – Post-Validation Axle Length Error by Speed – 18-Apr-12 31
Figure 5-17 – Post-Validation Overall Length Error by Speed – 18-Apr-12 32
Figure 5-18 – Post-Validation GVW Errors by Temperature – 18-Apr-12 33
Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 18-Apr-12 33
Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 18-Apr-12 34
Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 18-Apr-12 34
Figure 6-1 – Influence of Temperature on the Measurement Error of GVW 39
Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks 41

Figure 6-6 – Vehicle Record 52005 42
Figure 6-7 – Class 9 GVW Distribution 43
Figure 6-8 – Class 9 Steering Axle Weight Distribution 43

List of Tables

Table 1-1 – Post-Validation Results – 18-Apr-12 1
Table 1-2 – Post-Validation Test Truck Measurements 2
Table 2-1 – LTPP Data Availability 3
Table 2-2 – LTPP Data Availability by Month 3
Table 2-3 – Truck Distribution from W-Card 5
Table 2-4 – Class 9 GVW Distribution from W-Card 7
Table 2-5 – Class 9 Front Axle Weight Distribution from W-Card 9
Table 2-6 – Class 9 Axle 2 to 3 Spacing from W-Card 10
Table 4-1 – Recommended WIM Smoothness Index Thresholds 13
Table 4-2 – WIM Index Values 14
Table 5-1 – Pre-Validation Test Truck Weights and Measurements 16
Table 5-2 – Pre-Validation Overall Results – 17-Apr-12 17
Table 5-3 – Pre-Validation Results by Speed – 17-Apr-12 17
Table 5-4 – Pre-Validation Results by Temperature – 17-Apr-12 21
Table 5-5 – Pre-Validation Misclassifications by Pair – 17-Apr-12 24
Table 5-6 – Pre-Validation Classification Study Results – 17-Apr-12 25
Table 5-8 – Initial System Parameters – 18-Apr-12 26
Table 5-9 – Calibration 1 Equipment Factor Changes – 18-Apr-12 26
Table 5-10 – Calibration 1 Results – 18-Apr-12 27
Table 5-11 – Post-Validation Test Truck Measurements 28
Table 5-12 – Post-Validation Overall Results – 18-Apr-12 28
Table 5-13 – Post-Validation Results by Speed – 18-Apr-12 29
Table 5-14 – Post-Validation Results by Temperature – 18-Apr-12 32
Table 5-15 – Post-Validation Misclassifications by Pair – 18-Apr-12 35
Table 5-16 – Post-Validation Classification Study Results – 18-Apr-12 36
Table 5-18 – Final Factors 36
Table 6-1 – Table of Regression Coefficients for Measurement Error of GVW 38
Table 6-2 – Summary of Regression Analysis 40
Table 6-4 – Front Axle Weight Imbalance 44

Table 7-1 – Classification Validation History 45
Table 7-2 – Weight Validation History 45

1 Executive Summary

A WIM validation was performed on April 17 and 18, 2012 at the Tennessee SPS-6 site located on route I-40, 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, righthand driving lane. The site is equipped with quartz WIM sensors and an 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 February 16, 2011 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

The equipment is in working order. Electronic and electrical checks of the WIM components determined that the the equipment is operating within the manufacturer's tolerances. None of the in-road sensors show signs of damage or excessive wear and appear to be fully secured in the pavement. Further equipment discussion is provided in Section 3.

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

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

Table 1-1 – Post-Validation Results – 18-Apr-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	0.8 ± 3.8%	Pass
Tandem Axles	±15 percent	0.0 ± 4.9%	Pass
GVW	±10 percent	0.1 ± 3.5%	Pass
Vehicle Length	±3.0 percent (1.8 ft)	0.0 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	Pass

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was 0.4 ± 3.3 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 0.1 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.

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 4.9% from the 102 vehicle sample (Class 4 – 13) was due to the 5 cross-classifications of Class 3, 4, 5, and 8 vehicles.

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

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

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

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

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.3	11.2	16.4	16.4	16.6	16.6	19.5	4.3	28.1	4.1	56.0	60.8
2	68.6	11.3	15.6	15.6	13.0	13.0	19.8	4.3	28.5	4.3	56.9	61.0

The posted speed limit at the site is 70 mph. During the testing, the speed of the test trucks ranged from to 59 to 70 mph, a range of 11 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 50.9 to 105.0 degrees Fahrenheit, a range of 54.1 degrees Fahrenheit. The sunny weather conditions provided the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 25 shows that there are 5 years of level “E” WIM data for this site. This site does not require any additional 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 March 19, 2012 (Data) to the most recent two-week Comparison Data Set (CDS) from March 15, 2011. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 25 shows that there are 5 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2007 to 2011.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2007	214	7
2008	325	12
2009	365	12
2010	305	11
2011	261	9

As shown in the table, this site does not require any additional data to meet the minimum of five years of research quality data.

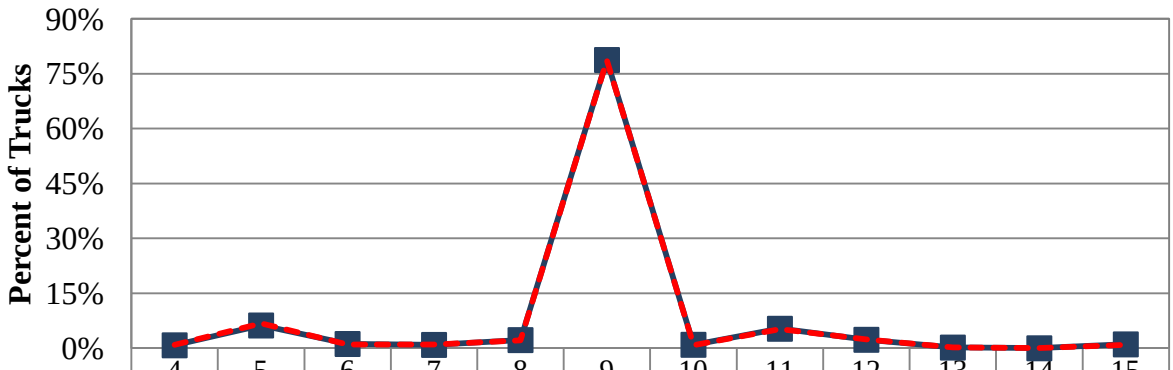
Table 2-2 provides a monthly breakdown of the available data for years 2007 through 2011.

Table 2-2 – LTPP Data Availability by Month

Year	Month												No. of Months
	1	2	3	4	5	6	7	8	9	10	11	12	
2007						30	31	31	30	31	30	31	7
2008	27	29	31	29	31	23	29	24	30	18	23	31	12
2009	31	28	31	30	31	30	31	31	30	31	30	31	12
2010	30	26	31	30	23		13	30	30	31	30	31	11
2011	31	28	31	30	31	30	31	31	18				9

2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site. Figure 2-1 provides a comparison of the truck type distributions between the sample dataset from March 19, 2012 (Data) and the most recent comparison Data Set (CDS) from March 15, 2011.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	0.8%	6.2%	1.2%	0.9%	2.2%	78.8%	1.0%	5.3%	2.3%	0.2%	0.0%	1.1%
CDS	0.9%	6.8%	1.0%	1.0%	2.1%	78.7%	0.9%	5.2%	2.4%	0.2%	0.0%	0.9%

Figure 2-1 – Comparison of Truck Distribution

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the two most frequent truck types crossing the WIM scale are Class 9 (78.8%) and Class 5 (6.2%) vehicles.

Table 2-3 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles. The table indicates that 1.1 percent of the vehicles at this site are unclassified.

Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS Data				Change
	Date				
	3/15/2011		3/19/2012		
4	607	0.9%	527	0.8%	-0.1%
5	4395	6.8%	4049	6.2%	-0.4%
6	657	1.0%	762	1.2%	0.2%
7	623	1.0%	597	0.9%	-0.1%
8	1386	2.1%	1452	2.2%	0.1%
9	51133	78.7%	51201	78.8%	0.1%
10	556	0.9%	619	1.0%	0.1%
11	3387	5.2%	3466	5.3%	0.1%
12	1577	2.4%	1507	2.3%	-0.1%
13	113	0.2%	127	0.2%	0.0%
14	0	0.0%	0	0.0%	0.0%
15	565	0.9%	692	1.1%	0.2%

From the table it can be seen that the percentage of Class 9 vehicles has increased by 0.1 percent from March 2011 and March 2012. Changes in the percentage of heavier trucks may be attributed to natural and seasonal variations in truck distributions and an increase in goods movement during current economic cycle. During the same time period, the percentage of Class 5 trucks decreased by 0.4 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

2.3 Speed Data Analysis

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

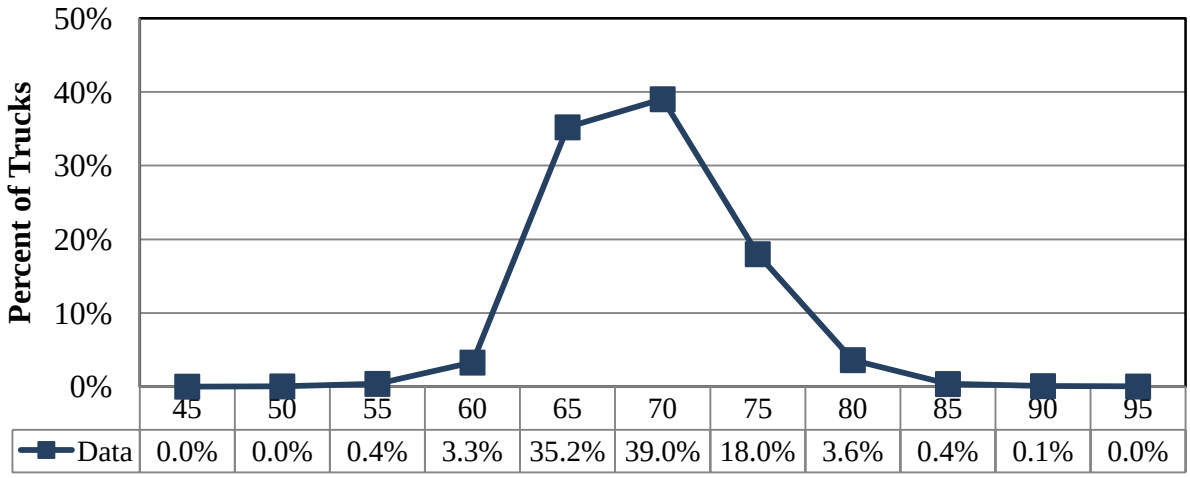


Figure 2-2 – Truck Speed Distribution – 18-Mar-12

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 60 to 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 March 2012 and the Comparison Data Set from March 2011.

As shown in Figure 2-3, there is a downward shift for the loaded peaks between the March 2011 Comparison Data Set (CDS) and the March 2012 two-week sample W-card dataset (Data). The results indicate that there may have been a small change in the types of commodity being transported by trucks traveling over the WIM system, a possible negative bias (underestimation of loads), or pavement condition or sensor deterioration.

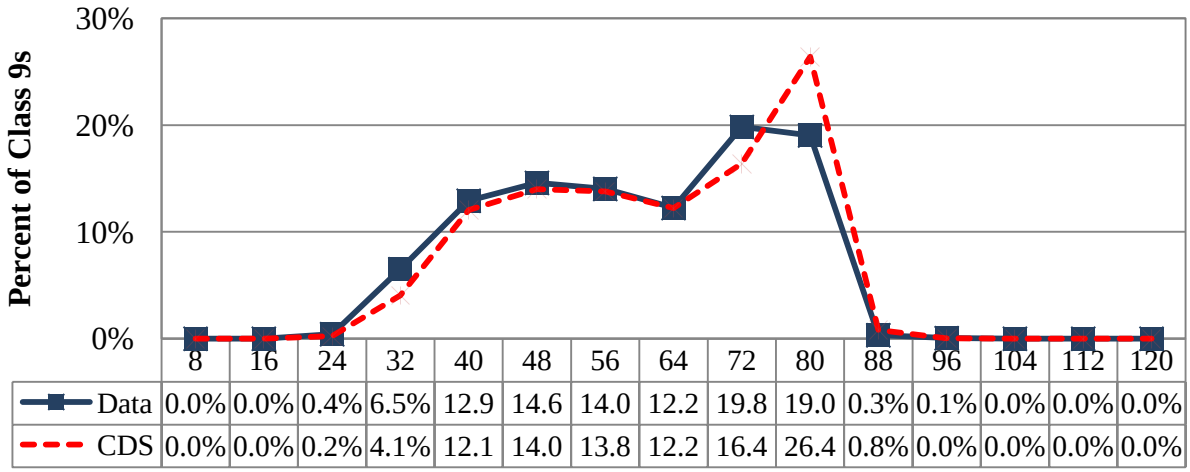


Figure 2-3 – Comparison of Class 9 GVW Distribution

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

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

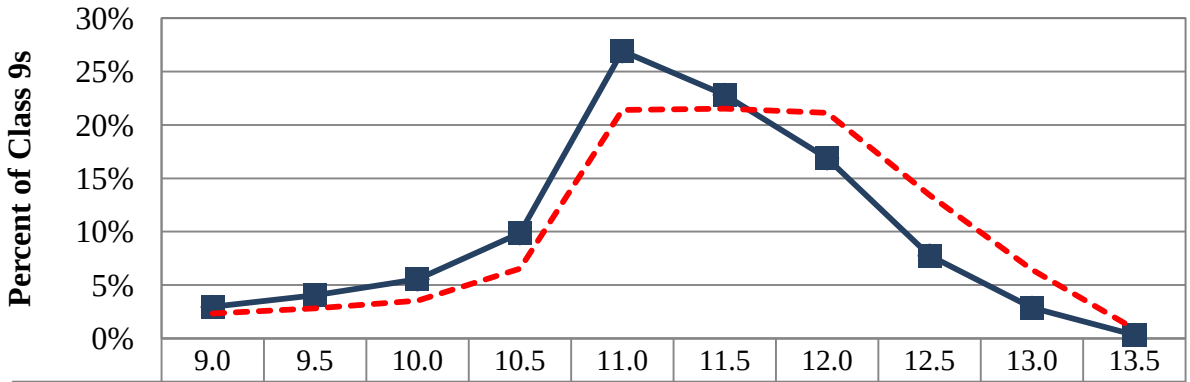
GVW weight bins (kips)	CDS		Data		Change
	Date				
	3/15/2011		3/19/2012		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	117	0.2%	218	0.4%	0.2%
32	2068	4.1%	3326	6.5%	2.4%
40	6155	12.1%	6605	12.9%	0.8%
48	7150	14.0%	7459	14.6%	0.6%
56	7038	13.8%	7170	14.0%	0.2%
64	6236	12.2%	6257	12.2%	0.0%
72	8371	16.4%	10137	19.8%	3.4%
80	13480	26.4%	9731	19.0%	-7.4%
88	417	0.8%	167	0.3%	-0.5%
96	15	0.0%	27	0.1%	0.1%
104	0	0.0%	1	0.0%	0.0%
112	0	0.0%	0	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	58.0 kips		55.8 kips		-2.2 kips

