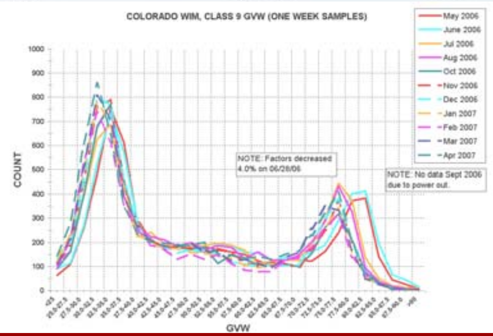
WIM Data Analyst's Manual

Publication No. FHWA-IF-10-018



U.S. Department of Transportation
Federal Highway Administration

FOREWORD

This manual provides information and recommended procedures to be utilized by an agency's Weigh-in-Motion (WIM) Office Data Analyst to perform validation and quality control (QC) checks of WIM traffic data. This manual focuses on data generated by WIM systems that have the capability to produce high quality data. Many of the recommended data QC procedures are dependent upon data containing wheel loads (in conformance with the Type I WIM system requirements of ASTM E 1318). However, the more basic QC procedures discussed may be of use to an analyst performing checks on data generated by systems generating only axle load data (conforming to Type II system requirements of ASTM E 1318) and/or systems relying upon autocalibration features deemed necessary to obtain loading data adequate for certain programs.

This document is intended to present the WIM data analysts with the necessary information and guidance to identify missing or invalid WIM data, to determine the cause and extent of missing or invalid data, and the course of action to correct problems. Basic information and recommendations are provided for the novice analyst, and more extensive procedures and guidelines are provided to develop and assist experienced analysts.

To follow the procedures recommended in this manual will take a great deal of time and effort by the data analyst. However, the proper installation and maintenance of high quality WIM systems is a costly investment. Such investment provides an agency only with the capability to obtain high quality traffic data. Such high quality data will not be achievable in the absence of following diligent data QC and system monitoring procedures.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-IF-10-018	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle WIM Data Analyst's Manual		5. Report Date June 2010
		6. Performing Organization Code:
7. Author(s) Rich Quinley		8. Performing Organization Report No.
9. Performing Organization Name and Address The Transtec Group 6111 Balcones Drive Austin, TX 78731		10. Work Unit No.
		11. Contract or Grant No. DTFH61-08-D-00026
12. Sponsoring Agency Name and Address FHWA Office of Pavement Technology 1200 New Jersey Ave. SE Washington, DC 20590		13. Type of Report and Period Covered Technical Manual
		14. Sponsoring Agency Code HIPT-30
15. Supplementary Notes FHWA Contracting Officer's Technical Representative (COTR): Mike Moravec		

16. Abstract

This manual provides information and recommended procedures to be utilized by an agency's Weigh-in-Motion (WIM) Office Data Analyst to perform validation and quality control (QC) checks of WIM traffic data. This manual focuses on data generated by WIM systems that have the capability to produce high quality data. Many of the recommended data QC procedures are dependent upon data containing wheel loads (in conformance with the Type I WIM system requirements of ASTM E 1318). This manual has been developed to ensure that high quality WIM data is collected and used to produce reliable and representative load spectra for input into the Mechanistic-Empirical Pavement Design Guide (M-E PDG) software resulting in reliable and predictable pavement designs. While this is the primary use, there are many other uses including performing checks on data generated by systems that produce only axle load data.

17. Key Words	18. Distribution Statement
WIM Data Analysis, WIM Data Validation, WIM Data Quality Control, Traffic Inputs for Pavement Design, M-E PDG, and Load spectra	No restrictions. This document is available to the public through the Federal Highway Administration (FHWA)

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	183	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1. INTRODUCTION

Weigh-in-Motion (WIM) systems meeting the Type I requirements of ASTM E 1318 have the capability of producing continuous high quality traffic data for multilane roadway locations. These WIM systems produce various data elements for each vehicle passing through the site, including:

- Time and Date
- Lane
- Speed
- Vehicle Classification
- Wheel Load
- Axle Load
- Axle Group Load
- Gross Vehicle Weight
- Individual Axle Spacings
- Overall Vehicle Length
- Violation Code

It is noted that some of the listed data elements may not actually be stored by the system as raw data onsite, but is instead generated during the data processing session following transfer of the raw data to the Office Computer (discussed below). The stored data element “Lane” is typically the “WIM” lane number as determined by a particular system’s sensor configuration and sensor inputs to the controller unit. However, for reporting purposes, the vendor’s or agency’s application software is programmed to display the data for a lane or lanes based upon the agency’s lane designation (e.g. “Northbound No. 1”).

1.1. OVERVIEW OF WIM DATA

A WIM system’s controller typically stores both summary (binned) data and vehicle record data for each day.

- Binned data
    - All of a day’s vehicles are typically binned by count for hour of day, lane, classification, and speed range (see previous explanation of “lane” as stored by the controller).
    - Contain no individual vehicle data elements.

- Individual vehicle record data
    - Include data elements for individual vehicles.
    - Typically the system allows the user to define parameters, such as classification or front axle weight threshold, which determine whether a record is stored for a particular vehicle or whether the vehicle is simply counted in bins.
    - These individual vehicle records are sometimes referred to as “Per Vehicle Records” (PVRs) or “Truck Records”.

It is the function of the WIM system's onsite controller to process inputs from the in-road sensors and to create and temporarily store the binned data and the individual records, typically in binary format. This raw data is routinely downloaded or otherwise transferred to the analyst's Office Computer (sometimes referred to as Host Computer). An application software program provided by the WIM system vendor is then utilized to process the raw data, including the generation of reports and ASCII files and the view of individual vehicle records. Some agencies utilize their own custom application software to process the raw data. Also, some agencies utilize their own or third party software to automate the raw data downloads and/or perform data validation checks.

1.2. SIGNIFICANCE OF HIGH QUALITY WIM DATA

Truck wheel loading data is of particular interest to determine inputs to the *Mechanistic-Empirical Pavement Design Guide* (M-E PDG) software. However, for loading data to be considered of high quality, such data must meet the ASTM E 1318 Type I requirements for accuracy displayed in Figure 1.

Data Item	Tolerance for 95% Compliance
Wheel load	± 25%
Axle load	± 20%
Axle-group load	± 15%
Gross vehicle weight	± 10%

Figure 1. List. ASTM E 1318 Type I WIM Systems Requirements.

Note that high quality WIM equipment properly installed in structurally sound and smooth pavement, at a site with proper roadway geometry and traffic operating characteristics, has the capability to produce loading data with much higher accuracy than those required by ASTM E 1318. However, to produce high quality data, the WIM system must be properly monitored and maintained.

1.3. OVERVIEW OF THE MANUAL

This Manual describes recommended procedures to be followed by an agency's WIM Office Data Analyst in performing data quality checks of WIM traffic data. This section (Section 1) provides an overview of a WIM system's function and its data output, describes the quality of WIM data that are addressed in this manual, and provides an overview of the manual itself.

SECTION 2 provides information on "WIM Basics" which may be helpful to the novice analyst.

SECTION 3 provides guidance and recommendations on performing data validation and performing system monitoring remotely from the office, including remote real time checks of traffic, reviewing reports generated by the office computer's WIM application software, and follow-up procedures to be performed when questionable data is identified.

SECTION 4 discusses procedures for performing extensive analyses of individual vehicle records by importing the WIM data into spreadsheet or database programs.

SECTION 5 discusses procedures for monitoring a system's calibration over time and procedures that may be taken to fine-tune a system's calibration factors in order to provide the most accurate size and weight data possible.

SECTION 2. WIM BASICS

2.1. WIM SYSTEM VS. WIM SITE

A WIM system, as used in this manual, refers to the following components:

- One controller, its computer, and associated electronics.
  - CPU
  - Sensor Interface Cards
  - Communication Interface
  - Data Storage Medium
  - Software and/or Firmware

- All roadway sensors and their leads for all lanes for which traffic data is being processed by the controller (at least one lane must have weigh sensors).

- Controller support items such as lightning protection, uninterruptable power supply, etc.

A WIM site, as used in this manual, refers to a specific roadway location at which a WIM system has been (or will be) installed. Such a site includes:

- All WIM system components.

- The power and communication service facilities.

- All wiring, conduits, pull boxes, and cabinets necessary to make the WIM system functional.

- The pavement section in which the roadway components are installed and the pavement approach and departure from the in-road sensors.

Figure 2 through Figure 6 display WIM system components and Figure 7 displays a two-lane WIM site.

Figure 2. Photo. Staggered weigh sensors (bending plates) and detection loops (single threshold system).

Figure 3. Photo. In-line weigh sensors (single load cells), a trailing axle sensor, and detection loops (single threshold system).

Figure 4. Photo. In-line weigh sensors (quartz piezos) and detection loops (double threshold system).

For single threshold weighing, each axle's right and left wheel or dual wheel is weighed once by the right and left sensors. For staggered (leading and trailing) sensors, a vehicle's speed is calculated based upon the time it takes for each axle's wheels to hit the leading and trailing sensors. For in-line (side-by-side) weigh sensors, speed can be calculated by one of two methods:

1. An axle sensor (non-weighing) may be installed downstream of the weigh sensors and speed is calculated based upon the time it takes for each axle's wheels to hit the weigh sensors and trailing axle sensor.

2. If no axle sensor is installed, the speed is calculated based upon the time between a vehicle's triggering the leading and trailing loops. This is not as accurate as using sensor-to-sensor time measurements.

For double threshold weighing, each axle's right and left wheel or dual wheel is weighed twice by the right and left sensors. The system then reports a single left weight and a single right weight for each axle. A vehicle's speed is calculated based upon the time it takes for each axle's wheels to hit the leading and trailing weigh sensors.

Throughout this manual, a WIM system's right and left weigh sensors are discussed in regard to weight data output analyses, diagnostics, calibration, etc. Such right and left sensors will be treated as single sensors even though for double threshold systems there are actually two right sensors and two left sensors.

Figure 5. Photo. Controller cabinet, front view.

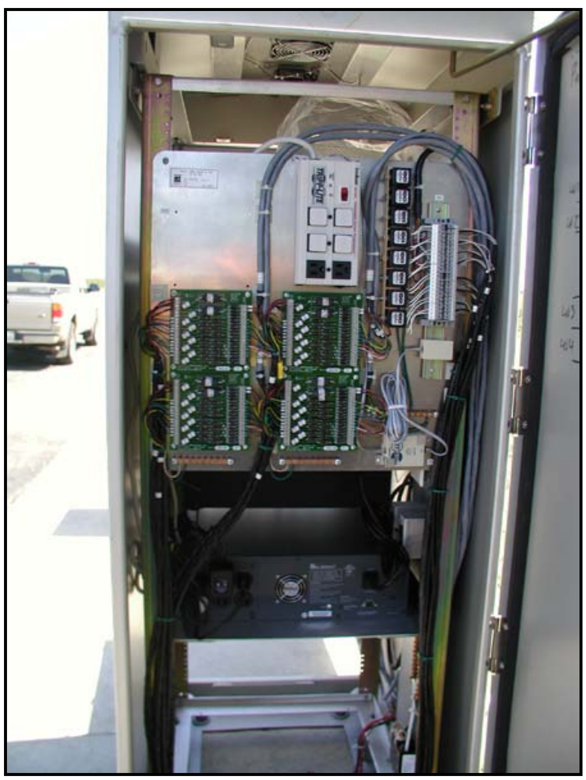


Figure 6. Photo. Controller cabinet, rear view, with in-road sensor inputs to controller and lightning protection.

Figure 7. Photo. Two-lane WIM site, with Portland cement concrete (PCC) pavement installed for approach and departure.

2.2. DEFINITIONS AND TERMS

2.2.1. WIM

As defined in ASTM E 1318:
"...the process of estimating a moving vehicle's gross weight and the portion of that weight that is carried by each wheel, axle, or axle group, or combination thereof, by measurement and analysis of dynamic vehicle tire forces."

2.2.2. Site Assessment

Refers to onsite activities preceding either an onsite evaluation or calibration to verify and document that:

- The WIM system is operational.
- The sensors have no visible problems.
- The pavement condition shows no apparent deterioration.

2.2.3. Weight

Throughout this manual, the term "weight" will be used, even though it may be technically appropriate to use another term such as "load" or "force". Weights will typically be expressed in kips (k), where 1 k equals 1000 pounds (lbs).

2.2.4. GVW

Throughout this manual, the term Gross Vehicle Weight (GVW) is used to refer to the sum of all of a vehicle's wheel weights or axle weights. GVWs will typically be expressed in units of kips.

2.2.5. Calibration and Validation (Using Test Trucks Onsite)

Both calibration and validation utilize a process by which the known static axle and/or wheel weights and known axle spacings of one or more test vehicle(s) are compared with the corresponding estimates from a WIM system's reported dynamic wheel weights and axle spacings for such test vehicle(s).

The purpose of calibration is to determine and implement the WIM system settings which will result in the system's generating the best possible estimate of static axle and/or wheel weights, axle spacing distances, and vehicle speeds for the most typical truck configurations in the traffic stream over the range of speeds typical of such truck configurations.

The purpose of validation is to check a system's accuracy for conformance to an agency's specified requirements. Once a system has been initially calibrated, test trucks should be run on a routine basis (or as otherwise deemed necessary) to check the system's calibration. This is also typically referred to as a validation. If such validation indicates that the system meets accuracy requirements but that accuracy could be improved, then the calibration factors may be adjusted and additional test truck runs made to confirm that the factor adjustments produced the desired effect.

2.2.5.1. Calibration Factor

Refers to a user-defined value that is used by a WIM system to convert raw sensor readings into weights.

2.2.5.2. Calibration Factor Speed Point

Also referred to as Speed Bin, refers to a user-defined speed for which a calibration factor can be entered for a weigh sensor. Certain WIM systems provide for three or more calibration factor speed points, which allow the user to determine appropriate calibration factors over a range of vehicle speeds which will best compensate for the effects of speed. For speeds between the speed points, the system uses linear interpolation to apply calibration factors to the sensor's readings.

2.2.5.3. WIM Error

Is the difference between a test truck's static weights and the corresponding WIM reported weights as derived from the test truck's dynamic readings.

2.2.6. LTPP

Refers to the Long-Term Pavement Performance (LTPP) program (http://www.fhwa.dot.gov/pavement/ltpp/), a 20-year study of in-service pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures. The LTPP program evaluates different pavement materials under different traffic loading, environmental and subgrade soil conditions. Different pavement maintenance practices are evaluated as well. The LTPP program was established in 1987 under the Strategic Highway Research Program (SHRP), and is now managed by the Federal Highway Administration (FHWA).

2.2.7. LTPP SPS TPF Study

Refers to the LTPP Specific Pavement Study (SPS) Traffic Pooled Fund Study, TPF-5(004). Phase I of this study consists of assessing, evaluating, and calibrating WIM systems used to collect traffic data at the SPS sites across the country. Phase II consists of the installation and maintenance of new WIM equipment as necessary to ensure high-quality data collection.

This Manual cites a number of LTPP and LTPP SPS TPF Study documents such as the LTPP Field Operations WIM Guide, the WIM Model Specifications (See Appendix A) and the LTPP Classification Scheme. These documents are extensive and contain valuable information for WIM equipment and site maintenance.

2.2.8. Traffic ETG

Refers to the Transportation Research Board (TRB) Expert Task Group (ETG) on LTPP Traffic Data Collection and Analysis. The Traffic ETG is composed of individuals with significant experience and involvement in the collection and/or analysis of truck traffic data. The Traffic ETG provides advice and guidance to the staff of the LTPP program regarding the reliability and precision of traffic data, among other things.

2.3. VEHICLE CLASSIFICATION VERSUS VEHICLE TYPE

As used in this manual, vehicle classification refers to the identification of vehicles according to FHWA's 13 Class Scheme as described in the Traffic Monitoring Guide (http://www.fhwa.dot.gov/ohim/tmguide/). However, individual classes within this scheme include vehicles with different axle configurations and operating characteristics that need to be uniquely identified by a WIM system's classification algorithm. Additionally, the ability to perform analyses on vehicles with similar axle configurations and operating characteristics, regardless of FHWA classification, can be of great benefit in performing data analyses. Vehicle type is used in this manual to refer to vehicles with similar axle configurations and operating characteristics. A few examples of vehicle types follow.

Class 7 includes all trucks on a single-frame with four or more axles. For trucks with "variable load suspensions" or "lift axles" (as shown in Figure 8), only the axles in contact with the pavement are counted to determine classification.

Figure 8. Photo. Class 7, single-unit truck with four of its five axles in contact with pavement.

Class 8 includes several common three- and four-axle single-trailer configurations. Figure 9 displays a two-axle tractor with a single axle semi-trailer and Figure 10 displays a three-axle tractor with a single axle semi-trailer. For this method of defining a truck combination type, the first value is the number of axles on the power unit (tractor or straight truck), the "S" signifies a semi-trailer, and the following value is the number of axles on the trailer.

Figure 9. Photo. Class 8, Type 2S1.

Figure 10. Photo. Class 8, Type 3S1.

Class 9 includes five-axle single-trailer trucks. Figure 11 displays the three-axle tractor and two-axle semi-trailer, which is by far the most predominant Class 9 type. Figure 12 displays the same type but with a "spread" tandem on the trailer. If this axle spread exceeds eight feet it is not a true tandem axle and is considered to be two individual axles. Figure 13 displays a three-axle straight truck pulling a two-axle full trailer. As such, there is no "S" preceding the value defining the trailer's number of axles.

Figure 11. Photo. Class 9, Type 3S2.

Figure 12. Photo. Class 9, Type 3S2 with "spread" rear tandem.

Figure 13. Photo. Class 9, Type 32.

Class 10 includes six-axle single trailer trucks. Figure 14 displays the most common configuration, the Type 3S3 which has a semi-trailer with a tridem axle.

Figure 14. Photo. Class 10, Type 3S3.

Class 11 includes five-axle multi-trailer trucks. Figure 15 displays the most common configuration, the Type 2S12. The first value defines the number of axles on the power unit, the “S1” defines the single axle semi-trailer, and the last value defines the second trailer as a two-axle full trailer.

Figure 15. Photo. Class 11, Type 2S12.

Class 12 includes six-axle multi-trailer trucks. Figure 16 displays the most common configuration, the Type 3S12.

Figure 16. Photo. Class 12, Type 3S12.

Class 13 includes multi-trailer trucks with seven or more axles for which there are a large number of possible axle configurations. Although there are exceptions, most agencies do not find it necessary to uniquely define these by type since they account for a very low percentage of the truck traffic stream. Some states allow very heavy mining or timber hauling “trains” with many axles, which they may find beneficial to capture by type for analyses. Some states allow Longer Combination Vehicles (LCVs), which do have consistent configurations as displayed in Figure 17.

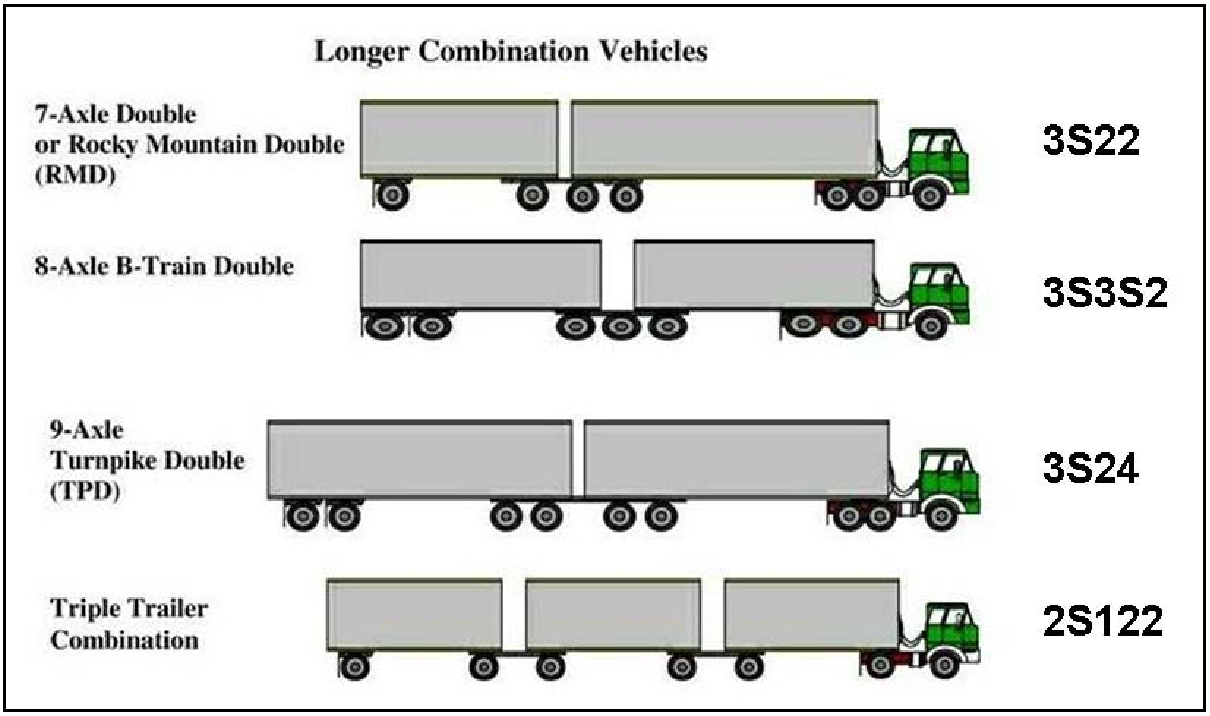


Figure 17. Picture. Class 13, Longer Combination Vehicles (LCVs).

Table 1 displays the basic class scheme that was recommended for use in the LTPP study by the Traffic ETG. The intent of this scheme is to include the most common vehicle types found nationwide and to be supplemented with additional vehicle types unique to certain regions. It is important to note that the axle spacing and weight parameters of any desired scheme must be set up as an algorithm specifically formatted for use by a particular WIM system.

Note that although the "LTPP Classification Scheme for SPS WIM Sites" displayed in Table 1 is currently in use, it is considered a work in progress subject to revisions and enhancements. For more information regarding this document contact ltppinfo@dot.gov.

Table 1. Example Class Scheme.

LTPP CLASSIFICATION SCHEME FOR SPS WIM SITES (ADOPTED MARCH 2006 BY TRAFFIC ETG)

Class	Vehicle Type	No. Axles	Spacing 1	Spacing 2	Spacing 3	Spacing 4	Spacing 5	Spacing 6	Spacing 7	Spacing 8	Gross Weight Min-Max	Axle 1 Weight Min *
1	Motorcycle	2	1.00-5.99								0.10-3.00	
2	Passenger Car	2	6.00-10.10								1.00-7.99	
3	Other (Pickup/Van)	2	10.11-23.09								1.00-7.99	
4	Bus	2	23.10-40.00								12.00 >	
5	2D Single Unit	2	6.00-23.09								8.00 >	2.5
2	Car w/ 1 Axle Trailer	3	6.00-10.10	6.00-25.00							1.00-11.99	
3	Other w/ 1 Axle Trailer	3	10.11-23.09	6.00-25.00							1.00-11.99	
4	Bus	3	23.10-40.00	3.00-7.00							20.00 >	
5	2D w/ 1 Axle Trailer	3	6.00-23.09	6.30-30.00							12.00-19.99	2.5
6	3 Axle Single Unit	3	6.00-23.09	2.50-6.29							12.00 >	3.5
8	Semi, 2S1	3	6.00-23.09	11.00-45.00							20.00 >	3.5
2	Car w/ 2 Axle Trailer	4	6.00-10.10	6.00-30.00	1.00-11.99						1.00-11.99	
3	Other w/ 2 Axle Trailer	4	10.11-23.09	6.00-30.00	1.00-11.99						1.00-11.99	
5	2D w/ 2 Axle Trailer	4	6.00-26.00	6.30-40.00	1.00-20.00						12.00-19.99	2.5
7	4 Axle Single Unit	4	6.00-23.09	2.50-6.29	2.50-12.99						12.00 >	3.5
8	Semi, 3S1	4	6.00-26.00	2.50-6.29	13.00-50.00						20.00 >	5.0
8	Semi, 2S2	4	6.00-26.00	8.00-45.00	2.50-20.00						20.00 >	3.5
3	Other w/ 3 Axle Trailer	5	10.11-23.09	6.00-25.00	1.00-11.99	1.00-11.99					1.00-11.99	
5	2D w/ 3 Axle Trailer	5	6.00-23.09	6.30-35.00	1.00-25.00	1.00-11.99					12.00-19.99	2.5
7	5 Axle Single Unit	5	6.00-23.09	2.50-6.29	2.50-6.29	2.50-6.30					12.00 >	3.5
9	Semi, 3S2	5	6.00-30.00	2.50-6.29	6.30-65.00	2.50-11.99					20.00 >	5.0
9	Truck+FullTrailer (3-2)	5	6.00-30.00	2.50-6.29	6.30-50.00	12.00-27.00					20.00>	3.5
9	Semi, 2S3	5	6.00-30.00	16.00-45.00	2.50-6.30	2.50-6.30					20.00 >	3.5
11	Semi+FullTrailer, 2S12	5	6.00-30.00	11.00-26.00	6.00-20.00	11.00-26.00					20.00 >	3.5
10	Semi, 3S3	6	6.00-26.00	2.50-6.30	6.10-50.00	2.50-11.99	2.50-10.99				20.00 >	5.0
12	Semi+Full Trailer, 3S12	6	6.00-26.00	2.50-6.30	11.00-26.00	6.00-24.00	11.00-26.00				20.00 >	5.0
13	7 Axle Multi's	7	6.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00			20.00 >	5.0
13	8 Axle Multi's	8	6.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00		20.00 >	5.0
13	9 Axle Multi's	9	6.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	3.00-45.00	20.00 >	5.0

Spacings in feet
Weights in kips (Lbs/1000)
* Suggested Axle 1 minimum weight threshold if allowed by WIM system's class algorithm programming

2.4. TASKS OF THE OFFICE DATA ANALYST

The primary tasks of the Office Data Analyst are as follows:

- Identify any missing or invalid data.

- For missing or invalid data, attempt to determine:
    - Cause
        - Ongoing
        - Intermittent
        - Isolated, one time event(s)
    - Extent
        - What part of the day's data should be flagged as invalid?
            - All data by time frame
            - One lane only
            - Classification counts valid, but not loading data
    - Course of action to correct ongoing or intermittent problem
        - Fix remotely from office
        - Call for field visit

- Monitor each WIM system for maintenance of calibration.

2.4.1. Causes of Missing or Invalid Data

Missing data for all lanes would most likely be due to a power outage at the system's controller or the controller being otherwise shut down. The primary causes of invalid data are as follows:

- System component malfunction
    - Failure vs. intermittent

- Improper system settings
    - System component operational variables, such as
        - Loop timeout
        - Weigh sensor thresholds
    - System processing variables, such as
        - Classification algorithm
        - Calibration factors

- Site conditions
    - Rough pavement
    - Roadway geometry

- Traffic conditions
    - Congestion
    - Lane closure or alignment shift

    - Changing lanes when crossing sensors

- Weather
    - Effects on system components, such as
        - Moisture intrusion
        - Bending plate scale pit filled with ice
    - Effects on traffic, such as
        - Crosswind
        - Traffic not within lane/shoulder striping due to heavy snow on pavement
    - Weather web site address
        - http://www.nws.noaa.gov/

In regard to system settings, classification algorithms and calibration factor values have no bearing, within reason, on a system's proper operation. Determination of classification algorithms and calibration factor values are more of a "fine tuning" process to generate the most accurate data possible as opposed to generating valid versus invalid data (unless the values are obviously erroneous). However, settings related to component operation, such as loop timeout and weigh sensor thresholds, will determine whether vehicles and vehicle combinations are properly detected and their wheels are properly counted and weighed.

2.4.2. Factors Affecting WIM Data Quality Which Can Be Controlled

- Site conditions
    - Roadway geometry
    - Pavement stability and smoothness
- Equipment quality and performance capabilities
- Equipment installation and routine maintenance
- Pavement maintenance

2.4.3. Factors Affecting WIM Data Quality Which Can Be Somewhat Controlled (By Site Selection)

- Traffic characteristics
    - Changing lanes through site
    - Wheels on or partially on shoulder
    - Speed changes or stop and go
        - Merging vehicles
        - Congested traffic

Power Point presentations that describe site conditions and traffic operating characteristics that should be considered in determining a suitable location for a WIM system installation are available online at www.QualityWIM.com

2.4.4. Factors Affecting WIM Data Quality Which Cannot Be Controlled

- Out of round tires

- Dynamically unbalanced wheels
- Tire inflation pressure
- Vehicle suspension
- Wind
- Vehicle aerodynamic features
- Type of load, particularly liquid, and/or method of loading
- Acceleration/deceleration
- Undesirable traffic conditions due to weather or work on roadway

2.5. WHAT QUALITY OF DATA SHOULD BE EXPECTED?

No WIM system can produce perfect data, even with high quality equipment and ideal site conditions. It is expected that any data file is going to contain some invalid data. The analyst must consider the characteristics of the WIM site, the characteristics and features of the WIM system, and the traffic characteristics in determining if the system is producing the best data possible. Regardless of what the minimum data quality requirements are, any WIM system should be monitored and maintained as to produce the best possible data given the system's potential. The key is to keep bad data to a minimum, giving consideration to each WIM system's potential, and to quickly recognize, identify, isolate, and correct the cause of erroneous data.

Many data problems can be corrected from the office. Even if a problem does require a service call, the service technician's time onsite can be greatly reduced if the analyst has narrowed down the potential causes of the problem. Neither the purging of entire daily data files nor major WIM system corrective actions are necessary if only a scattering of bad data is found when performing routine data quality control checks. If the amount of bad data starts to increase and goes from random to chronic, the analyst needs to take corrective action, unless the problem can be tied to an atypical site condition (e.g. traffic or roadwork).

SECTION 3. STEPS FOR DATA VALIDATION AND SYSTEM MONITORING FROM OFFICE

This section provides guidance and recommendations as to the steps to be taken by the Office WIM Data Analyst to validate data (Data Quality Control, or Data QC) and to monitor a WIM system's operation. Such steps include:

- Access the system from the office and perform initial real-time reviews.
- Perform reviews of canned reports to determine if a system is consistently operating properly, and if traffic is moving through the site within the lane lines at consistent speeds within the operating range of the system.
- Access the system from the office to perform system diagnostics if the data indicates that the system is not operating correctly.

WIM system site controller access display screens and setup procedures, as well as the application software provided by the WIM manufacturers for the user's Office Computer, vary by manufacturer. It is far beyond the scope of this manual to provide procedures applicable to each specific manufacturer or a manufacturer's specific equipment type or version of application software. The screen shots and sample report displays utilized in this manual are mostly taken from systems of two different manufacturers of WIM equipment. The intent is to provide general guidance on what to look for, as well as procedures to follow. Documentation on specific equipment and software provided by the WIM equipment manufacturer should be thoroughly reviewed by the analyst to determine how the examples in this manual can be applied.

The following recommendations on performing data QC and system monitoring do not include all possible procedures. The intent is for the novice analyst to use these recommendations as a starting point, and then develop additional procedures and checks as experience is obtained in working with the features of specific systems and Office Computer application software. For the experienced analyst, perhaps the following recommend procedures will provide additional tools to those already developed such that more thorough data QC and system monitoring analyses can be performed.

In addition, it is not the intent that the data QC checks monitor the fine-tuning aspects of a system's calibration. Calibration monitoring will be covered in SECTION 5. Calibration monitoring is only effective when using data from a system that is operating correctly and for which the traffic operating characteristics are normal. The intent of the data QC checks of each day's data file is to ensure that invalid data, whether caused by system malfunction or atypical traffic operating characteristics, is identified and flagged such that only data appropriate for its intended use is disseminated.

3.1. INITIAL REAL-TIME REVIEW

For agencies utilizing fully automated and unattended WIM data file download, calling up each system prior to the predetermined start of the download may not be feasible. In this case, if a system (or its communication link) is not operating properly, it will be evident following the download session. Otherwise, it is recommended that prior to downloading a significant number of data files from the system that it be accessed remotely from the office and spot-checked, as described below, to verify that the system is, in general, operating correctly. These checks are intended to identify any significant ongoing system problems without waiting for the data to be downloaded and reviewed, as well as to identify data files which contain significant amounts of missing and/or invalid data which do not need to be downloaded.

1. Does the onsite modem answer?

If not, first ensure that the Office Computer's communication software and modem are properly configured. The quickest test for this is to call another WIM system similar to the one that is not responding. If it is confirmed that the Office Computer is communicating with other systems normally, a site visit is necessary to determine if the power or phone service is out, or if the site's modem is not working.

2. Does the onsite modem answer, but the system is not responding?

If so, a site visit is necessary to check the modem configuration, and if the modem configuration is correct, the status of the controller.

3. Is the system's time and date correct? See Figure 18 for examples from two different systems.

If not, correct time and/or date and determine if the affected files may still be of use for the intended purposes.

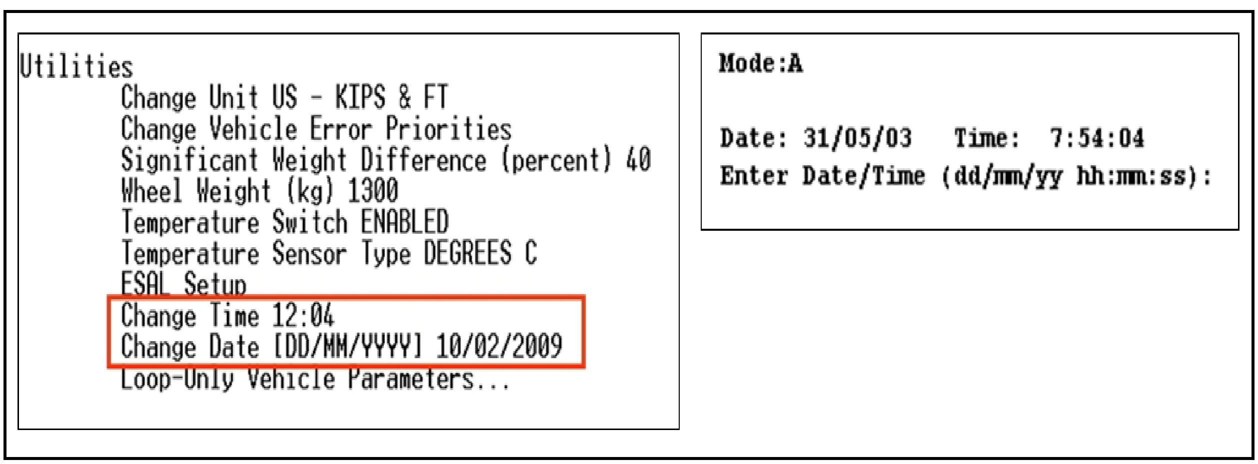


Figure 18. Screen shot. Site menu, time and date.

4. Do the stored files appear to be complete, and their file sizes appropriate? See Figure 19 for example.

For the site used in the example, it is typical for the weekday files to average about 500,000 bytes and the weekend files to average about 270,000 bytes, so these file sizes appear to be reasonable. The partial current day's file size also appears to be reasonable given it is for almost 12 hours. If the file sizes appear to be unreasonable, determine if the affected files may still be of use for the intended purposes. Unreasonable file sizes sometimes result from changes in the number of individual vehicle records that are being captured by the system, which may indicate that a system component is malfunctioning or that a system setting has changed. If it is obvious that a number of the daily data files are not usable, it may be beneficial to download only one of the files initially, in order to analyze and determine the cause of the problem.

```
        List Vehicle Record Files
   File                Size     Time       Date
20090208.105         271193   00:00:00   09/02/2009
20090210.105         260824   11:55:21   10/02/2009 <-- Current day's file
20090119.105         422945   00:00:00   20/01/2009
20090120.105         523130   00:00:00   21/01/2009
20090121.105         527850   00:00:00   22/01/2009
20090122.105         495096   00:00:00   23/01/2009
20090124.105         319524   00:00:00   25/01/2009
20090125.105         274560   00:00:00   26/01/2009
20090127.105         523057   00:00:00   28/01/2009
20090128.105         518312   00:00:00   29/01/2009
20090129.105         498967   00:00:00   30/01/2009
20090131.105         325170   00:00:00   01/02/2009
20090201.105         261184   00:00:00   02/02/2009
20090203.105         518495   00:00:00   04/02/2009
20090204.105         525382   00:00:00   05/02/2009
20090205.105         491899   00:00:00   06/02/2009
20090206.105         461103   00:00:00   07/02/2009
20090207.105         320216   00:00:00   08/02/2009

<ESC> to quit, any other key to continue
```

Figure 19. Screen shot. Site menu, stored data files.

5. In viewing real-time vehicles, do their data elements appear to be reasonable for each lane (it is recommended that each lane be checked individually)?

Check the following items:

- Classifications
- Axle Spacings
- Speeds
- Weights
- System error or warning flag codes

Figure 20 displays a few records from a system's Lane 1 real-time truck traffic stream. In analyzing the records with "Ve.-Code: 15" (unclassified vehicles in the classification algorithm being used by this system), it should be obvious to the analyst that the three vehicles classified as "15" have spacings and weights which are typical of the Class 9's Type 3S2. This should quickly prompt a check of the system's settings for the classification algorithms.

```
--------------------------------------------------------------------------------
12830     54  mph       Lane:   1     11: 0:23     2-14-2003     Violations: 00
Ve.-Code:  15           Total     1       2       3       4       5
Weight    (kips)         32.6   10.5    7.0     6.4     5.3     3.3
Spacings (feet)          68.5       19.7    4.2    28.6    4.0
--------------------------------------------------------------------------------
12835     46  mph       Lane:   1     11: 0:33     2-14-2003     Violations: 00
Ve.-Code:   5           Total     1       2
Weight    (kips)          9.5    4.6    4.9
Spacings (feet)          22.3       12.1
--------------------------------------------------------------------------------
12839     52  mph       Lane:   1     11: 0:44     2-14-2003     Violations: 00
Ve.-Code:  15           Total     1       2       3       4       5
Weight    (kips)         47.1   10.5   10.6     9.4     9.0     7.5
Spacings (feet)          57.6       17.1    4.4    27.9    4.1
--------------------------------------------------------------------------------
12873     56  mph       Lane:   1     11: 0:45     2-14-2003     Violations: 00
Ve.-Code:  15           Total     1       2       3       4       5
Weight    (kips)         61.3    9.4   11.6    10.3    15.9    13.9
Spacings (feet)          67.2       15.4    4.1    33.5    3.8
--------------------------------------------------------------------------------
12842     52  mph       Lane:   1     11: 0:46     2-14-2003     Violations: 00
Ve.-Code:   5           Total     1       2
Weight    (kips)         14.6    6.4    8.1
Spacings (feet)          31.9       19.0
--------------------------------------------------------------------------------
```

Figure 20. Screen shot. Site real-time "View Vehicles" mode for system's Lane 1.

In reviewing the system's classification scheme algorithm setup displayed in Figure 21, it is evident that a system malfunction has occurred. This is a classification algorithm setup convention in which the two rightmost numbers for the axle distances (spacings) are decimal places (values in feet). What is supposed to be Type 9, the FHWA Class 9 - 3S2 configuration, is instead a Type 75, with some random spacing definitions. Since this system's classification algorithm does not include a Type 9, all vehicles conforming to the intended Type 9 axle spacing parameters are labeled Class 15 (unclassified). The next classification algorithm in Figure 21, shown as Type 14, is the Agency's Class 14 (FHWA's Class 9 – 32 configuration), which has maintained the correct axle spacing scheme.

Figure 22 displays an example of two vehicles with "Significant Weight Difference" warning flags. In monitoring all Lane EB#2 vehicles for a longer time frame the analyst notes that many or even all are flagged with this warning. For this system, this warning flag indicates that the left versus right sensor weight outputs of one or more of a vehicle's axles exceed a 40 percent difference. In examining the left and right sensor weight outputs, the left weights appear to be reasonable. However, the right weight outputs appear to be only about half of the left weight outputs. This should prompt a check of the calibration factors for obviously erroneous low values for this lane's right weigh sensor.

As found

Type	75
Dist. axle low:	2947
Dist. axle high:	8251
Dist. axle low:	1939
Dist. axle high:	7445
Dist. axle low:	2242
Dist. axle high:	6713
Dist. axle low:	1561
Dist. axle high:	1090
Total weight low:	1000
Total weight high:	0
Lim. Total weight:	8000

Type	14
Dist. axle low:	600
Dist. axle high:	2600
Dist. axle low:	300
Dist. axle high:	599
Dist. axle low:	600
Dist. axle high:	2300
Dist. axle low:	1100
Dist. axle high:	2700
Total weight low:	1200
Total weight high:	0
Lim. Total weight:	8000

As originally entered

Type	9
Dist. axle low:	600
Dist. axle high:	2600
Dist. axle low:	300
Dist. axle high:	599
Dist. axle low:	600
Dist. axle high:	4600
Dist. axle low:	300
Dist. axle high:	1099
Total weight low:	1200
Total weight high:	0
Lim. Total weight:	8000

Figure 21. Screen shots. Menu screen displaying portion of classification algorithm entries.

Record Number	32405	Dir/Ln	East/2	GVW	31.5 kips	Length	65 ft
	Class	9	Speed	59 mph	Max GVW 80.0 kips	ESAL	0.066
Monday	Feb. 24, 2003		Time	23:21:52.63			

Axle	Spacing (ft)	Left WT. (kips)	Right WT (kips)	Total WT (kips)	Allowable (kips)
1		4.8	2.5	7.3	20.0
2	16.8	4.7	2.4	7.1	17.0
3	4.3	4.2	2.1	6.3	17.0
4	33.2	3.8	1.9	5.7	17.0
5	4.2	3.4	1.8	5.2	17.0

Warning: Significant Weight Difference!

Record Number	32415	Dir/Ln	East/2	GVW	48.1 kips	Length	75 ft
	Class	9	Speed	61 mph	Max GVW 80.0 kips	ESAL	0.365
Monday	Feb. 24, 2003		Time	23:21:18.53			

Axle	Spacing (ft)	Left WT. (kips)	Right WT (kips)	Total WT (kips)	Allowable (kips)
1		5.8	1.8	7.6	20.0
2	17.2	7.5	3.0	10.4	17.0
3	4.3	8.4	3.1	11.5	17.0
4	34.0	6.1	3.8	9.9	17.0
5	4.1	5.4	3.3	8.6	17.0

Warning: Significant Weight Difference!

Figure 22. Screen shot. Site real-time "View Vehicles" mode.

Figure 23 displays the menu "path" for this particular system to view the current calibration factor settings for the weigh sensor ("WIM Sensor 3") in question. The analyst should compare these factors with those on record to see if they are correct. If these factors are correct, additional diagnostics can be performed on this sensor as will be discussed later.

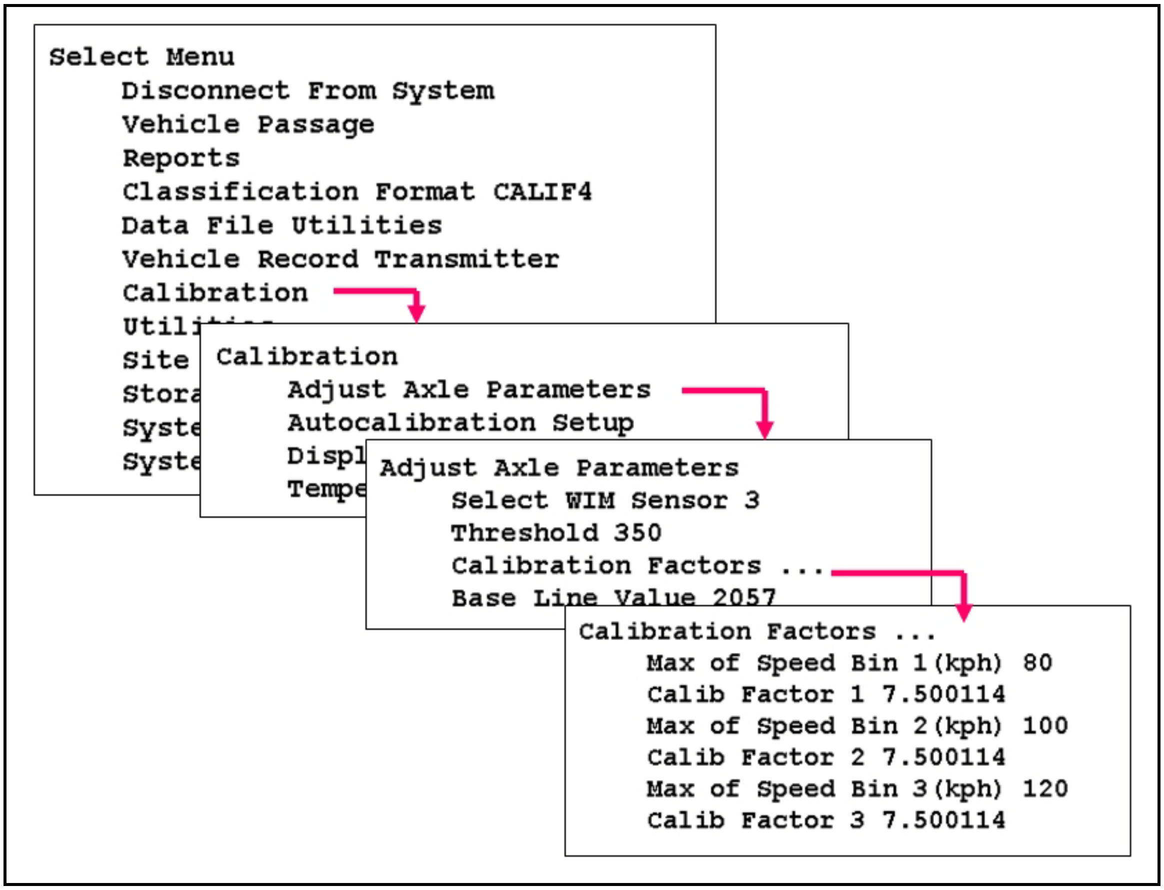


Figure 23. Screen shots. Site real-time menu screen displaying calibration factors.

This short term monitoring session of individual vehicles passing through the system in real-time is intended to catch only significant and ongoing problems with the system. Data QC is necessary to detect problems that are not so obvious or problems of an intermittent nature.

3.2. DATA REVIEW USING CANNED REPORTS

Following the downloading of a WIM system's daily data file (or files) to the Office Data Analyst's Office Computer, a data QC check is performed to determine if the data is suitable for its intended use.

3.2.1. Class and Speed Reports

It is recommended that the first check be made using daily class and speed reports summarizing the binned raw data. The purpose of this check is to take a quick look at each day's data to identify:

- Any missing vehicles for hour(s) in:
  - All lanes
  - One lane only
- Any atypical class count distributions
- Any atypical speed patterns

Figure 24 displays two reports with daily vehicle counts by hour for Lane Numbers SB1 and SB2. For this site, Lane SB1 is the outside lane, or “driving” lane, which normally carries most of the traffic. In the first report, it is obvious that the counts decrease significantly for Lane SB1 starting sometime after Hour 7 and ending sometime prior to Hour 16. However, a look at the counts for this time frame for the adjacent Lane SB2 (inside lane, or “passing” lane) indicates that the counts significantly increase. The total counts for both lanes are normal. This example represents a typical lane closure situation and the system is counting vehicles just fine. In the second report, both lanes are exhibiting a large drop in counts starting sometime after Hour 18 and ending sometime prior to Hour 21. This indicates that, for some reason, the system was not counting during this period or that some major event caused the closure of both lanes.

Figure 25 displays a report for a system that covers all four lanes (two lanes in each direction) of the roadway. This is an obvious case of either a temporary loss of power or the system simply malfunctioning for several hours (Hour 9 through Hour 14).

Lane by Hour Report

Site: 507-VIRGINIA_SPS-1 Lanes: SB1_LTPP SB2
Classification: LTPP_2 Start Class 0 End Class 15
FROM: Tue Mar 27 00:00:00 2007 TO: Wed Mar 28 00:00:00 2007
Number of Vehicles

Hour	Lane Number SB1_LTPP	SB2	Total
0->1	29	5	34
1->2	23	2	25
2->3	29	0	29
3->4	47	2	49
4->5	54	5	59
5->6	123	24	147
Qtr Tot	305	38	343
6->7	303	96	399
7->8	344	121	465
8->9	25	334	359
9->10	3	283	286
10->11	1	230	231
11->12	1	241	242
Qtr Tot	677	1305	1982
12->13	0	255	255
13->14	1	244	245
14->15	0	293	293
15->16	0	354	354
16->17	1	298	299
17->18	176	87	263
Qtr Tot	178	1531	1709
18->19	206	59	265
19->20	109	21	130
20->21	111	17	128
21->22	95	18	113
22->23	67	9	76
23->24	44	4	48
Qtr Tot	632	128	760
Total	1792	3002	4794
Percent	37.4	62.6	100.0

LANE CLOSURE AND TRAFFIC SHIFT

Site: 507-VIRGINIA_SPS-1 Lanes: SB1_LTPP SB2
Classification: LTPP_2 Start Class 0 End Class 15
FROM: Wed Mar 28 00:00:00 2007 TO: Thu Mar 29 00:00:00 2007
Number of Vehicles

Hour	Lane Number SB1_LTPP	SB2	Total
0->1	33	7	40
1->2	24	2	26
2->3	33	1	34
3->4	38	7	45
4->5	41	6	47
5->6	142	23	165
Qtr Tot	311	46	357
6->7	312	120	432
7->8	312	122	434
8->9	304	76	380
9->10	214	52	266
10->11	232	54	286
11->12	220	43	263
Qtr Tot	1594	467	2061
12->13	203	49	252
13->14	230	38	268
14->15	218	68	286
15->16	241	64	305
16->17	255	65	320
17->18	249	57	306
Qtr Tot	1396	341	1737
18->19	80	21	101
19->20	0	0	0
20->21	43	7	50
21->22	86	12	98
22->23	76	16	92
23->24	38	5	43
Qtr Tot	323	61	384
Total	3624	915	4539
Percent	79.8	20.2	100.0

MISSING DATA

Figure 24. Reports. Missing hourly data for lane or lanes.

