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Guides for System to Render M-E Traffic Data for Pavement Design: Student Guide

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Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE

COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
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GUIDES FOR SYSTEM TO RENDER M-E TRAFFIC DATA FOR PAVEMENT DESIGN

Student Guide

by

Lubinda F. Walubita
Research Scientist
Texas A&M Transportation Institute

Sang Ick Lee
Assistant Research Engineer
Texas A&M Transportation Institute

and

Aldo Aldo
Research Associate
Texas A&M Transportation Institute

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DISCLAIMER

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LIST OF SYMBOLS AND NOTATIONS

AADTT	Average annual daily truck traffic
ADT	Average daily traffic
ALD	Axle load spectra data
ALDF	Axle load distribution factor
ATHWLD	Average ten heaviest wheel loads daily
CRCP	Continuously reinforced concrete pavement
DC	Dry-cold
DW	Dry-wet
EB	Eastbound
HDF	Hourly distribution factor
ESAL	Equivalent single axle load
FPS	Flexible pavement system
Gr	Growth rate
GVW	Gross vehicle weight
LEF	Load equivalency factor
LS	Load spectra
M	Moderate
MAF	Monthly adjustment factor
M-E	Mechanistic empirical
NB	Northbound
OV	Overlay
OW	Overweight
PTT	Pneumatic traffic tube
SB	Southbound
T-DSS	Traffic data storage system
TP&P	Transportation planning and programming
TTI	Texas A&M Transportation Institute
TxACOL	Texas asphalt concrete overlay design
TxDOT	Texas Department of Transportation
TxME	Texas Mechanistic-Empirical pavement design
VCD	Vehicle classification distribution
WB	Westbound
WC	Wet-cold
WIM	Weigh-in-motion
WW	Wet-warm

SECTION I. INTRODUCTION

This guideline is to demonstrate and provide the key findings of Texas Department of Transportation (TxDOT) Project 0-6940 *Develop System to Render Mechanistic-Empirical Traffic Data for Pavement Design*. It can be used as a guide for rendering the traffic data required for FPS and mechanistic-empirical (ME) pavement designs for TxDOT engineers. This guide is to understand, mainly:

- Traffic data sources to obtain the applicable M-E traffic data
- Traffic data parameters calculated and generated using the collected traffic data such as traffic volume, speed, classification, and weight data
- Traffic data inputs required for pavement design (for FPS and ME design software)
- The traffic data storage system (The T-DSS) to store and provide ME-compatible traffic data support
- Data analysis macros to automatically analyze and generate the ME-compatible traffic data

SECTION II. TRAFFIC DATA SOURCES

In order to develop traffic data clusters, the traffic data should be assembled from available permanent traffic data collectors and supplemented with portable collectors from sites lacking permanent collector stations. Also, easy-to-obtain traffic data (e.g., pneumatic tube volume-classification data) were collected to aid in validating the clustering algorithms where needed and on selected highways.

TRAFFIC DATA PARAMETERS AND COLLECTORS

For the Project 0-6940, various types of traffic data were measured, collected, and assembled from three traffic data sources, namely: (a) permanent weigh-in-motion (WIM) stations, (b) portable WIM units, and (c) pneumatic traffic tube (PTT) counters. As indicated in Figure 1, the permanent and portable WIM systems provide the following minimum type of traffic data:

- Traffic volume counts
- Vehicle classification
- Vehicle speed
- Vehicle weights, i.e., gross vehicle weight (GVW)
- Axle load spectra data
- Number of axles
- Individual axle loads
- Axle spacing

a) Permanent WIM stations (2013-2016)

b) Portable WIM stations

c) Pneumatic traffic tube (PTT) counters

Traffic Data Type	Traffic Parameter	Permanent WIM	Portable WIM	Pneumatic Traffic Tube (PTT)Counters
Traffic Volume	Average Annual Daily Traffic (AADT)	✓	✓	✓
	Average Annual Daily Truck Traffic (AADTT)	✓	✓	✓
	Truck percentage	✓	✓	✓
	Axles per truck	✓	✓	
Classification	Vehicle Classification Distribution (VCD)	✓	✓	✓
Vehicle Speed	Vehicle speeds (mph)	✓	✓	✓
Adjustment Factors	Monthly Adjustment Factors (MAF)	✓		
	Hourly Distribution Factors (HDF)	✓	✓	✓
Growth Rate	Yearly Volume Growth Rate (Gr)	✓		
Weight	Gross Vehicle Weight (GVW)	✓	✓	
	Axle Load Distribution Factors (ALDF) or Axle Load Spectra (ALS)	✓	✓	

Figure 1 Type of Traffic Source and Collected Data.

In addition to the detailed per vehicle measurements, the WIM systems also provide traffic volume and vehicle classification data including the per hour number of vehicles for different vehicle classes. The permanent WIM data are obtained continuously during the year while the portable WIM data are obtained during the short-term deployment periods, which is at minimum seven consecutive days up to 1-year with routine periodic service maintenance. Unlike the WIM systems that also measures vehicle weights, pneumatic tube counters are installed to measure and collect only traffic volume counts, vehicle speed, axle spacing, and vehicle classification for at least 48-hours up to 7-days – but with no vehicle weight data.

TRAFFIC STATIONS AND HIGHWAY SITES

As mentioned above, the traffic data include permanent WIM, portable WIM, and pneumatic traffic tube counter data from a combined total of 59 stations/sites as presented in Figure 2. All the permanent WIM data were obtained from TxDOT's Transportation Planning and Programming (TP&P) division. The portable WIM data were measured and collected by Texas A&M Transportation Institute (TTI) through the short-term (minimum 7-days thru to 1-year) deployment of portable WIM units on selected highway sites around the State. Likewise, the pneumatic traffic tube data were also measured and collected by TTI through the short-term (minimum 48-hrs thru to 7-days) deployment of pneumatic traffic tube counters.

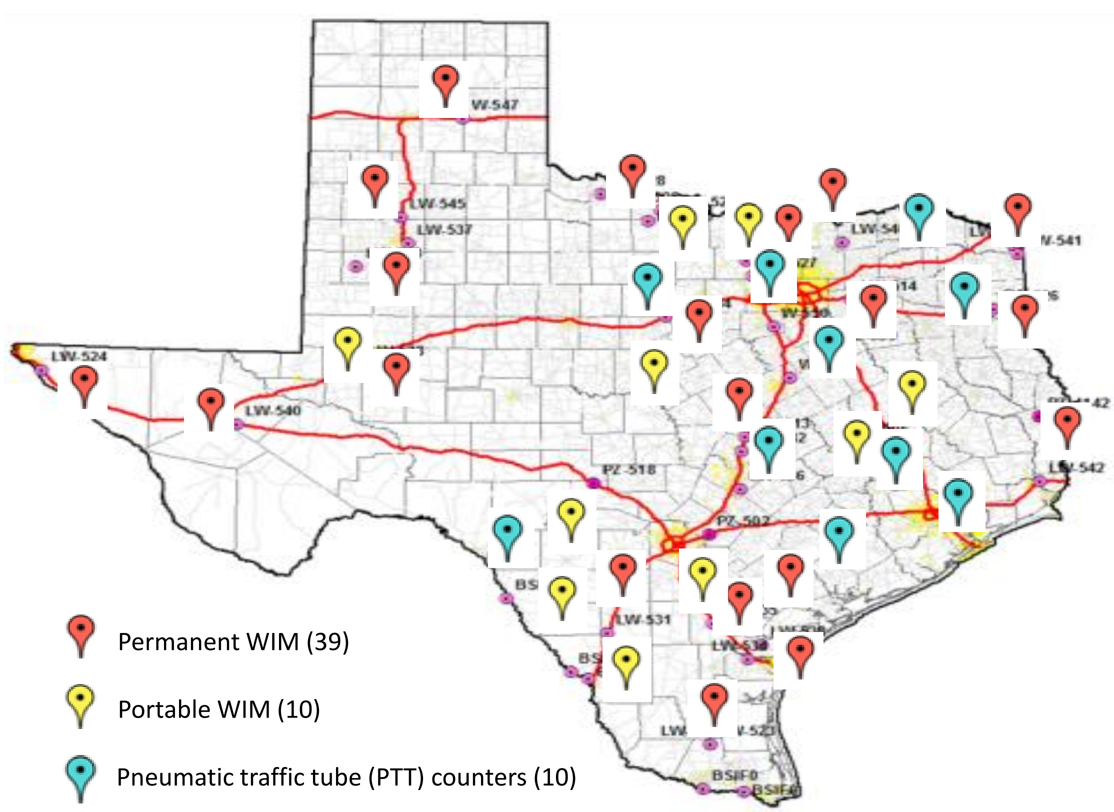


Figure 2 Location of WIMs and PTT Sites for Traffic Data Collection.

Table 1 lists an example of the site information where permanent WIM, portable WIM, and PTT counters were installed to obtain the traffic data.

Table 1 Example of Permanent WIM Stations, Portable WIM Sites, and PTT Sites.

No.	Station ID	District(County)	Climate	HWY	Direction	RM	GPS
Permanent WIM Stations							
1	W513	Waco (Bell)	M	IH 35	All (NB & SB)	276-280	N 30° 51' 36" W 97° 35' 18"
2	W523	Pharr (Hidalgo)	M	US 281	All (NB & SB)	750-748	N 26° 41' 09" W 98° 06' 53"
3	W524	El Paso (El Paso)	DW	IH 10	All (EB &WB)	40-41	N 31° 37' 59" W 106° 13' 08"
4	W527	Fort Worth (Wise)	WC	SH 114	All (NB & SB)	582	N 33° 02' 11" W 97° 25' 56"
5	W531	Laredo (La Salle)	DW	IH 35	All (NB & SB)	50-55	N 28° 13' 05" W 99° 18' 10"
6	W534	Corpus Christi (Nueces)	M	IH 69	All (NB & SB)	145	N 27° 50' 23" W 97° 37' 59"
7	W541	Atlanta (Cass)	WC	FM3129	NB & SB (L1)	232-230	N 33° 13' 32" W 94° 05' 56"
8	W542	Beaumont (Orange)	WW	IH 10	All (EB &WB)	860-865	N 30° 07' 35" W 94° 01' 25"
9	W547	Amarillo (Potter)	DC	IH 40	All (EB & WB)	110-120	N 35° 11' 39" W101° 04' 26"
Portable WIM Sites							
1	TS001	Laredo (Webb)	DW	US 83	NB (L1)	678-680	N 28° 02’ 37" W 99° 32’ 60"
2	TS002	Bryan (Robertson)	WW	SH7	All (EB & WB)	618-616	N 31° 15' 27" W 96° 21' 09"
3	TS003	Bryan (Leon)	WW	SH7	WB (L1)	658-660	N 31° 18' W 95° 35'
4	TS007	Fort Worth (Wise)	WC	SH 114	EB (L1)	582-584	N 33°02' W 97°25'
5	TS004	Laredo (Dimmit)	DW	FM 468	EB (L1)	432-434	N 28°33' W 99°30'
6	TS005	Corpus Christi (Live Oak)	M	US 281	NB & SB (L1)	620-622	N 28°27'59" W 98°10'51"
7	TS006	Beaumont (Comanche)	DW	SH 6	NB-L1	386-384	N 32°13' W 98°57'
8	TS008	Odessa (Midland)	DW	FM 1787	All (EB & WB)	280	N 31°41' W 102°07'
9	TS009	Laredo (Webb)	DW	US 83	NB (L1)	696-698	N 27°46' 46" W 99° 27' 00"
Pneumatic Traffic Tube Sites							
1	TTI00001	Atlanta (Panola)	WC	US 59	SB (L1)	308-310	N 32° 12' 05.3" W 94° 20' 35.5"
2	TTI00051	Austin (Bastrop)	M	SH 304	SB	450-452	N 30° 06' 06.8" W 97° 21' 08.5"
3	TTI00024	Yoakum (Lavaca)	WW	SH 95	SB	522-524	N 29° 22' 34.6" W 97° 09' 52.0"
4	TTI00002	Fort Worth (Wise)	WC	SH 114	EB (L1)	582-584	N 33° 02' 12.1" W 97° 25' 34.5"
5	TTI00005	Laredo (Maverick)	DW	Loop 480	SB & NB (L1)	570-567	N 28° 40' 58.9" W 100° 30' 10"
6	TTI00016	Houston (Harris)	WW	FM 2100	NB & SB	456-454	N 29° 55' 32.6" W 95° 04' 18.2"
7	TTI00007	Paris (Lamar)	WC	US 271	NB & SB	187-188	N 33° 51' 06.5" W 95° 30' 33.2"
8	TTI00019	San Antonio (Comal)	DW	IH 35	SB (L1)	190-189	N 29° 42' 34.8" W 98° 05' 23.8"
9	TTI00009	Waco (Bell)	M	IH 35F	NB & SB	269-268	N 30° 58' 25.90" W 97° 30' 55.2"