As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range increased by 0.8 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 7.4 percent. During this time period the percentage of overweight trucks increased by 0.5 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site decreased by 4.0 percent, from 58.0 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 current data sample set with the expected average front axle weight average from the Data Comparison Set.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from March 2012 and the Comparison Data Set from March 2011. The percentage of light axles (9.5 to 10.5 kips) increased by approximately 5.4 percent and the percentage of heavy axles (11.5 to 12.5 kips) decreased by approximately 9.8 percent, indicating possible negative bias (underestimation of loads) in front axle measurement.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	3.0%	4.0%	5.5%	9.9%	26.9%	22.8%	16.9%	7.8%	2.9%	0.3%
CDS	2.3%	2.8%	3.5%	6.5%	21.4%	21.5%	21.1%	13.4%	6.5%	0.9%

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

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 11.0 and 12.0 kips. The percentage of trucks in this range has decreased between the March 2011 Comparison Data Set (CDS) and the March 2012 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the March 2011 Comparison Data Set (CDS) and the March 2012 dataset (Data).

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

F/A weight bins (kips)	CDS		Data		Change
	Date				
	3/15/2011		3/19/2012		
9.0	1182	2.3%	1509	3.0%	0.7%
9.5	1429	2.8%	2060	4.0%	1.2%
10.0	1791	3.5%	2827	5.5%	2.0%
10.5	3327	6.5%	5027	9.9%	3.4%
11.0	10875	21.4%	13711	26.9%	5.5%
11.5	10945	21.5%	11626	22.8%	1.3%
12.0	10740	21.1%	8601	16.9%	-4.2%
12.5	6825	13.4%	3955	7.8%	-5.6%
13.0	3281	6.5%	1464	2.9%	-3.6%
13.5	452	0.9%	172	0.3%	-0.6%
Average =	11.3 kips		11.0 kips		-0.3 kips

The table shows that the average front axle weight for Class 9 trucks has decreased by 0.3 kips, or 2.7 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.0 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 from the sample data (Data) with the expected average tractor tandem spacing from the comparison data set (CDS).

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

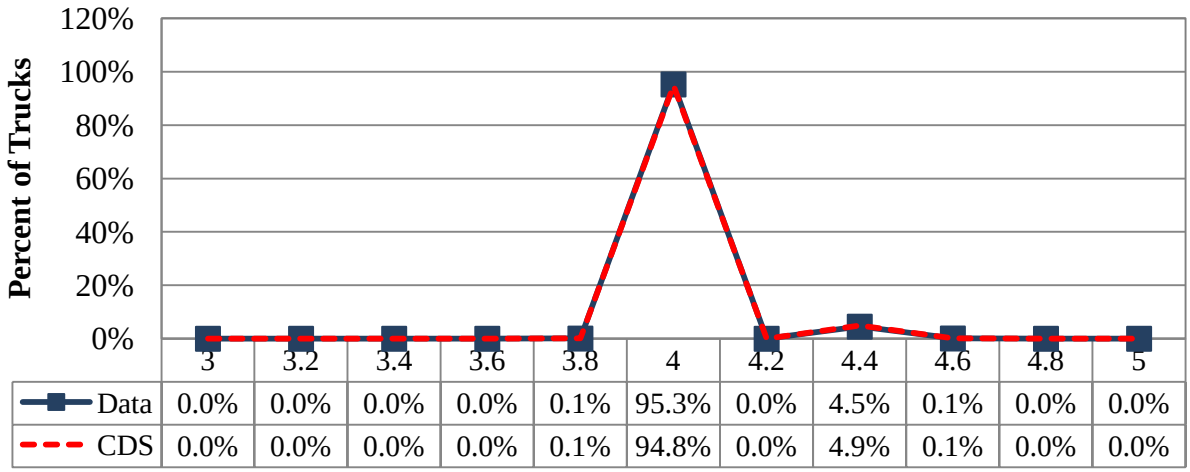


Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacings for the March 2011 Comparison Data Set and the March 2012 Data are nearly identical.

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

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

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	3/15/2011		3/19/2012		
3.0	0	0.0%	0	0.0%	0.0%
3.2	0	0.0%	1	0.0%	0.0%
3.4	0	0.0%	2	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	36	0.1%	37	0.1%	0.0%
4.0	48410	94.8%	48688	95.3%	0.4%
4.2	0	0.0%	0	0.0%	0.0%
4.4	2525	4.9%	2316	4.5%	-0.4%
4.6	73	0.1%	52	0.1%	0.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	3	0.0%	2	0.0%	0.0%
Average =	4.0 feet		4.0 feet		0.0 feet

From the table it can be seen that the drive tandem spacing of Class 9 trucks at this site is between 4.0 and 4.6 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.0, which is identical to to the expected

average of 4.0 from the CDS per vehicle records. Further axle spacing analyses are performed during the validation and post-validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent two-week Comparison Data Set (March 2011) based on the last calibration with the most recent two-week WIM data sample from the site (March 2012). Comparison of vehicle class distribution data indicates a 0.1 percent increase in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have decreased by 2.7 percent and average Class 9 GVW has decreased by 4.0 percent for the March 2012 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical to the expected average of 4.0 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on February 16, 2011 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. 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. Electronic tests of the power and communication devices indicated that they were operating normally.

3.4 Equipment Troubleshooting and Diagnostics

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

3.5 Recommended Equipment Maintenance

No unscheduled equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

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

4.2 LTPP Pavement Profile Data Analysis

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

Table 4-1 – Recommended WIM Smoothness Index Thresholds

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

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

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the 3 left, 3 right and 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	0.623	0.550			0.564
		SRI (m/km)	*0.319*	0.940	0.538			0.599
		Peak LRI (m/km)	0.558	0.623	0.585			0.589
		Peak SRI (m/km)	*0.355*	1.010	*0.558*			*0.641*
	RWP	LRI (m/km)	0.620	0.713	1.293			0.875
		SRI (m/km)	*0.462*	0.767	**4.129**			1.786
		Peak LRI (m/km)	0.681	0.713	1.293			0.896
		Peak SRI (m/km)	***0.601***	***0.808***	***4.392***			***1.934***
Center	LWP	LRI (m/km)	0.548	0.656	0.544	0.647	0.527	0.584
		SRI (m/km)	0.619	0.974	*0.319*	0.687	*0.439*	0.608
		Peak LRI (m/km)	0.599	0.692	0.686	0.649	0.532	0.632
		Peak SRI (m/km)	*0.716*	1.232	*0.326*	1.102	*0.527*	0.781
	RWP	LRI (m/km)	*0.426*	0.547	*0.464*	0.657	*0.437*	0.506
		SRI (m/km)	*0.313*	0.921	*0.206*	0.592	*0.381*	*0.483*
		Peak LRI (m/km)	0.567	0.547	0.555	0.657	0.597	0.585
		Peak SRI (m/km)	*0.485*	0.961	*0.450*	0.777	*0.461*	*0.627*
Right	LWP	LRI (m/km)	*0.474*	*0.464*	*0.487*			*0.475*
		SRI (m/km)	*0.251*	*0.214*	*0.375*			*0.280*
		Peak LRI (m/km)	0.609	0.664	0.625			0.633
		Peak SRI (m/km)	*0.304*	*0.240*	*0.412*			*0.319*
	RWP	LRI (m/km)	1.592	0.535	1.454			1.194
		SRI (m/km)	0.859	*0.241*	1.278			0.793
		Peak LRI (m/km)	1.694	0.631	1.454			1.260
		Peak SRI (m/km)	1.440	*0.350*	1.478			1.089

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

4.3 Profile and Vehicle Interaction

Profile data was collected on January 18, 2012 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 52 in/mi and is located approximately 489 feet prior to the WIM scale. The highest IRI value within the 400 foot approach section was 77 in/mi and is located approximately 6 feet prior to the WIM scale. These areas of the pavement were closely investigated during the validation visit, and truck dynamics in this area were closely observed. There were no distresses observed at these locations that would influence truck dynamics in the WIM scale area.

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

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

The following section provides summaries of data collected during the pre-validation, the calibration, and the 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 40 pre-validation test truck runs were conducted on April 17, 2012, beginning at approximately 9:56 AM and continuing until 4:11 PM.

The two test trucks consisted of:

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

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

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

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

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.5	11.4	16.4	16.4	16.6	16.6	19.5	4.3	28.1	4.1	56.0	60.8
2	68.7	11.4	15.7	15.7	13.0	13.0	19.8	4.3	28.5	4.3	56.9	61.0

Test truck speeds varied by 11 mph, from 59 to 70 mph. The measured pre-validation pavement temperatures varied 3.6 degrees Fahrenheit, from 62.2 to 65.8. The overcast weather conditions prevented the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

As shown in Table 5-2, the site met all LTPP requirements except vehicle length as a result of the pre-validation test truck runs. In addition, negative bias in GVW measurements deviates from zero by over 4 percent.

Table 5-2 – Pre-Validation Overall Results – 17-Apr-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-1.4 ± 6.1%	Pass
Tandem Axles	±15 percent	-2.7 ± 4.8%	Pass
GVW	±10 percent	-4.6 ± 4.1%	Pass
Vehicle Length	±3.0 percent (1.8 ft)	2.0 ± 1.1 ft	FAIL
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was -0.3 ± 4.1 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.1 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 similar acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 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 – 17-Apr-12

Parameter	95% Confidence Limit of Error	Low	Medium	High
		59.0 to 62.7 mph	62.8 to 66.4 mph	66.5 to 70.0 mph
Steering Axles	±20 percent	-1.6 ± 8.9%	-0.9 ± 4.6%	-1.7 ± 4.1%
Tandem Axles	±15 percent	-6.8 ± 4.0%	-4.3 ± 3.8%	-4.3 ± 6.0%
GVW	±10 percent	-5.8 ± 3.8%	-3.7 ± 3.3%	-3.8 ± 4.9%
Vehicle Length	±3.0 percent (1.8 ft)	2.0 ± 1.1 ft	2.2 ± 1.1 ft	1.7 ± 1.2 ft
Vehicle Speed	± 1.0 mph	-1.0 ± 6.3 mph	0.1 ± 1.6 mph	0.3 ± 2.1 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.1 ft	0.1 ± 0.1 ft

From the table, it can be seen that, on average, the WIM equipment underestimates all weights at all speeds. For steering axles, the range in error appears to decrease as speed increases. For tandem axles and GVW, the range in error appears to greater at the higher speeds.

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

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment generally underestimated GVW at all speeds. The underestimation appears to decrease as speed increases. The range in error is similar throughout the speed range.

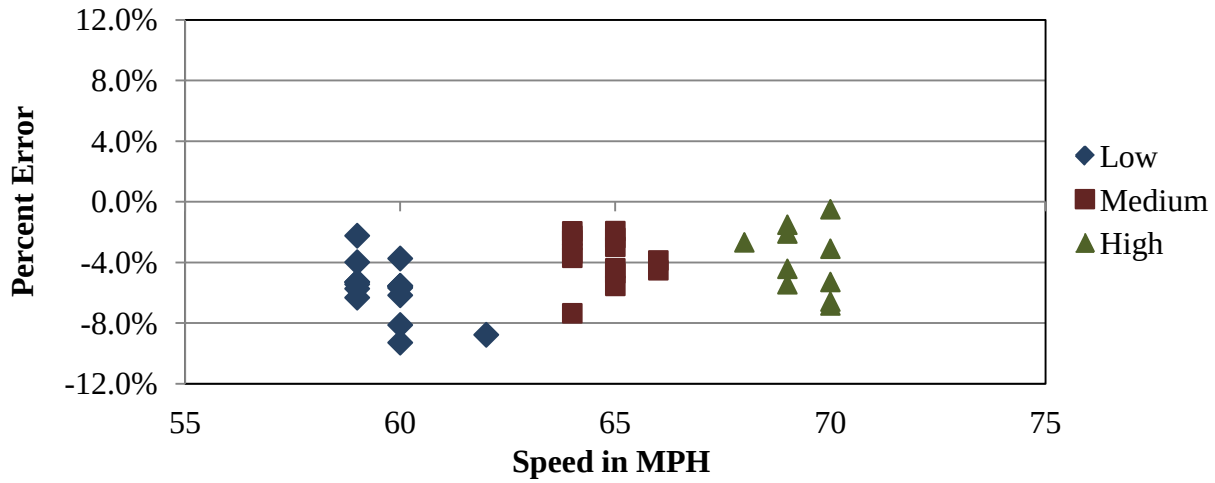


Figure 5-1 – Pre-Validation GVW Error by Speed – 17-Apr-12

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment estimates steering axle weights with fairly similar bias at all speeds. The range in error is similar throughout the speed range. One outlier data point was observed at a low speed.

