# Louisiana Transportation Research Center

## Final Report 582

## Prep-ME Software Implementation and Enhancement

by

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16. Abstract

Highway agencies across the United States are moving from empirical design procedures towards the mechanistic-empirical (ME) based pavement design. Even though the Pavement ME Design presents a new paradigm shift with several dramatic improvements, it requires extensive data needs for the calibration and implementation process. Through the transportation pooled fund study TPF-5(242), the Prep-ME software is released with the capabilities of pre-processing, importing, checking the quality of Weigh-In-Motion (WIM) traffic data, and generating three levels of traffic data inputs with built-in clustering analysis methods for Pavement ME Design. This Phase III project is to assist participating state DOTs on the full implementation of Prep-ME software by delivering on-site and webinars training, providing timely technical support on a need basis, and addressing state's feedback and comments. A new generation of Prep-ME software is delivered to the participating states with enhanced and customized features, which can be used by pavement design engineers to prepare input for Pavement ME Design, and traffic data collection engineers to collect better traffic data and manage those data for other applications.

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# ABSTRACT

Highway agencies across the United States are moving from empirical design procedures towards the mechanistic-empirical (ME) based pavement design. Even though the Pavement ME Design presents a new paradigm with several dramatic improvements, it requires extensive data needs for the calibration and implementation process. Through the transportation pooled fund study TPF-5(242), the Prep-ME software is released with the capabilities of pre-processing, importing, checking the quality of Weigh-In-Motion (WIM) traffic data, and generating three levels of traffic data inputs with built-in-clustering analysis methods for Pavement ME Design. This Phase III project is to assist participating state DOTs on the full implementation of Prep-ME software by delivering on-site and webinars training, providing timely technical support on a need basis, and addressing states' feedback and comments. A new generation of Prep-ME software is delivered to the participating states with enhanced and customized features, which can be used by pavement design engineers to prepare input for Pavement ME Design, and traffic data collection engineers to collect better traffic data and manage those data for other applications.

# ACKNOWLEDGMENTS

This pooled-fund study was led by the Louisiana Transportation Research Center (LTRC), supported by nine participating states including Louisiana, North Carolina, Michigan, Wisconsin, Maryland, Kentucky, New Hampshire, Hawaii, and Nevada. This project would not have been possible without their technical assistance and financial support. Special thanks go to Christopher Wagner at Federal Highway Administration (FHWA) for his support and encouragement during the development of the Prep-ME software.

# IMPLEMENTATION STATEMENT

Upon completion of this project, participating states will have the ready-to-implement Prep-ME database tool set to prepare inputs for Pavement ME Design and collect more robust traffic data for other potential applications. This tool will serve as the companion tool that can seamlessly communicate with Pavement ME Design in a full-production environment for the local calibration and implementation. In particular, the customized Prep-ME software can be used by state highway agencies by:

- Helping state traffic data collection engineers to conduct an effective quality control and quality assurance (QC/QA) on traffic data collected for various applications, such as pavement design, HPMS, traffic planning, bridge design, etc.
- Helping state pavement design engineers to analyze the traffic loading data collected through the WIM technology and select the best load spectra for pavement design purpose among WIMs, national, and local defaults.
- Improving the productivity of the above tasks operation.

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# INTRODUCTION

Pavement ME Design (previously MEPDG/DARWin-ME) is a significant advancement in pavement design, but requires more inputs from various sources *[1, 2]*. In mid-2011, through efforts by LTRC, FHWA, and the Louisiana Department of Transportation and Development (DOTD) initiated a state pooled-fund study TPF-5(242) with nine participating agencies to expand the functions of the originally developed Prep-ME software program. In this Phase II study, a unified and consistent architecture was re-designed, documented, and implemented for Prep-ME.  The redesign results have created extensive improvements of the user interfaces, software efficiency, software functionality, and software stability based on close consultation with participating states' requirements *[3]*. The Prep-ME software produced from the Phase II project is capable of pre-processing, importing, checking the quality of raw Weigh-In-Motion (WIM) traffic data, and generating three levels of traffic data inputs with built-in clustering analysis methods for Pavement ME Design. This software complies with FHWA Traffic Monitoring Guide (TMG) and TMAS for quality assurance and quality control (QA/QC) *[4]*. Additionally, Prep-ME can be used by state highway agencies for the QA/QC of traffic data collection, analysis of truck loading data, and preparation of input for AASHTO Pavement ME software.

The Prep-ME software can reduce the efforts in data preparation for the implementation and local calibration of Pavement ME Design. Most participating state DOTs plan to use Prep-ME software for ME-based pavement design and the local calibration of Pavement ME Design in the near future. Although several face-to-face group meetings were held in Phase II of this project, such training was targeted for a wide range of audience and focused on reporting of project progress and gaining feedback for future directions. This training may not be sufficient and effective for training state engineers on how to implement the Prep-ME software for their usages. Therefore, hands-on training and continuing support was desired for the full implementation of Prep-ME software. Software training, testing and support of the Prep-ME software was an integral and important phase for the software development life-cycle (SDLC). Engineers from pavement, traffic, materials, and other relevant areas should be encouraged to attend the on-site training. Real data sets from state DOTs should be used for the training so that discussions of the data, software functionality, and future enhancements and directions can be initiated and implemented in Prep-ME. This process ensured that defects were recognized as soon as possible and software enhancements were developed. Issues that arose during Phase III external testing through this project should be addressed immediately.

The objective of the proposed Phase III project was to assist participating state DOTs on the full implementation of Prep-ME software for traffic data collection and Pavement ME Design and to deliver new generation of Prep-ME software with enhanced and customized features for each individual state. Upon completion of this project, participating state DOTs would have a software and database tool set used by pavement design engineers to prepare input for Pavement ME Design and traffic data collection engineers to collect traffic data with better quality and manage those data for other applications. With the remaining funds from the Phase II project, a survey was conducted among participating states and the proposed tasks were prioritized and performed in Phase III as below:

- Task 1 - Provide On-Site and Webinar Training for Participating States,
- Task 2 - Develop Portable Version of Prep-ME for Field Data Collection and WIM Calibration,
- Task 3 - Enhance Existing Traffic Module in Prep-ME, and
- Task 4 - Provide Technical Support to Meet State Needs.

# OBJECTIVE

The objective of this project was to assist participating state DOTs on the full implementation of Prep-ME software for traffic data collection and Pavement ME Design and to deliver new generation of Prep-ME software with enhanced and customized features for each individual state.

Upon completion of this project, participating state DOTs would have a production level Prep-ME software and database tool used by pavement design engineers to prepare input for Pavement ME Design and by traffic data collection engineers to collect better traffic data and manage those data for other applications.

# SCOPE

The scope of this project was to assist TPF-5(242) participating state DOTs in the data preparation for the Pavement ME Design and improve the management and workflow for more accessible ME Design input data sets with high quality. A new generation of Prep-ME software with enhanced and customized features were developed per the request from each individual state. In addition, technical support was provided to individual states during their daily implementation of Prep-ME software for traffic data collection and Pavement ME Design.

# METHODOLOGY

The goal was to assist participating states fully implementing Prep-ME for Pavement ME Design and traffic data collection. Four research tasks were considered for this project based on comments and feedback from several participating states and FHWA, including:

- Task 1 - Provide On-Site and Webinar Training for Participating States
- Task 2 - Develop Portable Version of Prep-ME
- Task 3 - Enhance Existing Traffic Module in Prep-ME
- Task 4 - Provide Technical Support to Meet State Needs

Upon completion of this project, participating state DOTs would have a software and database tool set used by pavement design engineers to prepare input for Pavement ME Design and by traffic data collection engineers to collect better traffic data and manage those data for other applications.

## Provide On-Site and Webinar Training for Participating States

In this task, the OSU research team worked closely with each participating state and provided on-site and/or webinar training on how to implement the Prep-ME software for their Pavement ME Design, traffic data collection, and analysis. The research team conducted a survey within the participating states. Six states (Louisiana, Michigan, North Carolina, Wisconsin, Kentucky, and Nevada) expressed their interests in on-site software training. Additionally, webinars were provided to all participating states and other users as part of the training. Engineers from pavement, traffic, and other relevant areas attended the on-site training or webinar. Real data sets from participating states were obtained and used for the training to demonstrate the Prep-ME software functionality and its use by pavement design and traffic data collection engineers to improve operation productivities. Desired enhancements of software capabilities were discussed during the training for each state and software was improved and customized based on the comments.

The deliverables of Task 1 were on-site training courses for requested participating states, and online webinar training sessions.