Legend: DC=dry-cold; DW=dry-warm; M=moderate; WC=wet-cold; WW=wet-warm; EB=eastbound; NB=northbound; SB=southbound; WB=westbound

SECTION III. TRAFFIC PARAMETERS AND EXAMPLE RESULTS

As described in Section II, traffic data were collected and assembled for 59 stations/sites including 39 permanent WIM, 10 portable WIM, and 10 pneumatic traffic counter sites. The statewide WIM traffic data were processed, analyzed, and evaluated under Task 2 of this project, namely: Task 2 – Collection and Assembly of Statewide Traffic WIM Data. The analytical approaches used, the results, and key findings of the project are reported in this section.

TRAFFIC DATA ANALYSIS AND RESULTS

Based on the WIM traffic volume, speed, classification, and weight data, the pertinent traffic parameters were calculated. The computed/generated traffic parameters are useful traffic inputs for designing, planning, and monitoring highways infrastructures. As a minimum and as listed in Figure 1, the calculated traffic parameters include the following:

- Average daily traffic (ADT), which is computed as the total number of vehicles (all classes) recorded divided by the duration of record (i.e., number of days).
- Average daily truck traffic (ADTT), which is calculated as the total number of trucks (FHWA vehicle class 4-13) recorded divided by the duration of record (i.e., number of days) (Figure 3).
- Percentage of truck (%truck) = ADTT/ADT (%).
- Vehicle class distribution (VCD), the percentage of each vehicle class in the ADT.
- Average vehicle speed and the percentage of over-speeding vehicles estimated relatively to the speed limit at the highway section in question.
- Axle per truck inputs, computed as the average number of single/tandem/tridem/quad axles per truck.
- Total 20-years' and 30-years' 18-kips ESALs, estimated using the load spectra of trucks and the annual traffic growth rate.
- Average ten heaviest wheel loads daily (ATHWLD).
- Daily gross vehicle weight (GVW) distribution, the daily single/tandem/tridem/quad load distribution.
- Daily overweight vehicles estimated based on the recorded GVW values and the consideration of 80 kips as the limit allowed for GVW.
- Daily overweight axles, estimated based on the different axle threshold loads, e.g., 20-kips for single axles, 34-kips for tandem axles, 42-kips for tridem axles, and 50-kips for quad axles.
- Axle load distribution (ALD), estimated through the load spectra (LS) analysis.

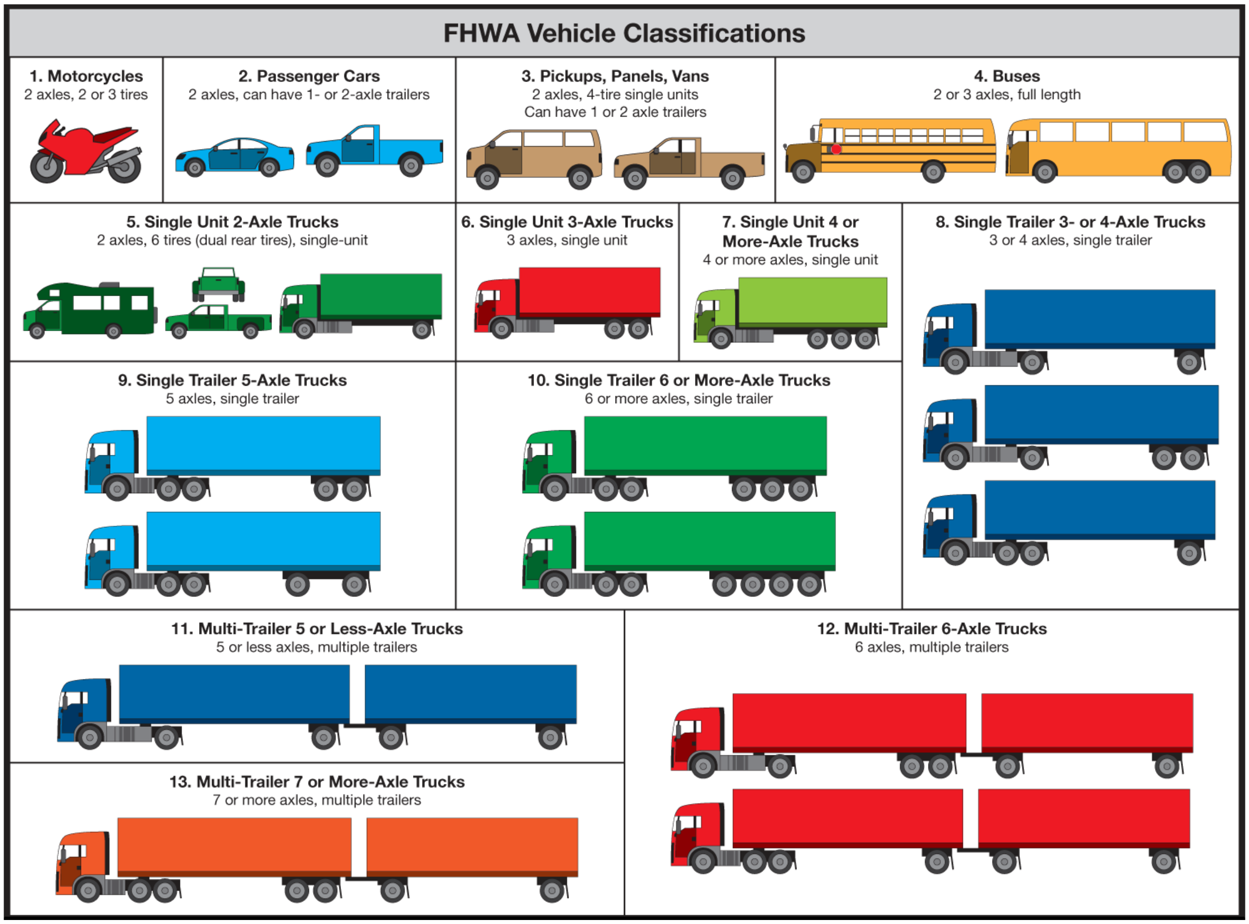


Figure 3 FHWA Vehicle Classification.

For the LS data analysis, the weight data for each axle category (i.e., steering, other single, tandem, tridem, and quad) are addressed separately for each truck classification from Class 4 to 13. The results are reported for individual months of the year (i.e., from January to December) and then, organized to generate the ALD input files for the M-E software including TxME, M-E PDG, and AASHTOWare. Along with the traffic parameters, historical traffic volume data, predominantly permanent WIM data, were utilized to compute the monthly adjustment factors (MAF) and the annual traffic growth rate (Gr). In general, the latest three consecutive year's traffic volume data are needed to accurately generate the MAF and Gr data for a given highway section. In the event this minimum 3-years' data requirement is not met, then default values are used such as 3% for Gr. Among others, the LS estimates are useful for designing and quantifying the damage on pavement structures. Hence, the study provides 18-kip ESAL estimates for both flexible and concrete pavements.

TRAFFIC DATA FOR PAVEMENT DESIGN: FPS AND M-E TRAFFIC INPUTS

Based on the analysis of WIM and PTT traffic data, pertinent traffic parameters and inputs were calculated and provided for pavement design using FPS and M-E design software as listed in Table 2.

Table 2 General Traffic Data and Pavement Design Software.

General Traffic Data	Pavement Design Software
• Volume counts (ADT, ADTT, %Trucks, etc) • Vehicle speed • Vehicle classification • Hourly & daily distributions • Growth rates • Vehicle weights • Axle load distribution • Overweight's & overloading statistics • ATHWLDs • Load equivalency factor (LEF)	• FPS • TxCRCP-ME (concrete) • TxM-E • TxACOL • TxCrackPro • M-E PDG • AASHTOWare • PerRoad

Examples of traffic data analysis results are presented in the following tables and figures, including FPS/M-E inputs, WIM/PTT data, GVW/axle weight distribution data, truck overweight data, overloading statistics, WIM-PTT traffic data comparisons, and portable WIM accuracy.

FPS Input and Traffic Data from Permanent WIM

Table 3 FPS Traffic Input Data from Permanent WIM (Station W531, IH 35 near Cotulla).

FPS Parameter	NB-L1 (Outside)	NB-L2 (Inside)	SB-L1 (Outside)	SB-L2 (Inside)	Comment
ADT-Beginning	6,113	2,699	6,213	2,656	ADT at the beginning of the design period
ADT-END 20 Year	23,001	10,155	23,377	9,994	ADT at the end of the design period (20 yrs)
18 kip ESALs 20 Years (millions)	39.08	5.49	40.11	5.76	@ 6.85% Gr
Avg. vehicle speed (mph)	~65	~65	~65	~65	Approach speed assumed to be equal to operational speed
% Trucks in ADT	47%	13%	51%	14%	
ATHWLD (kips)	14.3	11.8	12.3	12.7	
%Tandem axles	55.5%	51.1%	57.9%	54.9%	

Table 4 Truck Overweight and Overloading Statistics from Permanent WIM.