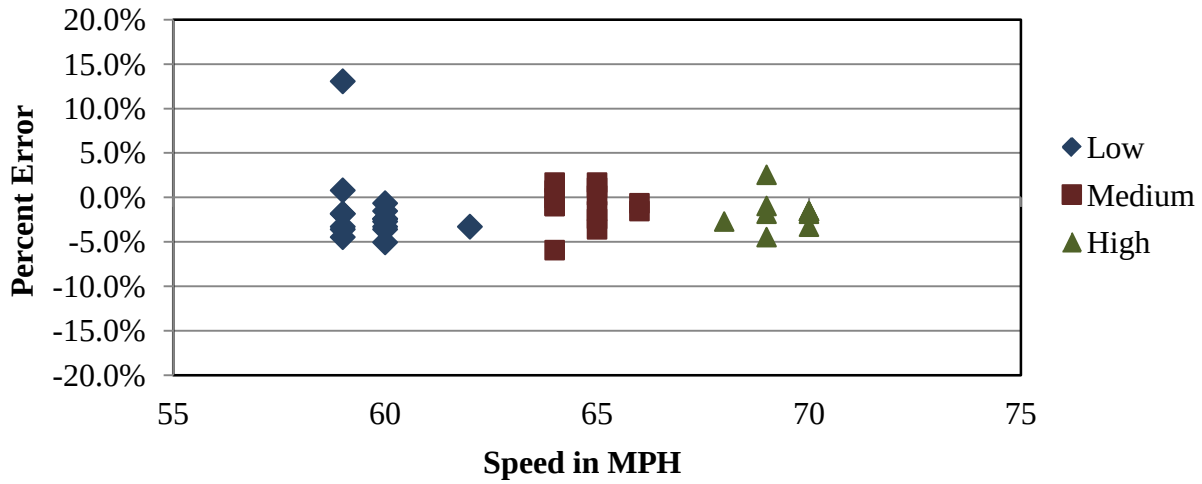


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 17-Apr-12

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment generally underestimates tandem axle weights all speeds. The bias is more negative at low speeds and moves closer to zero as speed increases. The range in error appears to be slightly greater at the high speeds when compared with low and medium speeds.

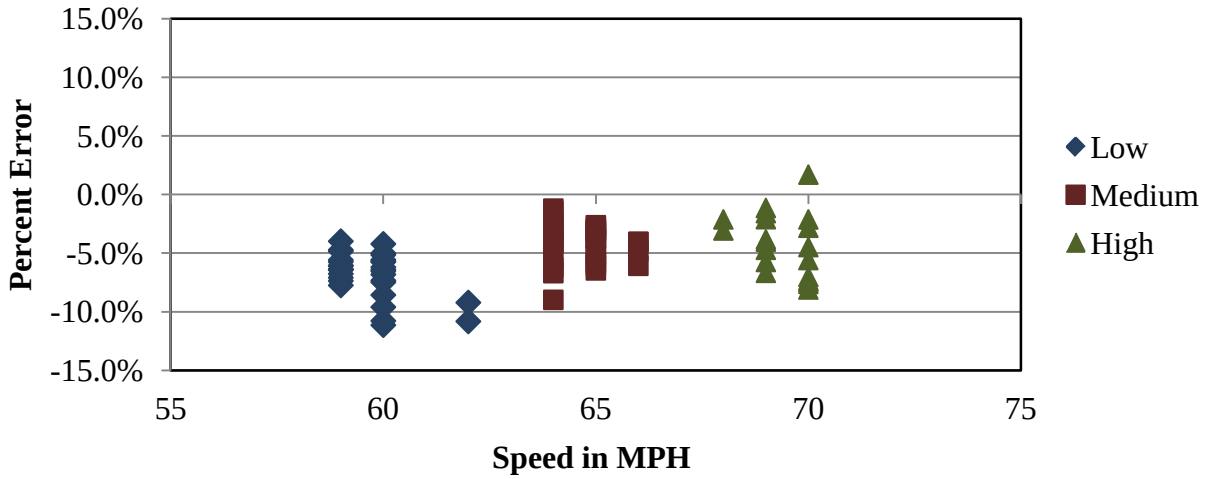


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 17-Apr-12

5.1.1.4 GVW Errors by Speed and Truck Type

When the GVW error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment underestimates GVW for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. The negative bias for the primary truck appears to be greater at the lower speeds. Distribution of errors is shown graphically in Figure 5-4.

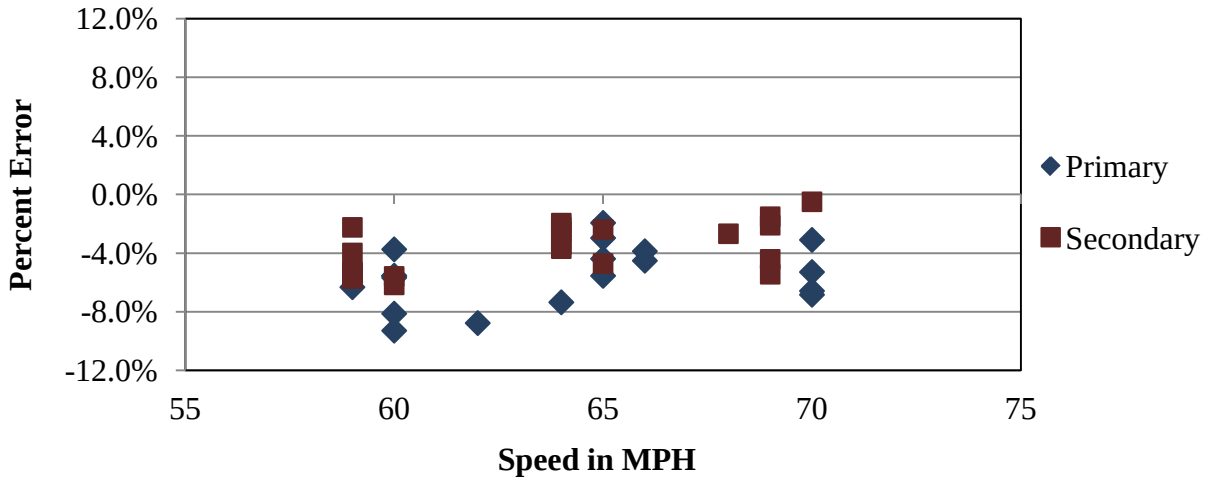


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 17-Apr-12

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from 0.0 feet to 0.2 feet. Distribution of errors is shown graphically in Figure 5-5.

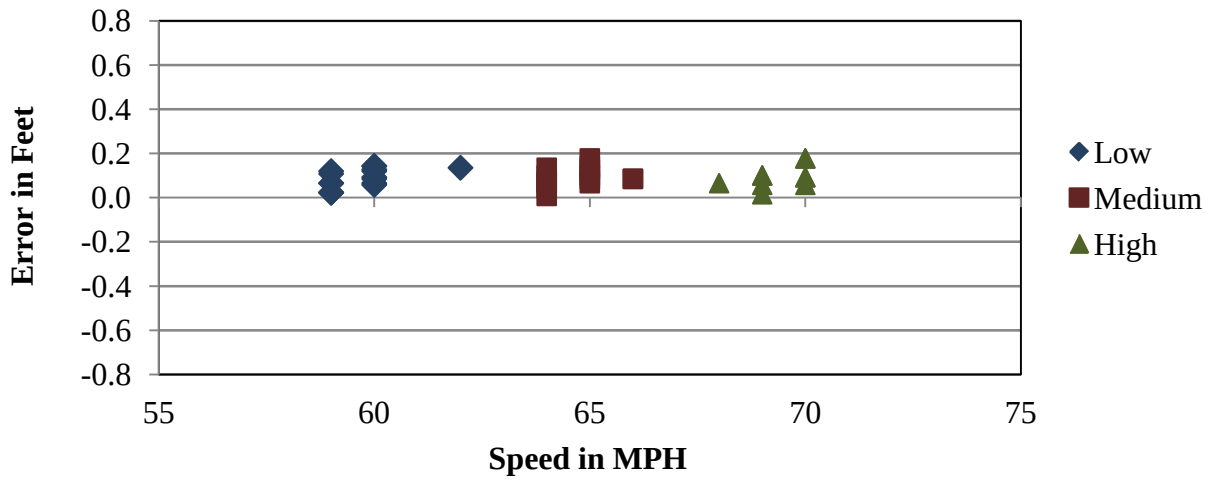


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 17-Apr-12

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment overestimated overall vehicle length consistently over the entire range of speeds, with an error range of 1.0 to 3.2 feet. Distribution of errors is shown graphically in Figure 5-6.

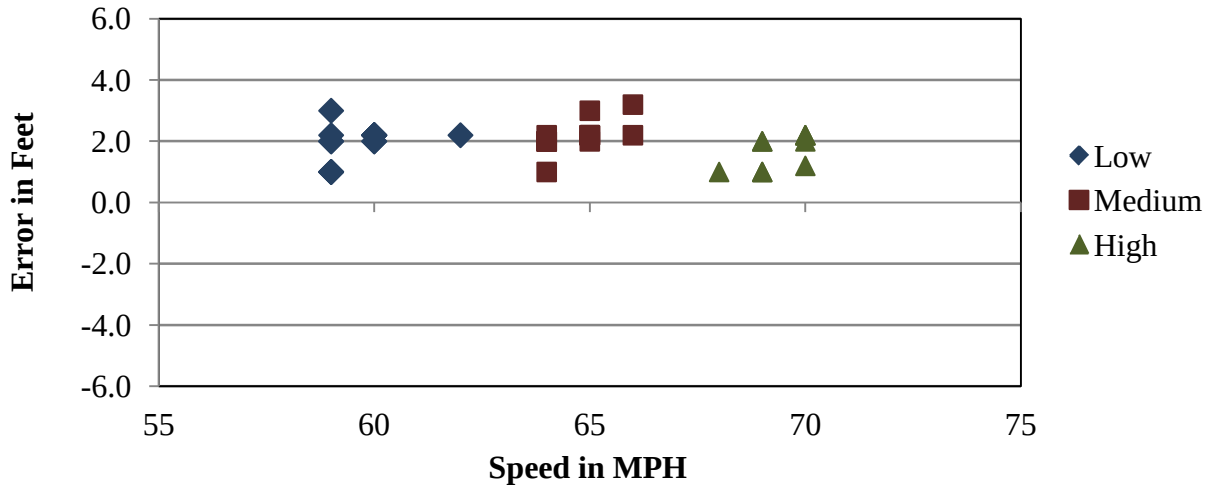


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 17-Apr-12

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 3.6 degrees, from 62.2 to 65.8 degrees Fahrenheit. Since the desired 30 degree temperature range was not met, the pre-validation test runs are being reported under one temperature group – medium as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 17-Apr-12

Parameter	95% Confidence Limit of Error	Medium
		62.2 to 65.8 degF
Steering Axles	±20 percent	-1.4 ± 6.1%
Tandem Axles	±15 percent	-5.3 ± 4.8%
GVW	±10 percent	-4.6 ± 4.1%
Vehicle Length	±3.0 percent (1.8 ft)	2.0 ± 1.1 ft
Vehicle Speed	± 1.0 mph	-0.3 ± 4.1 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft

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

5.1.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment generally underestimates GVW across the range of temperatures observed in the field.

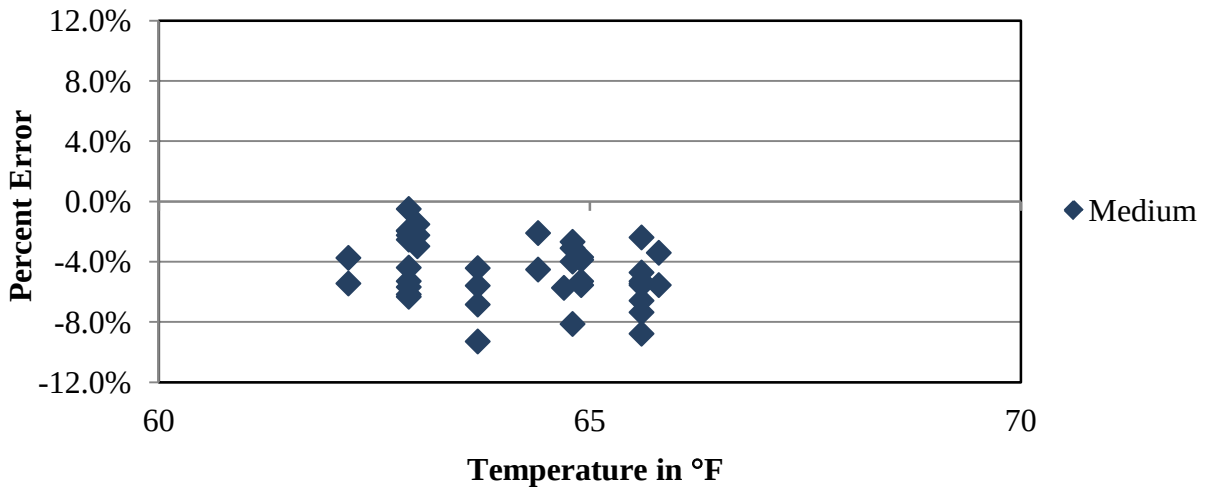


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 17-Apr-12

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 illustrates that for steering axles, the WIM equipment estimates weights with similar accuracy across the range of temperatures observed in the field. One outlier data point was observed at a lower temperature.

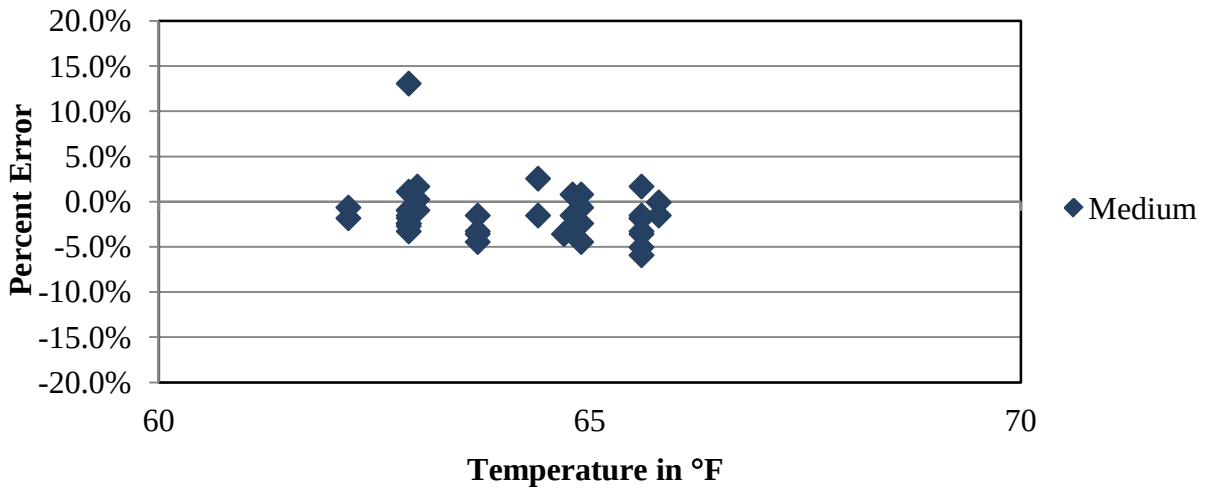


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 17-Apr-12

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment generally underestimates tandem axle weights across the range of temperatures observed in the field.

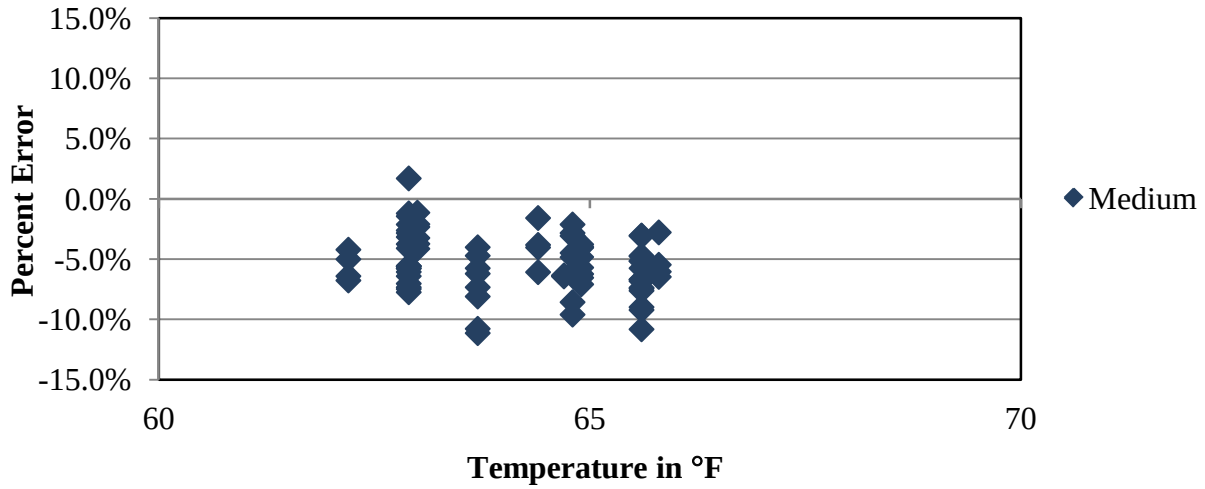


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 17-Apr-12

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, it can be seen that the WIM equipment bias is more negative for the heavily loaded (Primary) truck than the partially loaded (Secondary) truck. For both trucks, the range of errors is consistent over the range of temperatures. Primary truck shows slightly higher negative bias in GVW measurements comparing to the secondary truck. Distribution of errors is shown graphically in Figure 5-10.

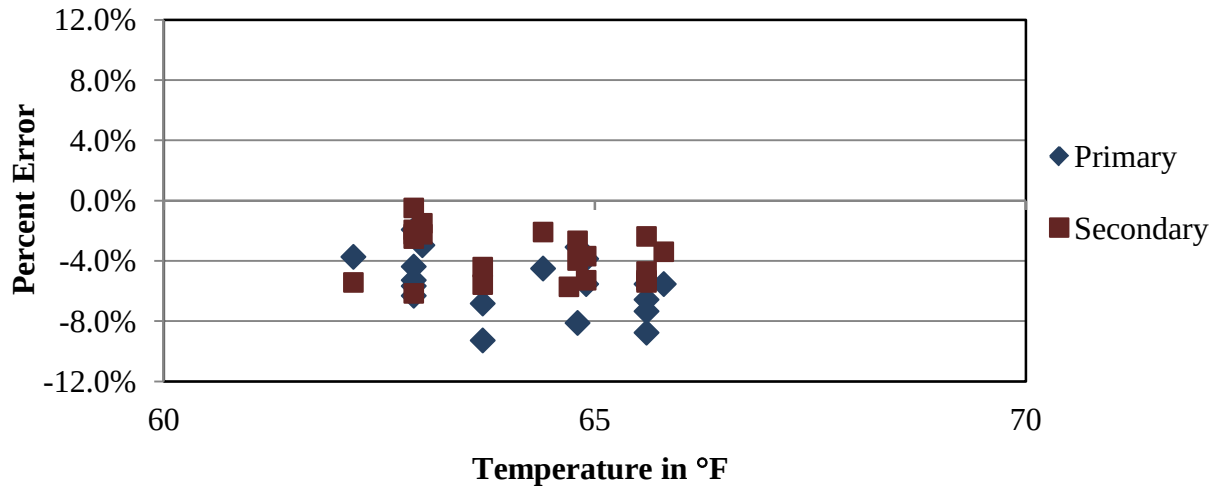


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 17-Apr-12

5.1.3 Classification and Speed Evaluation

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

For the pre-validation classification study at this site, a manual sample of 104 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one class of vehicle but identified by the WIM equipment as another class of vehicle. The misclassifications by pair are provided in Table 5-5. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-5, two Class 3 vehicles were misclassified as Class 5 vehicles, one Class 5 vehicle was misclassified as Class 3, one Class 5 was misclassified as a Class 4 vehicle, and five Class 5 vehicles were misclassified as Class 8 vehicles. One Class 10 vehicle was misclassified as a Class 13 vehicle by the equipment.

Table 5-5 – Pre-Validation Misclassifications by Pair – 17-Apr-12

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

As shown in the table, a total of 10 vehicles, including 1 heavy truck (vehicle classes 6 – 13) were misclassified by the equipment. Based on the vehicles observed during the pre-validation study, the misclassification percentage is 1.2% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 9.6%, primarily due to misclassifications of lightweight Class 3 and Class 5 vehicles. The causes for the misclassifications were not investigated in the field.

The combined results produced an undercount of one Class 3 vehicle, five Class 5 vehicles, and one Class 10 vehicle as well as an overcount of one Class 4 vehicle, five Class 8 vehicles, and one Class 13 vehicle, as shown in Table 5-6. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-6 – Pre-Validation Classification Study Results – 17-Apr-12

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	4	0	19	0	2	1	69	4	4	1	0
WIM Count	3	1	14	0	2	6	69	3	4	1	1
Observed Percent	3.8	0.0	18.3	0.0	1.9	1.0	66.3	3.8	3.8	1.0	0.0
WIM Percent	2.9	1.0	13.5	0.0	1.9	5.8	66.3	2.9	3.8	1.0	1.0
Misclassified Count	2	0	7	0	0	0	0	1	0	0	0
Misclassified Percent	50.0	0.0	36.8	0.0	0.0	0.0	0.0	25.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

For speed, the mean error for WIM equipment speed measurement was 0.1 mph; the range of errors was 1.6 mph.

5.2 Calibration

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

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

Table 5-7 – Initial System Parameters – 18-Apr-12

Speed Point	MPH	Left		Right	
		1	3	2	4
88	55	2986	2986	3170	3170
96	60	2962	2962	3144	3144
104	65	3036	3036	3222	3222
112	70	3034	3034	3221	3221
120	75	3034	3034	3221	3221
Axle Distance (cm)		305			
Dynamic Comp (%)		106			
Loop Width (cm)		246			

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 -6.25%, -4.13%, and -4.30% at the 60, 65 and 70 mph speed points respectively. To compensate for these errors, the changes in Table 5-9 were made to the compensation factors.

Table 5-8 – Calibration 1 Equipment Factor Changes – 18-Apr-12

Speed Points	Old Factors				Error	New Factors			
	Left		Right			Left		Right	
	1	3	2	4		1	3	2	4
88	2986	2986	3170	3170	-6.25%	3185	3185	3381	3381
96	2962	2962	3144	3144	-6.25%	3160	3160	3354	3354
104	3036	3036	3222	3222	-4.13%	3167	3167	3361	3361
112	3034	3034	3221	3221	-4.30%	3170	3170	3366	3366
120	3034	3034	3221	3221	-4.30%	3170	3170	3366	3366
Axle Distance (cm)	305				0.16%	305			
Dynamic Comp (%)	106				-1.43%	103			
Loop Width (cm)	246				2.0 ft	306			

The results of the 12 first calibration verification runs are provided in Table 5-10 and Figure 5-11. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the first calibration iteration.

Table 5-9 – Calibration 1 Results – 18-Apr-12

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.2 ± 4.2%	Pass
Tandem Axles	±15 percent	0.3 ± 5.4%	Pass
GVW	±10 percent	0.4 ± 3.4%	Pass
Vehicle Length	±3.0 percent (1.8 ft)	-0.3 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	Pass

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

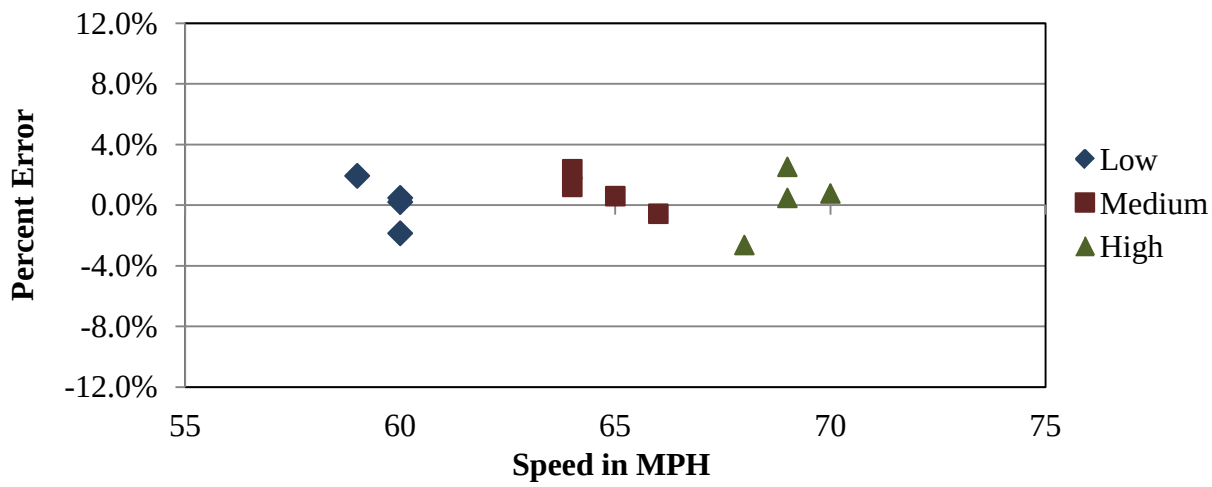


Figure 5-11 – Calibration 1 GVW Error by Speed – 18-Apr-12

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

5.3 Post-Validation

The 41 post-validation test truck runs were conducted on April 18, 2012, beginning at approximately 7:35 AM and continuing until 2:49 PM.

The two test trucks consisted of:

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

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

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

Table 5-10 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.3	11.2	16.4	16.4	16.6	16.6	19.5	4.3	28.1	4.1	56.0	60.8
2	68.6	11.3	15.6	15.6	13.0	13.0	19.8	4.3	28.5	4.3	56.9	61.0

Test truck speeds varied by 11 mph, from 59 to 70 mph. The measured post-validation pavement temperatures varied 54.1 degrees Fahrenheit, from 50.9 to 105.0. The sunny weather conditions provided the desired minimum 30 degree temperature range. Table 5-12 is a summary of post validation results.

Table 5-11 – Post-Validation Overall Results – 18-Apr-12

Parameter	**95% Confidence Limit of Error**	**Site Values**	**Pass/Fail**
Steering Axles	±20 percent	0.8 ± 3.8%	Pass
Tandem Axles	±15 percent	0.0 ± 4.9%	Pass
Axle Groups	±15 percent	0.0 ± 4.9%	Pass
GVW	±10 percent	0.1 ± 3.5%	Pass
Vehicle Length	±3.0 percent (1.8 ft)	0.0 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was 0.4 ± 3.3 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 0.1 feet, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within similar acceptable ranges.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 70 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-13.

Table 5-12 – Post-Validation Results by Speed – 18-Apr-12

Parameter	95% Confidence Limit of Error	Low	Medium	High
		59.0 to 62.7 mph	62.8 to 66.4 mph	66.5 to 70.0 mph
Steering Axles	±20 percent	0.9 ± 4.0%	0.8 ± 4.0%	0.7 ± 4.5%
Tandem Axles	±15 percent	0.0 ± 3.7%	-0.2 ± 6.4%	-0.2 ± 5.9%
GVW	±10 percent	0.1 ± 2.7%	0.1 ± 4.8%	0.0 ± 4.1%
Vehicle Length	±3.0 percent (1.8 ft)	0.2 ± 1.4 ft	-0.2 ± 1.1 ft	-0.2 ± 0.9 ft
Vehicle Speed	± 1.0 mph	-0.4 ± 4.6 mph	0.8 ± 1.9 mph	0.8 ± 2.8 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.1 ft	0.1 ± 0.1 ft

From the table, it can be seen that the WIM equipment estimates all weights with similar accuracy at all 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 5-12, the equipment estimated GVW with similar accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

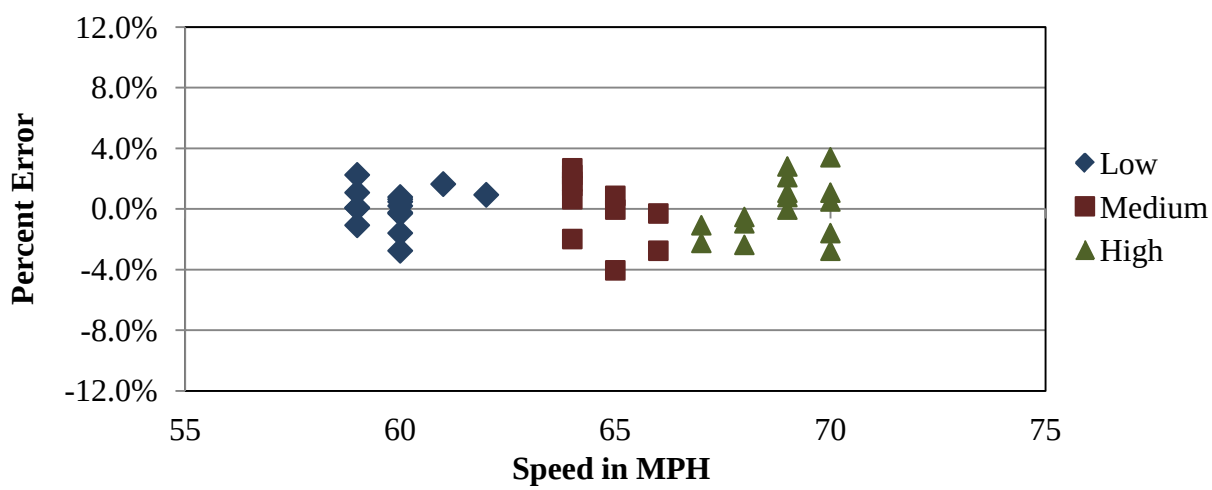


Figure 5-12 – Post-Validation GVW Errors by Speed – 18-Apr-12

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-13, the equipment estimated steering axle weights with similar accuracy at all speeds. The range in error is similar throughout the entire speed range. There does not appear to be a correlation between speed and weight estimates at this site.

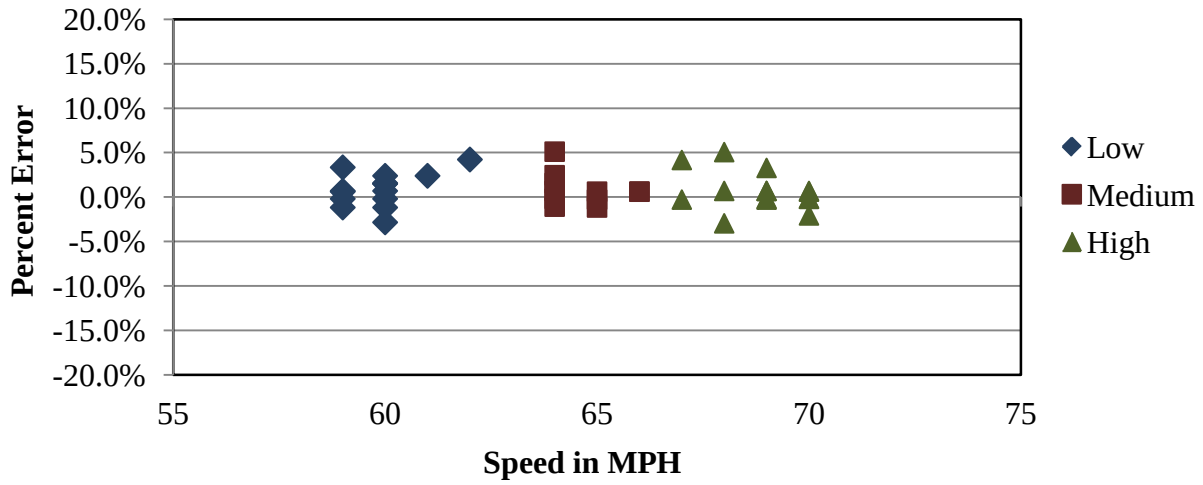


Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 18-Apr-12

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-14, the equipment estimated tandem axle weights with similar accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

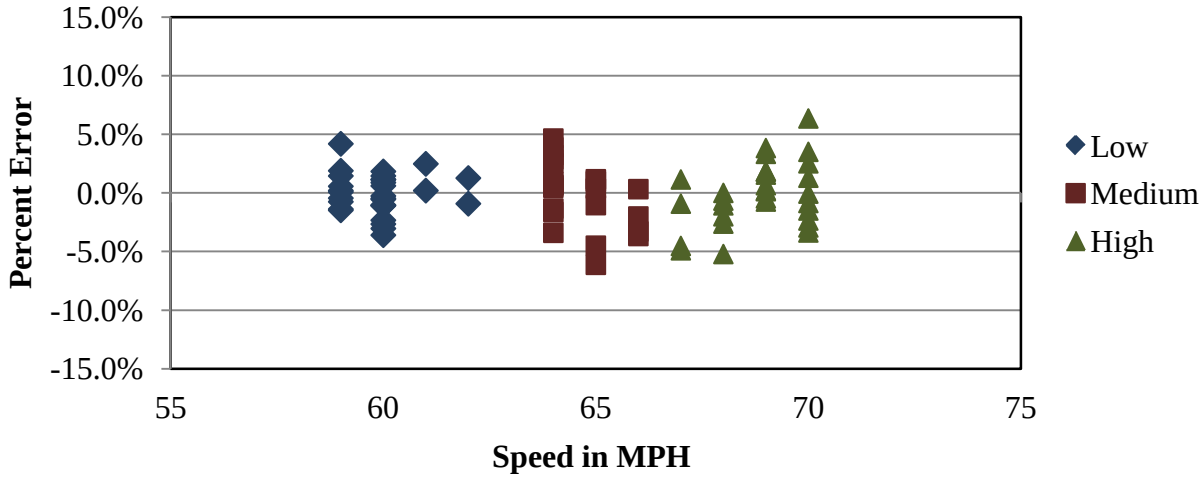


Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 18-Apr-12

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-15 that when the GVW errors are analyzed by truck type, the WIM equipment appears to accurately estimate GVW for the partially loaded (Secondary) truck and underestimate GVW for the heavily loaded (Primary) truck. Range in error appears to be similar for both trucks.

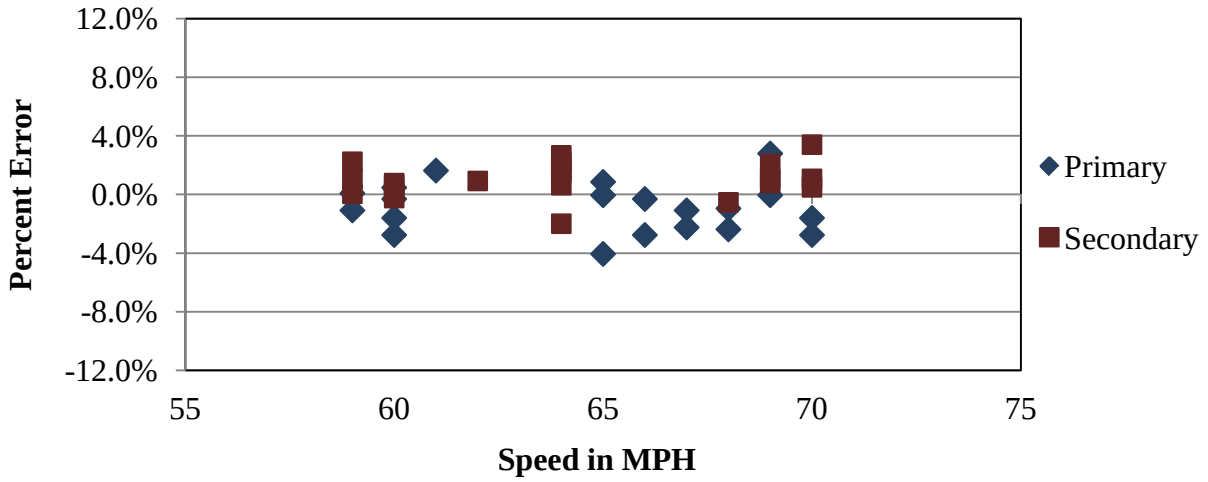


Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 18-Apr-12

5.3.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from 0.0 feet to 0.2 feet. Distribution of errors is shown graphically in Figure 5-16.

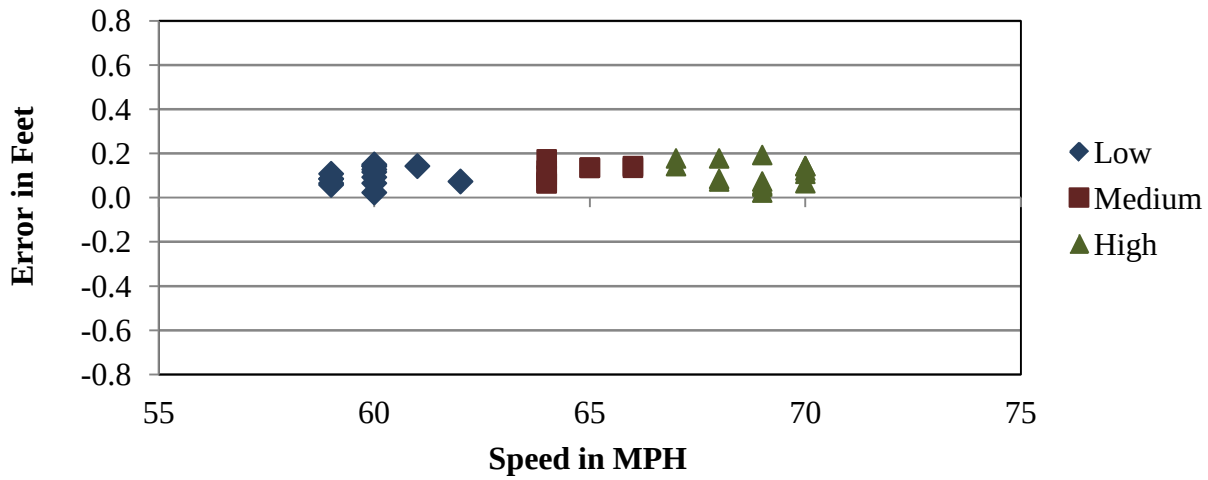


Figure 5-16 – Post-Validation Axle Length Error by Speed – 18-Apr-12

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length consistently over the entire range of speeds, with errors ranging from -1.0 to 1.2 feet. Distribution of errors is shown graphically in Figure 5-17.

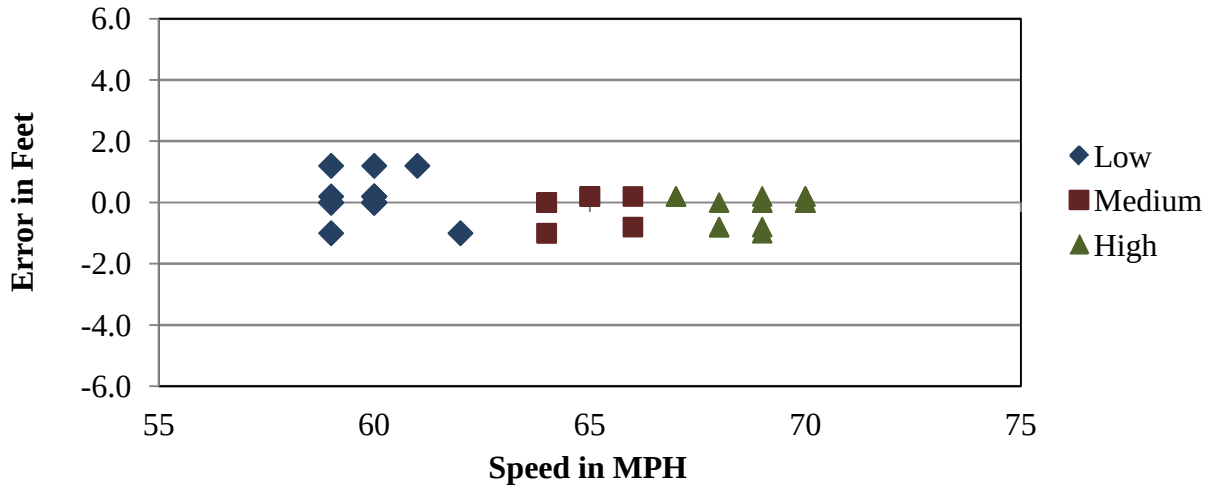


Figure 5-17 – Post-Validation Overall Length Error by Speed – 18-Apr-12

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 54.1 degrees, from 50.9 to 105.0 degrees Fahrenheit. The post-validation test runs are reported under three temperature groups – low, medium and high, as shown in Table 5-14 below.

Table 5-13 – Post-Validation Results by Temperature – 18-Apr-12

Parameter	95% Confidence Limit of Error	Low	Medium	High
		50.9 to 70 degF	70.1 to 90.0 degF	90.1 to 105.0 degF
Steering Axles	±20 percent	1.9 ± 4.2%	1.2 ± 3.0%	-0.3 ± 3.6%
Tandem Axles	±15 percent	0.5 ± 5.4%	-0.1 ± 6.2%	-0.6 ± 4.3%
GVW	±10 percent	0.7 ± 3.5%	0.2 ± 4.7%	-0.5 ± 3.0%
Vehicle Length	±3.0 percent (1.8 ft)	-0.3 ± 1.1 ft	0.2 ± 1.3 ft	0.0 ± 1.1 ft
Vehicle Speed	± 1.0 mph	0.3 ± 1.7 mph	0.9 ± 5.2 mph	0.0 ± 3.2 mph
Axle Length	± 0.5 ft [150mm]	0.1 ± 0.1 ft	0.1 ± 0.1 ft	0.1 ± 0.1 ft

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

5.3.2.1 GVW Errors by Temperature

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

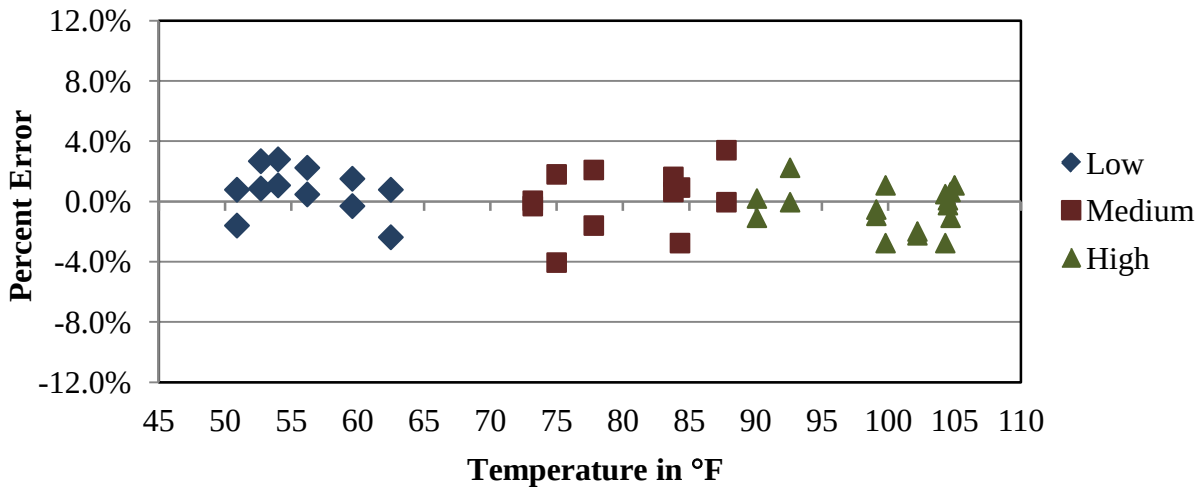


Figure 5-18 – Post-Validation GVW Errors by Temperature – 18-Apr-12

5.3.2.2 Steering Axle Weight Errors by Temperature

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

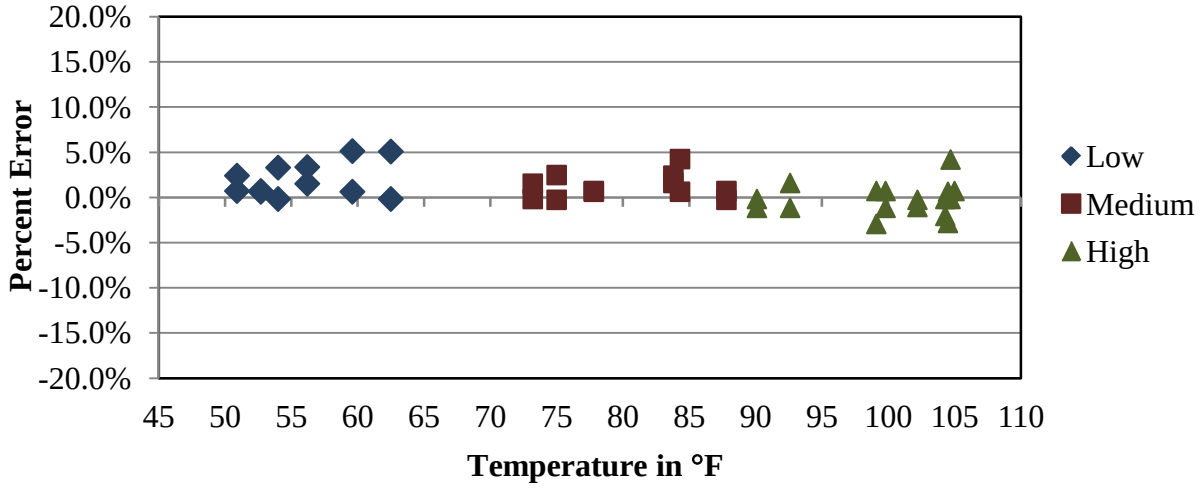


Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 18-Apr-12

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-20, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. There does not appear to

be a correlation between temperature and tandem axle weight estimates at this site. The range in tandem axle errors is consistent for the three temperature groups.

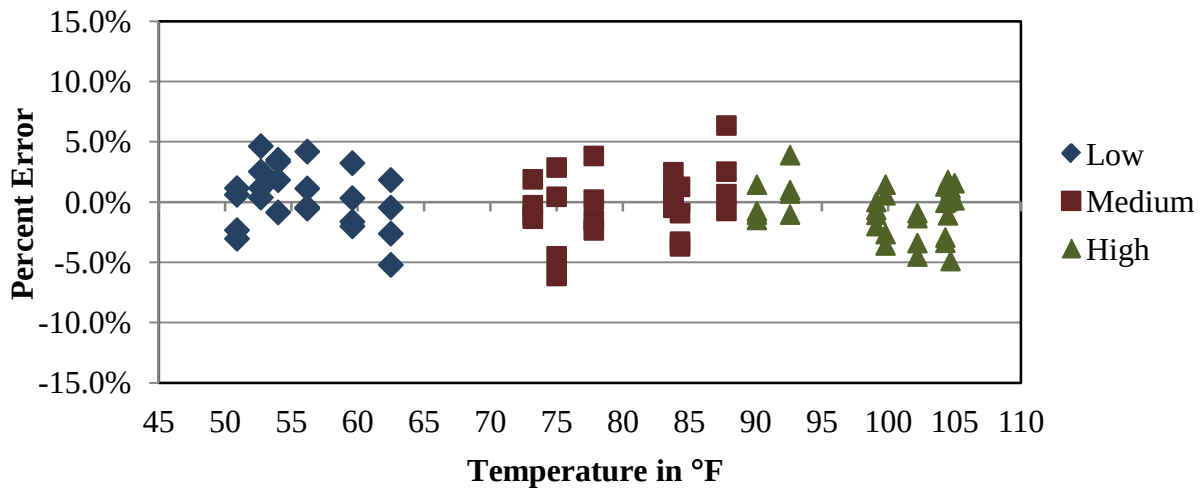


Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 18-Apr-12

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, when analyzed by truck type, GVW measurement errors for both trucks are similar at all temperatures. GVW measurements are slightly overestimated for the primary truck and slightly underestimated for the secondary truck. The range of errors is reasonably consistent over the range of temperatures.

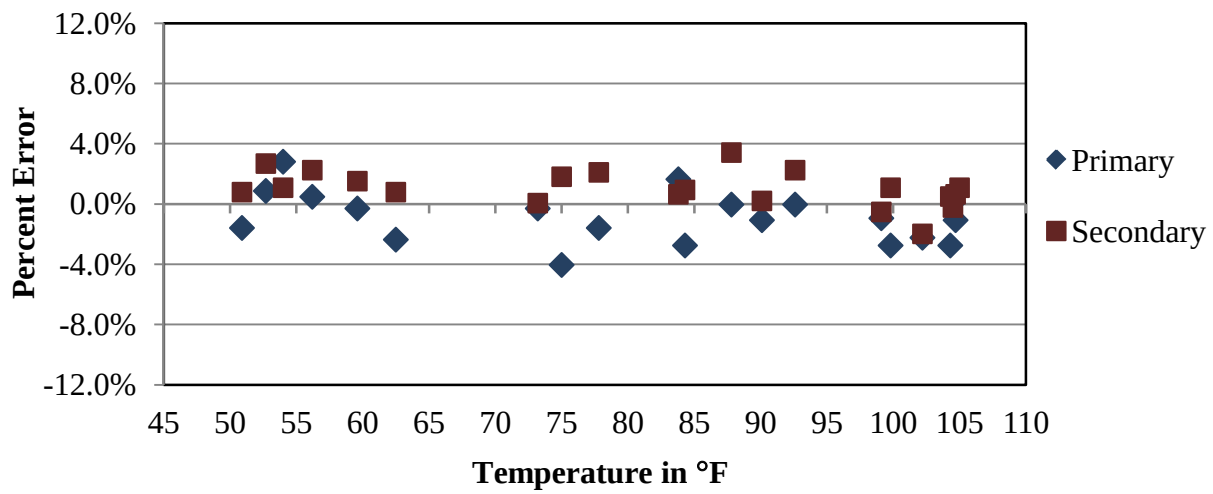


Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 18-Apr-12

5.3.3 Classification and Speed Evaluation

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

For the post-validation classification study at this site, a manual sample of 102 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one type of vehicle but identified by the WIM equipment as another type of vehicle. The misclassifications by pair are provided in Table 5-15. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-15, two Class 3 vehicles were misclassified as Class 5 vehicles, two Class 5 vehicles were misclassified as Class 4 vehicles, and one Class 5 vehicle was misclassified as a Class 8 vehicle by the equipment.

Table 5-14 – Post-Validation Misclassifications by Pair – 18-Apr-12

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

As shown in the table, a total of 5 vehicles, including 0 heavy trucks (6 – 13) were misclassified by the equipment. Based on the vehicles observed during the post-validation study, the misclassification percentage is 0.0% for heavy trucks (vehicle classes 6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 4.9 percent, primarily due to misclassification of lightweight Class 3, Class 4 and Class 5 vehicles. The causes for the misclassifications were not investigated in the field.

The combined results of the misclassifications resulted in an undercount of two Class 3 vehicles and one Class 5 vehicle, as well as an overcount of two Class 4 vehicles and one Class 8 vehicle,

as shown in Table 5-16. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample.

Table 5-15 – Post-Validation Classification Study Results – 18-Apr-12

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	2	1	8	6	1	0	72	5	6	1	0
WIM Count	0	3	7	6	1	1	72	5	6	1	0
Observed Percent	2.0	1.0	7.8	5.9	1.0	0.0	70.6	4.9	5.9	1.0	0.0
WIM Percent	0.0	2.9	6.9	5.9	1.0	1.0	70.6	4.9	5.9	1.0	0.0
Misclassified Count	2	0	3	0	0	0	0	0	0	0	0
Misclassified Percent	100.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

For speed, the mean error for WIM equipment speed measurement was 0.5 mph; the range of errors was 1.0 mph.

5.3.4 Final WIM System Compensation Factors

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

Table 5-16 – Final Factors

Speed Point	MPH	Left		Right	
		1	3	2	4
88	55	3185	3185	3381	3381
96	60	3160	3160	3354	3354
104	65	3167	3167	3361	3361
112	70	3170	3170	3366	3366
120	75	3170	3170	3366	3366
Axle Distance (cm)		305			
Dynamic Comp (%)		103			
Loop Width (cm)		306			

6 Post-Visit Data Analysis

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

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

6.1 Regression Analysis

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

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

6.1.1 Data

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

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

- Truck type. Primary truck and Secondary truck.
- Truck test speed. Truck test speed ranged from 59 to 70 mph.
- Pavement temperature. Pavement temperature ranged from 50.9 to 105.0 degrees Fahrenheit.

6.1.2 Results

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

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

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value (p-value)
Intercept	0.2989	3.8099	0.0784	0.9379
Speed	0.0162	0.0573	0.2833	0.7786
Temp	-0.0278	0.0119	-2.3493	0.0244
Truck	1.9410	0.4469	4.3438	0.0001

The lowest probability value given in Table 6-1 was 0.0001 for truck type. This means that there is about 0.1 percent chance that the value of regression coefficient for truck type (1.9410) can occur by chance alone. The regression coefficient for truck type in Table 6-1 represents the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1). As an example, the relationship between temperature and GVW measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 6-1 provides quantification and statistical assessment of the relationship.

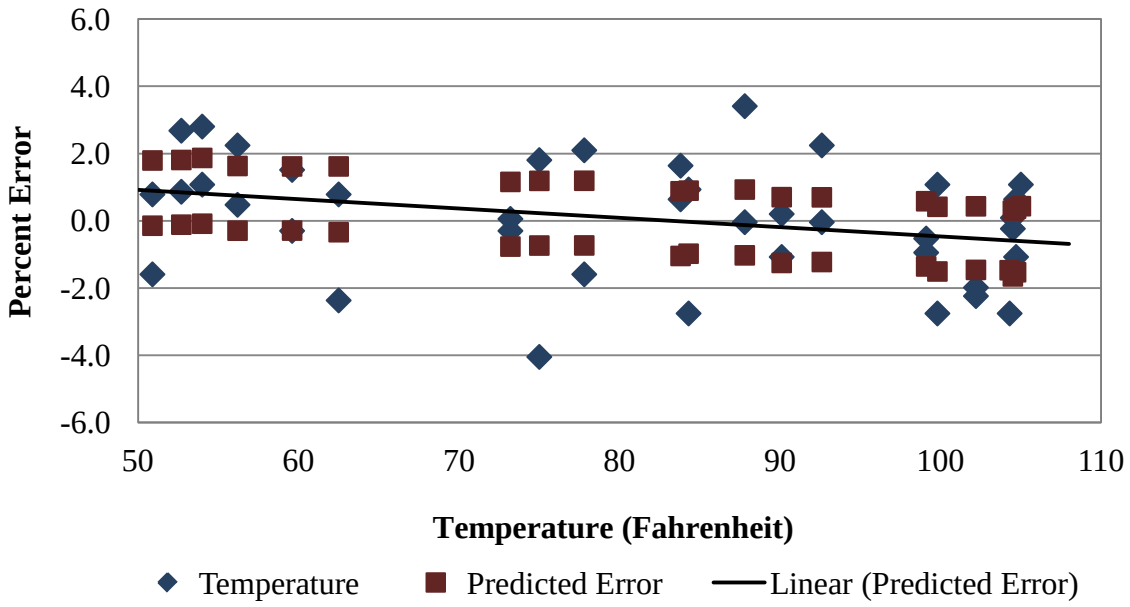


Figure 6-1 – Influence of Temperature on the Measurement Error of GVW

The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.0287 (in Table 6-1). This means, for example, that for a 10-degree increase in temperature, the error is decreased by about 0.3 percent (-0.0287 x 10). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0244) and is statistically significant at about 2 percent level. However, it should be noted that although the effect of temperature on the measurement errors is statistically significant it is very small and does not have practical influence on the verification and calibration process.

6.1.3 Summary Results

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

Table 6-2 – Summary of Regression Analysis

Parameter	Factor					
	Speed		Temperature		Truck type	
	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)
GVW	-	-	-0.0278	0.0244	1.9410	0.0001
Steering axle	-	-	-0.0433	0.0067	-	-
Tandem axle tractor	-	-	-0.0398	0.0229	2.5115	0.0003
Tandem axle trailer	-	-	-	-	-	-

6.1.4 Conclusions

1. According to Table 6-2, speed had no statistically significant effect on measurement errors.

2. Temperature affected measurement error of GVW, steering axles, and tandem axle on tractor. Even thought the effect was statistically significant, the values of the regression coefficients close to zero indicate that this relationship has no practical significance.

3. Truck type had statistically significant effect on GVW and tractor tandem axle errors. The regression coefficients for truck type in Table 6-2 represent the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). The effect of truck type is further analyzed in Section 6.1.5.

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

6.1.5 Contribution of Two Trucks to Calibration

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

be the calibration factors (calibration results) if only one truck (either Primary or Secondary) was used?

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

Figure 6-2 and associated statistical analysis show that speed had similar influences on the GVW measurement for each truck and that trends in GVW errors are similar for both trucks with primary truck showing slightly higher negative bias (about 2 percent increase in bias). Overall GVW error dependency on speed was very low for both trucks.

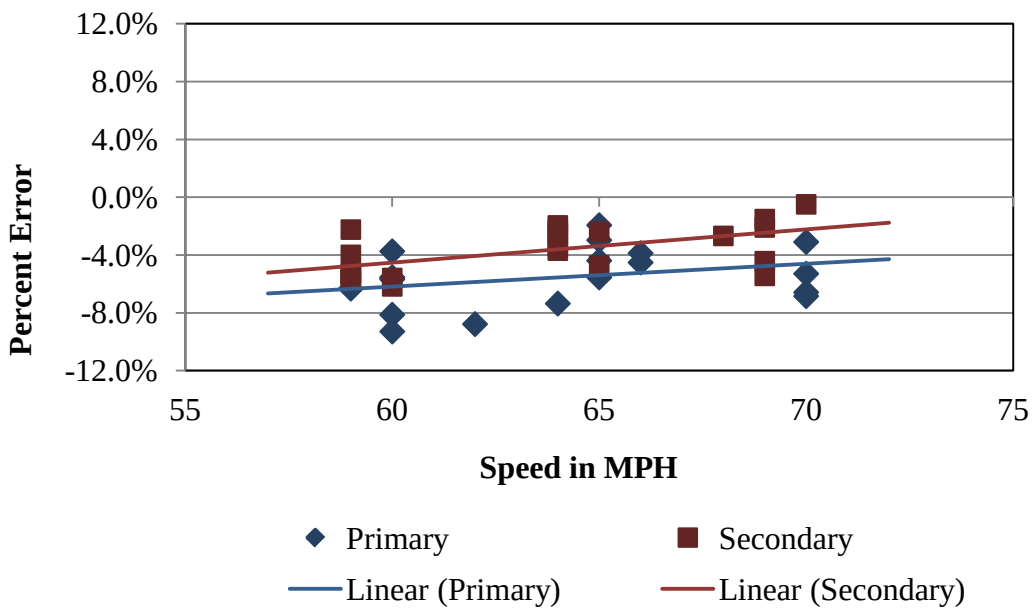


Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks

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

It should be noted that the analysis presented in this section are based on the pre-validation test truck data. It is probable that somewhat different results would be obtained using post-validation test truck data, or using both pre-and-post-validation data.

More detailed analysis of the influence of calibration trucks on the verification/calibration results would be beneficial. In this case, the Primary and the Secondary trucks had similar dimensions and suspension systems, and also similar influence on the verification/calibration results.

6.2 Misclassification Analysis

A post-visit analysis was conducted on the truck misclassifications identified during the post-validation conducted in the field that involved heavy truck classes (6-13). For this site, a total of 5 vehicles, including 0 heavy trucks (6 – 13) were misclassified by the equipment. However, one Class 5 was identified by the WIM system as a Class 8 vehicle. According to the Sheet 20, this vehicle was vehicle number 52005. The capture of the real-time record for vehicle 52005 is provided in Figure 6-6.

(52005) LANE #4 CLASS 8 GVW 36.4 kips LENGTH 59 ft
SPEED 64 mph MAX GVW 74.5 kips Wed Apr 18 2012 10:06:24 (1071)

AXLE	SEPARATION (ft)	LEFT WT (kips)	RIGHT WT (kips)	TOTAL WT (kips)	ALLOWABLE (kips)
1 S		6.2	6.2	12.4	20.0
2 S	21.0	10.5	9.0	19.5	20.0
3 S	19.9	1.2	1.3	2.5	20.0
4 S	8.9	1.0	1.0	2.0	20.0

Figure 6-3 – Vehicle Record 52005

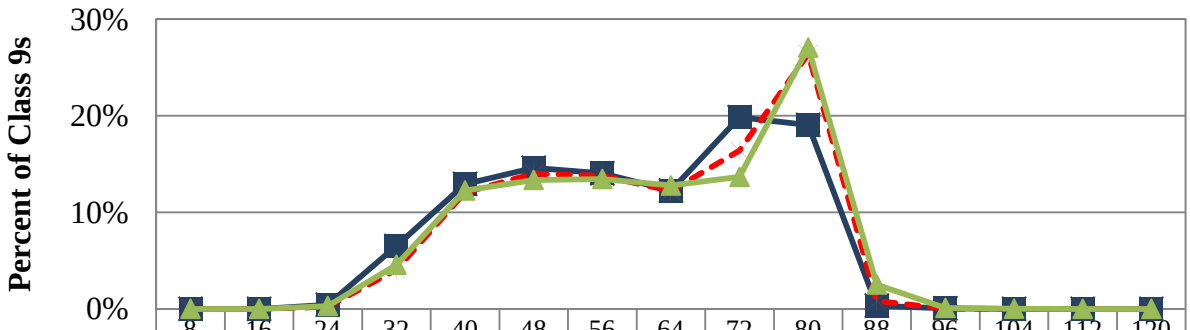
The video capture of vehicle 52005 is provided in Photo 6-1. As the photo illustrates, the misclassification involved an RV camper that was towing a car. Due to the axle spacing configuration, the WIM system identified the RV/car combination as a Class 8 vehicle. Setting minimum weight limit on trailer axles could prevent this misclassification in the future.

Photo 6-1 – Video Capture of Vehicle 52005

6.3 Traffic Data Analysis

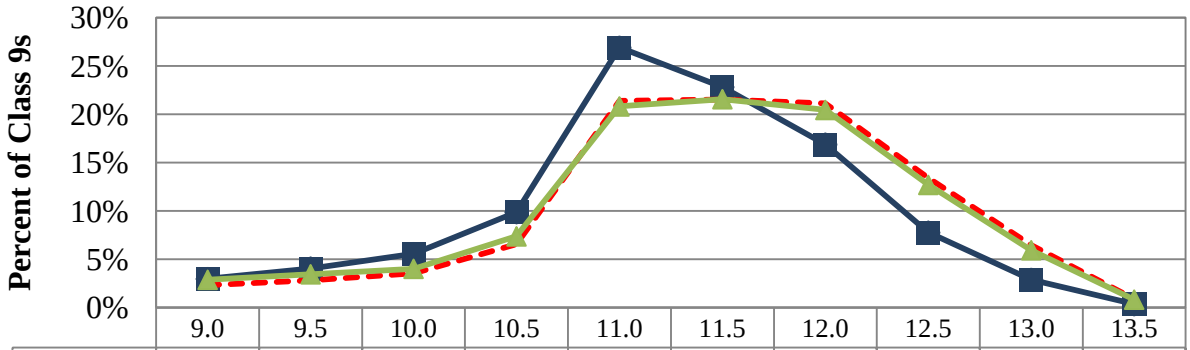
6.3.1 GVW and Steering Axle Weight Distributions

As a result of the Post-Visit Traffic Data Analysis, it appears that the loaded and unloaded peaks for GVW and the steering axle weight distribution from the Post-Visit Sample of April 29, 2012 and the Comparison Data Set of March 15, 2011 are similar, as illustrated in Figure 6-7 and Figure 6-8.



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.4%	6.5%	12.9%	14.6%	14.0%	12.2%	19.8%	19.0%	0.3%	0.1%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.2%	4.1%	12.1%	14.0%	13.8%	12.2%	16.4%	26.4%	0.8%	0.0%	0.0%	0.0%	0.0%
Post	0.0%	0.0%	0.3%	4.6%	12.3%	13.3%	13.4%	12.8%	13.7%	27.0%	2.5%	0.1%	0.0%	0.0%	0.0%

Figure 6-4 – Class 9 GVW Distribution



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Data	3.0%	4.0%	5.5%	9.9%	26.9%	22.8%	16.9%	7.8%	2.9%	0.3%
CDS	2.3%	2.8%	3.5%	6.5%	21.4%	21.5%	21.1%	13.4%	6.5%	0.9%
Post	2.9%	3.4%	4.0%	7.4%	20.8%	21.6%	20.5%	12.7%	5.9%	0.8%

Figure 6-5 – Class 9 Steering Axle Weight Distribution

6.3.2 Imbalance

A post-visit data analysis was conducted using an 11-day sample immediately following the date of the validation. The results of the post-visit imbalance analysis are presented in Table 6-4.

Table 6-3 – Front Axle Weight Imbalance

Data Set	Date	Mean Wheel Weight (kips)		Imbalance	PCT
		Left	Right		
Pre-Visit Sample	March 30, 2012	5.57	5.44	Left	2.3%
Post-Visit Sample	April 29, 2012	5.69	5.53	Left	2.8%
	Change	+2.2 %	+1.7%		+.5%

For the validation, the GVW compensation factors were increased by an average of approximately 5.0 percent, while the front axle dynamic Compensation factor was reduced by 3.0 percent. It is expected that the validation would have resulted in overall increase in steering axle weights of 2.0 percent. As shown in Table 6-4, the left and right wheel weights for the steering axles increased by a combined 2.0 percent as a result of the validation. The post-validation imbalance is similar to the pre-visit imbalance.

6.3.3 WIM System Factor Adjustments

Since the average GVW and steering axle weights provided during the Post-Visit data analysis are reasonably similar to those provided by the Comparison Data Set from March 2011, and the imbalance from the Pre-Visit Data Sample is similar to the Post-Visit Data Sample, as shown in Table 6-4, no further adjustments to the WIM system factors established during the validation performed on April 18, 2012 are recommended.

7 Previous WIM Site Validation Information

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

7.1 Classification

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

Table 7-1 – Classification Validation History

Date	Misclassification Percentage by Class											Pct Unclass
	3	4	5	6	7	8	9	10	11	12	13	
12-Jun-07	-	100	75	0	0	0	0	0	0	0	-	0
13-Jun-07	-	-	-	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
17-Apr-12	50	0	37	0	0	0	0	25	0	0	0	0
18-Apr-12	100	0	38	0	0	0	0	0	0	0	0	0

7.2 Weight

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

Table 7-2 – Weight Validation History

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
12-Jun-07	1.4 ± 2.9	0.3 ± 5.0	1.0 ± 5.9
13-Jun-07	1.1 ± 4.3	-1.5 ± 5.6	1.4 ± 7.4
30-Sep-08	-2.9 ± 3.1	-0.1 ± 5.1	-3.3 ± 4.7
1-Oct-08	1.0 ± 2.8	3.1 ± 5.6	0.6 ± 5.4
15-Feb-11	-4.6 ± 3.9	-4.4 ± 5.6	-4.3 ± 4.9
16-Feb-11	-1.3 ± 3.7	-2.9 ± 8.9	-1.1 ± 4.2
17-Apr-12	-4.6 ± 4.1	-1.4 ± 6.1	-2.7 ± 4.8
18-Apr-12	0.1 ± 3.5	0.8 ± 3.8	0.0 ± 4.9

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. It appears that the system demonstrates a tendency for the equipment to move toward an underestimation of weights over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

8 Additional Information

The following information is provided in the attached appendix:

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

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

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

WIM System Field Calibration and Validation - Photos

Tennessee, SPS-6
SHRP ID: 470600

Validation Date: April 17, 2012

APPLIED RESEARCH ASSOCIATES, INC.

Photo 1 – Cabinet Exterior

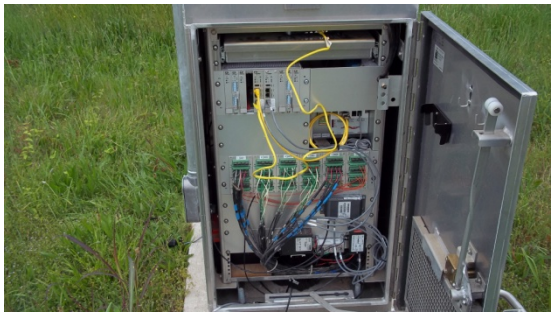


Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior (Back)

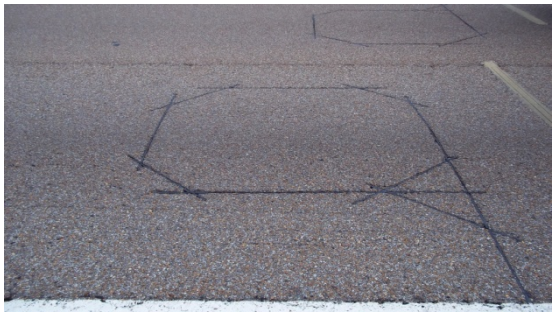


Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Power Service Box

Photo 9 – Telephone Service Box

Photo 10 – Downstream

Photo 11 – Upstream

Photo 12 – Truck 1

Photo 13 – Truck 1 Tractor

Photo 14 – Truck 1 Trailer and Load

Photo 15 – Truck 1 Suspension 1

Photo 16 – Truck 1 Suspension 2

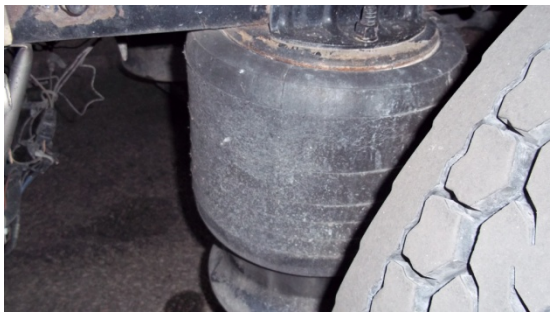


Photo 17 – Truck 1 Suspension 3

Photo 18 – Truck 1 Suspension 4

Photo 19 – Truck 1 Suspension 5

Photo 20 – Truck 2

Photo 21 – Truck 2 Tractor

Photo 22 – Truck 2 Trailer and Load

Photo 23 – Truck 2 Suspension 1

Photo 24 – Truck 2 Suspension 2

Photo 25 – Truck 2 Suspension 3

Photo 26 – Truck 2 Suspension 5

Photo 27 – Truck 2 Suspension 4

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 47 SPS WIM ID: 470600 DATE (mm/dd/yyyy) 4/17/2012

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 4/17/12

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

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

a. Inductance Loops c. _____

b. Quartz Piezo d. _____

5. EQUIPMENT MANUFACTURER: IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks

Number of Trucks Compared: _____

Number of Test Trucks Used: 2

Passes Per Truck: 20

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

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

Mean Difference Between -

Dynamic and Static GVW:	-4.6%	Standard Deviation:	2.0%
Dynamic and Static Single Axle:	-1.4%	Standard Deviation:	3.0%
Dynamic and Static Double Axles:	-2.7%	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	-	59.0	to	62.7	16
b.	Medium	-	62.8	to	66.4	14
c.	High	-	66.5	to	70.0	10
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 4/17/2012

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3034 | 3221

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

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

CLASSIFIER TEST SPECIFICS

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

Manual

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

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	0.0	FHWA Class	5	-	-26.0
FHWA Class 8:	500.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean J. Wolf**
Contact Information: Phone: 717-975-3550
E-mail: dwolf@ara.com

Traffic Sheet 16 LTPP MONITORED TRAFFIC DATA SITE CALIBRATION SUMMARY	STATE CODE: 47 SPS WIM ID: 470600 DATE (mm/dd/yyyy) 4/18/2012

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 4/18/12

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

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

a. Inductance Loops c.
b. Quartz Piezo 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	steel spring	air
Truck 2:	9	steel spring	standard
Truck 3:			

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

Mean Difference Between -

Dynamic and Static GVW:	0.1%	Standard Deviation:	1.7%
Dynamic and Static Single Axle:	0.8%	Standard Deviation:	1.9%
Dynamic and Static Double Axles:	0.0%	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	-	59.0	to	62.7	15
b.	Medium	-	62.8	to	66.4	11
c.	High	-	66.5	to	70.0	15
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 4/18/2012

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3170 | 3366

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:	Unk	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean J. Wolf**
Contact Information: Phone: 717-975-3550
E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 47 SPS WIM ID: 470600 DATE (mm/dd/yyyy) 4/17/2012

Count - 104 Time = 4:40:14 Trucks (4-15) - 100 Class 3s - 4

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
67	9	20790	66	9	65	9	21280	65	9
67	9	20803	66	9	65	9	21290	65	9
68	9	20825	69	9	70	10	21301	70	10
65	9	20834	65	9	**65**	**4**	**21328**	**66**	**5**
59	9	20863	59	9	62	11	21344	64	11
60	5	20889	60	5	70	9	21352	69	9
55	**8**	**20897**	**55**	**5**	67	9	21360	67	9
59	9	20923	65	9	62	9	21375	61	9
68	9	20934	67	9	64	9	21404	65	9
64	9	20961	64	9	68	9	21415	69	9
70	9	20975	70	9	62	9	21424	62	9
62	5	20983	60	5	64	7	21436	63	7
62	**8**	**20986**	**62**	**5**	64	9	21447	63	9
68	9	21026	67	9	62	9	21503	61	9
61	9	21040	62	9	64	9	21538	63	9
60	5	21061	61	5	67	9	21543	66	9
59	9	21087	59	9	60	3	21568	59	3
57	**5**	**21094**	**58**	**3**	**62**	**8**	**21573**	**66**	**5**
57	**5**	**21104**	**57**	**3**	65	9	21594	65	9
62	9	21115	61	9	63	9	21602	63	9
64	9	21237	64	9	66	9	21651	64	9
67	9	21295	65	9	65	8	21653	65	8
64	5	21258	65	5	65	9	21686	65	9
71	9	21270	70	9	66	9	21828	66	9
67	5	21272	67	5	70	9	21833	68	9

Sheet 1 - 0 to 50 Start: 11:37:18 Stop: 12:05:47

Recorded By: djw Verified By: 0

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) 4/17/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	9	22468	62	9	65	9	24353	63	9
62	9	22480	63	9	54	5	24362	54	5
70	9	22516	70	9	52	5	24363	54	5
73	9	22526	73	9	65	12	24378	64	12
70	9	22539	69	9	62	9	24392	63	9
75	**3**	**22550**	**75**	**5**	67	9	24398	65	9
63	**8**	**22622**	**63**	**5**	63	5	24415	69	5
65	9	22637	65	9	65	9	24447	64	9
62	9	22643	62	9	64	9	24452	66	9
58	9	22650	56	9	68	10	24457	68	10
65	5	22660	64	5	68	9	24498	66	9
64	**8**	**22667**	**64**	**5**	62	9	24510	61	9
67	9	22684	67	9	65	9	24534	64	9
65	9	22692	67	9	52	9	24662	53	9
66	5	22706	64	5	68	7	24672	69	7
63	9	22725	64	9	61	9	24693	61	9
65	5	22734	63	5	62	11	24699	61	11
66	9	22760	62	9	72	9	24727	71	9
62	3	22765	61	3	64	9	24741	65	9
70	9	22769	68	9	70	9	24755	68	9
63	10	22795	63	10	68	9	24760	68	9
65	11	22808	71	11	61	9	24778	61	9
65	11	22812	64	11	66	5	24809	66	5
67	9	24334	65	9	62	9	24821	61	9
68	9	24341	68	9	**65**	**13**	**24831**	**65**	**10**

Sheet 2 - 51 to 100 Start: 12:24:46 Stop: _____

Recorded By: djw Verified By: 0

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) 4/17/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
64	9	31178	65	9					
65	9	31184	64	9					
59	9	31195	59	9					
65	9	31204	65	9					

Sheet 3 - 101 - 150 Start: 16:16:58 Stop: 16:17:32

Recorded By: djw Verified By: 0

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) 4/18/2012

Count - 102 Time = 1:16:06 Trucks (4-15) - 100 Class 3s - 2

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	10	51533	64	10	70	9	51982	69	9
66	11	51542	65	11	65	9	51993	65	9
73	**4**	**51560**	**70**	**5**	68	5	51997	65	5
71	5	51567	69	5	**64**	**8**	**52005**	**63**	**5**
62	9	51575	59	9	64	9	52474	60	9
65	9	51579	66	9	65	9	52484	65	9
65	9	51598	63	9	70	9	52517	69	9
65	9	51606	66	9	62	6	52522	61	6
64	9	51687	62	9	69	9	52541	68	9
68	10	51745	68	10	64	9	52544	63	9
64	9	51751	65	9	56	9	52547	56	9
63	9	51776	64	9	71	9	52554	69	9
64	9	51817	63	9	65	9	52564	65	9
62	9	51831	60	9	65	9	52572	66	9
62	9	51834	62	9	64	9	52584	65	9
72	5	51845	71	5	62	11	52586	62	11
67	9	51850	65	9	67	9	52604	67	9
65	9	51855	65	9	59	9	52605	59	9
61	6	51861	63	6	65	9	52608	65	9
62	9	51870	61	9	70	9	52614	71	9
70	9	51894	70	9	68	9	52616	66	9
65	11	51902	64	11	60	9	52622	61	9
62	**5**	**51909**	**62**	**3**	72	9	52630	71	9
72	9	51954	71	9	69	9	52746	69	9
64	9	51964	63	9	67	10	52749	66	10

Sheet 1 - 0 to 50 Start: 9:52:29 Stop: 10:28:44

Recorded By: djw 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) 4/18/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
62	9	52767	62	9	73	4	53653	71	4
70	9	52780	69	9	68	5	53668	68	5
69	9	52801	68	9	65	11	53676	65	11
67	9	52815	68	9	65	10	53825	64	10
67	**4**	**52816**	**68**	**5**	62	9	53834	62	9
69	11	52834	69	11	65	9	53852	65	9
65	9	52841	64	9	61	9	53587	61	9
70	9	52850	70	9	77	7	53867	76	7
62	9	52856	61	9	62	9	53888	61	9
68	9	52872	68	9	66	9	53918	66	9
68	9	52890	67	9	67	9	53928	67	9
73	9	52898	72	9	72	9	53949	72	9
68	5	52907	67	5	66	9	53951	66	9
68	9	52944	68	9	65	9	53969	66	9
63	9	52949	63	9	65	9	53975	65	9
68	9	52971	68	9	65	10	53984	65	10
64	9	52993	65	9	65	9	54002	65	9
63	9	53033	63	9	59	9	54019	58	9
65	11	53109	64	11	70	9	54035	69	9
72	**5**	**53119**	**71**	**3**	68	12	54038	68	12
60	9	53467	59	9	64	6	54051	64	6
64	9	53469	62	9	64	6	54053	63	6
67	9	53479	65	9	72	9	54066	71	9
66	9	53485	66	9	68	6	54068	69	6
70	9	53503	69	9	73	6	54085	73	6

Sheet 2 - 51 to 100 Start: 10:29:12 Stop: 11:07:18

Recorded By: djw 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) 4/18/2012

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
71	9	54121	70	9					
68	9	54153	67	9					

Sheet 3 - 101 - 150 Start: 11:07:55 Stop: 11:08:35

Recorded By: djw Verified By: kt

Validation Test Truck Run Set - Post