## Develop Portable Version of Prep-ME

The Prep-ME software from Phase II was capable of conducting comprehensive data check for permanent WIM traffic data. Due to the high construction and maintenance costs of continuous WIM systems, portable WIM and short-term count programs are used by many state DOTs. Therefore, developing a portable version of Prep-ME that was capable to check traffic data in the field was necessary in Phase III of this project. With the assistance of the portable Prep-ME software, data issues could be identified immediately in the field and correction activities might be taken on-site, saving participating states' time and costs. More importantly, it assured state DOTs collect high-quality traffic data that could be used for Pavement ME Design. The portable version of Prep-ME software would also help engineers view WIM data and conduct relevant data analysis and comparisons in the field operations.

## Enhance Existing Traffic Capabilities in Prep-ME

The Prep-ME software from Phase II of this project had robust traffic module, which could be used by state highway agencies for the QA/QC of field traffic data collection, analysis of truck loading data, and preparation of input for AASHTO Pavement ME software. In this Phase III project, the research team continued improving the Prep-ME software based on further feedback from participating states during the implementation process. Any issues or bugs were addressed or corrected in the enhanced Prep-ME software. New desired features from participating states during Phase III of this project were added to enhance the existing capabilities in Prep-ME. Below were two desired features identified in Phase II from participating states, which were developed in the Phase III software.

- Fully testing the software compatibility and developing new features for WIM data collected following the 2013 TMG *[4]*, and
- Developing site-specific traffic parameters, such as AADTT, percentage of trucks in design lane, percentage of traffic in design direction etc., for Level 1 output.
  The deliverable of Task 3 was the enhanced/customized Prep-ME software.

## Provide Technical Support to Meet States' Special Needs

During the implementation of Prep-ME for daily traffic data collection and ME-based pavement design, technical support was provided on a need basis during the execution of this project aiming to help state DOTs deploying the Prep-ME software. Any special needs that arose from participating states during the implementation process were addressed on a timely manner for the entire time period of this project. Desired enhancement of particular software features or modules were developed with close consultation with the participating states.

The deliverable of Task 4 was to provide timely technical support for participating states.

# DISCUSSION OF RESULTS

During the implementation of Prep-ME for daily traffic data collection and Pavement ME Design, the project team interacted with individual states to address their questions and newly discovered bugs via face-to-face, on-site, remote webinar meetings, emails, and phone calls. Software debugging efforts and many improvements have been made in the final version of Prep-ME software.

## Capabilities of the Enhanced Prep-ME Software

Through this project, the Prep-ME software had 21 iterations of improvements based on comments and feedback from participating states. The enhanced Pre-ME software has the following capabilities.

### Traffic Data Import

The enhanced Prep-ME software is able to:

- Import traffic data that comply with the data formats recommended in the 2001 and the 2013 TMG. Such data sets can be collected with various data collection techniques (such as weigh-in-motion and automatic vehicle classification) and time coverage (such as permanent long-term and short-term counts).
- Conduct Travel Monitoring Analysis System (TMAS 2.0) data check for each line of raw data, and report errors into an error log file for each imported file. Duplicate data and data with fatal and critical errors are not imported into the Prep-ME database. The software interface reports the number of rows of data importation, number of records that failed the TMAS check, failure rate in percentage, and number of rows that are duplicate in the data import, as shown in Figure 1.
- Activate the most recent geo-referenced Google Map API (version 3.27) after data importation. This mapping utility has all major functions of Google Map and allow users to retrieve detailed information for each data input site (Figure 2).
- Process the data that passed the TMAS data check and save them in the Prep-ME database tables.

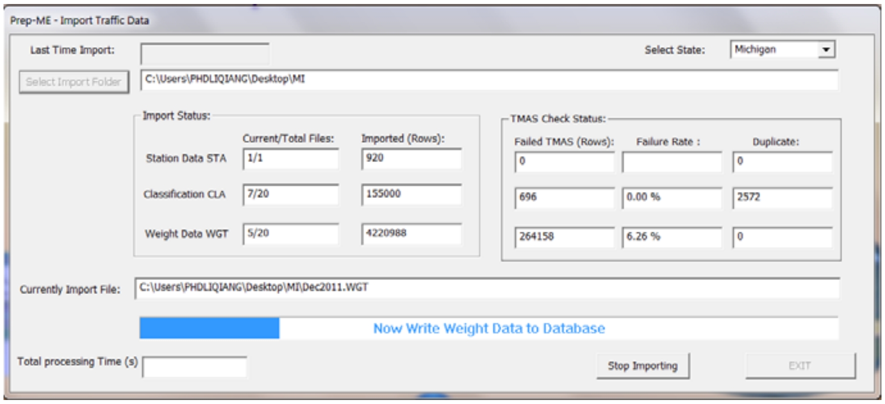



**Figure 1**

**Traffic data import**

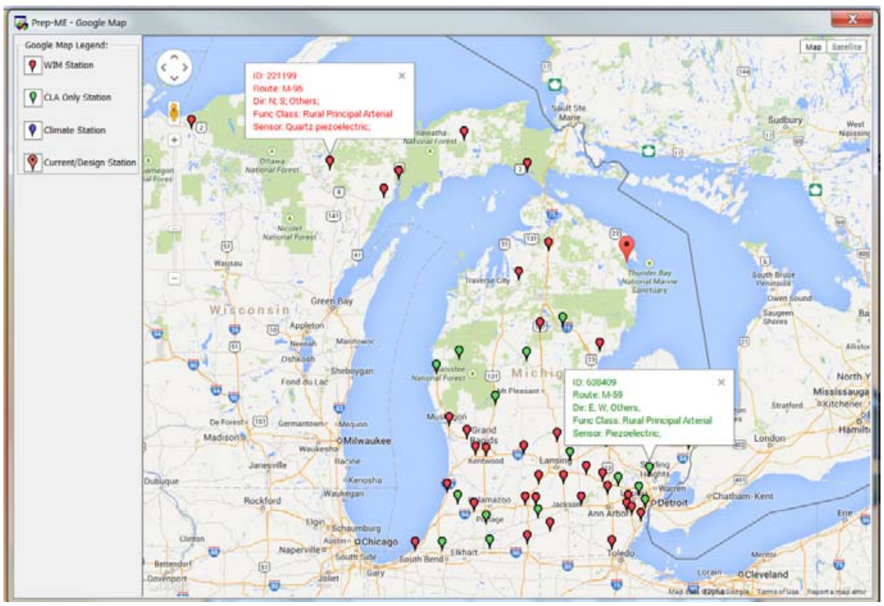



**Figure 2**

**Google map utility**

**Traffic Data Check**

The Traffic Data Check sub-menu is able to:

Conduct QC check for weight data by direction and lane of traffic using data check algorithms defined in the TMG (Figure 3). Weight data check algorithms defined in the 2001 third edition of TMG are integrated in the Prep-ME software to evaluate weight data for Class 9 vehicles. Specific weight bounds can be defined for the front axle and drive tandem axle weights of Class 9 trucks. In addition, the histogram plot of gross vehicle weights of Class 9 trucks should have two peaks, one representing unloaded Class 9 trucks between

28,000 and 36,000 lb (32,000 ± 4,000 lb), and the second peak representing loaded vehicle condition with a weigh between 72,000 and 80,000 lb (76,000 ± 4,000 lb).

- Provide interfaces for users to review monthly, weekly, and daily traffic data.
- Provide four sampling and repair options to analyze and utilize incomplete (that not have a minimum of 12-month data) or failed data (that cannot pass the automatic TMG data check algorithms), including **Manual Operation** (**Accept** and **Reject**), **Replacement** (**Copy** and **Paste**), **and Sampling Operation** (**Daily Sampling** and **Monthly Sampling**).
    - Manual Operation (Accept/Reject) allows users to review and double check the automated QC results.
    - **Replacement** (**Copy** and **Paste**) operation can be used to check the similarity of the data in adjacent months, opposite direction, or different lane, same month but different year, and then identify a suitable month which can be used as the "source month" to substitute the failed or missing month (the "target month").
    - **Daily Sampling** operation can be used as a diagnostic tool to investigate the reason(s) for bad data that cannot pass automatic data check, and sample weekly data with good quality to represent this month. (Figure 4)
    - **Monthly Sampling** can be used to select twelve months of data with the highest data quality, either right after a WIM system calibration or any 12 months' data based on engineering judgment.
- Conduct QC check for classification data by direction and lane of traffic using data check algorithms defined in the TMG. The data check criteria include the check of percentages of unclassified vehicles, Class 1 vehicles, and the consistency check in the vehicle mix so that no significant changes are observed. The consistency check is executed by comparing the current truck percentages by class with the corresponding historical percentages. The Prep-ME software provides similar software interface (Figure 5), which is able to perform automatic data check, daily check, replacement, and sampling operations for classification data. Daily sampling function is illustrated in Figure 6.