Station No.	Overload Lane	ADTT	Daily OW Trucks (>80 kips)	%OW	% age number/count of OW axles			
					Single (>20kips)	Tandem (>34kips)	Tridem (>42kips)	Quad (>50kips)
W523 (US 281)	SB-L1	1,968	98	5.0	2.0	8.0	21.3	40.0
W524 (IH 10)	EB-L1	3,432	77	2.2	0.5	7.8	16.9	0.0
W527 (SH 114)	EB-L1	1,670	333	19.9	1.0	33.0	90.5	58.3
W531 (IH 35)	NB-L1	2,400	144	6.0	0.8	7.9	20.0	34.8
W541 (FM 3129)	NB-L1	192	70	36.5	0.5	41.5	4.9	0.0
W547 (IH 40)	WB-L1	2,400	159	5.9	1.3	12.0	91.8	0.0

Legend: OW = Overweight

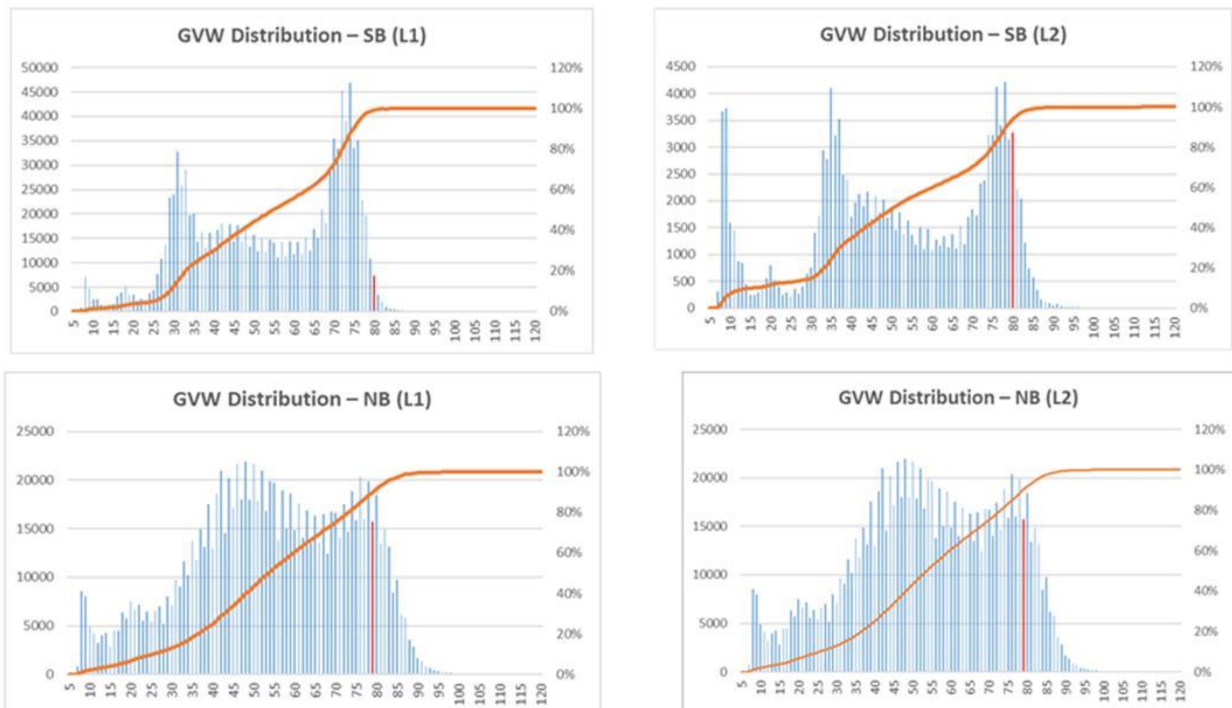


Figure 4 GVW Distribution of Station W531 (IH 35 near Cotulla).

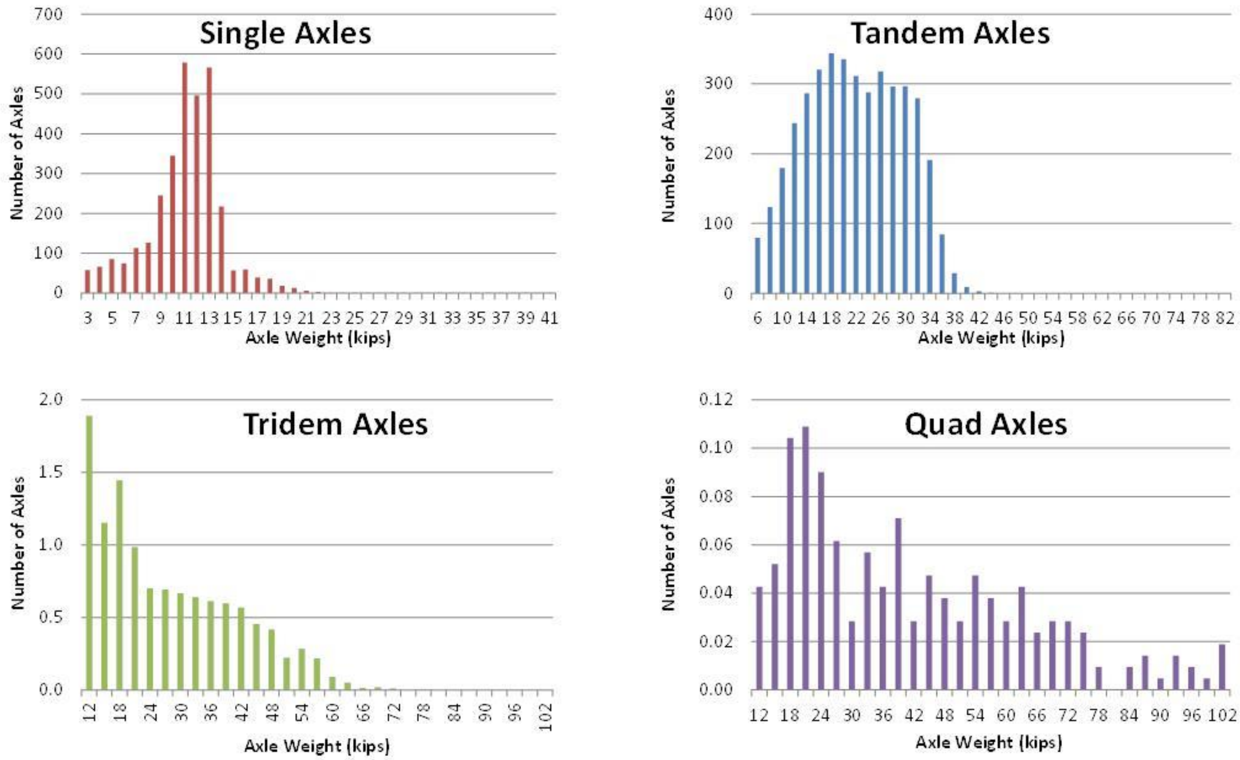


Figure 5 Axle Weight Distribution of W531 (IH 35 near Cotulla).

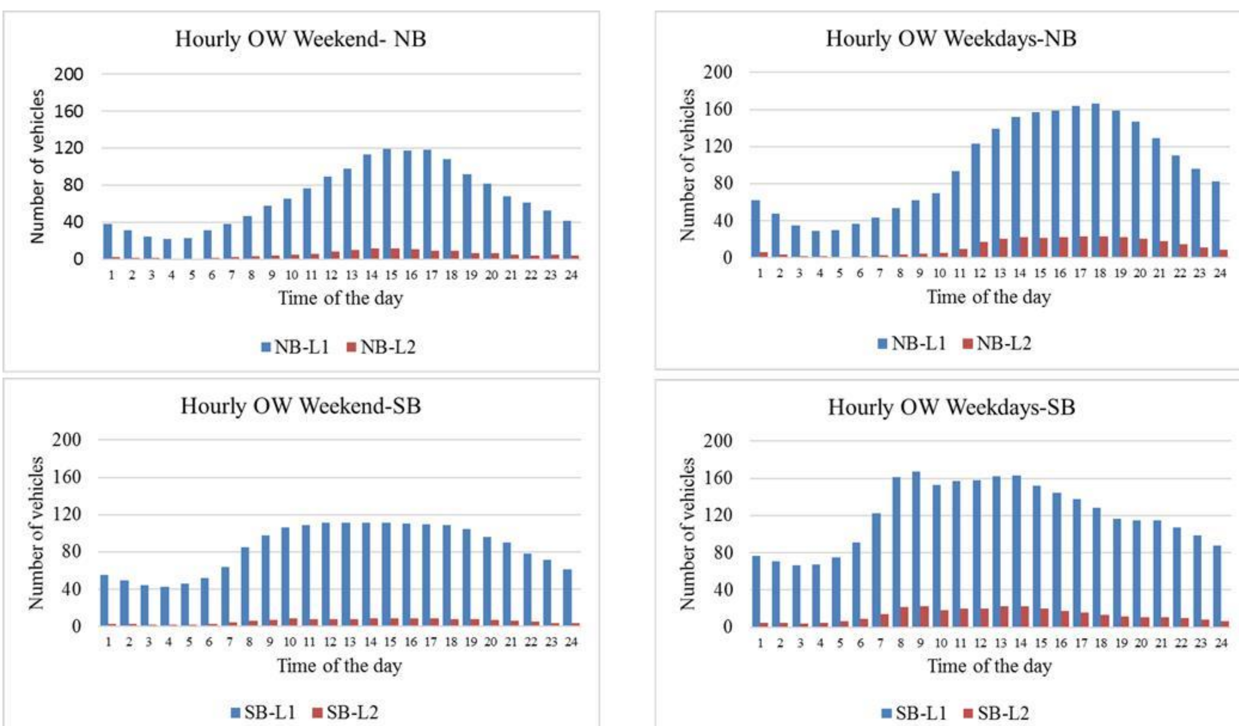


Figure 6 Overweigh Hourly Distribution of W531 (IH 35 near Cotulla).

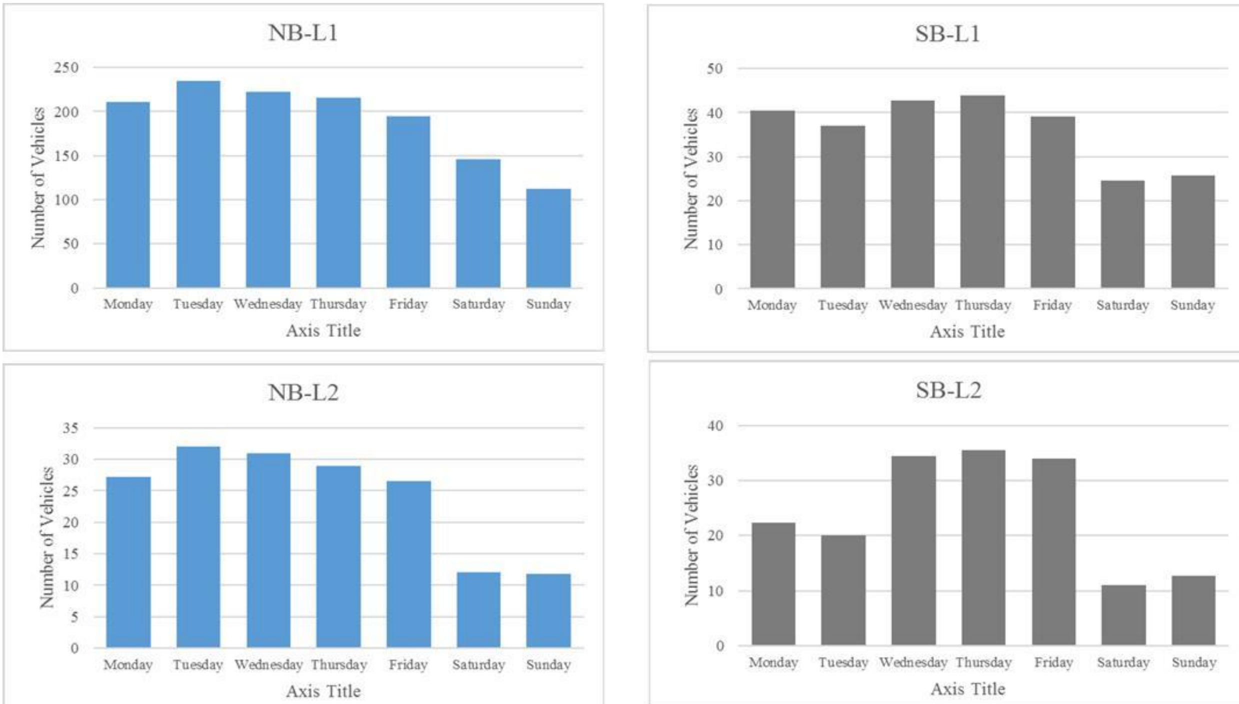
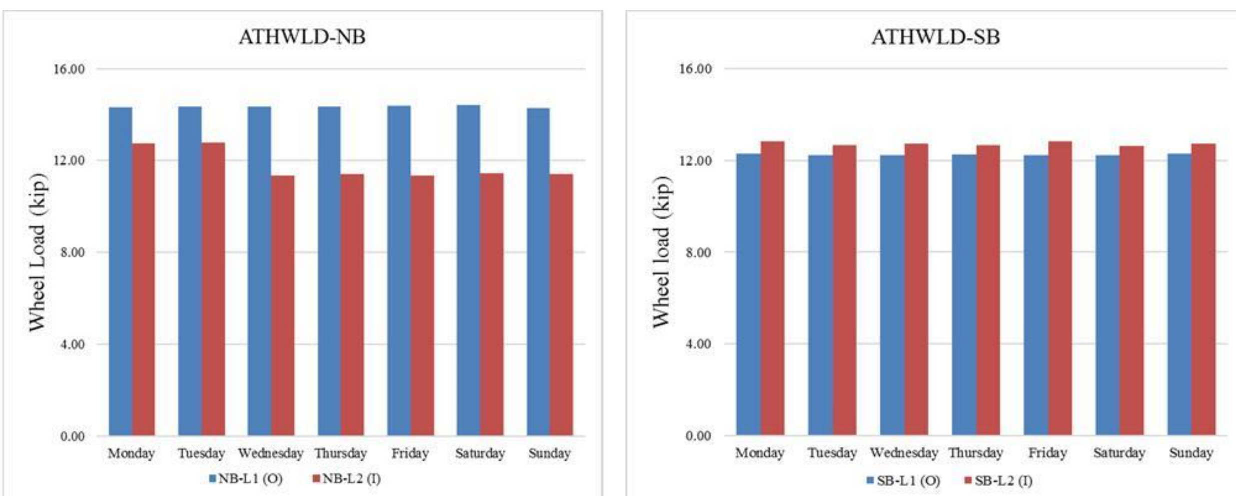


Figure 7 Overweight Daily Distribution of W531 (IH 35 near Cotulla).



Direction-Lane	ATHWLD	%Tandom Axles
NB-L1	14.34 kips	55.5 %
NB-L2	11.78 kips	51.1 %
SB-L1	12.25 kips	57.9 %
SB-L2	12.74 kips	54.9 %

Figure 8 Daily ATHWLD Distribution of W531 (IH 35 near Cotulla).

M-E Input Data from Portable WIM

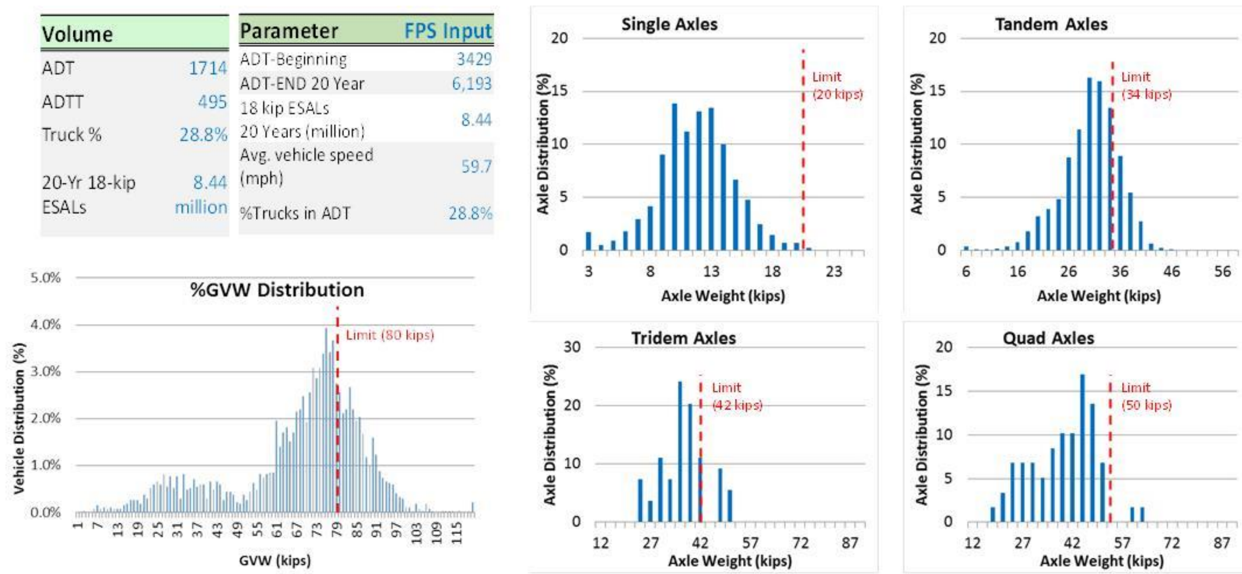


Figure 9 General M-E Traffic Data Collected using Portable WIM (US 83 NB in Laredo).

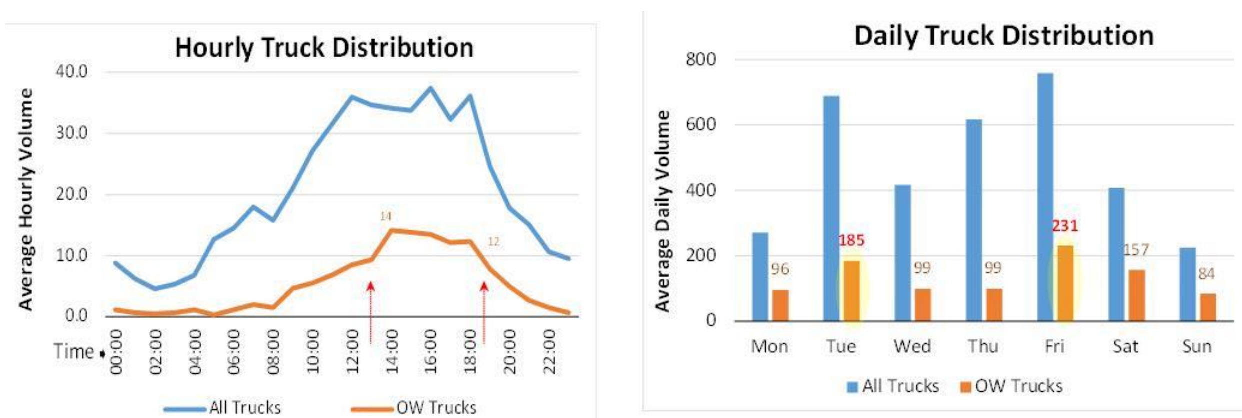


Figure 10 Hourly and Daily Truck Distributions from Portable WIM (US 83 NB Laredo).

SECTION IV. THE TRAFFIC DATA STORAGE SYSTEM

The M-E traffic data storage system (T-DSS) was developed, being maintained and managed in the user-friendly MS Access platform to provide M-E traffic data support for the FPS and other M-E software such as the TxME. The Microsoft Access® is compatible with most computer machines and almost all the engineering professionals are conversant with MS office/access; hence, this was selected as the platform for the T-DSS. As shown in Figure 11, the data are arranged and stored in tabular format along with zipped attachments such as MAF and ALD files. As shown in Figure 11, the main traffic data tables are:

- Tables 01-03: Traffic volume and classification data.
- Table 04: FPS input data.
- Table 05: TxME input data.
- Table 06: TxACOL and TxCrackPro data.
- Table 07: M-E PDG and AASHTOWare input data.

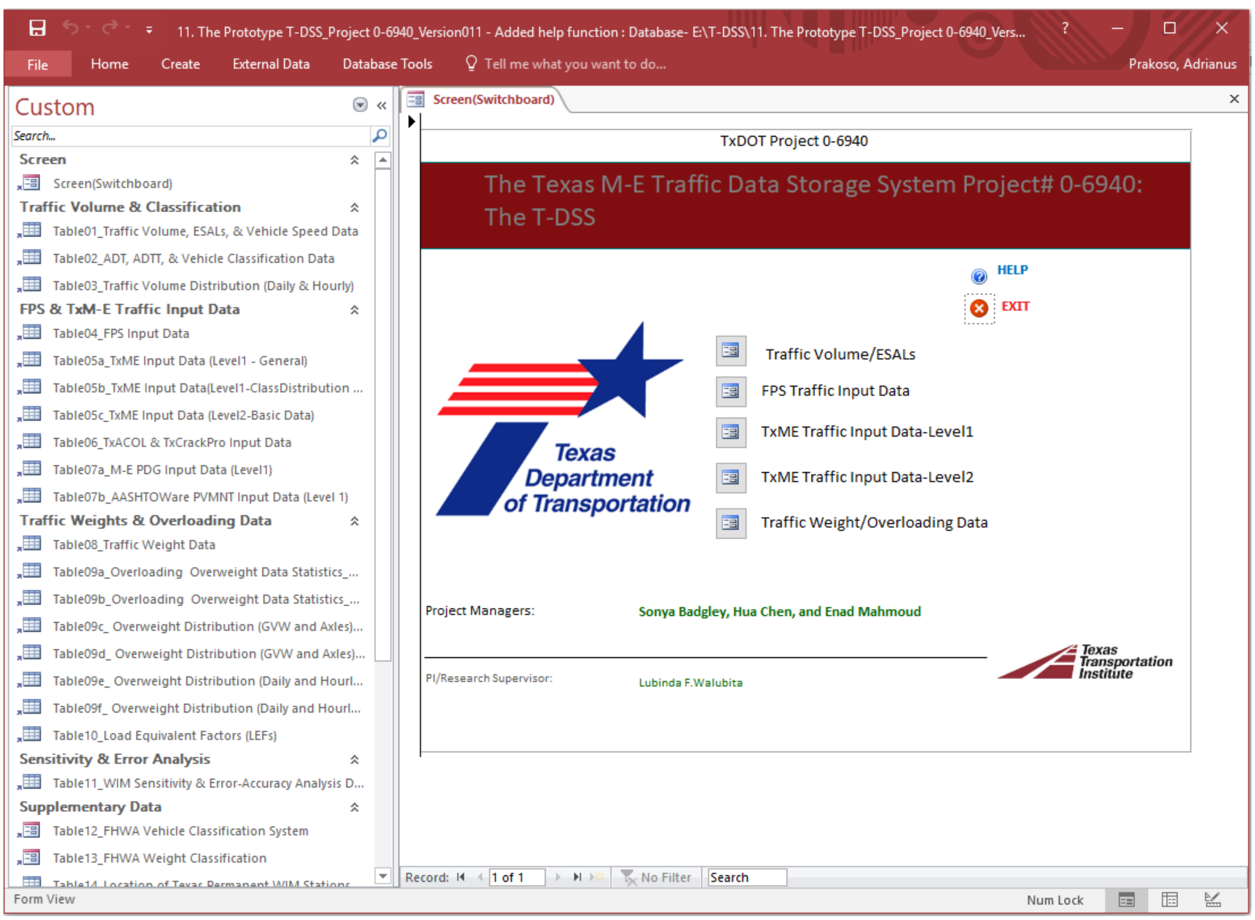


Figure 11 The T-DSS Main Screen.