Lane by Hour Report

Site: 510-TENNESSEE_SPS-6 Lanes: #1 #2 #3 WB2_LTPP
Classification: LTPP_2 Start Class 1 End Class 15
FROM: Wed Jul 09 00:00:00 2008 TO: Thu Jul 10 00:00:00 2008

Number of Vehicles

Lane Number

Hour	#1	#2	#3	WB2_LTPP	Total
0->1	251	66	147	376	840
1->2	390	156	342	525	1413
2->3	525	253	468	608	1854
3->4	568	341	396	593	1898
4->5	605	398	363	607	1973
5->6	615	408	437	671	2131
Qtr Tot	2954	1622	2153	3380	10109
6->7	657	478	441	656	2232
7->8	628	465	563	666	2322
8->9	571	388	468	650	2077
9->10	39	19	38	39	135
10->11	0	0	0	0	0
11->12	0	0	0	0	0
Qtr Tot	1895	1350	1510	2011	6766
12->13	0	0	0	0	0
13->14	0	0	0	0	0
14->15	668	595	477	588	2328
15->16	669	496	409	624	2198
16->17	757	682	452	647	2538
17->18	685	589	465	586	2325
Qtr Tot	2779	2362	1803	2445	9389
18->19	577	356	372	559	1864
19->20	516	282	267	463	1528
20->21	457	228	246	443	1374
21->22	451	216	189	378	1234
22->23	405	201	105	329	1040
23->24	332	119	75	253	779
Qtr Tot	2738	1402	1254	2425	7819
Total	10366	6736	6720	10261	34083
Percent	30.4	19.8	19.7	30.1	100.0

Figure 25. Report. Missing data all lanes.

Figure 26 displays a portion of a daily report with hourly counts by classification for the system's Lane 2. Starting during Hour 12 - 13 there was a large increase in counts for Class 1 and unclassified vehicles (Class 15, for this particular system). Also, a significant decrease in counts for the "good" classes is evident (although this lane has very few large trucks).

Figure 27 displays a portion of a daily report with speed range counts by hour for the same system, day, and lane as the Classification by Hour report displayed in Figure 26. At the same time that there were significant changes in the classifications, there were significant changes in the speeds as well. Also, Figure 28 displays that a vast majority of the invalid speeds are attributable to Class 1s and Class 15s (unclassifieds).

In that this site is located in an urban area with commute traffic, some of the low speeds may very well be legitimate. These three reports are from a system for which loop or loop-processing problems will typically result in Class 1 and/or Class 15 vehicles and unrealistic speeds. Although consideration must always be given to the possibility that a system's erroneous data may be attributable to congestion, an accident, or work on the roadway causing stop and go traffic conditions, the fact that the erroneous data continued for the entire afternoon suggests that for this example the system simply is not processing properly for Lane 2. As an additional check, Figure 29 displays a report comparing class and speed data for Lane 2 with that of adjacent Lane 1. Although Lane 1 does appear to have some erroneous data (probably due to the traffic conditions), its reasonable class and speed distributions make it evident that the Lane 2 problems are not due to major traffic issues.

DISTRIBUTION OF VEHICLE CLASSIFICATIONS BY HOUR OF DAY

SITE NO : 014 Location : SAN MARCOS - 078, 10.7 Lane(s) : 2
DATE : 08/04/08 County : SD State-ID : CA Direction : E

HOURLY SUMMARY — VEHICLE COUNTS

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
0- 1	0	199	45	0	5	0	0	0	1	0	0	0	0	0	0	250
1- 2	0	107	20	0	4	0	0	0	1	0	0	0	0	0	0	132
2- 3	0	80	15	0	2	0	0	0	0	0	0	0	0	0	0	97
3- 4	0	73	17	0	1	0	0	0	2	0	0	0	0	0	0	93
4- 5	0	147	59	0	7	0	0	1	0	0	0	0	0	0	1	215
5- 6	0	417	158	0	19	0	0	0	4	0	0	1	0	0	0	599
QTR TOTALS	0	1023	314	0	38	0	0	1	8	0	0	1	0	0	1	1386
6- 7	0	748	325	1	50	3	0	2	3	0	0	0	0	0	1	1133
7- 8	0	941	308	3	49	2	0	5	9	0	1	0	0	0	2	1320
8- 9	0	899	295	0	66	12	0	3	5	1	1	0	0	0	3	1285
9-10	0	785	269	4	77	12	1	3	12	0	0	0	0	1	1	1165
10-11	0	857	225	1	50	3	0	3	7	0	1	0	0	1	1	1149
11-12	0	616	189	2	53	8	0	0	3	0	1	0	0	1	7	880
QTR TOTALS	0	4846	1611	11	345	40	1	16	39	1	4	0	0	3	15	6932
12-13	28	618	175	1	56	5	0	4	6	0	0	0	0	0	342	1235
13-14	66	88	15	0	7	0	0	0	0	0	0	0	0	0	1117	1293
14-15	94	101	12	0	14	0	0	0	0	0	0	0	0	0	1153	1374
15-16	101	126	13	0	6	0	0	0	0	0	0	0	0	0	1170	1416
16-17	123	101	17	0	10	0	0	0	0	0	0	0	0	0	1116	1367
17-18	116	104	19	0	5	0	0	0	0	0	0	0	0	0	1089	1333
QTR TOTALS	528	1138	251	1	98	5	0	4	6	0	0	0	0	0	5987	8018
18-19	69	114	6	0	5	0	0	0	0	0	0	0	0	0	1010	1204
19-20	38	108	5	0	1	0	0	0	0	0	0	0	0	0	902	1054
20-21	31	80	0	0	0	0	0	0	0	0	0	0	0	0	793	904
21-22	12	53	2	0	1	0	0	0	0	0	0	0	0	0	631	699
22-23	4	64	0	0	1	0	0	0	0	0	0	0	0	0	534	603
23-24	6	57	1	0	0	0	0	0	0	0	0	0	0	0	361	425
QTR TOTALS	160	476	14	0	8	0	0	0	0	0	0	0	0	0	4231	4889

Figure 26. Report. Erroneous classification for lane

DISTRIBUTION OF VEHICLE SPEEDS BY HOUR OF DAY

SITE NO : 014 Location : SAN MARCOS - 078, 10.7 Lane(s) : 2
DATE : 08/04/08 County : SD State-ID : CA Direction : E

SPEED RANGE, (mph)

HOUR	00-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	> 85	TOTALS
0- 1	0	0	0	1	5	38	83	75	30	12	3	3	250
1- 2	0	0	1	2	2	21	50	36	15	4	1	0	132
2- 3	0	0	0	0	1	16	28	31	16	2	3	0	97
3- 4	0	0	0	0	4	9	32	25	16	5	2	0	93
4- 5	0	0	0	1	7	13	76	69	34	12	2	1	215
5- 6	0	0	0	0	3	76	253	157	86	19	2	3	599
QTR TOTALS	0	0	1	4	22	173	522	393	197	54	13	7	1386
6- 7	0	0	0	4	34	199	471	291	98	27	5	4	1133
7- 8	0	0	0	7	96	316	576	224	70	19	2	10	1320
8- 9	1	0	0	3	47	268	553	286	91	20	6	10	1285
9-10	0	0	0	9	80	264	504	214	65	18	3	8	1165
10-11	0	0	0	6	55	294	522	191	60	15	0	6	1149
11-12	6	0	0	8	59	231	338	154	59	19	0	6	880
QTR TOTALS	7	0	0	37	371	1572	2964	1360	443	118	16	44	6932
12-13	383	3	3	9	71	240	342	122	36	12	2	12	1235
13-14	1235	13	12	4	2	4	5	0	0	1	0	17	1293
14-15	1316	10	11	3	1	4	1	3	2	3	1	19	1374
15-16	1329	14	14	9	6	3	2	6	0	2	1	30	1416
16-17	1295	11	5	9	7	6	2	3	3	4	1	21	1367
17-18	1275	10	1	7	3	3	3	2	2	2	1	24	1333
QTR TOTALS	6833	61	46	41	90	260	355	136	43	24	6	123	8018
18-19	1159	14	5	3	3	4	2	0	2	0	1	11	1204
19-20	1018	6	2	4	5	3	3	1	2	2	0	8	1054
20-21	890	4	2	0	1	2	0	0	0	0	0	5	904
21-22	692	4	0	0	1	0	0	0	0	0	0	2	699
22-23	597	0	0	0	1	1	0	0	1	0	0	3	603
23-24	420	0	2	0	1	0	0	0	0	1	0	1	425
QTR TOTALS	4776	28	11	7	12	10	5	1	5	3	1	30	4889

Figure 27. Report. Erroneous speeds for lane.

DISTRIBUTION OF SPEEDS BY VEHICLE CLASSIFICATION

SITE NO : 014 Location : SAN MARCOS - 078, 10.7 Lane(s) : 2
DATE : 08/04/08 County : SD State-ID : CA Direction : E

VEHICLE COUNTS

SPEED (mph)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
1- 5	149	359	5	0	3	0	0	0	0	0	0	0	0	0	4737	5253
6- 10	97	161	5	0	2	0	0	0	0	0	0	0	0	0	3078	3343
11- 15	210	79	3	0	0	0	0	0	0	0	0	0	0	0	1221	1513
16- 20	153	35	0	0	1	0	0	0	0	0	0	0	0	0	551	740
21- 25	41	32	2	0	2	0	0	0	0	0	0	0	0	0	315	392
26- 30	20	26	1	0	5	0	0	0	0	0	0	0	0	0	170	222
31- 35	14	33	0	0	8	0	0	0	0	0	0	0	0	0	98	153
36- 40	3	41	1	0	10	0	0	0	0	0	0	0	0	0	34	89
41- 45	1	40	0	0	7	0	0	0	0	0	0	0	0	0	10	58
46- 50	0	65	16	0	6	0	1	0	0	0	0	0	0	0	1	89
51- 55	0	320	87	2	43	14	0	9	17	1	0	0	0	1	1	495
56- 60	0	1376	397	9	166	24	0	11	25	0	3	1	0	2	1	2015
61- 65	0	2713	941	1	173	6	0	1	10	0	1	0	0	0	0	3846
66- 70	0	1406	438	0	44	1	0	0	1	0	0	0	0	0	0	1890
71- 75	0	506	177	0	5	0	0	0	0	0	0	0	0	0	0	688
76- 80	0	141	54	0	4	0	0	0	0	0	0	0	0	0	0	199
81- 85	0	28	8	0	0	0	0	0	0	0	0	0	0	0	0	36
86- 90	0	4	8	0	1	0	0	0	0	0	0	0	0	0	0	13
91- 95	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	5
96-100	0	6	12	0	0	0	0	0	0	0	0	0	0	0	0	18
> 100	0	110	32	0	9	0	0	0	0	0	0	0	0	0	17	168
TOTALS	688	7483	2190	12	489	45	1	21	53	1	4	1	0	3	10234	21225

Figure 28. Report. Speed by class for lane.

	1		2	
	COUNT	%	COUNT	%
CLASS				
1	12	0.1	688	3.2
2	9910	64.8	7483	35.3
3	2651	17.3	2190	10.3
4	12	0.1	12	0.1
5	1380	9.0	489	2.3
6	192	1.3	45	0.2
7	24	0.2	1	0.0
8	151	1.0	21	0.1
9	461	3.0	53	0.2
10	2	0.0	1	0.0
11	47	0.3	4	0.0
12	2	0.0	1	0.0
13	4	0.0	0	0.0
14	25	0.2	3	0.0
15	423	2.8	10234	48.2
TOTAL	15296	100.0	21225	100.0
SPEED (mph)				
1- 5	15	0.1	5253	24.7
6- 10	0	0.0	3343	15.8
11- 15	1	0.0	1513	7.1
16- 20	1	0.0	740	3.5
21- 25	4	0.0	392	1.8
26- 30	19	0.1	222	1.0
31- 35	31	0.2	153	0.7
36- 40	97	0.6	89	0.4
41- 45	461	3.0	58	0.3
46- 50	1729	11.3	89	0.4
51- 55	4252	27.8	495	2.3
56- 60	4290	28.0	2015	9.5
61- 65	2947	19.3	3846	18.1
66- 70	926	6.1	1890	8.9
71- 75	298	1.9	688	3.2
76- 80	94	0.6	199	0.9
81- 85	21	0.1	36	0.2
86- 90	8	0.1	13	0.1
91- 95	2	0.0	5	0.0
96-100	8	0.1	18	0.1
> 100	92	0.6	168	0.8

Figure 29. Report. Class and speed distributions, Lane 1 versus Lane 2.

Figure 30 displays a Speed by Hour report for Lane #1 for a WIM site that routinely experiences traffic congestion. For such a site, an increase in system errors and/or questionable classification counts should prompt the analyst to review the traffic speed distributions for the period of time in question. In analyzing the speed pattern and traffic volumes it is apparent that this site actually did experience very slow speeds for a two-hour period (probably stop and go). In this case, congestion appears to be the cause of invalid data, and not improper system operation.

For sites that experience routine traffic congestion, the onsite testing following initial installation and start-up should have confirmed whether or not the system met functional requirements in regard to its ability to properly generate data when traffic is travelling at the minimum speed of the required speed range. For example, if the specifications require that the system must function properly when traffic is travelling within a range of 5 mi/h to 100 mi/h, and onsite observation confirmed that errors start occurring only when vehicles actually stop when over the sensors, the system was functioning correctly. If, on the other hand, errors started occurring when vehicles were moving in excess of 5 mi/h, the system was not functioning correctly and the system should not have been accepted. If this type of testing was not performed prior to system acceptance, it should be performed as soon as the Office Data Analyst identifies low speeds as the potential cause of invalid data. Such onsite observations of the effect of low speed traffic on the system's data output should be documented such that the analyst will be able to make a judgment as to whether invalid data is due to system error or traffic conditions.

It is important that the analyst develop rules for each WIM site in regard to what levels of routine data errors caused by traffic operating characteristics may be expected without raising a flag that a system might be malfunctioning. A site located on a wide-open rural interstate freeway should experience very few routine data errors due to traffic operating characteristics whereas a site located on an urban roadway might experience a relatively high level of routine data errors which are caused by traffic, not system malfunction.

Figure 31 also displays a portion of a daily report displaying hourly counts by classification for a system's Lane #1. However, this system has the capability to identify specific types of system errors and include such error counts in a Classification bin (Class 14, for this particular system). For Hours 7 through 10 there was an increase in counts of system errors and unclassified vehicles (Class 15, for this particular system) and an apparent decrease of counts for the other vehicle classes.

Figure 32 displays a portion of another daily report for the system, date, and lane displayed in Figure 31. This report makes it evident that between Hours 7 and 10 there was an increase in loop errors/warnings ("Dwn Only"), as well as an increase in both unequal left sensor versus right sensor axle detections ("Uneq Det"), and no axle detections ("Zero Axl"). Although these system errors would not appear to be significant, they indicate either erratic traffic patterns or that the system was having some problems during this period of time. This system should be carefully monitored to determine if this problem was an isolated event or if it is occurring (or worsening) on a regular basis.

Speed by Hour Report --------------------

Site: 502-MARYLAND_SPS-5 Lanes: #1

Classification: LTPP_2 Start Class 1 End Class 15

FROM: Thu Sep 04 00:00:00 2008 TO: Fri Sep 05 00:00:00 2008

Number of Vehicles

Speed Range, mph

Hour	0->31	31->36	36->41	41->46	46->51	51->56	56->61	61->66	66->71	71->76	76->81	81 +	Total
0->1	0	0	0	0	3	11	28	11	1	0	1	0	55
1->2	0	0	0	1	3	8	12	7	2	0	0	0	33
2->3	0	0	0	0	1	1	6	1	2	0	0	1	12
3->4	0	0	0	0	1	8	8	3	2	0	0	0	22
4->5	0	0	0	0	0	12	27	14	4	1	0	0	58
5->6	1	0	0	0	4	51	54	22	3	2	0	0	137
Qtr Tot	1	0	0	1	12	91	135	58	14	3	1	1	317
6->7	1	0	0	8	30	99	103	44	2	0	0	0	287
7->8	0	0	0	0	8	124	212	86	9	2	1	0	442
8->9	0	0	4	25	31	121	186	117	12	3	0	0	499
9->10	0	0	0	2	19	146	201	56	7	1	0	0	432
10->11	0	0	0	7	39	98	140	79	12	1	1	1	378
11->12	0	0	0	0	10	129	150	48	11	5	0	0	353
Qtr Tot	1	0	4	42	137	717	992	430	53	12	2	1	2391
12->13	0	0	0	0	19	133	150	81	10	2	1	1	397
13->14	0	0	0	0	16	112	135	48	15	1	0	1	328
14->15	0	0	0	3	16	147	151	66	12	0	1	0	396
15->16	0	6	13	21	101	241	243	94	30	6	3	0	758
16->17	86	24	32	49	63	224	240	124	12	5	2	1	862
17->18	572	26	17	14	44	114	93	27	5	0	0	0	912
Qtr Tot	658	56	62	87	259	971	1012	440	84	14	7	3	3653
18->19	0	1	3	18	91	285	278	123	23	4	1	0	827
19->20	0	0	2	35	43	150	193	81	19	6	0	0	529
20->21	0	0	5	10	38	115	77	28	7	0	0	0	280
21->22	0	0	0	0	27	82	73	26	6	2	1	0	217
22->23	0	0	0	4	20	49	55	17	2	3	0	0	150
23->24	0	0	0	1	5	25	45	15	3	2	0	0	96
Qtr Tot	0	1	10	68	224	706	721	290	60	17	2	0	2099
Total	660	57	76	198	632	2485	2860	1218	211	46	12	5	8460

Figure 30. Report. Traffic congestion; legitimate low speeds.

Class by Hour Report --------------------
Site: 501-ILLINOIS_SPS-6 Lanes: #1
Classification: LTPP_2 Start Class 0 End Class 15
FROM: Tue Mar 27 00:00:00 2007 TO: Wed Mar 28 00:00:00 2007

System Errors effecting loss of data (note change in pattern)

Number of Vehicles
Classification

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
0->1	0	0	32	15	0	3	1	0	0	75	0	2	3	0	1	0	132
1->2	0	0	24	6	0	2	0	0	0	68	0	1	1	0	0	0	102
2->3	0	0	23	17	1	2	0	0	1	55	0	2	0	0	0	1	102
3->4	0	0	25	12	0	4	2	0	1	66	0	2	1	0	1	1	115
4->5	0	1	30	11	1	10	1	0	1	67	0	6	3	0	0	0	131
5->6	0	0	65	39	3	9	1	0	2	90	0	10	2	0	0	0	221
Qtr Tot	0	1	199	100	5	30	5	0	5	421	0	23	10	0	2	2	803
6->7	0	0	171	89	3	14	1	0	1	96	0	10	2	0	2	1	390
7->8	0	0	176	66	1	23	2	0	3	83	2	3	0	0	20	6	385
8->9	0	0	79	36	0	13	2	2	9	79	3	1	0	0	30	15	269
9->10	0	0	74	25	0	8	3	0	2	68	0	0	2	0	42	8	232
10->11	0	0	159	57	3	20	2	0	10	149	3	2	4	0	1	0	410
11->12	0	1	207	54	3	18	6	0	10	130	2	1	0	1	4	3	440
Qtr Tot	0	1	866	327	10	96	16	2	35	605	10	17	8	1	99	33	2126
12->13	0	0	205	58	0	21	3	1	6	143	0	0	1	0	5	3	446
13->14	0	0	230	83	1	17	5	0	10	119	0	4	0	0	2	3	474
14->15	0	0	224	84	2	20	3	0	7	138	1	8	4	0	1	2	494
15->16	0	0	228	91	2	21	2	0	7	151	2	3	5	0	2	2	516
16->17	0	1	250	59	0	20	2	0	7	158	2	3	6	1	1	2	512
17->18	0	1	230	65	3	20	0	0	6	147	3	2	4	1	5	3	490
Qtr Tot	0	2	1367	440	8	119	15	1	43	856	8	20	20	2	16	15	2932

Figure 31. Report. Change in class count pattern and increase in system errors for lane.

Error Vehicle by Hour Report ----------------------------

Site: 501-ILLINOIS_SPS-6 Lanes: #1

Classification: LTPP_2 Start Class 0 End Class 15

FROM: Tue Mar 27 00:00:00 2007 TO: Wed Mar 28 00:00:00 2007

Number of Vehicles

Hour

Error Num	0->1	1->2	2->3	3->4	4->5	5->6	6->7	7->8	8->9	9->10	10->11	11->12	12->13
Legal	124	93	98	107	118	209	372	336	195	152	390	416	427
Too Long	0	0	0	0	0	0	0	0	0	0	0	0	0
Smpl Qu	0	0	0	0	0	0	0	0	0	0	0	0	0
Axl Qu	0	0	0	0	0	0	0	0	0	0	0	0	0
Up Loop	0	0	0	0	0	0	1	1	5	3	0	0	1
Too Fast	0	0	0	0	0	0	0	0	0	0	0	0	0
Uneq Axl	0	0	0	0	0	0	0	0	0	0	0	0	0
Dwn Only	1	0	0	0	0	0	1	10	17	21	0	2	2
UpBounce	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Axle	0	0	0	0	0	0	0	0	0	0	0	0	0
Zero Axl	0	0	0	1	0	0	0	5	8	16	1	2	2
One Axle	0	0	0	0	0	0	0	3	0	1	0	0	0
Too Slow	0	0	0	0	0	0	0	1	0	0	0	0	0
Axl Ordr	0	0	0	0	0	0	0	0	0	0	0	0	0
Lp Ordr	0	0	0	0	0	0	0	0	0	1	0	0	0
OfHit(E)	0	0	0	0	0	0	0	0	0	0	0	0	0
OfHit(W)	0	0	0	0	0	0	0	0	0	0	0	0	0
Ovr Hght	0	0	0	0	0	0	0	0	0	0	0	0	0
Spd Chng	0	0	0	0	0	0	0	0	1	0	0	0	0
Wt Diff	0	0	0	0	0	0	1	0	0	0	0	0	0
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0
Uneq Det	1	1	0	0	1	4	2	19	38	32	8	8	5
Wrong Ln	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailgate	1	0	0	0	0	0	0	0	1	0	0	0	0
Onscl	0	0	0	0	0	0	0	0	0	0	0	0	0
Safety	0	0	0	0	0	0	0	0	0	0	0	0	0
Invalid	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 32. Report. System error identification.

In monitoring the distribution of vehicle classification counts, certain anomalies are best checked by "drilling down" to individual vehicle records by means of a process that will be covered in detail in Section 4. A few examples follow:

- Too many Class 13s and/or Class 15s caused by:
    - Improper loop delay setting, which results in two or more vehicles being combined into a single vehicle when traffic is dense.
    - Malfunctioning weigh sensor or improper sensor sensitivity setting, which results in a system adding axles ("ghost" axles) to vehicles.

- Too many Class 8s in relation to Class 9s caused by a system dropping one or more axles from some Class 9s.

- Too many Class 6s in relation to Class 9s caused by improper loop delay setting, which results in some Class 9s' tractor and trailer being split into two individual vehicles.

Note that a "drill down" to individual records can only be performed on vehicles meeting the user's criteria for a system's storing data as individual vehicle records (as opposed to a vehicle being only a "count" in various bins). Identification of erroneous data via review of reports generated from binned data is the first step in determining whether or not a system is, in general, functioning correctly and whether or not each day's data is suitable for its intended use.

The review of reports generated from individual vehicle records, as covered by the procedures that follow, provides more insight as to whether or not a drill down to certain individual vehicle records in order to determine the cause(s) of erroneous data is feasible. Subject to a system's data storage capacity, it may be of benefit to program the system to capture <u>all</u> vehicles to individual vehicle records for a day, or even a partial day, so that more comprehensive analyses can be performed on erroneous and/or questionable data.

3.2.2. Individual Vehicle Record Summary Reports

The next step in the QC process is a check of reports that summarize data contained in the individual vehicle records. Typically, a system is programmed to capture trucks, either by classification or by steer axle weight threshold, to individual vehicle records. The primary purpose of this check is to:

- Identify classification problems caused by:
    - Improper classification algorithms
    - Improper loop settings
    - Improper weigh sensor threshold setting

- Identify inaccurate weights caused by:
    - A malfunctioning weigh sensor
        - On-going vs. intermittent
    - Improper weigh sensor threshold setting

- Identify obvious calibration problems.

3.2.2.1. Identification of Classification Problems

Although some of these classification checks may appear to duplicate checks made on the binned data, they lead the way to a drill down process to analyze individual vehicle records in order to determine the cause of erroneous and/or questionable data.

Figure 33 displays a report that summarizes data from individual vehicle records for one lane of a system. This system is programmed to capture any vehicle with a steer axle weight of 3,500 pounds or greater, regardless of class, as a stored vehicle record. However, this report includes only truck classes (4 through 14) and unclassified vehicles (Class 15 for this system). A review of this type of report provides the analyst with a good overview of whether or not the system is functioning properly, and if not, what to look for in a drill down to individual vehicle records for further analyses.

Classification distributions and the number of unclassified vehicles can vary significantly from site to site and the analyst must be knowledgeable as to what type of pattern is typical for each site. The report displayed in Figure 33 is for a site in Michigan that does experience a relatively high volume of Class 13 vehicles. Although for most states a seven percent Class 13 count would indicate a problem, the summary data included in this particular report does not suggest any significant problems with the system. However, if this type of report did indicate a classification problem, the analyst might want to take a quick look at a few individual records generated by the Office Computer application software before going to the effort of importing data into a spreadsheet or database program for extensive analyses (as will be discussed later).

DISTRIBUTION OF WEIGHT VIOLATIONS AND INVALID MEASUREMENTS FOR VEHICLES CLASSES 4-15

SITE NO : 315 Location : MICHIGAN 315 - US 23(NB) Lane(s) : 1

DATE : 10/01/02 County : MI State-ID : CA Direction : N

CLASSIFICATION	TOTAL VEHICLE COUNTED	VEHICLES WITH INVALID MEASURE	TOTAL VEHICLES WEIGHED	TOTAL VEHICLES OVERWT.	PERCENT VEHICLES OVERWT.	******** NUMBER OF WEIGHT VIOLATIONS ********** AXLE	TANDEM	GROSS	BRIDGE
4	61	0	61	1	2	1	0	0	0
5	384	4	380	9	2	9	0	0	0
6	114	2	112	8	7	3	6	0	6
7	12	0	12	6	50	2	3	0	5
8	255	8	247	10	4	8	2	0	3
9	3106	117	2989	311	10	133	192	53	234
10	109	7	102	59	58	20	29	44	59
11	141	6	135	2	1	2	0	0	0
12	43	0	43	0	0	0	0	0	0
13	310	33	277	221	80	49	183	208	218
14	3	0	3	0	0	0	0	0	0
15	104	7	97	19	20	0	19	2	11
TOTALS	4642	184	4458	646	14	227	434	307	536

NUMBER OF VEHICLES WITH DATA ERRORS : 0

PERCENT VEHICLES NOT CLASSFIED (CLASS 15) : 2.2

PERCENT VEHICLES WITH INVALID MEASUREMENTS : 4.0

Figure 33. Report. Individual vehicle record class and weight summary data for one lane.

Figure 34 displays three examples of unclassified vehicles (Class 15 for this system). The first record is actually a Class 9 vehicle that was not properly classified due to its short Axle 2-3 spacing. The average drive tandem spacing for the Class 9's predominant Type 3S2 vehicle is 4.3 feet. From this record, it cannot be determined if any of the items below apply:

- This was an unordinary Class 9 with very small drive tandem wheels.
- The system did not properly process the Axle 2-3 spacing.
- All of the spacings are too short because the system is not properly processing the axle spacings.

It is noted that the "Speed" is reasonable, as is the "Veh.Length" (overall vehicle length). For systems that have been calibrated for overall vehicle length, if a vehicle record suggests that the system has elongated axle spacings or has added one or more trailing "ghost" axles, a comparison of the overall wheelbase (sum of all axle spacings) with the overall vehicle length is in order. With very rare exceptions, the overall length should be greater than the overall wheelbase.

The second record's data indicates that the system properly processed the vehicle's data elements. The system's classification algorithm should be checked to see if one of the items below applies:

- A three-axle vehicle with an Axle 1-2 spacing of 24.9 is not accounted for.
- The axle spacings are covered but the subject vehicle's gross weight is not accounted for in conjunction with the axle spacings.

The third record includes a "ghost" axle (Axle No. 3). This could be caused by either a malfunctioning weigh sensor, or an improper weigh sensor threshold setting.

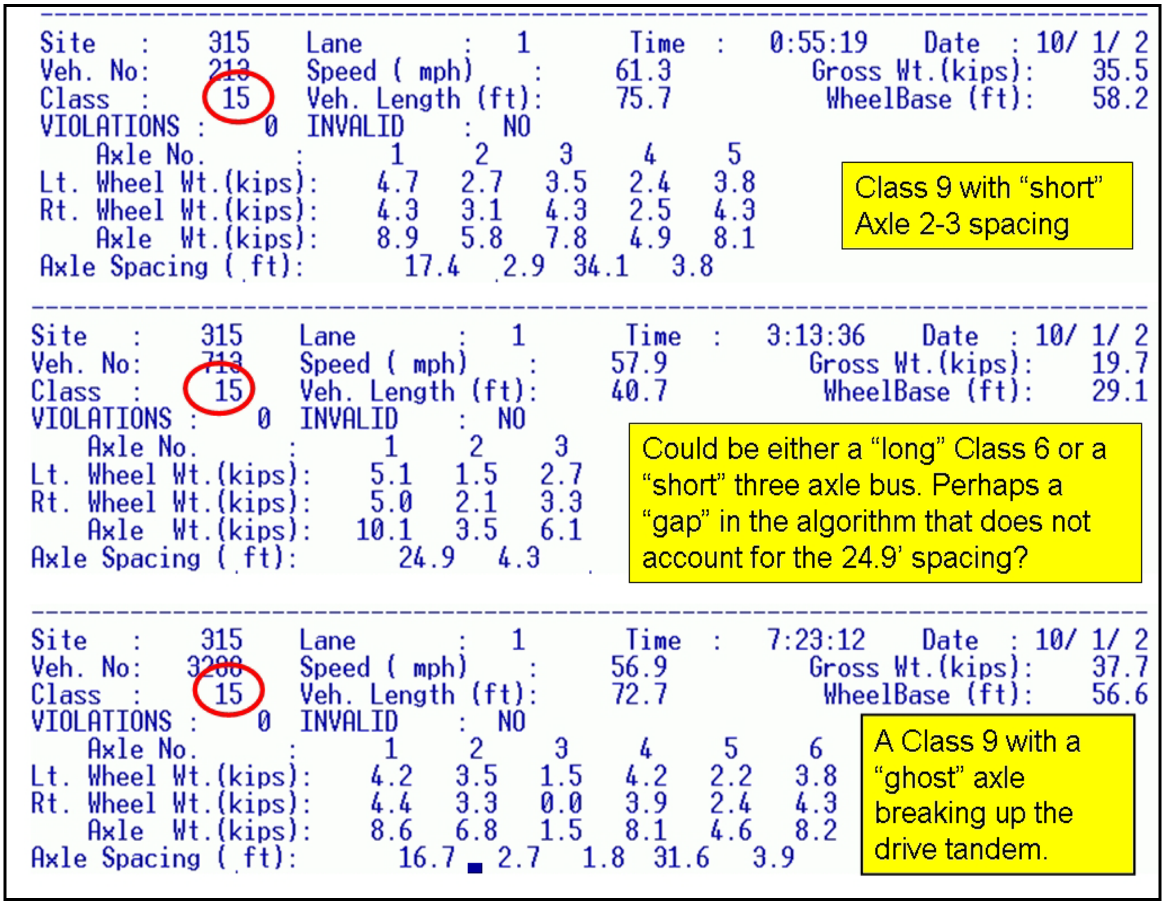


Figure 34. Screenshots. Examples of vehicles not classified by the system.

Figure 35 displays two vehicle records which would appear to be legitimate Class 13s based upon the vehicles' data elements. Figure 36 displays a vehicle labeled as Class 13 due to its axle spacings and gross weight meeting the classification algorithm's parameters for Class 13. However, it is evident that this record contains "ghost" axles.

If a system generates a significant number of vehicle records that contain "ghost" axles, and a diagnostic check indicates that the signals from the weigh sensors look ok, try adjusting the sensors' threshold settings and observe the effect on the sensors' weight reading outputs. These adjustments must be made with care such that the system does not start to drop axles from its vehicle data outputs. One check for this is a before and after comparison of the Class 9 versus Class 8 ratio. If the Class 8 counts increase and the Class 9 counts decrease, it is a good indicator that the system is dropping axles for some of the Class 9s.

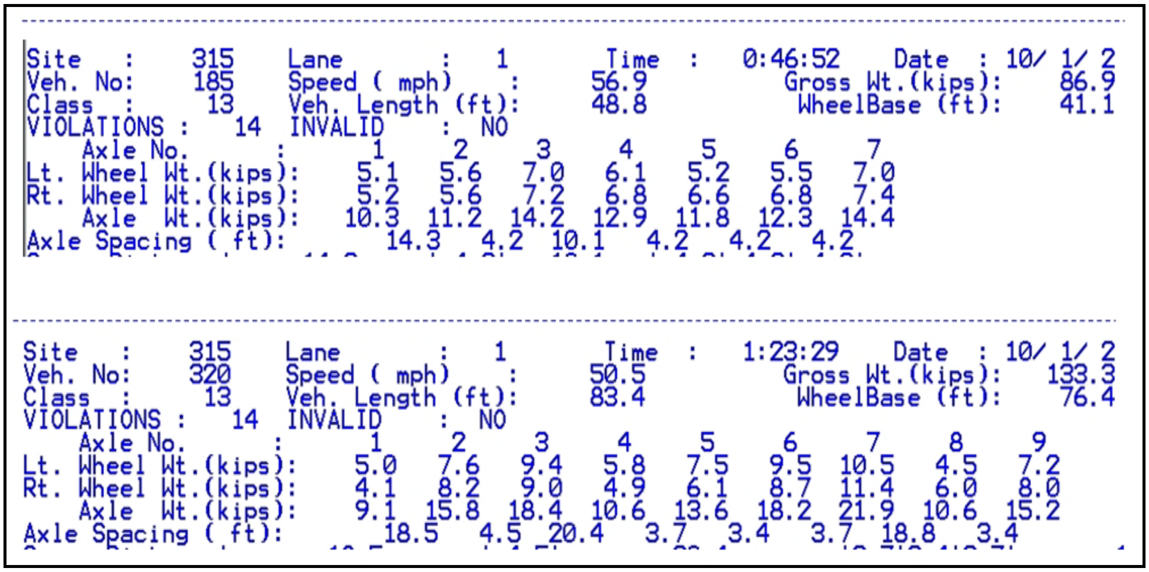


Figure 35. Screen shots. Legitimate Class 13 vehicles.

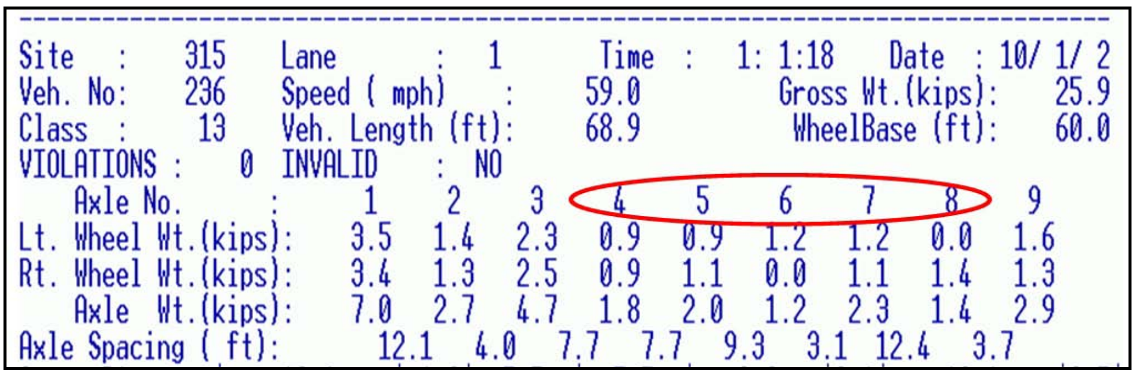


Figure 36. Screen shot. Vehicle misclassified as Class 13 due to "ghost" axles.

Figure 37 displays two vehicle records in succession, the first a Class 6 and the second a Class 5. Note that these two records are in the same lane at the same time (at least to the nearest second). It is also noted that the second vehicle has a recorded speed of 144.3 mi/h, which is another indicator that the WIM record is not valid. These two records are actually for a single combination vehicle, probably a Type 32 truck-trailer (Class 9) with a long tow bar (something similar to the photo in Figure 38). Since the loops did not pick up the tow bar and "timed out" before detecting the trailer, the system treated this combination vehicle as two individual vehicles.

Figure 39 displays a Class 9 logging truck. This vehicle is comprised of a three-axle tractor and a tandem trailer connected to the tractor by only the logs and a tubular steel connector. This is another configuration that can result in a system treating the combination vehicle as two individual vehicles. However, in this case, the second record would have an Axle 1-2 spacing of approximately 4.3 feet and, due to the tandem's being too heavy for a Class 1 vehicle under most class algorithms, would probably have been labeled as an "Unclassified" by the system.

```
--------------------------------------------------------------------------------
Site   :    109    Lane          :   4       Time  :   8:26:33    Date  :  9/10/ 2
Veh. No:    828    Speed ( mph)    :        57.1           Gross Wt.(kips):    45.9
Class  :      6    Veh. Length (ft):        26.5             WheelBase (ft):    23.9
VIOLATIONS :     0  INVALID      :  NO
    Axle No.          :      1     2     3
Lt. Wheel Wt.(kips):     6.4   7.5   7.7
Rt. Wheel Wt.(kips):     6.4   8.8   9.0
    Axle  Wt.(kips):    12.8  16.4  16.7
Axle Spacing ( ft):          16.6   4.5
--------------------------------------------------------------------------------
Site   :    109    Lane          :   4       Time  :   8:26:33    Date  :  9/10/ 2
Veh. No:    830    Speed ( mph)    :       144.3           Gross Wt.(kips):    31.8
Class  :      5    Veh. Length (ft):        10.5             WheelBase (ft):    13.3
VIOLATIONS :     0  INVALID      :  NO
    Axle No.          :      1     2
Lt. Wheel Wt.(kips):     8.3   7.9
Rt. Wheel Wt.(kips):     8.1   7.5
    Axle  Wt.(kips):    16.5  15.4
Axle Spacing ( ft):          10.5
--------------------------------------------------------------------------------
```

Figure 37. Screen shot. Two records for one combination vehicle.

Figure 38. Photo. Class 9 Type 32 with long towbar.

Figure 39. Photo. Class 9 logging truck.

To prevent a system's loops from dropping out and creating two individual records for certain combination vehicles, the typical fix is to increase the system's loop time-out setting. However, for a site that at times experiences heavy traffic, an increase in the loop time-out setting may result in a system combining two or more tailgating vehicles into a single record. For this type of site the adjustment of the loop time-out setting may be a trial and error process to determine what setting produces the fewest errors. Consideration should also be given to the intended use of the data. If the priority is to collect the most accurate truck size and weight data as possible, it may not be deemed important if some tailgating autos are not counted and classified properly.

Any system is going to label some "real" vehicles as unclassified and misclassify some vehicles as displayed in the above examples. This is particularly the case when vehicles do not pass through the site within the lane lines or at normal speeds. A few random misclassified vehicles are not normally cause for concern. However, if a system's percentage of unclassified or misclassified vehicles starts to increase in the absence of verification that traffic characteristics have changed, a more in-depth analysis of vehicle records should be performed.

3.2.2.2. Identification of Weight Data Problems

Reports generated by a WIM vendor's application software should also include summary information on the weight data contained in the individual vehicle records. The report shown in Figure 33 displays information on the number of vehicles having "invalid measurements" (as per criteria programmed by the user) as well as information on the number of vehicles flagged as being in violation of weight limits, and a breakdown of the types of weight violations. This particular system conforms to LTPP's "model specification" (refer to Appendix A), which states:

An "invalid measurement" code shall be assigned to any vehicle ... when:

- *The left and right wheel weights of any axle have a difference of 40 percent or more; and*
- *Either of the wheel weights of such axle exceeds 2.0 kip. Both the 40 percent and 2 kip values shall be programmable by the operator.*

Regardless of a system's method(s) for flagging potentially erroneous weights, any system is going to generate some weights that are not valid estimates of static weights. As with erroneous classification, the number of erroneous weights can vary significantly among WIM sites depending upon truck operating characteristics, pavement conditions, type of equipment, etc. Based upon documentation gathered during onsite testing and observation, as well as initial analyses of vehicles being flagged as having potentially erroneous weights, the analyst should develop rules for each WIM site in regard to what levels of routine weighing errors caused by truck operating characteristics may be expected without raising a flag that a system might be malfunctioning.

Figure 40 displays a report that provides weight summary information from individual vehicle records for each of a system's three WIM lanes. For this system, a warning flag is applied to a vehicle's record when an "invalid measurement" (as discussed above) is detected, as well as other detections by the system (such as unequal detection counts by the sensors of left versus right wheel hits) that the vehicle's axle weights and GVW might be erroneous. Although the system's assignment of warning flags for 13 percent of the trucks in Lane 1 is certainly not indicative that a weigh sensor is not working, it is a relatively high percentage and should prompt a more detailed analysis to determine which weigh sensor is causing the problem. Upon such determination, real-time checks of the system's settings for the sensor can be made, and depending upon the particular features of the system, diagnostics on the sensor can be performed.

If all real-time checks of the sensor do not indicate a problem, more extensive analyses should be performed to try to determine a pattern of intermittent malfunction. This system provides detailed reporting information on system errors and warnings, so the next step is to generate a report on the errors and warnings.

Site: 051-WESTSAC(EB)_YOL-50-0.6 Lanes: EB4 EB3 EB2 EB1
Classification: CALIF3 Start Class 0 End Class 15
FROM: Tue Feb 11 00:00:00 2003 TO: Wed Feb 12 00:00:00 2003

	Lane Number					
Class	1	1	2	2	3	3
	Count	%	Count	%	Count	%
2	32	2.5	57	2.8	26	6.5
3	96	7.4	205	10.0	118	29.5
4	19	1.5	40	2.0	21	5.3
5	311	24.1	554	27.1	204	51.0
6	73	5.7	110	5.4	11	2.8
7	2	0.2	1	0.0	0	0.0
8	138	10.7	176	8.6	5	1.3
9	434	33.7	651	31.8	14	3.5
10	5	0.4	4	0.2	0	0.0
11	113	8.8	127	6.2	0	0.0
12	8	0.6	18	0.9	0	0.0
13	1	0.1	1	0.0	0	0.0
14	31	2.4	64	3.1	0	0.0
15	26	2.0	40	2.0	1	0.3
Total	1289	34.5	2048	54.8	400	10.7

	Lane Number					
Status	1	1	2	2	3	3
Good	1098	85.2	1939	94.7	399	99.8
Violating	23	1.8	29	1.4	0	0.0
Warning	168	13.0	80	3.9	1	0.3

Figure 40. Report. Class distribution, weight violation counts, and warning counts by lane.

Figure 41 displays an abbreviated report listing counts of vehicles having system errors or warning flags by hour of day for the system's Lane EB4. This report makes it evident that the relatively high percentage of warnings displayed in the Figure 40 report is due to "Wt Dif" flags, which indicates that these vehicles met the criteria for "invalid measurement" as discussed previously. It is also noted that this problem is occurring on an intermittent basis. During each of the hours 2 to 3, 10 to 11, and 23 to 24, over 26 percent of the vehicles were flagged. It would appear that the problem occurs to a much lesser extent during the afternoon hours, rather than late night and morning hours. Any number of conditions, including the effects of temperature or moisture on conductor connections, can cause intermittent erroneous outputs by a weigh sensor, as shown in this report.

Error Vehicle by Hour Report ----------------------------
Site: 051-WESTSAC(EB)_YOL-50-0.6 Lanes: EB4
Classification: CALIF3 Start Class 5 End Class 15
FROM: Tue Feb 11 00:00:00 2003 TO: Wed Feb 12 00:00:00 2003

Hour	Good	Too Long	Smpl Qu	Axl Qu	Up Loop	Too Fast	Uneq Axl	SpdChng	Wt Dif	HdwyShrt	Uneq Det	Wrong Ln	Tailgate	Total
0->1	15	0	0	0	0	0	0	0	4	0	0	0	0	19
1->2	14	0	0	0	0	0	0	0	5	0	0	0	0	19
2->3	15	0	0	0	0	0	0	0	6	0	0	0	0	21
3->4	11	0	0	0	0	0	0	0	2	0	0	0	0	13
4->5	28	0	0	0	0	0	0	0	4	0	0	0	0	32
5->6	21	0	0	0	0	0	0	0	5	0	1	0	0	27
6->7	63	0	0	0	0	0	0	0	13	0	0	0	0	76
7->8	59	0	0	0	0	0	0	0	14	0	3	0	0	76
8->9	79	0	0	0	0	0	0	0	10	0	2	0	0	91
9->10	76	0	0	0	0	0	0	0	6	0	3	0	0	85
10->11	72	0	0	0	0	0	0	0	29	0	1	0	0	102
11->12	66	0	0	0	0	0	0	0	5	0	3	0	0	74
12->13	75	0	0	0	0	0	0	0	6	0	3	0	0	84
13->14	82	0	0	0	0	0	0	0	2	0	1	0	0	85
14->15	68	0	0	0	0	0	0	0	9	0	0	0	0	77
15->16	64	0	0	0	0	0	0	0	3	0	2	0	0	69
16->17	44	0	0	0	0	0	0	0	2	0	1	0	0	47
17->18	43	0	0	0	0	0	0	0	1	0	1	0	0	45
18->19	41	0	0	0	0	0	0	0	4	0	1	0	0	46
19->20	26	0	0	0	0	0	0	0	4	0	0	0	0	30
20->21	13	0	0	0	0	0	0	0	0	0	0	0	0	13
21->22	13	0	0	0	0	0	0	0	1	0	1	0	0	15
22->23	18	0	0	0	0	0	0	0	1	0	0	0	0	19
23->24	19	0	0	0	0	0	0	0	7	0	0	0	0	26
Total	1025	0	0	0	0	0	0	0	143	0	23	0	0	1191

Figure 41. Report. Error and warning vehicles by hour for lane.

For sites that experience strong crosswinds and also have a relatively high percentage of combination vehicles with empty or very light trailers, a review of some of the vehicle records with “Weight Difference” warning flags might reveal that a high percentage of these records look similar to the display in Figure 42. This vehicle, traveling in a bidirectional site’s eastbound lane, is an empty 2S12 Class 11 with very little weight on the trailer wheels and the trailers’ lighter wheel weights are all on the left side. If the analyst can verify that the site did experience windy conditions for the time frames that the “Weight Difference” warning flags were higher than normal and that the winds were in a direction (from the north) that would hit the trailers of the eastbound vehicles on their left sides, the odds are very good that the left weigh sensor is functioning properly. Likewise, if the right weights of the empty trailers in the site’s westbound lanes have lower readings, it is very likely that wind is causing the warning flags.

(1052) LANE EB3 TYPE 11 GVW 26.1 kips LENGTH 62 ft
18-K ESAL 0.074 SPEED 60 mph MAX GVW 80.0 kips Tue Feb 11 04:21:18.65 2003

UNIT	SEPARATION (ft)	LEFT WT (kips)	RIGHT WT (kips)	TOTAL WT (kips)	ALLOWABLE (kips)
1		3.1	3.9	7.0	20.0
2	14.3	3.6	4.2	7.9	20.0
3	17.2	1.3	2.1	3.4	20.0
4	10.9	1.5	2.9	4.4	20.0
5	17.4	1.1	2.3	3.4	20.0

Warning 19: Significant Weight Difference !

Figure 42. Screen shot. Vehicle with “light” wheel weights on left side.

For the example vehicle record displayed in Figure 42, the trailers’ left and right wheel weight differences are insignificant from both axle weight and gross weight perspectives. If vehicles flagged by a system as having potentially erroneous weights due to the left versus right axle weight imbalance percentage are automatically discarded from weight reporting by the analyst for a site that routinely experiences crosswinds, many legitimately weighed empty vehicles may be discarded. This might drastically skew data utilized for both weight violation and loading analyses purposes. It is strongly recommended that for a system including features allowing the analyst to program parameters for assignment of left versus right imbalance flags that the system be programmed not to flag vehicles that are obviously empty and have minor left versus right weight imbalances for the trailer axles. For the example displayed in Figure 42, increasing the minimum wheel weight threshold to 3.0 k would result in this vehicle not being flagged.

For systems utilizing some type of “off-scale” sensors, which detect and flag any vehicle with one or more wheels not fully hitting a weigh sensor, there is no guesswork. If a wheel hits an off-scale sensor, the wheel’s full weight is not being reported by the system.