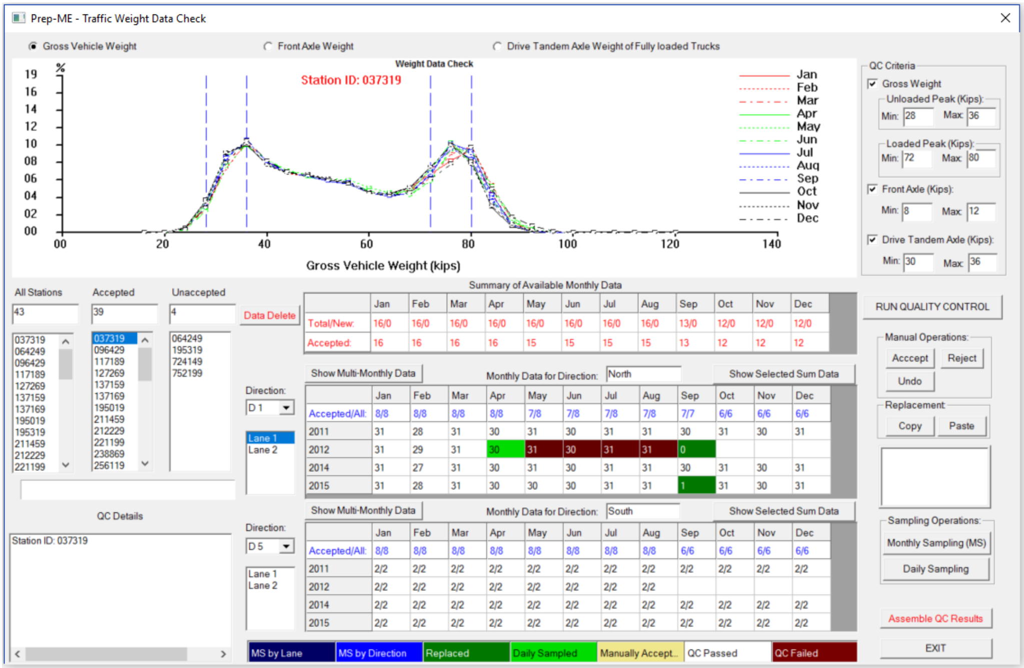



**Figure 3**

**Weight data check by direction and by lane**


**Figure 4**

**Daily check and sampling**

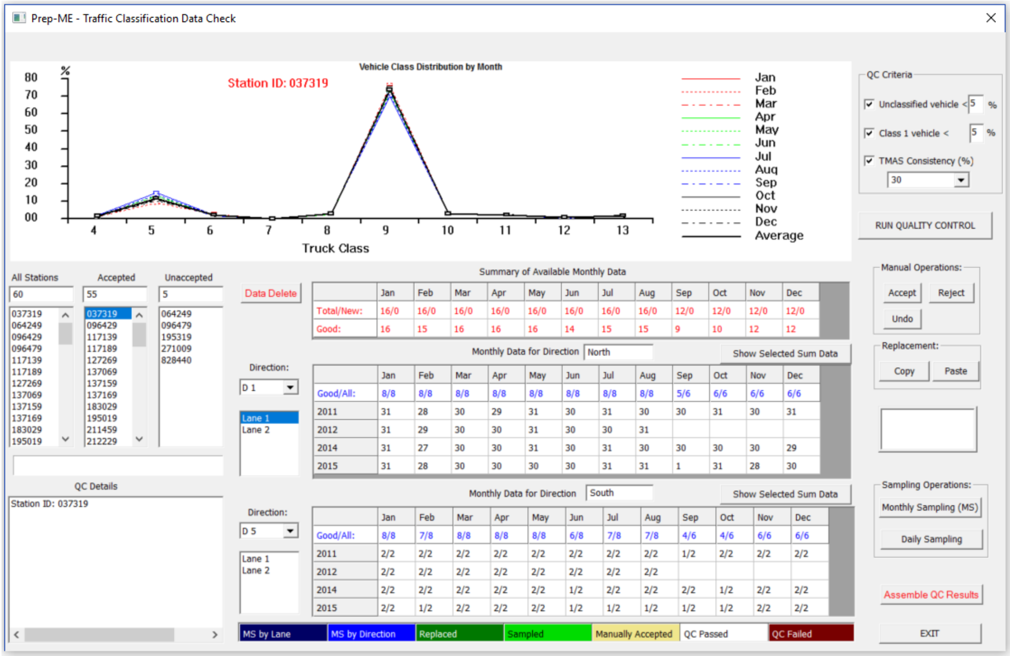


**Figure 5**

**Classification data check by direction and by lane**

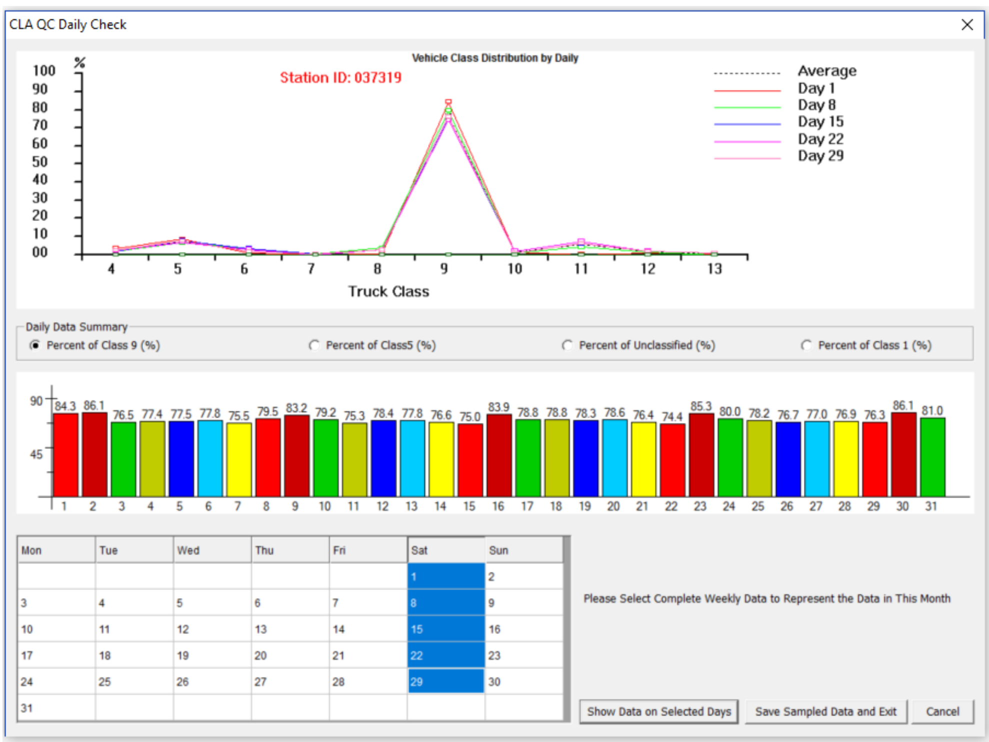


**Figure 6**

**Classification daily data check**

**Traffic Data Export**

The Export Traffic Data for traffic data is able to:

- Generate three levels of traffic outputs for Pavement ME Design (Figure 7): Level 1 Site Specific, Level 2 Clustering Average, and Level 3 State Average. The Level 1 traffic inputs can be generated for both directions and/or one direction of traffic of a specific WIM station. There are in total six clustering methods for Level 2 traffic inputs, including the NCDOT method, Michigan DOT method, KYTC method, Truck Traffic Classification (TTC) method, and simplified TTC methods, or flexible clustering. State average values, LTPP-5(004) method, or Pavement ME Design defaults can be used for Level 3 inputs. Detailed descriptions on how to use Prep-ME software for traffic inputs for Pavement ME Design can be found in the Prep-ME User's Manual *[3]*.
- Calculate two-way annual average daily truck traffic (AADTT), percentage of trucks in design direction, and percentage of trucks in design lane for Level 1 site-specific traffic output at a particular WIM site, and the state average values for number of axles by truck type (Figure 8).
- Review traffic output data and make modifications if necessary (Figure 9) on traffic output data and/or output levels before exporting XML files for Pavement ME Design or text files for MEPDG. Prep-ME allows the user to obtain outputs at different levels for the different traffic data types. For example, Level 1 is selected for Vehicle Class Distribution (VCD) data, while Level 3 data may be used for hourly adjustment factors.
- Implement independent C++ codes of Ward-based Hierarchical Agglomerative clustering algorithm, which is used in both NCDOT and MDOT clustering analysis. This algorithm will allow users to evaluate existing clusters and define new clusters if necessary (Figure 10).
- Generate 11 traffic input files in text file format for MEPDG and two XML traffic files for Pavement ME Design software.

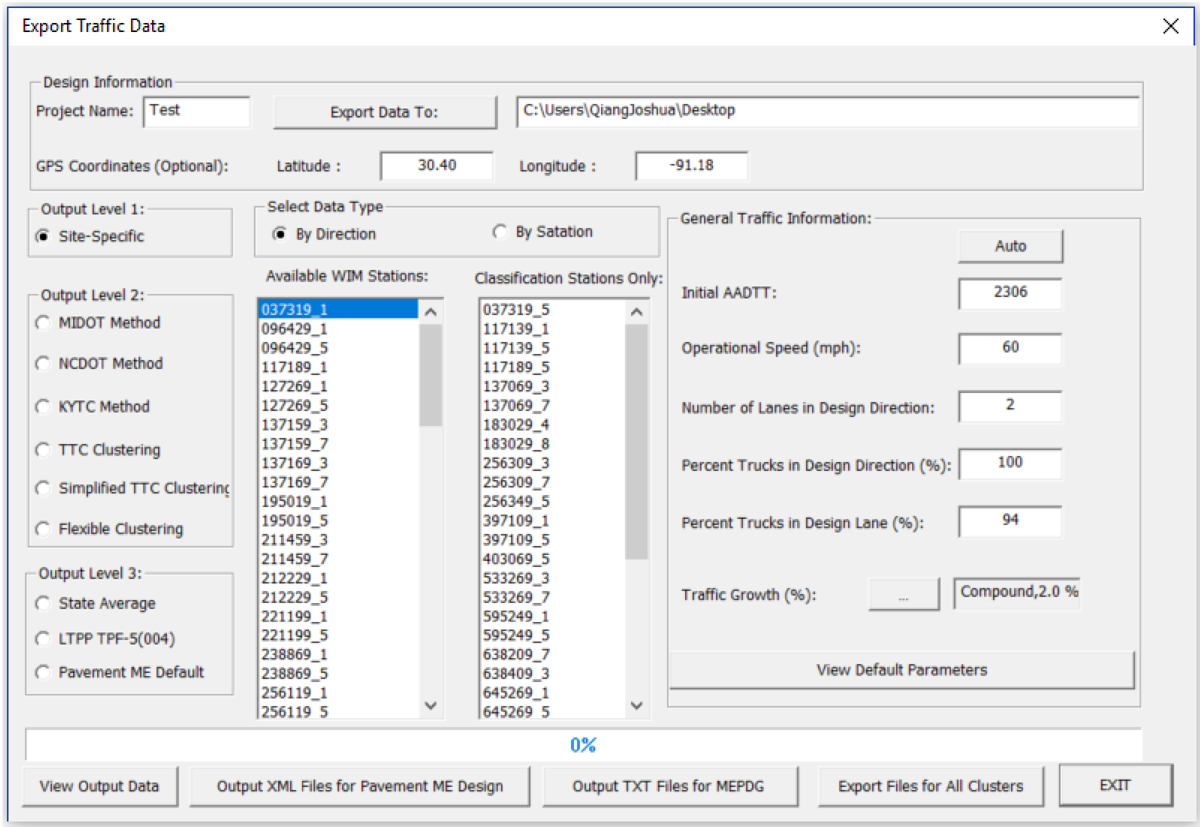



**Figure 7**

**Three-level traffic outputs for Pavement ME Design**

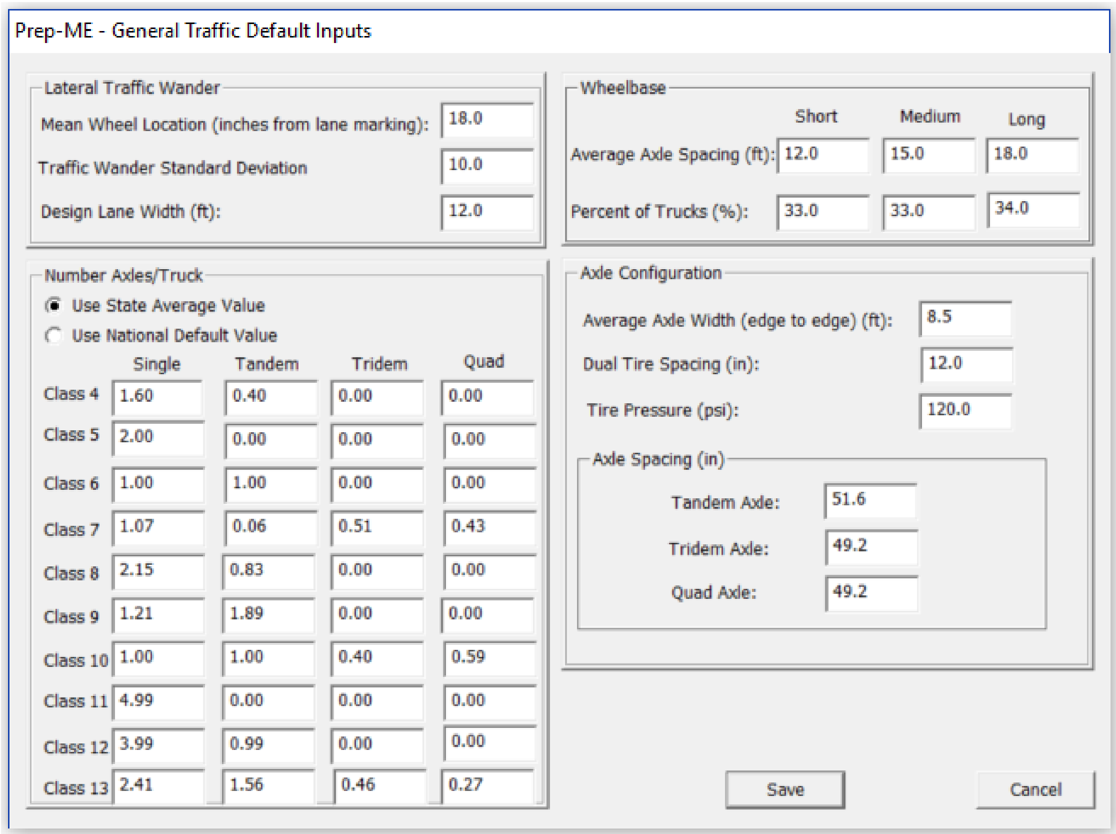



**Figure 8**

**State average for number axles/truck**

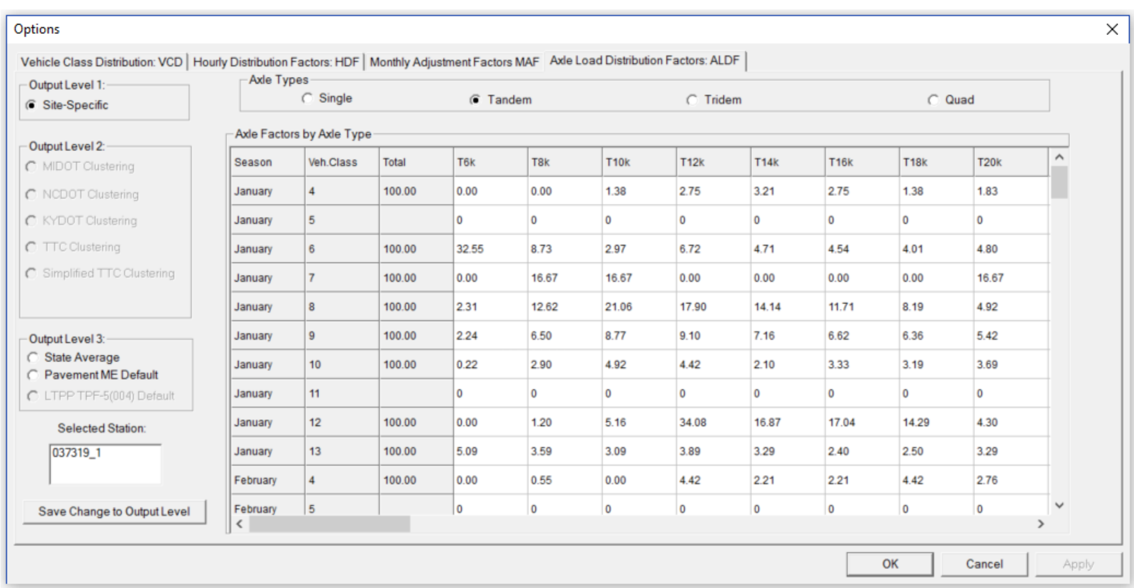



**Figure 9**

**Displaying output data**

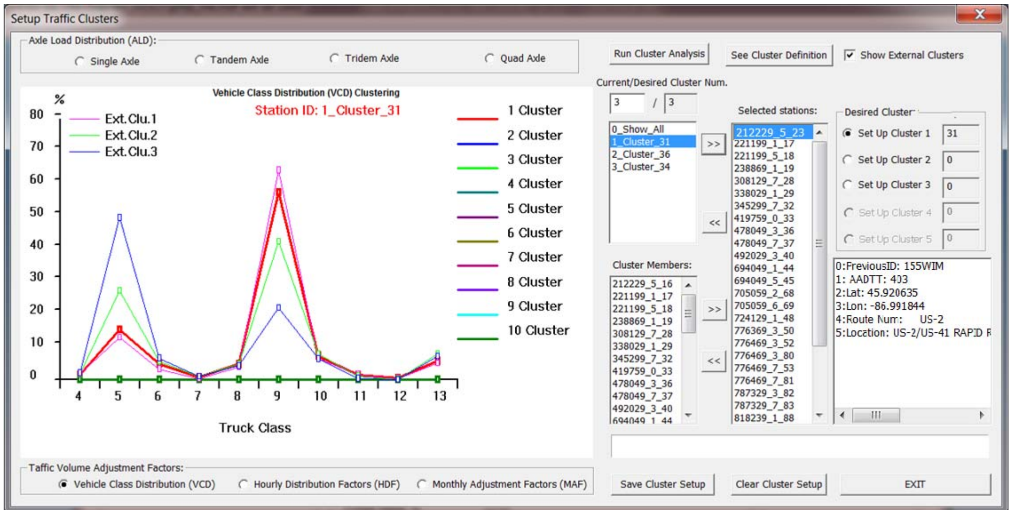



**Figure 10**
**Flexible clustering method**

## Climate Module

The Climate Module in Prep-ME 3.0 is able to:

- Import Hourly Climate Data (HCD) files, including those from the Pavement ME Design software and new data sources provided by state DOTs, into Prep-ME database.
- Conduct preliminary data checks to the raw climate data.
- Interpolate ICM file and XML file that can be directly imported to MEPDG and the Pavement ME Design software (Figure 11).

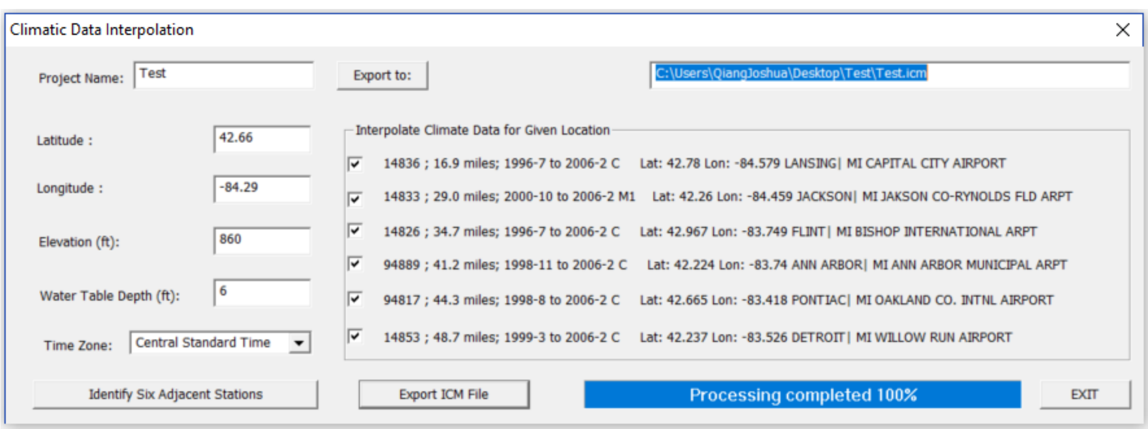



**Figure 11**
**Interpolating climate files**

## Material Module

The Material Module in Prep-ME 3.0 is able to:

- Import raw FWD F25 data into Prep-ME database, output a summary report for back-calculation software, and generate FWD XML file for Pavement ME Design.
- Retrieve dynamic modulus (E*) data for hot mix asphalt materials from statewide material library for Pavement ME Design (Figure 12). The Prep-ME software can retrieve dynamic modulus data based on binder grade, nominal maximum aggregate size, air void level, and coarse aggregate type.
- Retrieve Coefficient of Thermal Expansion (CTE) data for PCC materials from statewide material library for Pavement ME Design (Figure 13). The Prep-ME software can retrieve CTE data based on coarse aggregate type, cementitious paste, and mixture age.
- Retrieve subgrade soil map data developed in the NCHRP 9-23A project: *Implementing a National Catalog of Subgrade Soil-Water Characteristic Curve (SWCC) Default Inputs for Use with the MEPDG*, for Pavement ME Design (Figure 14). The group index, soil gradation, Atterberg limits, and the parameters describing the soil-water characteristic curves (SWCC) can be obtained to further subdivide soil classifications and improve the default inputs for Pavement ME Design. A soil report with all the required soil parameters is generated for users to view (Figure 15).