FPS TRAFFIC INPUT DATA

FPS is the primary software that is routinely used by TxDOT for the design of flexible pavements. Figure 12Figure 13 show the main FPS21 and traffic-data input screens, respectively. Table 5 and Figure 14 lists the specific FPS21 traffic data inputs and the data source from the T-DSS.

Figure 12 Main FPS Screen.

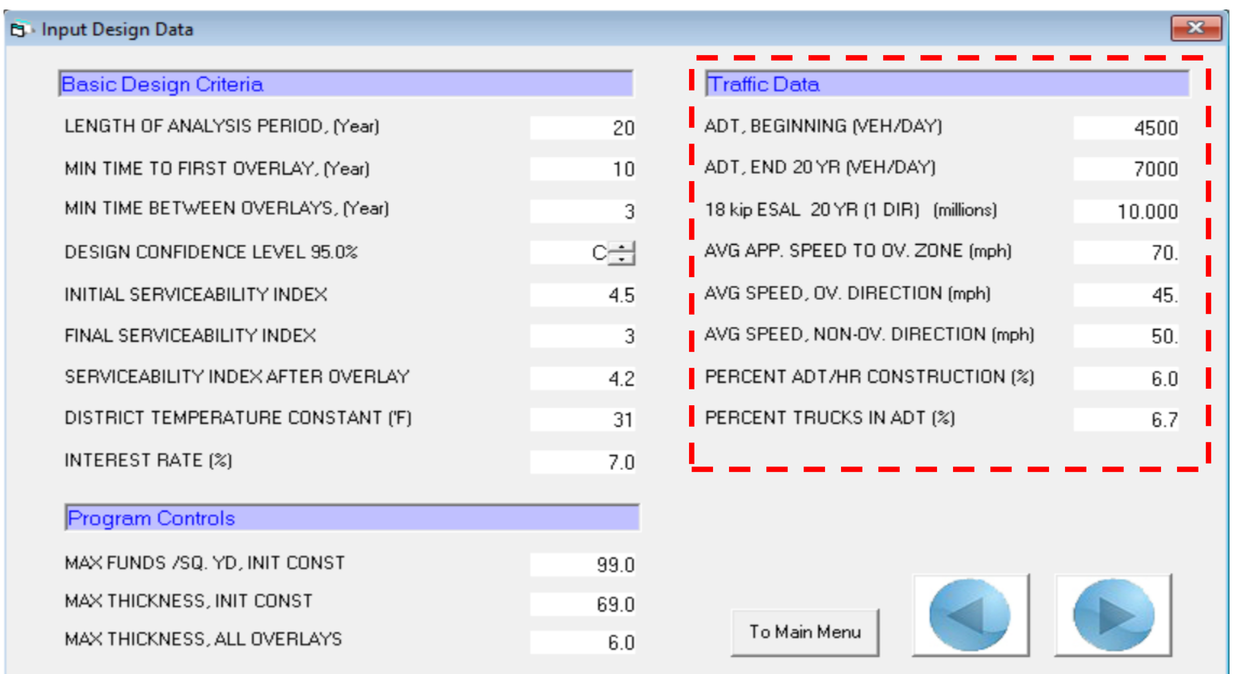
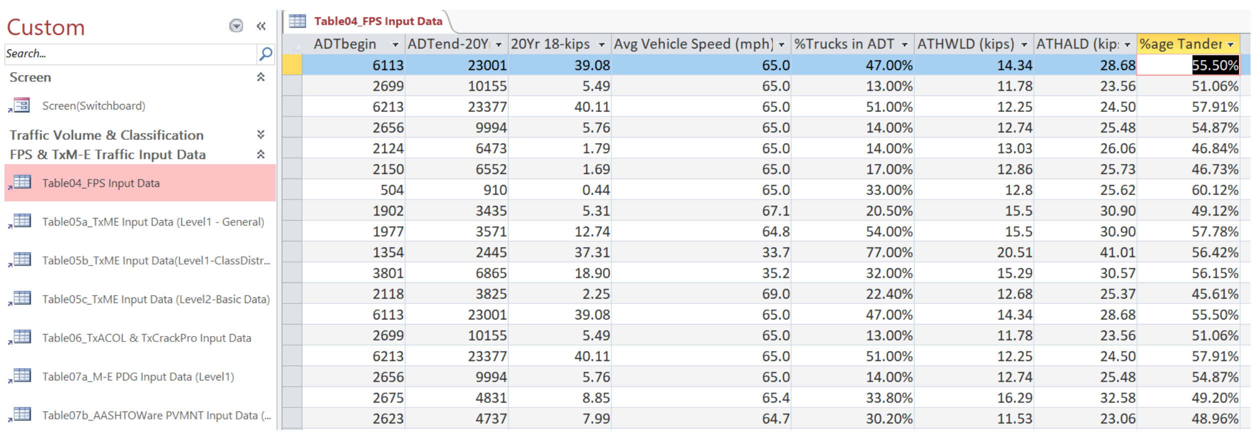


Figure 13 FPS Traffic-Data Input Screen.

As illustrated in Table 5 and Figure 14, the traffic input data required for the FPS21 software are contained in Table04 of the T-DSS, namely “Table04_FPS Input Data.” These data are visually/manually accessed from the T-DSS and manually entered into the FPS software.

Table 5 List of Main Traffic Data Input for FPS.

No.	Input Data	Data Source/ Location in the T-DSS
1	ADT begin (veh/day)	Table04_FPS Input Data
2	ADT end 20 Yr (veh/day)	
3	18 kip ESALs 20 Yr – 1 Direction (millions)	
4	Avg. App. Speed to Overlay (OV) Zone	
5	Avg. Speed OV & Non-OV Direction	
6	Percent ADT/HR Construction	
7	Percent trucks in ADT	



ADTbegin	ADTend-20Y	20Yr 18-kips	Avg Vehicle Speed (mph)	%Trucks in ADT	ATHWLD (kips)	ATHALD (kip	%age Tander
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%
2656	9994	5.76	65.0	14.00%	12.74	25.48	54.87%
2124	6473	1.79	65.0	14.00%	13.03	26.06	46.84%
2150	6552	1.69	65.0	17.00%	12.86	25.73	46.73%
504	910	0.44	65.0	33.00%	12.8	25.62	60.12%
1902	3435	5.31	67.1	20.50%	15.5	30.90	49.12%
1977	3571	12.74	64.8	54.00%	15.5	30.90	57.78%
1354	2445	37.31	33.7	77.00%	20.51	41.01	56.42%
3801	6865	18.90	35.2	32.00%	15.29	30.57	56.15%
2118	3825	2.25	69.0	22.40%	12.68	25.37	45.61%
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%
2656	9994	5.76	65.0	14.00%	12.74	25.48	54.87%
2675	4831	8.85	65.4	33.80%	16.29	32.58	49.20%
2623	4737	7.99	64.7	30.20%	11.53	23.06	48.96%

Figure 14 Table04 in the T-DSS.

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 15, 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 are sourced from Table 6 in the T-DSS, namely “Table01_Traffic Volume, ESALs, and Vehicle Speed Data.” As exemplified in Figure 16, the data are accessed visually/manually but with future plans for automated export into the TxCRCP-ME program as both the TxCRCP-ME program and the T-DSS are based on the MS Excel platform.

CRCP DESIGN PROGRAM BASED ON MECHANISTIC-EMPIRICAL PRINCIPLES

Developed under TxDOT Research Project 0-5832

Version: TxCRCP-ME v07b

A. Project Identification

District	
County	
Highway	
CSJ	
Direction	
Station (Begin)	
Station (End)	

B. Design Parameters

Design Life (year)	30
Number of Punchouts per Mile	10

C. Design Traffic

Total Number of Lanes in One Direction	
Total Design Traffic in One Direction (million ESALs)	

D. Concrete Layer Information

Thickness of Concrete Layer (in.)	
28-Day Modulus of Rupture (psi)	570

E. Support Layers Information

Soil Classification System	USCS
Soil Classification of Subgrade	
Base Type	CTB
Base Thickness (in.)	6
Modulus of Base Layer (ksi)	
Composite K (psi/in.)	0

Input | Temperature | Soil Classification | K-Table | Composite K | S-Table | Stress | Analysis Result | Final Result | Time vs. Punchout

Figure 15a. Main MS Excel Worksheet for the TxCRCP-ME.

Concrete - Inputs (Based on Concrete Daily ESAL)	NB-L1	NB-L2	SB-L1	SB-L2	Comment
Design Life	30	30	30	30	Years
Annual Growth Rate	6.72	6.72	6.72	6.72	%
Number of Lanes in one direction	2	2	2	2	
18 kip ESALs 30 Years (million)	221.53	26.20	168.20	14.99	

Figure 15b. Example TxCRCP-ME Inputs for Station W531 (IH 35, Cotulla, LRD District).

Table 6 List of Main Traffic Data Input for TxCRCP-ME.

No.	Input Data	Data Source/ Location in the T-DSS
1	Number of lanes in one direction	Table01_Traffic Volume, ESALs, and Vehicle Speed Data
2	30-year 18-kip ESALs in one direction	

Table01_Traffic Volume, ESALs, & Vehicle Speed Data

HWY	LaneDirection	LaneDesignation	NoOfLanesIn	Year	Estimated 20-Yr 18-kip E!	Estimated 30-Yr 18-kip ESALs (Millions)
IH 35	NB	Outside (L1)	2	2015	39.08	70.18
IH 35	NB	Inside (L2)	2	2015	5.49	9.15
IH 35	SB	Outside (L1)	2	2015	40.11	78.01
IH 35	SB	Inside (L2)	2	2015	5.76	9.24

District	County	HWY	LaneDirection	LaneDesignation	NoOfLanesInOneDirection	Year	Estimated 30-Yr 18-kip ESALs (Millions)
Laredo	La Salle	IH 35	NB	Outside (L1)	2.00	2015	70.18
Laredo	La Salle	IH 35	NB	Inside (L2)	2.00	2015	9.15
Laredo	La Salle	IH 35	SB	Outside (L1)	2.00	2015	78.01
Laredo	La Salle	IH 35	SB	Inside (L2)	2.00	2015	9.24

Figure 16 TxCRCP-ME Traffic Input Data (T-DSS and Excel-Export Tables).

TXACOL AND TXCRACKPRO TRAFFIC INPUT DATA

TxACOL and TxCrackPro software are overlay design and M-E analysis programs. Figure 17 shows the main software screens. The basic traffic input data requirements are listed in Table 7 along with data source location in the T-DSS, namely Table06 (i.e., Table06_TxACOL and TxCrackPro Input Data; see Figure 18). Data export from the T-DSS to both these two M-E software is visual/manual based. Automated data import will require interfacial modules as the T-DSS and the software use different code platforms. Both the two M-E software were developed at TTI along with the T-DSS. Therefore, exploring for a bridging module to allow for automated data export/import is feasible.

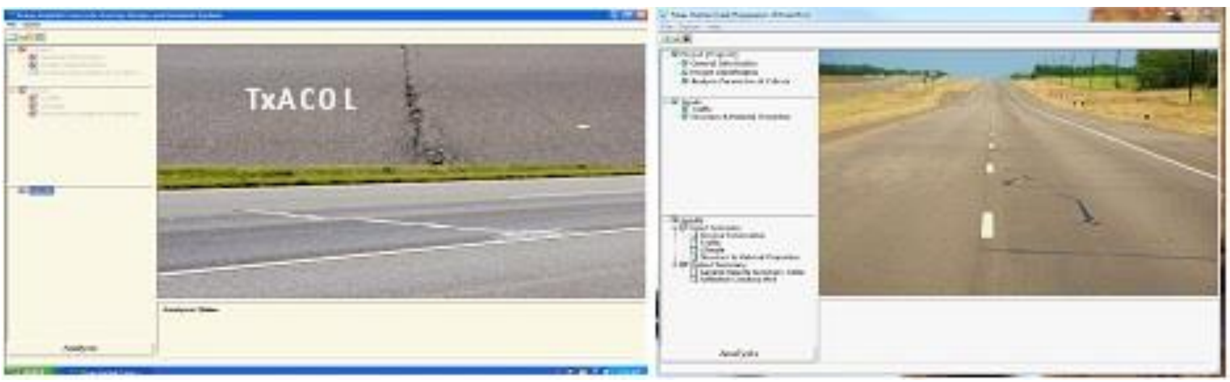
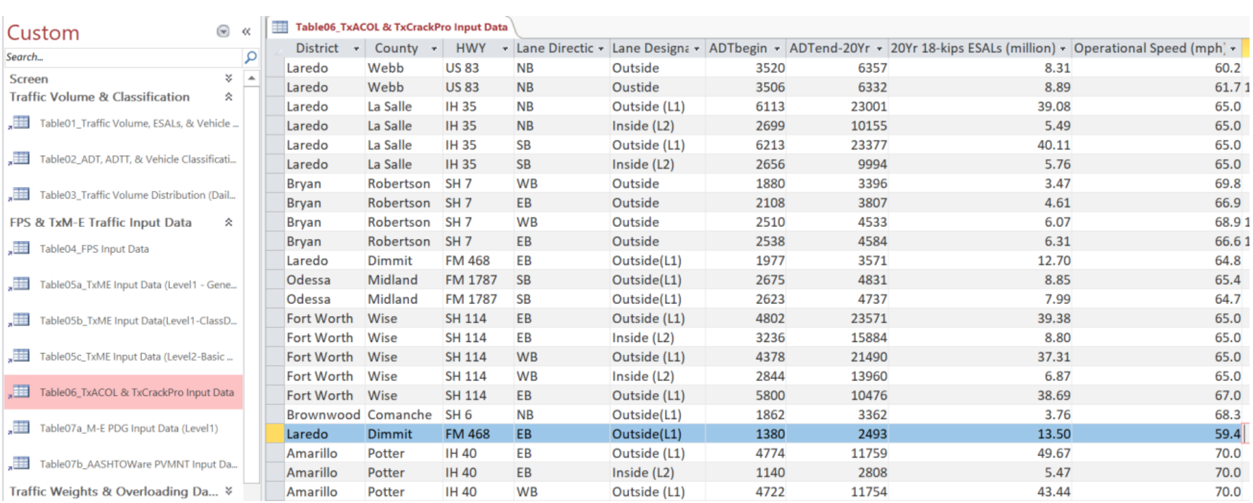


Figure 17 Main Screens for TxACOL and TxCrackPro.

Table 7 List of Main Traffic Data Inputs for TxACOL and TxCrackPro.

No.	Input Data	Data Source/ Location in the T-DSS
1	ADT begin (veh/day)	Table06_TxACOL and TxCrackPro Input Data
2	ADT end 20 yr. (veh/day)	
3	18 kip ESALs 20 yr.-1 Direction (millions)	
4	Operation speed (mph)	



District	County	HWY	Lane Directic	Lane Designa	ADTbegin	ADTend-20Yr	20Yr 18-kips ESALs (million)	Operational Speed (mph)
Laredo	Webb	US 83	NB	Outside	3520	6357	8.31	60.2
Laredo	Webb	US 83	NB	Outside	3506	6332	8.89	61.7 1
Laredo	La Salle	IH 35	NB	Outside (L1)	6113	23001	39.08	65.0
Laredo	La Salle	IH 35	NB	Inside (L2)	2699	10155	5.49	65.0
Laredo	La Salle	IH 35	SB	Outside (L1)	6213	23377	40.11	65.0
Laredo	La Salle	IH 35	SB	Inside (L2)	2656	9994	5.76	65.0
Bryan	Robertson	SH 7	WB	Outside	1880	3396	3.47	69.8
Bryan	Robertson	SH 7	EB	Outside	2108	3807	4.61	66.9
Bryan	Robertson	SH 7	WB	Outside	2510	4533	6.07	68.9 1
Bryan	Robertson	SH 7	EB	Outside	2538	4584	6.31	66.6 1
Laredo	Dimmit	FM 468	EB	Outside(L1)	1977	3571	12.70	64.8
Odessa	Midland	FM 1787	SB	Outside(L1)	2675	4831	8.85	65.4
Odessa	Midland	FM 1787	SB	Outside(L1)	2623	4737	7.99	64.7
Fort Worth	Wise	SH 114	EB	Outside (L1)	4802	23571	39.38	65.0
Fort Worth	Wise	SH 114	EB	Inside (L2)	3236	15884	8.80	65.0
Fort Worth	Wise	SH 114	WB	Outside (L1)	4378	21490	37.31	65.0
Fort Worth	Wise	SH 114	WB	Inside (L2)	2844	13960	6.87	65.0
Fort Worth	Wise	SH 114	EB	Outside (L1)	5800	10476	38.69	67.0
Brownwood	Comanche	SH 6	NB	Outside(L1)	1862	3362	3.76	68.3
Laredo	Dimmit	FM 468	EB	Outside(L1)	1380	2493	13.50	59.4
Amarillo	Potter	IH 40	EB	Outside (L1)	4774	11759	49.67	70.0
Amarillo	Potter	IH 40	EB	Inside (L2)	1140	2808	5.47	70.0
Amarillo	Potter	IH 40	WB	Outside (L1)	4722	11754	43.44	70.0

Figure 18 TxACOL and TxCrackPro Traffic Input Data in The T-DSS (Table06).

TXME TRAFFIC INPUT DATA

TxME is an M-E based software used for the design, structural analysis, and performance predictions of flexible pavements. Figure 19 illustrates the TxME screen for traffic input (Level 2). Table 8 lists the main traffic data inputs for the TxME by the traffic input levels along with the source location from the T-DSS. Data access is visual/manually based with the need for an interface module to facilitate automated data export/import between the T-DSS and TxME.

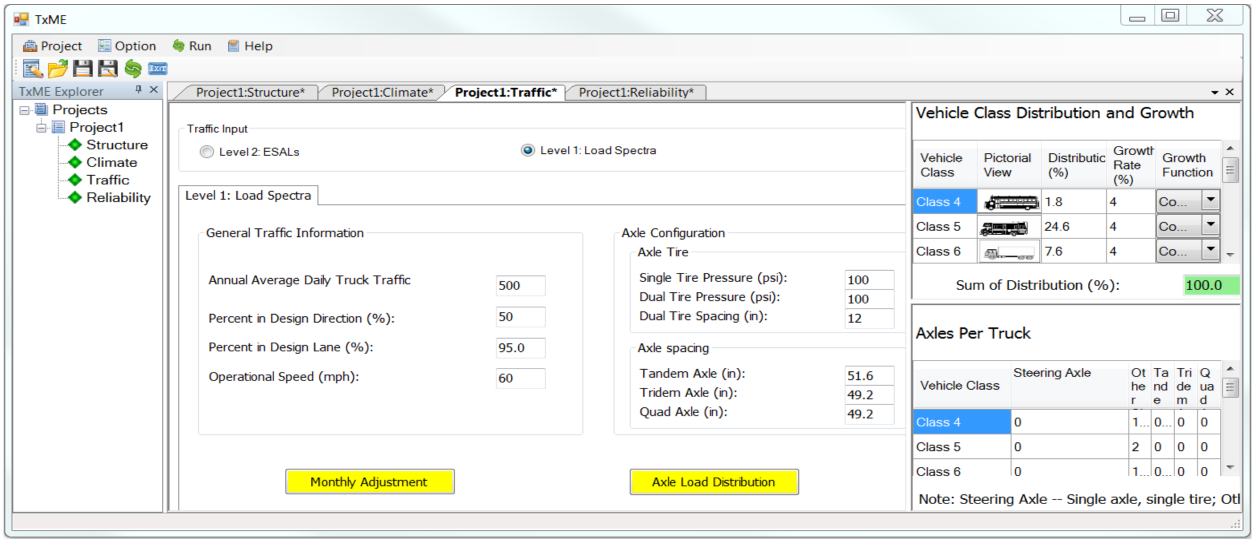


Figure 19 TxME Traffic Input Screen.

Table 8 List of Main Traffic Data Input (by Level) for TxME.

Level	Input Data		Data Source/ Location in the T-DSS
1	Tire Pressure (psi) ADT Beginning (Veh/Day) ADT-End 20 YR (Veh/Day) 18 kip ESALs 20 YR (1 DIR, million) Operation Speed (mph)		Table05c_TxME Input Data (Level2-Basic Data)
2	General Traffic Information		Table05a_TxME Input Data (Level1-General)
		Traffic 2-Way AADTT No. of lanes in design direction % of trucks in design direction % of trucks in design lane Operation speed	
	Axle Configuration		Table05a_TxME Input Data (Level1-General)
		Axle tire (Single & dual tire pressure) Axle Spacing (Tandem/Tridem/Quad)	
	MAF and ALD files		Table05a_TxME Input Data (Level1-General) – under attachments
	Axle load distribution Vehicle class distribution and growth Axle per truck		Table05b_TxME Input Data (Level1-Class Distribution and Axles Per Truck)

MEPDG/AASHTOWARE ME PAVEMENT ME DESIGN TRAFFIC INPUT DATA

Similar to the TxME, the M-E PDG and AASHTOWare Pavement ME Design are M-E based software used for the design, structural analysis, and performance predictions of pavements. Figure 20 illustrates the AASHTOWare Pavement ME Design main screen. Table 9 lists the main traffic data inputs for the M-E PDG and AASHTOWare along with the source location from the T-DSS (i.e., Table07_M-E PDG and AASHTOWare Input Data). Data access is visual/manually with no possibilities of automated data export/import as these are federal developed/managed software.

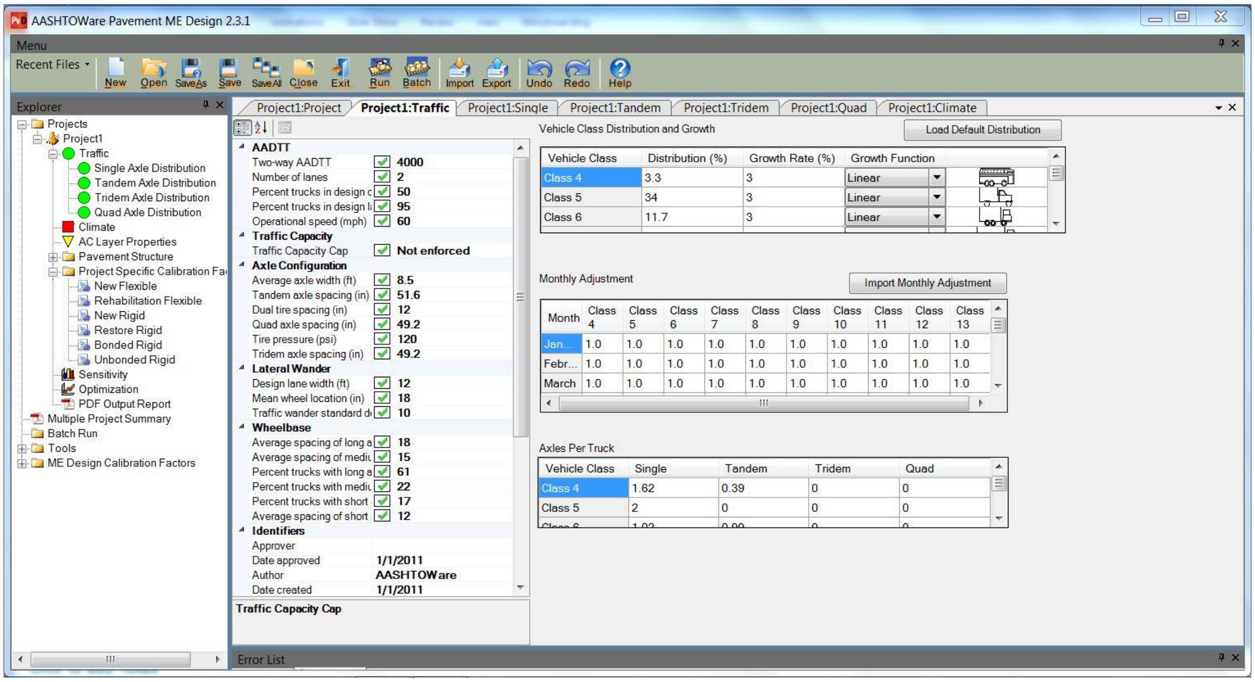


Figure 20 AASHTOWare Pavement ME Design Traffic Input Screen.

Table 9 List of Traffic Data Input for M-E PDG and AASHTOWare Pavement ME Design.

Item	Description (Location in the T-DSS = Table07a & 07b)	Comment
AADTT	Design Life (yrs.) Opening Date Initial two-way AADTT Number of lanes in design direction Percent of trucks in design direction (%) Percent of trucks in design lane (%) Operational Speed (mph)	User Construction
Axle Configuration	Average Axle width (ft.) Dual tire spacing (inches) Tire Pressure (psi) Tandem/Tridem/Quad Axle spacing (inches)	Default Default Default Default
Lateral Wander	Mean wheel location (inches from the lane marking) Traffic wander standard deviation (inches) Design lane width (ft.) (Note: Not slab width)	
Wheelbase	Average Axle spacing of long/medium axles(ft.) Percent of trucks with long/med/short axles (%)	Default
Traffic Volume Adjustment Factors	Monthly adjustment Vehicle Class Distribution Hourly Distribution Traffic growth factors	
Axle Load Distribution Factors	Single/Tabdem/Tridem/Quad axle	
Number Axles/Truck	Single/Tandem/Tridem/Quad (Class 4 to 13)	

EXPORTING TRAFFIC DATA

Other traffic data contained in the T-DSS include traffic weights, overloading, and supplementary data such as the location of the WIM stations from Table08 to Table15. Accessing of the T-DSS data is typically achieved through the Microsoft Access function "External Data" that exports the data (selected table and/or data) into a tabular Excel format. This is exemplified in Figure 21 and Figure 22. The zipped attachments simply download by left-clicking on them just like any other standard download operation.

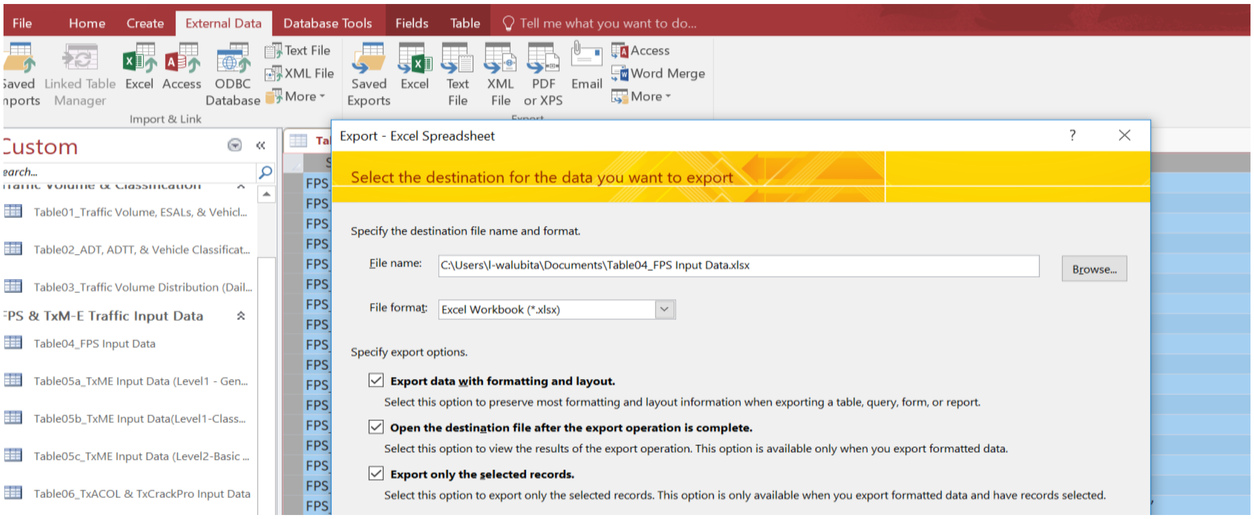


Figure 21 The T-DSS Data Export (External Data ⇒ Excel).

District	County	HWY	LaneDirection	LaneDesignation	ADTbegin	ADTend-20Yr	8-kips ESALs (mi	Avg Vehicle Speed (mph)	%Trucks in ADT	ATHWLD (kips)	ge Tandem Axles
Laredo	La Salle	IH 35	NB	Outside (L1)	6113	23001	39.08	65.00	47.00%	14.34	55.50%
Laredo	La Salle	IH 35	NB	Inside (L2)	2699	10155	5.49	65.00	13.00%	11.78	51.06%
Laredo	La Salle	IH 35	SB	Outside (L1)	6213	23377	40.11	65.00	51.00%	12.25	57.91%
Laredo	La Salle	IH 35	SB	Inside (L2)	2656	9994	5.76	65.00	14.00%	12.74	54.87%
Pharr	Hidalgo	US 281	NB	Inside (L2)	2124	6473	1.79	65.00	14.00%	13.03	46.84%
Pharr	Hidalgo	US 281	SB	Inside (L2)	2150	6552	1.69	65.00	17.00%	12.86	46.73%
Atlanta	Cass	FM 3129	SB	Outside (L1)	504	910	0.44	65.00	33.00%	12.8	60.12%
Bryan	Leon	SH 7	WB	Outside(L1)	1902	3435	5.31	67.10	20.50%	15.5	49.12%
Laredo	Dimmit	FM 468	EB	Outside(L1)	1977	3571	12.74	64.80	54.00%	15.5	57.78%
Corpus Christi	Live Oak	US 281	NB	Outside(L1)	1354	2445	37.31	33.70	77.00%	20.51	56.42%
Corpus Christi	Live Oak	US 281	SB	Outside(L2)	3801	6865	18.90	35.20	32.00%	15.29	56.15%
Brownwood	Comanche	SH 6	NB	Outside(L1)	2118	3825	2.25	69.00	22.40%	12.68	45.61%
Laredo	La Salle	IH 35	NB	Outside (L1)	6113	23001	39.08	65.00	47.00%	14.34	55.50%
Laredo	La Salle	IH 35	NB	Inside (L2)	2699	10155	5.49	65.00	13.00%	11.78	51.06%
Laredo	La Salle	IH 35	SB	Outside (L1)	6213	23377	40.11	65.00	51.00%	12.25	57.91%
Laredo	La Salle	IH 35	SB	Inside (L2)	2656	9994	5.76	65.00	14.00%	12.74	54.87%
Odessa	Midland	FM 1787	SB	Outside(L1)	2675	4831	8.85	65.40	33.80%	16.29	49.20%
Odessa	Midland	FM 1787	SB	Outside(L1)	2623	4737	7.99	64.70	30.20%	11.53	48.96%
Fort Worth	Wise	SH 114	EB	Outside (L1)	4802	23571	39.38	65.00	33.00%	16.97	44.70%
Fort Worth	Wise	SH 114	EB	Inside (L2)	3236	15884	8.80	65.00	16.00%	17.48	28.40%
Fort Worth	Wise	SH 114	WB	Outside (L1)	4378	21490	37.31	65.00	39.00%	11.56	36.90%
Fort Worth	Wise	SH 114	WB	Inside (L2)	2844	13960	6.87	65.00	15.00%	8.37	28.10%
Fort Worth	Wise	SH 114	EB	Outside (L1)	5800	10476	38.69	67.01	47.10%	12.53	54.12%
Brownwood	Comanche	SH 6	NB	Outside(L1)	1862	3362	3.76	68.34	22.10%	9.28	46.00%
Laredo	Dimmit	FM 468	EB	Outside(L1)	1380	2493	13.50	59.43	47.30%	11.14	61.30%
Amarillo	Potter	IH 40	EB	Outside (L1)	4774	11759	49.67	70.00	58.00%	16.57	55.91%
Amarillo	Potter	IH 40	EB	Inside (L2)	1140	2808	5.47	70.00	28.00%	14.27	45.57%
Amarillo	Potter	IH 40	WB	Outside (L1)	4722	11754	43.44	70.00	58.00%	17.12	54.86%
Amarillo	Potter	IH 40	WB	Inside (L2)	1340	3301	7.07	70.00	21.00%	14.35	46.75%

Figure 22 Example Data Export from The T-DSS (FPS Input Data).

SECTION V. DATA ANALYSIS MACROS AND CLUSTERING ALGORITHMS

Three types of data analysis macros were developed to ensure consistent and efficient data analysis procedure. These macros are managed in the 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. The three data analysis macros are:

a) Portable WIM data analysis macro
b) Permanent WIM data analysis macro
c) Clustering analysis macro

THE PORTABLE WIM DATA ANALYSIS MACRO

Once the raw data from the portable WIM unit is downloaded, it can be quickly parsed to several excel files each representing one-day data set. These daily raw data will usually still be in an unorganized state and doesn't represent any meaningful or interpretable data. The purpose of the portable WIM macro is to obtain the excel raw data and then, generate the M-E compatible traffic data for pavement design. Figure 23 shows the Portable WIM macro main screen.

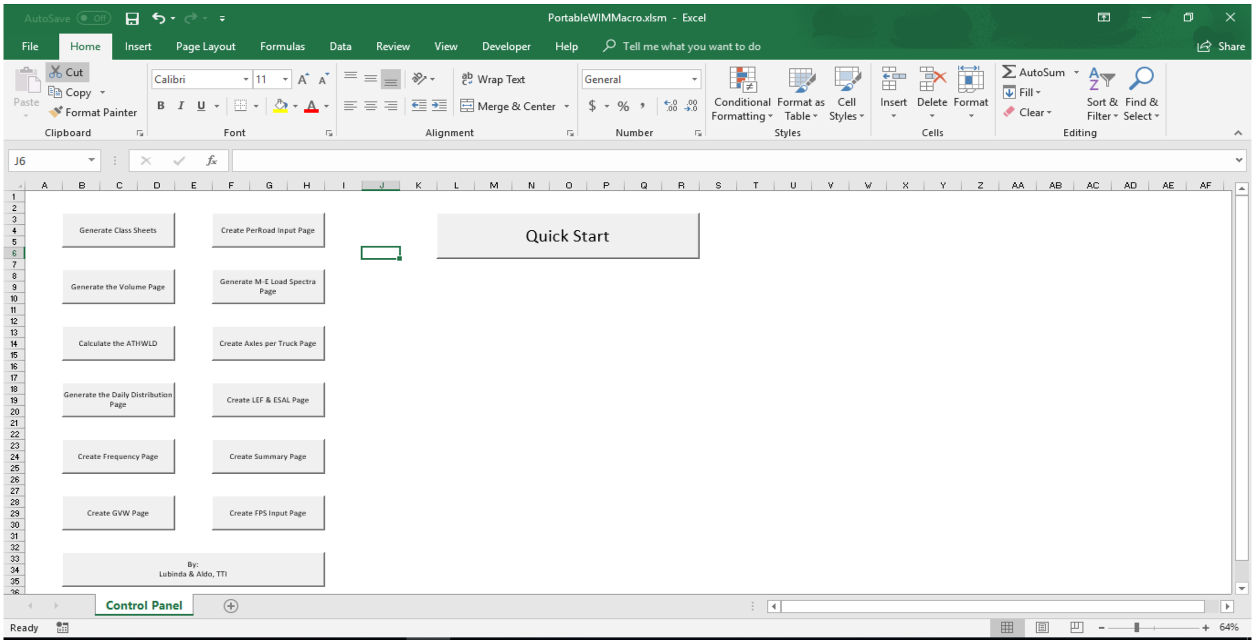


Figure 23 Portable WIM Macro Main Screen

In order to operate the Portable WIM macro, the user can simply clicks on the "Quick Start" button, pick the destination folder where the result of the macro will be saved, then pick the raw data files that are going to be analyzed. It is recommended to have at least 7 days of data to ensure complete weekly data analysis. Additionally, the user can also generate specific desired outputs from one of the 12 buttons on the left side of the control panel. The macro running time ranges from 10 minutes to one hour depending on a highway's traffic volume and data quantity.

THE PERMANENT WIM DATA ANALYSIS MACRO

The Permanent WIM data analysis macro has a similar purpose like the portable WIM macro but it is custom designed specifically for permanent WIM data analysis. Both Permanent WIM and portable WIM systems have two different formats of raw data, thus two separate macros were created for each system. Figure 24 shows the main screen for the permanent WIM Macro:

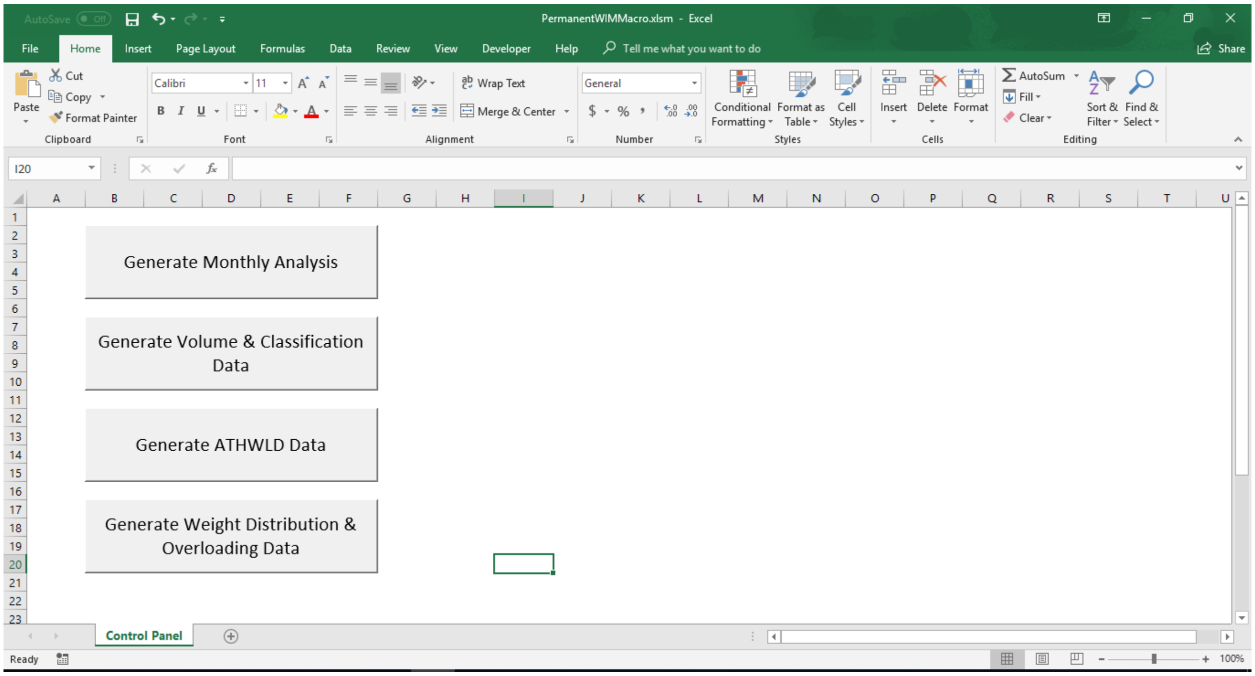


Figure 24 Permanent WIM Main Screen

Due to the huge data size and different format of the permanent WIM station raw data, the permanent WIM station has slightly different methodology than portable WIM raw data. Users can click on the "Generate Monthly Analysis" button, pick the destination folder for monthly analysis, then select all of the raw data that needs to be analyzed. This will generate an analyzed version for each raw data selected, this type of files are the ones needed for the next three analysis outputs, namely: Volume Analysis, Weight Analysis, and Class Analysis. Each of the outputs can be generated from the "Generate Volume & Classification Data", "Generate ATHWLD Data", & "Generate Weight Distribution & Overloading data" buttons, respectively. The minimum macro running time is 8 hours and can go up to over 48 hours depending on the station data quantity.

THE CLUSTER ANALYSIS MACRO

The purpose of the cluster analysis macro is to predict the most similar WIM stations based on the input given from the user. The program takes on four inputs as its indicator: Functional Class, AADTT, % Truck, & C5/C9 Ratio. Once the inputs are submitted, the macro will analyze the data and suggest the stations with the most similar attributes based on a scoring system. As of now, there are 36 stations in the clustering macro database, further addition of station data would improve the prediction analysis of the macro. Figure 25 shows the main screen of the Cluster macro:

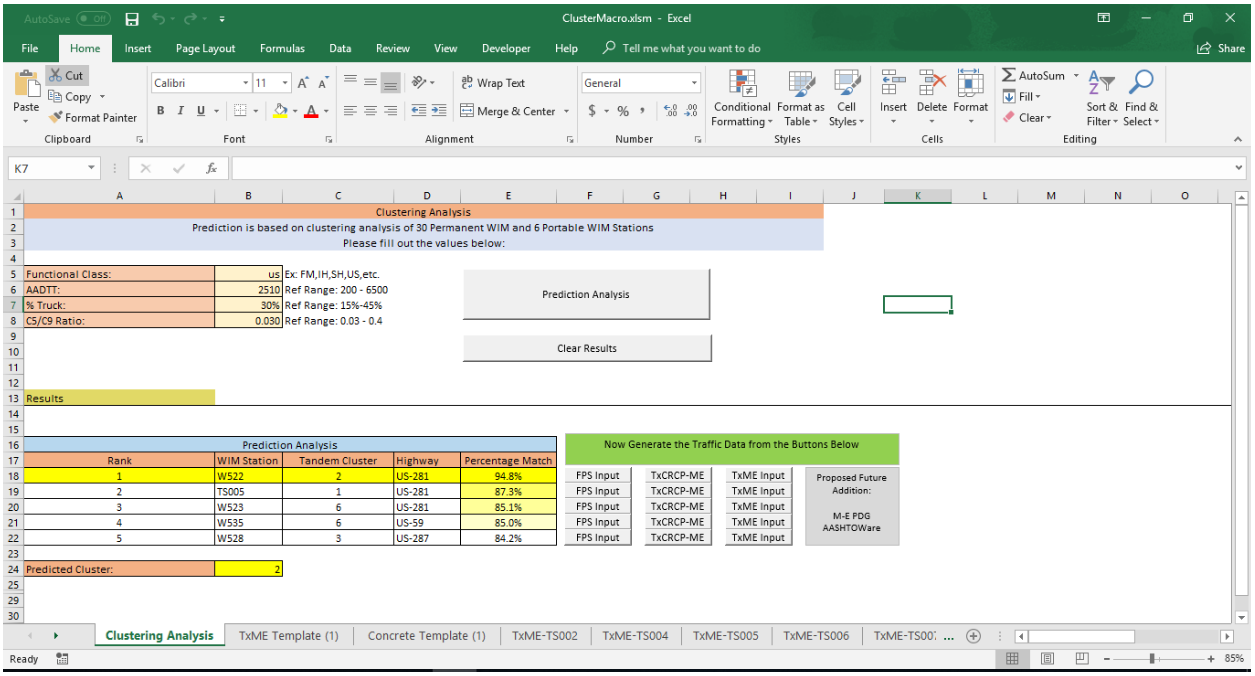


Figure 23 Cluster Macro Main Screen

The cluster macro outputs 5 of the most similar stations and presents each station's FPS Input, TxCrCRCP-ME Input, and TxME Input data. The user can then select his preference and then generate the required traffic data. Current running time is less than 10 minutes.