For sites that do not have extremely smooth pavement profiles, the pavement may cause enough bouncing of truck wheels (particularly those of empties) to cause a significant left versus right wheel weight imbalance. If it is not feasible to fix the pavement smoothness problem, the analyst will need to determine what level of potential weight error flags is normal for the site and whether or not the system should be re-programmed to ignore imbalances for the lighter axles (if the system has this feature). This may also be the case where a weigh sensor is not perfectly even with the adjacent pavement, due to either a poor installation or post-installation rutting in the pavement.

Also, some sites experience occasional trucks that travel with their right wheels very close to, or even on, the shoulder stripe of the outside lane. Unless the weigh sensors at such a site extend to the right of the shoulder stripe, the system may report only partial weights for the right wheels of these trucks. Although this condition is simple to verify by onsite observation or by use of off-scale sensors, to determine by data analyses alone requires extensive effort.

A system's reporting of the types and/or times of error and warning flags is very beneficial to the analyst in isolating the cause and extent of erroneous weight problems. However, intermittent malfunction problems can be very difficult to diagnose, and the analyst may have to make extensive detailed analyses of individual vehicle records. This is best performed by importing the vehicle records into a spreadsheet or database program, as will be discussed in SECTION 4.

In the absence of adjustments in a system's calibration factors or a change in a site's truck operating characteristics, a significant increase or decrease in a system's weight violations suggests a problem with weight outputs beyond "fine tuning" of calibration factors. Weight violation data contained in reports such as those displayed in Figure 33 and Figure 40 should be monitored by the analyst for significant changes from the norm.

Figure 43 displays a report listing gross weight distributions for each truck classification for the system's Lane 4. If the WIM vendor's application software or the agency's software provides for generation of a daily report displaying gross vehicle weight averages and/or distributions, it would be a good idea for the analyst to also monitor these for any significant changes. The monitoring of the 3S2 steer axle average weights for any significant increase or decrease is also a good check if the application software provides for such reporting.

It may be difficult to determine if a change in weight outputs during cold weather is due simply to a seasonal variability in truck operating characteristics, or if cold temperatures are having an effect on either the weigh sensors themselves or a system's electronics. Although long-term monitoring, as will be discussed in SECTION 5, may provide an answer, performing an onsite validation with test trucks during cold weather would be of great benefit. For bending plate systems, consideration should always be given to the possibility of the scale pits being filled with ice.

If it is apparent that a weigh sensor is generating erroneous weights (or no weights) and the problem cannot be fixed from the office, it may be possible to access the system and, via the system software, remove the problem sensor and double the good sensor's output as a temporary fix until an onsite fix can be performed.

DISTRIBUTION OF GROSS WEIGHTS FOR VEHICLE CLASSIFICATIONS 4 THROUGH 15

SITE NO : 007 — Location : SANTA NELLA - 005, 20.2 — Lane(s) : 4
DATE : 07/08/03 — County : MER — State-ID : CA — Direction : N

VEHICLE COUNTS

GROSS WT (kips)	X	X	X	4	5	6	7	8	9	10	11	12	13	14	15	TOTALS
0- 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5- 10	0	0	0	0	104	0	0	0	0	0	0	0	0	0	0	104
10- 15	0	0	0	1	164	3	0	0	0	0	0	0	0	0	3	171
15- 20	0	0	0	4	148	26	0	0	1	0	2	0	0	0	12	193
20- 25	0	0	0	5	58	9	0	41	9	0	41	0	0	4	8	175
25- 30	0	0	0	2	24	4	0	25	93	0	27	3	0	15	4	197
30- 35	0	0	0	4	3	3	0	37	260	5	13	3	0	3	9	340
35- 40	0	0	0	3	2	4	0	31	291	3	11	6	0	2	4	357
40- 45	0	0	0	5	1	3	0	20	331	2	22	11	0	0	4	399
45- 50	0	0	0	7	1	2	0	7	405	2	35	7	0	1	1	468
50- 55	0	0	0	0	0	0	0	2	327	2	52	4	0	1	4	392
55- 60	0	0	0	0	0	0	0	0	311	1	67	11	0	1	4	395
60- 65	0	0	0	0	0	0	0	1	304	2	52	11	0	1	1	372
65- 70	0	0	0	0	0	0	0	0	450	5	48	13	1	2	8	527
70- 75	0	0	0	0	0	0	0	0	855	6	69	6	0	9	5	950
75- 80	0	0	0	0	0	0	0	0	702	13	26	1	0	2	2	746
80- 85	0	0	0	0	0	0	0	0	82	2	0	0	0	1	2	87
85- 90	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
90- 95	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	4
95-100	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
100-105	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
105-110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110-115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
115-120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
> 120	0	0	0	0	0	0	0	0	4	0	1	0	4	0	1	10
TOTALS	0	0	0	31	505	54	0	164	4434	43	466	76	5	42	75	5895

Figure 43. Report. Gross weight distribution for each truck class for lane.

3.2.2.2.1. Recap of Erroneous Weight Output Checks and Analyses

A system's generating erroneous weight outputs for a particular lane may be caused by:

- A malfunctioning weigh sensor.
- An improper system setting for a weigh sensor.
- An obviously erroneous calibration factor or factors.
- Trucks not traveling within lane lines.
- Strong crosswinds.
- Effects of very cold temperatures on weigh sensors or electronics.
- For bending plates, a scale pit filled with ice.

To identify the cause, extent, and action to be taken the analyst should use a "drill down" process. By reviewing canned reports the analyst can typically determine that the weights for a particular lane either have changed from the norm or are obviously erroneous, and whether or not the problem is ongoing or intermittent. Depending upon the extent of the erroneous weight outputs, the analyst may need to review only a sampling of individual vehicle records generated by the vendor's application software to identify the cause. It is very beneficial to understand and utilize any error and/or warning flags applied to the vehicle records by a particular system. If the cause of a problem cannot be identified by a quick review of a few vehicle records, it may be necessary to perform extensive analyses of individual vehicle records as will be discussed in SECTION 4.

As a summary, to check for erroneous weight outputs, the analyst should:

1. Determine which weigh sensor is generating erroneous weights by checking for:
    - "0" outputs.
    - Partial weight outputs.
    - Weight outputs that have significantly increased.
    - Erratic weight outputs.

2. Determine if a sensor is generating erroneous weights consistently or intermittently.
    - If consistent:
        - Check sensor's calibration factor settings.
        - Remotely access system and perform any sensor diagnostics available by the system.
    - If intermittent, attempt to determine if there is any type of pattern that provides a clue to the cause, such as:
        - Time of day.
            - Temperature or moisture.
        - Heavy versus light traffic.
        - Ongoing roadwork in the vicinity of the site.
        - Crosswinds.

3.3. AUTOMATED VALIDATION PROGRAMS

Several agencies validate WIM data utilizing proprietary software programs, which flag any vehicle in the individual vehicle records that does not conform to user defined rules and generate summary reports on flagged vehicles.

The Travel Monitoring Analysis System (TMAS) is an example of an automated validation program. TMAS is currently used to submit monthly traffic volume data to FHWA and will be used to submit vehicle classification and truck weight data to FHWA as well, replacing the Vehicle Travel Information System (VTRIS). Figure 44 presents a summary of the TMAS quality control checks for WIM data. It is noted that the TMAS checks are performed utilizing TMG formatted data files which do not contain all WIM data elements (such as a warning or system error code) whereas some automated validation programs perform checks utilizing the "raw" data files.

FHWA Travel Monitoring Analysis System
Quality Control checks

Class Quality Control checks

24 hours of data check
Consecutive zero's check
% Class by day Maximum
% Class by day based on historical value

Weight Quality Control checks

Total Weight vs. Sum of Axle Weights
Any Axle Weight Range Check
Any Axle Spacing Range Check
Sum or Axles by Vehicle Class
Minimum Number of Axles Per Class
Steering Axle Weight Average vs Historical Average
(class 9 by day by lane)
Average Tandem Spacing vs Historical Average
(class 8 and above by day by lane)

Figure 44. List. Summary of FHWA TMAS QC Checks.

Appendix B lists a multitude of possible validation rules that were developed under the Transportation Pooled-Fund Study SPR-2 (182), titled Traffic Data Edit Procedures Pooled Fund Study, Traffic Data Quality "TDQ". Additional information on this study is available online at http://www.fhwa.dot.gov/policy/ohpi/tdep.htm.

3.4. DATA QC – FOLLOW-UP PROCEDURES

If routine QC checks suggest a problem with a system's operation, the analyst should remotely access the system and perform a check of the system's setup parameters and the settings for any component that might be causing the problem. If the setup parameters and component settings appear to be correct, any diagnostics of the components provided for by the system should be performed. The data analyst may need technical assistance in performing and analyzing certain component diagnostics. It may also be beneficial to perform extensive data analyses, as discussed in SECTION 4. In this section it is discussed how to determine which component is malfunctioning, and if the problem is intermittent, at what time of day or under what conditions the malfunction occurs.

<u>It is extremely important to determine whether sensor and/or processing problems are caused by system malfunction, by improper system settings, by traffic conditions, or by environmental conditions!</u>

3.4.1. Real-Time System Check of Parameters and Settings

The purpose of this check is to utilize the remotely accessible features of a system to check, and if necessary, modify parameters, settings, values, etc. affecting system operation and data output. Such modifications made from the office can often eliminate various data problems without the need to make a visit to a site. Checks may include (but certainly not limited to):

- System/site setup configurations.
- Time and date.
- Parameters for data file collection, vehicle record capture, etc.
- Parameters for assigning flags for potentially erroneous weights, warnings, system errors, etc.
- Parameters for assigning weight violation codes.
- Classification algorithm.
- Loop time out settings.
- Weigh sensor thresholds (including "zero").
- Calibration factors for weights, speed (and thereby axle spacings), and overall vehicle length.

It is critical that upon acceptance of a WIM system from the contractor or vendor all system parameters, settings, values, etc. be documented and that any subsequent adjustments be documented and maintained as well.

It is far beyond the scope of this manual to go into detail on all of the various WIM system features available by the various system manufacturers. Several examples are displayed, but it is the responsibility of the analyst (perhaps with some dependency on available technical support) to become familiar with available features of any particular system.

Figure 45 displays an example of a record of the various parameters and values for Lane 4 of a particular system that is utilizing Quartz Piezo weigh sensors. The information on the lane's sensor configuration should not change unless modifications are made to the layouts of the site's lanes and/or sensors.

- The "Axle Sensors" parameters provide the system with each weigh sensor's input information and the distances from the leading edge of the lead loop to each of the weigh sensors.

- The "Loop" parameters provide similar type information for the loops. The loop "Width (cm)" values are used by the system to generate each vehicle's overall length, and these values are "fine tuned" by analysis of calibration or validation test truck data.

- The "Processing" parameters include:

    - A "MaxTimeout" value, which is the time allowed (in milliseconds (ms)) between a vehicle's triggering the lead loop and when the vehicle has been considered to have completed passage through the system (thus completing the vehicle's record).

    - User defined values for flagging vehicles with left versus right axle weight imbalances.

    - The distance between the leading and trailing weigh sensors ("Axl Sep"), which is used by the system to generate each vehicle's speed.

    - A value (in percent) for adjusting steer axle calibration factors ("Dynamic Comp")

The values for the "Axl Sep" and the "Dynamic Comp" are typically fine-tuned based upon analysis of calibration or validation test truck data.

Tennessee	LTPP Lane - 4	Current As of Date:	May 31, 2007				
Site Parameters >				Site Parameters >			
Lane Name			4				
Lane State			ENABLED				
Axle Sensors >		Select Axle	1	Upstream Loop >		Loop State	ENABLED
		Axle State	ENABLED			Module UID	9
		Module UID	7			Channel Num	2
		Channel Num	0			Polarity Active	LOW
		Polarity Active	HIGH			Width (cm)	285
		Type	KISTLER_DUAL	Downstream Loop >		Loop State	ENABLED
		Distance(cm)	274			Module UID	9
		Temp State	ENABLED			Channel Num	3
		Temp Module UID	5			Polarity Active	LOW
		Temp Channel Num	0			Width (cm)	285
Axle Sensors >		Select Axle	2			Distance(cm)	670
		Axle State	ENABLED	Processing >	MaxTimeout(ms)		3000
		Module UID	7		Dynamic Comp(%)		103
		Channel Num	1		Sig Wt Diff(%)		40
		Polarity Active	HIGH		Min Axle Wt(kg)		1360
		Type	KISTLER_DUAL		Veh Rec Mode		Split
		Distance(cm)	274		Axl Sep(cm)		306
		Temp State	ENABLED	DIOM Debounce Time	Loop On (ticks)	40	
		Temp Module UID	5		Loop Off (ticks)	40	
		Temp Channel Num	0		OvrHgt On (ticks)	40	
Axle Sensors >		Select Axle	3		OvrHght Off (ticks)	0	
		Axle State	ENABLED		Axle On (ticks)	40	
		Module UID	7		Axle Off (ticks)	40	
		Channel Num	2	Axle Snsor Debounce	Type	KISTLER_DUAL	PIEZO
		Polarity Active	HIGH		On (ticks)	8	8
		Type	KISTLER_DUAL		Off (ticks)	40	40
		Distance(cm)	579				
		Temp State	ENABLED				
		Temp Module UID	5				
		Temp Channel Num	0				
Axle Sensors >		Select Axle	4				
		Axle State	ENABLED				
		Module UID	7				
		Channel Num	3				
		Polarity Active	HIGH				
		Type	KISTLER_DUAL				
		Distance(cm)	579				
		Temp State	ENABLED				
		Temp Module UID	5				
		Temp Channel Num	0				

Figure 45. Screen shot. Example of a record of a system's setup parameters for one lane.

Figure 46 displays a record of the same system's calibration factors for its Lane 4. It is noted that this system provides for calibration factors for five speed points.

Tennessee	LTPP Lane - 4	Current As of Date:	May 31, 2007				
Calibration >							
Select Lane		4					
Select Axle Sensor		1					
Threshold		16	(55 mph)	(60 mph)	(65 mph)	(70 mph)	(75 mph)
WIM Calib Factors >		Select Speed Bin	1	2	3	4	5
		Max Speed (kph)	88	96	105	112	120
		Calib Factor	2764	2764	2764	2764	2764
Select Lane		4					
Select Axle Sensor		2					
Threshold		16					
WIM Calib Factors >		Select Speed Bin	1	2	3	4	5
		Max Speed (kph)	88	96	105	112	120
		Calib Factor	2934	2934	2934	2934	2934
Select Lane		4					
Select Axle Sensor		3					
Threshold		16					
WIM Calib Factors >		Select Speed Bin	1	2	3	4	5
		Max Speed (kph)	88	96	105	112	120
		Calib Factor	2764	2764	2764	2764	2764
Select Lane		4					
Select Axle Sensor		4					
Threshold		16					
WIM Calib Factors >		Select Speed Bin	1	2	3	4	5
		Max Speed (kph)	88	96	105	112	120
		Calib Factor	2934	2934	2934	2934	2934

Figure 46. Screen shot. Example of a record of a system's weight calibration factors for one lane.

Figure 47 displays a remotely accessible onsite menu page from another system type that also shows various parameters for the site, system sensor channel inputs, and the current value for "Loop delay constant" (which is the loop "timeout" or "drop out" previously discussed in this manual).

```
Mode:1
Weight select:  lbs
Length select:  feet
Speed  select:  mph
Number of Lanes: 4
Station code    :  109
Station name    :  INYO

Lane  1:
Lane sensor config.    [0-9,A,B]: 7
Distance (Front-Front) Loop 1-2:   1616
Length of Loop 1              :    800
Loop 1 input channel          :      1
Loop 2 input channel          :      2
WP 1 Input Channel     [0,1-16]:      1
WP 2 Input Channel     [0,1-16]:      2
Assign def. class      [0,1-15]:      0
Loop delay constant    [%]     :     20
```

Figure 47. Screen shot. Example of a system's sensor configuration and loop delay constant for one lane.

It is important that the analyst have available all system setup parameter records. It is also important that the analyst be made aware of any changes in a system's values and/or factors related to calibration, and that the analyst record and maintain such values and factors for reference.

3.4.2. Remote Real-Time Tests and Diagnostics of System Component Operation

The purpose of this check is to utilize the remotely accessible features of a system to check signal outputs and/or other operational aspects of individual components of a system.

Again, it is far beyond the scope of this manual to go into detail on all of the WIM system features available by the various system manufacturers. Several examples will be displayed, but it is the responsibility of the analyst (perhaps with some dependency on available technical support) to become familiar with the features of any particular system. For certain systems, very detailed analyses can be performed on a sensor's raw signal output, but obtaining and analyzing such signal output is typically best left to engineers or technicians well versed in a system's operation.

Figure 48 displays a remote accessible onsite menu page from a system as well as three of the tests that can be accessed from the menu.

- Menu Item "5" displays how long each passing vehicle is sensed by the leading and trailing loops for each of the site's four lanes. The values are displayed in timer "ticks", each tick being the number of milliseconds set up in the system's setup menu (4.5 ms for this system). A value less than 20 usually indicates a misadjusted or faulty loop.

- Menu Item "6" displays the frequency, detuning, and output status for each of the four loop channels on the selected "DIP" loop board.

- Menu Item “C” displays the analog to digital conversion value for the bending plate assigned to the system’s Channel 1 with no traffic crossing the sensor. For this system, this value should be approximately 800. Although the “Measured value” will briefly increase when a vehicle crosses the weighpad, and the “max. value” will also increase; the “min. value” should not decrease. An extreme reading, such as “0” or “4096”, typically indicates failure of either the bending plate or its amplifier board.

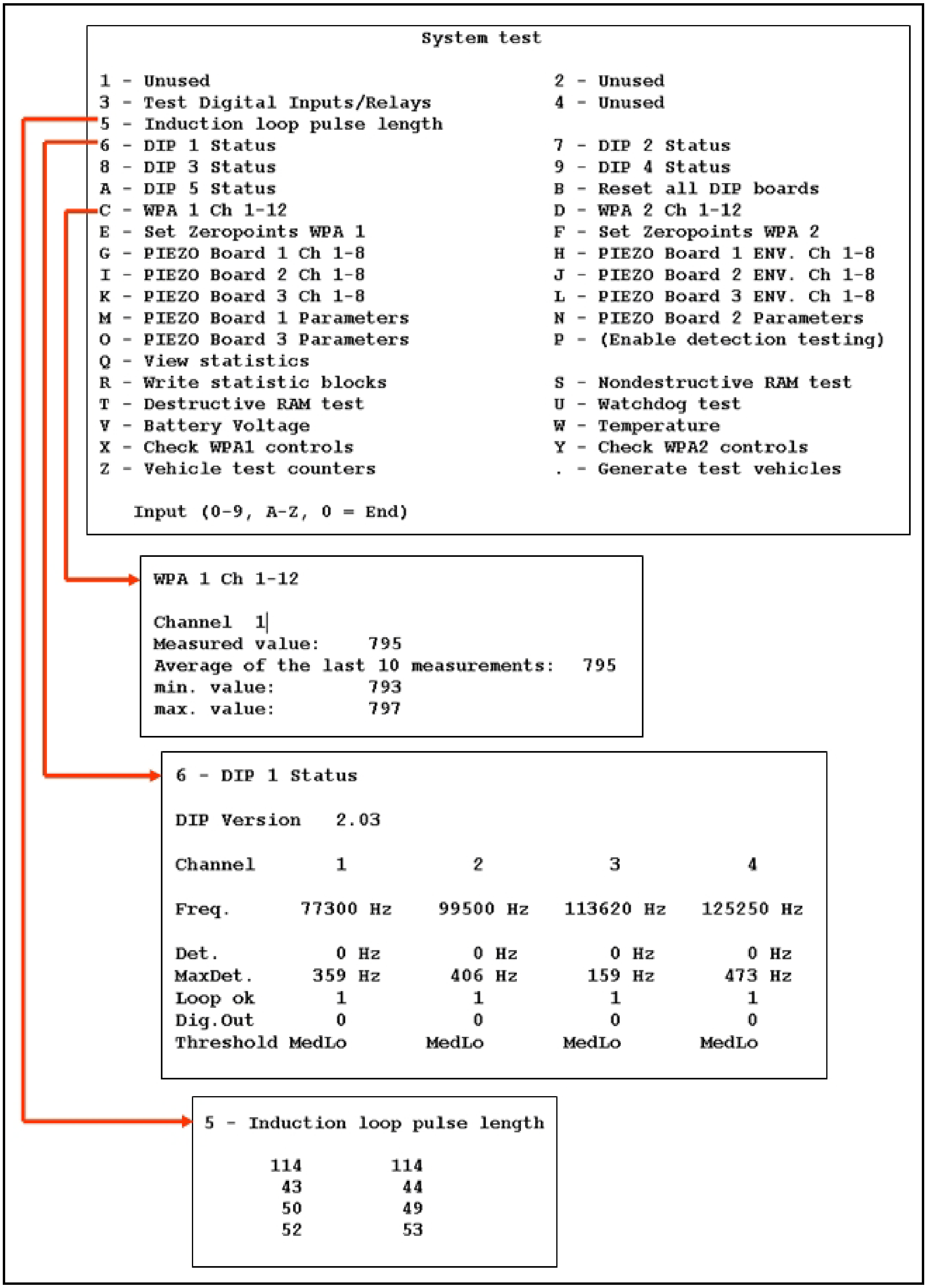


Figure 48. Screen shots. Example of a system's menu screen for selecting system tests ("System test") and three examples of the tests.

Figure 49 displays Lane SB#2 real time vehicles in another system's "Diagnostics" mode. For each vehicle, the lead and trail loop durations, as well as the axle count detections and their durations for each of the two bending plate weigh sensors are displayed. Observing the real time traffic for several minutes per lane in this mode provides a good idea if the loops and weigh sensors are functioning correctly.

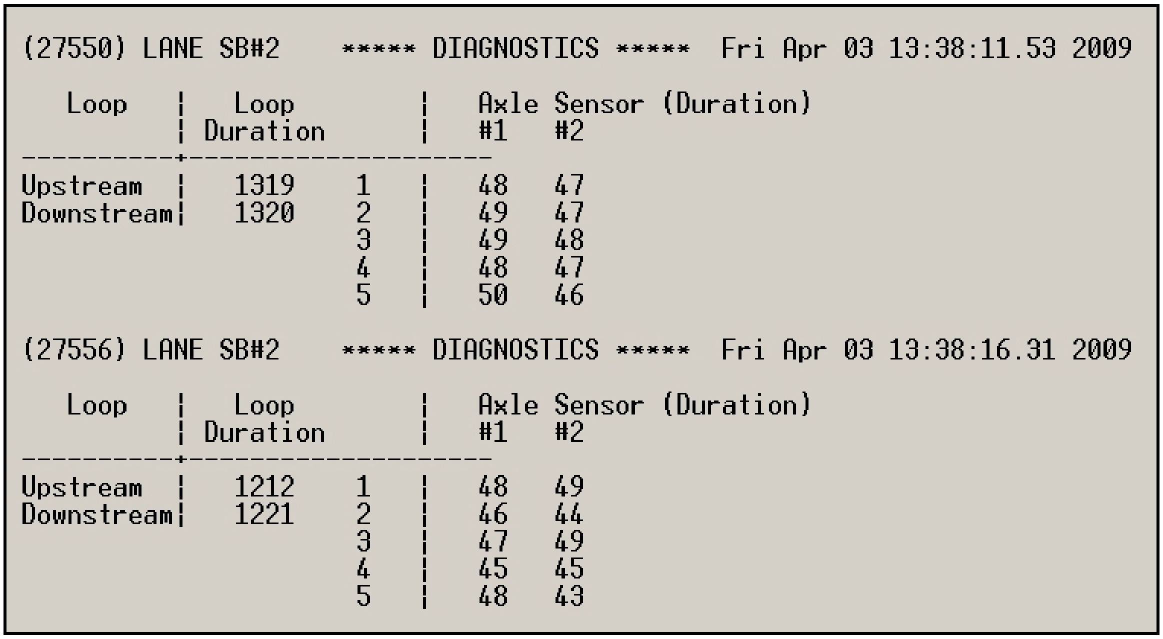


Figure 49. Screen shot. Example of a system's loop and weigh sensor duration diagnostics.

Figure 50 displays the same system's remotely accessible onsite menu page showing the current "Base Line Value" for the system's "WIM Sensor 1". This value should be 2048, plus or minus 100. For this system type, if a sensor's base line is out of range it will require an onsite visit to make adjustments to the sensor's interface card. An extreme value, such as 0 or 4096, typically indicates failure of the sensor or its interface card.

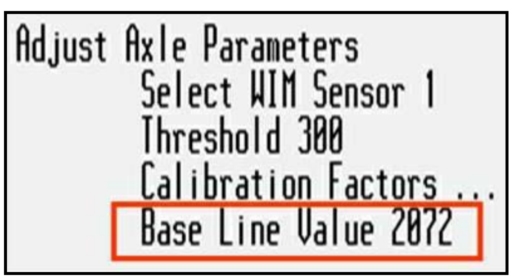


Figure 50. Screen shot. Example of system's menu page displaying a bending plate sensor's baseline value.

It is typical that at times the analyst may be able to attribute invalid data to traffic and/or environmental conditions instead of system malfunction. There may also be times that the analyst or technical support personnel can make corrections or adjustments to a system's setup parameters or various component settings remotely from the office to correct data problems. Unfortunately, at times it is necessary either to replace a failed system component or to make an adjustment to a hardware component that cannot be accomplished remotely via software or firmware. However, the more information the analyst can provide to the field technician as to which component is possibly causing data problems, the better prepared the field technician can be in having the necessary tools and equipment to fix the problem.

SECTION 4. EXTENSIVE DATA ANALYSES UTILIZING INDIVIDUAL VEHICLE RECORDS

The purpose of performing extensive analyses of the individual vehicle records is to attempt to isolate and identify system component problems not identifiable by routine real time reviews, data QC, or real time checks of a system's parameters and settings. Such analyses are typically necessary when system component problems are intermittent and/or subtle in nature.

The method for performing these analyses is to import the individual vehicle records into a spreadsheet or database program and perform search, filter, sort, or other procedures as well as to have the program generate tables and graphs necessary to find any pattern which might isolate intermittent system component malfunction. It may also well be that analyses of questionable data indicates such data is probably attributable to conditions other than component malfunction. The ability to import the individual vehicle records is, of course, somewhat dependent upon the data file format of the records. Appendix C provides guidance on data import using Excel and ASCII data files formatted in accordance with LTPP's model specifications.

Figure 51 displays a snapshot of a portion of a simple spreadsheet that was created by importing data from an ASCII text file as per the procedures contained in Appendix C. This spreadsheet includes only the data elements from the individual vehicle record included in the ASCII text file, although as displayed in Figure 51, it has been filtered for records of vehicles that could not be classified by the system using its classification algorithm. This system assigns a "Class 15" to its unclassified vehicles. It is often beneficial to delineate the Axle Spacing columns as has been done in this example. By performing sorting and filtering schemes on unclassified vehicles, the analyst may be able to detect flaws in the classification scheme or possibly an error in how the classification scheme was entered into the system's classification algorithm. Also, analysis of the records may indicate that the vehicles were not properly processed by the system (as would appear to be the case in this example).

It is noted that almost all of the records displayed in the Figure 51 sampling have a "VIOL" flag "21" which is this system's code for an "Unequal Axle Detection" (the right and left weigh sensors did not detect the same number of wheel hits for the vehicle). It is noted that when this system experiences a vehicle for which a wheel hit is detected on one side of an axle but not the other, the system "invents" the missed wheel's weight by copying the detected wheel's weight to the opposite wheel. In that this may or may not provide a reasonably valid estimate of the axle's static weight, the vehicle is flagged with the warning. Most of the vehicles flagged with the "Unequal Detection" flag would appear to have legitimate wheel and axle weights for the first four axles followed by weights and/or axle spacings that appear to be erroneous. This suggests a problem with a weigh sensor or its signal processing.

	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	CL	GVW	LGTH	SPEED	VIOL	AX1RT	AX1LT	AX2RT	AX2LT	AX1-2	AX3RT	AX3LT	AX2-3	AX4RT	AX4LT	AX3-4	AX5RT	AX5LT	AX4-5	AX6RT	AX6LT	AX5-6	AX7RT	AX7LT	AX6-7
2	15	88.0	48	65	21	5.6	5.5	8.2	9.2	15.8	7.6	8.6	4.5	10.5	10.5	11.7	10.5	10.7	8.5	0.5	0.5	2.0			
3	15	84.5	49	66	21	5.4	5.3	7.7	7.6	17.1	6.8	7.1	4.3	12.0	10.3	12.2	0.6	0.6	2.1	11.1	10.1	6.4			
4	15	73.5	69	61	21	5.5	6.2	7.6	8.0	11.8	5.4	5.5	4.5	8.3	8.8	34.4	0.5	0.5	1.9	8.3	8.7	2.1			
5	15	63.9	74	54	21	5.7	5.6	6.4	5.8	16.2	5.0	5.9	4.3	7.8	6.9	31.5	6.4	7.2	4.0	0.6	0.6	1.7			
6	15	47.5	96	50	21	2.4	3.1	8.6	9.1	11.4	1.4	1.4	52.1	1.8	1.8	2.6	3.7	3.7	2.7	3.5	3.5	2.8	1.8	1.8	2.7
7	15	46.8	66	68	21	6.5	6.5	4.5	4.5	17.1	4.8	4.8	4.3	2.3	2.3	32.8	4.0	4.0	3.9	1.3	1.3	0.8			
8	15	45.0	76	66	21	3.7	5.0	1.4	2.9	17.3	3.0	3.0	4.1	3.8	3.8	34.2	2.8	2.8	0.8	5.3	5.3	3.2	1.1	1.1	0.7
9	15	43.1	58	64	0	1.7	2.6	4.5	7.1	15.5	7.2	7.5	4.0	5.4	7.2	29.7									
10	15	42.1	11	17	21	5.6	5.6	6.7	0.9	4.2	7.1	1.3	1.1	3.8	3.8	7.8	3.7	3.7	1.0						
11	15	41.8	72	62	21	5.9	5.9	3.7	3.7	16.7	4.3	4.3	4.0	3.7	3.7	32.3	1.4	1.4	0.7	1.9	1.9	3.9			
12	15	41.4	51	63	21	2.5	5.5	5.8	8.0	13.1	5.2	6.0	21.3	2.1	2.1	9.4	2.0	2.0	0.7						
13	15	40.6	69	68	21	5.8	5.8	3.0	3.0	17.0	2.1	2.1	4.1	3.1	3.1	36.9	4.3	4.3	3.9	1.9	1.9	0.7			
14	15	40.5	70	68	21	6.6	6.6	4.0	4.0	19.7	3.8	3.8	4.1	2.6	2.6	30.0	1.1	1.1	0.7	2.2	2.2	9.1			
15	15	39.7	63	66	21	6.1	6.1	3.7	3.7	16.8	3.1	3.1	4.0	2.6	2.6	31.2	2.8	2.8	3.9	1.5	1.5	0.7			
16	15	38.7	56	69	21	5.4	5.5	1.8	3.6	16.7	4.2	1.8	4.0	1.9	1.9	18.5	0.8	0.8	0.7	3.1	2.4	3.7	1.4	4.1	4.8
17	15	37.7	59	61	21	5.0	5.0	2.8	2.8	13.3	2.5	2.5	4.0	2.9	2.9	29.0	1.8	1.8	0.7	3.9	3.9	3.1			
18	15	37.6	76	72	21	5.3	5.2	2.0	3.6	19.3	2.2	4.0	4.3	1.4	2.2	32.5	3.9	3.9	3.6	2.0	2.0	0.7			
19	15	36.3	70	65	21	3.5	6.2	1.6	4.4	16.1	1.2	4.4	4.3	1.6	1.6	31.7	3.7	3.7	3.4	2.2	2.2	0.7			
20	15	36.3	63	70	21	4.3	4.3	1.8	1.8	11.9	5.1	5.1	4.2	2.4	2.4	29.5	2.8	2.8	9.7	1.7	1.7	0.7			
21	15	35.2	68	62	21	6.6	6.6	3.3	3.3	17.1	3.0	3.0	4.2	1.8	1.8	29.4	1.9	1.9	9.6	1.0	1.0	0.7			
22	15	34.9	61	66	21	5.0	5.0	2.8	2.8	16.6	3.2	3.2	4.1	1.5	1.5	29.4	3.3	3.3	3.8	1.7	1.7	0.7			
23	15	32.3	2148	8	21	3.8	3.8	5.0	5.0	0.5	4.9	4.9	3.9	2.4	2.4	0.5									
24	15	30.9	72	67	21	2.7	2.7	3.2	3.2	4.1	2.7	2.7	18.6	3.8	3.8	9.2	3.1	3.1	21.0						
25	15	28.4	41	64	21	4.9	4.9	4.0	4.0	12.5	2.8	2.8	20.0	2.4	2.4	0.7									
26	15	26.0	79	74	18	2.2	4.0	3.1	4.4	28.0	0.9	3.3	20.4	3.3	4.8	16.3									
27	15	26.0	46	53	21	3.0	3.0	7.7	7.7	17.1	0.8	0.8	17.4	0.9	0.9	0.6	0.6	0.6	5.5						
28	15	25.9	47	62	21	2.9	2.9	2.3	2.3	0.6	4.2	4.2	13.4	1.9	1.9	18.3	1.6	1.6	8.1						
29	15	23.9	32	75	21	1.5	1.5	4.4	6.4	14.5	5.4	4.8	4.1												
30	15	22.1	42	69	21	1.6	1.6	5.2	5.2	13.7	1.5	1.5	17.9	1.9	1.9	2.7	0.9	0.9	0.8						
31	15	22.0	66	66	21	1.8	1.8	2.5	2.5	11.6	1.8	1.8	4.2	2.9	2.9	35.6	1.9	1.9	3.9						
32	15	21.5	43	71	21	2.9	2.9	3.7	3.7	12.5	1.0	1.0	17.8	2.2	2.2	2.7	1.0	1.0	0.7						
33	15	19.6	72	75	0	1.5	2.4	3.0	3.9	13.5	2.0	1.1	35.3	2.1	1.2	2.9	0.7	1.8	3.2						
34	15	19.3	61	72	21	3.2	3.8	1.4	1.3	16.1	1.6	2.8	4.7	1.5	1.5	29.6	1.2	1.2	4.7						
35	15	19.0	41	67	21	2.5	2.5	2.1	2.1	13.7	1.0	1.0	15.1	2.4	2.4	2.5	1.5	1.5	0.7						
36	15	18.6	39	63	21	1.8	1.8	1.2	1.2	0.7	2.5	2.5	10.3	1.4	1.4	0.8	0.8	0.8	15.1	1.5	1.5	2.7			
37	15	15.9	18	66	21	2.6	2.6	1.3	1.3	0.7	2.5	2.5	9.8	1.4	1.4	0.7									
38	15	15.9	32	60	21	2.0	2.0	1.5	1.5	0.6	2.2	2.2	10.1	1.5	1.5	0.7	0.8	0.8	12.1						
39	15	15.2	36	70	0	1.0	1.3	2.2	2.0	11.4	2.3	1.9	14.4	2.5	1.9	2.8									
40	15	14.9	20	65	21	3.5	3.5	0.8	0.8	0.7	3.1	3.1	11.6												
41	15	14.8	18	67	21	2.8	2.8	2.8	2.8	10.4	1.8	1.8	0.8												
42	15	13.6	33	66	21	1.0	1.0	1.5	1.5	9.3	2.6	2.6	14.9	1.6	1.6	0.7									
43	15	13.5	18	57	21	2.1	2.1	1.5	1.5	0.6	2.0	2.0	9.9	1.1	1.1	0.6									
44	15	13.3	18	61	21	2.3	2.3	1.5	1.5	0.7	1.9	1.9	9.9	1.0	1.0	0.7									
45	15	13.2	23	64	21	2.5	2.5	1.4	1.4	0.7	2.6	2.6	12.3												
46	15	13.0	20	65	21	2.6	2.6	1.7	1.7	0.7	2.1	2.1	11.6												
47	15	13.0	15	64	21	2.0	2.0	1.2	1.2	0.7	2.0	2.0	8.3	1.3	1.3	0.7									
48	15	12.8	21	60	21	2.6	2.6	2.3	2.3	13.7	1.5	1.5	0.6												
49	15	12.6	20	68	21	2.9	2.9	1.6	1.6	0.7	1.8	1.8	10.3												
50	15	12.5	24	60	21	2.3	2.3	1.5	1.5	0.6	2.4	2.4	10.9												
51	15	12.2	42	69	0	0.7	1.5	2.0	2.2	11.0	1.6	0.9	17.5	1.8	1.4	2.7									

Figure 51. Screen shot. Portion of simple spreadsheet filtered for unclassified vehicles.

In looking at some of the records in Figure 51 from a classification only standpoint:

- The vehicle in Row 9 has the axle count and spacings of a Class 8's Type 3S1, but the steer axle weight (1.7 k + 2.6 k) is too light for a typical 3S1 tractor's steer axle (minimum 7 k).

- The vehicle in Row 23 would appear to have a loop-processing problem based upon its overall length (2148 feet), speed (8 mi/h), and axle spacing readings, or else the vehicle was not entirely in its lane.

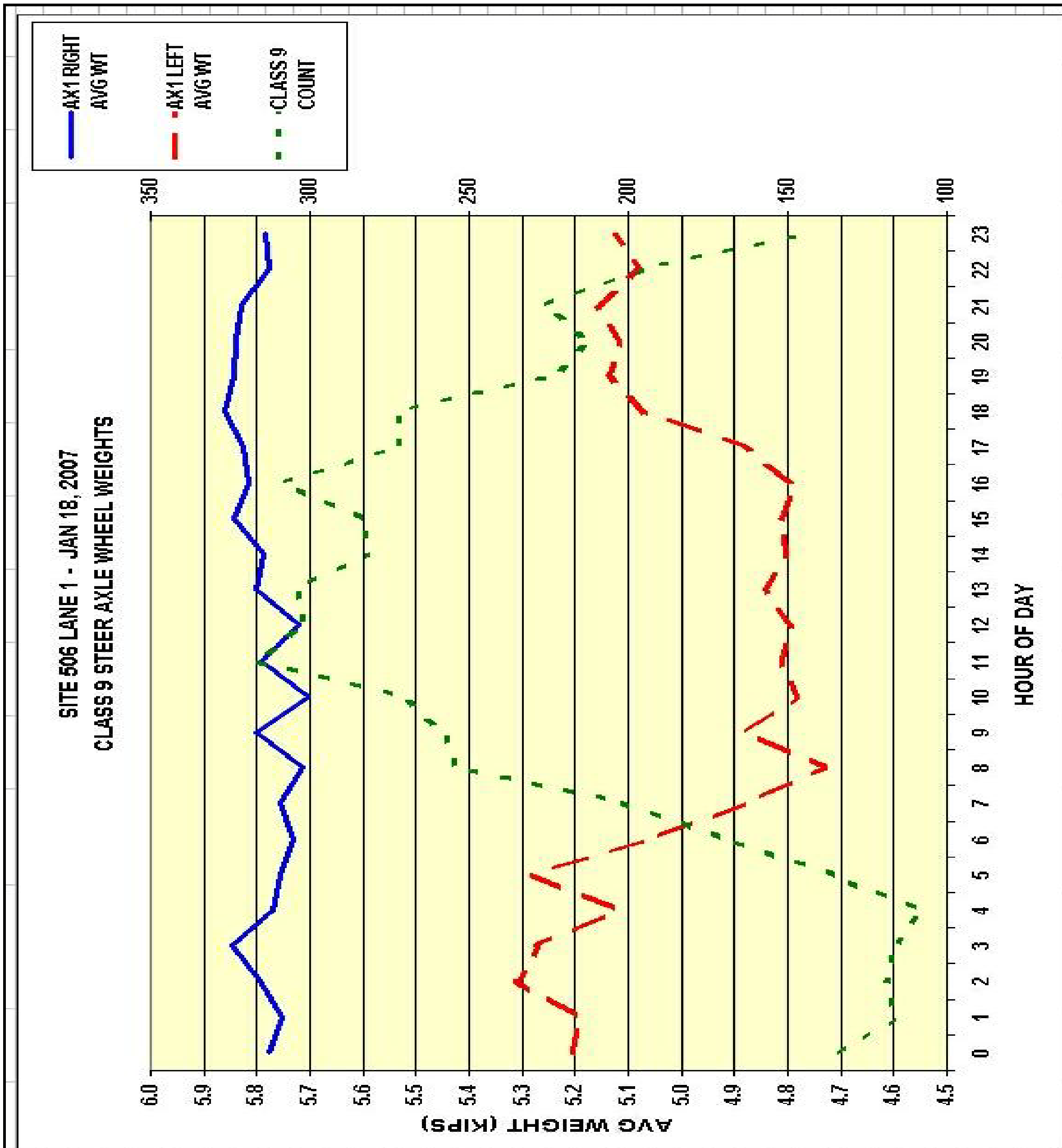
- The vehicle in Row 33 meets the LTPP Classification Scheme for a Class 3 vehicle pulling a small 3-axle trailer, except for the long Axle 2-3 spacing length. This is probably a legitimate vehicle.

- The vehicle in Row 39 has axle spacings meeting the LTPP Classification Scheme for both a Class 3 pulling a 2-axle trailer and a Class 5 pulling a 2-axle trailer. However, the GVW is too heavy to conform to the Class 3 and the steer axle is a bit too light to conform to the Class 5 for this scheme. This is probably a legitimate vehicle.

Therefore, an analysis of the unclassified vehicles in this sampling indicates the problem is in a weigh sensor, not the classification scheme or algorithm. This should prompt the analyst to perform simple diagnostics on the sensors, and if necessary, call for engineering or technical support to perform sensor signal analyses. The extent that this can be performed from the office would be subject to the features of the system.

This system's coding of system errors and warnings by type is of great benefit to the analyst. However, a detailed analysis of the records displayed in Figure 51 would still indicate a sensor problem even in the absence of the warning flag.

Figure 52 displays a plot of a day's Class 9 steer axle right and left wheel weight averages by hour of day. There is an obvious problem in that the system is generating right and left weights being very different, which is attributable to either improper calibration factors or one of the two sensors generating erroneous weight outputs. This situation will be discussed in detail in SECTION 5. The purpose of this analysis is to confirm that the right weigh sensor is outputting a consistent weight whereas the left weigh sensor is not. Between the hours of 6 AM and 6 PM the left sensor's weight outputs drop dramatically, suggesting that the sensor is at times generating only partial weights. This problem, in itself, is not related to calibration factor values. Although the Class 9 volume is at its highest during this same time frame, it is doubtful that the drop in the sensor's steer axle weights is due to the sensors having a "recovery time" problem, given that steer axle hits are relatively well separated from other axle hits. The problem would also not be caused by a large number of the Class 9s riding the shoulder stripe, which would only affect the right sensor's weights. Consideration might be given to the daytime and nighttime difference in temperature or moisture. Regardless, this plot points out a sensor problem and the need for further investigation of the sensor's operation. This type of check should be performed for additional days to see if the pattern is consistent.



HOUR	AX1 RIGHT AVG WT	AX1 LEFT AVG WT	CLASS 9 COUNT
0	5.8	5.2	133
1	5.8	5.2	116
2	5.8	5.3	119
3	5.8	5.3	117
4	5.8	5.1	108
5	5.8	5.3	136
6	5.7	5.1	169
7	5.8	4.9	202
8	5.7	4.7	254
9	5.8	4.9	258
10	5.7	4.8	271
11	5.8	4.8	317
12	5.7	4.8	302
13	5.8	4.8	304
14	5.8	4.8	282
15	5.8	4.8	283
16	5.8	4.8	308
17	5.8	4.9	272
18	5.9	5.1	272
19	5.8	5.1	224
20	5.8	5.1	212
21	5.8	5.2	226
22	5.8	5.1	194
23	5.8	5.1	143
ALL	5.8	5.0	5222

Figure 52. Screen shot. Plot of Class 9 steer axle wheel weights by hour of day.

Figure 53 displays a snapshot from a portion of the spreadsheet used to generate the Figure 52 graph with the “AX1LT” field sorted for ascending values. Many of the “AX1LT” weights are significantly less than the “AX1RT” weights even though the following tandem’s “AX2LT” and “AX3LT” weights are reasonably close to their right wheel counterparts. The tandem’s left wheel weights are generally somewhat lower than the right wheel weights, but based upon the consistency this is probably due for the most part to improper calibration factors.

	J	K	L	M	N	O	P	Q	R	S	T	U
1	GVW	LGTH	SPEED	VIOL	AX1RT	AX1LT	AX2RT	AX2LT	AX1-2	AX3RT	AX3LT	AX2-3
3	68.0	73	63	0	6.2	1.7	9.3	7.7	16.4	8.7	5.6	4.1
4	67.4	73	66	0	4.2	1.7	8.5	7.6	16.3	8.4	5.6	4.6
5	53.9	73	65	0	5.7	1.7	5.8	4.7	17.1	5.6	4.9	4.3
6	39.2	73	63	0	5.6	1.7	4.7	3.7	16.6	4.4	3.7	4.3
7	38.3	74	63	0	5.6	1.7	5.4	3.9	16.7	5.2	4.1	4.2
8	39.2	75	64	0	5.7	1.8	5.0	4.0	17.0	4.5	3.8	4.4
9	69.6	74	63	0	5.5	1.9	7.7	5.5	18.3	7.7	5.8	4.4
10	65.7	74	62	0	6.0	1.9	7.5	6.1	16.7	7.5	5.8	4.4
11	63.5	68	64	0	4.8	1.9	9.6	7.0	15.5	9.8	7.0	4.3
12	41.0	71	63	0	6.1	1.9	5.8	4.2	15.0	5.3	4.1	4.4
13	37.4	74	64	0	5.8	1.9	4.9	3.8	17.2	4.4	3.9	4.2
14	36.8	73	65	0	5.7	1.9	5.1	3.6	15.3	5.1	3.9	4.3
15	32.1	76	63	0	5.5	1.9	4.2	3.2	19.7	4.0	2.9	4.3
16	71.8	72	64	0	5.6	2.0	9.4	7.1	16.5	8.7	7.4	4.1
17	70.8	73	63	0	6.3	2.0	8.4	6.8	16.7	8.5	7.2	4.3
18	70.2	65	65	0	6.1	2.0	9.6	7.8	20.1	9.2	7.3	4.4
19	69.4	62	64	0	5.1	2.0	9.0	7.7	16.9	8.4	7.7	4.4
20	68.9	74	64	0	6.2	2.0	8.8	7.2	16.7	8.6	7.3	4.2
21	63.0	71	64	0	4.7	2.0	7.9	6.5	19.4	7.3	7.0	4.4
22	61.1	73	63	0	6.1	2.0	6.9	4.9	17.3	6.4	5.2	4.4
23	60.5	74	65	0	5.9	2.0	7.7	5.3	16.5	7.6	4.2	4.2
24	59.9	73	65	0	6.1	2.0	6.9	5.3	16.0	6.2	4.5	4.4
25	59.8	74	63	0	5.9	2.0	6.7	5.2	17.5	7.2	4.4	4.4
26	53.4	73	62	0	5.7	2.0	5.9	4.4	17.0	6.5	4.0	4.3
27	45.7	74	62	0	5.8	2.0	5.2	4.0	16.6	5.1	3.9	4.4
28	43.2	63	62	0	5.1	2.0	5.6	4.8	11.5	5.6	5.2	4.1
29	41.4	74	63	0	5.8	2.0	5.4	4.5	17.5	5.2	4.4	4.3

Figure 53. Screen shot. AX1LT sorted for ascending values.

Figure 54 displays a similar screen shot of the spreadsheet but with the “AX1RT” field sorted for ascending values. As is obviously apparent, the right weigh sensor is not displaying the partial weight problem noted for the left sensor.

It would be a virtual impossibility for a Class 9’s left steer axle wheel to only partially hit the left sensor when the trailing tandem’s left wheels fully hit the same sensor, as displayed in Figure 55.

J	K	L	M	N	O	P	Q	R	S	T	U
GVW	LGTH	SPEED	VIOL	AX1RT	AX1LT	AX2RT	AX2LT	AX1-2	AX3RT	AX3LT	AX2-3
49.3	72	69	19	2.6	2.6	4.0	7.0	14.8	3.0	7.8	4.3
39.5	72	63	0	2.7	5.2	5.3	2.6	16.9	5.3	2.1	4.2
22.7	60	55	21	2.7	2.3	4.6	3.7	17.2	2.4	2.0	4.0
42.7	58	68	21	2.9	2.9	1.3	5.6	13.4	1.5	6.6	4.2
24.3	61	73	21	3.1	3.1	3.3	3.3	18.5	2.9	2.9	4.3
44.5	74	70	21	3.3	3.3	3.8	6.0	17.0	3.8	5.7	4.3
36.8	51	69	21	3.3	3.3	3.8	3.8	15.4	3.3	3.3	4.3
27.9	74	71	21	3.3	2.7	2.2	5.2	17.1	1.9	6.1	4.3
58.6	72	72	21	3.4	3.4	5.9	5.9	19.7	5.8	5.8	4.3
33.3	69	69	21	3.4	3.4	3.5	3.5	17.0	2.8	2.8	4.3
48.5	68	66	21	3.5	3.5	6.5	5.3	16.9	4.3	5.3	4.3
22.7	59	65	21	3.5	3.5	1.7	1.7	18.0	1.8	1.8	4.1
52.1	73	65	0	3.6	3.3	3.5	5.5	19.1	3.7	5.9	4.3
49.3	67	68	21	3.6	3.6	5.8	5.8	16.8	3.9	3.9	4.4
26.1	72	68	0	3.6	3.2	2.1	3.2	16.3	1.7	3.5	4.2
74.6	77	68	28	3.7	3.5	5.9	8.4	14.3	6.7	8.0	4.2
49.6	67	65	0	3.7	2.4	3.5	7.8	15.4	3.2	6.2	4.3
74.0	41	68	28	3.8	3.9	8.5	6.8	12.8	7.9	7.6	4.3
65.4	57	67	0	3.8	2.6	7.8	6.1	10.1	8.4	8.0	4.3
35.0	59	63	21	3.8	3.8	3.7	3.7	17.5	3.1	3.1	4.2
32.6	60	76	0	3.8	4.1	4.5	3.3	15.0	3.3	3.0	4.4
32.5	73	68	21	3.9	3.9	2.8	4.6	17.2	2.8	4.0	4.2
66.1	58	70	21	4.0	4.0	7.5	7.5	18.1	7.3	7.3	4.2
44.8	66	67	21	4.0	4.0	4.4	4.4	12.4	4.4	4.4	4.4
36.2	77	66	21	4.0	4.0	3.0	4.5	20.6	3.3	4.7	4.2
23.7	74	66	21	4.0	4.0	1.6	1.6	17.2	1.6	2.5	4.2
74.2	41	67	28	4.1	3.7	8.8	6.4	12.8	8.7	7.3	4.2

Figure 54. Screen shot. AX1RT sorted for ascending values.

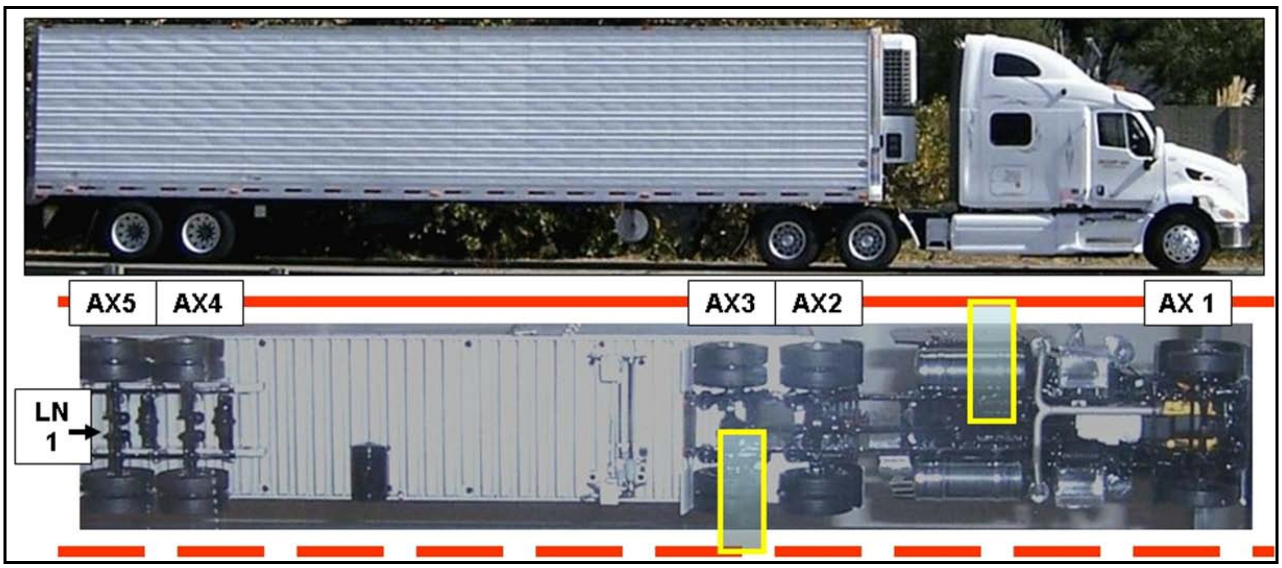


Figure 55. Photo. Class 9, Type 3S2 typical axle and wheel alignment crossing right and left weigh sensors.

The contractor performing data QC and system monitoring for the LTPP Specific Pavement Study (SPS) Traffic Pooled Fund study developed several procedures, utilizing Excel, for analyzing performance of the individual weigh sensors. The spreadsheet is set up to import individual vehicle records from data files that contain specified vehicle types included in Class 9, as well as the vehicles in Classes 10 through 13. This import process is described in Appendix C. For the data files used, columns A through AN of the spreadsheet are populated with the data elements for each imported vehicle record. Columns A through AM include the data elements required by the LTPP Model Specifications and column AN provides for a "Vendor Specific Optional Field". Although various analyses can be performed with this data utilizing only filter and sort procedures, several additional features were added to the spreadsheet's template for automating certain analyses, including the following.

Figure 56 displays the spreadsheet's calculated fields. An "X" flag is displayed in Column AO, labeled "IMBALANCE", for any record for which the vehicle meets the criteria for "Invalid Measurement" in accordance with LTPP's model specifications. The two conditions for this calculated field are:

(1) The left and right wheel weights of any axle have a difference of 40 percent or more.
(2) Either of the wheel weights of such axle exceeds 2.0 kip.

There may be different interpretations as to how "...a difference of 40 percent or more" is calculated, but the intent is that the recorded weight of the lighter of an axle's right and left wheels must be at least 60 percent the weight of the heavier wheel for the axle weight to be deemed a valid measurement.

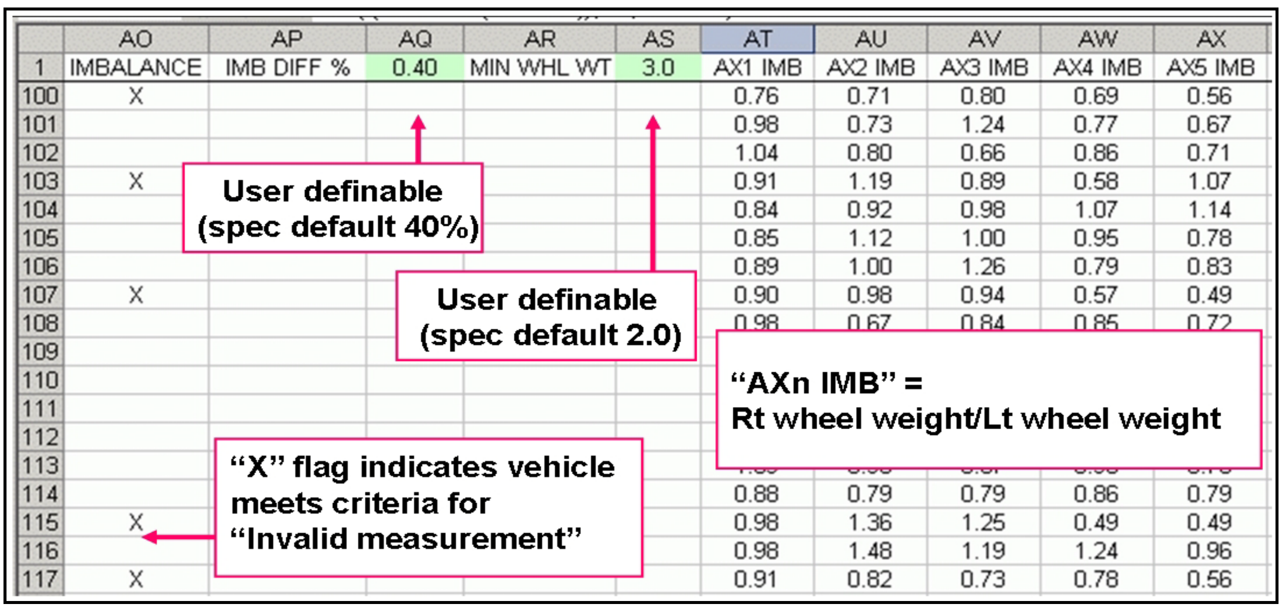


Figure 56. Screen shot. Calculated fields for testing "Invalid Measurement" flags and analyzing axle imbalances.

The actual wheel weight data in each record are used to determine if the "Invalid Measurement" criteria are met, regardless of whether or not a flag was assigned by the system. Cell AQ1 provides for user input of the percent difference value to utilize for condition (1) and Cell AS1 provides for user input of the wheel weight threshold to utilize for condition (2) of the specification. The analyst can experiment and play "what if" with these two values to determine what works best for each site. The default values may work well for sites which have a high percentage of trucks with loaded trailers, but may flag far too many vehicles at sites that have a high percentage of trucks with empty or very light trailers. For the spreadsheet displayed in Figure 55 the user has changed the condition (2) default value from 2.0 to 3.0. It must be remembered that the intent of the Invalid Measurement flag is to identify vehicles appearing to have one or more wheels that did not fully hit the appropriate weigh sensor. As was discussed following Figure 42, an empty trailer's right and left wheel weight difference is insignificant from both axle weight and gross weight perspectives.

For a site that has a large number of trucks with empty trailers, if vehicles flagged by a system as having potentially erroneous weights due to the right versus left axle weight imbalance are automatically discarded from weight reporting by the analyst, then many legitimately weighed vehicles may be discarded. This might drastically skew data utilized for both weight violation and loading analyses purposes. It is strongly recommended that for a system that has features allowing the analyst to program parameters for assignment of right versus left imbalance flags that the system be programmed not to flag vehicles that are obviously empty and have minor right versus left imbalances in terms of weights, not just percentage, for the trailer axles. Simply increasing the minimum wheel weight threshold from 2.0 kip to 3.0 kips might significantly decrease the percentage of vehicles flagged as meeting the criteria for Invalid Measurement.

Columns AT through AX in Figure 56 display the ratio of the right versus left wheel weight for each of axles 1 through 5 for each record. This provides the analyst with a "quick look" at each axle's ratio for the vehicles with flags in the "IMBALANCE" field. If all of the axles have a significant imbalance on the same side it is a good indication that the vehicle may not have been tracking well within the lane lines. If the AX1 imbalance is significant whereas the other four axles look normal, this is typically an indication that a sensor has not reported an accurate weight. If one of a tractor's tandem axles displays a significant imbalance whereas the other does not, this is also an indication that a sensor has not reported an accurate weight.

Figure 57 displays a screen shot of the spreadsheet's table that lists the counts and percentages of the sample's Class 9 vehicles flagged as having Invalid Measurement weights by GVW distribution. As used for this analysis, these flagged vehicles meet the criteria "Invalid Measurement" discussed following Figure 56. This table makes it evident that for this site Invalid Measurement weights are exhibited by lighter vehicles much more than by the heavier vehicles. The lighter the trailer, the more subject it is to effects of bouncing and crosswinds. If the heavier vehicles start to exhibit an increase in the percentage of Invalid Measurement weights, it might well be an indication that one of the sensors is starting to malfunction.

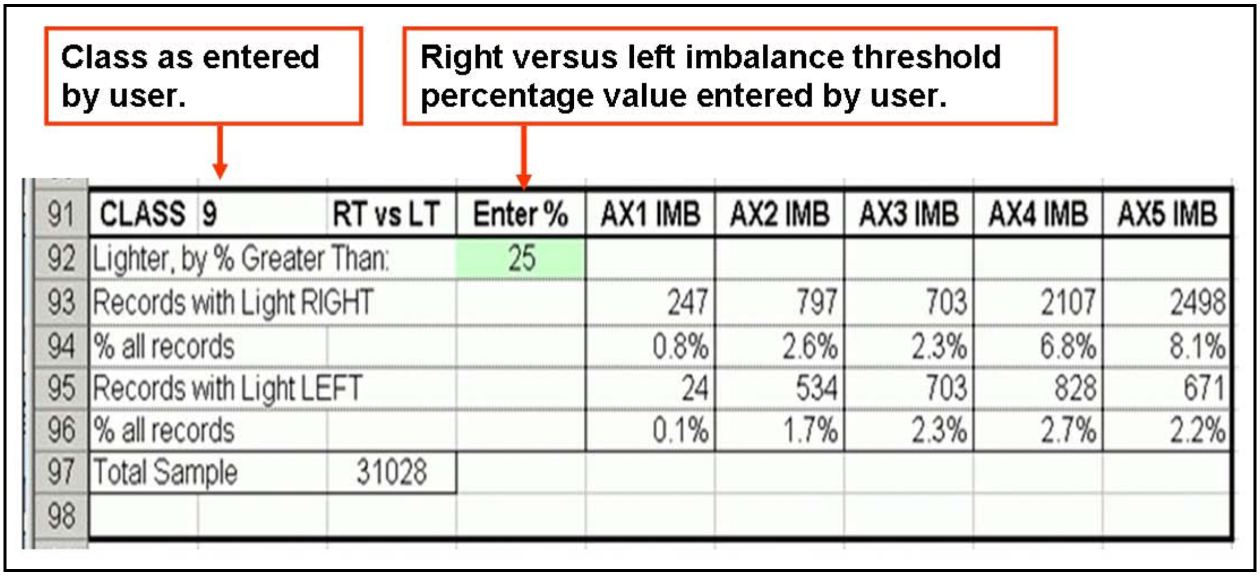
For any data analyst desiring to create spreadsheets with the enhanced analyses features, as displayed in Figures 56, 57, and 58, Excel ASCII Import workbooks and documentation are provided online at www.QualityWIM.com. It is noted that this spreadsheet also includes the additional calibration monitoring analyses features that will be discussed in SECTION 5, for Figure 68through Figure 72.

INVALID WEIGHT		
BY GVW RANGE		
GVW Range	Invalid Weight Count	% Invalid Weight Count
<25	18	54.5%
25-30	62	37.6%
30-35	135	13.1%
35-40	113	7.0%
40-45	120	4.9%
45-50	93	3.1%
50-55	73	2.5%
55-60	77	3.0%
60-65	80	3.3%
65-70	90	3.3%
70-75	198	4.0%
75-80	92	1.5%
80-85	1	0.1%
85-90	0	0.0%
90-95	0	0.0%
95-100	0	0.0%
>100	0	0.0%
All	1152	3.7%

Figure 57. Screen shot. Invalid Measurement weights by GVW range.

Figure 58 displays a snapshot of the spreadsheet's table showing summaries of counts and percentages utilizing the individual Axle 1 through 5 imbalance ratios from the Figure 56 spreadsheet (Columns AT through AX). The purpose of this table is not to identify the extent of the vehicles meeting the criteria for Invalid Measurement but to identify any pattern that might suggest one of the following:

- The right or left sensor is malfunctioning on an intermittent basis.
- A significant number of the trucks' right wheels are not fully hitting the weigh sensor.
- Crosswinds may be having an effect on the right versus left axle weights.



91	CLASS	9	RT vs LT	Enter %	AX1 IMB	AX2 IMB	AX3 IMB	AX4 IMB	AX5 IMB
92	Lighter, by % Greater Than:			25					
93	Records with Light RIGHT				247	797	703	2107	2498
94	% all records				0.8%	2.6%	2.3%	6.8%	8.1%
95	Records with Light LEFT				24	534	703	828	671
96	% all records				0.1%	1.7%	2.3%	2.7%	2.2%
97	Total Sample		31028						
98									

Figure 58. Screen shot. Table displaying summary of axle right versus left weight imbalance statistics.

The analyst can enter the desired percentage value to ascertain the threshold for determining what right versus left weight difference constitutes an axle imbalance. The percentage of imbalances for Axle 1 should always be quite low (unless the trucks at a particular site do travel with their right wheels on the shoulder stripe). On the other hand, at a site with a high percentage of empty trucks the imbalance percentage for Axles 4 and 5 might be quite high (as in the example, using a 25 percent threshold).As the analyst becomes familiar with the different axle weight imbalance patterns, he or she will be able to identify the more subtle sensor problems even when a significant percentage of vehicles are not flagged as meeting criteria for Invalid Measurement.

Is it really necessary to go through the effort of performing such extensive analyses on the right versus left weigh sensor outputs? For some sites or system types perhaps not, but in the absence of these analyses a weigh sensor may be intermittently reporting weights that are inaccurate but too subtle to be noticed by means of less extensive data QC procedures. These types of analyses can also be quite useful in determining whether sensor outputs which appear to be inaccurate estimates of static weights are caused by actual sensor malfunction or by conditions related to truck operating characteristics or crosswinds. Once a spreadsheet or database program has been set up to automatically produce the types of information shown in these examples, it takes very little effort to make quick checks to ensure a sensor's output is not changing. Additional procedures for monitoring individual sensor outputs will be addressed in SECTION 5.

It is noted that for most WIM sites the Class 9 is the predominant truck class and that the steer axle wheel weights are much less affected by a Class 9's loading than the wheel weights of its other axles. As such, many of the extensive data analyses utilizing individual truck records focus on the Class 9 vehicles (particularly the 3S2). In addition, the Class 9 steer axle weights are also a focus of analyses regarding individual sensor weight outputs.

There are many extensive analysis procedures that an analyst can perform, either on routine or ad hoc bases, other than those used in these few examples. Note that such analyses are time consuming and require knowledge of each site's traffic and data characteristics, knowledge of a spreadsheet or database program, and even some imagination. However, these analyses can be extremely beneficial in identifying, isolating, quantifying, and diagnosing a system's data problems.

SECTION 5. STEPS FOR MONITORING SYSTEM CALIBRATION FROM OFFICE

SECTION 3 and SECTION 4 focus on data QC procedures that are intended to ensure that a WIM system is operating to the best of its capabilities. Although such procedures are intended to identify significant size and weight accuracy problems due to improper system settings, malfunctioning components, or traffic operational anomalies, they are not designed to monitor the "fine tuning" of a system's calibration.

The objectives of the calibration monitoring procedures discussed in this section include:

- Maintain system calibration throughout the life of the system.
- Verify the desired effects of calibration factor adjustments on WIM weight, axle spacing, and vehicle length outputs.
- Identify weigh sensors that are intermittently and/or subtly malfunctioning.
- Adjust calibration factors for a weigh sensor exhibiting calibration drift pending onsite recalibration using test trucks.
- Temporarily assign calibration factors for a weigh sensor replacement pending onsite recalibration using test trucks.
- Schedule onsite calibrations/validation for sites with most need when funding and/or resources for running test trucks is limited.

5.1. GENERATE WEIGHT AND AXLE SPACING STATISTICS FOR SAMPLE OF TRUCK TRAFFIC STREAM

The method of this monitoring is to use large traffic stream samples (at least seven consecutive days of validated data) of a selected truck type or types (typically the Class 9's Type 3S2) to generate reports displaying statistical data on:

- Steer axle and gross vehicle weight distributions.
- Individual outputs of right and left weigh sensors.
- Effect of speed on weight.
- Axle spacings (and thereby speed).

For sites that have a significant number of the Class 11's Type 2S12 or the Class 12's Type 3S12 statistical data can be generated for checking overall vehicle length calibration.

For calibration monitoring analyses to be effective using these recommended procedures, it is imperative that the data used for the samples have passed all data QC checks. Also, data for days when the truck volumes and/or operating characteristics may not be typical, such as a major holiday, should not be used in the sample. If a particular month contains days with invalid data and/or days with atypical truck traffic such that a consecutive seven-day sample cannot be obtained, simply substitute the same day(s) of the week from the closest week in the same month to make up a composite week's sample. It is important that the traffic stream sample, regardless of the vehicle class(es) or type(s) selected for analysis, include only "real" trucks. Smaller power units such as pickups, Class 5s pulling trailers (see Figure 59), recreational vehicles pulling trailers or autos can skew the statistics.

Figure 59. Photo. This vehicle combination may conform to a Class 9 Type 2S3 under some classification schemes.

For sites with low volumes of Class 9 vehicles, the sample should be for 14 consecutive days. It is up to the data analyst to determine what size sample is actually needed to perform a meaningful calibration monitoring analysis, but it is noted that the contractor performing the Phase II calibration monitoring for the LTPP Specific Pavement Study (SPS) Traffic Pooled Fund Study obtained 14 day samples for any site for which a seven-day sample would typically contain less than 1500 Class 9 Type 3S2 vehicles.

It is also important to note that these calibration monitoring procedures are intended to supplement, not replace, onsite calibrations using test trucks. Based upon analyses of the traffic stream statistics that indicate one or more sensors are not maintaining calibration (referred to as "calibration drift") or otherwise not reporting accurate weights, the analyst may deem it necessary to do one of the following:

- Call for an immediate onsite validation/recalibration with test trucks.

- Make calibration factor adjustments from the office deemed necessary to maintain calibration until test trucks can be run at the site.

In discussing and making recommendations on calibration monitoring procedures, examples of reports generated by a custom software program as well as tables and graphs from an off-the-shelf spreadsheet program will be displayed. Although the discussions may state something to the effect that "this report should be generated...", the intent is that information and statistics similar to what is included in the displayed example should be generated for review by the analyst. It is not intended that the programs used for example purposes be considered as the only recommended tools to generate necessary statistics.

The reports and graphs used for the following examples were generated by the "WIMSys" application of "CTWIM Suite" which is available from Caltrans at http://www.dot.ca.gov/hq/traffops/trucks/datawim/install.htm. A Power Point presentation on the CTWIM's WIMSys application can be downloaded on the same website (http://www.dot.ca.gov/hq/traffops/trucks/datawim/install.htm).

Figure 60 displays a report for a seven-day sample of Class 9 vehicles for a site with weigh sensors installed in the system's lane numbers 1 and 2 (northbound), and 5 and 6 (southbound). GVW distributions are displayed in 5.0 k ranges for each lane. The dashed line following the "30.0 TO 34.9" row is the typical break point for empty Class 9 trucks and the dashed line following the "75.0 TO 79.9" row is the GVW legal limit. This particular site experiences a moderate volume of both empty and loaded Class 9 trucks. This report, generated for a seven-day sample immediately following a system's being calibrated or validated using test trucks, provides an excellent reference for distribution comparisons with subsequent analyses.

DISTRIBUTION OF LANE COUNTS BY GROSS WEIGHT
SITE #075 - Keyes Sep 23, 2006
**** CLASS 9 **** (#Files = 7)

	LANE #1			LANE #2			LANE #5			LANE #6			ALL		
Gross Wt Range	Count	%	Avg Speed	Count	%	Avg Speed	Count	%	Avg Speed	Count	%	Avg Speed	Count	%	Avg Speed
< 20.0	1	0.0	60.9	0	0.0	0.0	0	0.0	0.0	4	0.0	59.6	5	0.0	59.9
20.0 TO 24.9	31	0.1	57.7	16	0.2	56.7	55	0.8	56.2	361	1.6	58.1	463	0.8	57.8
25.0 TO 29.9	1280	6.4	58.5	360	5.4	61.7	402	6.0	61.4	2007	8.9	58.3	4049	7.3	58.9
30.0 TO 34.9	2666	13.4	58.7	952	14.4	62.0	1366	20.6	62.1	4450	19.8	58.5	9434	17.0	59.4
35.0 TO 39.9	2141	10.8	58.7	736	11.1	62.4	1014	15.3	61.7	2276	10.1	58.2	6167	11.1	59.4
40.0 TO 44.9	1260	6.3	58.7	393	5.9	62.1	373	5.6	61.6	1097	4.8	58.2	3123	5.6	59.3
45.0 TO 49.9	1116	5.6	58.6	372	5.6	62.3	338	5.1	61.5	974	4.3	57.9	2800	5.0	59.2
50.0 TO 54.9	1128	5.7	58.8	369	5.6	61.8	306	4.6	60.9	1028	4.5	58.1	2831	5.1	59.2
55.0 TO 59.9	1076	5.4	58.6	335	5.0	61.8	289	4.3	60.9	976	4.3	57.9	2676	4.8	59.0
60.0 TO 64.9	1002	5.0	58.3	345	5.2	61.7	356	5.3	61.5	1110	4.9	57.9	2813	5.0	59.0
65.0 TO 69.9	1334	6.7	58.3	412	6.2	61.9	512	7.7	61.7	1448	6.4	57.9	3706	6.6	59.0
70.0 TO 74.9	2580	13.0	58.2	815	12.3	61.8	1030	15.5	61.6	2617	11.6	58.1	7042	12.7	59.1
75.0 TO 79.9	3443	17.4	58.4	1104	16.7	61.8	523	7.9	61.7	2959	13.1	58.3	8029	14.4	59.0
80.0 TO 84.9	618	3.1	58.5	346	5.2	62.0	46	0.6	61.8	971	4.3	57.9	1981	3.5	58.9
85.0 TO 89.9	54	0.2	58.7	22	0.3	62.7	6	0.0	62.1	137	0.6	57.5	219	0.3	58.4
90.0 TO 94.9	9	0.0	56.0	2	0.0	59.6	0	0.0	0.0	27	0.1	57.2	38	0.0	57.0
>= 95.0	16	0.0	55.0	3	0.0	63.6	2	0.0	60.5	18	0.0	56.7	39	0.0	56.7
All	19755	35.6	58.5	6582	11.8	62.0	6618	11.9	61.6	22460	40.5	58.2	55415	100.0	59.2
Avg Gross Wt	55.4	n/a		55.6	n/a		50.7	n/a		52.4	n/a		53.7	n/a	
Standard Dev	18.3	n/a		18.5	n/a		17.5	n/a		19.4	n/a		18.8	n/a	
Avg Axle 1 Wt	10.6	n/a		10.4	n/a		10.5	n/a		10.6	n/a		10.6	n/a	
Standard Dev	1.1	n/a		1.1	n/a		1.0	n/a		1.1	n/a		1.1	n/a	

Figure 60. Tabular Report. Distribution of lane counts by GVW, for site with mix of both loaded and empty Class 9 vehicles.

Figure 61 displays the same gross weight distributions but in graphical format. It is apparent that Lane #6 weights are a bit lighter than those for Lane #1. However, it must be noted that many WIM sites with bidirectional lanes do not experience the same GVW distribution patterns for each direction. For this sample, Lane #1 has more loaded than unloaded Class 9s whereas Lane #6 has more unloaded than loaded Class 9s. It is not uncommon for these patterns to change by day of week (hence the need for a sample from seven continuous days) or by season of the year (hence the need for tracking over time, as will be discussed later). Regardless of the Class 9 Type 3S2 empty versus loaded distribution mix, it is typical for the empty distributions to peak at "30 TO <35" k (as they do in this example) when using the five k ranges. The loaded distributions peak will vary a bit depending upon a particular site's truck operating characteristics, but the peak will typically occur at "70 TO <75" or "75 TO <80" k. For this example, the Lane #6 loaded peak being at the "65 TO 70" distribution is a bit suspicious, but its empty peak appears to be reasonable.

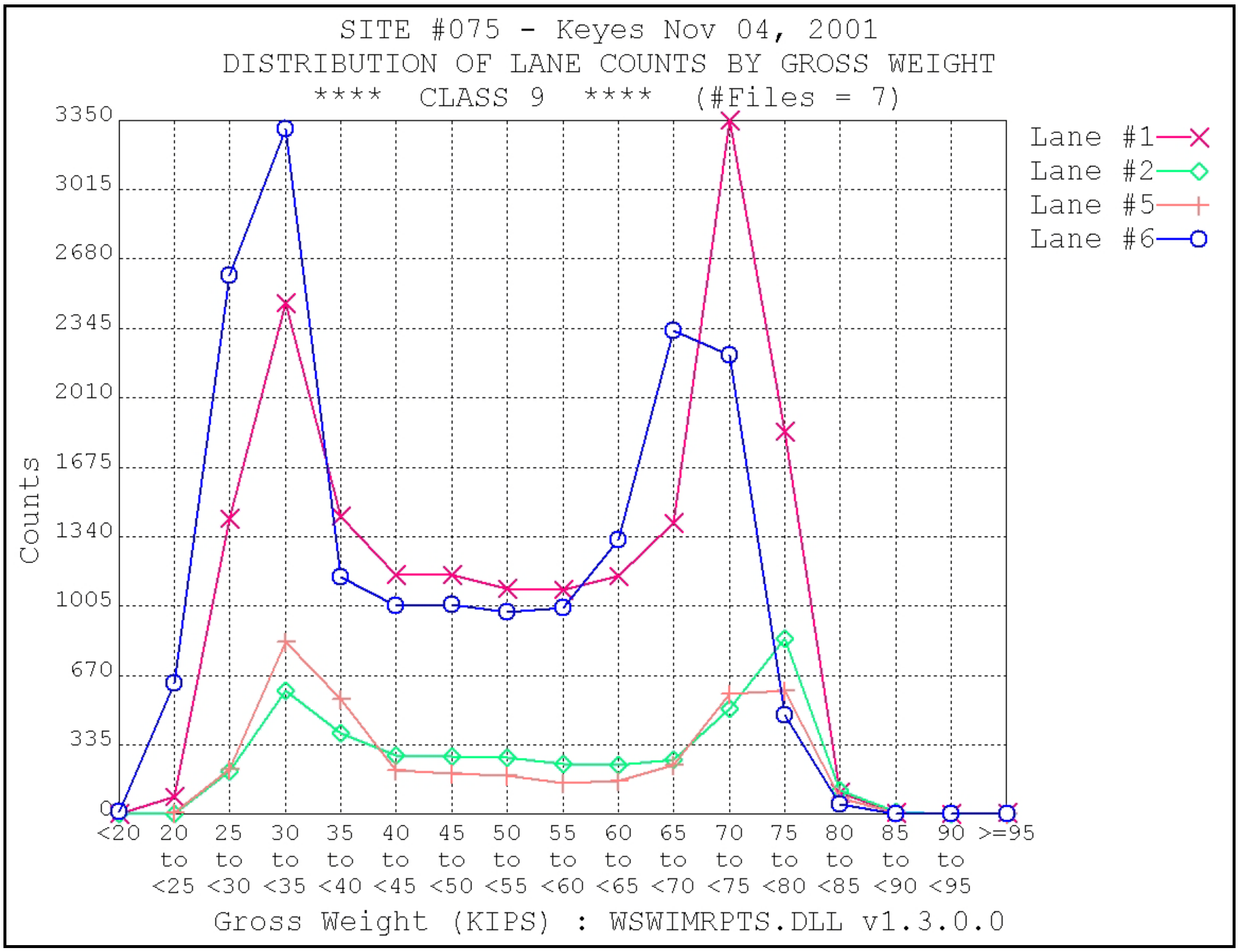


Figure 61. Report Graph. Distribution of lane counts by GVW, for site with mix of both loaded and empty Class 9 vehicles.

Figure 62 displays the same report as that displayed in Figure 60, but this report is for a seven-day sample from a site on a long haul route in the middle of the desert. As would be expected, this site has a very low percentage of empty Class 9s.

DISTRIBUTION OF LANE COUNTS BY GROSS WEIGHT
SITE #025 - Newberry May 04, 2003
**** CLASS 9 **** (#Files = 7)

Gross Wt Range	LANE #1 Count	LANE #1 %	LANE #1 Avg Speed	LANE #2 Count	LANE #2 %	LANE #2 Avg Speed	LANE #3 Count	LANE #3 %	LANE #3 Avg Speed	LANE #4 Count	LANE #4 %	LANE #4 Avg Speed	ALL Count	ALL %	ALL Avg Speed
< 20.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
20.0 TO 24.9	3	0.0	57.0	2	0.1	64.4	0	0.0	0.0	16	0.1	60.2	21	0.0	60.2
25.0 TO 29.9	15	0.0	58.0	8	0.5	66.2	19	2.1	64.3	183	1.2	59.7	225	0.6	60.2
30.0 TO 34.9	76	0.4	59.7	15	0.9	61.2	21	2.3	64.9	558	3.8	59.3	670	2.0	59.5
35.0 TO 39.9	199	1.2	60.0	43	2.8	62.6	39	4.4	62.8	658	4.5	59.4	939	2.9	59.8
40.0 TO 44.9	450	2.9	59.4	70	4.6	61.8	57	6.4	65.2	990	6.8	59.2	1567	4.8	59.6
45.0 TO 49.9	799	5.1	59.7	100	6.6	61.7	63	7.1	64.4	1177	8.2	59.4	2139	6.6	59.8
50.0 TO 54.9	1133	7.3	59.5	118	7.8	62.8	77	8.7	65.1	1216	8.4	59.6	2544	7.9	59.9
55.0 TO 59.9	1304	8.4	59.5	153	10.1	63.0	83	9.4	65.0	1176	8.1	59.5	2716	8.4	59.8
60.0 TO 64.9	1665	10.7	59.6	177	11.7	62.4	83	9.4	64.7	1172	8.1	59.7	3097	9.6	59.9
65.0 TO 69.9	1916	12.3	59.3	203	13.4	63.7	89	10.1	64.1	1419	9.8	59.8	3627	11.2	59.8
70.0 TO 74.9	2532	16.3	59.4	299	19.8	62.1	170	19.2	64.5	2672	18.6	59.6	5673	17.6	59.7
75.0 TO 79.9	3749	24.2	59.1	278	18.4	61.9	157	17.8	65.0	2743	19.1	58.9	6927	21.5	59.2
80.0 TO 84.9	1513	9.7	59.2	41	2.7	61.7	21	2.3	67.3	354	2.4	58.6	1929	5.9	59.2
85.0 TO 89.9	99	0.6	59.6	0	0.0	0.0	1	0.1	75.1	11	0.0	60.6	111	0.3	59.8
90.0 TO 94.9	1	0.0	57.3	0	0.0	0.0	1	0.1	72.6	0	0.0	0.0	2	0.0	64.9
>= 95.0	0	0.0	0.0	1	0.0	55.4	0	0.0	0.0	3	0.0	58.3	4	0.0	57.6
All	15454	48.0	59.4	1508	4.6	62.5	881	2.7	64.8	14348	44.5	59.4	32191	100.0	59.7
Avg Gross Wt	67.4	n/a		64.0	n/a		61.8	n/a		61.5	n/a		64.5	n/a	
Standard Dev	11.7	n/a		12.3	n/a		14.0	n/a		14.5	n/a		13.4	n/a	
Avg Axle 1 Wt	11.4	n/a		10.6	n/a		11.4	n/a		10.9	n/a		11.1	n/a	
Standard Dev	0.7	n/a		0.8	n/a		0.9	n/a		0.8	n/a		0.8	n/a	

Figure 62. Tabular Report. Distribution of lane counts by GVW, site with very few empty Class 9 vehicles.

Figure 63 displays the same gross weight distributions but in graphical format.

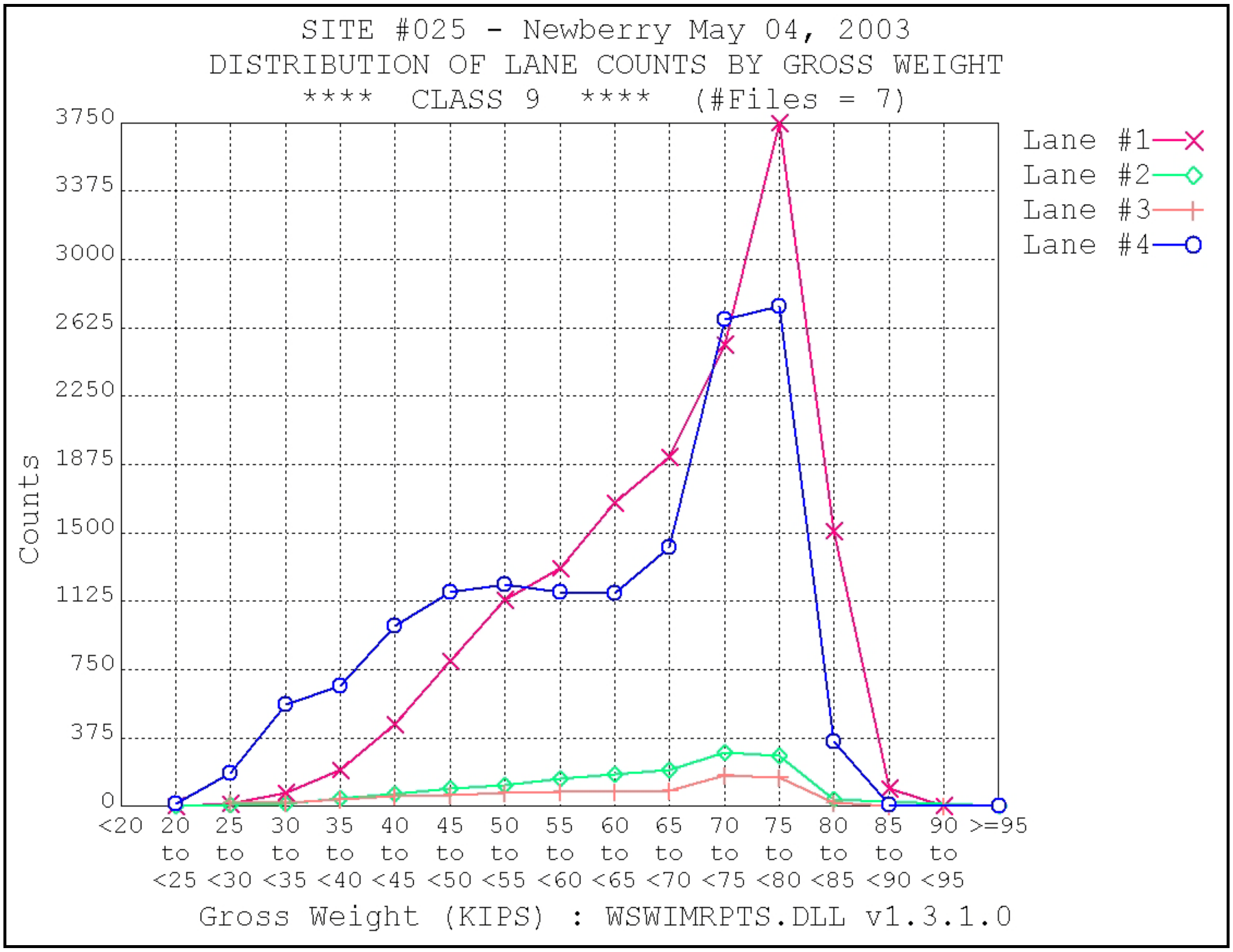


Figure 63. Report Graph. Distribution of lane counts by GVW, site with very few empty Class 9 vehicles.

When reviewing GVW distributions, the analyst is trying to identify the following:

- Reasonableness of empty and loaded peak distributions given site's truck operational characteristics.

- Consistency of overall distribution patterns with:
  - Those in previous reports.
  - Those in a report for a sample taken immediately following the last onsite calibration or validation using test trucks.

For sites that do have seasonal variations in truck operational characteristics, it may take a couple years to verify that the changes in GVW distributions are due to these variations and not calibration drift. It is always a good idea to perform an onsite validation using test trucks the first time a site's GVW distributions change.

The next step is to check the weight outputs of each individual sensor and to monitor the effects of speed on the Axle 1 weight and GVW outputs for each lane.

A key element in the monitoring of a system's calibration and weigh sensor performance is the assumption that for a large traffic stream sample of Class 9 vehicles the average right and left steer axle weights should be approximately equal. A 2004 study (Nichols and Bullock 2004) determined this to be a logical assumption based upon a review of vehicle geometry with several truck manufacturers and an accounting for the effect of roadway cross slope. Regardless of any argument that this assumption is not "ground truth", the monitoring of the balance between the average right and left steer axle weights is an excellent tool for identifying any drift in a sensor's calibration or any subtle problem in a sensor's performance. It is recognized that some Type I WIM systems have double threshold weighing whereby each right and left wheel track has two weigh sensors instead of one. However, such a system reports, as data elements, a single right wheel weight and a single left wheel weight for each axle for each individual vehicle record. In discussions related to right and left weigh sensors, such sensors will be treated as single sensors even though in some cases a system may actually have two right sensors and two left sensors.

Onsite calibrations are typically based upon the test vehicles' static axle weights (as opposed to individual right and left static wheel weights) as reference values for determining WIM error. Therefore, it is recommended that prior to running test trucks, a sampling of the traffic stream's Class 9 data be obtained and the right and left sensor calibration factors be adjusted such that the traffic stream's average right and left steer axle WIM weights will be approximately equal. For example, if a pre-calibration Class 9 traffic stream sampling for Lane #1 showed an Axle 1 Right Wheel average of 5.2 k and an Axle 1 Left Wheel average of 5.6k, the calibration factors for the system's Lane #1 would be adjusted as per the calculations displayed in Figure 64. These right and left sensor factors would then be equally increased or decreased based upon the WIM error as determined from test truck axle weight data. This procedure would apply to each lane being calibrated.

TO BALANCE RIGHT AND LEFT SENSOR WEIGHT OUTPUTS PRIOR TO PERFORMING CALIBRATION WITH TEST TRUCKS BASED UPON SAMPLING OF TRAFFIC STREAM DATA (TYPICALLY CLASS 9):

EXIST AVERAGE AXLE 1 WEIGHTS	EXIST CALIB FACTORS FOR 1st SPEED BIN
RIGHT : 5.2	RIGHT SENSOR : 3200
LEFT : 5.6	LEFT SENSOR : 3500
AXLE : 10.8	

DESIRED AVERAGE WEIGHTS	ADJUSTMENTS TO FACTORS FOR 1st SPEED BIN
10.8/2 = 5.4 EACH	
RIGHT : 5.4/5.2 = 1.04	RIGHT SENSOR : 1.04 x 3200 = 3328
LEFT : 5.4/5.6 = 0.96	LEFT SENSOR : 0.96 x 3500 = 3360
	(ADJUST FACTORS IN SAME MANNER FOR EACH SPEED BIN)

All weights in kips

Figure 64. Procedure. Pre calibration - right and left sensor balance.

Another key element in system calibration and calibration monitoring is the recognition that vehicle speed is a very important aspect of a system's proper calibration. ASTM E 1318 states, under Section 7.5.5.5, "*Every vehicle interacts with the road surface differently at different speeds, but about the same at the same speed.*" Typically, the loaded Class 9 vehicles travel at approximately the same speeds as the unloaded Class 9 vehicles for a WIM site with all of the conditions listed below:

- A significant volume of Class 9s.
- Truck traffic that maintains a steady cruising speed.
- A roadway grade of less than 0.5 percent.

Figure 65 displays a report for LANE #1 for the same seven-day Class 9 sample used for the report and graph displayed in Figure 62 and Figure 63.

DISTRIBUTION OF AVERAGE WEIGHTS & SPACINGS BY SPEED
SITE #025 - Newberry May 04, 2003 (#Files = 7)
*** LANE #1 *** **** CLASS 9 ****

	WEIGHTS						COUNTS			SPACINGS	
Speed Range	Axle 1 Left Wheel	Axle 1 Right Wheel	Steer Axle	Tractor Tandem Axles	Trailer Tandem Axles	Vehicle Gross	All	Over Weight	Percent Over Weight	Tractor Tandem Axles	Trailer Tandem Axles
< 25.0	5.4	5.3	10.7	17.9	19.6	48.2	1	0	0.0	4.2	3.4
25.0 TO 29.9	6.0	6.0	12.0	29.1	30.3	71.5	4	1	25.0	4.4	4.1
30.0 TO 34.9	5.6	5.6	11.3	29.3	29.7	70.4	9	1	11.1	4.2	4.7
35.0 TO 39.9	5.7	5.6	11.4	29.2	30.0	70.6	59	13	22.0	4.2	4.5
40.0 TO 44.9	5.6	5.6	11.3	29.5	29.3	70.2	275	54	19.6	4.3	4.5
45.0 TO 49.9	5.6	5.5	11.2	29.9	29.1	70.3	706	207	29.3	4.2	4.5
50.0 TO 54.9	5.7	5.6	11.3	28.0	27.2	66.6	1646	378	22.9	4.3	4.5
55.0 TO 59.9	5.8	5.6	11.4	28.2	27.4	67.1	5198	1324	25.4	4.3	4.5
60.0 TO 64.9	5.7	5.6	11.3	28.5	27.3	67.2	5314	1375	25.8	4.3	4.6
65.0 TO 69.9	5.5	5.6	11.1	29.2	27.3	67.7	1593	451	28.3	4.3	4.6
70.0 TO 74.9	5.4	5.5	10.9	29.7	27.3	68.0	528	129	24.4	4.3	4.7
>= 75.0	5.2	5.3	10.6	29.4	26.7	66.7	121	22	18.1	4.5	4.9
Average All	5.7	5.6	11.4	28.6	27.5	67.4	15454	3955	25.5	4.3	4.6
Standard Dev	0.4	0.4	0.7	5.7	6.6	11.7	n/a	n/a	n/a	0.2	1.7

Figure 65. Report. Distribution of Class 9 weights and axle spacings by speed for one lane, flat roadway grade.

When reviewing a report similar to the one displayed in Figure 65, the analyst should check the following (refer to the numbered blocks highlighted in Figure 65):

1. Consistency of the Axle 1's average right and left wheel weights, and maintenance of the balance between the two.

For this sample the right and left weights are only 0.1 k apart, which is acceptable. Although some WIM sites are exceptions and a site's variance in seasonal truck operational characteristics may come into play, the Class 9 average steer axle wheel weight should remain relatively consistent. A concurrent change in both weights suggests either calibration drift or a change in truck operational characteristics. Once the right and left average weights are brought into balance (no more than 0.2 k difference), they should remain balanced. Any shift in this balance suggests that a sensor may be intermittently malfunctioning.

1. Consistency of the standard deviation for Axle 1's average right and left wheel weights.

For this sample both average weights have a standard deviation of 0.4 k, which is acceptable. Given good site and traffic conditions, these standard deviations should typically not exceed 0.5 k. If either of these standard deviations starts to increase, it is an indication that the sensor may be malfunctioning on an intermittent or subtle basis.

2. For sites with ideal geometry and traffic conditions, consistency of the average Steer Axle and Gross Vehicle Weights throughout the speed ranges for which a significant number of the Class 9 vehicles are travelling.

For this sample the average GVW for the "45.0 TO 49.9" speed distribution is approximately four percent higher than for the higher speed distributions. Given that the sample comes from a rural interstate roadway with high-speed traffic, it could very well be that the calibration or validation test trucks were not run at speeds this low in deriving data for verifying or determining calibration factors. Regardless of site and traffic conditions, the Figure 65 report should be generated for a traffic stream sample immediately following an onsite calibration or validation using test trucks. For a system to be properly calibrated, the system's calibration factors should be based upon data from test trucks that were run throughout the entire operating range of a significant majority (at least 80 percent) of the truck traffic stream.

It is recognized that at many WIM sites a majority of the truck traffic stream travels at speeds well above the posted speed limit. It is not in any way recommended that an agency run test trucks exceeding posted speed limits in the absence of jurisdictional approval. However, it would certainly be beneficial if an agency could obtain proper approval for running test trucks at speeds consistent with the truck traffic stream flow.

3. Reasonableness and consistency of the percentage of overweight vehicles in the sample.

Even though there are no weigh stations in the immediate vicinity of this WIM site, it is very doubtful if 25.5 percent of the Class 9 vehicles would actually be cited for being overweight if statically weighed. Most vehicles passing through this site are "long haul" and will at some point have to go through a weigh station. There are at least a couple reasons why a WIM system, even if well calibrated, might flag a relatively high percentage of its trucks as being in violation of weight limits (assuming the system is programmed to use the actual weight violation parameters in-lieu of allowing some tolerance):

- For the Class 9 Type 3S2 to achieve maximum allowable GVW (typically 80 k) both tandems must be loaded as closely as possible to the maximum allowable tandem weight (typically 34 k). As such, if the WIM reads just a slight percent high for any of a tandem's wheels the vehicle will be flagged as overweight. Although a WIM system's slight overestimates and underestimates of static weights may be well within accuracy tolerances and average out overall in terms of reported weight, weight violation flags do not average out, and a WIM system's reporting of weight violation percentage based upon a sample's dynamic weight readings may be somewhat higher than if the same sample were weighed statically.

- To get a better ride on the open road, it is quite common for a trucker to move a vehicle's king pin setting back a bit to shift weight from the steer axle to the tractor's drive tandem following an exit from a weigh station. This revised king pin setting could well result in the drive tandem's being overweight even if statically reweighed. It is also somewhat common for a trucker to move the semi-trailer's slider tandem, which shifts weight from one tandem to the other. Such king pin setting and trailer tandem slider settings are readjusted before entering the next weigh station, but at the time these vehicles pass through a WIM site they may very well actually be in violation of weight limits.

4. Reasonableness and consistency of the Tractor Tandem Axles average spacing and its standard deviation.

For most locations in the U.S., the Type 3S2 vehicle's average spacing should be 4.3 feet. This would also apply if the sample included the Class 9 Type 32 (although the power unit is not technically a "tractor"). This average (or a tight standard deviation) would not apply if the sample includes Class 9 Type 2S3 vehicles. For locations that have Canadian truck traffic or specialty truck types, consideration would need to be given to observed axle spacing configurations and the percentage of such atypical vehicles.

Figure 66 displays the same report as that in Figure 65 but for a seven-day Class 9 sample from LANE #4 of a site that has a long two percent uphill grade approach in that lane's direction. As is obvious from the vehicle gross average weights column, such weights drop drastically for the speed ranges above 50 mi/h. This is due to the fact that the heavier the vehicle the less ability the vehicle has to maintain a cruising speed. For the fully loaded vehicles, with exception of those with the most powerful engines, their speed has dropped considerably by the time they reach the WIM site.

DISTRIBUTION OF AVERAGE WEIGHTS & SPACINGS BY SPEED

SITE #021 - Mojave Sep 08, 2002 (#Files = 7)

*** LANE #4 *** **** CLASS 9 ****

	WEIGHTS						COUNTS			SPACINGS	
Speed Range	Axle 1 Left Wheel	Axle 1 Right Wheel	Steer Axle	Tractor Tandem Axles	Trailer Tandem Axles	Vehicle Gross	All	Over Weight	Percent Over Weight	Tractor Tandem Axles	Trailer Tandem Axles
< 25.0	5.5	4.0	9.5	15.9	9.7	35.1	1	0	0.0	3.9	3.2
25.0 TO 29.9	6.2	5.3	11.6	24.0	17.5	53.1	2	0	0.0	4.2	3.9
30.0 TO 34.9	5.2	4.9	10.2	28.3	29.2	67.7	11	1	9.0	4.3	4.1
35.0 TO 39.9	5.2	4.9	10.1	28.9	26.9	66.0	82	8	9.7	4.2	4.9
40.0 TO 44.9	5.2	5.1	10.3	29.8	27.3	67.5	469	73	15.5	4.2	4.8
45.0 TO 49.9	5.2	5.0	10.3	28.8	27.6	66.8	2293	584	25.4	4.2	4.7
50.0 TO 54.9	5.0	5.0	10.0	24.2	23.4	57.7	5241	922	17.5	4.2	4.6
55.0 TO 59.9	4.8	4.9	9.7	19.9	18.5	48.1	2737	197	7.1	4.2	4.6
60.0 TO 64.9	4.5	4.9	9.5	17.0	14.8	41.3	431	25	5.8	4.2	4.6
65.0 TO 69.9	4.4	4.6	9.0	14.7	11.9	35.6	20	2	10.0	4.2	4.7
70.0 TO 74.9	5.6	4.5	10.1	14.5	9.3	33.9	2	0	0.0	4.1	3.8
>= 75.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	-	0.0	0.0
Average All	5.0	5.0	10.0	24.1	22.9	57.1	11289	1812	16.0	4.3	4.7
Standard Dev	0.6	0.5	0.9	7.5	9.7	17.1	n/a	n/a	n/a	0.2	1.9

Figure 66. Report. Distribution of Class 9 weights and axle spacings by speed for one lane, uphill grade.

Installing WIM systems on roadways with grades greater than 0.5 percent should be avoided for several reasons listed below.

- Due to the lower speeds of the loaded trucks, the onsite calibration with test trucks must encompass a larger range of speeds to properly calibrate the system.

- One or both of the test trucks may not be able to attain the higher speeds necessary for proper calibration.

- When a truck is passing through the site under heavy throttle, weight is transferred from the steer axle to the drive axle(s). Although the WIM may accurately determine the dynamic wheel weights, they are not accurate estimates of the truck's static wheel weights.

- The empty trucks travelling at the higher speeds may be passing the slower trucks through the site.

- Since the loaded and empty trucks travel at different speeds, the calibration monitoring is more difficult to perform.

    - This report should be generated for a seven-day traffic stream sample immediately following a legitimate onsite calibration or validation with test trucks to use as a reference for subsequent comparisons.

Figure 67 displays a report for a seven-day sample for the same site, time frame, and lane as the Figure 66 report, but this report is for Class 11 vehicles. The only difference in the two report formats is that instead of providing statistics on Class 9 axle spacings, statistics are provided for the Class 11 overall vehicle length and wheelbase (Axles 1 through 5). For Class 11 Type 2S12s, the overall vehicle length typically exceeds the wheelbase by approximately six feet, so, in comparing the sample's average vehicle length and average wheelbase, the difference should be approximately six feet. This report was designed for use by California, which calibrates its systems for overall vehicle lengths and has a significant number of Class 11 vehicles at many of its WIM sites. It is recognized that many states' WIM sites have very few Class 11 vehicles and as such would have no need to generate reports for Class 11 samples.

DISTRIBUTION OF AVERAGE WEIGHTS & SPACINGS BY SPEED

SITE #021 - Mojave Sep 08, 2002 (#Files = 7)

*** LANE #4 *** **** CLASS 11 ****

	WEIGHTS				COUNTS			OVER ALL	
Speed Range	Axle 1 Left Wheel	Axle 1 Right Wheel	Steer Axle	Vehicle Gross	All	Over Weight	Percent Over Weight	Vehicle Length	Wheel Base
< 25.0	0.0	0.0	0.0	0.0	0	0	-	0.0	0.0
25.0 TO 29.9	0.0	0.0	0.0	0.0	0	0	-	0.0	0.0
30.0 TO 34.9	4.5	3.8	8.3	75.1	3	1	33.3	68.0	61.7
35.0 TO 39.9	4.2	4.0	8.3	66.5	38	3	7.8	67.7	61.3
40.0 TO 44.9	4.3	4.2	8.5	69.3	123	8	6.5	67.3	61.0
45.0 TO 49.9	4.5	4.3	8.8	64.7	318	25	7.8	69.7	63.3
50.0 TO 54.9	4.2	4.2	8.4	48.7	260	5	1.9	68.7	62.4
55.0 TO 59.9	4.0	4.2	8.2	35.1	130	1	0.7	68.7	62.5
60.0 TO 64.9	3.5	3.8	7.4	23.2	11	0	0.0	64.8	59.0
65.0 TO 69.9	0.0	0.0	0.0	0.0	0	0	-	0.0	0.0
70.0 TO 74.9	0.0	0.0	0.0	0.0	0	0	-	0.0	0.0
>= 75.0	0.0	0.0	0.0	0.0	0	0	-	0.0	0.0
Average All	4.3	4.3	8.6	55.9	883	43	4.8	68.8	62.5
Standard Dev	0.6	0.5	1.1	19.7	n/a	n/a	n/a	5.4	5.1

Figure 67. Report. Distribution of Class 11 weights, vehicle length, and wheelbase by speed for one lane.

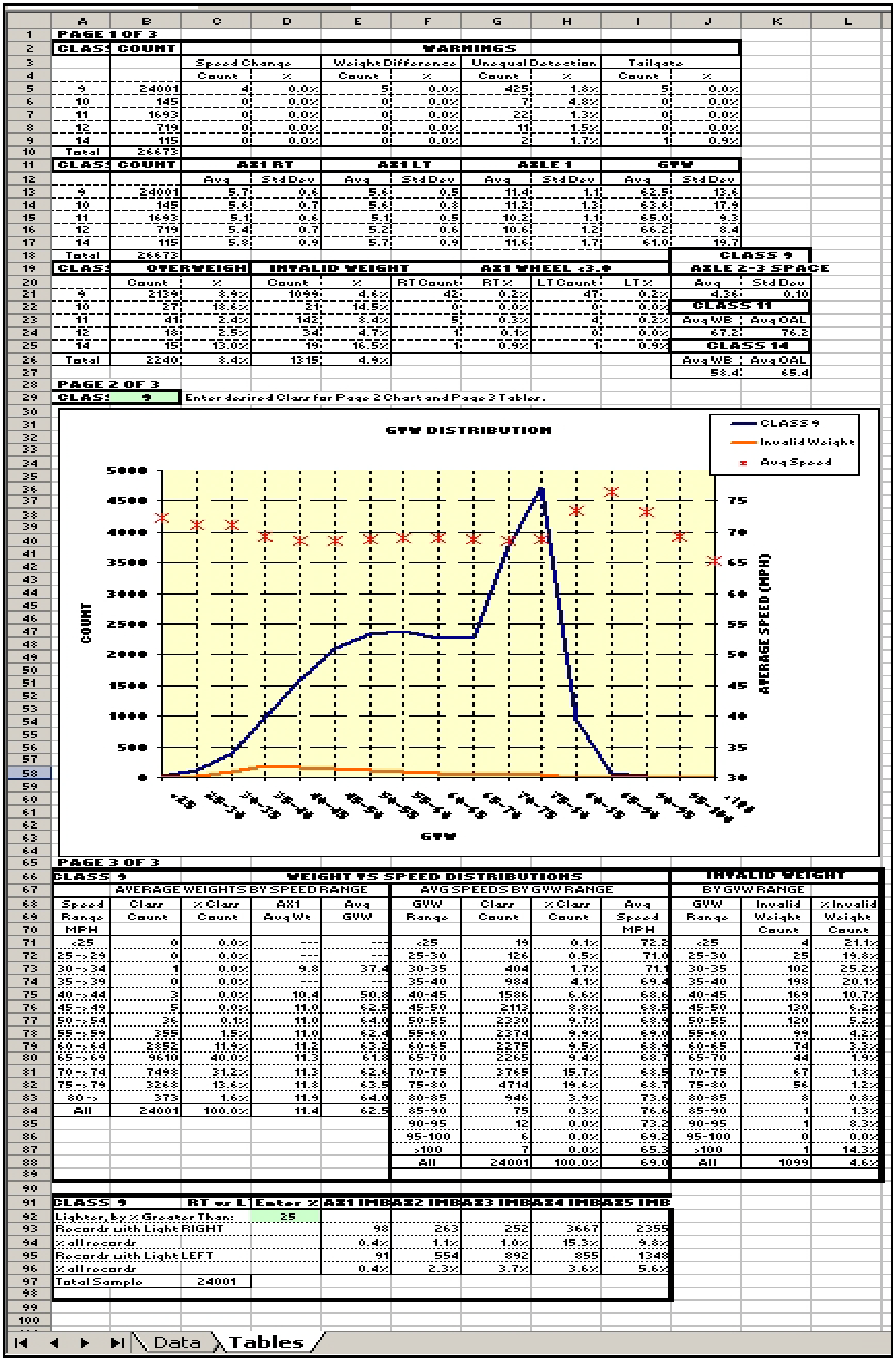
SECTION 4 discussed the use of Excel by the LTPP contractor for performing extensive WIM data analyses. This Excel workbook was expanded to generate some of the statistical information contained in the CTWIM WIMSys reports for use in calibration monitoring. In that an agency's WIM data analyst may find it easier and/or more practical to use a spreadsheet or database program for performing calibration monitoring than using the CTWIM WIMSys application, portions of the Excel workbook used for the LTPP study are described in the following examples. For any data analyst desiring to create spreadsheets with the calibration monitoring features displayed in Figure 68 through Figure 72, Excel ASCII Import workbooks and documentation are provided online at www.QualityWIM.com.

For most of the LTPP study sites a seven-day sample is used. For a few sites with low truck volumes a 14-day sample is used. As previously noted, for the calibration monitoring to be meaningful only data that has passed QC checks for days which have typical truck traffic should be included in the samples. The workbook that is used for the following examples is for one lane (the LTPP test section lane) and as such does not provide for user input of other lanes. The workbooks which are provided online at www.QualityWIM.com allow the user to enter a specific lane number, in addition to the vehicle class, when generating the tables and graphs.

Also, regardless of what type of traffic stream sampling is performed and what statistics are generated for calibration monitoring, it is imperative to perform a minimum seven-day sampling immediately following a system's onsite calibration or validation using test trucks, and to generate the set of statistics to be used as a reference set for comparison with subsequent sampling statistics.

Figure 68 displays the entire worksheet, which includes calibration monitoring tables and a graph, as well as other tables useful for the monitoring of weigh sensor performance. The Classes listed in these tables are based upon a scheme whereby vehicles with five or more axles are classified as listed below. Note that these classes are utilized solely for the purpose of performing analyses using this worksheet. They are not intended to conform to schemes used to classify vehicles in compliance with the Traffic Monitoring Guide requirements for general data submission. The analyst will need to perform post-processing of the downloaded WIM data to generate the following classes by specific vehicle configuration type.

- CLASS 9 : Type 3S2
- CLASS 10 : Type 3S3
- CLASS 11 : Type 2S12
- CLASS 12 : Type 3S12
- CLASS 14 : Type 32



PAGE 1 OF 3

CLASS	COUNT	Speed Change Count	Speed Change %	Weight Difference Count	Weight Difference %	Unequal Detection Count	Unequal Detection %	Tailgate Count	Tailgate %
		WARNINGS							
9	24001	4	0.0%	5	0.0%	425	1.8%	5	0.0%
10	145	0	0.0%	0	0.0%	7	4.8%	0	0.0%
11	1693	0	0.0%	0	0.0%	22	1.3%	0	0.0%
12	719	0	0.0%	0	0.0%	11	1.5%	0	0.0%
14	115	0	0.0%	0	0.0%	2	1.7%	1	0.9%
Total	26673								

CLASS	COUNT	AX1 RT Avg	AX1 RT Std Dev	AX1 LT Avg	AX1 LT Std Dev	AXLE 1 Avg	AXLE 1 Std Dev	GVW Avg	GVW Std Dev
9	24001	5.7	0.6	5.6	0.5	11.4	1.1	62.5	13.6
10	145	5.6	0.7	5.6	0.8	11.2	1.3	63.6	17.9
11	1693	5.1	0.6	5.1	0.5	10.2	1.1	65.0	9.3
12	719	5.4	0.7	5.2	0.6	10.6	1.2	66.2	8.4
14	115	5.8	0.9	5.7	0.9	11.6	1.7	61.0	19.7
Total	26673								

CLASS	OVERWEIGHT Count	OVERWEIGHT %	INVALID WEIGHT Count	INVALID WEIGHT %	AX1 WHEEL <3.0 RT Count	RT %	LT Count	LT %
9	2139	8.9%	1099	4.6%	42	0.2%	47	0.2%
10	27	18.6%	21	14.5%	0	0.0%	0	0.0%
11	41	2.4%	142	8.4%	5	0.3%	4	0.2%
12	18	2.5%	34	4.7%	1	0.1%	0	0.0%
14	15	13.0%	19	16.5%	1	0.9%	1	0.9%
Total	2240	8.4%	1315	4.9%				

CLASS 9 AXLE 2-3 SPACE Avg	Std Dev
4.36	0.10

CLASS 11 Avg WB	Avg OAL
67.2	76.2

CLASS 14 Avg WB	Avg OAL
58.4	65.4

PAGE 2 OF 3

CLASS 9 Enter desired Class for Page 2 Chart and Page 3 Tables.

PAGE 3 OF 3

CLASS 9 WEIGHT VS SPEED DISTRIBUTIONS

AVERAGE WEIGHTS BY SPEED RANGE

Speed Range MPH	Class Count	% Class Count	AX1 Avg Wt	Avg GVW
<25	0	0.0%	---	---
25 -> 29	0	0.0%	---	---
30 -> 34	1	0.0%	9.8	37.4
35 -> 39	0	0.0%	---	---
40 -> 44	3	0.0%	10.4	50.8
45 -> 49	5	0.0%	11.0	62.5
50 -> 54	36	0.1%	11.0	64.0
55 -> 59	355	1.5%	11.0	62.4
60 -> 64	2852	11.9%	11.2	63.2
65 -> 69	9610	40.0%	11.3	61.8
70 -> 74	7498	31.2%	11.3	62.6
75 -> 79	3268	13.6%	11.8	63.5
80 ->	373	1.6%	11.9	64.0
All	24001	100.0%	11.4	62.5

AVG SPEEDS BY GVW RANGE

GVW Range	Class Count	% Class Count	Avg Speed MPH
<25	19	0.1%	72.2
25-30	126	0.5%	71.0
30-35	404	1.7%	71.1
35-40	984	4.1%	69.4
40-45	1586	6.6%	68.6
45-50	2113	8.8%	68.5
50-55	2330	9.7%	68.9
55-60	2374	9.9%	69.0
60-65	2275	9.5%	68.9
65-70	2265	9.4%	68.7
70-75	3765	15.7%	68.5
75-80	4714	19.6%	68.7
80-85	946	3.9%	73.6
85-90	75	0.3%	76.6
90-95	12	0.0%	73.2
95-100	6	0.0%	69.2
>100	7	0.0%	65.3
All	24001	100.0%	69.0

INVALID WEIGHT BY GVW RANGE

GVW Range	Invalid Weight Count	% Invalid Weight Count
<25	4	21.1%
25-30	25	19.8%
30-35	102	25.2%
35-40	198	20.1%
40-45	169	10.7%
45-50	130	6.2%
50-55	120	5.2%
55-60	99	4.2%
60-65	74	3.3%
65-70	44	1.9%
70-75	67	1.8%
75-80	56	1.2%
80-85	8	0.8%
85-90	1	1.3%
90-95	1	8.3%
95-100	0	0.0%
>100	1	14.3%
All	1099	4.6%

CLASS 9	RT or LT	Enter %	AX1 IMB	AX2 IMB	AX3 IMB	AX4 IMB	AX5 IMB
Lighter, by % Greater Than:		25					
Records with Light RIGHT			98	263	252	3667	2355
% all records			0.4%	1.1%	1.0%	15.3%	9.8%
Records with Light LEFT			91	554	892	855	1348
% all records			0.4%	2.3%	3.7%	3.6%	5.6%
Total Sample	24001						

Data | Tables

Figure 68. Screen shot. “Tables” Worksheet.

The portions of this worksheet useful for calibration monitoring include those described below.

Figure 69 displays average weights and their standard deviations for each listed vehicle class's steer axle wheel weights, steer axle weight, and GVW. Analyses of these statistics have been discussed previously.

11	CLASS	COUNT	AX1 RT		AX1 LT		AXLE 1		GVW	
12			Avg	Std Dev	Avg	Std Dev	Avg	Std Dev	Avg	Std Dev
13	9	24001	5.7	0.6	5.6	0.5	11.4	1.1	62.5	13.6
14	10	145	5.6	0.7	5.6	0.8	11.2	1.3	63.6	17.9
15	11	1693	5.1	0.6	5.1	0.5	10.2	1.1	65.0	9.3
16	12	719	5.4	0.7	5.2	0.6	10.6	1.2	66.2	8.4
17	14	115	5.8	0.9	5.7	0.9	11.6	1.7	61.0	19.7
18	Total	26673								CLA

Figure 69. Screen shot. Weight statistics for calibration monitoring and tracking.

Figure 70 displays statistics for each listed class as discussed below.

- OVERWEIGHT- Analysis of this statistic has been discussed previously.

- INVALID WEIGHT- More pertinent to sensor performance than calibration monitoring.

- AX1 WHEEL <3.0 - The CTWIM WIMSys application filters out any record for which the vehicle's right or left steer axle weight is less than 3.0 k. This spreadsheet does not filter out such records, but displays how many of the right and left steer axle weights are less than 3.0 k. To use the sample for calibration monitoring purposes, these should be a very low percentage. If the percentage increases for either right or left weight, it is an indication of either intermittent sensor malfunction or an increased number of truck wheels not fully hitting the sensor.

- CLASS 9 AXLE 2-3 SPACE - Analysis of this statistic has been discussed previously.

- CLASS 11 - The correlation between the Class 11's wheelbase and overall vehicle length has been discussed previously.

- CLASS 14 - For those sites with a significant number of the Type 32 truck trailer (a Class 9 using Traffic Monitoring Guide criteria), this vehicle's overall length is typically approximately six feet longer than the Axle 1 to Axle 5 wheelbase.

18	Total	26673									CLASS 9	
19	CLASS	OVERWEIGHT		INVALID WEIGHT		AX1 WHEEL <3.0					AXLE 2-3 SPACE	
20		Count	%	Count	%	RT Count	RT %	LT Count	LT %		Avg	Std Dev
21	9	2139	8.9%	1099	4.6%	42	0.2%	47	0.2%		4.36	0.10
22	10	27	18.6%	21	14.5%	0	0.0%	0	0.0%		CLASS 11	
23	11	41	2.4%	142	8.4%	5	0.3%	4	0.2%		Avg WB	Avg OAL
24	12	18	2.5%	34	4.7%	1	0.1%	0	0.0%		67.2	76.2
25	14	15	13.0%	19	16.5%	1	0.9%	1	0.9%		CLASS 14	
26	Total	2240	8.4%	1315	4.9%						Avg WB	Avg OAL
27											58.4	65.4

Figure 70. Screen shot. Additional statistics for calibration monitoring and tracking.

Figure 71 displays the GVW distribution plot for the vehicle class entered into Cell B29 by the analyst. Also plotted are the average speed and the number of Invalid Measurement weights in conjunction with the GVW plot.

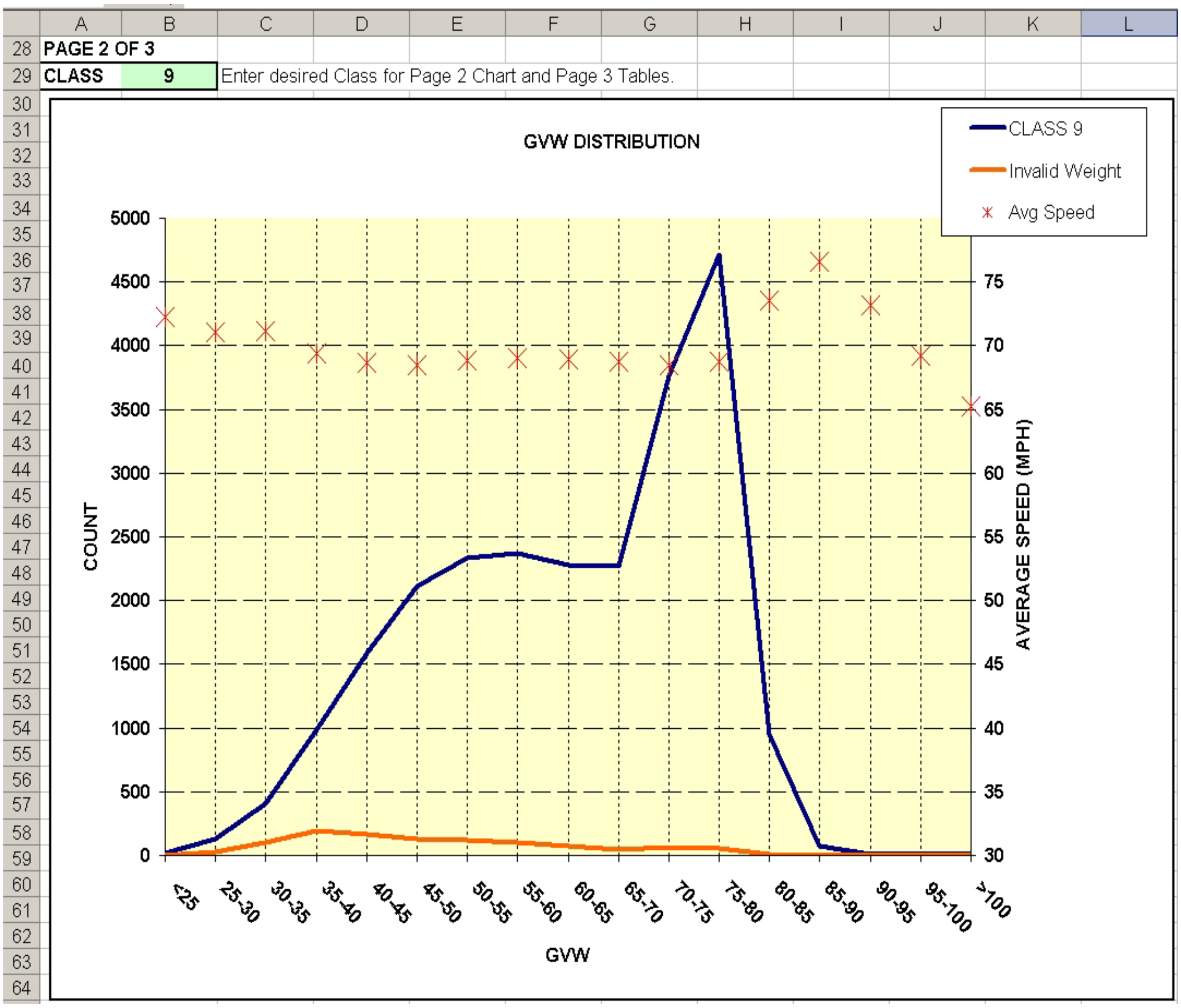


Figure 71. Screen shot. GVW distribution plot.

Figure 72 displays weights versus speeds in two different ways for the class of vehicle entered by the analyst into Cell B29 (see Figure 71). As discussed previously, for a site with suitable roadway geometry and traffic conditions, the empty and loaded trucks typically travel at approximately the same speeds. For “Speed Range” distributions that have a significant number of samples the “Avg GVW” should be reasonably consistent among those distributions, and for “GVW Range” distributions that have a significant number of samples the “Avg Speed” should be reasonably consistent among those distributions.

65	PAGE 3 OF 3								
66	**CLASS**	**9**		**WEIGHT VS SPEED DISTRIBUTIONS**					
67		AVERAGE WEIGHTS BY SPEED RANGE				AVG SPEEDS BY GVW RANGE			
68	Speed	Class	% Class	AX1	Avg	GVW	Class	% Class	Avg
69	Range	Count	Count	Avg Wt	GVW	Range	Count	Count	Speed
70	MPH								MPH
71	<25	0	0.0%	---	---	<25	19	0.1%	72.2
72	25 -> 29	0	0.0%	---	---	25-30	126	0.5%	71.0
73	30 -> 34	1	0.0%	9.8	37.4	30-35	404	1.7%	71.1
74	35 -> 39	0	0.0%	---	---	35-40	984	4.1%	69.4
75	40 -> 44	3	0.0%	10.4	50.8	40-45	1586	6.6%	68.6
76	45 -> 49	5	0.0%	11.0	62.5	45-50	2113	8.8%	68.5
77	50 -> 54	36	0.1%	11.0	64.0	50-55	2330	9.7%	68.9
78	55 -> 59	355	1.5%	11.0	62.4	55-60	2374	9.9%	69.0
79	60 -> 64	2852	11.9%	11.2	63.2	60-65	2275	9.5%	68.9
80	65 -> 69	9610	40.0%	11.3	61.8	65-70	2265	9.4%	68.7
81	70 -> 74	7498	31.2%	11.3	62.6	70-75	3765	15.7%	68.5
82	75 -> 79	3268	13.6%	11.8	63.5	75-80	4714	19.6%	68.7
83	80 ->	373	1.6%	11.9	64.0	80-85	946	3.9%	73.6
84	All	24001	100.0%	11.4	62.5	85-90	75	0.3%	76.6
85						90-95	12	0.0%	73.2
86						95-100	6	0.0%	69.2
87						>100	7	0.0%	65.3
88						All	24001	100.0%	69.0
89									

Figure 72. Screen shot. Weights versus speed statistics.

5.2. MONITORING TRUCK TRAFFIC STREAM STATISTICS OVER TIME

Up to this point this Section's examples and discussion have focused on generating and analyzing traffic stream truck traffic statistics for individual samples. It is recommended that this be performed routinely on a monthly basis, as well as any time calibration factors are revised for a particular system, or a system undergoes equipment or software modifications. The following examples and discussion will focus on monitoring and tracking these statistics over time to accomplish the items listed below:

- Identifying true calibration drift as opposed to seasonal variations in a site's truck operational characteristics.
- Verifying the effects of calibration factor adjustments on traffic stream weights.
- Identifying degradation of a weigh sensor's performance.

Figure 73 displays the monthly GVW distribution plots over a one-year time frame using the seven-day Class 9 traffic stream sample sets used for the Figure 68 through Figure 72 statistics screen shots. This site is located on a long haul interstate route with high truck volumes. As is obvious from the plots, there are variations in the volumes but the loading characteristics are extremely consistent. It is noted that the GVW graph uses 2.5 k distributions, which identifies weight distribution variations to a much finer degree than the more typical graphs using 5.0 k distributions.

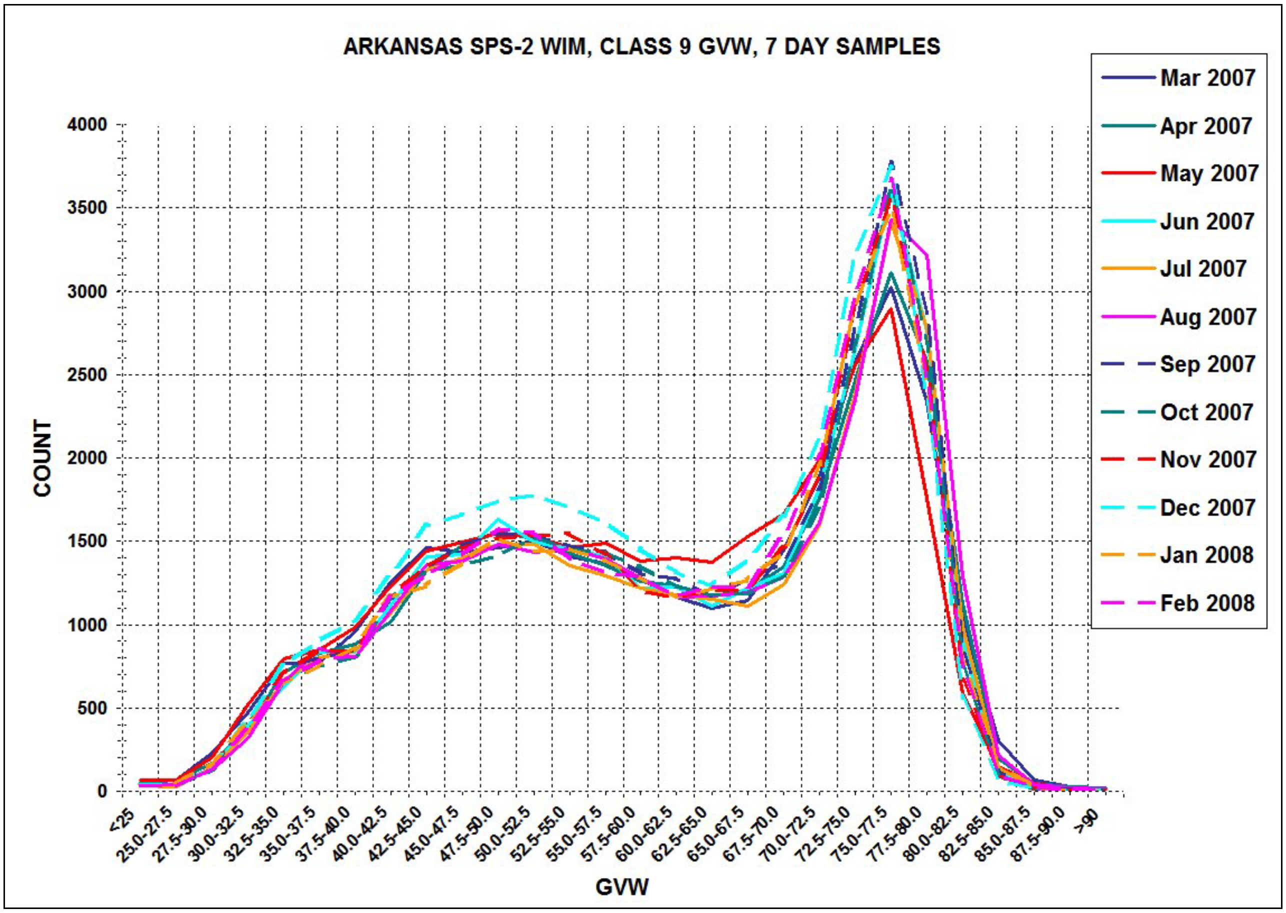


Figure 73. Graph. Traffic stream Class 9 GVW distribution plots for 12 consecutive months, long haul high volume.

Figure 74 displays the monthly steer axle weight distributions for the same sample as that used for the GVW plots displayed in Figure 73. The weight of a tractor-semitrailer's steer axle increases only slightly as the loading of the trailer(s) is increased. As such, monitoring of the steer axle is an excellent tool for identifying calibration problems or subtle system operational problems. Although tracking of steer axle weight distributions over time may of benefit, the more routine checks such as those described in Section 5.1 (e.g.: discussions regarding Figure 52 and Figure 65) are of much greater importance.

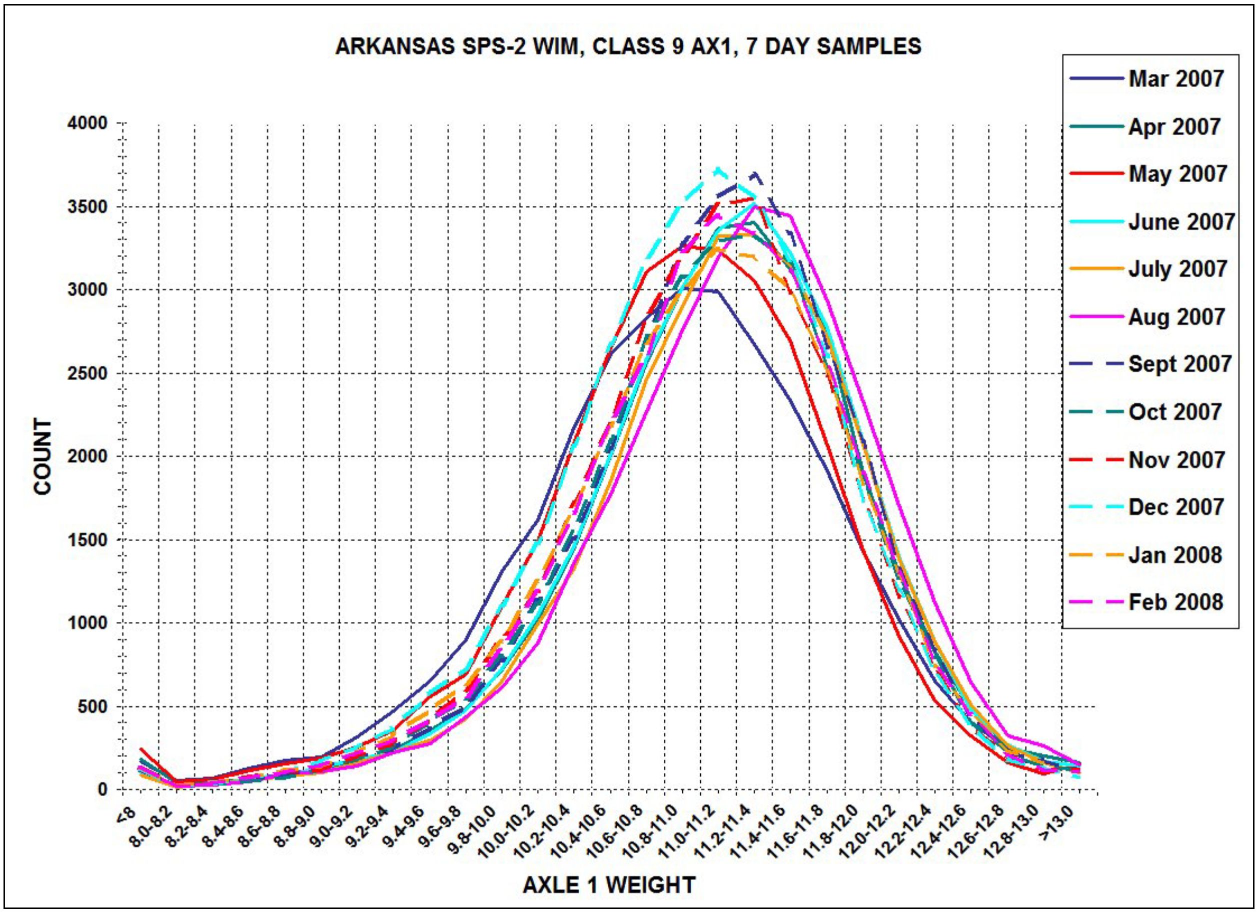


Figure 74. Graph. Traffic stream Class 9 Axle 1 weight distribution plots for 12 consecutive months.

Figure 75 displays the GVW distributions for a site with low truck volumes and a high percentage of empty trucks for the spring season months of three consecutive years. After tracking traffic stream GVW plots beyond the first year, seasonal comparisons can start to be made. For this example, there are variations in volumes but it is evident there is little, if any, calibration drift taking place.

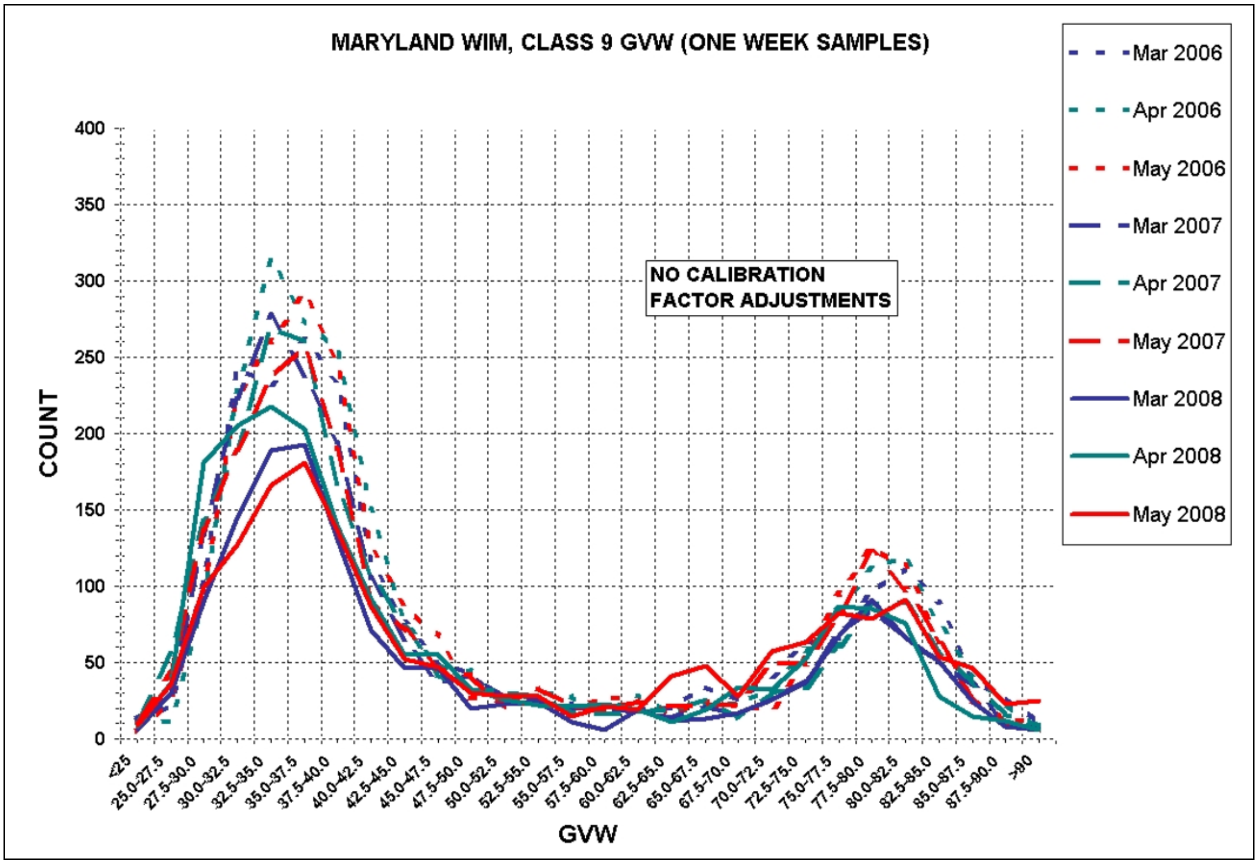


Figure 75. Graph. Class 9 GVW distribution plots for spring season over three-year period, local traffic.

Figure 76 displays the GVW distribution plots over a one-year time frame using 14-day Class 9 traffic stream sample sets. This site is located on a rural route with very low truck volumes and experiences extreme snow and ice conditions. Although there are definable empty and loaded distributions, they are not nearly as pronounced or consistent as in the long haul high truck volume site displayed in Figure 73. Sites such as this are more difficult to monitor for calibration in that the truck operating characteristics are not consistent.

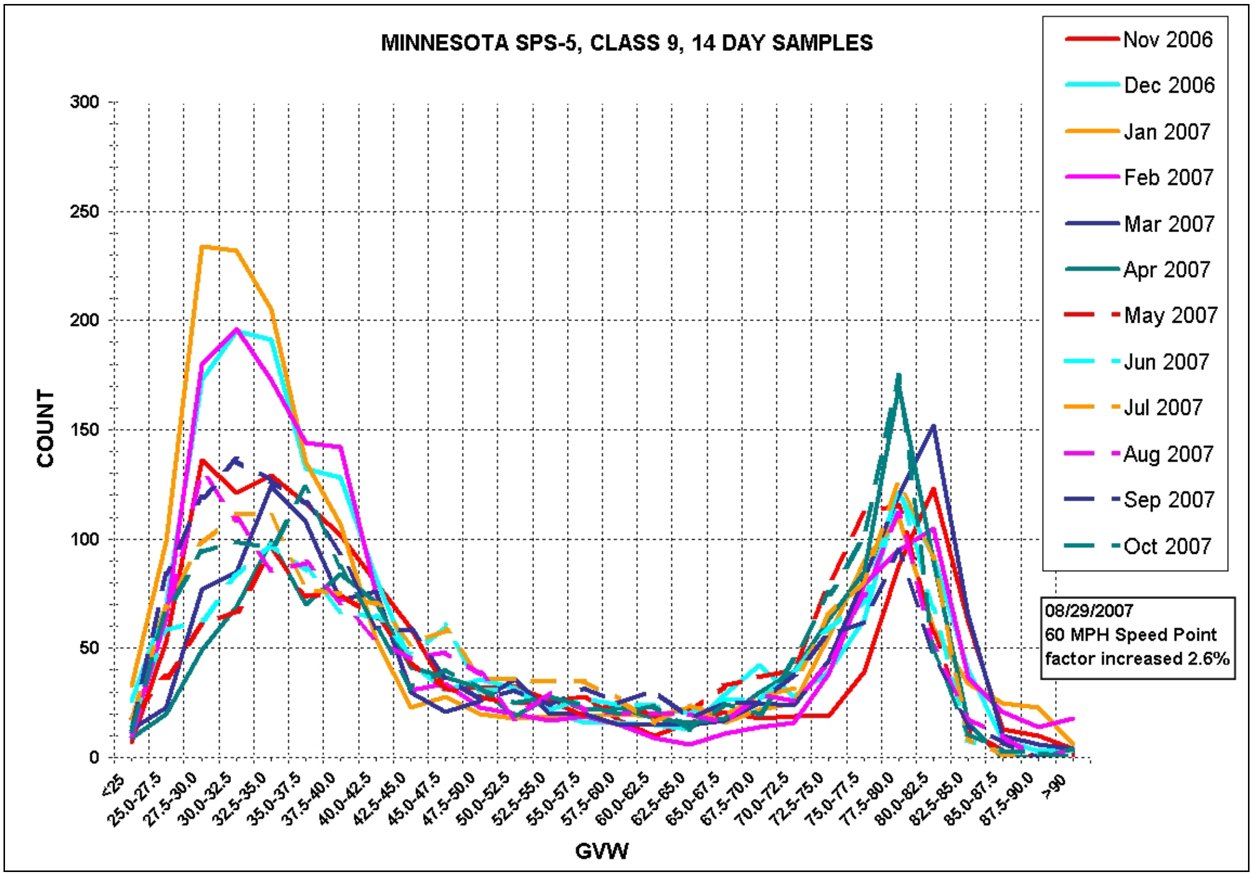


Figure 76. Graph. GVW distribution plots for 12 consecutive months, low volume.

5.3. EFFECTS OF CALIBRATION FACTOR ADJUSTMENTS ON TRUCK TRAFFIC STREAM DATA

Figure 77 displays the monthly Class 9 traffic stream GVW distribution plots over a one-year time frame, but this system had its calibration factors decreased by four percent in late June. The effects are dramatic, particularly on the loaded peak distribution. It is noted that the drop in weights starting in July was initially attributed to calibration drift. This example emphasizes the importance of considering any weight calibration factor adjustments when performing calibration monitoring.

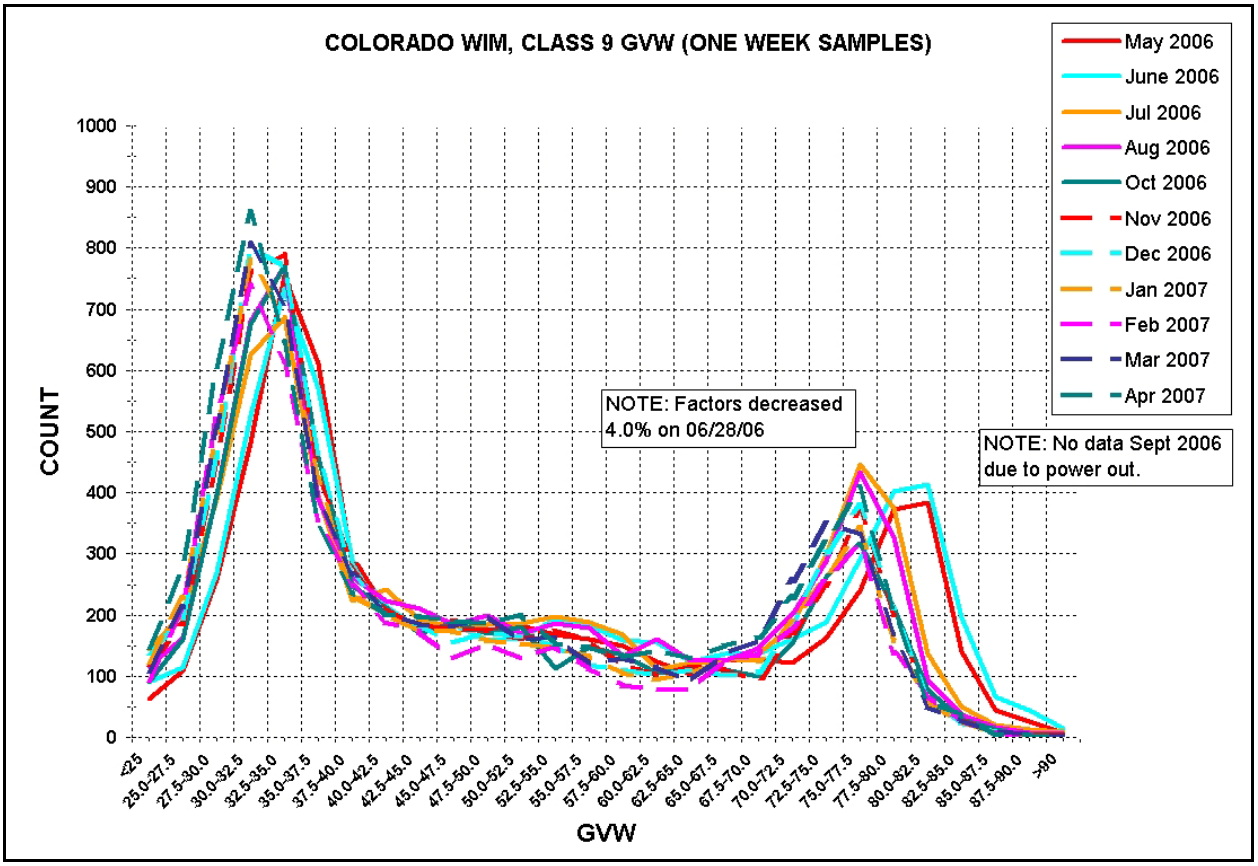


Figure 77. Graph. Class 9 GVW distribution plots for 12 consecutive months, weight shift.

Procedures for performing onsite calibrations and validations using test trucks are not within the scope of this Manual. However, it is of benefit to the data analyst to be able to analyze the test truck data for the purpose of comparing such data with the traffic stream data, and determining the effect of calibration factor adjustments on the traffic stream weights. If the analyst must make the assumption that the calibration was performed correctly, the best tool for use by the analyst is a graph displaying the test trucks' GVW WIM error by speed plots. WIM error is determined by comparing a test truck's static weight with its corresponding WIM reported dynamic weight. For example, if a test truck's static GVW is 75.0 k and, for a particular run, the WIM reports a GVW of 76.0 k, the GVW WIM error for that truck's run is +1.3 percent, as calculated from the following equation:

$$\text{WIM Error} = 100*[(GVW_{WIM} - GVW_{static})/ GVW_{static}]$$

In addition, it must be remembered that system calibration and its monitoring is performed on an individual lane basis. The Excel workbook used to generate the test trucks' GVW WIM error by speed plots in the following examples is available online at www.QualityWIM.com, along with the corresponding detailed documentation.

Figure 78 actually displays two individual graphs that have been sized and aligned to exhibit the importance of considering speed when performing calibrations, or when analyzing the effect of calibration factor adjustments on the WIM weights for the truck traffic stream. The top graph displays the percent of WIM GVW error for each run for two test trucks. The solid symbols ("PRE VAL") are for the WIM GVW errors using the system's weight calibration factors in effect at the start of the first set of test truck runs and the non-solid symbols ("POST VAL") are for the WIM GVW errors using the system's weight calibration factors as adjusted based upon the PRE VAL test truck data. The amount of adjustment for each of four of the system's five calibration speed points, in percent, is displayed immediately above the corresponding speed.

As is evident from the plots, it would appear that for the higher speeds, either the desired effect of the adjustment was not achieved or a mistake was made in either calculating the adjustment or entering the revised factor for the 60 mi/h speed point. The calibration factor for the 70 mi/h speed point probably should have also been increased. The lower graph displays the site's truck traffic stream speeds in comparison to the speeds at which WIM error data was obtained by the calibration test trucks. Although the posted speed limit in effect at the site probably prevented the test trucks from making runs at higher speeds, it is evident in comparing the two graphs that a majority of the runs made by the test trucks were meaningless. In effect, the calibration factor adjustments will probably have little noticeable effect on the WIM weights outputs for the truck traffic stream.

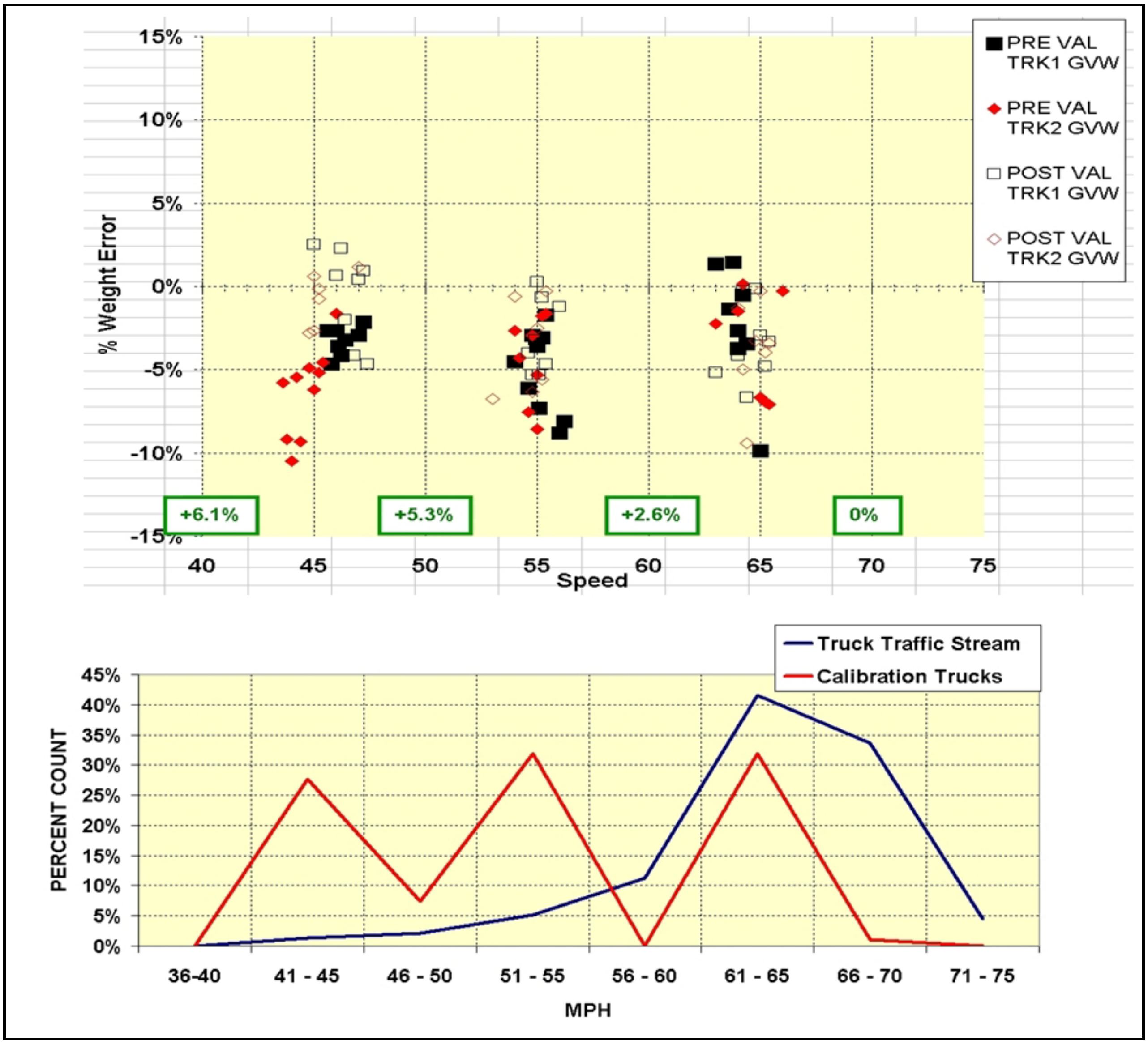


Figure 78. Graphs. Calibration test truck GVW WIM error versus speed plots, and truck traffic stream speeds versus calibration test truck speeds plots.

Figure 79 displays, for the system calibrated shown in Figure 78, the Class 9 traffic stream GVW distributions for samples from the two months preceding and the two months following the calibration factor adjustments. Although the “Oct” empty truck distribution is somewhat random, it is evident that the factor adjustments had no noticeable effect on the traffic stream WIM weights.

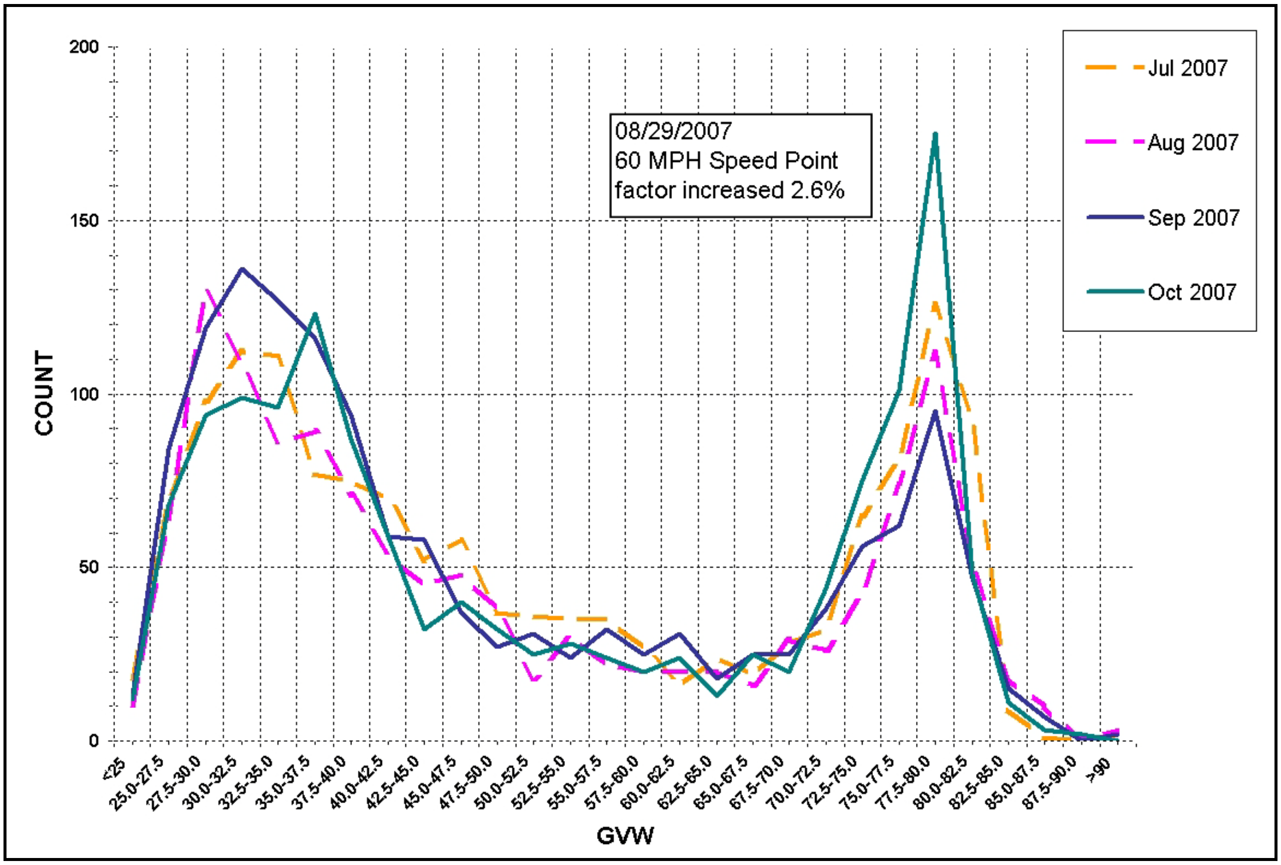


Figure 79. Graph. Class 9 traffic stream GVW distribution plots before and after calibration factor adjustments.

Another issue regarding calibrations utilizing test trucks that must be considered by the data analyst is that even when proper trucks are used and the calibration procedures are performed correctly, different trucks or pairs of trucks may get different results in terms of WIM error.

Figure 80 displays the GVW distributions for the monthly samples over a 15-month period for a site during which time no calibration factor adjustments were made. As is evident from the plots, the loaded distribution peak and to some extent the empty trucks peak remained extremely consistent over the entire period indicating that no calibration drift occurred.

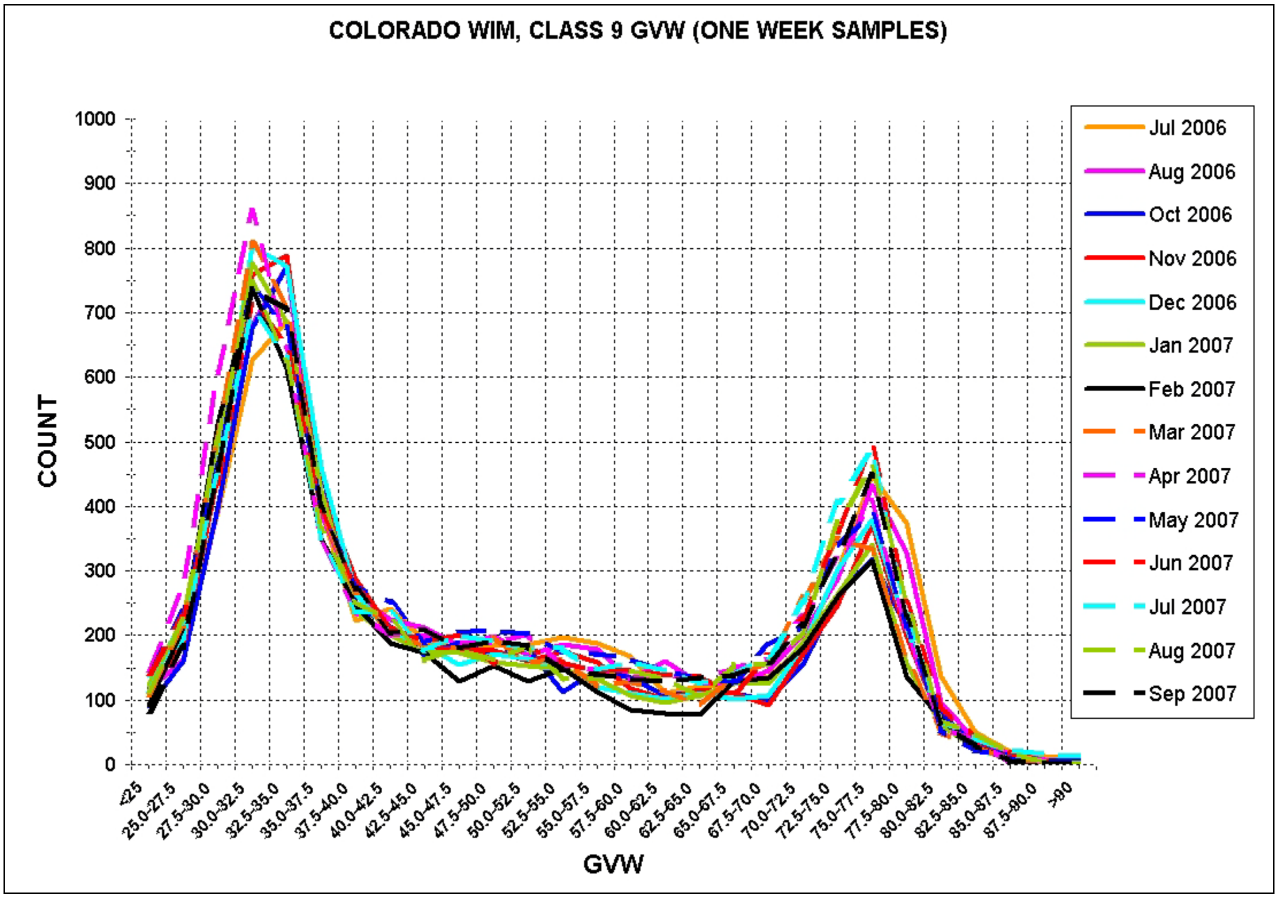


Figure 80. Graph. Class 9 traffic stream GVW distribution plots over period with no calibration factor changes.

Figure 81 displays the percent WIM GVW error plots for two different sets of test truck runs (two trucks each), 16 months apart, at the site displayed in Figure 80. The solid symbols ("JUN '06") are for the WIM GVW errors verifying the system's weight calibration factors in effect at the time. The non-solid symbols ("OCT '07") are for the WIM GVW errors using those same calibration factors, based upon the second set of test truck runs 16 months later. At the higher speeds there is a significant difference in the WIM error between the two sets of test truck runs even though the traffic stream data indicates that no calibration drift occurred during the time between the two sets of test truck runs.

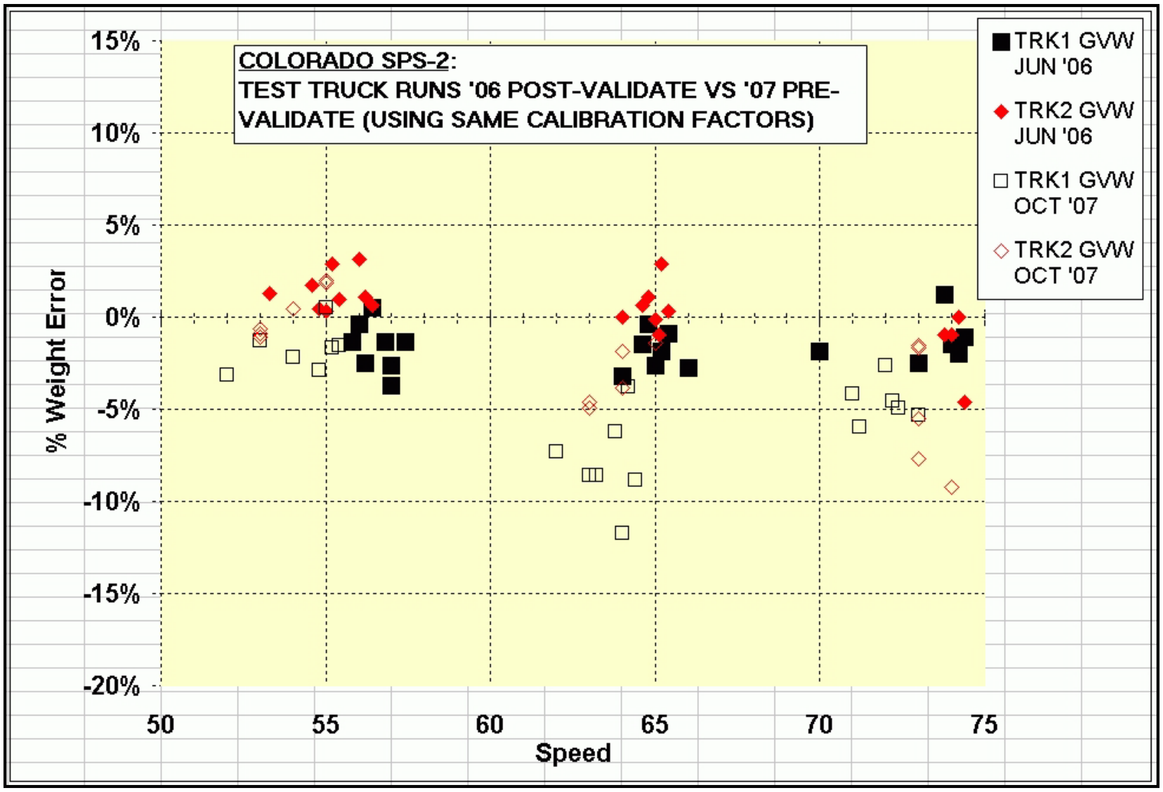


Figure 81. Graph. Calibration test truck GVW WIM error versus speed plots.

Figure 82 displays the percent of WIM GVW error for the initial set of runs for the "OCT '07" validation displayed in Figure 81, as well as the follow-up set of runs after calibration factor adjustments. The non-solid symbols ("PRE-VAL") are for the WIM GVW errors using the system's weight calibration factors that had been in effect for the preceding 16 months and the solid symbols ("POST-VAL") are for the WIM GVW errors using the system's weight calibration factors as adjusted based upon the PRE-VAL test truck data. The percentage of factor adjustment for each of the system's five calibration speed points is shown above the corresponding speed. As is evident from the plots, it would appear that the desired effects were attained, although as the speeds increase, the difference in WIM error between the two trucks also increases.

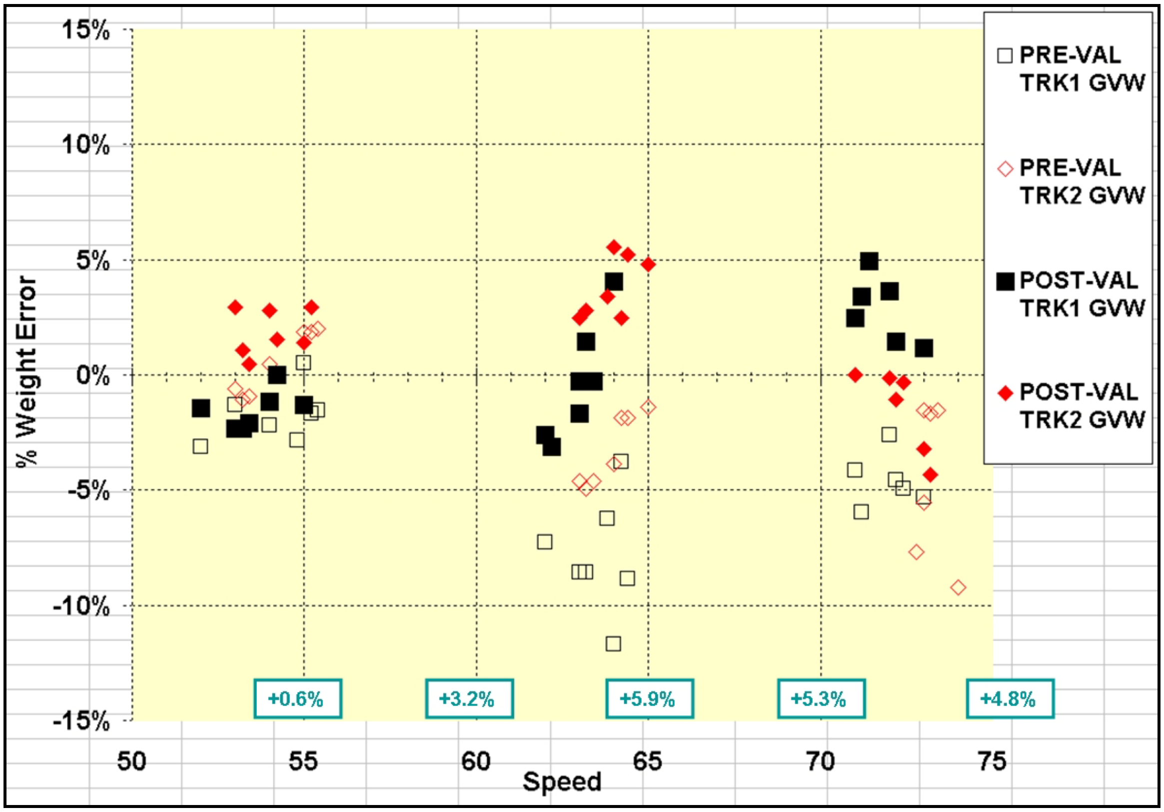


Figure 82. Graph. Calibration test truck GVW WIM error x speed plots, before and after factor adjustments.

From a test truck data standpoint this would be deemed a successful calibration. However, from the standpoint of monitoring the effects of calibration factors on the traffic stream's WIM weights it is like trying to hit a moving target, as evidenced by Figure 83.

Figure 83 displays the effects of three different sets of calibration factor adjustments, which were based upon test truck data, on the traffic stream WIM weights over a two-year period for the site displayed in Figure 80 through Figure 82. It would appear that in actuality the WIM system has maintained its calibration very well, whereas the WIM error based upon test truck data has been inconsistent for the initial calibration and three subsequent sets of validation/recalibrations. For the loaded trucks, it would appear that the WIM weights generated utilizing calibration factors based upon test truck data for the initial calibration and the October 2007 runs are too high. However, WIM weights generated utilizing calibration factors based upon test truck data for the June 2006 and April 2008 runs appear to be too low.

To anybody not paying attention to the various calibration factor changes it would appear that this system is not maintaining its calibration. In fact, it is being extremely consistent and is simply doing what it is being programmed to do. Perhaps at some point system accuracy might benefit from simply splitting the differences of the test truck data sets' WIM errors. One thing a graph such as Figure 83 illustrates is the excellent linearity of the system in that the traffic stream WIM weight outputs change in direct relationship to the changes in the calibration factors.

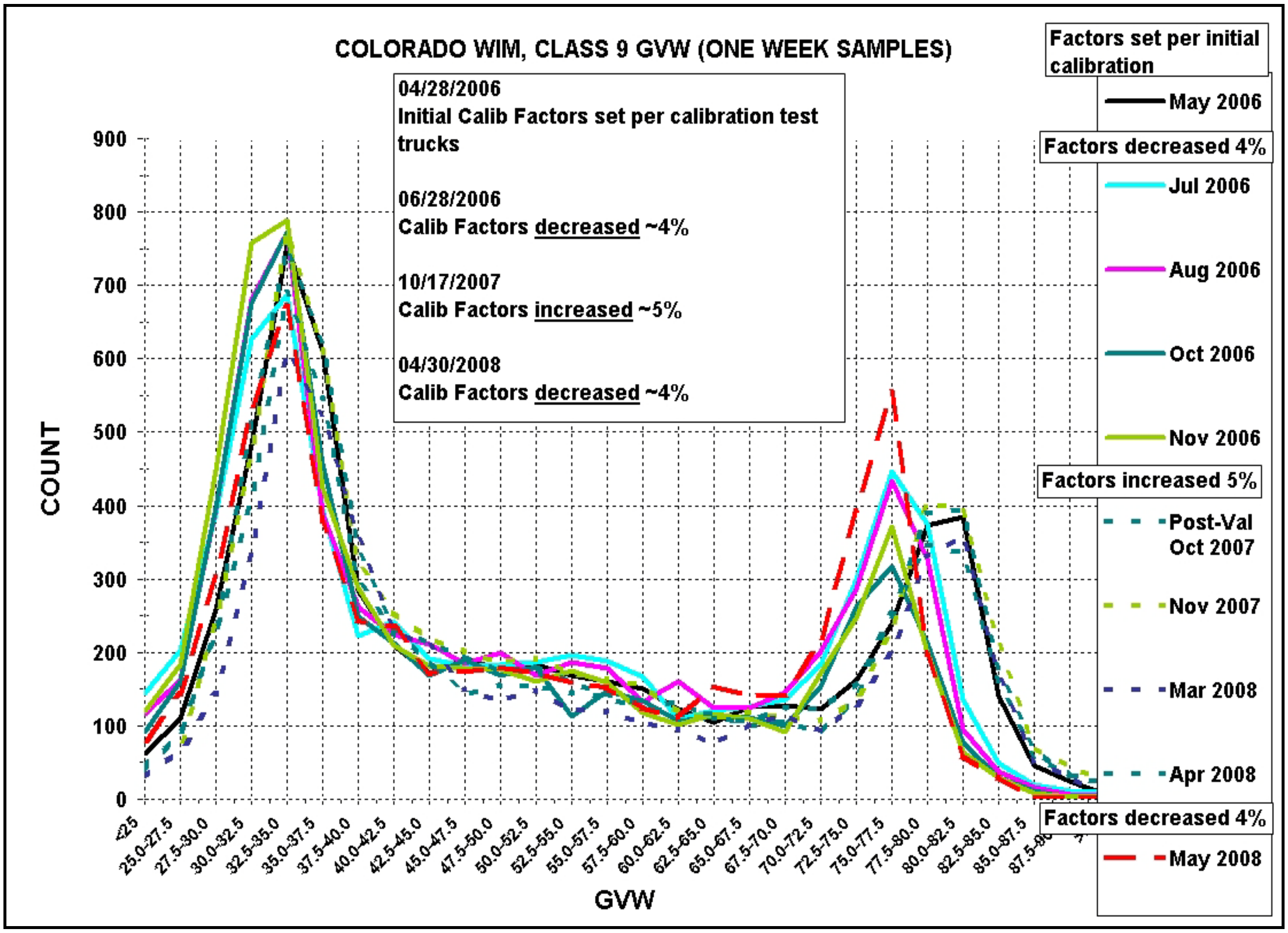


Figure 83. Graph. Effects of calibration factor adjustments on traffic stream WIM weights.

Figure 84 displays an example of tracking the statistics from the monthly Class 9 traffic stream samples in conjunction with any hardware, software/firmware, or system settings (including calibration factors) that may have an effect on the system's output of weights. This tracking sheet is for the site displayed in Figure 80 through Figure 83. As this tracking sheet is filled out each month, the analyst can make various determinations in regard to a system's maintenance of calibration and the effects of system modifications, as described below.

SITE:	503- COLORADO SPS-2				CLASS 9 STATS							WIM LANE:	1 (EB #2)				
	Bending Plates				(3S2 Only)						AC Power, Tel Line						
YR				AVG	AX1 RT		AX1 LT		AXLE 1		GVW		%	AX SP	OAL	%	%
MO	DATES	DAYS	SAMPLE	SPEED	AVG	STD	AVG	STD	AVG	STD	AVG	STD	OVWT	2-3	+/-	INVAL	UNEQ DET
2006																	
04	28										INITIAL CALIBRATION						
05	14 - 20	7	6,098	70.1	5.6	0.5	5.5	0.5	11.1	1.0	51.4	19.0	15.3	4.3			
06	18 - 24	7	6,306	70.0	5.6	0.6	5.5	0.5	11.1	1.0	52.6	19.5	17.4	4.3			
06	28		65 MPH BIN		-4.0%		-4.0%				POST VALIDATION						
07	16 - 22	7	6,188	70.1	5.4	0.5	5.3	0.5	10.7	0.9	50.1	18.7	8.8	4.3			
08	04 - 10	7	6,134	70.0	5.4	0.5	5.3	0.5	10.7	0.9	49.5	18.1	7.5	4.3	+3		
10	22 - 28	7	5,617	69.4	5.3	0.5	5.3	0.5	10.6	0.9	47.2	17.6	5.8	4.3			
11	12 - 18	7	5,844	69.9	5.2	0.5	5.3	0.5	10.5	0.9	46.8	17.6	5.3	4.3			
12	10 - 16	7	5,915	70.0	5.3	0.5	5.2	0.5	10.5	0.9	46.8	17.8	5.6	4.3			
2007																	
01	24		REPLACE SCALE INTERFACE CARD														
01	25 - 31	7	5,679	69.9	5.2	0.5	5.1	0.5	10.3	0.9	46.4	17.6	5.5	4.3	+3		
02	11 - 17	7	5,282	69.4	5.2	0.6	5.1	0.5	10.3	0.9	46.4	17.8	6.2	4.3			
03	12 - 18	7	6,006	70.2	5.3	0.5	5.1	0.5	10.4	0.9	47.3	17.7	5.5	4.3		13.8	1.9
04	16 - 22	7	6,333	69.7	5.3	0.6	5.1	0.5	10.4	0.9	47.4	18.0	5.9	4.3		16.8	2.0
05	14 - 20	7	6,282	69.8	5.3	0.5	5.1	0.5	10.5	0.9	48.2	17.8	5.6	4.3	+3	13.7	1.7
06	11 - 17	7	6,230	69.9	5.3	0.6	5.1	0.5	10.5	0.9	49.4	18.5	7.9	4.3		13.5	1.9
07	16 - 22	7	6,264	69.9	5.4	0.5	5.1	0.5	10.5	0.9	49.8	18.6	7.4	4.3	+3	11.6	1.9
08	13 - 19	7	6,124	70.4	5.3	0.5	5.2	0.5	10.5	0.9	49.0	18.6	7.2	4.3	+2	12.2	2.1
09	16 - 22	7	6,087	70.2	5.4	0.5	5.2	0.5	10.6	0.9	48.6	18.0	5.9	4.3	+2	13.6	2.2
10	09 - 15	7	6,088	70.1	5.4	0.5	5.2	0.5	10.6	0.9	48.7	18.1	6.8	4.3	+2	16.0	2.9
10	17		60MPH:+3.2%; 65MPH:+5.9%; 70MPH:+5.3%; 75MPH:+4.8%									POST VALIDATION					
10	19 - 25	7	5,875	70.1	5.7	0.6	5.5	0.6	11.2	1.0	50.8	19.0	15.4	4.3	+2	18.4	3.2
11	04 - 10	7	6,134	70.1	5.8	0.6	5.5	0.6	11.3	1.0	52.1	19.3	18.1	4.3	+2	18.2	3.4
12	10 - 16	7	5,466	68.6	6.0	0.7	5.6	0.6	11.6	1.1	53.6	19.6	21.0	4.30	+3	22.3	5.0
2008																	
01	14 - 20	7	5,290	69.9	6.1	0.7	5.6	0.6	11.8	1.1	54.3	20.2	23.3	4.29	+3	25.2	10.5
02	08 - 14	7	5,241	69.1	5.9	0.7	5.6	0.6	11.4	1.4	52.8	19.7	20.5	4.27	+2	26.4	12.0
02	26	0900	BALANCE RT vs LT FACTORS														
03	10 - 16	7	5,039	69.5	5.7	0.6	5.6	0.6	11.3	1.2	52.2	19.2	17.9	4.28	+2	22.2	6.2
04	09	16:35	UPGRADE WCU-II FIRMWARE TO REV N														
04	14 - 20	7	5,667	69.2	5.6	0.6	5.6	0.6	11.2	1.3	52.6	19.5	17.8	4.30	+2	21.8	3.9
04	22		REPLACE RUBBER STRIPS ON RETAINING BARS; UPGRADE SSM FIRMWARE TO REV E														
04	23	07:43	ADJUST CALIBRATION FACTORS														
04	23 - 27	5	3,728	69.0	5.5	0.5	5.8	0.6	11.3	1.1	56.0	19.3	22.2	4.30	+2	10.6	1.4
04	28	07:30	ADJUST CALIBRATION FACTORS														
04	30		65MPH:-2.2%; 70MPH:-3.5%; 75MPH:-5.0%									POST VALIDATION					
05	05 - 11	7	5,717	69.0	5.2	0.5	5.3	0.5	10.6	1.0	50.6	18.1	5.2	4.30	+2	9.6	1.7

Figure 84. Screen shot. Tracking of system modifications and monthly calibration monitoring statistics.

- In June 2006, factors for both right and left sensors were decreased 4.0 percent based upon test truck data. Was the desired effect on weights achieved?
    - Yes, for the July 2006 sample, the average GVW dropped between four and five percent, and the average steer axle weight dropped between three and four percent.

- For the 16 months following the June 2006 calibration:
    - Is the system exhibiting any calibration drift?
        - Although the average GVW drops gradually from 50.1 k to 46.4 k (seven percent) before starting to increase again, the loaded distribution peaks per the GVW distribution plots (Figure 80) remain quite steady. This would indicate the calibration is not drifting. Also, the fact that by the 2007

summer months these weights have returned to their 2006 summer weights indicates that the decrease in average weights is probably attributable to a seasonal change in truck operating characteristics.

  - Are the right and left weigh sensors in balance and exhibiting acceptable standard deviations?
    - With exception of the July 2007 sample, the right and left balances are ok; standard deviations are marginal, but there is no indication of sensor problems.

  - In January 2007, the scale sensor interface card was replaced. Did this replacement affect the weight output?
    - No, all weight statistics remained reasonably constant.

  - Is the Axle 2-3 spacing remaining constant at 4.3?
    - Yes.

  - Is the overweight percentage remaining constant?
    - Yes.

- In October 2007, factor adjustments were made based upon test truck data. Was the desired effect on weights achieved?
  - Yes, for the October 2007 sample, the average GVW increased between four and five percent, and the average steer axle weight between five and six percent.

- For the months following the October 2007 calibration, is the system exhibiting any calibration drift?
  - The GVW is increasing. However, the increasing weight output of only the right weigh sensor and corresponding increase in its standard deviation, in conjunction with increasing "Invalid" and "Unequal Detection" flag percentages, indicate a sensor problem, not a calibration drift problem.

- In February 2008, balancing of right and left weight outputs was attempted by lowering right sensor's calibration factors. Was the desired effect on the weights achieved?
  - Yes, for the March 2008 sample, the right weight output is back to where it was following the October 2007 calibration.

  Note that this action is only a temporary measure to make data as accurate as possible pending resolving the right sensor problem.

- In April 2008, firmware was upgraded. Did this upgrade affect the weight output?
  - No, all weight statistics remained reasonably constant.

- In April 2008, there was onsite repair work on weigh sensors, a firmware upgrade, and adjustment of calibration factors from the office based upon a small traffic stream sample. Are the WIM weights where they should be in readiness for a planned onsite validation using test trucks?

    - No, a five-day sample indicates the following:
        - Although the Axle 1 weight is consistent with that following the October 2007 calibration, the GVW is almost 10 percent higher.
        - The right and left weights are slightly out of balance.
    - Calibration factors were adjusted from the office again.

- In April 2008, there were factor adjustments based upon test truck data. Was the desired effect on weights achieved?
    - In some respects, yes. Based upon the May 2008 sample, the loaded peak indicates lower weight readings, although it is back to where it was following the June 2006 calibration (refer to the GVW distribution plots displayed in Figure 82). It is also noted that the weight statistics are now very close to those immediately following the June 2006 calibration.

As an example from another site, Figure 85 displays the GVW distributions for the monthly samples over an 11-month period. Validations with test trucks were performed in August 2007, with no calibration factor adjustments. In March 2008, calibration factor increases were made which would affect only the weights of the very low percentage of slower moving trucks. As is evident from both the loaded and empty truck distribution peaks, this system is reporting WIM weights that are too high. The empty peaks are consistently at the “35.0-37.5” k distribution instead of “30.0-32.5” or “32.5-35.0” as is typical. The loaded peaks, although moving around a bit, are at times in excess of the maximum GVW limit of 80 k. Why is this problem not being corrected by running test trucks? Again, the answer is speed.

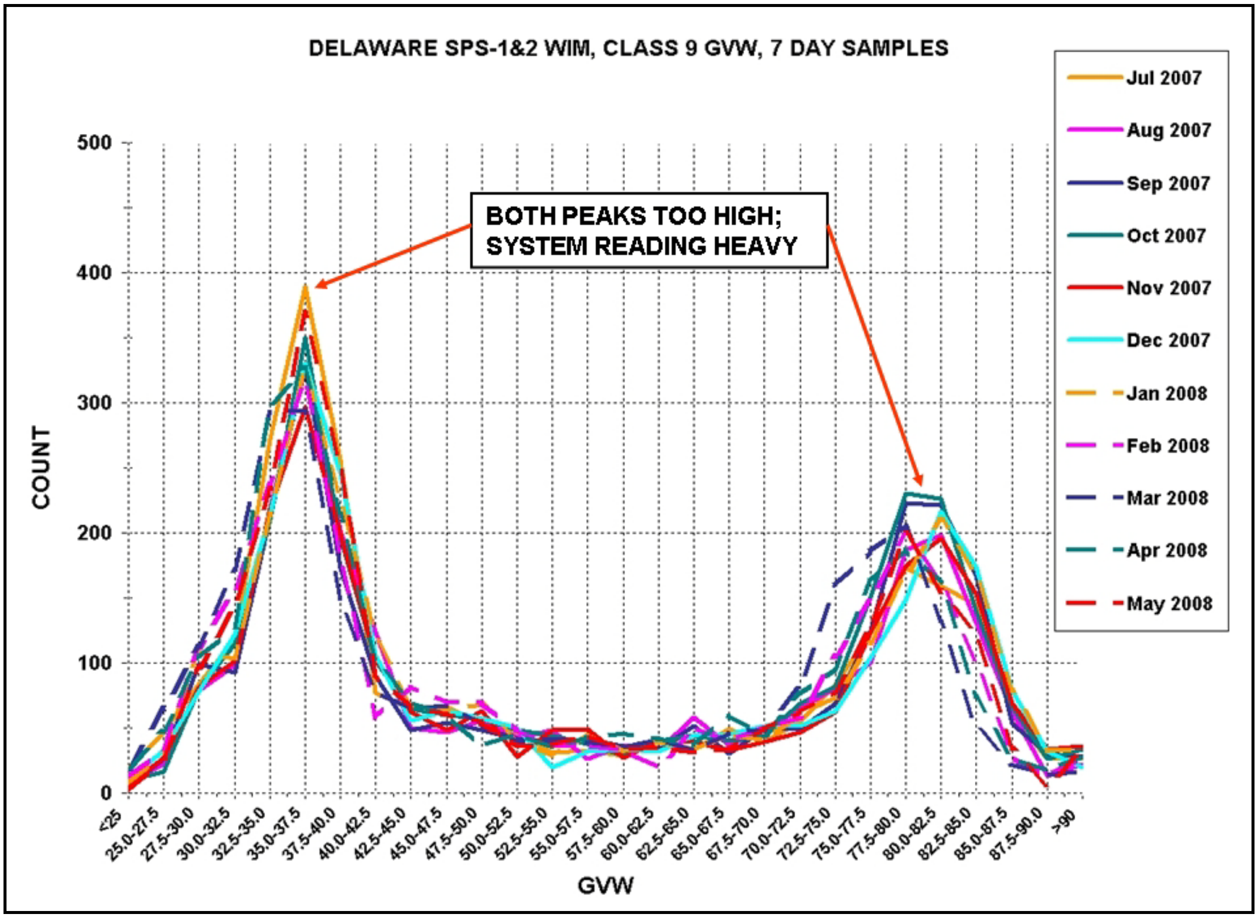


Figure 85. Graph. Class 9 GVW distribution plots, empty and loaded peaks too heavy.

Figure 86, like Figure 78, displays two individual graphs that have been sized and aligned to exhibit the importance of considering speed when performing calibrations, or when analyzing the effect of calibration factor adjustments on the WIM weights for the truck traffic stream. However, this example portrays a system that really has not been calibrated even though time and resources were expended to go through the motions of performing a validation/calibration using test trucks.

The top graph displays the percent of WIM GVW error for each run for the two test trucks. The solid symbols ("PRE-VAL") are for the WIM GVW errors using the system's weight calibration factors in effect at the start of the first set of test truck runs. The non-solid symbols ("POST-VAL") are for the WIM GVW errors using the system's weight calibration factors as adjusted based upon the PRE-VAL test truck data. The percentage of factor adjustment for each of the system's five calibration speed points is displayed immediately above the corresponding speed. As is evident from the plots, it would appear that the desired effects were attained even though there was an obvious problem with the PRE-VAL Truck 2 data. The WIM error plots follow the "0%" error axis for the 41 mi/h to 57 mi/h speed range. The problem is that very few traffic stream trucks are traveling within this speed range as evidenced by the lower graph. Figure 87 exhibits additional rationale for the statement that the system "…really has not been calibrated."

Figure 87 displays weight by speed range statistics for a seven-day Class 9 sample from this site using a portion of the Excel table discussed previously in regard to Figure 72. This table indicates that the range of speeds traveled by the calibration test trucks cover only five percent of the speed range traveled by the Class 9 traffic stream (which, per the lower graph in Figure 86, corresponds with all of the truck traffic stream speeds). This table also indicates that the average steer axle weights and average GVW for 77 percent of the Class 9s are considerably higher than that for the very small sample within the speed range covered by the calibration test truck data. This is probably the reason that the Class 9 traffic stream GVW distributions displayed in Figure 85 suggest that the system's weight readings are too high. The system has simply not been calibrated (or validated) for speeds above 55 mi/h.

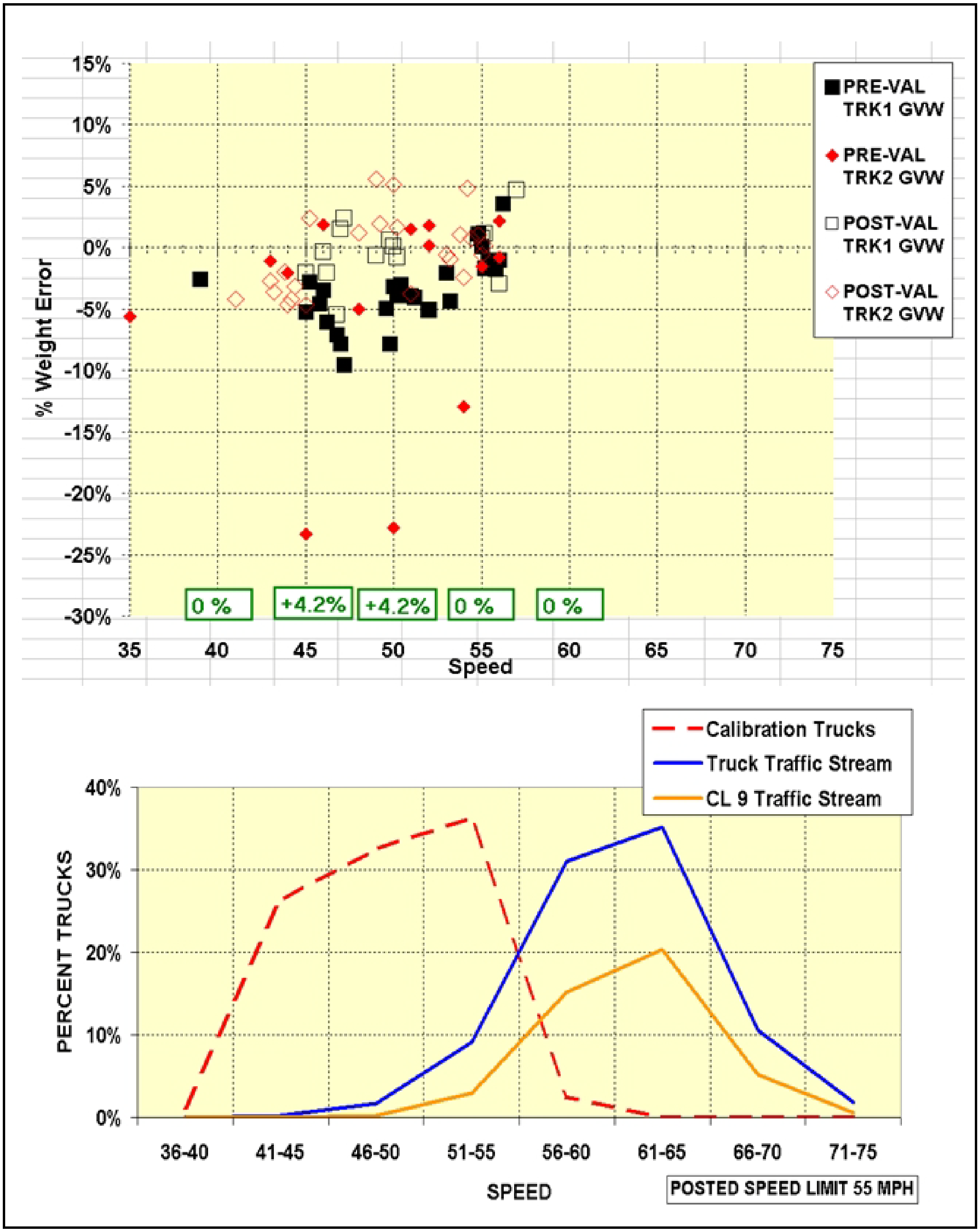


Figure 86. Graphs. Calibration test truck GVW WIM error x speed plots and truck traffic stream speeds versus calibration test truck speeds plots, ineffective calibration.

AVERAGE WEIGHTS BY SPEED RANGE				
Speed Range MPH	Class Count	% Class Count	AX1 Avg Wt	Avg GVW
<25	2	0.1%	8.0	67.4
25 -> 29	0	0.0%	---	---
30 -> 34	0	0.0%	---	---
35 -> 39	0	0.0%	---	---
40 -> 44	1	0.0%	9.0	30.1
45 -> 49	9	0.3%	10.7	50.8
50 -> 54	122	4.7%	10.4	52.3
55 -> 59	746	28.9%	10.8	55.8
60 -> 64	1244	48.1%	10.8	57.0
65 -> 69	405	15.7%	10.9	52.0
70 -> 74	47	1.8%	11.1	53.9
75 -> 79	9	0.3%	11.3	43.0
80 ->	0	0.0%	---	---
All	2585	100.0%	10.8	55.5

Speed range covered by calibration test truck data

Figure 87. Screen shot. Weights versus speed statistics, ineffective calibration.

5.4. ADJUSTMENT OF CALIBRATION FACTORS BASED UPON TRUCK TRAFFIC STREAM DATA

This section has provided recommended procedures and methods of analyses that can be performed by the Office Data Analyst to monitor a WIM system's calibration. A recap of problems that may become apparent to the analyst in performing calibration monitoring, as well as options available to the analyst to improve the system's accuracy will be provided. However, in that for certain situations the adjusting of calibration factors based upon analyses of traffic stream data instead of only test truck data will be offered as an option, the appropriateness and validity of such factor adjustments need to be addressed first. There are several reasons that may prompt the analyst to adjust calibration factors, including the following:

- Balancing weight outputs of right and left sensors.
    - If the analyst uses proper procedures to modify calibration factors for the sole purpose of balancing the right and left sensor weight outputs, and such modifications do not affect any increase or decrease in axle weights, it should not be necessary to validate calibration by use of test truck data. However, verification that steer axle weights and GVW have not changed must be conducted by subsequent sampling and data analysis of the traffic stream.

- Maintaining accuracy pending test truck validation/recalibration.

- In order to continue collecting accurate data it may be beneficial to modify calibration factors based upon traffic stream data as an interim measure until such time that onsite validation and/or recalibration by use of test trucks can be performed to address one of the following:
  - The analyst can confirm that calibration drift is occurring.
  - A weigh sensor has been replaced or repaired.
  - System software/firmware has been modified or an electronic component repaired or replaced.

  If the test truck data indicates that the interim calibration factors resulted in data conforming to accuracy requirements such data may be disseminated. If the test truck data indicates that the interim factors did not result in data conforming to accuracy requirements, such data should be purged or its use limited.

- Inconsistent test truck data.
  - As displayed in Figure 81, even testing by use of proper procedures using test trucks that meet testing requirements may result in test truck data varying by five percent or more in terms of determining WIM error. Also, as displayed in Figure 83, such differences in test truck data, particularly over a period of time, may make it apparent to the analyst that the data would probably be more accurate if the differences in the test truck data were averaged out in order to calculate calibration factor adjustments.
  - In the absence of evidence that test truck data is invalid, any determination of calibration factors based upon considerations other than the most current test truck data is not “truth in data”. However, analyses of test truck data to determine what factors will result in a system’s best estimates of static weights are much more of an art than a science. The extent to which the analyst is allowed to utilize subjective procedures in determining calibration factor adjustments is a policy decision. It is also noted that a site must have somewhat consistent (and thereby predictable) truck operating characteristics for an analyst to consider “trusting” traffic stream data statistics in questioning the reliability of test truck data.

- Ineffective or useless test truck data.
  - Figure 86 and Figure 87 display examples of a test truck calibration that was ineffective due to the fact that the test truck speeds covered only a very small percentage of the speeds traveled by the truck traffic stream. The only way to obtain test truck data that would be useful in properly calibrating the system used for this example would be to run the test trucks at speeds up to at least 65 mi/h, which would be in violation of the 55 mi/h posted speed limit. This, obviously, cannot be recommended.
  - However, it is suggested that for such a site, the owner agency discuss the situation with both its legal department and the appropriate enforcement agency to determine if there is a possible solution. For example, the use of marked pilot and/or shadow vehicles for the trucks or some type of signing on the trucks might be deemed an adequate procedure to permit the test truck to run at the same speeds as the truck traffic stream.

- In the absence of having test truck data to properly determine calibration factors, the agency has two choices, described below.

    1. Accept the fact that the system is not calibrated and acknowledge such when disseminating data.

    2. Subject to a site's having somewhat consistent truck operating characteristics, adjust the calibration factors to provide weights consistent with predictable weights over the range of speeds traveled by the truck traffic stream. It is acknowledged that this is not "truth in data", but neither is weight data based upon calibration factors that are not based upon test truck data.

5.5. RESOLVING ACCURACY PROBLEMS IDENTIFIED BY MONITORING OF TRUCK TRAFFIC STREAM

Typical calibration monitoring problems and options for improving a system's accuracy include those described below.

5.5.1. Gross Weight Distribution

If distributions appear to be unreasonable and/or inconsistent, continue analyses to determine if it is potentially due to one of the items listed below.

- Change in average weight outputs.
    - Either the right or left Axle 1.
    - Both right and left Axle 1.

- Calibration factors changed.

- Calibration factors based upon inconsistent test truck results.
    - Consider adjusting calibration factors using combination of traffic stream data and review of test truck data from all calibration/validation sessions.

- Calibration factors for entire range of speeds traveled by truck traffic stream not based upon valid test truck data.
    - Consider adjusting calibration factors for each speed point based upon traffic stream data.

- Calibration drift.
    - If confirmed to be probable, adjust calibration factors based upon traffic stream data as interim measure until such time calibration can be checked by use of test trucks.

- Seasonal change in truck operating characteristics.
    - Need minimum one year of tracking distributions.

5.5.2. Individual Sensor Weight Outputs

- If Axle 1 weights and GVWs appear to be accurate but Axle 1 right and Axle 1 left average weights are different by more than 0.2 k, adjust both right and left sensor's factors to bring right and left average weights into balance (see Figure 88). This should have no effect on either the Axle 1 weight or the GVW.

- If Axle 1 weight and GVW weight have both increased or decreased, and the entire increase or decrease is attributable to a weight output change in either the right or left sensor, adjust the factors for only the sensor for which the weights have changed (see Figure 88). The percentage change in GVW output should be approximately half of the percentage of change in the sensor's factor.
    - Note that regardless of whether the sensor's weight output change is attributable to subtle malfunction or actual calibration drift (which would be unusual for just one of the two sensors), calibration should be verified by test trucks as soon as possible.

- If a significant change is noted in either the right or left Axle 1 average weight:
    - Check calibration factor.
    - If calibration factor is correct, perform real-time diagnostics and extensive data analyses (per SECTION 4) of sensor for potential malfunction.

- If there is more than a 0.1 k increase in either sensor's average weight standard deviation, perform real-time diagnostics and extensive data analyses (per SECTION 4) of sensor for potential malfunction.

TO INCREASE OR DECREASE AXLE 1 WEIGHTS AND GVW WHEN RIGHT AND LEFT SENSOR OUTPUTS ARE IN BALANCE, SIMPLY INCREASE OR DECREASE ALL WEIGHT CALIBRATION FACTORS BY THE PERCENTAGE OF DESIRED PERCENTAGE OF INCREASE OR DECREASE IN WEIGHT OUTPUTS:

EXIST AVERAGE WEIGHTS	EXIST CALIB FACTORS FOR 1st SPEED BIN
RIGHT AXLE 1 : 5.4	RIGHT SENSOR : 3200
LEFT AXLE 1 : 5.4	LEFT SENSOR : 3500
AXLE 1 : 10.8	
GVW : 65.0	

DESIRED AVERAGE WEIGHTS	ADJUSTMENT TO FACTORS FOR 1st SPEED BIN
RIGHT AXLE 1 : 5.7	RIGHT SENSOR (11.4 / 10.8) x 3200 = 3378
LEFT AXLE 1 : 5.7	LEFT SENSOR (11.4 / 10.8) x 3500 = 3694
AXLE 1 : 11.4	(ADJUST ALL OTHER FACTORS IN SAME MANNER)
GVW : 68.6 (APPROXIMATELY)	

TO BALANCE RIGHT AND LEFT SENSOR WEIGHT OUTPUTS WHILE MAINTAINING SAME AXLE WEIGHT AND GVW OUTPUT:

EXIST AVERAGE AXLE 1 WEIGHTS	EXIST CALIB FACTORS FOR 1st SPEED BIN
RIGHT : 5.2	RIGHT SENSOR : 3200
LEFT : 5.6	LEFT SENSOR : 3500
AXLE : 10.8	

DESIRED AVERAGE WEIGHTS	ADJUSTMENTS TO FACTORS FOR 1st SPEED BIN
10.8/2 = 5.4 EACH	
RIGHT : 5.4/5.2 = 1.04	RIGHT SENSOR : 1.04 x 3200 = 3328
LEFT : 5.4/5.6 = 0.96	LEFT SENSOR : 0.96 x 3500 = 3360
	(ADJUST FACTORS IN SAME MANNER FOR EACH SPEED BIN)

TO BRING WEIGHT OUTPUTS OF ONLY THE RIGHT OR LEFT SENSOR BACK TO HISTORICAL WEIGHT OUTPUTS (OR TO ASSIGN TEMPORARY FACTORS TO A SENSOR THAT HAS BEEN REPLACED OR REPAIRED):

EXIST AVERAGE WEIGHTS	EXIST CALIB FACTORS FOR 1st SPEED BIN
RIGHT AXLE 1: 5.2	RIGHT SENSOR : 3200
LEFT AXLE 1 : 5.6	LEFT SENSOR : 3500
AXLE 1 : 10.8	
GVW : 65.0	

DESIRED AVERAGE WEIGHTS	ADJUSTMENTS TO FACTORS FOR 1st SPEED BIN
RIGHT AXLE 1 : 5.2	RIGHT SENSOR : NO ADJUSTMENT
LEFT AXLE 1 : 5.2	LEFT SENSOR : 5.2/5.6 x 3500 = 3250
AXLE 1 : 10.4	(ADJUST FACTORS IN SAME MANNER FOR EACH SPEED BIN)

NEW AVERAGE GVW SHOULD BE APPROXIMATELY (10.4/10.8) x 65.0 = 62.6

All weights in kips

Figure 88. Procedure. Procedures and examples for adjusting calibration factors based upon traffic stream data statistics.

5.5.3. Axle Spacings (and thereby speed)

If the average Axle 2-3 spacing for the sample of the Class 9's Type 3S2 is not 4.3 feet, adjust the system's sensor-to-sensor or loop-to-loop parameter value to bring the average spacing to 4.3 feet (refer to Figure 89).

Note that a vast majority of the Type 3S2 vehicles in the U.S. has Axle 2-3 (drive tandem) spacings, which, for a large sample, average 4.3 feet. However, for locations that have Canadian truck traffic or "specialty" truck types, 4.3 feet may not be a valid constant. Consideration needs to be given to observed axle spacing configurations and the percentage of such atypical vehicles. The parameter values for determining axle spacing and speed should be initially determined based upon test truck data.

TO INCREASE OR DECREASE WIM AXLE SPACING LENGTHS (AND THEREFORE SPEEDS) BASED UPON SAMPLING OF TRAFFIC STREAM DATA (TYPICALLY CLASS 9 TYPE 3S2), ADJUST SENSOR-TO-SENSOR OR LOOP-TO-LOOP PARAMETER VALUE BY 4.3 / AVERAGE AXLE 2 - 3 SPACING.

EXAMPLE:

EXIST WIM AVERAGE AXLE 2-3 SPACING FOR LANE #1 : 4.5
EXIST LANE #1 SENSOR SEPARATION PARAMETER VALUE: 10.0
REVISE VALUE (4.3 / 4.5) x 10.0 = 9.6

REVISE LOOP SEPARATION PARAMETER VALUE IN SAME MANNER.

PERFORM SAME PROCEDURE FOR EACH LANE.

All values in feet

Figure 89. Procedure. Procedure and example for adjusting axle spacing lengths (and thereby speeds).

5.5.4. Overall Vehicle Length

If the average Overall Vehicle Length is not five to seven feet longer than the average Axle 1 to 5 wheelbase for a sample of Class 11's Type 2S12 vehicles (or the average Axle 1 to 6 wheelbase for Class 12's 3S12 vehicles), adjust the loop length parameter values (see Figure 90).

Note that the procedure described in Figure 90 assumes that the particular system calculates Overall Vehicle Length based upon the time of a vehicle's inductance for either or both loops.

TO INCREASE ACCURACY OF WIM OVERALL VEHICLE LENGTHS BASED UPON SAMPLING OF TRAFFIC STREAM DATA (TYPICALLY CLASS 11 TYPE 2S12), FIRST ESTIMATE WIM ERROR BY:

(OVERALL LENGTH – WHEELBASE) – 6 = ESTIMATED ERROR

TO DECREASE THE WIM VEHICLE LENGTH, INCREASE THE LOOP LENGTH PARAMETER VALUE BY THE ESTIMATED ERROR. TO INCREASE THE VEHICLE LENGTH, DECREASE THE LOOP LENGTH VALUE BY THE ESTIMATED ERROR.

EXAMPLE:

EXIST AVERAGE OVERALL VEHICLE LENGTH FOR LANE #1 : 75
EXIST AVERAGE WHEELBASE FOR LANE #1 : 65
EXIST LOOP LENGTH PARAMETER : 6

WIM ERROR = (75 – 65) - 6 = + 4

TO DECREASE VEHICLE LENGTHS BY 4, INCREASE LOOP LENGTH PARAMETER BY 4

CHANGE EXIST PARAMETER TO (6 + 4) = 10

PERFORM SAME PROCEDURE FOR EACH LANE.

All values in feet

Figure 90. Procedure. Procedure and example for adjusting overall vehicle lengths.

As stated previously, the procedures for using traffic stream data to make calibration factor adjustments presented in this section are temporary, short-term measures and not a replacement for using data from on-site test truck sessions. On-site validations with test trucks should be performed at least on an annual basis for systems with no operational problems. Test truck validations should be performed as soon as possible when one or more sensors are replaced or other modifications made which might affect a system's calibration or when calibration monitoring by use of traffic stream data indicates calibration drift. Furthermore, these procedures should be performed by experienced data analysts and need to be documented (why, how, which method).

5.6. MAKING BEST USE OF AVAILABLE RESOURCES

One of the many benefits in performing calibration monitoring is the ability to best allocate available resources for performing onsite calibrations/validations with test trucks. Few agencies, if any, have the resources to run test trucks at every WIM site every six months on a routine basis, and also every time a system's maintenance of calibration is questionable.

If the monitoring of a particular system indicates very consistent truck traffic stream operating characteristics with little if any seasonal variation after a couple years of monitoring, there is little need to routinely validate calibration with test trucks every six months. If calibration factors are adjusted based upon truck traffic stream monitoring for more than one site, validation of the sites' calibrations with test trucks should be scheduled in the order of not only the importance of each site's data but also in the analyst's confidence of the factor adjustments based upon monitoring.

For sites with inconsistent truck traffic stream operating characteristics, factor adjustments based upon traffic stream statistics are not dependable, and any such adjustments should be validated with test trucks as soon as possible.

SECTION 6. REFERENCES

- Flinner, M and H. Horsey. *Traffic Data Editing Procedures: Traffic Data Quality "TDQ"*. Final Report, Transportation Pooled Fund Study SPR-2 (182), Federal Highway Administration, Washington, D.C., no date. This report is available at http://www.fhwa.dot.gov/policy/ohpi/tdep.htm.

- *LTPP Field Operations Guide for SPS WIM Sites*, Version 1.0, Long Term Pavement Performance, Federal Highway Administration, McLean, VA, 2006. A May 2009 revision is under review and may be obtained by contacting LTPP Customer Service at ltppinfo@dot.gov.

- *LTPP Weigh-in-Motion System: Model Performance Specifications and Application Requirements for Equipment - Hardware and Software*, Long Term Pavement Performance, Federal Highway Administration, McLean, VA.

- Nichols, A.P. and D.M. Bullock, *Quality Control Procedures for WIM Data*, Final Report, FHWA/IN/JTRP-2004/12, Purdue University, West Lafayette, Ind., June 2004. This report can be downloaded online at http://docs.lib.purdue.edu/jtrp/176.

- Papagiannakis, A.T., et al., NCHRP Synthesis of Highway Practice 386: *High Speed Weigh-in-Motion System Calibration Practices*, Transportation Research Board, Washington, D.C., 2008. This report is available at http://www.trb.org/news/blurb_detail.asp?id=9955.

- Quinley, R., *Session 6-WIM Site Selection and Session 7-WIM Site Pavement Preparation and Considerations*, FHWA WIM/Traffic Workshop, Raleigh, NC, Feb 24-26, 2009.

- *State's Successful Practices Weigh-in-Motion Handbook*, Federal Highway Administration, Washington, D.C., 1997. WIM Data Analysts are referred to section 7.3 for WIM Data QC procedures followed by Caltrans in the mid 1990s. This report is available from http://www.ctre.iastate.edu/research/wim_pdf/Secti7.pdf.

- *Traffic Analysis Software Volume 1-User's Guide Draft*, Long Term Pavement Performance, Federal Highway Administration, McLean, VA, 2008. A copy of this guide can be obtained by contacting LTPP Customer Service at ltppinfo@dot.gov.

- *Traffic Monitoring Guide*, Federal Highway Administration, Washington, D.C., 2001. This document is available at http://www.fhwa.dot.gov/ohim/tmguide/.

- *Vehicle Travel Information System (VTRIS)*, Federal Highway Administration, Website can be accessed at http://www.fhwa.dot.gov/ohim/ohimvtis.cfm. The FHWA W-Tables (Truck Weight Data Summaries) can be accessed at https://apps.fhwa.dot.gov/VTRIS/default.aspx.

APPENDIX A.

This appendix contains a copy of the draft for the model specification:

- *LTPP Weigh-in-Motion System: Model Performance Specifications and Application Requirements for Equipment - Hardware and Software,* by the Long Term Pavement Performance, Federal Highway Administration, McLean, VA.

Note that this document is still a work in progress. Please contact ltppinfo@dot.gov for more information.

LTPP Weigh-in-Motion System:

Model Performance Specifications and Application Requirements for Equipment - Hardware and Software

Version 2.0

NOTE: This document is still a "work in progress".

Federal Highway Administration
Office of Infrastructure Research, Development and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, HRDI-13
McLean, Virginia 22101-2296

ETG MODS

U.S. Department of Transportation
Federal Highway Administration

LTPP Weigh-in-Motion System Model Performance Specifications and Application Requirements for Equipment- Hardware and Software

Introduction

It is the intent of these specifications to establish the minimum requirements for high speed weigh-in-motion equipment utilized the purpose of collecting traffic data at Long-Term Pavement Performance (LTPP) Specific Pavement Studies (SPS) sites.

High Speed Weigh-In-Motion System

Description

The Weigh-In-Motion System (hereafter WIM system) shall include equipment and software for collecting, processing, storing, transmitting and manipulating information related to the counting, classifying and speed monitoring of all vehicles and the weighing of trucks and buses at highway speeds.

On-site Equipment

The WIM system shall provide for single threshold weighing, and operate over a speed range of 5 mph to 100 mph. Single threshold weighing shall consist of scales in each lane of measurement. The weigh sensors shall cover the entire lane width. The WIM system shall consist of the following components:

1. Wheel scales shall report weight data for each wheel track (right axle weight and left axle weight). Such wheel weight data shall be uniform across the total width of the scale.

2. A WIM controller shall be installed in the controller cabinet. The WIM controller shall include all of the equipment and software to calculate, store and transmit to a host computer all data specified in these specifications. Either a keyboard and monitor or a portable personal computer (including protective case) for the purpose of accessing the WIM controller shall be furnished as part of the WIM controller. The WIM controller shall operate on AC power with a DC battery backup system to provide uninterrupted power to the WIM controller during AC power outages for a minimum of one hour. The system shall be able to operate on solar power if AC power is unavailable. The modem to be installed in the controller cabinet shall be compatible with the host computer modems described elsewhere in these specifications. The user shall have the capability of entering a site designation code up to three characters.

3. Surge protection devices against lightning and other transient high voltage consisting of:

A. Power Source Protection
B. Phone Line Protection
C. Loop Input Protection
D. WIM Sensor Protection
E. Grounding
    1. All conduit shall be metal and bonded with #8 bare copper wire.
    2. A ground rod with an impedance of 10 ohms or less shall be placed at the cabinet foundation.
    3. The ground rod shall be connected to the electronics backplane with #6 bare wire.
    4. If solar powered, a lightning rod shall be placed on top of the solar panel pole, and shall be independently grounded.

4. All necessary interconnecting cables and miscellaneous materials to make an operational system.

Functional Requirements

1. The WIM system shall be able to accommodate vehicles and vehicle combinations with up to eleven axles and shall automatically determine for each vehicle, by lane of travel:

    A. Weight of each axle by left and right wheel weights, speed, axle spacing, and vehicle length.

    The WIM system shall provide for calibration features such that the accuracy required under LTPP standards for equipment performance verification can be met

    B. Vehicle classification:

    The WIM system shall provide for a minimum of 15 vehicle classifications. Class 1 through Class 13 shall be used according to the classification scheme shown in Section 4, Appendix A, of the Federal Highway Administration 3d edition of the Traffic Monitoring Guide, February 1995. Class 14 will identify special vehicles as determined by the user. Class 15 will identify any vehicle not conforming to the classification criteria for Classes 1 through 14. Classification criteria for Classes 1 through 14 shall be programmable by the user.

    The WIM system shall provide sufficient flexibility in spacings and weights (axle and/or gross) for each of these classes so that accurate classifying is achievable.

    C. Invalid measurements:

    An “invalid measurement” code shall be assigned to any vehicle meeting the front axle weight threshold (discussed below) when (1) the left and right wheel weights of any axle have a difference of 40 percent or more; and (2) either of the wheel weights of such axle exceeds 2.0 kip. Both the 40 percent and 2.0 kip values shall be programmable by the operator. Any vehicle assigned an “invalid measurement” code shall not be considered a “Weighed Vehicle” but shall be classified and counted and all vehicle data shall be stored in the vehicle record.

D. Determination of weight violations:

For any vehicle meeting the front axle weight threshold (discussed below), the WIM system shall determine which, if any, axle(s) or axle grouping(s) exceed the weight limits set forth in the “Weight Violation Table” contained in these specifications. Any vehicle with one or more weight violations will be coded as to such a violation or combination of violations. The weight limitations set forth in the “Weight Violation Table” shall be the default settings. Such weights shall be programmable by the user.

2. The WIM controller shall calculate and store all specified data on a storage medium. The on-site data storage device shall have the capacity to store a minimum of fourteen days of vehicle count data and individual vehicle records. The storage device shall be completely solid state with no mechanical components and shall be a type not susceptible to loss of accumulated data should electrical power be interrupted. The WIM controller shall continue to calculate and store data for all vehicles passing through the system during periods of access, both on-site by portable PC and by the host computer for purposes of programming, real-time view and downloading of data.

The WIM controller shall store the following data:

A. Hourly vehicle counts by lane, by class and by speed range for each 24-hour period (Class/Count Summary).

B. Individual vehicle records for all vehicles with a front axle weight greater than 3.5 kip (hereafter referred to as “truck records”). The front axle weight threshold for truck records shall be programmable by the operator with 3.5 kip as default setting. Each truck record shall include, as a minimum, the following data:

i. Time and Date.
ii. Lane Number.
iii. Vehicle Number.
iv. Speed.
v. Vehicle Classification.
vi Weight in kips of each wheel or dual set of wheels by left and right side and by axle number.
vii. Spacing in feet between each sequentially numbered axle.
viii. Overall length of each vehicle or combination of vehicles in feet.
ix. Code for weight violation(s).
x. Code for invalid measurement(s).

3. Data shall be calculated and formatted such that all data can be accessed and all required reports can be generated by use of the WIM system application software.

4. All equipment with exception of the WIM controller's modem shall operate properly within an atmospheric temperature range of -40°C to +70°C or –40°F to 158°F without the need of an added heating or cooling device.

5. The WIM controller shall have the communication capabilities to allow off-site personnel to view the operation of the WIM site and to allow for data transfer through telemetry over a dial-up, voice-grade telephone line. The WIM controller's modem shall be fully compatible with the host computer modem. The modem shall be specified by the WIM vendor. The WIM controller shall also allow on-site personnel to connect a computer to the WIM system for on-site observation and for the transfer of data.

High Speed WIM System Application Software

An application program, hereafter referred to as the "system program", which can be run on the host computer shall be furnished as part of the high speed WIM system. The host computer will be furnished by others and will consist of:

1. Personal computer using the current version of the Windows Operating System.
2. Printer
3. A 56,600 Baud modem.

The system program shall provide communications between the host computer and the on-site WIM controller and shall process downloaded data to generate the specified ASCII files. Although referred to herein as a single software program, communications functions and data processing functions may be provided as two separate programs as long as all functional requirements are met. The system program shall be "user friendly", hierarchical menu driven and shall perform the following applications:

Communications

1. The communications portion of the system program shall include the following applications:

   A. Real time view:

   The real time view application shall provide for the on-line monitoring of traffic. The display on the host computer shall depict the axle configuration of each vehicle passing through the site. The contents and format for the real time display shall be similar to the sample display contained in these specifications. The user shall have the options of displaying either all traffic or only vehicle classifications 4 through 15 as well as the option of displaying a selected individual lane or all lanes.

Printing of the real time data on the host computer printer shall be facilitated by means of an on/off toggle key from the keyboard.

B. System data programming:

The system data programming application shall provide for on-line modification to the WIM controller's software parameters, such as speed and weight calibration factors, vehicle classification parameters, weight violation table parameters, and front axle weight threshold.

C. Manual downloading:

The manual downloading application shall provide for the downloading of selected daily data files from the storage medium of the WIM controller to the storage medium of the host computer. The program shall provide for a listing of the daily data files stored in the WIM controller and shall provide for user selection of the file or files to be downloaded from such a listing. The program shall provide for the downloading of the current day's data stored as of the time of downloading.

D. Automatic downloading:

The automatic downloading applications shall provide for unattended downloading of daily data files stored in the WIM controller's storage medium to the storage medium of the host computer. The program shall provide the following:

i. User's input for the date and time that unattended downloading is to begin.
ii. Downloading of all daily files not previously downloaded by the automatic downloading application.
iii. At least three attempts to make telephone connection with the WIM controller.
iv. At least three attempts to download files from the WIM controller before aborting download.
v. Discontinuation of telephone connection after downloading of files from the WIM controller (or after an abort)) and returning the host computer to a standby mode.

E. History file:

The history file application shall create a daily file, which chronologically records events occurring during manual and automatic downloading sessions. Such events shall include, but not be limited to, modem result messages, start and end time of each file download and any pertinent messages generated by the program. The program shall provide for either:

i. The history file shall be in the form of an ASCII text file which can be viewed or sent to the printer or,

ii. A menu selection which shall provide for a listing of available history files and user selection of a file to be sent to the printer in the form of a report.

2. The communications portion of the system program shall meet the following functional requirements:

   A. Host computer's modem configuration:

   The program shall initialize the host computer's modem so that all necessary operating characteristics are set.

   B. Baud rate:

   The program will provide for operation at a minimum rate of 19200 baud.

   C. Error control:

   The program shall not in any way disable the modems' error-checking features, which prevent phone-line noise from corrupting data during file downloading.

   D. File downloading monitoring:

   The program shall display a window that allows the user to monitor the progress of file downloading. The program shall also provide for the abort of a file download.

Report Preparation

The report preparation application shall generate specified reports using the downloaded data. Such reports shall be sent to the host computer printer or to file. The program shall prepare the following reports:

1. From vehicle class/count summary file:
   A. Distribution of class and speed counts by lane.
   B. Distribution of vehicle counts by hour of day by lane.
   C. Distribution of vehicle classifications by hour of day.
   D. Distribution of vehicle classifications by day of month.
   E. Distribution of vehicles by speed by hour of day.

2. From individual truck records file:
   A. Distribution of truck record data by lane.
   B. Distribution of weight violations and invalid measurements of vehicle classifications 4 through 15.
   C. Distribution of weight violations by hour of day for vehicle classifications 4 through 14.
   D. Distribution of overweight vehicles by hour of day for vehicle classifications 4 through 14.
   E. Distribution of gross weights for vehicle classifications 4 through 14.

F. Distribution of 18 kip equivalent single axle loadings (ESALS) by hour of day for vehicle classifications 4 through 14. Program provides for user input of:
   i. Pavement type:
      (1) flexible pavement and structural number; or,
      (2) rigid pavement and slab thickness.
   ii. Vehicle status:
      (1) “all “ weighed vehicles (default); or,
      (2) “legal only” weighed vehicles; or,
      (3) “overweight only” weighed vehicles.

G. Distribution of axles by groups (single, tandem, tridem) by hour of day for vehicle classifications 4 through 14.

H. Distribution of trucks by day of month for classifications 4 through 15.

The reports shall include all information contained in and formatted similarly to the sample reports contained in these specifications (See Appendix A). The reports shall be printed in condensed print when necessary to fit on 8-½ inch x 11-inch sheets.

Determination of 18 kip equivalent single axle loads shall be in accordance with the methodology of the 1993 AASHTO Pavement Design Guide.

The program shall provide for the generation of reports in the following two modes:

1. Manual Mode:

For daily reports the program shall provide for user selection of the date and the specific report. For monthly reports, the program shall provide for user selection of the month/year and the specific report. The selected month report shall include the data from all downloaded daily data files resident with the system program on a directory or subdirectory of the host computer’s storage medium. The program shall also provide for user selection of the lane or lanes to be covered by the specific report (not applicable to the “Distribution of Class and Speed Counts by Lane”, the:”Distribution of Vehicle Counts by Hour of Day by Lane” and the “Distribution of truck Record Data by Lane” reports”).

The default shall be “all lanes.” The printed report shall note which lanes are represented.

2. Automatic Mode:

The program shall provide for user designation of one or a combination of the specific daily reports for automatic processing. User selection of lane or lanes is not required (the “all lanes” default may be used). User selection of vehicle status for the 18 kip ESAL report is not required (the “all” weighed vehicles default may be used). Such designations shall be effected by means of either:

A. An ASCII text file, which can be revised with text editor or word processor, supplied with a “Sample” designation; or,

B. A menu selection, which shall provide for user input designation.

Upon selection of automatic mode of report preparation by the user, the program shall send to the printer all pre-designated reports for all downloaded daily data files resident with the system program on a directory or subdirectory of the host computer's storage medium.

The designated reports shall remain in effect for subsequent automatic mode sessions unless report designation, is revised by the user.

Truck Record Batch Print

The truck record batch print application shall provide for the display of, all on/off printer-toggle of, individual truck records. The program shall provide for a listing of the daily truck records files available on the storage medium of the host computer and the user's selection of one of those files. The program shall also provide for the user's selection of the vehicle class or classes for which individual truck records will be displayed or printed as well as the starting hour of day.

The user shall have the following options in viewing and printing the individual truck records.

1. Scroll and print continuously all records for the selection of class(es); user has capability to stop/resume scrolling or terminates program.

2. Scroll each record one at a time; user has capability to:
   1. Print displayed record and display next record.
   2. Display next record.
   3. Terminate program.

An example of the truck record batch print is included in these specifications. (See Appendix A.)

ASCII Export Utility

The ASCII export utility application shall allow the user to generate specified ASCII files using downloaded files. The user will have the choice of:

1. From vehicle class/count summary file:
   A. ASCII classification file.
   B. ASCII speed file.

2. From individual truck record file:
   A. ASCII truck record file

The file formats for these files are contained in Appendix A.

TRAFFIC MONITORING GUIDE Files Utility

The TMG files utility shall allow the user to generate ASCII files conforming to the instructions contained in Section 6 of the FHWA Traffic Monitoring Guide 3rd edition using downloaded files.

Data Files

Notwithstanding the method of data manipulation and formatting used by the WIM controller, data files shall conform to the following:

1. Individual daily data files shall be created and stored in the storage medium of the WIM controller. Each daily data file shall include data for each 00:00 hour through a 23:59 hour period and shall have a file name which uniquely identifies the file as to site designation, date, and file contents (i.e., class/count summary data, individual truck record data, or both).

2. The daily data files shall be created at the start of each day. Data for each vehicle shall be filed within one hour of the vehicle's passing through the site, and the current day's files shall be accommodative to efficient use of storage medium space and rapid downloading via modem to the host computers.

3. Daily files containing class/count summary data and individual truck records data may be created in the storage medium of the WIM controller as two separate daily files or as one daily file. However, if one daily file is created and downloaded as such, the system program shall create two separate daily files, each with a file name which uniquely identifies it as to site, date and whether it is a vehicle class/count summary file or an individual truck records file.

<u>Acceptance Test</u>

The WIM Vendor shall demonstrate that the WIM system is available for use by the owner by successfully completing the acceptance test for each lane of data collection.

The acceptance test shall consist of the following:

1. Verification of WIM system accuracy:

Step One

Obtain at least 2 trucks to use for testing the WIM system accuracy. Select truck types that are most representative of the trucks that frequent the WIM location. One of the test trucks shall be a class 9 truck that has air ride suspension for both tractor and trailer, a non-liquid load, and loaded to a minimum of 90 percent of the truck's legal operating weight. The other truck will be of the 2nd most commonly occurring type of truck, and loaded to 80 – 90% of the truck's legal operating weight. If the class 9 truck is the most common type of truck at the WIM location, it is OK to use two class 9 trucks for testing the WIM system's accuracy. No unloaded trucks will be used for testing the WIM system's accuracy. The procedure for weighing and measuring the test vehicle(s) to obtain reference values is found in sections 7.1.3 to 7.1.3.7 of ASTM E 1318-02:

7.1.3.1 "Measure the center-to-center spacing between successive axles on each test vehicle and record this data to the nearest 0.1 ft (0.03m) as axle-spacing reference values."

7.1.3.2 " Weigh each test vehicle a minimum of three times, with brakes released, as described in 7.1.1 and 7.1.2 to measure tire loads for the wheel(s) on each end of every axle on the static vehicle. Move the vehicle completely away from the scale or weigher before beginning a new set of tire-load measurements, and always approach the weighing devices from the same direction for weighing. Sum the applicable tire loads to determine wheel ,axle, and tandem-axle loads as well as gross-vehicle weight each time the vehicle is weighed." (A scale which weighs individual axle and tandem loads is acceptable).

7.1.3.3 " Calculate the arithmetic mean for all wheel load, axle-load, tandem-axle-load, and gross-vehicle-weight values that result from weighing each test vehicle three or more times; …"

Average the three "static weight values" of the test vehicle(s) for the drive axle-load(s), 1st tandem-axle load(s), 2nd tandem-axle load(s), and gross-vehicle weight(s) to derive the static weights used in the accuracy verification.

Some type of communication, (cellular phone, CB radio, etc.), with the driver(s) of the test vehicle(s) will need to be established before the initial calibration begins.

Step Two

The communications software shall have a history file, (log file), applications which will create a daily file, in an ASCII type format, which chronologically records events occurring during initial calibration runs (and the final verification runs). Such events shall include, but not be limited to, recording the initial calibration factors of the WIM system, the calibration runs, final calibration factors, and any changes made to the calibration factors during the initial calibration runs, (and the final verification runs).

Step Three

The test truck(s) is driven over the WIM sensors in each lane a minimum of three times at each set speed point, and three times at each 8kph (5mph) increment between the first and third speed points.

Due to the temperature variations usually occurring during the course of the day, the truck will start at the lowest speed point and continue in sequence to the highest speed point. If the three speed points are set at 40 mph, 55 mph, and 70 mph, then the test truck(s) will start at 40mph and then go in sequence to 45 mph, then to 50 mph, etc., until the 70 mph point is reached. The truck(s) will then start all over again and repeat the same sequence two more times until there are a total of 21 runs for each test truck used in the validation.

The gross weight percent error is calculated for each run and plotted on a "Gross Weight Percent Error By Vehicle Speed" graph for each WIM lane. These graphs are analyzed to make the final adjustments to the WIM weight factors if necessary. They are also used to record pavement effects on vehicle dynamics for the site history.

If for any reason an adjustment needs to be made to the WIM Weight or Spacing factors, before all runs are completed, the validation runs will have to start all over again.

Step Four

Down load the data file and close and save the history (log) file.

For the site calibration to be accepted, the gross weight percent error of the validation data will have to be evenly distributed around the zero axis of the “Gross Weight Percent Error By Vehicle Speed” graph for each speed point in each WIM lane.

For a Type I WIM System the validation data will meet (or exceed) the functional performance requirements as found in table 2 under Section 5 of the ASTM E 1318-02 of the Standard Specifications for Highway WIM with a tolerance for 95% probability of conformity:

1. Gross-Vehicle Weight: +/- 10%
2. Axle-Group Load: +/- 15%
3. Axle Load: +/- 20%

2. Continuous operation of WIM system on-site equipment for 15 consecutive days following completion of the WIM system accuracy validation testing. Failure of the system to record and store data meeting the requirements set forth in these specifications for an accumulated time exceeding 3 hours during the 15 day-period shall be cause for the acceptance test to be repeated.

3. Testing of the WIM system application software during the above noted 15 day-period and the full working day following the 15 day-period. Failure of the software to perform any application meeting the requirements set forth in these specifications shall be cause for the acceptance test to be repeated.

Failure of the host computer or its peripheral equipment or of a communication line not furnished by the WIM vendor to transmit data may not be considered unacceptable performance, provided the WIM vendor demonstrates to the satisfaction of the owner that the failure is not caused by any of the WIM vendor furnished equipment.

Maintenance and Operations Manuals

The WIM vendor shall furnish a maintenance manual for the WIM controller, including vehicle detector sensor units and an operation manual for the system. The maintenance manual and operation manual may be combined into one manual. The manual(s) shall include, but need not be limited to, the following items:

1. Specifications.

2. Design characteristics.
3. General operation theory.
4. Function of all controls.
5. Trouble shooting procedure (diagnostic routine).
6. Block circuit diagram.
7. Geographical layout of components.
8. Schematic diagrams, signal responses and acceptable thresholds.
9. List of component parts with stock numbers.
10. Documentation for application software.

Appendix A.1

Sample Reports

PENDING: DESIGN OF ”THE “DISTRIBUTION OF AXLES BY GROUPS (SINGLE, TANDEM, TRIDEM) BY HOUR OF DAY FOR VEHICLE CLASSIFICATIONS 4 THROUGH 14” REPORT(S) AS REQUIRED BY **High Speed WIM System Application Software, Report Preparation, (2) (G)**

DISTRIBUTION OF CLASS AND SPEED COUNTS BY LANE

SITE DESIGNATION:
DATE:

LANE NUMBER <number of lanes varies with contract requirements>

	1		2		3		4		5		6		ALL LANES	
	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
CLASS														
1	0	0.0	0	0.0					0	0.0	6	0.0	6	0.0
2	22521	82.4	24464	82.7					28540	90.6	23974	87.6	99499	85.9
3	2687	9.8	2395	8.1					2324	7.4	1919	7.0	9325	8.1
4	14	0.1	21	0.1					16	0.1	13	0.0	64	0.1
5	1152	4.2	1297	4.4	"COUNT" entries for				486	1.5	56	0.2	2991	2.6
6	82	0.3	101	0.3	example only				9	0.0	917	3.3	1109	1.0
7	1	0.0	3	0.0					0	0.0	24	0.1	28	0.0
8	280	1.0	402	1.4					3	0.0	32	0.1	717	0.6
9	340	1.2	544	1.8					4	0.0	0	0.0	888	0.8
10	10	0.0	1	0.0					0	0.0	1	0.0	4	0.0
11	84	0.3	104	0.4					0	0.0	0	0.0	188	0.2
12	3	0.0	5	0.0					0	0.0	0	0.0	8	0.0
13	1	0.0	0	0.0					0	0.0	0	0.0	1	0.0
14	28	0.1	46	0.2					0	0.0	0	0.0	74	0.1
15	142	0.5	206	0.7					127	0.4	434	1.6	909	0.8
TOTAL	27337	100.0	29589	100.0					31509	100.0	27376	100.0	115811	100.0
SPEED (MPH)														
1- 5	2	0.0	6	0.0					2	0.0	4	0.0	14	0.0
6-10	0	0.0	0	0.0					4	0.0	10	0.0	14	0.0
11-15	10	0.0	5	0.0					32	0.1	28	0.1	75	0.1
16-20	48	0.2	33	0.1					75	0.2	88	0.3	244	0.2
21-25	271	1.0	280	0.9					269	0.9	179	0.7	999	0.9
26-30	641	2.3	615	2.1					480	1.5	349	1.3	2085	1.8
31-35	1047	3.8	838	2.8					731	2.3	606	2.2	3222	2.8
36-40	1165	4.3	1073	3.6					1077	3.4	891	3.3	4206	3.6
41-45	1645	6.0	913	3.1					927	2.9	997	3.6	4482	3.9
46-50	5140	18.8	2063	7.0					1027	3.3	893	3.3	9123	7.9
51-55	9487	34.7	5641	19.1					2508	8.0	1147	4.2	18783	16.2
56-60	5613	20.5	13537	45.8					14134	44.9	3243	11.8	36527	31.5
61-65	1872	6.8	3284	11.1					7211	22.9	9701	35.4	22068	19.1
66-70	277	1.0	1170	4.0					2749	8.7	6614	24.2	10810	9.3
71-75	79	0.3	90	0.3					234	0.7	2240	8.2	2643	2.3
76-80	24	0.1	34	0.1					45	0.1	327	1.2	430	0.4
81-85	13	0.0	7	0.0					4	0.0	51	0.2	75	0.1
86-90	3	0.0	0	0.0					0	0.0	8	0.0	11	0.0
91-95	0	0.0	0	0.0					0	0.0	0	0.0	0	0.0
96-100	0	0.0	0	0.0					0	0.0	0	0.0	0	0.0
> 100	0	0.0	0	0.0					0	0.0	0	0.0	0	0.0
TOTAL	27337	100.0	29589	100.0					31509	100.0	27376	100.0	115811	100.0
AVG.SPEED	51		55						57		61		56	

```
DISTRIBUTION OF VEHICLE COUNTS BY HOUR OF DAY BY LANE
===============================================================================================
SITE DESIGNATION:
DATE:
===============================================================================================

HOURLY SUMMARY                     LANE NUMBER  <number of lanes varies with contract requirements>
--------------                     -----------
                                                                                        HOURLY
 HOUR            1         2         3         4         5         6                    TOTALS
------         -----     -----     -----     -----     -----     -----                  -------
00-01
01-02
02-03
03-04
04-05
05-06
------         -----     -----     -----     -----     -----     -----                  -------
QTR TOTALS
===============================================================================================
06-07
07-08
08-09
09-10
10-11
11-12
------         -----     -----     -----     -----     -----     -----                  -------
QTR TOTALS
===============================================================================================
12-13
13-14
14-15
15-16
16-17
17-18
------         -----     -----     -----     -----     -----     -----                  -------
QTR TOTALS
===============================================================================================
18-19
19-20
20-21
21-22
22-23
23-24
------         -----     -----     -----     -----     -----     -----                  -------
QTR TOTALS

===============================================================================================
===============================================================================================

DAILY SUMMARY                           DAILY COUNTS BY LANE
-------------                           --------------------
                                                                                        DAILY
                 1         2         3         4         5         6                    TOTALS
               -----     -----     -----     -----     -----     -----                  ------

===============================================================================================
===============================================================================================
```

DISTRIBUTION OF VEHICLE CLASSIFICATIONS BY HOUR OF DAY

SITE DESIGNATION: LANE NO's <display user's entry as to selected lane(s)>

DATE:

HOURLY SUMMARY

VEHICLE COUNTS

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	HOURLY TOTALS
00-01																
01-02																
02-03																
03-04																
04-05																
05-06																
QTR TOTALS																
06-07																
07-08																
08-09																
09-10																
10-11																
11-12																
QTR TOTALS																
12-13																
13-14																
14-15																
15-16																
16-17																
17-18																
QTR TOTALS																
18-19																
19-20																
20-21																
21-22																
22-23																
23-24																
QTR TOTALS																

DAILY SUMMARY

VEHICLE COUNTS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL VEHICLES
COUNT																
PERCENT																

```
DISTRIBUTION OF VEHICLE CLASSIFICATIONS BY DAY OF MONTH
==========================================================================================================================
SITE DESIGNATION:              LANE NO's <display user's entry as to selected lane(s)>
DATE: 01/92
==========================================================================================================================
DAILY                                                  VEHICLE COUNTS
SUMMARY       1      2        3      4      5      6      7     8      9      10     11     12     13    14     15       TOTALS
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
 1 WED
 2 THU
 3 FRI
 4 SAT
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
DAILY AVG
==========================================================================================================================
 5 SUN
 6 MON
 7 TUE
 8 WED
 9 THU
10 FRI
11 SAT
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
DAILY AVG
==========================================================================================================================
12 SUN
13 MON
14 TUE
15 WED
16 THU
17 FRI
18 SAT
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
DAILY AVG
==========================================================================================================================
19 SUN
20 MON
21 TUE
22 WED
23 THU
24 FRI
25 SAT
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
DAILY AVG
==========================================================================================================================
26 SUN
27 MON
28 TUE
29 WED
30 THU
31 FRI
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
DAILY AVG
==========================================================================================================================
MONTHLY                                                VEHICLE COUNTS
SUMMARY       1      2        3      4      5      6      7     8      9      10     11     12     13    14     15       TOTALS
------       ---  -------  ------  ----  ------  -----  ----  -----  ------  -----  -----  -----  ----  -----  -----    --------
TOTALS
PERCENT
DAILY AVG
```

```
DISTRIBUTION OF VEHICLES BY SPEED BY HOUR
========================================================================================================================
SITE DESIGNATION:                 LANE NO's <display user's entry as to selected lane(s)>
DATE:
========================================================================================================================

                                                              SPEED RANGE, MPH
                                                              ----------------
HOUR
RANGE           00-30    31-35    36-40    41-45    46-50    51-55    56-60    61-65    66-70    71-75    76-80     > 80
--------        -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----

00 - 01
01 - 02
02 - 03
03 - 04
04 - 05
05 - 06
--------        -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----
QTR TOTALS
==========
06 - 07
07 - 08
08 - 09
09 - 10
10 - 11
11 - 12
--------        -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----
QTR TOTALS
==========
12 - 13
13 - 14
14 - 15
15 - 16
16 - 17
17 - 18
--------        -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----     -----
QTR TOTALS
==========
18 - 19
19 - 20
20 - 21
21 - 22
22 - 23
23 - 24
--------        -----    -----    -----    -----    -----    -----    -----    -----    -----    -----    -----     -----
QTR TOTALS
==========


DAILY SPEED SUMMARY
-------------------

Total Vehicles    :                 Total Vehicles > 55 MPH :              Percentage Vehicles > 55 MPH :
Average Speed     :                 Total Vehicles > 60 MPH :              Percentage Vehicles > 60 MPH :
Median Speed      :                 Total Vehicles > 65 MPH :              Percentage Vehicles > 65 MPH :
85th Percentile   :                 Total Vehicles > 70 MPH :              Percentage Vehicles > 70 MPH :

========================================================================================================================
========================================================================================================================
```

DISTRIBUTION OF TRUCK RECORD DATA BY LANE <report to cover all records contained in truck records file>

SITE DESIGNATION:
DATE:

LANE NUMBER <number of lanes varies with contract requirements>

CLASS	1		2		3		4		5		6		ALL LANES	
	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
1	0	0.0	0	0.0					0	0.0	0	0.0	0	0.0
2	0	0.0	0	0.0					0	0.0	0	0.0	0	0.0
3	152	3.7	342	14.7					87	4.0	74	1.9	655	5.2
4	18	0.4	13	0.6					3	0.1	5	0.1	39	0.3
5	560	13.6	354	15.2	"COUNT" entries for				306	14.2	574	14.7	1794	14.3
6	129	3.1	67	2.9	example only				66	3.1	104	2.7	366	2.9
7	3	0.1	0	0.0					0	0.0	27	0.7	30	0.2
8	350	8.5	134	8.8					278	12.9	357	9.1	1119	8.9
9	1775	43.1	918	39.4					961	44.4	1698	43.5	5352	42.7
10	3	0.1	1	0.0					4	0.2	4	0.1	12	0.1
11	783	19.0	332	14.2					302	14.0	754	19.3	2171	17.3
12	56	1.4	30	1.3					32	1.5	68	1.7	186	1.5
13	5	0.1	2	0.1					0	0.0	7	0.2	14	0.1
14	122	3.0	34	1.5					37	1.7	104	2.7	297	2.4
15	158	3.8	66	2.8					78	3.6	128	3.3	430	3.4
TOTAL	4121	100.0	2330	100.0					2161	100.0	3907	100.0	12520	100.0

LANE NUMBER

STATUS	1		2		3		4		5		6		ALL LANES	
	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
LEGAL	3353	81.4	1866	80.1					1976	91.4	3076	78.7	10271	82.0
OVR'WT	662	16.0	384	16.5					127	5.9	715	18.3	2249	18.0
INVALID	106	2.6	80	3.4					59	2.7	116	3.0	361	2.9
TOTAL	4121	100.0	2330	100.0					2162	100.0	3907	100.0	12520	100.0

Note:
The line items under "STATUS" are to be based upon the Contractor's coding scheme for weight violation and invalid measurements. If the coding system identifies invalid measurements other than imbalance (such as "out-of-range" values, system errors, etc.), each unique type of invalid measurement should be broken down as a "STATUS" line item.

DISTRIBUTION OF WEIGHT VIOLATIONS AND INVALID MEASUREMENTS FOR VEHICLE CLASSIFICATIONS 4 THROUGH 15

SITE DESIGNATION: LANE NO's <display user's entry as to selected lane(s)>

DATE:

CLASS	TOTAL VEHICLES COUNTED	VEHICLES WITH INVALID MEASUREMENTS	TOTAL VEHICLES WEIGHED	TOTAL VEHICLES OVERWEIGHT	PERCENT VEHICLES OVERWEIGHT	NUMBER OF WEIGHT VIOLATIONS: AXLE	TANDEM	GROSS	BRIDGE
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
TOTALS									

PERCENT VEHICLES NOT CLASSIFIED (CLASS 15) : _____

PERCENT VEHICLES WITH INVALID MEASUREMENTS : _____

Notes:

"Percent Vehicles Not Classified" = Class 15 Total Vehicle Count / Total Vehicles Counted
"Percent Vehicles With Invalid Measurements" = Total Vehicles With Invalid Measurements / Total Vehicles Counted
"Vehicles Counted" - "Vehicles With Invalid Measurements" = "Vehicles Weighed"

All weight and weight violation reporting and calculations based on data for "weighed vehicles"

```
DISTRIBUTION OF WEIGHT VIOLATIONS BY HOUR OF DAY FOR VEHICLE CLASSIFICATIONS 4 THROUGH 14
=============================================================================================================
SITE DESIGNATION:                  LANE NO's <display user's entry as to selected lane(s)>
DATE:
=============================================================================================================

HOURLY SUMMARY
--------------                                                            *************    NUMBER OF     **************
                  TOTAL         TOTAL         PERCENT                     ************* WEIGHT VIOLATIONS **************
                 VEHICLES      VEHICLES       VEHICLES
 HOUR            WEIGHED      OVERWEIGHT     OVERWEIGHT                   AXLE          TANDEM         GROSS       BRIDGE
-------          -------      ----------     ----------                   ----          ------         -----       ------
00-01
01-02
02-03
03-04
04-05
05-06
------            -----         -----         -----                      -----          -----          -----       -----
QTR TOTALS
=============================================================================================================
06-07
07-08
08-09
09-10
10-11
11-12
------            -----         -----         -----                      -----          -----          -----       -----
QTR TOTALS
=============================================================================================================
12-13
13-14
14-15
15-16
16-17
17-18
------            -----         -----         -----                      -----          -----          -----       -----
QTR TOTALS
=============================================================================================================
18-19
19-20
20-21
21-22
22-23
23-24
------            -----         -----         -----                      -----          -----          -----       -----
QTR TOTALS

=============================================================================================================
=============================================================================================================

DAILY SUMMARY
-------------                                                             *************    NUMBER OF     **************
                  TOTAL         TOTAL         PERCENT                     ************* WEIGHT VIOLATIONS **************
                 VEHICLES      VEHICLES       VEHICLES
                 WEIGHED      OVERWEIGHT     OVERWEIGHT                   AXLE          TANDEM         GROSS       BRIDGE
                 -------      ----------     ----------                   ----          ------         -----       ------

=============================================================================================================
=============================================================================================================
```

DISTRIBUTION OF OVERWEIGHT VEHICLES BY HOUR OF DAY FOR VEHICLE CLASSIFICATIONS 4 THROUGH 14

SITE DESIGNATION: LANE NO's <display user's entry as to selected lane(s)>
DATE:

HOURLY SUMMARY

				NUMBER OVERWEIGHT VEHICLES										
HOUR	TOTAL VEH'S WEIGHED	TOTAL VEH'S OVERWT	PERCENT VEH'S OVERWT	4	5	6	7	8	9	10	11	12	13	14
00-01														
01-02														
02-03														
03-04														
04-05														
05-06														
QTR TOTALS														
06-07														
07-08														
08-09														
09-10														
10-11														
11-12														
QTR TOTALS														
12-13														
13-14														
14-15														
15-16														
16-17														
17-18														
QTRTOTALS														
18-19														
19-20														
20-21														
21-22														
22-23														
23-24														
QTR TOTALS														

DAILY SUMMARY

			NUMBER OVERWEIGHT VEHICLES										
TOTAL VEH'S WEIGHED	TOTAL VEH'S OVERWT	PERCENT VEH'S OVERWT	4	5	6	7	8	9	10	11	12	13	14

DISTRIBUTION OF GROSS WEIGHTS FOR VEHICLE CLASSIFICATIONS 4 THROUGH 14

SITE DESIGNATION: LANE NO's <display user's entry as to selected lane(s)>

DATE:

VEHICLE COUNTS

GROSS WT KIPS	4	5	6	7	8	9	10	11	12	13	14	TOTALS
0- 5												
5- 10												
10- 15												
15- 20												
20- 25												
25- 30												
30- 35												
35- 40												
40- 45												
45- 50												
50- 55												
55- 60												
60- 65												
65- 70												
70- 75												
75- 80												
80- 85												
85- 90												
90- 95												
95-100												
100-105												
105-110												
110-115												
115-120												
> 120												
TOTALS												

```
DISTRIBUTION OF 18 KIP ESALS BY HOUR OF DAY FOR VEHICLE CLASSIFICATIONS 4 THROUGH 14
FOR ___________________________________ <display user's entries as to pavement type and str. no. or slab thickness>
===================================================================================================================
SITE DESIGNATION:                 LANE NO's    <display user's entry as to selected lane(s)>
DATE:                             VEH STATUS   <display user's entry as to "LEGAL ONLY", "OVWT ONLY" or "ALL" (default)
===================================================================================================================
HOURLY SUMMARY
--------------
                                                              ESALS BY HOUR BY CLASS
                    TOTAL                                     ----------------------
                    VEH'S    TOTAL
HOUR               WEIGHED   ESALS        4      5      6      7      8      9     10     11     12     13     14
-----              -------- --------  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----
00-01
01-02
02-03
03-04
04-05
05-06
-----              -------- --------  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----
QTR TOTALS
===================================================================================================================
06-07
07-08
08-09
09-10
10-11
11-12
-----              -------- --------  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----
QTR TOTALS
===================================================================================================================
12-13
13-14
14-15
15-16
16-17
17-18
-----              -------- --------  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----
QTR TOTALS
===================================================================================================================
18-19
19-20
20-21
21-22
22-23
23-24
-----              -------- --------  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----
QTR TOTALS

===================================================================================================================
===================================================================================================================
DAILY SUMMARY
-------------
                              TOTALS      4      5      6      7      8      9     10     11     12     13     14
                              ------  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----  -----
VEH'S WEIGHED :
18 KIP ESALS  :
AVERAGE ESAL  :

===================================================================================================================
===================================================================================================================
```

DISTRIBUTION OF TRUCKS BY DAY OF MONTH FOR CLASSIFICATIONS 4 THROUGH 15

SITE DESIGNATION: LANE NO's <display user's entry as to selected lane(s)>
DATE:

DAILY SUMMARY

DAY	TOTAL VEHS CNTD	TOTAL VEHS WGHD	TOTAL VEHS OVWT	PCT VEHS OVWT	COUNTED VEHICLES 4	5	6	7	8	9	10	11	12	13	14	15
1 WED																
2 THU																
3 FRI																
4 SAT																
5 SUN																
6 MON																
7 TUE																
8 WED																
9 THU																
10 FRI																
11 SAT																
12 SUN																
13 MON																
14 TUE																
15 WED																
16 THU																
17 FRI																
18 SAT																
19 SUN																
20 MON																
21 TUE																
22 WED																
23 THU																
24 FRI																
25 SAT																
26 SUN																
27 MON																
28 TUE																
29 WED																
30 THU																
31 FRI																

MONTHLY SUMMARY

	TOTAL VEHS CNTD	TOTAL VEHS WGHD	TOTAL VEHS OVWT	PCT VEHS OVWT	COUNTED VEHICLES 4	5	6	7	8	9	10	11	12	13	14	15
TOTALS																
PERCENT																

ASCII SPEED FILE FORMAT

FIELD	LENGTH	STARTS IN COLUMN
Lane	2	1
Hour	2	4
Count, 0-35 MPH	4	7
Count, 36-40 MPH	4	12
Count, 41-45 MPH	4	17
Count, 46-50 MPH	4	22
Count, 51-55 MPH	4	27
Count, 56-60 MPH	4	32
Count, 61-65 MPH	4	37
Count, 66-70 MPH	4	42
Count, 71-75 MPH	4	47
Count, 76-80 MPH	4	52
Count, 81-85 MPH	4	57
Count, >85 MPH	4	62

ASCII CLASSIFICATION FILE FORMAT

FIELD	LENGTH	STARTS IN COLUMN
Lane	2	1
Hour	2	4
Count, Class 1	4	7
Count, Class 2	4	12
Count, Class 3	4	17
Count, Class 4	4	22
Count, Class 5	4	27
Count, Class 6	4	32
Count, Class 7	4	37
Count, Class 8	4	42
Count, Class 9	4	47
Count, Class 10	4	52
Count, Class 11	4	57
Count, Class 12	4	62
Count, Class 13	4	67
Count, Class 14	4	72
Count, Class 15	4	77

For the above two files :

Each field shall be comma delimited.
For each day's file, there is one record for each lane for each hourly period.

ASCII TRUCK RECORD FILE FORMAT

FIELD	LENGTH	DECIMAL PLACES	STARTS IN COLUMN
LANE	1		1
MONTH	2		3
DAY	2		6
YEAR	2		9
HOUR	2		12
MINUTE	2		15
SECOND	2		18
VEHICLE NO.	5		21
CLASS	2		27
GROSS WEIGHT	6	1	30
LENGTH	6	1	37
SPEED	5	1	44
VIOLATION CODE	3		50
AXLE 1 RT. WEIGHT	4	1	54
AXLE 1 LT. WEIGHT	4	1	59
AXLE 2 RT. WEIGHT	4	1	64
AXLE 2 LT. WEIGHT	4	1	69
AXLE 1-2 SPACING	4	1	74
AXLE 3 RT. WEIGHT	4	1	79
AXLE 3 LT. WEIGHT	4	1	84
AXLE 2-3 SPACING	4	1	89
AXLE 4 RT. WEIGHT	4	1	94
AXLE 4 LT. WEIGHT	4	1	99
AXLE 3-4 SPACING	4	1	104
AXLE 5 RT. WEIGHT	4	1	109
AXLE 5 LT. WEIGHT	4	1	114
AXLE 4-5 SPACING	4	1	119
AXLE 6 RT. WEIGHT	4	1	124
AXLE 6 LT. WEIGHT	4	1	129
AXLE 5-6 SPACING	4	1	134
AXLE 7 RT. WEIGHT	4	1	139
AXLE 7 LT. WEIGHT	4	1	144
AXLE 6-7 SPACING	4	1	149
AXLE 8 RT. WEIGHT	4	1	154
AXLE 8 LT. WEIGHT	4	1	159
AXLE 7-8 SPACING	4	1	164
AXLE 9 RT. WEIGHT	4	1	169
AXLE 9 LT. WEIGHT	4	1	174
AXLE 8-9 SPACING	4	1	179
VENDOR SPECIFIC OPTIONAL FIELDS			184

This file shall include every "truck record" contained in the daily data file. Each field shall be comma delimited and padded with blanks to complete the fixed logical record length.

For axle weight only weighing (in lieu of right and left wheel weighing), either the "AXLE n RT. WEIGHT" or the "AXLE n LT. WEIGHT" field may be used for the "AXLE n WEIGHT".

REAL TIME VIEW
================

****

Veh No.: ______ Class: ______ Lane: ______ Speed: ______

Time: ______ Date: ______ GVW: _______ Wheelbase: _______ Vehicle Length: ______

Invalid Measurement Code:_________ Wt. Violation(s):______________

	AXLE NO. 1	2	3	4	5	6	7	8	9
Rt. Wheel Wt. (kips)	5.5	8.0	8.5	8.2	7.8				
Lt. Wheel Wt. (kips)	5.4	7.0	7.2	7.8	8.8				
Axle Space (ft.)	11.8	4.5	36.4	4.2					

****

Note: Entries following Wheel Wt. and Axle Space are for example purposes only.

TRUCK RECORD BATCH PRINT

```
                                         TRUCK RECORD BATCH PRINT
                                        ==========================
******************************************************************************************************************************

Site Designation: _________________      Lane: ________      Time: ______       Date: ______       Speed: _______

Vehicle No.: ______     Class: ______   Invalid Code: ______    Veh. Wheelbase: ________    Veh. Length: _________

Gross Wt.(kips): ___________      Weight Violation(s): __________

Axle No.                   1         2         3         4         5         6         7         8         9

Rt. Wheel Wt.(kip)         5.4       7.3       8.0       8.5       8.3
Lt. Wheel Wt.(kip)         5.5       7.7       8.2       8.7       8.5
                         ---------------------------------------------------------------------------------------------
Axle Wt.(kips)            10.9      15.0      16.2      17.2      16.8
Axle Space (feet)              11.8       4.5      36.4       4.2

******************************************************************************************************************************
```

Note: Entries following Axle Wt. and Axle Space are for example purposes only.

WEIGHT VIOLATION TABLE
===

(All weights in pounds)

AXLE WEIGHT

Axle No. 1 ------------------------	12500
All other axles ---------------------	20000

TANDEM AXLE WEIGHT

Two consecutive axles with an axle spacing not exceeding 8.4 feet ------	34000

GROSS VEHICLE WEIGHT

All vehicles ------------------------	80000

BRIDGE WEIGHT

See page following ----

BRIDGE WEIGHT

Distance in nearest whole foot between the extremes of any group of 2 or more consecutive axles	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles	7 Axles	8 Axles	9 Axles
< 8	34000	34000	34000	34000	34000	-----	-----	-----
8	34000	34000	34000	34000	34000	-----	-----	-----
9	39000	42500	42500	42500	42500	-----	-----	-----
10	40000	43500	43500	43500	43500	-----	-----	-----
11	40000	44000	44000	44000	44000	-----	-----	-----
12	40000	45000	50000	50000	50000	-----	-----	-----
13	40000	45500	50500	50500	50500	-----	-----	-----
14	40000	46500	51500	51500	51500	-----	-----	-----
15	40000	47000	52000	52000	52000	-----	-----	-----
16	40000	48000	52500	52500	52500	-----	-----	-----
17	40000	48500	53500	53500	53500	-----	-----	-----
18	40000	49500	54000	54000	54000	-----	-----	-----
19	40000	50000	54500	54500	54500	-----	-----	-----
20	40000	51000	55500	55500	55500	-----	-----	-----
21	40000	51500	56000	56000	56000	-----	-----	-----
22	40000	52500	56500	56500	56500	-----	-----	-----
23	40000	53000	57500	57500	57500	-----	-----	-----
24	40000	54000	58000	58000	58000	74000	-----	-----
25	40000	54500	58500	58500	58500	74500	80000	-----
26	40000	55500	59500	59500	59500	75000	80000	-----
27	40000	56000	60000	60000	60000	76000	80000	80000
28	40000	57000	60500	60500	60500	76500	80000	80000
29	40000	57500	61500	61500	61500	77000	80000	80000
30	40000	58500	62000	62000	62000	77500	80000	80000
31	40000	59000	62500	62500	62500	78000	80000	80000
32	40000	60000	63500	63500	63500	78500	80000	80000
33	40000	60000	64000	64000	64000	79500	80000	80000
34	40000	60000	64500	64500	64500	80000	80000	80000
35	40000	60000	65500	65500	65500	80000	80000	80000
36	40000	60000	68000	66000	66000	80000	80000	80000
37	40000	60000	68000	66500	66500	80000	80000	80000
38	40000	60000	68000	67500	67500	80000	80000	80000
39	40000	60000	68000	68000	68000	80000	80000	80000
40	40000	60000	68500	70000	70000	80000	80000	80000
41	40000	60000	69500	72000	72000	80000	80000	80000
42	40000	60000	70000	73280	73280	80000	80000	80000
43	40000	60000	70500	73280	73280	80000	80000	80000
44	40000	60000	71500	73280	73280	80000	80000	80000
45	40000	60000	72000	76000	80000	80000	80000	80000
46	40000	60000	72500	76500	80000	80000	80000	80000
47	40000	60000	73500	77500	80000	80000	80000	80000
48	40000	60000	74000	78000	80000	80000	80000	80000
49	40000	60000	74500	78500	80000	80000	80000	80000
50	40000	60000	75500	79000	80000	80000	80000	80000
51	40000	60000	76000	80000	80000	80000	80000	80000
52	40000	60000	76500	80000	80000	80000	80000	80000
53	40000	60000	77500	80000	80000	80000	80000	80000
54	40000	60000	78000	80000	80000	80000	80000	80000
55	40000	60000	78500	80000	80000	80000	80000	80000
56	40000	60000	79500	80000	80000	80000	80000	80000
57	40000	60000	80000	80000	80000	80000	80000	80000
58	40000	60000	80000	80000	80000	80000	80000	80000
>58	40000	60000	80000	80000	80000	80000	80000	80000

APPENDIX B.

This appendix contains excerpts from the following report:

- Flinner, M and H. Horsey. *Traffic Data Editing Procedures: Traffic Data Quality "TDQ"*. Final Report, Transportation Pooled Fund Study SPR-2 (182), Federal Highway Administration, Washington, D.C., no date. This report is available at http://www.fhwa.dot.gov/policy/ohpi/tdep.htm.

Traffic Data Editing Procedures

Traffic Data Quality "TDQ"

FINAL REPORT

By

Mark Flinner, Minnesota Department of Transportation
Henry Horsey, Intelligent Decision Technologies, Inc.

For

Transportation Pooled-Fund Study SPR-2 (182)

Traffic Data Edit Procedures - TDQ prototype software Rule List

Rule_ID	A.3 Rule #	Rule Name	Rule Description
0	V42	Date is Correct and Unique	If the date of the input data is not correct or unique, the record will not be loaded into the database. An input error message will be reported.
1	V43	Lane and Direction are Correct	If the lane or direction fields in the input data do not match the station record, the input data will not be loaded into the database. An input error message will be reported.
2	C49	Number of Axles = Number of Axle Spaces + 1	Any vehicle record where the number of axles does not equal the number of axle spaces plus one will be flagged.
3	W70	Number of Axles = Number of Axle Weights	Any vehicle record where the number of axles does not equal the number of axle weights will be flagged.
4	W35	Sum of Axle Weights Does Not = GVW	Any vehicle record where the sum of the axle weights does not equal the recorded GVW will be flagged.
5	V1	Completeness of Data	If the input data is insufficient or invalid in any way, an error message will be reported.
6	V2	Zero Volume for an Hour	Any hourly volume of zero in any lane will be flagged.
7	V4	Extreme Hourly Volume per Lane	The hourly volume in any lane will be reported as anomalous if exceeds this global extreme maximum:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
8	V32	1:00 AM to 2:00 AM Volume vs. 1:00 PM to 2:00 PM Volume	If the 1:00 AM to 2:00 AM volume is greater than the 1:00 PM to 2:00 PM volume of the same day, a warning will be reported.
9	C1	No Classification Data	If no volumes for any vehicle classes are present in the input data, an error message will be reported.
10	W51	Record Contains Valid Date	Any vehicle record containing an invalid or unexpected date will be flagged.
11	W52	Record Contains Valid Lane Number	Any vehicle record containing a lane that does not match the station record will be flagged.
12	W53	Record Contains Valid Class Number	Any vehicle record containing an invalid class number will be flagged.
13	C24	Number of Axles Min/Max	Any vehicle having more or less than the number of axles in this range will be flagged:
14	W36	Wheelbase Exceeds Value for Class	Any vehicle of this class having a recorded wheelbase greater than this maximum will be flagged:
15	W39	GVW Exceeds Value for Class	Any vehicle of this class having a recorded GVW greater than this maximum will be flagged:
16	W28	Front Overhang Out of Range	Any vehicle with a front overhang outside of this range will be flagged:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
17	W26	Rear Overhang Out of Range	Any vehicle with a rear overhang outside of this range will be flagged:
18	W30	Sum of Axle Spaces > or = Recorded Vehicle Length	Any vehicle where the sum of the axle spaces is greater than the recorded vehicle length will be flagged.
19	W24	Record Contains Off-Scale Warning	Any vehicle record containing a vendor's off-scale warning code will be flagged.
20	W46	Wheelpath Imbalance Exceeds Threshold	Any vehicle with the total weight on one side exceeding the total weight on the other side by more than this maximum will be flagged:
21	C35	Vehicle Exceeding Speed Min/Max	Any vehicle with a recorded speed outside of this range will be flagged:
22	W25	Extreme Speed	Any vehicle with a recorded speed greater than this global extreme maximum will be flagged:
23	W43	Heavy Class 6 Vehicle With Close Follower	Any class 6 vehicle with an excessive GVW and followed within 2 seconds by another vehicle will be flagged.
24	C26	Extreme Axle Spacing	Any vehicle with any axle space greater than this maximum will be flagged:
25	C27	Minimum First Axle Space	Any vehicle with a first axle space (following the steering axle) less than this minimum will be flagged:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
26	C28	Minimum Subsequent Axle Space	Any vehicle with any axle space less than this minimum will be flagged:
27	C29	Minimum Spacing Between Axle Groups	Any vehicle with a tandem or tridem axle space less than this minimum will be flagged:
28	W37	Axle Spacings vs. Min/Max Default Values for Class	Any vehicle of this class will be flagged if this particular axle space is greater or less than this range :
29	W40	Axle Weights vs. Min/Max Default Values for Class	Any vehicle of this class will be flagged if this particular axle weight is greater or less than this range :
30	C30	3S-2 Drive Tandem Spacing	Any 3S-2 tractor with a drive tandem spacing outside of this range will be flagged:
31	W50	Class 9 Front Axle Weight vs. Default Min/Max	This rule is implemented by rule W40 in the TDQ Prototype
32	W50	Class 11 Front Axle Weight vs. Default Min/Max	This rule is implemented by rule W40 in the TDQ Prototype
33	V3	Consecutive Hourly Zero Volumes	The number of consecutive zero-volume hours in any one lane will be reported as anomalous if it exceeds this daily maximum:
34	V7	Consecutive Hours with Same Non-Zero Volume	The number of consecutive hours with the same non-zero volume in the same lane will be reported as anomalous if it exceeds this daily maximum:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
35	V28	Sunday Hourly Directional Split	Sunday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
36	V28	Monday Hourly Directional Split	Monday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
37	V28	Tuesday Hourly Directional Split	Tuesday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
38	V28	Wednesday Hourly Directional Split	Wednesday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
39	V28	Thursday Hourly Directional Split	Thursday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
40	V28	Friday Hourly Directional Split	Friday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
41	V28	Saturday Hourly Directional Split	Saturday's hourly directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
42	V9	Hourly Volume vs. Next/Prior Day	The total hourly volume will be reported as anomalous if it is greater than or less than the total volume for that hour of the previous or following day by these tolerances:
43	V17a	Daily Directional Volume vs. AADT	The daily directional volume will be reported as anomalous if it is greater or less than the previous year's adjusted directional AADT by this tolerance:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
44	V33	Daily Combined Volume vs. AADT	The daily combined volume will be reported as anomalous if it is greater or less than the previous year's adjusted AADT by these tolerances:
45	V5	Sunday Daily Directional Split	Sunday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
46	V5	Monday Daily Directional Split	Monday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
47	V5	Tuesday Daily Directional Split	Tuesday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
48	V5	Wednesday Daily Directional Split	Wednesday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
49	V5	Thursday Daily Directional Split	Thursday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
50	V5	Friday Daily Directional Split	Friday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
51	V5	Saturday Daily Directional Split	Saturday's daily directional split will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
52	C48	Full Day of Data Exists	If less than 24hours of data is present, a warning will be reported as anomalous.

Rule_ID	A.3 Rule #	Rule Name	Rule Description
53	C4	Extreme Daily Percent in Any Class Except 2	The daily percent of vehicles binned to any class except 2 (cars) will be reported as anomalous if it exceeds this maximum:
54	C37	Excessive Daily Percent by Class	The daily percent of vehicles binned to any class except 2 or 3 will be reported as anomalous if it exceeds this maximum:
55	C38	Excessive Daily Volume by Class	The daily volume of vehicles binned to any class except 2 or 3 will be reported as anomalous if it exceeds this maximum:
56	W16	Unloaded Class 9 GVW Distribution Peak	The majority of unloaded class 9 GVWs are expected to fall within this weight range:
57	W16	Unloaded Class 11 GVW Distribution Peak	The majority of unloaded class 11 GVWs are expected to fall within this weight range:
58	W17	Loaded Class 9 GVW Distribution Peak	The majority of loaded class 9 GVWs are expected to fall within this weight range:
59	W17	Loaded Class 11 GVW Distribution Peak	The majority of loaded class 11 GVWs are expected to fall within this weight range:
60	W68	Percent of Vehicles With GVW Out of Range for Class	The daily percent of vehicles flagged for excessive GVW will be reported as anomalous if it exceeds this maximum:
61	W67	Percent of Vehicles With Invalid Class	The daily percent of vehicles flagged for an invalid class disignation will be reported as anomalous if it exceeds this maximum:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
62	W21	Average Class 9 Steering Axle Weight	The daily average class 9 front axle weight will be reported as anomalous if it falls outside of this range:
63	W21	Average Class 11 Steering Axle Weight	The daily average class 11 front axle weight will be reported as anomalous if it falls outside of this range:
64	W65	Percent of RecordsWith Invalid Dates	The daily percent of vehicle records flagged for an invalid date will be reported as anomalous if it exceeds this maximum:
65	W66	Percent of Records With Invalid Lane	The daily percent of vehicle records flagged for an invalid lane will be reported as anomalous if it exceeds this maximum:
66	W56	Average Steering Axle Weight for Light-GVW Class 9s	The average steering axle weight of all class 9 vehicles with a GVW of less than 32,000 lbs. will be reported as anomalous if it falls outside of this range:
67	W56	Average Steering Axle Weight for Mid-GVW Class 9s	The average steering axle weight of all class 9 vehicles with a GVW of between 32,000 lbs. And 70,000 lbs. will be reported as anomalous if it falls outside of this range:
68	W56	Average Steering Axle Weight for Heavy-GVW Class 9s	The average steering axle weight of all class 9 vehicles with a GVW of more than 70,000 lbs. will be reported as anomalous if it falls outside of this range:
69	W56	Average Steering Axle Weight for Light-GVW Class 11s	The average steering axle weight of all class 11 vehicles with a GVW of less than 32,000 lbs. will be reported as anomalous if it falls outside of this range:
70	W56	Average Steering Axle Weight for Mid-GVW Class 11s	The average steering axle weight of all class 11 vehicles with a GVW of between 32,000 lbs. And 70,000 lbs. will be reported as anomalous if it falls outside of this range:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
71	W56	Average Steering Axle Weight for Heavy-GVW Class 11s	The average steering axle weight of all class 11 vehicles with a GVW of more than 70,000 lbs. will be reported as anomalous if it falls outside of this range:
72	W58	Percent of Class 9s With Front Axle Weight Flags	The daily percent of class 9 vehicles flagged for an out-of-range front axle weight will be reported as anomalous if it exceeds this maximum:
73	W58	Percent of Class 11s With Front Axle Weight Flags	The daily percent of class 11 vehicles flagged for an out-of-range front axle weight will be reported as anomalous if it exceeds this maximum:
74	C2	Percent of Records With Vendor Warning Codes	The daily percent of vehicle records containing a vendor's warning code will be reported as anomalous if it exceeds this maximum:
75	W62	Percent of Vehicles Where GVW Is Not = Sum of Axle Weights	The daily percent of vehicle records where the GVW is not equal (within rounding error) to the sum of the axle weights will be reported as anomalous if it exceeds this maximum:
76	W60	Percent of Vehicles With Overhang Flags	The daily percent of vehicles with overhang flags will be reported as anomalous if it exceeds this maximum:
77	W8	Percent of Vehicles Where Length < Wheelbase	The daily percentage of vehicles where the sum of the axle spaces is greater than the recorded vehicle length will be reported as anomalous if it exceeds this maximum:
78	W10	Class 9 Average Length Within Range + Average Wheelbase	The average class 9 vehicle length and wheelbase relationship will be reported as anomalous if the average length is not within the sum of the average wheelbase and this range:
79	W10	Class 11 Average Length Within Range + Average Wheelbase	The average class 11 vehicle length and wheelbase relationship will be reported as anomalous if the average length is not within the sum of the average wheelbase and this range:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
80	W45	Percent of Records With Off-Scale Warnings	The daily percent of vehicle records containing a vendor's off-scale warning will be reported as anomalous if it exceeds this maximum:
81	W47	Pattern of Vehicles With Wheelpath Imbalance	An otherwise anomalous percent of wheelpath imbalances will not be reported as anomalous if opposite wheelpath imbalances are detected in opposite directions (likely due to crosswinds).
82	W54	Percent of Vehicles With Wheelpath Imbalance	The daily percent of vehicles with wheelpath imbalance flags will be reported as anomalous if it exceeds this maximum:
83	W59	Percent of Vehicles that Exceed Extreme Max Speed	The daily percent of vehicles with globally extreme speed flags will be reported as anomalous if it exceeds this maximum:
84	C40	Percent of Vehicles Slower Than Speed Min	The daily percent of vehicles with speeds less than the station minimum will be reported as anomalous if it exceeds this maximum:
85	C40	Percent of Vehicles Faster Than Speed Max	The daily percent of vehicles with speeds greater than the station maximum will be reported as anomalous if it exceeds this maximum:
86	W61	Percent of Heavy Class 6 Vehicles With Close Follower	The percent of class 6 vehicles flagged for excessive GVW with a closely following vehicle will be reported as anomalous if it exceeds this maximum:
87	C15	Average 3S-2 Drive Tandem Spacing	The daily average drive tandem spacing for 3S-2 vehicles will be reported as anomalous if it falls outside of this range:
88	W63	Percent of Vehicles With Wheelbase or Axle Spacing Flags	The daily percent of vehicles with wheelbase or axle spacing flags set by the default values for their class will be reported as anomalous if it exceeds this maximum:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
89	W64	Percent of Vehicles With an Axle Weight Flag	The daily percent of vehicles with an axle weight flag set by the default values for their class will be reported as anomalous if it exceeds this maximum:
90	W55	Average Left Axle Weight vs. Average Right Axle Weight	The average left and right axle weights for all vehicles will be reported as anomalous if they differ by more than this maximum percent:
91	V19	Hourly Directional Volume vs. History	An hourly directional volume will be reported as anomalous if it differs from its historical minimum or maximum for that hour by more than these tolerances:
92	V40	Hourly Combined Volume vs. Recent History	An hourly combined volume will be reported as anomalous if it differs from its historical minimum or maximum for that hour by more than these tolerances:
93	V39	Daily Combined Volume vs. Recent History	A daily combined volume will be reported as anomalous if it differs from its historical minimum or maximum by more than these tolerances:
94	V17b	Daily Directional Volume vs. History	A daily directional volume will be reported as anomalous if it differs from its historical minimum or maximum by more than these tolerances:
95	V29	Daily Percent Distribution by Lane vs. History	The daily lanal distribution will be reported as anomalous if any lane differs from its historical average percent by more than these tolerances:
96	C12	Daily Volume Binned to One Class vs. History	The daily volume binned to a single vehicle class except 2 or 3 will be reported as anomalous if it differs from its historical minimum or maximum volume by more than these tolerances:
97	C11	Daily Percent Binned to One Class vs. History	The daily percent binned to a single vehicle class will be reported as anomalous if it differs from the historical average percent for that class by more than these tolerances:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
98	C23	Daily Volume of Both Class 6 and 1 Exceed History	The daily volumes of class 1 and class 6 vehicles will be reported as anomalous if both are greater than their average historical values.
99	C22	Daily Ratio of Class 2 to 3 vs. History	The daily ratio of class 2 vehicles to class 3 vehicles will be reported as anomalous if the number of class 2s per one class 3 varies by more than these tolerances:
100	C42	Daily Ratio of Class 9 to 8 by Lane vs. History	The daily ratio of class 9 vehicles to class 8 vehicles in a lane will be reported as anomalous if the number of class 9s per one class 8 differs from the historical minimum or maximum ratio by more than these tolerances:
101	C19	Daily Ratio of Class 9 to 8 by Direction vs. History	The daily ratio of class 9 vehicles to class 8 vehicles in each direction will be reported as anomalous if the number of class 9s per one class 8 differs from the historical minimum or maximum ratio by more than these tolerances:
102	C41	Daily Sum of Class 8 and 9 vs. History	The daily sum of class 8 and class 9 vehicles will be reported as anomalous if it differs from the historical minimum or maximum sum of these two classes by more that these tolerances:
103	C14	Daily Class 8 Directional Split vs. History	The daily directional split percentages for class 8 vehicles will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
104	C13	Daily Class 9 Directional Split vs. History	The daily directional split percentages for class 9 vehicles will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
105	C43	Daily Sum of Class 8 and 9 Directional Split vs. History	The daily directional split percentages for the sum of class 8 and class 9 vehicles will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more than these tolerances:
106	C46	Daily Directional Split of Any Class (not 8 or 9) vs. History	The daily directional split percentages for any vehicle class will be reported as anomalous if if the leading direction's percentage varies from its historical minimum or maximum by more that these tolerances:

Rule_ID	A.3 Rule #	Rule Name	Rule Description
107	C17	Daily Directional Split of Sum of Class 4 thru 13 vs. History	The daily directional split percentages for the sum of all commerical vehicles will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more that these tolerances:
108	C47	Daily Directional Split of Class Groups vs. History	The daily directional split percentages for any class group (passenger, truck, semi-truck and multi-trailer) will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more that these tolerances:
109	C16	Monthly Directional Split of Sum of Class 4 thru 13 vs. History	The monthly directional split percentages for the sum of all commercial vehicles will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more that these tolerances:
110	C47	Monthly Directional Split of Class Groups vs. History	The monthly directional split percentages for any class group (passenger, truck, semi-truck and multi-trailer) will be reported as anomalous if the leading direction's percentage varies from its historical minimum or maximum by more that these tolerances:
111	W18	Unloaded Class 9 GVW Distribution Peak Shift	A shift in the unloaded GVWs for class 9 vehicles will be reported if the central tendancy of the input data is not within these percents of the historical central tendancy
112	W19	Loaded Class 9 GVW Distribution Peak Shift	A shift in the loaded GVWs for class 9 vehicles will be reported if the central tendancy of the input data is not within these percents of the historical central tendancy
113	W23	Loaded vs. Unloaded Class 9 GVW Distribution Peaks	A parallel shift in Class 9 GVWs will be reported if the loaded central tendancy's shift from its historical value minus the unloaded central tendancy's shift from its historical value is not within these percent tolerances:
114	W20	Incidental Class 9 GVW Distribution Peak Shift	A shift in the major incidental GVW peak for class 9 vehicles (if there is one) will be reported if the central tendancy of the input data is not within these percents of a matching historical central tendancy
115	W18	Unloaded Class 11 GVW Distribution Peak Shift	A shift in the unloaded GVWs for class 11 vehicles will be reported if the central tendancy of the input data is not within these percents of the historical central tendancy

Rule_ID	A.3 Rule #	Rule Name	Rule Description
116	W19	Loaded Class 11 GVW Distribution Peak Shift	A shift in the loaded GVWs for class 11 vehicles will be reported if the central tendancy of the input data is not within these percents of the historical central tendancy
117	W23	Loaded vs. Unloaded Class 11 GVW Distribution Peaks	A parallel shift in Class 11 GVWs will be reported if the loaded central tendancy's shift from its historical value minus the unloaded central tendancy's shift from its historical value is not within these percent tolerances:
118	W20	Incidental Class 11 GVW Distribution Peak Shift	A shift in the major incidental GVW peak for class 11 vehicles (if there is one) will be reported if the central tendancy of the input data is not within these percents of a matching historical central tendancy
119	C6	Daily Average Speed per Lane vs. History	The average vehicle speed in each lane will be reported as anomalous if it differs from the historical average speed for that lane by more than these tolerances:

APPENDIX C.

This appendix contains a sample set of procedures for WIM data import, specifically ASCII truck record data.

Is it difficult to import ASCII truck record data into a spreadsheet? No, not once the procedure has been set up. Following is a quick walk-through of how it is done using Excel and the ASCII vehicle records conforming to that specified by LTPP's model specifications (following):

ASCII TRUCK RECORD FILE FORMAT

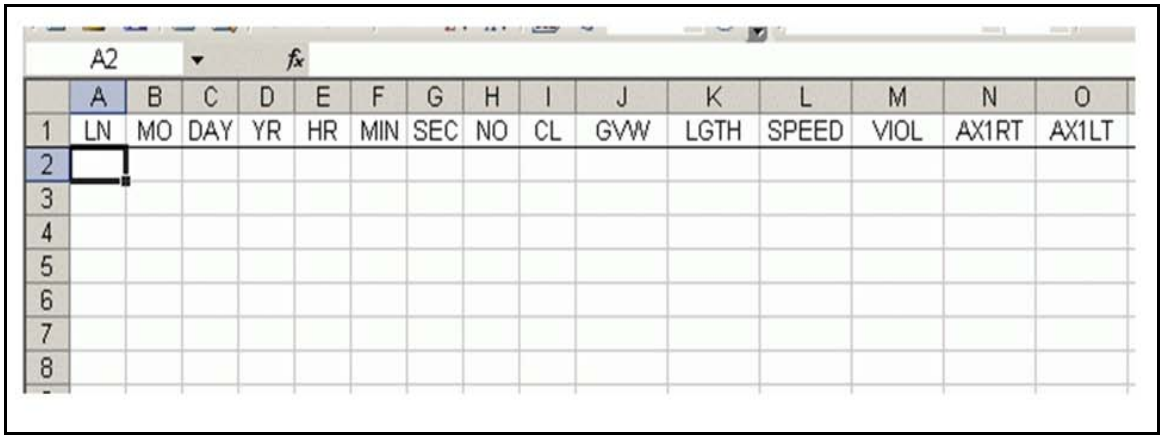
FIELD	LENGTH	DECIMAL PLACES	STARTS IN COLUMN
LANE	1		1
MONTH	2		3
DAY	2		6
YEAR	2		9
HOUR	2		12
MINUTE	2		15
SECOND	2		18
VEHICLE NO.	5		21
CLASS	2		27
GROSS WEIGHT	6	1	30
LENGTH	6	1	37
SPEED	5	1	44
VIOLATION CODE	3		50
AXLE 1 RT. WEIGHT	4	1	54
AXLE 1 LT. WEIGHT	4	1	59
AXLE 2 RT. WEIGHT	4	1	64
AXLE 2 LT. WEIGHT	4	1	69
AXLE 1-2 SPACING	4	1	74
AXLE 3 RT. WEIGHT	4	1	79
AXLE 3 LT. WEIGHT	4	1	84
AXLE 2-3 SPACING	4	1	89
AXLE 4 RT. WEIGHT	4	1	94
AXLE 4 LT. WEIGHT	4	1	99
AXLE 3-4 SPACING	4	1	104
AXLE 5 RT. WEIGHT	4	1	109
AXLE 5 LT. WEIGHT	4	1	114
AXLE 4-5 SPACING	4	1	119
AXLE 6 RT. WEIGHT	4	1	124
AXLE 6 LT. WEIGHT	4	1	129
AXLE 5-6 SPACING	4	1	134
AXLE 7 RT. WEIGHT	4	1	139
AXLE 7 LT. WEIGHT	4	1	144
AXLE 6-7 SPACING	4	1	149
AXLE 8 RT. WEIGHT	4	1	154
AXLE 8 LT. WEIGHT	4	1	159
AXLE 7-8 SPACING	4	1	164
AXLE 9 RT. WEIGHT	4	1	169
AXLE 9 LT. WEIGHT	4	1	174
AXLE 8-9 SPACING	4	1	179
VENDOR SPECIFIC OPTIONAL FIELDS			184

NOTE: Axle spacings in feet and axle weights in kips (pounds/1000)

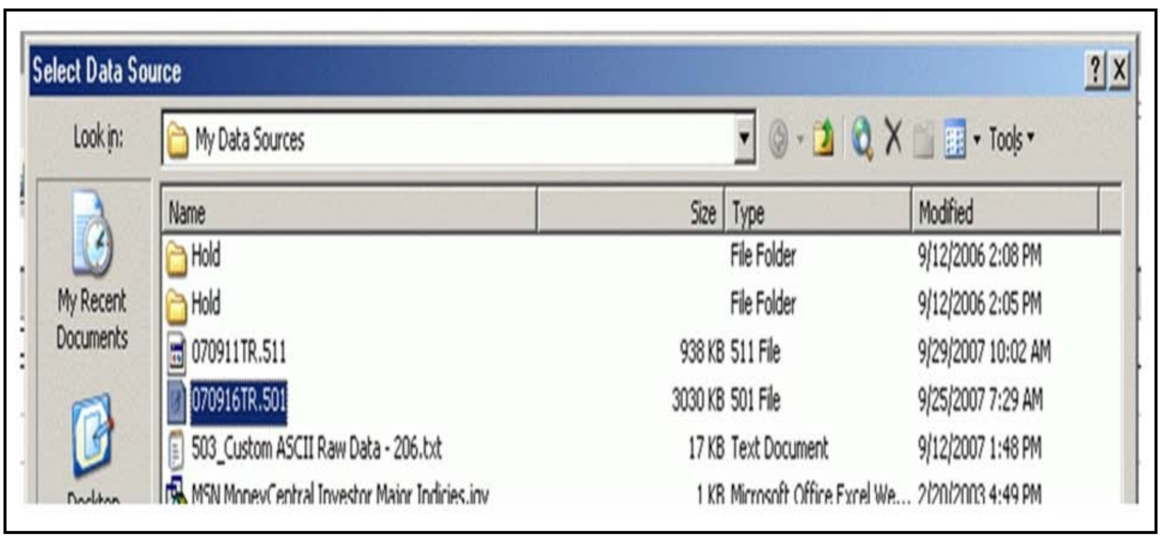
This file shall include every "truck record" contained in the daily data file. Each field shall be comma delimited and padded with blanks to complete the fixed logical record length.

For axle weight only weighing (in lieu of right and left wheel weighing), either the "AXLE n RT. WEIGHT" or the "AXLE n LT. WEIGHT" field may be used for the "AXLE n WEIGHT".

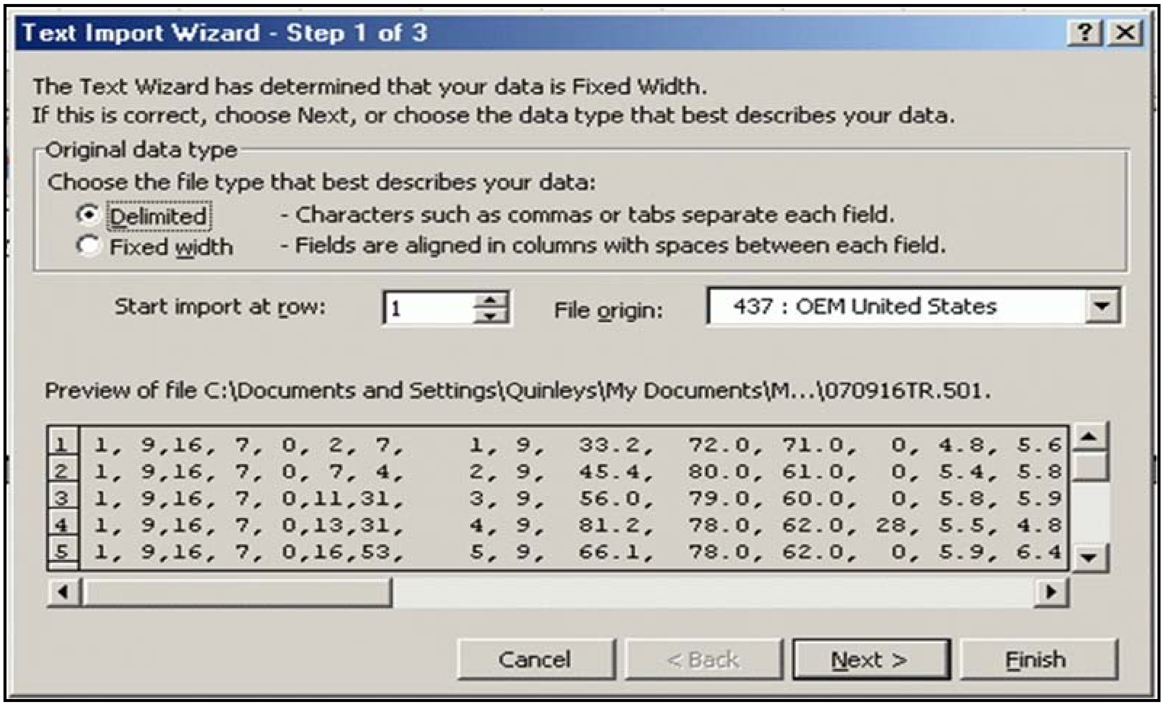
Each field included in the ASCII file is entered into the Excel worksheet's Row A in the same sequence as those fields in the ASCII file. The column widths can be adjusted and the cell formats fixed after playing a bit with the first few imports. To perform the import, start with the cursor in cell A2:



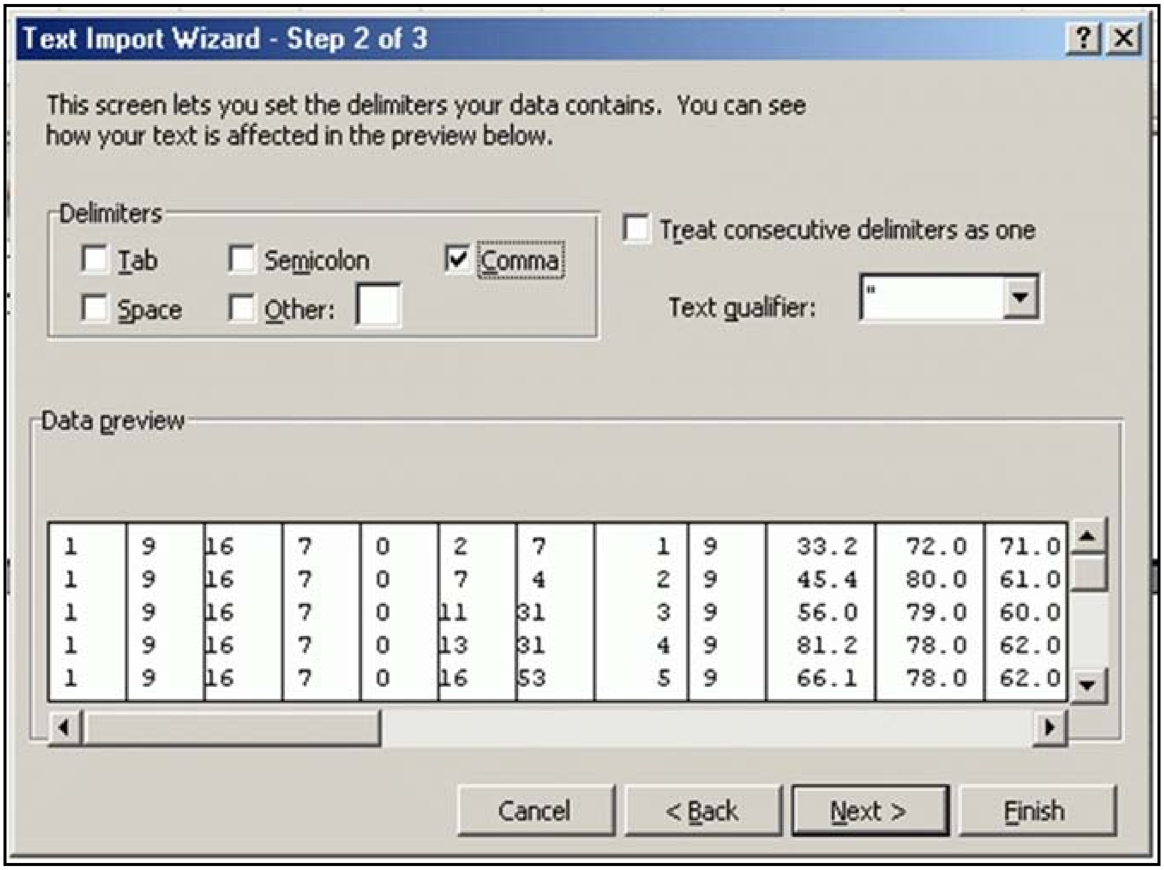
Then go to Excel Menu's
Data → Import External Data →Import Data
Browse to the directory in which the ASCII vehicle record files are stored and locate the vehicle records text data file to import. (Remember - need to look in files of "all types" to locate text files):



In the Text Import Wizard window's "Step 1 of 3" check "Delimited," then click "Next":

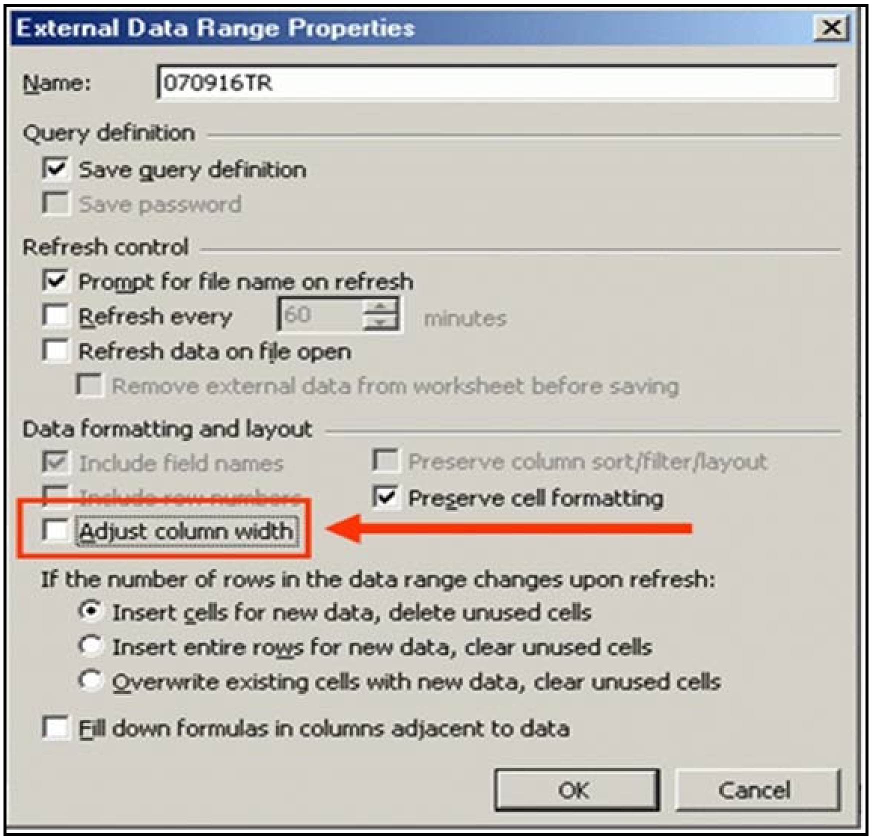


In the "Step 2 of 3" window, make sure only the "Comma" box is checked, then click on "Finish":

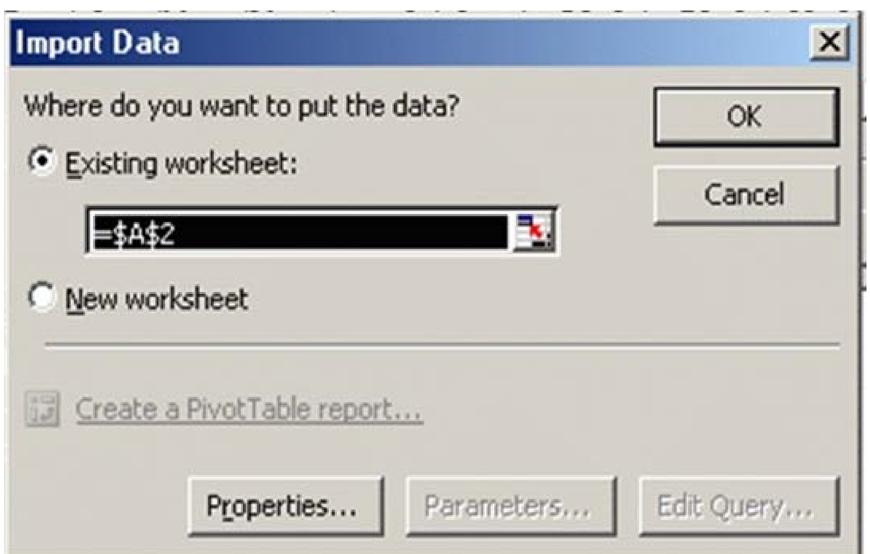


Click "Properties" in the "Import Data" window that appears:

Uncheck “Adjust column width” and then click “OK”:



Make sure the “Import Data” box’s “Existing worksheet” = A2, then click “OK” to perform the import:



All of the data field cells for columns A thru AN should populate for the number of records contained in the data file (starting in row 2):

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	
1	LN	MO	DAY	YR	HR	MIN	SEC	NO	CL	GVW	LGTH	SPEED	VIOL	AX1RT	AX1LT	AX2RT	AX2LT	AX1-2	AX3RT	AX3LT	AX2-3	AX
2	1	10	12	8	0	8	41	1	9	67.9	82	65	0	5.4	5.3	7.1	8.1	20.3	7.3	8.3	4.3	
3	1	10	12	8	0	16	51	2	9	63.4	77	60	0	6.1	5.7	7.1	8.1	15.7	7.0	7.7	4.3	
4	1	10	12	8	0	17	16	3	12	70.9	87	63	0	6.0	6.0	4.6	5.1	18.3	4.2	5.5	4.4	
5	1	10	12	8	0	17	21	4	9	70.1	80	65	0	6.0	6.0	7.1	7.8	18.4	6.4	8.4	4.4	
6	1	10	12	8	0	17	32	5	9	69.7	77	59	0	5.8	6.0	6.5	7.0	16.8	5.7	7.0	4.4	
7	1	10	12	8	0	20	54	6	9	32.7	79	65	0	4.8	5.4	3.3	3.4	17.4	2.8	3.5	4.3	
8	1	10	12	8	0	27	55	7	9	79.2	74	63	28	5.5	5.9	7.2	8.6	16.6	7.3	8.4	4.4	
9	1	10	12	8	0	30	20	8	9	40.9	78	55	0	5.3	5.5	4.0	4.2	16.0	3.3	4.2	4.4	
10	1	10	12	8	0	44	45	9	9	56.7	78	68	0	4.9	5.0	5.8	6.5	17.5	5.4	6.2	4.4	
11	1	10	12	8	0	48	22	10	9	36.7	77	65	0	4.9	5.1	3.8	3.2	15.7	3.2	3.2	4.4	
12	1	10	12	8	0	58	49	11	9	80.9	72	66	28	5.7	5.9	8.0	8.8	16.1	7.8	9.0	4.4	
13	1	10	12	8	1	3	37	12	9	61.8	78	63	0	6.1	6.1	5.8	6.4	17.3	5.5	6.5	4.3	
14	1	10	12	8	1	8	57	13	9	47.2	77	63	0	5.4	5.9	6.0	6.0	16.4	5.6	5.8	4.3	
15	1	10	12	8	1	9	19	14	9	79.6	80	63	28	5.7	6.0	7.9	8.9	20.2	8.0	8.9	4.3	
16	1	10	12	8	1	9	22	15	11	72.7	82	64	0	5.4	5.6	8.2	8.3	17.8	8.1	7.0	20.7	
17	1	10	12	8	1	13	23	16	12	65.6	84	60	0	5.6	5.6	5.1	4.4	17.2	4.4	5.2	4.3	
18	1	10	12	8	1	13	42	17	11	63.3	80	68	0	5.0	5.1	6.6	8.0	13.5	7.7	8.0	21.4	
19	1	10	12	8	1	15	33	18	9	45.2	73	63	0	5.3	5.3	4.8	4.6	17.3	4.8	4.9	4.4	

At such time that the import works well and the cells have been formatted as desired, delete all data from the spreadsheet and save (perhaps as a “template,” or similar) with some pertinent file name to use for all future data imports. Remember that once the original spreadsheet has been populated with “new” data, save it with a different file name (perhaps site identifier and date).