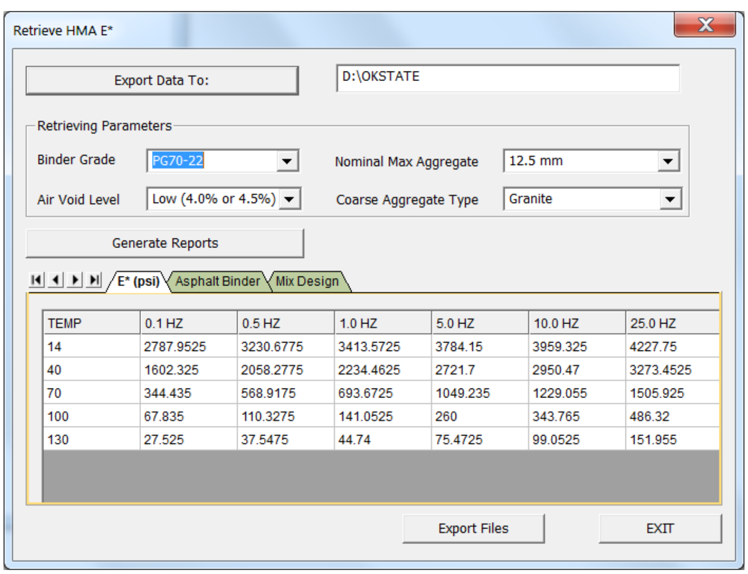



**Figure 12**
**Retrieving dynamic modulus (E*) data**

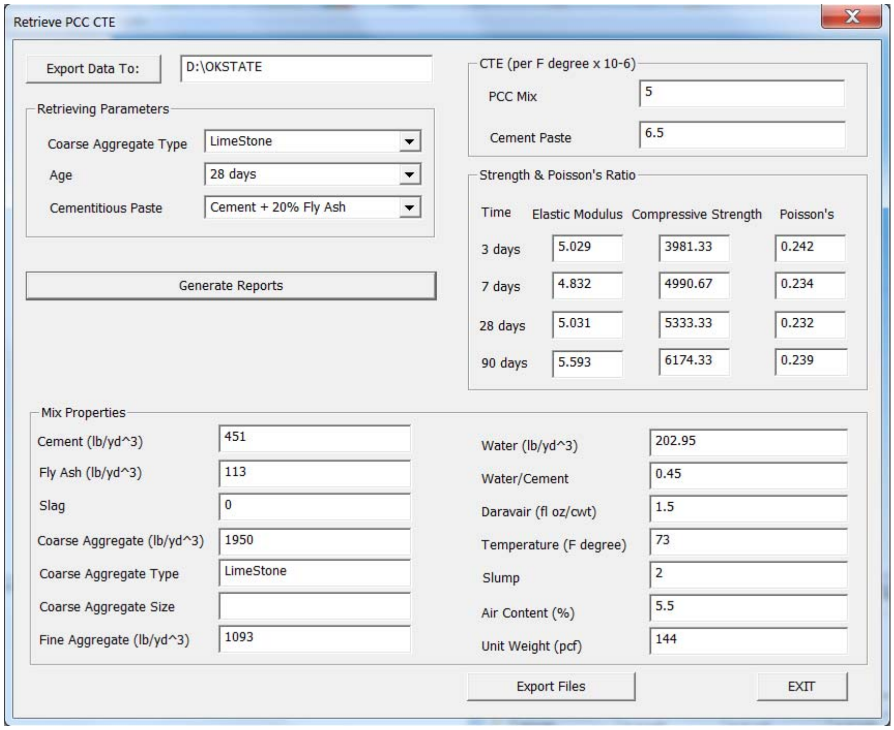



**Figure 13**
**Retrieving CTE data**

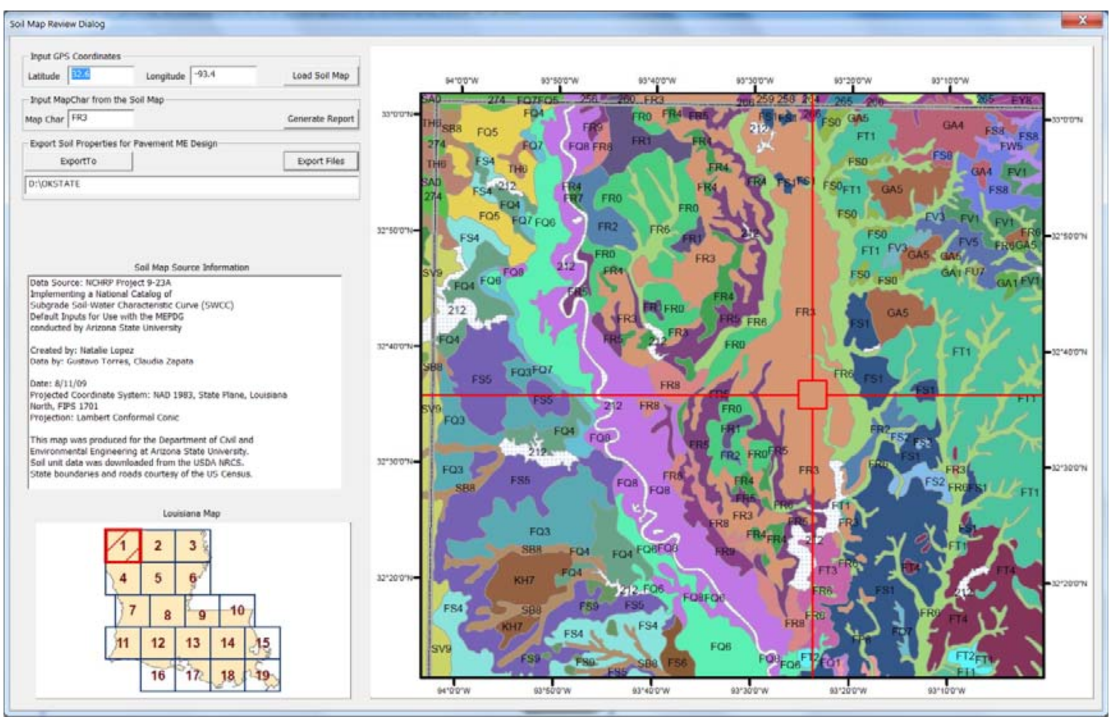



**Figure 14**
**Soil map module in Prep-ME**

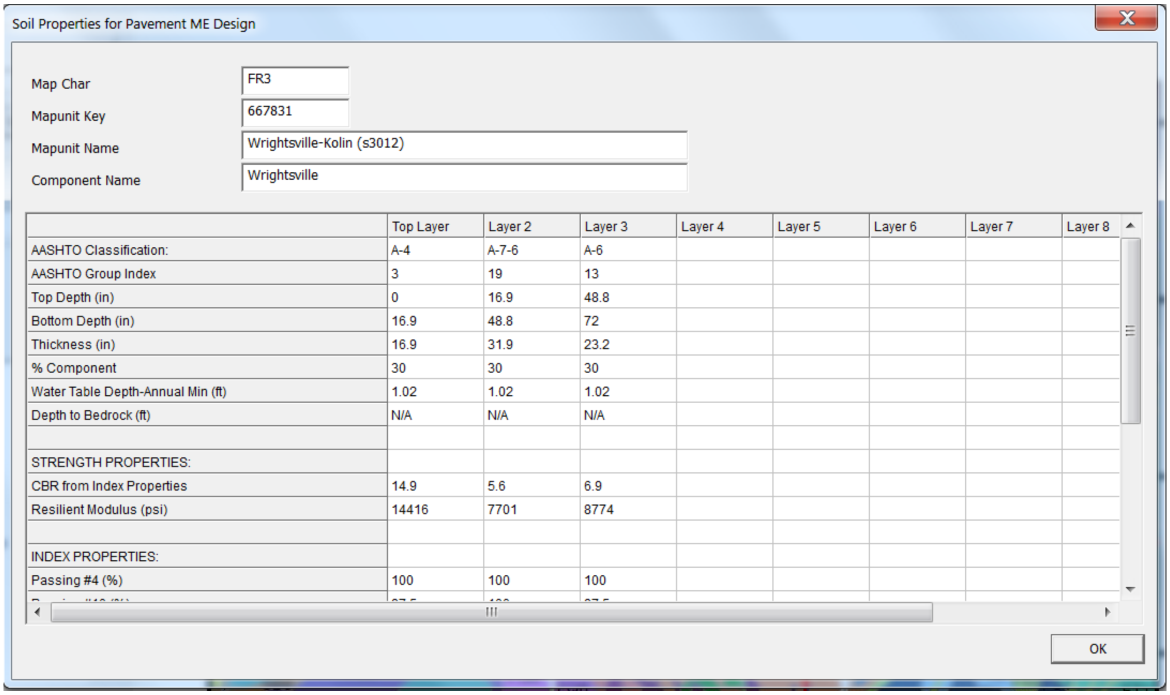



**Figure 15**
**Retrieved soil properties**

## Capabilities of Portable Prep-ME

The current version of Prep-ME is capable of conducting comprehensive data check for permanent WIM traffic data. Due to the high construction and maintenance costs of continuous WIM systems, portable WIM and short-term count programs are used by many state DOTs. Therefore, developing a portable version of Prep-ME that is capable to check traffic data in the field is critical. Data issues can be identified immediately in the field and correction activities may be taken on-site. This effort will save participating states' time and costs and more importantly assure state DOTs to collect high-quality traffic data that can be used for Pavement ME Design. The portable version of Prep-ME software will also help engineers view WIM data and conduct relevant data analysis and comparisons during WIM calibration process. Customized based on the full version Prep-ME software, the portable version of Prep-ME is customized based on the full version and has the following capabilities:

- Imports an agency's short-term WIM traffic data (up to a week) complying with FHWA TMG 2001 and 2013 file formats, and store the data in SQL server Local database.

- Conduct Travel Monitoring Analysis System (TMAS 2.0) data check and generate TMAS check error summary log for each imported raw file.
- Provide interface to review/check the quality and consistency of vehicle classification and weight data. The hardware and software requirements remain the same as those for the full version of Prep-ME. Portable Prep-ME has only one user interface with two modules: **Import Traffic Data** and **Review Traffic Data** (Figure 16).

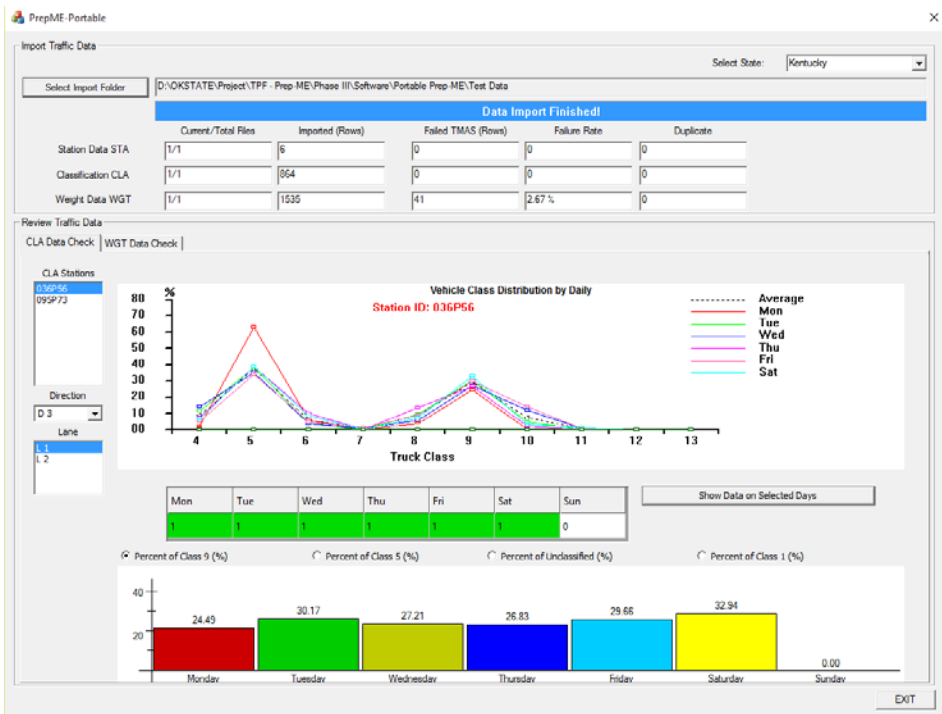



**Figure 16**
**Portable Prep-ME interface**

The portable Prep-ME can show daily data or multiple days of data up to a week to check the consistency of the collected traffic data by direction and by lane for each station (Figure 17). Similar to the full version of Prep-ME software, the weight data are checked according to the three criteria for Class 9 vehicles as defined in TMG. In addition, related information regarding the “Daily Class 9 Truck Counts,” “Percent of Front Axle within TMG Tolerance (%),” “Percent of Drive Tandem within TMG Tolerance for Fully Loaded Trucks (%)” are also provided for user’s reference.

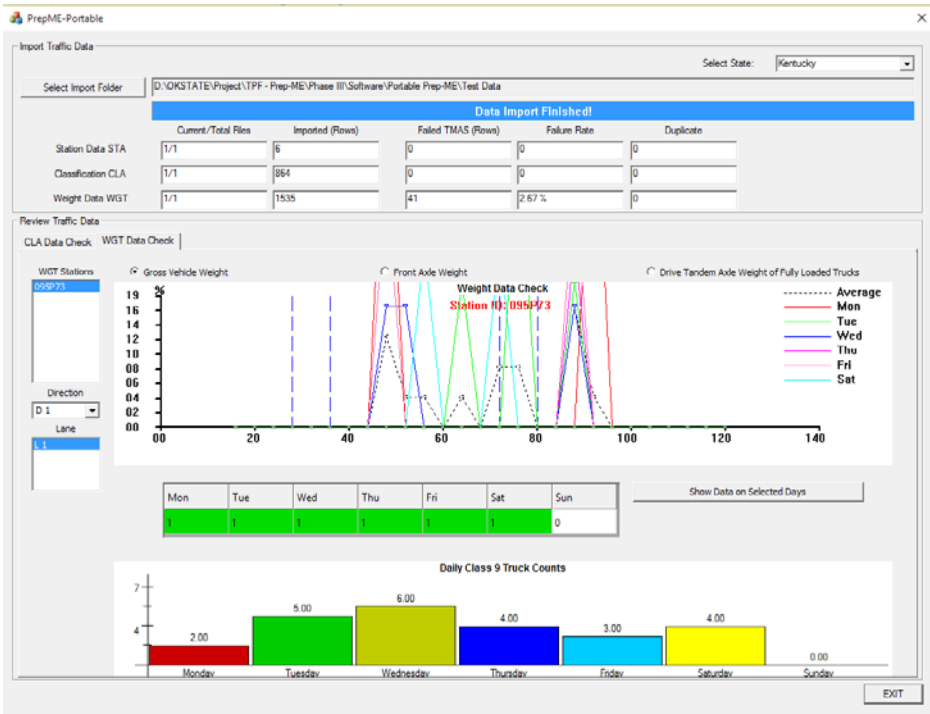



**Figure 17**
**Weight data check by direction and lane**

The Portable Prep-ME software can perform classification data check by direction and lane for each station (Figure 16). The percentages of Class 9, Class 5, Class 1, and unclassified vehicles within the truck stream are also provided to assist users in investigating the WIM data quality. It should be noted that the portable Prep-ME is designed for the preliminary check of short term WIM data in the field, but not the process and storage of the WIM data (which should be completed in the full version of Prep-ME software). Therefore the WIM data imported to the Portable Prep-ME database are discarded when the software is closed.

## Education and Training of Prep-ME

The project team has been working closely with participating states to assist them on the full implementation of Prep-ME software. Technical support is provided on a need basis during the execution of this project. Any special needs that arise from participating states during the implementation process are addressed on a timely manner, and desired enhancement of software features or modules are developed in close consultation with the participating states. In addition, the OSU team has been rigorously testing the software internally on a regular basis to assess the final quality of the software in terms of its accuracy, completeness, reliability, efficiency, maintainability, compatibility, and usability. A final version of the new generation Prep-ME software is developed with enhanced and customized features based on comments and feedback from individual states. The final version is delivered to the participating states.

The OSU team has provided training to assist participating states implementing Prep-ME for Pavement ME Design. First, six states have received on-site training, including Nevada (February 24 – 25, 2016, in Carson City, NV); Kentucky (March 8 – 9, 2016, in Frankfort, KY); North Carolina (April 14 – 15, 2016, in Garner, NC); Michigan (May 11 – 12, 2016, in Lansing, MI); Wisconsin (July 11 – 12, 2016, in Madison, WI); and Louisiana (February 1 - 2, 2016, in Baton Rouge, LA). Each training lasted for one full day to one and a half days with 10 to 30 attendees from pavement design, pavement management, traffic data collection, traffic analysis and forecasting, materials, and geotechnical divisions. The capabilities of Prep-ME were demonstrated using state specific WIM data sets. At the end of each training, a summary of the training was prepared including the data sources, level of input, the corresponding software tool, and the responsible personnel to generate the data for each traffic input parameter required in Pavement ME Design. Desired enhancements of software capabilities arouse from the face-to-face meeting are discussed with each state and subsequently the Prep-ME software is improved and customized based on the consensus between the individual state and the project team. Additionally, webinars were provided to all participating states and other users as another important part of the training. An example "Agenda for TPF-5(242) Project Meeting: Prep-ME Software Demonstration" for the on-site meeting with Michigan is attached in Appendix A, and the Microsoft PowerPoint slides for the webinar training are included in Appendix B.

# CONCLUSIONS

The final full-production Prep-ME software has been enhanced from this pooled-fund study. Prep-ME is capable of pre-processing, importing, checking the quality of raw WIM traffic data, and generating three levels of traffic data inputs with built-in clustering analysis methods for Pavement ME Design. This software complies with FHWA TMG and TMAS for QA/QC, and can be used by state highway agencies for the QA/QC of traffic data collection, analysis of truck loading data, and preparation of input for AASHTO Pavement ME software.

This project assisted participating state DOTs on the full implementation of Prep-ME software for traffic data collection and Pavement ME Design and delivered a new generation of Prep-ME software with enhanced and customized features for each individual state. The following tasks were performed to achieve the project objectives:

- A new generation of the Prep-ME software was developed with many enhancements and the capability to import WIM data based on both TMG 2001 and TMG 2013 format. Since the release of TMG 2013, several participating states have been collecting WIM data in accordance with the TMG 2013 format. This new capability has been tested with sample TMG 2013 WIM data from Kentucky and Wisconsin.
- A portable version of Prep-ME has been developed to assist field traffic data collection.
- The research team has coordinated with all the participating states on Prep-ME on-site trainings. Six states, including Nevada, Kentucky, North Carolina, Michigan, Wisconsin, and Louisiana, have received the training. In addition, online webinar training was provided for all participating states and other users. State WIM data were requested and used for the training to demonstrate the software functionality that can be utilized by pavement design and traffic data collection engineers to improve operation productivities. Desired enhancements of software capabilities were discussed during the training for each state and 21 rounds of software updates were released based on the comments.
- The team has been providing technical support on a needed basis in a timely manner to help states implement Prep-ME for daily traffic data collection and ME-based pavement design. Several bugs were fixed and improvements made during the execution of this project. In addition, several new features requested by participating states were added to enhance the existing capabilities in Prep-ME.

It is anticipated that the final full-production Prep-ME software and database tool set can be used by pavement design engineers to prepare input for Pavement ME Design and by traffic data collection engineers to collect better traffic data and manage those data for other applications.

# ACRONYMS, ABBREVIATIONS, AND SYMBOLS

| | |
|---|---|
| AADTT | annual average daily truck traffic |
| CTE | Coefficient of Thermal Expansion |
| DOTD | Louisiana Department of Transportation and Development |
| FHWA | Highway Administration |
| HCD | Hourly Climate Data |
| LTRC | Louisiana Transportation Research Center |
| ME | mechanistic-empirical |
| QC/QA | quality control and quality assurance |
| SDLC | software development life-cycle |
| SWCC | soil-water characteristic curves |
| TMAS | Travel Monitoring Analysis System |
| TMG | Traffic Monitoring Guide |
| TTC | Truck Traffic Classification |
| WIM | Weigh-In-Motion |
| VCD | Vehicle Class Distribution |

# REFERENCES


1. Wang, K., Li, Q., Nguyen, V., Moravec, M., Zhang, D. 2013. *Prep-ME: A Multi-Agency Effort to Prepare Data for DARWin-ME*. 2013 Airfield and Highway Pavements Conference, Los Angeles, CA.

2. NCHRP 1-37A. 2004. *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*. Applied Research Associates Inc. ERES Consultants Division, Urbana Champion, IL.

3. Wang, K., Li Q., Chen C. 2015. *Traffic and Data Preparation for AASHTO DARWin-ME Analysis and Design*, Final Report 538. Louisiana Transportation Research Center. Baton Rouge, LA.

4. Federal Highway Administration (FHWA). 2013. *Traffic Monitoring Guide*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

# APPENDIX A

## Example Prep-ME On-Site Training Agenda

# Agenda for TPF-5(242) Project Meeting: Prep-ME Software Demonstration

Michigan Dept. of Transportation
Horatio Earle Learning Center
7575 Crowner Dr., Dimondale, MI 48821
Lake Erie Room

**May 12, 2016**

| | |
|---|---|
| 8:00am | Welcome/Intro (MDOT) |
| 8:10am | Review of traffic inputs in ME (MDOT) |
| 8:40am | Review of MDOT PTR equipment locations/data (MDOT) |
| 9:10am | How Bureau of Transportation Planning provides traffic inputs for designs (MDOT) |
| 9:30am | Overview of Prep-ME (OSU) |
| **10:00am** | **Break** |
| 10:15am | Traffic import module (data format, TMAS data check, error log, common problems, Google Map) (OSU) |
| 10:30am | Weight data check module (automatic data check, replacement, monthly sampling, daily sampling etc) (OSU) |
| 11:05am | Classification data check module (OSU) |
| 11:30am | Discussions & feedback on traffic module (OSU) |
| **11:45am** | **Lunch** (attendees on their own) |
| 1:00pm | Traffic data for Pavement ME Design (Level 1, 2, and 3) (OSU/MSU)<br>MDOT clustering methodology (OSU/MSU)<br>Prep-ME traffic input and output (OSU) |
| 2:15pm | Other Modules: Climate, Material, Soil Map (OSU) |
| 2:40pm | Portable Prep-ME (OSU) |
| **3:00pm** | **Break** |
| 3:15PM | Discussion: traffic data for ME Design using Prep-ME in Michigan (MDOT) |
| 3:45pm | Future plan of Prep-ME (OSU) |
| 4:00pm | Comments and Q/A (All) |
| **4:15pm** | **Adjourn** |

# APPENDIX B

## Prep-ME Online Webinar Training PowerPoint

### Prep-ME Overview & Demonstration

for TPF-5(242) Participating States

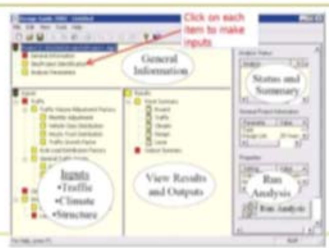
Joshua Q. Li, Ph.D., P.E.
Oklahoma State University
qiang.li@okstate.edu

### Outline

- Pavement ME Design Input Requirements
- Prep-ME Overview
- Software Demo
- Q/A

### Pavement ME Design Inputs

### MEPDG




### Input Requirements

- Traffic: loading spectra instead of ESALs
- Climate: hourly climate data
- Materials: E*, CTE, Mr
- Local calibration and implementation: AASHTO Guide

### Design Input Levels

- Level 1
  - Site and/or material specific inputs
- Level 2
  - Use of correlations to establish or determine the required inputs
- Level 3
  - Use of national or regional default values to define the inputs

Levels can be mixed and matched

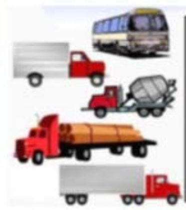
1

## Design Input Levels

- Sensitivity of performance to a given input
- The criticality of the project
- Information available at the time of design
- Resources & time available to the designer to obtain the inputs

**Increased flexibility for design & increased comfort level prior to investing significant dollars**

## Traffic Inputs for ME

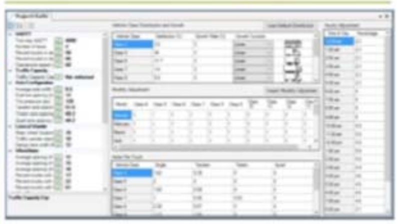


Number of axles by:
- Truck type
- Axle type
- Axle load interval

Number of axles within:
- Each year
- Season within a year
- Time of day

Wanger, 2006

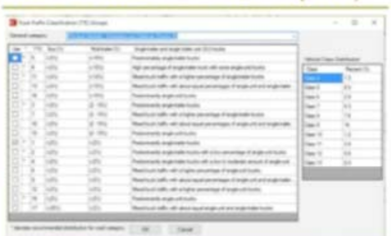
## Traffic Volume & Adjustments



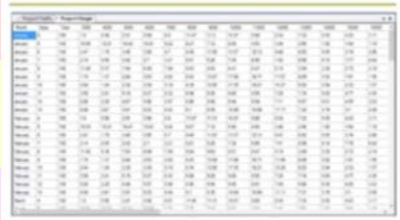
## Truck Traffic Classification (TTC)

- Highway Functional Classifications (HFC)
  - Do not properly describe the distribution of trucks traveling on the roadway
- Truck Traffic Classifications (TTC)
  - Buses (Vehicle Class 4)
  - Single Unit Trucks (Vehicle Classes 5, 6 and 7)
  - Tractor-Trailer or Truck-Single Trailer Units (Vehicle Classes 8, 9 and 10)
  - Multi-Trailer Trucks (Vehicle Classes 11, 12 and 13)

## Truck Traffic Classification (TTC)



## Axle Load Distribution Factors

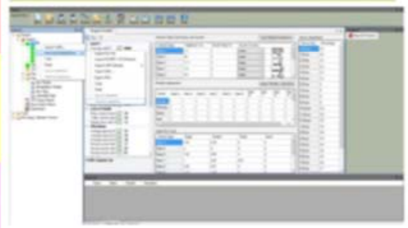


120 rows x 41 columns for each of the four axle types

## Axle Load Distribution Factors

- Percentage of axles in each load interval
  - Single axles – 3,000 lb to 40,000 lb at 1,000-lb intervals
  - Tandem axles – 6,000 lb to 80,000 lb at 2,000-lb intervals
  - Tridem and quad axles – 12,000 lb to 102,000 lb at 3000-lb intervals
- The axle load spectra for
  - All traffic classes (class 4 to class 13)
  - All axle types (single, tandem, tridem, quad
  - Each month of the year

## Traffic Import/Export Functionality



## Traffic Data Collection

- Traffic data collection programs following the Traffic Monitoring Guide (TMG) will meet ME traffic data needs
- Traffic Monitoring Elements
  - Traffic volume
  - Vehicle classification
  - Truck weight
- Continuous Count Programs
  - Automatic Traffic Recorders (ATR)
  - Automatic Vehicle Classifiers (AVC)
  - Weigh-in-Motion (WIM)

## Traffic Data Formats

- 2001 TMG Format
  - Station description data (STA)
  - Traffic volume data (#3 record ) (VOL)
  - Vehicle class. data (C-card) (CLA)
  - Truck weight data (W-card) (WGT)

**Appendix B of Chapter 6**

## Traffic Data Formats

- 2013 TMG Format
  - Station description data (STA)
  - Traffic volume data (#3 record ) (VOL)
  - Vehicle class. data (C-card) (CLA)
  - Truck weight data (W-card) (WGT)
  - Speed
  - Per vehicle data (PVF)

**Same data item: coding may be changed (such as GPS, functional class)**

## TMAS 2.0 QC Check

- Travel Monitoring Analysis System (TMAS): provides online data submitting capabilities for State traffic offices
- Data checks: for four data types (STA, VOL, CLA, WGT)
  - Errors: fatal, critical
  - Flags: caution, warning

**Appendix J of 2013 TMG**

3

## Classification Data Quality Control

(1) Compare manual classification counts with hourly AVC data
- Should be <5% for each of the primary vehicle categories
- The primary vehicle categories: VC 5, 9, 13

(2) Check the number of Class 1 (motorcycles)
- May mistakenly record trailers separated from tractors, & the last tandem of VC 13 recorded as a motorcycle
- Should be <5% unless their presence is noted

## Classification Data Quality Control

(3) Check the # of unclassified vehicles
- Should be <5% of the vehicles recorded
- May have axle sensing malfunctions

(4) Compare the current truck % by class with the corresponding historical data to determine if significant changes occurred
- Look for unexpected changes of similar vehicle classes, such as vehicle Classes 8 and 9

## Implementation of Classification QC

- