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# Guidelines for Portable Weight-in-Motion (WIM) System Installation and Traffic Data Analysis

Product 5-6940-01-P2

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Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE  
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Project 5-6940-01: Implementation of Portable Weigh-In-Motion (WIM) Technology  
on Texas Highways

## Product 5-6940-01-P2

# Guidelines for Portable Weight-in-Motion (WIM) System Installation and Traffic Data Analysis



by

Lubinda F. Walubita, Adrianus Prakoso, and Harshavardhan Rao Chunduri  
TTI – The Texas A&M University System, College Station  
| July 2022 |



# **GUIDELINES FOR PORTABLE WEIGHT-IN-MOTION (WIM) SYSTEM INSTALLATION AND TRAFFIC DATA ANALYSIS**

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## **Disclaimer**

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This report is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Lubinda F. Walubita.

The United States Government and the State of Texas do not endorse products or manufactures. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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## LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
AADTT	Annual Average Daily Truck Traffic
ADT	Average Daily Traffic
ALD	Axle Load Distribution
ATHWLD	Average Tenth Highest Wheel Load
ESAL	Equivalent Single Axle Load
FHWA	Federal Highway Administration
FM	Farm-to-Market
FPS	Flexible Pavement Design System
GVW	Gross Vehicle Weight
HMA	Hot Mix Asphalt
IH	Interstate
MAF	Monthly Adjustment Factor
M-E	Mechanistic-Empirical
RM	Ranch-to-Market
SH	State Highway
TxDOT	Texas Department of Transportation
TxME	Texas Mechanistic-Empirical Flexible Pavement Design System
TMA	Truck Mounted Attenuator
TRS	Traffic Recording System
TTI	Texas A&M Transportation Institute
T-DSS	Traffic Data Storage System
US	United States
USB	Universal Series Bus
WIM	Weight-in-Motion

## SECTION I. INTRODUCTION

As the portable weight-in-motion (WIM) technology has been successfully explored and practically used to collect site-specific traffic data in Texas Department of Transportation Research Project 0-6940 *Develop System to Render Mechanistic-Empirical Traffic Data for Pavement Design*, this standardized guideline was developed to aid users understand more thoroughly the portable WIM system deployment and its operation for traffic data collection. This draft guideline can be used as a main guide for the portable WIM system implementation on Texas highways. As a supporting material, this guideline covers and describes the following points:

- Portable WIM components and the required accessories.
- Preparation of the portable WIM installation and highway site selection.
- Portable WIM setup, installation, calibration, maintenance, uninstallation, and troubleshooting.
- Automated macros for processing and analyzing portable WIM traffic data, such as volume, speed, vehicle classification, and weight data.
- Automated macros for generating Flexible Pavement Design System (FPS) and Texas Mechanistic-Empirical Flexible Pavement Design System (TxME) traffic input data for pavement design.
- The MS Access Traffic Data Storage System (T-DSS).
- Demonstration case studies.

## SECTION II. PORTABLE WIM SYSTEM COMPONENTS AND ACCESSORIES

Portable WIM system consists of several main components and support accessories. The main components for the deployment of the portable WIM system for one lane requires a Traffic Recording System (TRS) unit, two piezoelectric sensors, two custom-made metal plates with the end caps, piezo channel box, and an energy recharging system that includes 12-volt battery, solar panel, and solar charger controller. A modem system can also be added to the system to enable real-time remote access to the WIM data and monitor the functionality of the deployed system. Two metal plates are installed on top of the pavement with the distance of 8 ft between each plate and placed to cross the roadway by half of the width of lane (typically about 6 ft). Each piezoelectric sensor is imbedded into a devised pocket tape then pasted on top of the metal plate.

When vehicles pass over the plates, the sensors record the vibration signals, which are thereafter, transmitted to the traffic counter TRS unit. The sensors are connected to the TRS unit via piezo channel box. The TRS records the pulses, processes them to generate per-vehicle data including the vehicle class, speed, axles spacing, axles weight, and gross vehicle weight (GVW). The traffic data are stored by the TRS unit, and each day per-vehicle data are individually stored as a .000 file. These raw files are downloadable remotely (if a modem is in use) or directly from the TRS using a universal serial bus (USB) flash drive. The raw files can then be converted into excel compatible (.csv) format using the Road Reporter II software.

### PORTABLE WIM SYSTEM MAIN COMPONENTS

The main components needed for the installation of portable WIM system on one lane of a road section include the following:

- **TRS Unit** – A traffic recording machine to collect traffic data in portable WIM system, which includes volume data, speed data, classification data, weight data, etc. (Figure 1).



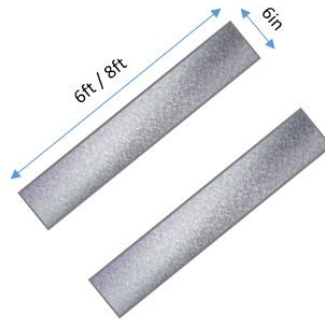
**Figure 1. TRS Unit.**

- **Set of two Polymer Piezoelectric Sensors** – 6-ft or 8-ft long sensors that can be used depending on the lane width and plates in use (Figure 2). The 8-ft sensors can only be used when there is a shoulder on the outside lane and 6-ft sensors can be used either on the inside lanes or outside lane having no shoulder.

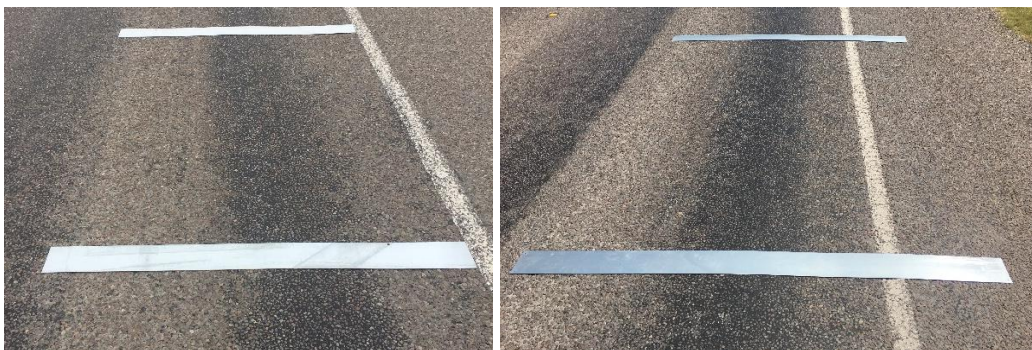


**Figure 2. Piezoelectric Sensor.**

- **Set of two Metal Plates** – Each of the metal plate should have a dimension of 6-ft or 8-ft long, 6-inch wide, and 0.04-inch thick (Figure 3–Figure 5). The use of the metal plates is essential as it homogenizes the vibration from vehicles and reduces potential noise on data quality due to pavement distresses.



**Figure 3. Metal Plates Dimension.**



(a)

(b)

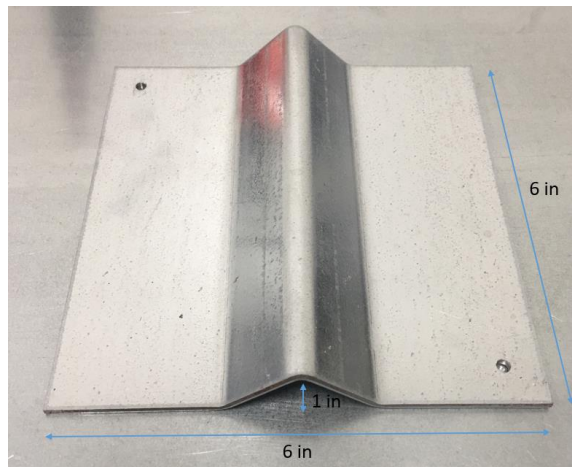
**Figure 4. (a) 6-ft Metal Plates Placement on the Road; (b) 8-ft Metal Plates Placement on the Road.**





**Figure 5. 8-ft Metal Plates Installed on the Road.**

- **Set of two custom-made metal ramps** – The metal ramp is used as end caps for the metal plates to cover the sensor cable connection (Figure 6 and Figure 7). When placed above the sensor cable connection, the metal ramp protects the cable sensor from incoming vehicles. Each of the metal ramp should have a dimension of 6-inch long, 6-inch wide, 0.1-inch thick, and 1-inch ramp height.



**Figure 6. Metal Ramp.**



**Figure 7. Metal Ramps Installed on the Road.**

- **Piezo Channel Box (Piezo Inputs)** – An adapter to connect multiple piezoelectric sensors (BNC connectors) to the TRS unit (18-pin connectors) (Figure 8).



**Figure 8. Piezo Channel Box.**

- **Battery (12 volt)** – Needed to keep the TRS unit charged continuously (Figure 9).



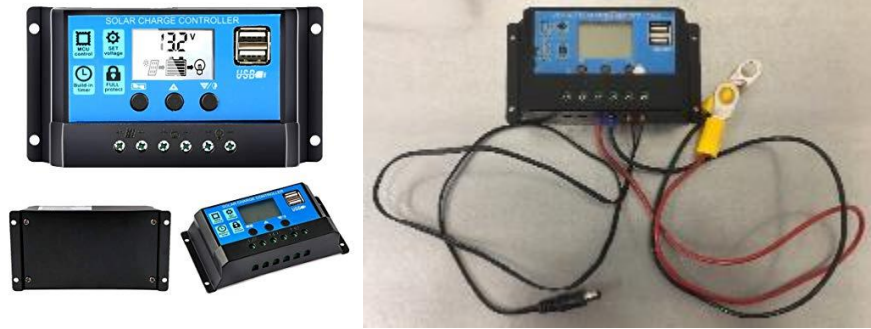
**Figure 9. 12-Volt Battery.**

- **Solar Panel** – Used for harnessing ambient solar energy to recharge the 12-volt battery, allowing the system to function properly with no energy outage in the long term (Figure 10).



**Figure 10. Solar Panel.**

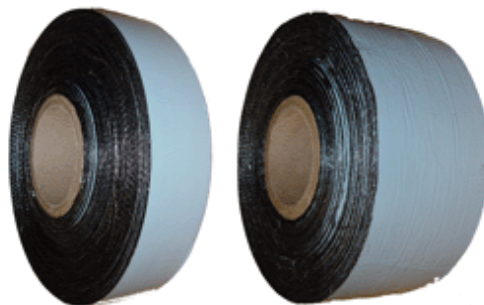
- **Solar Charger Controller** – A device used to regulate the voltage and current received from the solar panel to charge the 12-volt battery safely and keep the battery from overcharging (Figure 11). Solar charger controller usually comes without any electrical wiring cables; therefore, several electrical wires are needed to be installed on the unit beforehand. In addition, 5.5 mm × 2.5 mm barrel male plug connector and ring terminals are required to connect to the TRS unit and 12-volt battery, respectively.



**Figure 11. Solar Charger Controller.**

- **Mastic Tapes** – The mastic type uses a rubberized asphalt base as its adhesive (Figure 12–Figure 15). The tapes required for the sensor installation include the following:
  - Pocket tapes: Piezoelectric sensors are imbedded and protected in the 4-inch-wide pocket tapes to last longer, keep functioning properly, and provide accurate data.
  - Road tapes (4-inch and 6-inch wide): Road tapes are also necessary to provide more protection to the sensors. After placing the metal plates on the pavement along with the pocket tapes and sensors on the top of the metal plates, road tapes can be applied to provide more protection against traffic so that the sensors and the plates remain intact.

These mastic tapes are recommended to be used for temperatures of 55°F and higher, otherwise the tapes will not adhere properly. In order for mastic tapes to adhere properly, torch kit is needed to heat up both the pavement surface and asphalt base (adhesive) on the mastic tapes.



**Figure 12. Mastic Tapes.**



**Figure 13. 4-Inch Pocket Tape with a Sensor Installed on the Road.**



**Figure 14. 4-Inch Road Tape Installed on the Road.**



**Figure 15. 6-Inch Road Tape Installed on the Road.**

- **Metal Box** – It is highly recommended to keep all units, including TRS unit, sensor cables, piezo channel box, battery, solar charger controller, and modem, inside of the metal box to protect from extreme weather. The metal box (Figure 16) should be locked and placed close by the pole with chains for added security against theft. In addition, the metal box should have a small hole for cable management so that the sensor and other cables can be inserted, and the metal box can be closed securely without damaging the cables.



**Figure 16. Metal Box.**

## PORTABLE WIM SYSTEM ACCESSORIES

The required accessories for the installation of portable WIM system include the following:

- **Modem System** – It enables users to access real-time portable WIM traffic data remotely and monitor the functionality of the deployed portable WIM system using the Road Reporter II software (Figure 17).



**Figure 17. Modem System.**

- **Personal Protective Equipment** – Protective clothing, helmets, goggles, boots, gloves, and protective knee pads designed to protect the wearer from injury (Figure 18). The hazards addressed on the portable WIM installation work by this equipment include physical, electrical, and heat.



**Figure 18. Personal Protective Equipment.**

- **Accessories and Hand Tools** – Nails, liquid nails, caulk gun, measuring tape, traffic cones, marker, chains, locks, zip ties, duct tapes, screwdriver kit, broom, adjustable wrench, box-beam level, hammer, hand-digger, pick mattock, shovel, cutting plier, folding utility knife, heavy-duty scissors, crowbar, adhesive remover, rags, 12-volt battery charger, and torch kit (Figure 19).



**Figure 19. Accessories and Hand Tools.**

### **SECTION III. PORTABLE WIM SITE SELECTION, PREPARATION, AND MANAGEMENT**

Selecting portable WIM installation location is required before heading to the field and starting the installation. Google Map and Google Street View are useful tools that can be used to check and study the location. Additionally, conducting a site survey manually would also be helpful as the maps of several locations on Google Map are occasionally not updated. These are considerations in selecting an ideal highway site for a portable WIM system deployment:

- The portable WIM should be installed at minimum or more than 200 ft away from a bridge, intersection, curve, etc., to ensure all vehicle axles (steering and rear axles) pass through the sensors.
- Install portable WIM sensors where there is a continuous flow of traffic and avoid installing in an area where vehicles will stop, accelerate, or slow down on the sensors (e.g., installing portable WIM sensors near intersection, parking areas, bus stops, areas with heavy congestion, loading zones, etc.).
- Install the portable WIM sensors perpendicular to the flow of traffic.
- A site with a permanent pole is preferable (not temporary pole) due to the needs of mounting a solar panel and attaching a modem antenna.
- Metal plates should be installed on flat pavement without any distresses such as cracking and rutting.

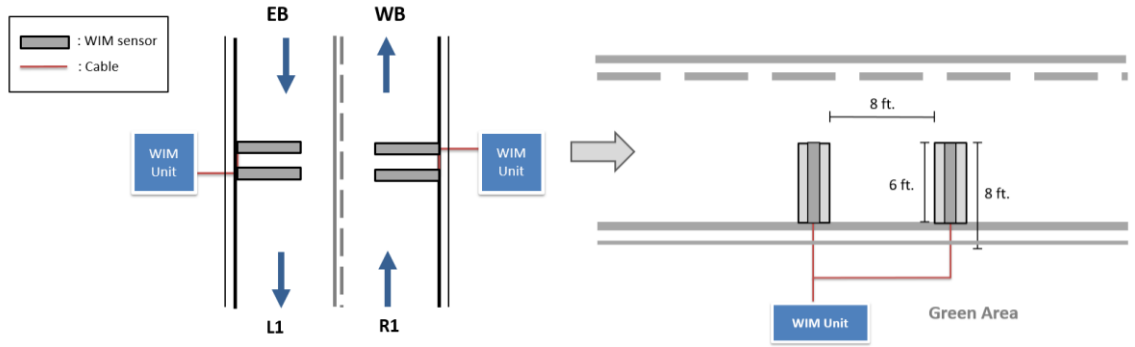
After choosing the locations for portable WIM installation, a document containing specific location(s), coordinates, a reference marker, maps, and schematic plan of portable WIM installation is made as a guide for users and traffic control crews.

#### **PLANNING PORTABLE WIM INSTALLATION**

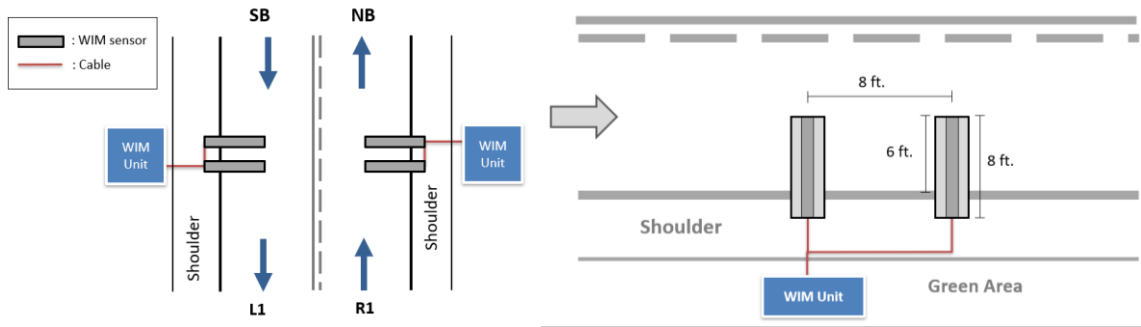
There are different schematic plans for installing portable WIM system, depending on the location conditions and total lanes for each direction as followings:

1. Single lane in each direction

Two 6-ft or 8-ft portable WIM sensors and one TRS unit installed for each lane. This portable WIM installation schematic was used on FM 281 in Moore County (See Figure 20–Figure 22).



**Figure 20. Portable WIM Installation Schematic Plan for Single Lane Using 6-ft Sensors.**



**Figure 21. Portable WIM Installation Schematic Plan for Single Lane Using 8-ft Sensors.**

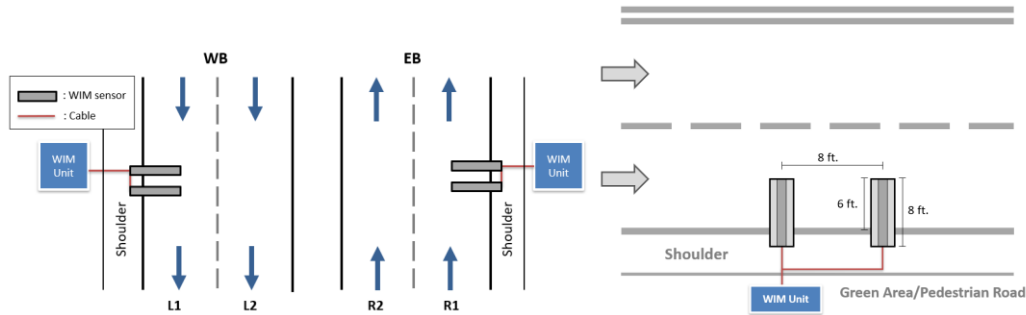


**Figure 22. Portable WIM Installation on FM 281 in Moore County.**

2. Two lanes in each direction (outside lane only)

Two 6-ft or 8-ft portable WIM sensors and one TRS unit installed on outside lane for each direction. This portable WIM installation schematic was used on US 290 in Travis County (See Figure 23–Figure 24).





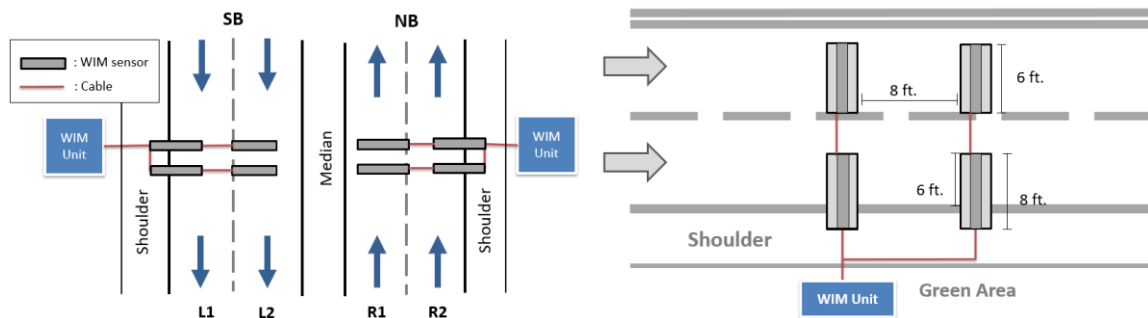
**Figure 23. Portable WIM Installation Schematic Plan for Outside Lane.**



**Figure 24. Portable WIM Installation on US 290 in Travis County.**

3. Two lanes in each direction (outside and inside lane)

Two 6-ft or 8-ft portable WIM sensors installed on outside and inside lanes with one TRS unit for each direction. This portable WIM installation schematic was used on SH 130 in Travis County (See Figure 25–Figure 26).



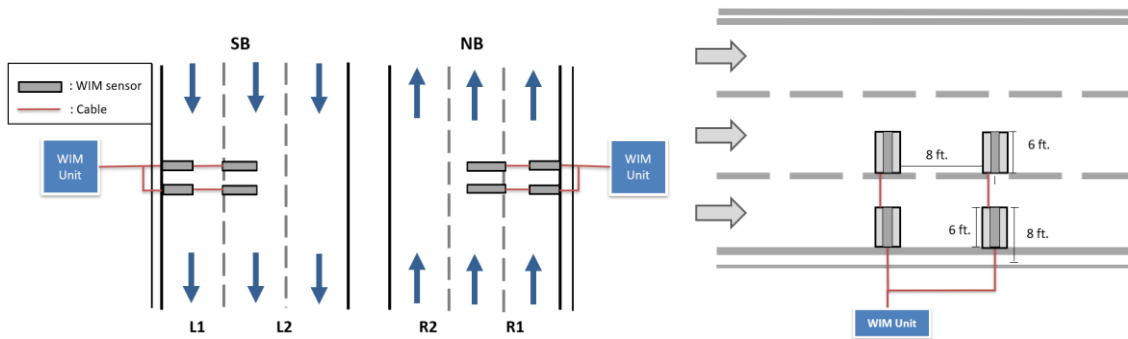
**Figure 25. Portable WIM Installation Schematic Plan for Outside and Inside Lanes.**



**Figure 26. Portable WIM Installation on SH 130 in Travis County.**

4. Multiple lanes in each direction (outside, inside, and/or middle lane)

Two 6-ft or 8-ft portable WIM sensors installed on outside, inside, and/or middle lanes with one TRS unit for each direction. This portable WIM installation schematic was used on IH 35 in Travis County (See Figure 27–Figure 28).



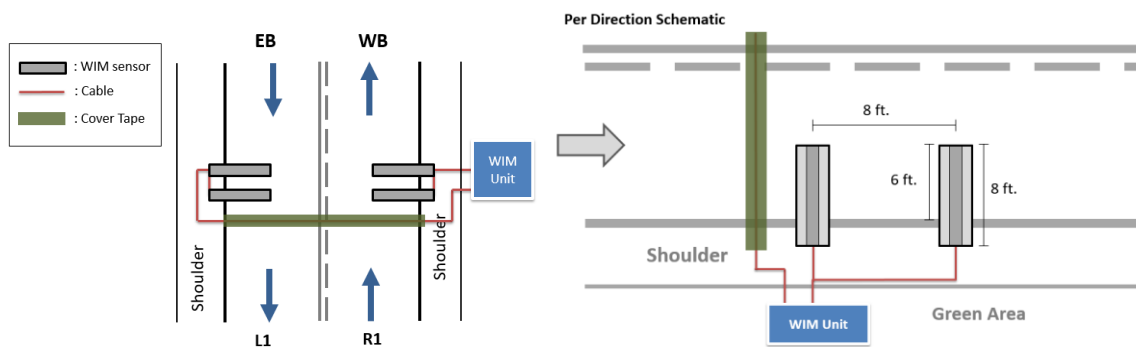
**Figure 27. Portable WIM Installation Schematic Plan for Outside and Middle Lanes.**



**Figure 28. Portable WIM Installation on IH 35 in Travis County.**

5. Multiple lanes in both directions

Two 6-ft or 8-ft portable WIM sensors installed for each direction and one TRS unit installed for both directions. This portable WIM installation schematic was used on RM 652 in Culberson County (See Figure 29–Figure 30).



**Figure 29. Portable WIM Installation Schematic Plan for Both Directions.**



**Figure 30. Portable WIM Installation on RM 652 in Culbertson County.**

### **INSPECTING PORTABLE WIM SYSTEM**

Inspecting the main portable WIM system components before installation is required to ensure each component, including TRS units, piezoelectric sensors, piezo channel boxes, and 12-volt batteries, function properly. These are the following steps to perform portable WIM system inspection:

1. Check whether the TRS unit will turn on and off and ensure the TRS unit battery is fully charged.
2. Check the 12-volt batteries should whether they are fully charged.
3. TRS units, piezoelectric sensors, and piezo channel boxes may be checked simultaneously by performing the diagnostic test. The purpose of the diagnostic test is to ensure that the sensors are able to convert any mechanical stresses (e.g., acceleration, pressure, force) into an electrical charge properly and the TRS unit can detect the piezoelectric sensor while being connected. Once the piezoelectric sensors are connected to the TRS unit via piezo channel box, the diagnostic test can be performed as follows:
  - a. Navigate to the SYSTEM menu by selecting F3 key.



- b. Navigate to the DIAG menu by selecting 3 key.



- c. The Diagnostics menu lists a number of options to display diagnostic information about the parts of the TRS. Navigate to the AX SENS menu by selecting 4 key.



- d. The Axle Sensors diagnostic display shows the number of every possible axle sensor connection to the TRS with a dotted vertical line to the left of the sensor number. When a sensor detects any pressure/force by an axle rolling over the sensor (or simply stomp on it or use any tool, such as hammer, to hit the sensor), the line adjacent to the number corresponding to that sensor will become solid black, meaning the sensor, the TRS unit, and the piezo channel box work perfectly fine and they are ready to use on the field.



## SECTION IV. PORTABLE WIM INSTALLATION, SETUP, REMOVAL, AND CALIBRATION

### PORTABLE WIM SYSTEM INSTALLATION

Depending on your environment or condition, some things may need to be changed/improvised. Always apply engineering judgment on each of the step. Assuming one is installing a portable WIM system (8-ft sensors) on an outside lane of a flat road section without any pavement distress, the following steps must be considered:

1. Identify an appropriate installation point at the designated WIM site. The installation point must be a flat section with no or minimal pavement distress (e.g., cracks, rutting, potholes). The box-beam level can be used to measure the flatness of the pavement.
2. Using the box-beam level or right-angle ruler, position the plates to be perpendicular (90°) from the lane direction.
3. Measure the distance between each plate using measuring tape. The plates should be 8-ft apart and extends to cover half of the width of the lane (Figure 31).



**Figure 31. Measuring Distance between Each Metal Plate.**

4. Using a marker, mark the position of the plates, lift them up, and clean the marked area using a broom. Ensure that there are no gravel or chunks present on the marked area or the plate (Figure 32–Figure 33).



**Figure 32. Marking the Position of the Metal Plates.**



**Figure 33. Cleaning the Marked Area.**

5. Apply silicon adhesive on the bottom of each plate then gently place the plate on the top of the pavement at the marked area (Figure 34–Figure 35).



**Figure 34. Applying Silicon Adhesive Using Caulk Gun.**



**Figure 35. Placing the Metal Plates on the Marked Area.**



6. Nail the plate on the top of the pavement using 1.5-inch drive pins with washer (Figure 36). However, it is recommended to use 2.5-inch drive pins for seal coat surface due to its thick layer.



**Figure 36. Nailing the Metal Plates.**

7. Cut two 8-ft long strips of 4-inch pocket tape.
8. Insert an 8-ft WIM piezoelectric sensor into the pocket tape (Figure 37).



**Figure 37. Inserting the Piezoelectric Sensors into the Pocket Tapes.**

9. For winter installation (pavement temperatures below 55°F), heating up the tapes (the sticky part of the tapes) (Figure 38. Heating up the Mastic Tapes) and the road surface with a torch kit are strongly recommended to allow proper adherence between the tape and pavement surface.



**Figure 38. Heating up the Mastic Tapes**

10. Tape the imbedded sensor on the top of each 8-ft metal plate (Figure 39).

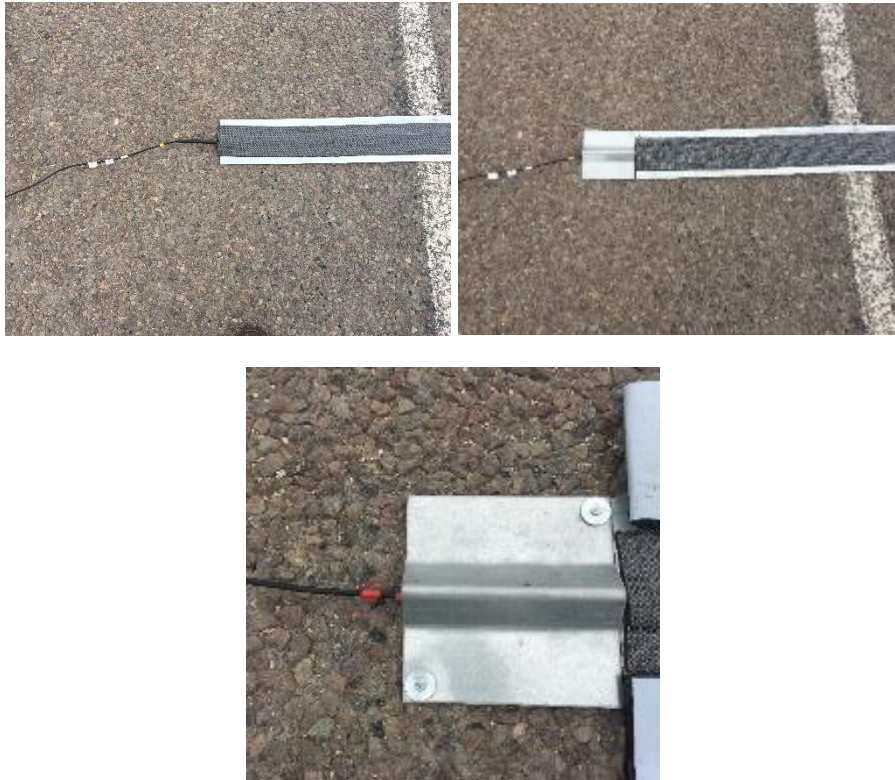


**Figure 39. Imbedded Sensors on Top of Each Metal Plate.**

11. Before proceeding to the next step, it is recommended to check and ensure the imbedded sensors are working. Checking the sensors can be performed by connecting the sensors to the ready-to-use TRS unit. Once the sensors are connected, run the vehicle three times at three different speeds to check whether the vehicle class and speed match with the FHWA

vehicle classification chart and speed read by the TRS unit, respectively. In addition, speed gun may be used as well to verify the speed read by both testing vehicle and the TRS unit.

12. Use the metal ramps (end-cap crown) as a cap to cover the cable connection at the edge of the sensor by placing and nailing them at the end of the plate (on the pavement shoulder) (Figure 40).



**Figure 40. Nailing the Metal Ramps (End-Cap Crown).**

13. Cut four strips of the 4-inch road tapes and 6-inch road tapes. Each strip should be about 9-ft long (for 6-ft sensors, each strip should be about 7-ft long). Two strips of 4-inch and 6-inch road tapes are needed for each plate.
14. Tape each strip of 4-inch road tape on each of left and right edge of the plate such that 1-inch wide covers the plate and 3-inch wide covers the surface of the pavement (Figure 41). The strip must cover both the plate and metal ramp (total length is about 8 feet and 6 inches) then overlap a bit from each edge.



**Figure 41. 4-Inch Road Tape Applied on the Pavement.**

15. In order for the plates and sensors to remain intact for a long time, add additional strip of 6-inch tape on each of left and right edge of the plate to provide more protection. Sensor cables on the shoulder should be covered as well with road tapes (Figure 42–Figure 43).



**Figure 42. Applying 6-Inch Road Tape.**



**Figure 43. 4-Inch Road Tape Applied on the Shoulder to Cover the Sensor Cables.**

16. Two or three horizontal road tape strips (about 20-inch long) are applied on the edge of each sensor to better hold the plates in place (Figure 44). Additionally, short road tape strips are applied as well on the tape which is used to cover the sensor cables. Depending on certain situation, it is optional to apply more road tape strips on the center of the sensors, however, for winter installation, it is recommended to apply one to three short horizontal road tape strips on the middle of the sensors (Figure 45. Extra Horizontal Road Tapes on the Center of the Sensors).



**Figure 44. Horizontal Road Tapes (about 20-Inch Long).**



(a)



(b)

**Figure 45. Extra Horizontal Road Tapes on the Center of the Sensors for Winter Installation: (a) SH 6 (Bryan District) and (b) SH 349 (Odessa District)**

17. Dig a trench using a hand-digger, pick mattock, and shovel to bury the remaining sensor cables (Figure 46–Figure 47).



**Figure 46. Digging a Trench.**



**Figure 47. Sensor Cables Are Buried in Trench.**

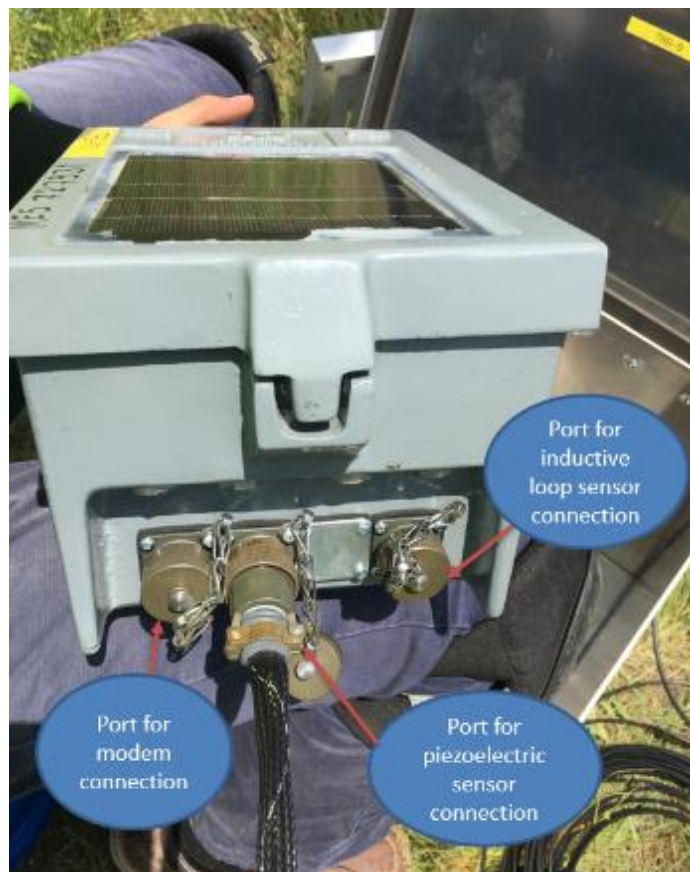
18. Connect the sensor cables to the piezo channel box. When connecting the sensor cables, make sure to use the channels in order (e.g., channel 1 and 2 or channel 3 and 4,

respectively). It is highly recommended to connect the odd number channel (e.g., channel 1, 3, 5, or 7) with the sensor that gets hit first by the incoming vehicle (Figure 48).



**Figure 48. Connecting the Sensor Cables to the Piezo Channel Box.**

19. Connect the piezo channel box to the TRS unit (Figure 49).



**Figure 49. Connecting the Piezo Channel Box Cable to the TRS Unit.**



20. Mount the solar panel on the pole using a bracket and connect the power cables to the solar charger controller (Figure 50).



**Figure 50. Solar Panel Mounted on a Pole.**

21. Connect the 5.5 mm × 2.5 mm barrel male plug connector and terminal rings on the solar charger controller to the TRS unit and 12-volt battery, respectively. Ensure the TRS unit is charged while being connected to the solar charger controller.
22. Ensure the solar charger controller is showing power indicators from the solar panel, 12-volt battery, and the TRS unit (See Figure 51).



**Figure 51. Solar Charger Controller Indicators.**

23. Once the portable WIM system is ready, run the testing vehicle three times again at three different speeds to check if the sensors are working properly and portable WIM system gives an accurate reading of vehicle class, speed, axle spacing, and weight measurements.
24. Store all the main portable WIM system components inside of the metal box. Once the TRS unit is ready to be operated, close and lock the metal box.

## TRS UNIT SETUP

This subsection presents a step-by-step guidance for setting the TRS unit after all the portable WIM main components are installed on the pavement. The purpose of this setting is to collect per-vehicle class, speed, GVW, axle weights, and axle spacing. The TRS unit should be initially charged. The sensor cables should all be connected to the TRS through the piezo channel box.

1. The first step is to turn on the TRS unit. The TRS will then display the Main menu as shown below. Then set the program mode by selecting F2 for PROGRAM.



2. Program menu will be displayed then select 1 for MODE. Different modes of data collection will be displayed.



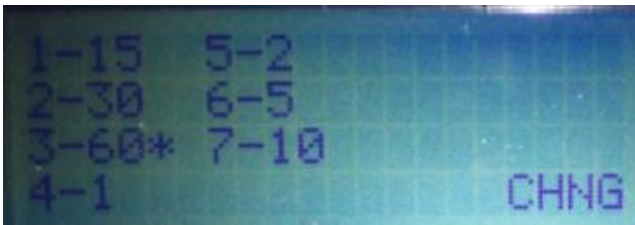
3. Select 8 for WIM, CLS, SPD, and PV type data will automatically be selected. Press F4 CHNG to save the mode changes and return to the Program menu. Other options can be selected for different data based upon the requirement.



4. Press N to turn back to the Program menu then select 2 for LAYOUT.
5. Choose number of lane(s) (01, 02, 03 or 04) and select || (all) for sensors option. Spacing shall be 08 (e.g., 8 ft space between the two plates). Press F4 CHNG to save the mode changes and return to the Program Menu.



6. Press N to turn back to the Program menu then select 4 for INTVL and select 3 for 60 minutes.



7. Press N to turn back to the Program menu then select 7 for SPEED and select 3 for TMG. Press F4 CHNG to save the mode changes and return to the Program menu.



8. Return to the Main menu then select F3 for SYSTEM to go to the System menu.



9. Press 8 for CONFIG, configuration menu will display.



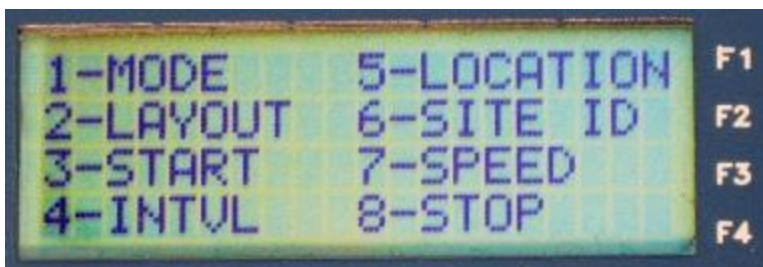
10. Select 8 WIM to open the WIM Configuration menu the select 1 for auto-calibration. Also ensure that there is no star \* in front of 3-BIN 1-3 if so then press 3 to remove the star \*. Press F4 CHNG to save the mode changes. Otherwise, all the non-truck vehicles (FHWA class 1, 2, and 3) will not be recorded.



11. Select 1 AUTO-CAL to open the WIM Automatic Calibration menu. Using the F2 button, toggle 1 AUTO-CAL to ON, press F4 CHNG to save the changes and return to the WIM Configuration menu.



12. Press N several times to return to the main menu, then press F2 to display the Program menu. Start the data collection by selecting 3.



13. In the start menu, set start time and date or select F1 for now and it will display the actual date and time. When the start time entry is complete, press the Y/ENT key to move to the END time and date. Then Press F4 CHNG to save the changes and begin data collection.



14. The display will return to the Main Menu and will show SET on the bottom line to indicate that the configuration was accepted, and the unit has been set to begin to collect data at the time entered. When the start time is reached, the display will change to REC to indicate that data are being recorded for data collection.

**Note:** It is recommended not to use the first few hours of weight data in the analyses when the TRS unit is set for auto calibration, with 250 vehicle C9.

### **PORTABLE WIM SYSTEM REMOVAL**

Once traffic data have been collected for specified days, portable WIM system needs to be removed from the site. The removal usually takes about 20–30 minutes, depending on certain situation. The removal of portable WIM system can be performed as follows:

1. Cut open the road tape using the utility knife.
2. Insert end of the crowbar underneath the metal plate and forcedly pull the plate.
3. Pull the plate out from the pavement. Use crowbar to remove the nails and clean up the pavement as needed.
4. Discard used sensors, metal plates, and mastic tapes.
5. Retrieve the TRS data if needed and turn off the TRS unit.
6. Disconnect the sensor cables from the piezo channel box.
7. Disconnect the piezo channel box connection from the TRS unit.
8. Disconnect all the cables on the solar charger controller.
9. Uninstall the solar panel bracket and remove the solar panel from the pole.
10. Remove all the portable WIM main components from the site.

### **PORTABLE WIM SYSTEM CALIBRATION**

After the deployment of portable WIM system, it is highly recommended for the WIM sensors to be calibrated so that the unit can report axle weight accurately. The TRS unit calculates axle

weights by multiplying the input signal from the piezoelectric sensors installed on the pavement by a scaling number to produce the axle weight. Theoretically, all sensors would produce an identical signal under all site conditions. However, in the field, each sensor output varies slightly and can change depending on installation method, temperature, pavement condition, and other variables. Therefore, calibration factor is needed as a parameter that can produce a weight that is closer to actual axle weight. The TRS unit has two methods for on-site calibration, namely: a) manual calibration, and b) auto calibration; and one off-site post calibration.

On-Site Manual Calibration: Performing an initial manual calibration can greatly reduce time it takes for auto-calibration of the sensors. The calibration factor is manually set for each axle sensor using a test vehicle with known axle weights and axle spacing (Figure 54 - Figure 55). Performing manual calibration is described as follows:

1. Pass over the piezoelectric sensors using a test vehicle at a constant speed, preferably a Class 9 truck. In lieu of Class 6 truck, a Class 6 dump truck that is readily available in most TxDOT districts can be used.
2. After the vehicle information is displayed, record all axle weights and the gross weight.
3. Calibration factors should be adjusted, until the TRS unit is weighing the test vehicle within tolerance of about  $\pm 5\%$  for the steering axle weight. Note that for calibration purposes, a stringent  $\pm 5\%$  error difference from the static weight measurements should be used for the steering axle weight. The steering axle weight is generally used as the reference datum as its weight is theoretically consider not to vary much as compared to the other axles, particularly as the gross vehicle weight changes.
4. Once the unit is weighing within tolerance, several passes of the test vehicle should be recorded and add up the total GVW to obtain the average GVW.
5. Divide the static weight by the average WIM GVW.
6. Multiply the old calibration factor by the ratio in order to get the new calibration factor. The basic formula for the final calibration factor is:

$$\text{New Factor} = \text{Old Factor} * \frac{\text{Static Weight}}{\text{Average WIM Weight}}$$

**Example:**

Static weight = 84000 lb

Average WIM weight = 80000 lb

Old calibration factor = 2000

$$\text{New calibration factor} = 2000 * \frac{84000}{80000} = 2100$$

On-Site Auto Calibration: Selecting the auto calibration option makes the TRS unit automatically calibrate axle weights using a statistical method to keep a running average of the front axle weights of a specified vehicle class. The way TRS unit does auto calibration is by averaging the front axle weight of a specified vehicle class for a specified number of that vehicle type. It compares the average sampled weight with the entered statistical mean weight of the front axle for that vehicle class, and if there is a difference between the two weights, the calibration factor for each sensor will be automatically adjusted by the system so that the calculated values match the configured target weight. These are the recommended parameters used for auto calibration option:



- **AUTO – CAL:** – toggles the auto-calibration function on or off.
- **#: (<=250)** – this parameter sets the number of vehicles of the class specified to be sampled for auto-calibration. The larger the sample size, the more accurate the auto calibration adjustment is likely to be. The maximum sample size allowed is 250 vehicles.
- **TGT WT:** – the known mean front axle weight in pounds for the specified vehicle class. This number is typically determined from previously conducted traffic surveys or uses the Federal Highway Administration (FHWA) Class 9 typical front axle weight of 10,500 lb.
- **%:** – the maximum percentage change that can be made to the calibration factor at a time. The maximum value allowed is 25 percent.
- **CLASS:** – the FHWA class of vehicle to be sampled for front axle weights used in auto calibration. Typically, FHWA class 9 vehicles are used for auto calibration.

Off-Site Post Calibration: Post calibration primarily serves as a supplement and verification of the on-site calibration, but it is also very helpful in situations where on-site calibration was not conducted. Post calibration is generally conducted off-site during data processing and involves filtering all the Class 9 trucks, averaging their steering axle weights, and then, computing a representative *CF* as expressed below:

$$CF_{Post} = \frac{Wt_{std(C9)}}{Wt_{avg}}$$

$CF_{Post}$  is the calibration factor;  $Wt_{std(C9)}$  is the standard Class 9 truck steering axle weight, and  $Wt_{std}$  is the average of all the measured Class 9 truck steering axle weights. Post calibration is an automated process using an Excel Macro and is essentially conducted to recheck the accuracy of the axle weight measurements, and if needed, apply some post-calibration (namely *CF*) to the traffic data prior to analysis. If the on-site calibration was correctly executed,  $CF_{Post}$  should basically be equal to 1.0, i.e.,  $CF_{Post} \cong 1.0$ .

## SECTION V. PORTABLE WIM SYSTEM DATA COLLECTION

It is recommended to have at least 7 days of data to ensure complete weekly data. It is not recommended to include the data from the first day (the day of portable WIM system is initially installed) for portable WIM traffic data processing and analysis as the system is still calibrating. On a few cases, the weight calibration of the portable WIM system may take more than one day depending on the volume of the FHWA class 9 trucks (FHWA class 9 vehicles are used as a reference for auto calibration in most cases).

### DATA RETRIEVAL THROUGH USB

Traffic data download from the TRS unit can be done remotely or on site using a USB drive. The remote download is only possible when the system is connected to a modem. However, this section will emphasize the on-site download directly from the TRS unit using a USB flash drive. To export the data in an excel format, the Road Reporter II software must be used. The steps for this downloading and exporting data are now presented as following:

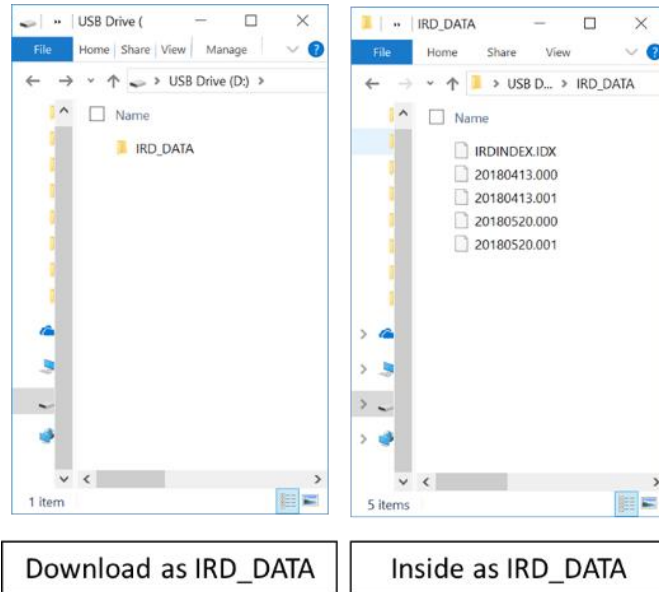
1. Directly insert a USB drive in the TRS unit's USB-port, select ALL to retrieve all the data in the TRS, then Y for yes. Once the download is completed, remove the USB drive (Figure 52).



**Figure 52. Data Retrieval through USB Flash Drive.**

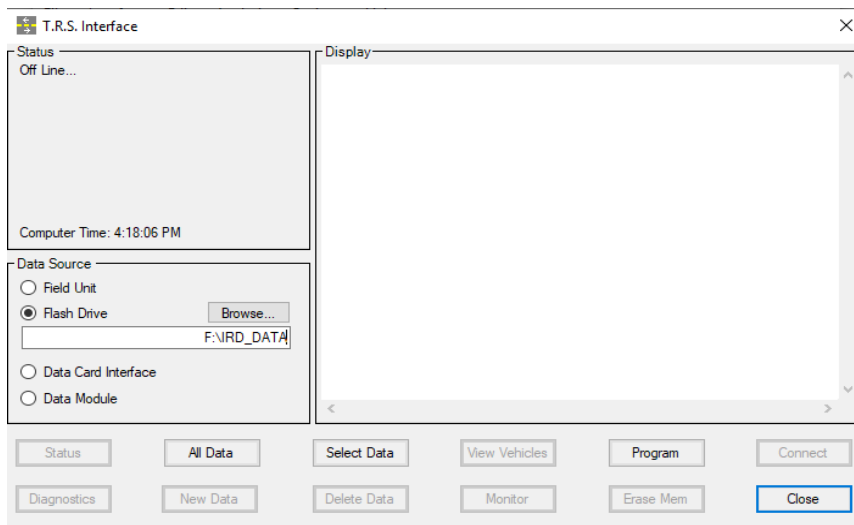
2. The data from the TRS unit are stored in a folder named IRD\_DATA, which contains files in the format .000. Each file corresponds to one day of traffic data (Figure 53).





**Figure 53. Traffic Raw Data.**

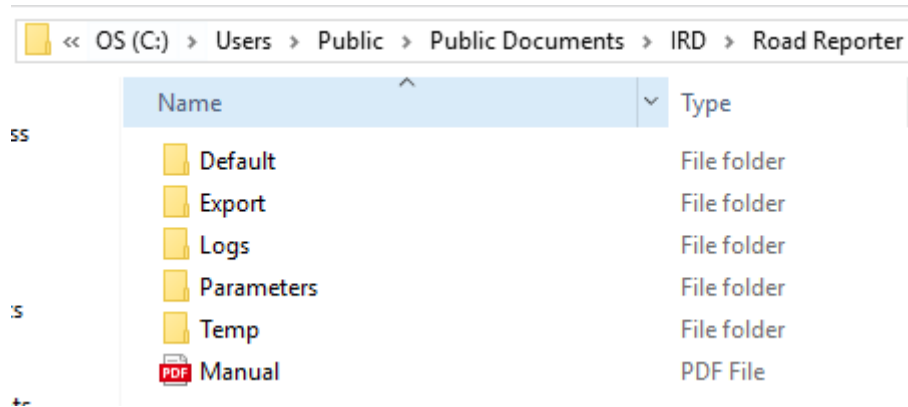
3. Insert the USB into a computer then turn on the Road Reporter II software and choose TRS from the menu bar (Figure 54).
4. On the Data Source section, choose Flash Drive and use the browse button to navigate to the IRD\_DATA folder.



**Figure 54. TRS Interface.**

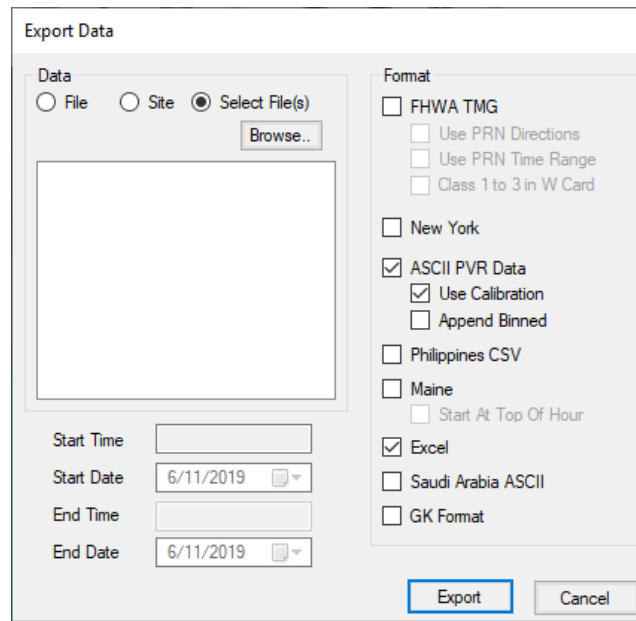
5. Click on Select Data, select the files that are to be analyzed then click on Get Files button.
6. On your computer, locate the Road Reporter folder and go to the folder called Default. This folder will contain the .ind and .prn versions of the files that were previously selected. The

location of the folder is usually in C:\Users\Public\Documents\IRD\Road Reporter by default (Figure 55).



**Figure 55. Road Reporter Folder Location.**

7. Go back to the Road Reporter II software, select Export from the menu bar and click on Select File(s) then Browse (Figure 56).



**Figure 56. Exporting Data.**

8. From the Road Reporter explorer, navigate to the Default folder and select the desired files to be exported.
9. Prior to exporting the files, the require format of the file has to be selected. Click on the Export Button and the software should give you a notification that the export process has been executed successfully.

10. To find the exported files, go to the Road Reporter folder and go to the folder called Export. This folder will now contain the .csv version of the files (Figure 57).



**Figure 57. .csv File of Traffic Data.**

## **DATA RETRIEVAL THROUGH MODEM**

Traffic data of the TRS Unit can also be retrieved by using a modem and the Road Reporter II software. This way, the TRS unit can be connected and monitored remotely and in real-time with a computer. Installing the modem to a portable WIM unit consists of three main setups:

- TRS Unit Setup.
- Modem Setup.
- Road Reporter II Setup.

### **TRS Unit Setup**

To ensure that the TRS Unit sends its signals to the modem, do these steps:

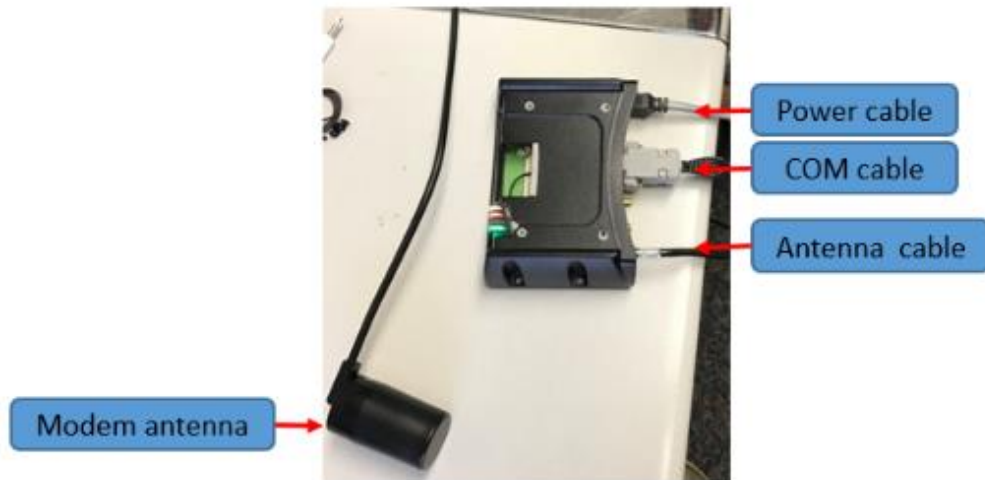
1. Turn on the TRS Unit and wait until the main menu comes out.
2. Go to System-> Modem -> (3) CDPD; and ensure that the CDPD is turned on. (An asterisk \* beside the label would indicate it is turned on).
3. Go to System-> Modem -> (4) COMM ON and ensure that the COMM ON is turned on. (It should have an asterisk \* symbol beside it).
4. Go to System-> BAUD-> and ensure that **38.4** is selected.

### **Modem Setup**

In order for the modem to be functional, ensure that these components are functional and follow these steps:

1. Connect the antenna cable to the modem, tape/attach the antenna to a high-leveled pole (See Figure 58–Figure 59).

2. Using the COM cable, connect the modem to the TRS unit, ensure that both units are turned off when plugging in.
3. Ensure that a SIM Card is present in the SIM card slot.
4. Connect the power cable to the modem, then connect the other end to a battery or any power supply.



**Figure 58. Modem Unit Cables.**



**Figure 59. Attached Modem Antenna.**

### **Road Reporter II Setup**

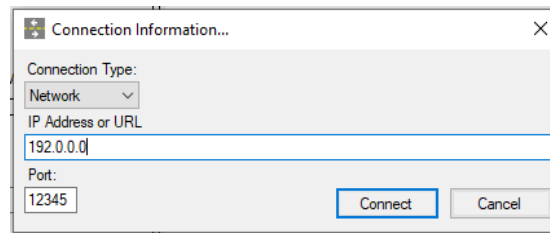
To be able to monitor the modem, connect the Road Reporter II software to the modem of the TRS Unit:

1. Install Road Reporter II on any laptop.

2. Open Road Reporter II.
3. Once in the home page, go to TRS -> Connect.
4. Ensure that the connection type is set to network.
5. Insert the IP Address that corresponds to a modem installed.
6. Insert the corresponding port number, usually 12345.
7. Once connected, go to status to check the condition of the modem. Once the modem status is listed, this means that the computer has been connected with the TRS Unit successfully.
8. To view real-time traffic data, click on View Vehicles.

The steps to retrieve data remotely are described as follows:

1. Open the Road Reporter II Software and choose TRS from the menu bar (Figure 60).
2. On the Data Source section, ensure that Field Unit is selected and select Connect.



**Figure 60. Remote Connection through Road Reporter II Software.**

3. On the Connection Information Window, ensure that the connection type is set to Network.
4. Insert the corresponding IP address and port number.
5. Once connected, user can click on Select Data then pick the data that wants to be downloaded from the TRS Unit.
6. Once the data has been downloaded, on your computer, locate the Road Reporter folder and go to the folder called Default. This folder will contain the .ind and .prn versions of the files that were previously selected. The location of the folder is usually in C:\Users\Public\Documents\IRD\Road Reporter by default.
7. Go back to the Road Reporter II software, select Export from the menu bar and click on Select File(s) then Browse.
8. From the Road Reporter explorer, navigate to the Default folder and select the desired files to be exported.

9. Click on the Export Button and the software should give you a notification that the export process has been executed successfully.
10. To find the exported files, go to the Road Reporter folder and go to the folder called Export. This folder will now contain the .csv version of the files.

## SECTION VI. TROUBLESHOOTING AND GENERAL PORTABLE WIM MAINTENANCE

### TROUBLESHOOTING

There are several problems that might occur during portable WIM installation, below are several tips on possible causes of the problem:

- TRS unit is not turning on:
  - Check the battery to make sure it is above 5.5 volts.
  - Verify battery harness is connected properly.
  
- TRS unit is not counting:
  - Check to see if the sensors are operating under the System/Diagnostics menu.
  - Ensure the TRS unit is programmed correctly, and the sensors are operating correctly.
  - Check the sensor connections to be sure they are attached properly in order.
  - Try different piezo channels or another piezo channel box.
  - Check the sensitivity settings on the TRS unit menu and change the sensitivity if no vehicle is being recognized by the TRS unit.
  - Ensure the piezo channel box is connected to the correct port.
  - If FHWA vehicle class 1, 2 and 3 are not being detected by the TRS unit, ensure to check and turn off BIN 1-3 from the WIM Configuration menu as explained in above sections.
  
- TRS unit is not getting charged by the 12-volt battery:
  - Check charger to ensure it is working properly by connecting it to other TRS units.
  - Check battery to ensure it will take and retain a charge.
  - Ensure the solar panel is installed on the proper position to receive good exposure to direct sunlight.
  - Ensure the solar panel is outputting enough voltage to charge the battery.
  - Check the solar charger controller to ensure it regulates the voltage and current coming from the solar panel to the battery properly.

- Ensure the positive and negative cables of the solar panel and solar charger controller are connected correctly.
- Modem unit is not functioning properly:
  - Ensure that the modem is connected to a sufficient power supply.
  - Ensure that the modem is getting cellular signal (check the green light indicator).
  - Check the light indicators of the modem and ensure that they are bright green.

## **PORTABLE WIM MAINTENANCE**

In order to ensure all the portable WIM system can function properly after the deployment of the system, maintenance of portable WIM system components need to be performed regularly. TRS unit is the main core of the portable WIM system; therefore, TRS system needs to be checked regularly before and after deployment. Ensuring the TRS units to be fully charged is important because once TRS battery reaches zero capacity; the unit can no longer be charged; therefore, the old battery inside of the TRS unit needs to be replaced with a new 6-volt battery. In addition, 12-volt batteries used to power the TRS battery continuously during data collection need to be kept fully charged as well.

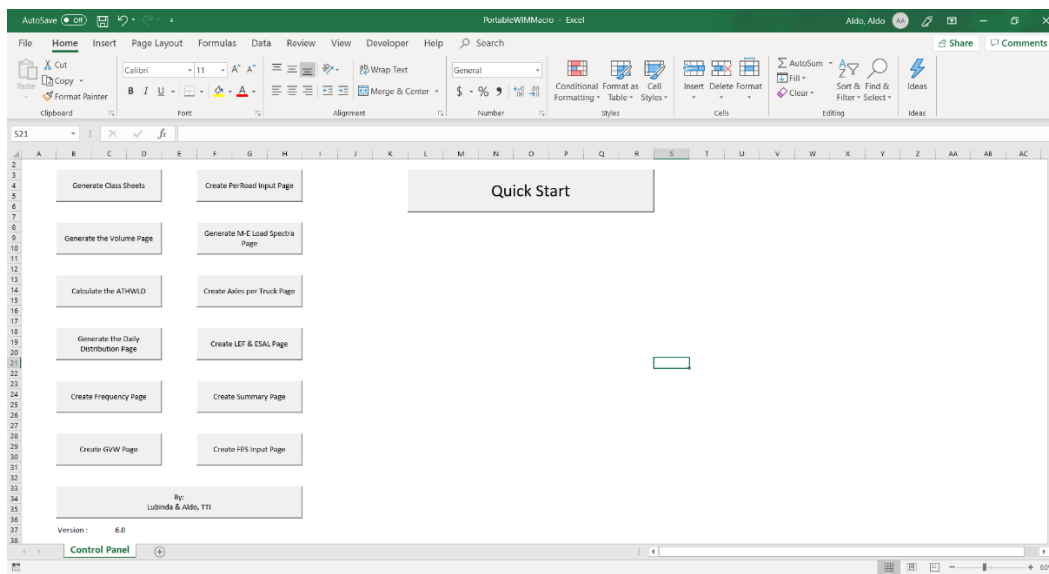
Once the portable WIM system is installed on the site, it is recommended to perform routine maintenance by going to the site and checking the TRS unit, the sensors, and the mastic tapes every day or two days. When performing routine maintenance, it is important to perform quality control on the mastic tapes applied on the pavement, whether they remain intact. If some parts of the tapes get worn out, applying more road tape is necessary. The TRS unit should also be still fully charged, recording data (REC indicator can be seen on the TRS unit display), and capturing the appropriate traffic data (Select Monitor from the Main Menu).

When a modem unit is installed, data retrieval can be done remotely using the Road Reporter II software as explained previously. However, the data can also be retrieved manually on the TRS unit using USB flash drive.



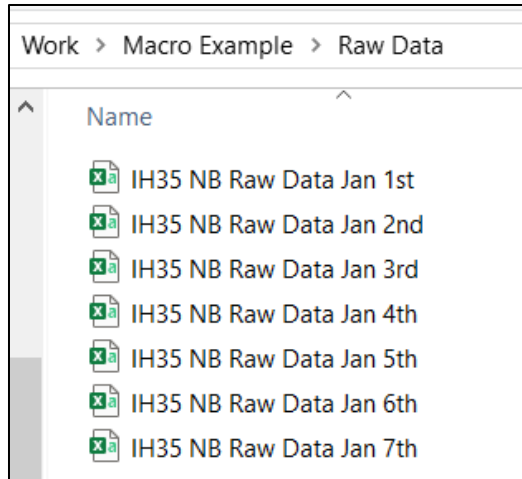
## SECTION VII. PORTABLE WIM TRAFFIC DATA PROCESSING AND ANALYSIS

The portable WIM macro is a Microsoft Excel (.xlsm) file that is used to analyze the raw data that has been retrieved and exported from the TRS Unit. The portable WIM macro is managed in MS Excel VBA platform as MS Excel is able to support various computing methodologies required for the data analysis and is compatible with most computer machines. Essentially, the macro requires the raw data from the TRS unit to generate Mechanistic-Empirical (M-E) compatible traffic data. The purpose of the Portable WIM Macro is to generate M-E compatible traffic data for pavement design from the raw data obtained through WIM. Figure 61 shows the main screen of the portable WIM macro.

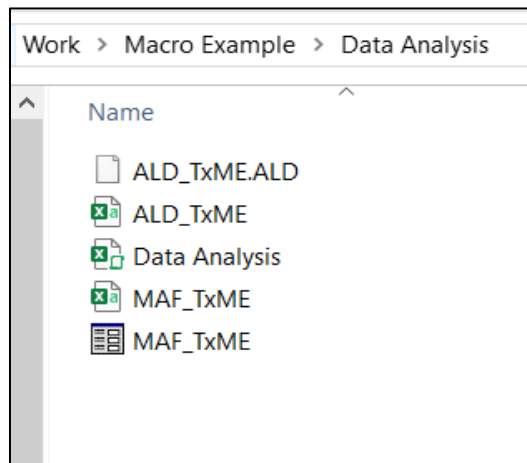


**Figure 61. Portable WIM Macro Main Screen.**

There are several buttons on the main screen of the program. The left side of the screen shows several options with different functions. These options allow more specific and customized data analysis if the user desires to do so. The right side of the screen shows an option labeled Quick Start, which allows user to do the complete data analysis process. Generally, it is recommended for users to select the Quick Start option since all data (e.g., volume, speed, weight, classification) can be generated in one single process. Additionally, user can also generate specific desired outputs from one of the 12 buttons on the left side of the control panel. Figure 62 shows an example of exported raw data files that serves as an input to the macro, while Figure 63 shows an example of the output files generated by the portable WIM macro.



**Figure 62. The Raw Data of IH 35 Highway Exported from the TRS Unit.**



**Figure 63. Output Data Generated by the Portable WIM Macro.**

During the data analysis process, the program will ask the user for several additional information about the current highway that is being analyzed. The user can always follow the default values if unsure. These are the questions asked by the portable WIM macro during the data analysis process:

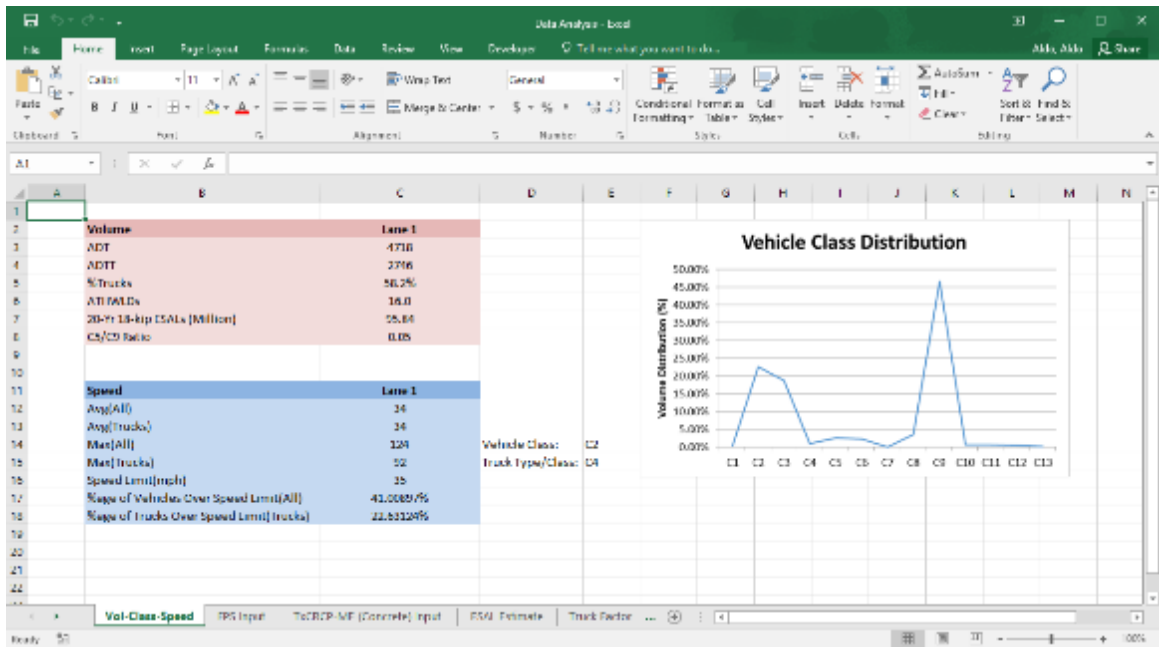
1. **Would you like to generate the ALD and MAF Files?** – If demanded, the macro can generate Axle Load Distribution (ALD) and Monthly Adjustment Factor (MAF) files needed for TxME input. Select No if you do not wish to generate the files or are not sure of the files.
2. **Are you analyzing both directions of the highway?** – Select Yes if you are going to pick both directions of the highway as the raw data input of the macro.
3. **How many lanes are there per direction of the site?**
4. **Pick or Create a folder that we can use to save the data analysis files** – Pick the folder where the output files of the macro should be saved.

5. **Pick the raw data files that we wish to analyze** – The input can be a single file or multiple files.
6. **(If prompted) It seems that the file contains multiple lanes, do you want to analyze all of the lanes?** – This is an added feature for users who has multiple lanes in one direction and wish to analyze only several of the lanes.
7. **Please enter the TRS Unit Error Safety Factor** – Users can also set the unit error safety factor value, if unsure, users can input 1.0 which is the default value.
8. **Please enter the speed limit of the road.**
9. **Please enter the annual growth rate for the road** – Default value is 3.0.
10. **Please locate the FHWA Vehicle Classification picture to insert to this sheet** – As an additional feature, the macro allows users to insert a FHWA Vehicle Classification Image. If user doesn't have the image, user can click on No.

With these inputs, the macro would be able to execute the data analysis process automatically. Once the process has finished, user can check the folder specified on question #4 to find the data analysis file, MAF files, and ALD files (assuming user selected Yes on question #1).

The data analysis file is in .xlsm format, and this file contains all the M-E compatible traffic data of the analyzed highway. The data analysis file consists of several worksheets containing the data results and calculations. Some of the featured worksheets are described as follow:

- **Vol-Class-Speed** – Summary sheet of the report, which contains the volume traffic data (ADT, ADTT, % Trucks, etc.), vehicle class distribution graph, and speed data.
- **FPS Input** – Contains input values necessary for the FPS Software.
- **TxCRCP-ME Input** – Contains input values necessary for TxCRCP-ME.
- **Truck Factor** – Shows the Truck Factor value of the highway based on both Flexible and Concrete ESAL calculation.
- **Volume** – Shows a deeper look at the traffic data of the highway such as daily traffic and daily class distribution.
- **Hourly Distribution** – Shows the average distribution of vehicles and trucks for each hour.
- **Daily Distribution** – Shows the average distribution of vehicles and trucks for each day.
- **Truck Overweight Statistics** – Contains statistics on the overweight trucks such as % Overweight Trucks, Max Overweight recorded, Average Hourly Overweight trucks, etc.



**Figure 64. Vol-Class-Speed Sheet from the Data Analysis File.**

Figure 64 shows an example of the data analysis file specifically on the Vol-Class-Speed worksheet. There are other worksheets that are present on the data analysis file:

- ATHWLD – Shows the details of the average ten heaviest wheel loads daily.
- Weight Summary – Explain weight distributions of various classes and axles.
- GVW- Shows statistics and analysis of the GVWs of all the classes.
- Load Spectra (M-E Input) - Shows load spectra calculations of truck-only vehicles (class 4 and above).
- Per Road Input – Shows inputs about each road.
- Axles per Truck – Shows axles per truck information which is required for M-E Design.
- Axle-Weight Distribution – Shows all the distribution of all the axle weights including single, steering, tandem, tridem and quad axle.
- Concrete Data – Shows all the details about the concrete pavement design
- Hourly Volume – Shows all hourly volume statistics.

These worksheets generate values that are already summarized on the featured worksheets (Vol-Class-Speed worksheet, FPS Input worksheet, etc.) and can also be used for backend calculation.

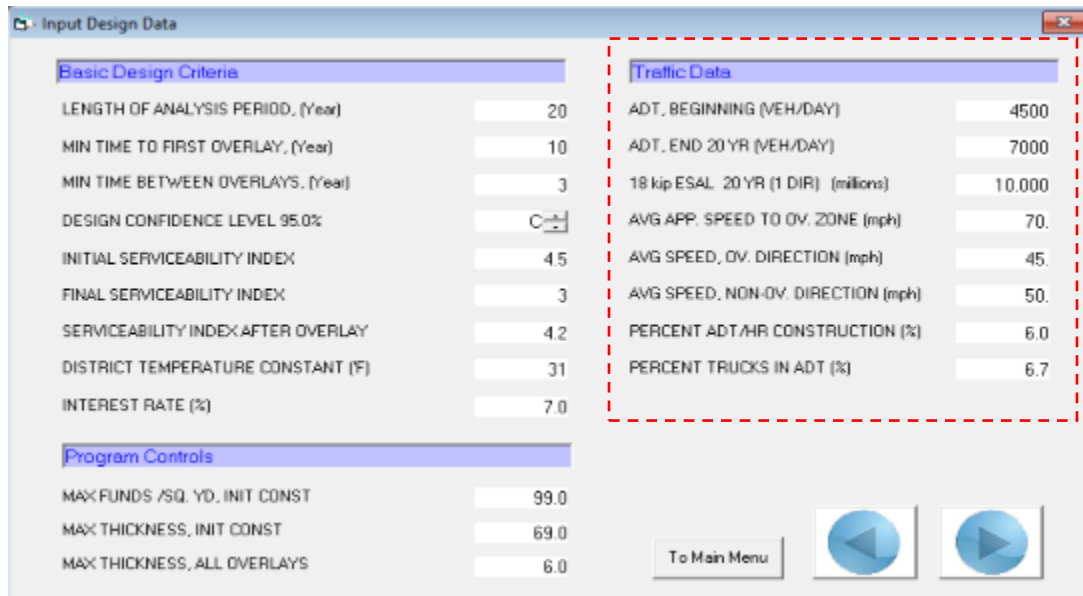
## SECTION VIII. GENERATION OF FPS AND M-E TRAFFIC INPUT PARAMETERS

### FPS TRAFFIC INPUT DATA

FPS is the primary software that is routinely used by TxDOT for the design of flexible pavements. Figure 65 and Figure 66 show the main FPS21 and traffic-data input screens, respectively. As shown from Figure 67, all the FPS21 traffic data inputs can be obtained from the output of portable WIM macro.



**Figure 65. Main FPS Screen.**



**Figure 66. FPS Traffic-Data Input Screen.**

	Value	Comment
Design Life (Years)	20	Can be changed as desired (typical = 20 years)
Annual Growth Rate (%)	3.0	Can be changed as desired (typical range = 2.5 to 5.0%)

FPS Input Parameters		
Parameter	Value	Comment
ADT-Beginning	8565	ADT (Both directions) at the beginning of the design period
ADT-END	20 Yrs 15470	ADT (Both directions) at the end of the design period
18 kip ESALs (million)	20 Yrs 5.41	Design lane ESALs
Avg. vehicle speed (mph)	64.14	Approach speed assumed to be equal to operational speed
% trucks in ADT	11.1%	

ATHWLD	10.25 Kips
% Tandem Axles	36.53%

**Figure 67. FPS Traffic Inputs Obtained from the Portable WIM Macro.**

### TXCRCP-ME AND CONCRETE TRAFFIC INPUT DATA

TxCRCP-ME, an algorithm in Microsoft Excel macro format, is one of the commonly used routine methods by TxDOT for designing concrete pavements. As shown in Figure 68, the key required traffic input parameters are the number of lanes and the 30-year 18-kip ESALs in one direction. As listed in, these two parameters can be obtained from the output of portable WIM macro (Figure 69).

CRCP DESIGN PROGRAM BASED ON MECHANISTIC-EMPIRICAL PRINCIPLES			
Developed under TxDOT Research Project 0-5832			
Version: <u>TxCRCP-ME v07b</u>			
<b>A. Project Identification</b>		<b>D. Concrete Layer Information</b>	
District		Thickness of Concrete Layer (in.)	
County		28-Day Modulus of Rupture (psi)	570
Highway			
CSJ		<b>E. Support Layers Information</b>	
Direction		Soil Classification System	USCS
Station (Begin)		Soil Classification of Subgrade	
Station (End)		Base Type	CTB
		Base Thickness (in.)	6
		Modulus of Base Layer (ksi)	
<b>B. Design Parameters</b>		Composite K (psi/in.)	0
Design Life (year)	30		
Number of Punchouts per Mile	10		
<b>C. Design Traffic</b>			
Total Number of Lanes in One Direction			
Total Design Traffic in One Direction (million ESALs)			
<input type="button" value="Input"/> <input type="button" value="Temperature"/> <input type="button" value="Soil Classification"/> <input type="button" value="K-Table"/> <input type="button" value="Composite K"/> <input type="button" value="S-Table"/> <input type="button" value="Stress"/> <input type="button" value="Analysis Result"/> <input type="button" value="Final Result"/> <input type="button" value="Time vs. Punchout"/>			

**Figure 68. Main MS Excel Worksheet for the TxCRCP-ME.**

TxCRCP-ME Input Parameters	Value	Comment
Design Life (Years)	30	Can be changed as desired (typical = 30 years)
Annual Growth Rate (%)	3.0	Can be changed as desired (typical range = 2.5 to 5.0%)
Assumed concrete slab thickness in Inches (t)	8.0	Can be changed as desired
Number of Lanes in one direction	1	
18 kip ESALs (million)	30 Yrs 12.18	Design Lane ESALs

**Figure 69. TxCRCP-ME Traffic Inputs Obtained from the Portable WIM Macro.**

## TXME TRAFFIC INPUT DATA

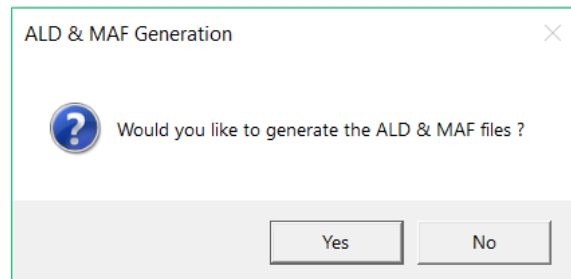
TxME is an M-E based software used for the design, structural analysis, and performance predictions of flexible pavements. When using the TxME software, the user needs to input the ALD and MAF files on the Level 1: Load Spectra section (See Figure 70).

Section	Parameter	Value
General Traffic Information	Annual Average Daily Truck Traffic (Two-Way AADTT):	500
	Percent in Design Direction (%):	50
	Percent in Design Lane (%):	95.0
	Operational Speed (mph):	60
Axle Configuration	Axle Tire	
	Single Tire Pressure (psi):	100
	Dual Tire Pressure (psi):	100
	Dual Tire Spacing (in):	12
	Axle spacing	
	Tandem Axle (in):	51.6
Tridem Axle (in):	49.2	
Quad Axle (in):	49.2	

**Figure 70. Level 1: Load Spectra Input on TxME Software.**

Inputting these values to the software is an extensive process. However, the portable WIM macro can generate the input files automatically. The user can then directly export both the ALD and MAF files to the TxME software by selecting the Monthly Adjustment and ALD option in the Level 1: Load Spectra screen menu.

To generate the MAF and ALD files, the user can simply run the data analysis process using the portable WIM macro and select Yes when prompted to generate MAF and ALD files (See Figure 71). The output files are found in the selected destination folder (See Figure 63).



**Figure 71. Generating the ALF and MAF Files.**

The portable WIM macro generates two file versions, .csv and .maf for the MAF input and .csv and .ald for the ALD input. Generating the .csv file provides an easy access for the user to see the values using a Microsoft Excel. Whereas both .maf and .ald file are used as an input for the TxME software. Despite having different versions, both files contain the same values.



## SECTION IX. THE MS ACCESS TRAFFIC DATA STORAGE SYSTEM(T-DSS)

In practice, the Microsoft Access is a platform, which enables the management and exploitation of large size database. Various traffic data were collected, processed, and analyzed to generate useful inputs values for pavement design. The outcomes were synthetized and stored as a Microsoft Access database. The Access format developed for this traffic database grants access to data and files as it provides a relational database management interface. Furthermore, the Microsoft Access provides the option of exporting filtered or partial data as directly usable MS supported format (e.g., Microsoft Word®, Excel®, portable document format, etc.).

### STRUCTURE OF T-DSS

The Microsoft Access is a user-friendly interface for database management and is therefore, considered as a platform for the T-DSS. The Microsoft Access is in general available on most computers as par the Microsoft package available on most computers. Hence, the T-DSS is a convenient data management system which will assist Texas Department of Transportation (TxDOT) engineers and general stakeholders to easily access traffic analysis results of highways across the State of Texas. Figure 72 presents the main menu of the T-DSS.

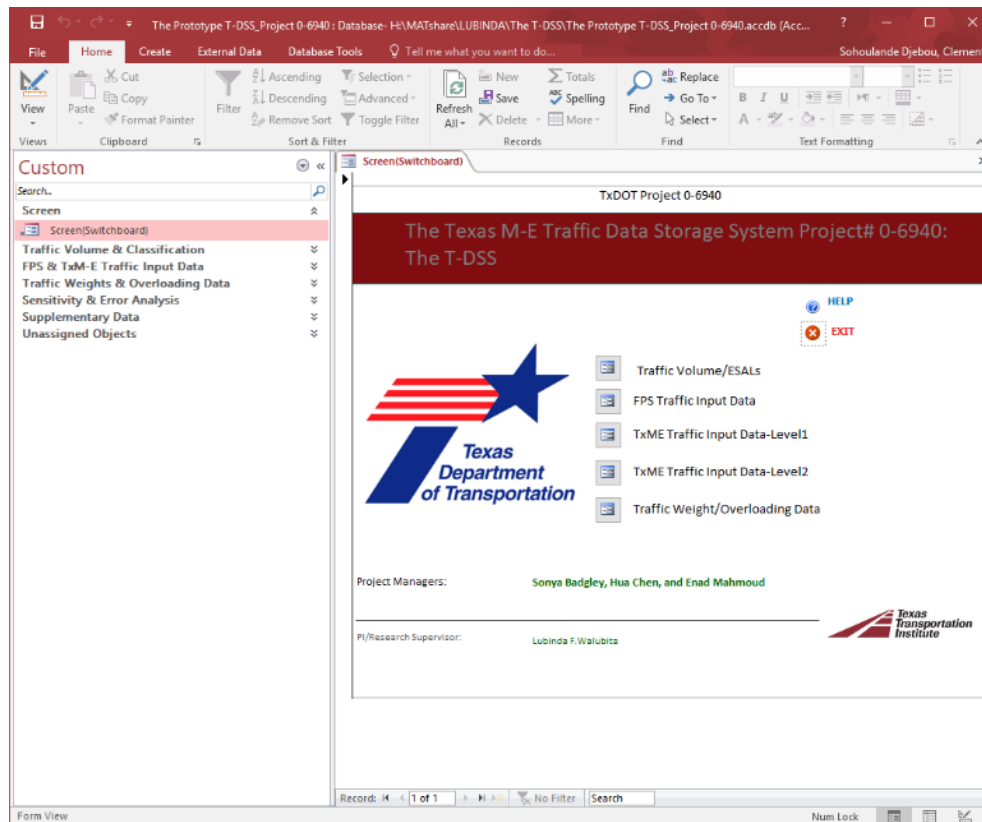


Figure 72. The T-DSS Main Screen.

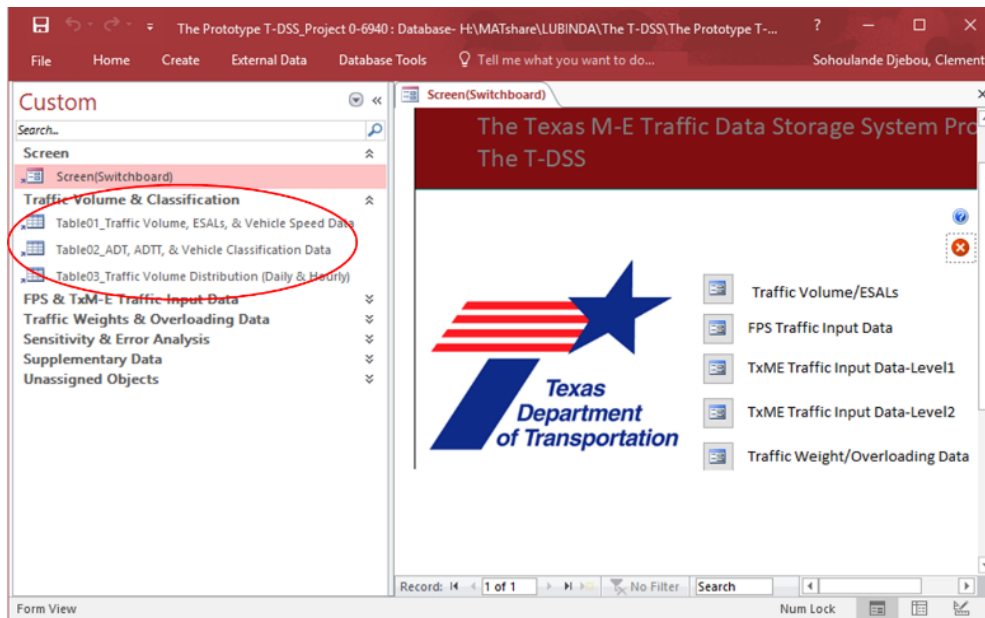
The actual version of T-DSS is structured in six groups as showed in Figure 72. Outcomes of the traffic data analyses are synthesized and organized under these groups. Each group is an interface containing a number of tables and total 30 tables are set under the groups. The structuration of the T-DSS enables interrelations between the groups which data can be easily populated upon users' quests. The data constituting the T-DSS include the following:

- Traffic volume and vehicle classification parameters
- FPS and ME traffic inputs
- Input parameters for TxM-E, M-E PDG, AASHTOWare, TxACOL, and TxCrackPro
- Axle load distribution
- Overweigh traffic statistics
- Cumulative 20-year 18-kip Equivalent single axle loads (ESALs) for flexible pavements and 30-year 18-kip ESALs for concrete pavements

The T-DSS is a collection of traffic parameters, ready to use for pavement design and transportation planning.

### TRAFFIC VOLUME AND CLASSIFICATION

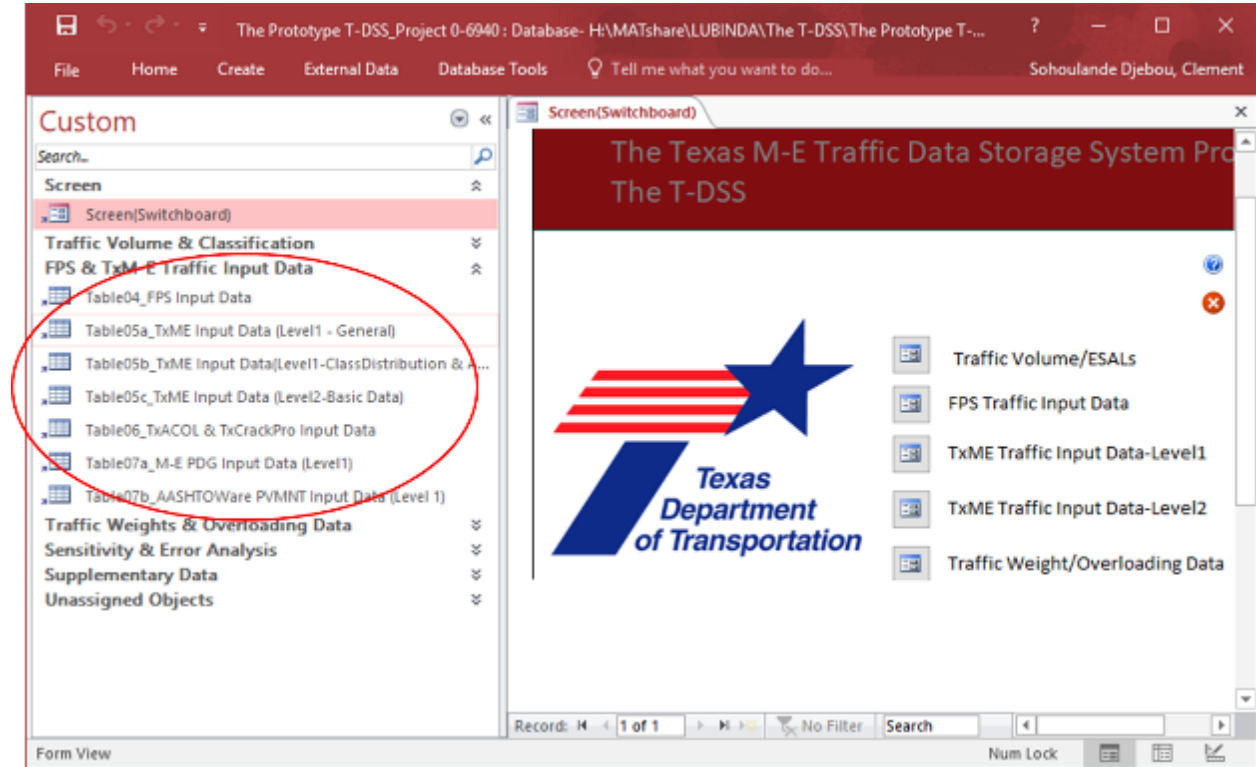
As shown in Figure 73, the group of traffic volume and classification contains three tables, namely, Table 01, 02 and 03. The Table 01 contains traffic volume data, estimated ESALs values, and statistics on vehicle speed. The Table 02 contains the traffic volume parameters including average daily traffic (ADT), average daily truck traffic (ADTT), vehicle classification (i.e. percentage of each class of vehicle/truck in the ADT and ADTT). Table 03 contains detailed data of hourly and daily traffic volume distribution. The hourly volume is reported as percentages of ADT corresponding to the different hours of the day (i.e. 00 am through 11:59 pm). The daily distribution is reported as the average absolute value of daily traffic corresponding to each day of week (i.e. Monday through Sunday).



**Figure 73. The Traffic Volume and Classification Interface.**

## FPS AND TXME TRAFFIC INPUT DATA

Figure 74 presents a screenshot of the FPS and TxME input data group. The interface is made of seven different tables, namely Tables 04, 05a, 05b, 05c, 06, 07a and 07b.



**Figure 74. FPS and TxME Traffic Input Data Interface.**

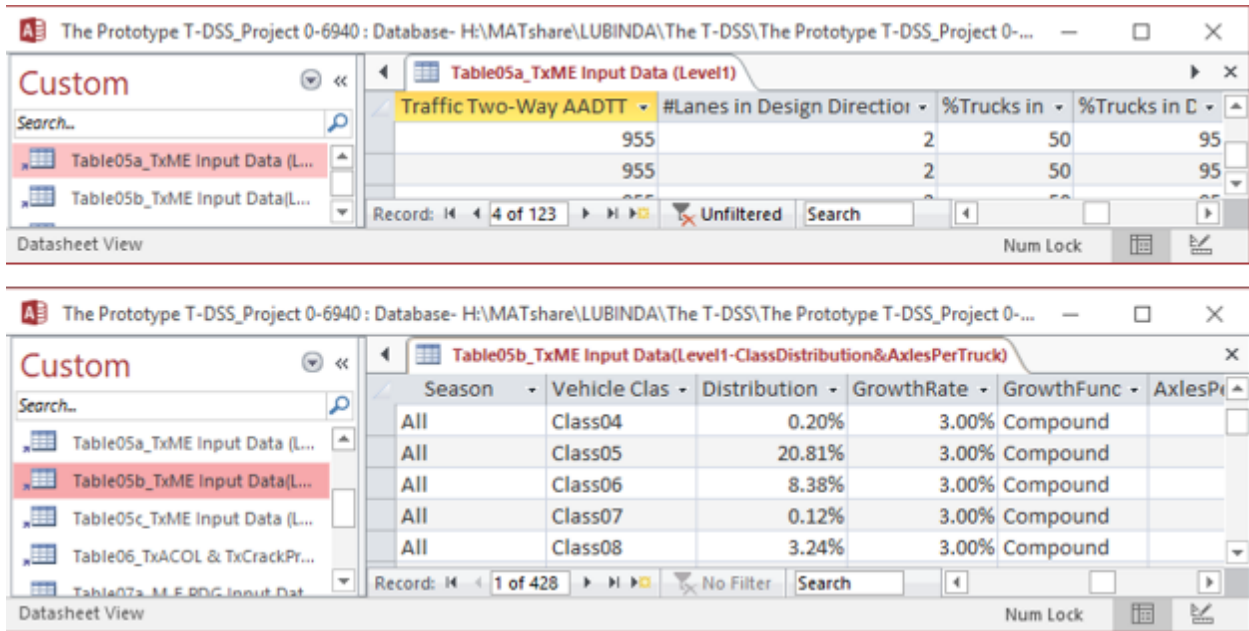
As shown in Figure 75, Table 04 recaps the FPS input data which include the computed ADT, the projected 20-year ADT, the 20-year cumulative 18 kips ESALs, the average speed, the percentage truck in ADT, the average tenth highest wheel load (ATHWLD), and the percentage of tandem axles.

ADTbegin	ADTend-20Y	20Yr 18-kips	Avg Vehicle Speed (mpl)	%Trucks in ADT	ATHWLD (kips)	ATHALD (kip)	%age Tande
3520	6357	8.31	60.2	37.40%	11.69	23.39	
3506	6332	8.89	61.7	37.40%			1
6113	23001	39.08	65.0	47.00%	14.34	28.68	55.50%
2699	10155	5.49	65.0	13.00%	11.78	23.56	51.06%
6213	23377	40.11	65.0	51.00%	12.25	24.50	57.91%

**Figure 75. FPS Input Data in the T-DSS.**

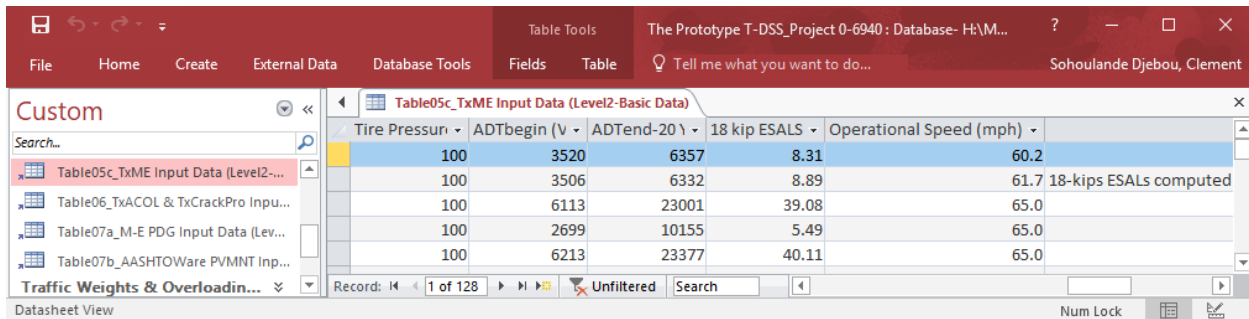
Table 05a summarizes the TxME input data (Level 1) which include the computed two-way Average annual daily truck traffic (AADTT), the number of lanes in the design direction, the percentage of trucks in the design direction, and the percentage of trucks in the design lane. The remaining TxME input data (Level 1) are summarized in the Table 05b which contains data on

vehicle class distribution, traffic growth rate, and average single, tandem, tridem, quad axles per truck. Figure 76 illustrates Tables 05a and 05b including the traffic data required for the TxME.



**Figure 76. TxME Input Data (Level 1 data) in the T-DSS.**

As displayed in Figure 77, the Table 05c is structured for compiling Level 2 TxME Input data computed for the different highway sections. Each highway section corresponds to a location where a permanent or portable WIM system is installed for traffic data collection. These data include the standard tire pressure value, the ADT at beginning, the projected 20-year ADT, the 20-year cumulative 18 kips ESALS, and the operational speed for each highway section.



**Figure 77. TxME Input Data (Level 2 data) in the T-DSS.**

Table 06 contains the input traffic parameter needed for TxACOL and TxCrackPro. As shown by Figure 78, these traffic parameters include the ADT at beginning, the projected 20-year ADT, the 20-year cumulative 18 kips ESALS and the operational speed associated with the highway.

Season	ADTbegin	ADTend-20Yr	20Yr 18-kips ESALs (million)	Operational Speed (mph)
Fall	3520	6357	8.31	60.2
Fall	3506	6332	8.89	61.7
All	6113	23001	39.08	65.0
All	2699	10155	5.49	65.0
All	6213	23377	40.11	65.0

**Figure 78. TxACOL and TxCrackPro Input Data in the T-DSS.**

As indicated in Figure 79, Tables 07a and 07b report the input needed for AASHTOWare Pavement design software, respectively. These inputs are essentially the monthly adjustment factors (MAF) and the axle load distribution (ALD) files. The MAF and ALD files are uploaded in the appropriate format in the corresponding tables.

The top screenshot shows the following data for Table07\_M-E PDG Input Data (Level 1):

Month#	Analysis Period (Days)	Season	Comment
November	14	Fall	1st attachment = MAF; 2nd attachment = ALD
January - December	224	All	1st attachment = MAF; 2nd attachment = ALD
January - December	224	All	1st attachment = MAF; 2nd attachment = ALD

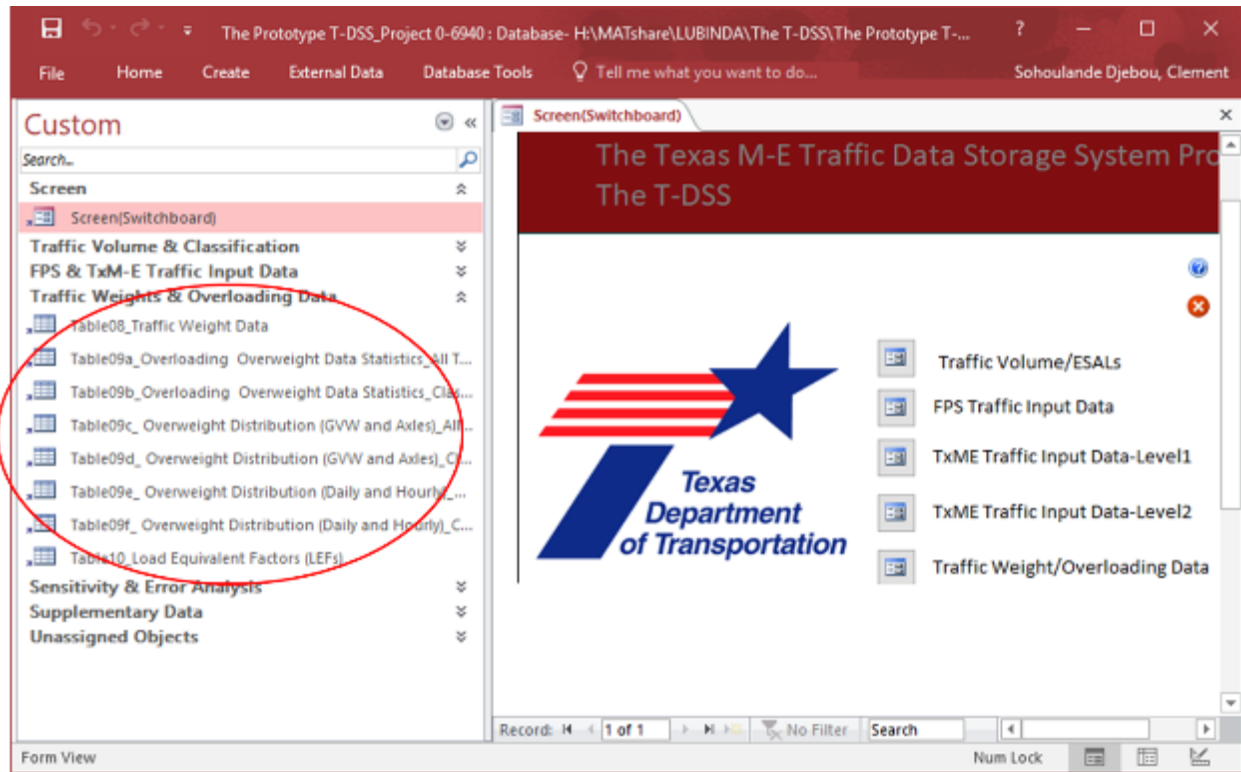
The bottom screenshot shows the following data for Table07b\_AASHTOWare PVMNT Input Data (Level 1):

Month#	Analysis Period (Days)	Season	Comment
November	14	Fall	1st attachment = MAF; 2nd attachment = ALD
January - December	224	All	1st attachment = MAF; 2nd attachment = ALD
January - December	224	All	1st attachment = MAF; 2nd attachment = ALD

**Figure 79. AASHTOWare Input Data in the T-DSS.**

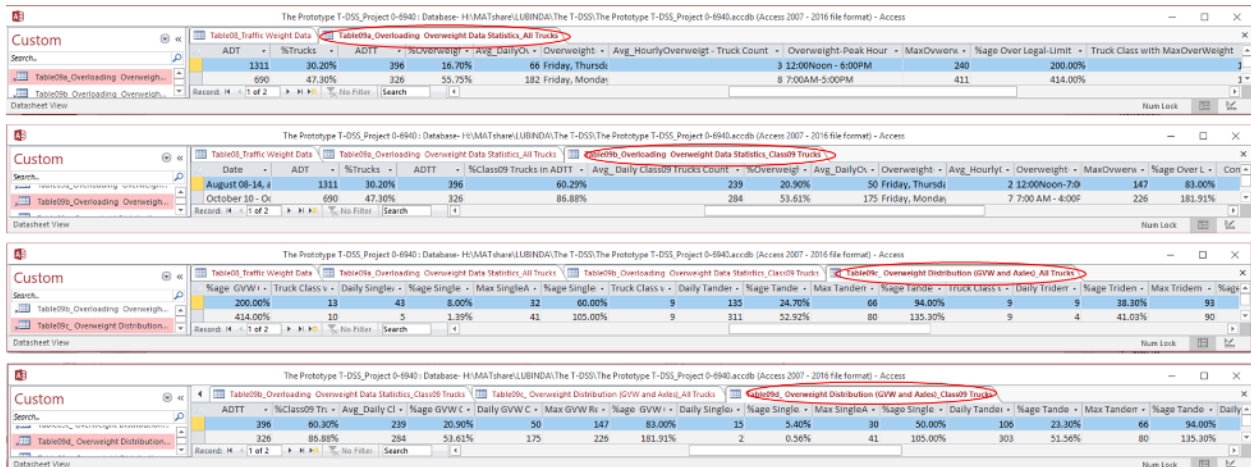
## TRAFFIC WEIGHTS AND OVERLOADING DATA

Figure 80 presents the traffic weights and overloading data interface as it is in the T-DSS. This interface contains eight different tables including Tables 08, 09a, 09b, 09c, 09d, 09e, 09f and 10. These tables summarize different levels of traffic load spectra analyses.



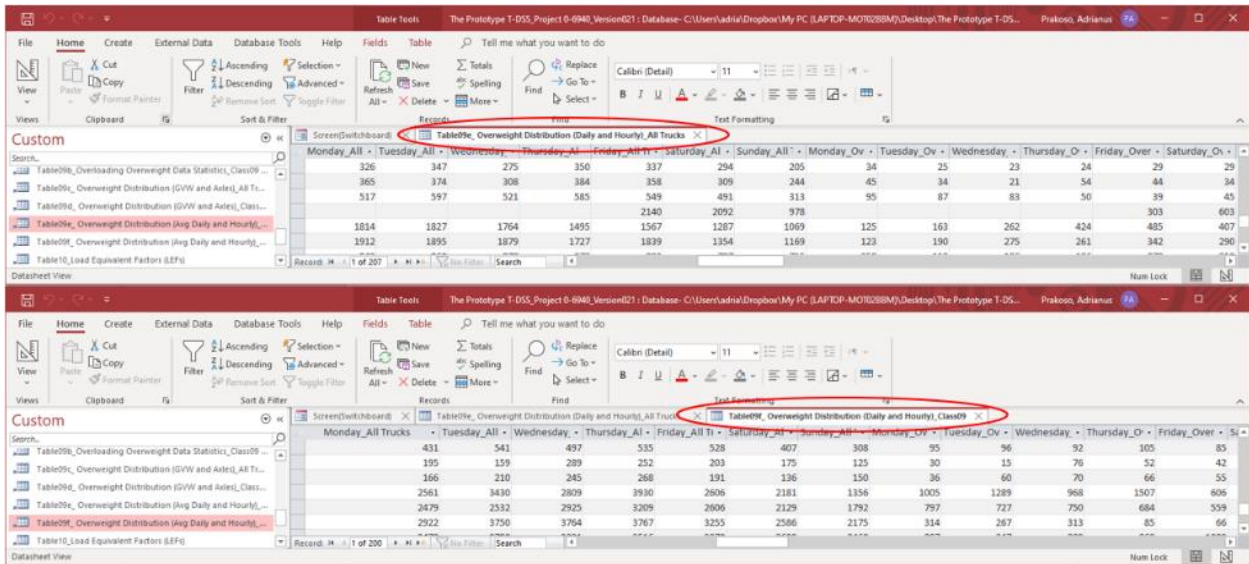
**Figure 80. Traffic Weights and Overloading Data Interface.**

In the T-DSS, Table 08 summarizes the general location data of the highway sections. Tables 9a, 9b, 9c and 9d summarize different types of overload statistics. As shown by Figure 81, these overload statistics include the gross vehicles weight (GVW), daily overload count, single axle overload statistics, tandem overload statistics, tridem overload statistics, and quad overload statistics.



**Figure 81. Interface of Overweight Analysis in the T-DSS.**

Figure 82 presents the interface for daily and hourly overload statistics. It is noted that Table 09e reports the daily and hourly overload statistics for all trucks while Table 09f reports the statistics only for class 9 truck that is the most represented truck on all the highways analyzed.



**Figure 82. Interface of Daily and Hourly Overweight Analysis in the T-DSS.**

## SECTION X. DEMONSTRATION CASE STUDIES

### PORTABLE WIM INSTALLATION ON FM 281, AMARILLO DISTRICT

As shown in Figure 83, portable WIM system was deployed for each direction on a single lane highway. Since there was no wide shoulder on the site location, 6-ft polymer piezo sensors were used in this case. Modem systems for both directions were installed as well to enable users to access real-time portable WIM traffic data, monitor the functionality of the deployed portable WIM system, and retrieve the traffic data remotely. Figure 84 shows the portable WIM installation layout used in FM 281, Amarillo District. Pavement surface was flat without any distress and far from any intersections; therefore, the site location was ideal for portable WIM installation. In addition, the installation was performed during summer season and the temperature was above 55°F; therefore, torch kit was not used to heat up the tapes and the pavement surface and there were no additional road tape strips applied on the center of the sensors.

In order for the system to collect complete weekly data, the portable WIM system was deployed for 7 days. After 7-day data was obtained, the raw data was retrieved from the TRS unit and converted to excel files using Road Reporter II software. Then, the excel raw data was processed using portable WIM macro in order to generate M-E compatible traffic data output for pavement design. Figure 85 and Figure 86 show a general traffic results and FPS inputs from portable WIM macro output, respectively.



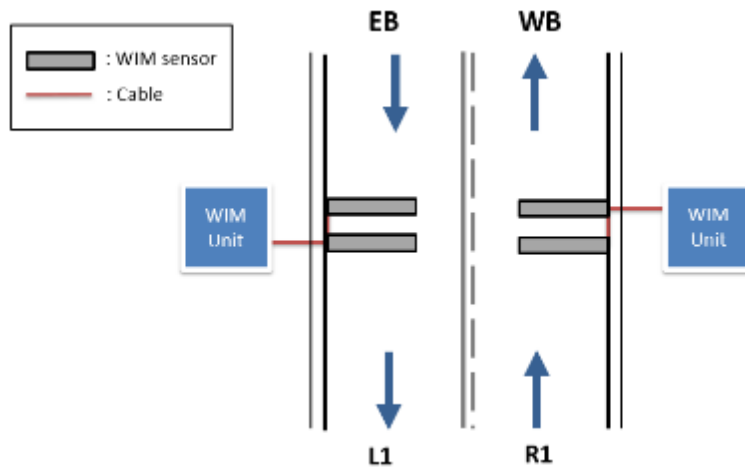
(a)





(b)

**Figure 83. Portable WIM Installation on FM 281, Amarillo District: (a) Eastbound Lane and (b) Westbound Lane.**

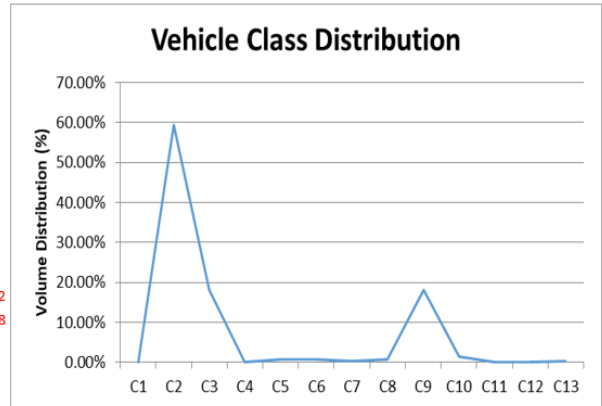


**Figure 84. Portable WIM Installation Layout Used on FM 281, Amarillo District.**

Volume	FM 281 EB Lane
ADT	1316
ADTT	296
%Trucks	22.5%
ATHWLDs	12.2
20-Yr 18-kip ESALs (Million)	4.52
TF	1.49
C5/C9 Ratio	0.04

Speed	FM 281 EB Lane
Avg(All)	64
Avg(Trucks)	62
Max(All)	91
Max(Trucks)	75
Speed Limit(mph)	70
%age of Vehicles Over Speed Limit(All)	4.26664%
%age of Trucks Over Speed Limit(Trucks)	0.37998%

Vehicle Class: C2  
Truck Type/Class: C8

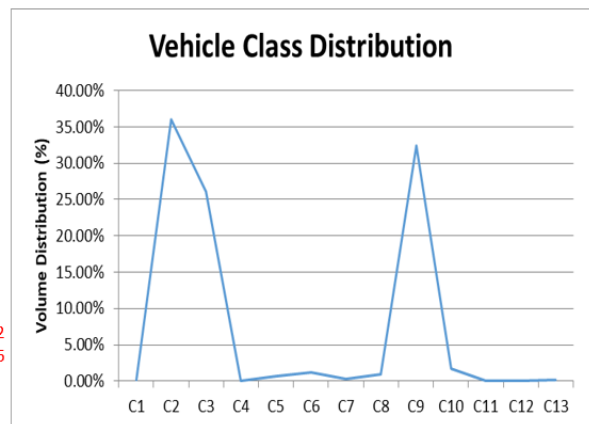


(a)

Volume	FM 281 WB Lane
ADT	923
ADTT	347
%Trucks	37.6%
ATHWLDs	13.2
20-Yr 18-kip ESALs (Million)	7.97
TF	1.78
C5/C9 Ratio	0.02

Speed	FM 281 WB Lane
Avg(All)	60
Avg(Trucks)	56
Max(All)	92
Max(Trucks)	71
Speed Limit(mph)	70
%age of Vehicles Over Speed Limit(All)	5.99257%
%age of Trucks Over Speed Limit(Trucks)	0.13936%

Vehicle Class: C2  
Truck Type/Class: C6



(b)

**Figure 85. Example of Traffic Volume and Vehicle Speed Data from FM 281, Amarillo District: (a) Eastbound Lane and (b) Westbound Lane.**

Design Life 20 Years  
Annual Growth Rate 3.00 %

**FPS Input Parameters**

Parameter	Value	Comment
ADT-Beginning	2238	ADT (Both directions) at the beginning of the design period
ADT-END 20 year	4043	ADT (Both directions) at the end of the design period
18-kip ESALs 20 Years (million)	4.52	Design lane ESAL
Avg. vehicle speed (mph)	63.51	Approach speed assumed to be equal to operational speed
% trucks in ADT	22.5%	
ATHWLD	12.15Kips	
% Tandem Axles	52.95%	

(a)

**FPS Input Parameters**

<i>Parameter</i>	<i>Value</i>	<i>Comment</i>
ADT-Beginning	2238 ADT	(Both directions) at the beginning of the design period
ADT-END 20 year	4043 ADT	(Both directions) at the end of the design period
18-kip ESALs 20 Years (million)	7.97	Design lane ESALs
Avg. vehicle speed (mph)	60.4	Approach speed assumed to be equal to operational speed
% trucks in ADT	37.6%	
ATHWLD	13.2Kips	
% Tandem Axles	53.6%	

(b)

**Figure 86. Example of FPS Inputs from FM 281, Amarillo District: (a) Eastbound Lane and (b) Westbound Lane.**

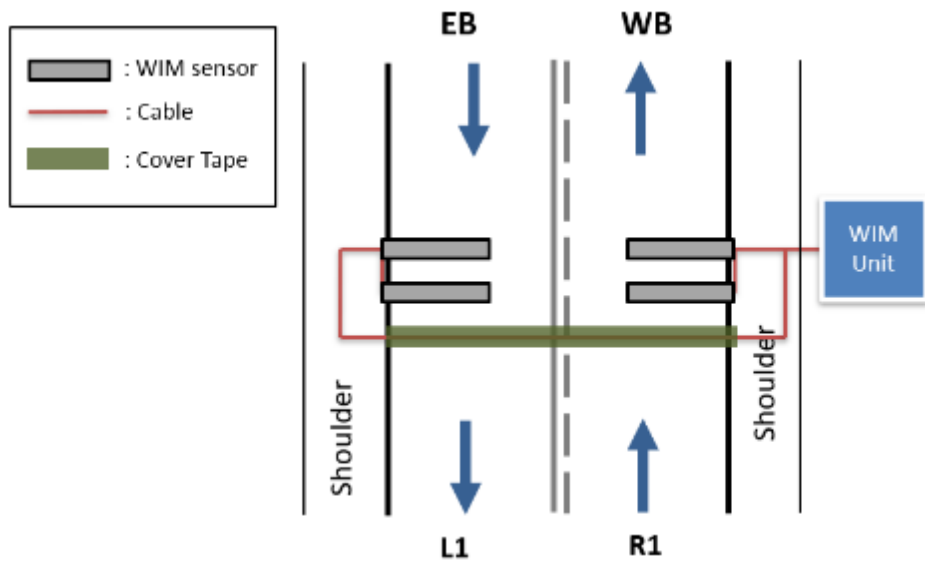
**PORTABLE WIM INSTALLATION ON US 190, BRYAN DISTRICT**

As shown in Figure 87, a set of polymer piezo sensors were installed on a single lane road for each direction and only a single portable WIM system was deployed to capture traffic data for both directions (TRS unit was located on eastbound direction). Figure 88 shows the portable WIM installation layout used on US 190, Bryan District. Since there were rumble strips located on the shoulder near outside lane, 6-ft polymer piezo sensors were used in this case. Using 8-ft sensors may cause a problem because placing 8-ft sensors will overlap the shoulders, reaching the rumble strip areas, and due to a gap between rumble strip and metal plate, water may enter the road tape and underneath the plates, causing moisture damage to the adhesive. Even though the installation was performed during summer season and the temperature was above 55°F, there was rutting with a very low severity level on the pavement surface where the sensors were going to be installed. Therefore, additional road tape strips were added on the center of the sensors for extra protection of the sensors being detached from the road. In addition, the site location was far from any intersections; therefore, the site location was ideal for portable WIM installation.

In order for the system to collect complete weekly data, the portable WIM system was deployed for 7 days. After 7-day data was obtained, the raw data was retrieved from the TRS unit and converted to excel files using Road Reporter II software. Then, the excel raw data was processed using portable WIM macro in order to generate M-E compatible traffic data output for pavement design. Figure 89 and Figure 90 show a general traffic results and FPS inputs from portable WIM macro output, respectively.



**Figure 87. Portable WIM Installation on US 190, Bryan District.**

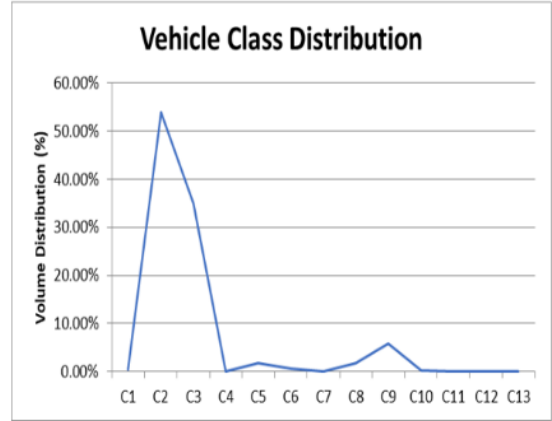


**Figure 88. Portable WIM Installation Layout Used on US 190, Bryan District.**

Volume	US 190 EB Lane
ADT	4245
ADTT	457
%Trucks	10.8%
ATHWLDs	10.4
20-Yr 18-kip ESALs (Million)	5.51
C5/C9 Ratio	0.32

Speed	US 190 EB Lane
Avg(All)	64
Avg(Trucks)	63
Max(All)	88
Max(Trucks)	88
Speed Limit(mph)	70
%age of Vehicles Over Speed Limit(All)	2.55%
%age of Trucks Over Speed Limit(Trucks)	0.04%

Vehicle Class: C2  
Truck Type/Class: C7

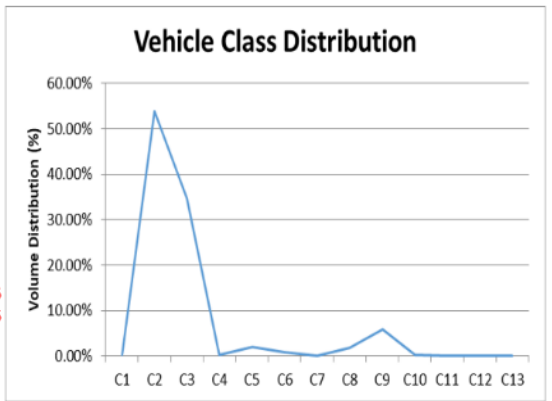


(a)

Volume	US 190 WB Lane
ADT	4320
ADTT	479
%Trucks	11.1%
ATHWLDs	10.2
20-Yr 18-kip ESALs (Million)	5.41
C5/C9 Ratio	0.35

Speed	US 190 WB Lane
Avg(All)	64
Avg(Trucks)	62
Max(All)	94
Max(Trucks)	94
Speed Limit(mph)	70
%age of Vehicles Over Speed Limit(All)	2.30%
%age of Trucks Over Speed Limit(Trucks)	0.04%

Vehicle Class: C5  
Truck Type/Class: C5



(b)

Figure 89. Example of Traffic Volume and Vehicle Speed Data from US 190, Bryan District: (a) Eastbound Lane and (b) Westbound Lane.

	Value	Comment
Design Life (Years)	20	Can be changed as desired (typical = 20 years)
Annual Growth Rate (%)	3.0	Can be changed as desired (typical range = 2.5 to 5.0%)

**FPS Input Parameters**

Parameter	Value	Comment
ADT-Beginning	8565	ADT (Both directions) at the beginning of the design period
ADT-END	20 Yrs 15469	ADT (Both directions) at the end of the design period
18 kip ESALs (million)	20 Yrs 5.51	Design lane ESALs
Avg. vehicle speed (mph)	64.26	Approach speed assumed to be equal to operational speed
% trucks in ADT	10.8%	

ATHWLD	10.35 Kips
% Tandem Axles	37.50%

(a)

	Value	Comment
Design Life (Years)	20	Can be changed as desired (typical = 20 years)
Annual Growth Rate (%)	3.0	Can be changed as desired (typical range = 2.5 to 5.0%)
<b>FPS Input Parameters</b>		
Parameter	Value	Comment
ADT-Beginning	8565	ADT (Both directions) at the beginning of the design period
ADT-END	20 Yrs 15470	ADT (Both directions) at the end of the design period
18 kip ESALs (million)	20 Yrs 5.41	Design lane ESALs
Avg. vehicle speed (mph)	64.14	Approach speed assumed to be equal to operational speed
% trucks in ADT	11.1%	
ATHWLD	10.25	Kips
% Tandem Axles	36.53%	

(b)

**Figure 90. Example of FPS Inputs from US 190, Bryan District: (a) Eastbound Lane and (b) Westbound Lane.**

### PORTABLE WIM INSTALLATION ON IH 35, AUSTIN DISTRICT

As shown in Figure 91, portable WIM system was deployed for each direction on a 3-lane highway. A set of 6-ft polymer piezo sensors were installed on outside lane and middle lane for each direction. Figure 92 shows the portable WIM installation layout used on IH 35, Austin District. Due to very high traffic volume on IH 35, portable WIM system installation was conducted during midnight (09:00 PM until 02:00 AM) on weekdays. Pavement surface was flat without any distress and far from any intersections; therefore, the site location was ideal for portable WIM installation. In addition, the installation was performed during fall season and the temperature was above 55°F; therefore, torch kit was not used to heat up the tapes and the pavement surface and there were no additional road tape strips applied on the center of the sensors.

In order for the system to collect complete weekly data, the portable WIM system was deployed for 7 days. After 7-day data was obtained, the raw data was retrieved from the TRS unit and converted to excel files using Road Reporter II software. Then, the excel raw data was processed using portable WIM macro in order to generate M-E compatible traffic data output for pavement design. Figure 93 and Figure 94 show a general traffic results and FPS inputs from portable WIM macro output, respectively.



(a)



(b)

**Figure 91. Portable WIM Installation on IH 35, Austin District: (a) Northbound Lane and (b) Southbound Lane.**

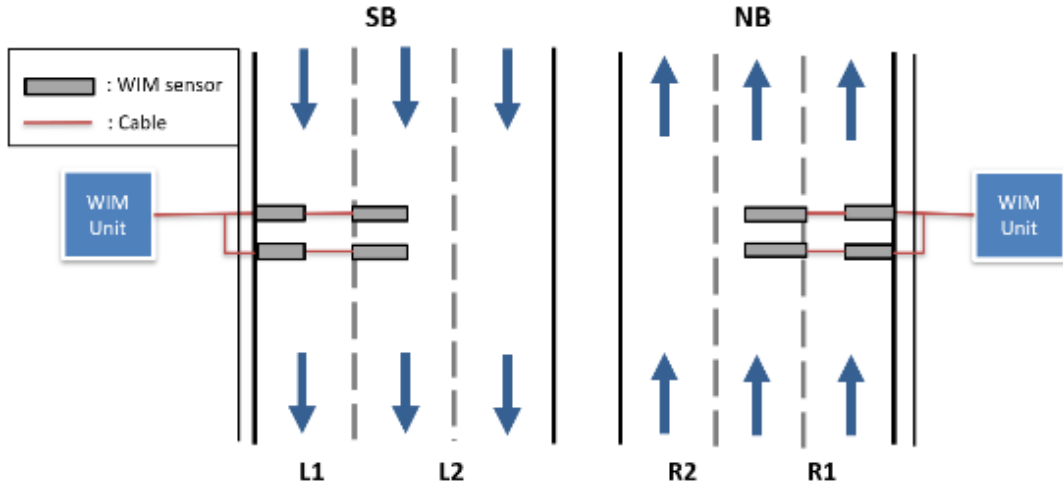
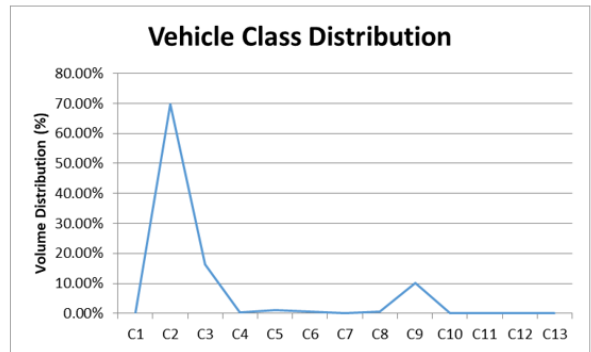


Figure 92. Portable WIM Installation Layout Used on IH 35, Austin District.

Volume	IH 35 NB Middle Lane (ML)
ADT	24530
ADTT	3361
%Trucks	13.7%
ATHWLDs	14.98
20-Yr 18-kip ESALs (Million)	50.89
C5/C9 Ratio	0.10

Speed	IH 35 NB Middle Lane (ML)
Avg(All)	60
Avg(Trucks)	58
Max(All)	99
Max(Trucks)	92
Speed Limit(mph)	70
%age of Vehicles Over Speed Limit(All)	0.55776%
%age of Trucks Over Speed Limit(Trucks)	0.01186%

Vehicle Class: C2  
Truck Type/Class: C5

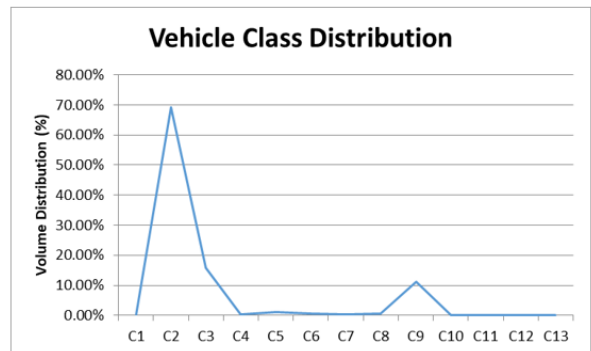


(a)

Volume	IH 35 SB Middle Lane (ML)
ADT	22594
ADTT	3335
%Trucks	14.8%
ATHWLDs	14.8
20-Yr 18-kip ESALs (Million)	47.91
C5/C9 Ratio	0.09

Speed	IH 35 SB Middle Lane (ML)
Avg(All)	59
Avg(Trucks)	58
Max(All)	89
Max(Trucks)	77
Speed Limit(mph)	70
%age of Vehicles Over Speed Limit(All)	0.68271%
%age of Trucks Over Speed Limit(Trucks)	0.01383%

Vehicle Class: C2  
Truck Type/Class: C5



(b)

Figure 93. Example of Traffic Volume and Vehicle Speed Data from IH 35, Bryan District:  
(a) Northbound Lane and (b) Southbound Lane.



	Value	Comment
Design Life (Years)	20	Can be changed as desired!
Annual Growth Rate (%)	2.50	Can be changed as desired!

FPS Input Parameters		Value	Comment
ADT-Beginning		147181	ADT (All lanes, both directions) at the beginning of the design period
ADT-END	20Yrs	241172	ADT (All lanes, both directions) at the end of the design period
18-kip ESALs (million)	20Yrs	50.89	Design lane MESALs (NB ML)
Avg. vehicle speed (mph)		59.66	Approach speed assumed to be equal to operational speed
% trucks in ADT		13.7%	

ATHWLD	14.98	Kips
% Tandem Axles	47.54%	

(a)

**Comment**

Design Life (Years)	20	Can be changed as desired (typical for TX flexible PVMNTs = 20 yrs)!
Annual Growth Rate (%)	2.50	Can be changed as desired (typical range = 2.5 ~ 5.0%)!

**FPS Input Parameters**

Parameter	Value	Comment
ADT-Beginning	141807	ADT (All lanes, both directions) at the beginning of the design period
ADT-END	20Yrs 232367	ADT (All lanes, both direction) at the end of the design period
18-kip ESALs (million)	20Yrs 47.91	Design lane ESALs (SB ML)
Avg. vehicle speed (mph)	59.29	Approach speed assumed to be equal to operational speed
% trucks in ADT	14.8%	

ATHWLD	14.76	Kips
% Tandem Axles	46.24%	

(b)

**Figure 94. Example of FPS Inputs from IH 35, Bryan District: (a) Northbound Lane and (b) Southbound Lane.**

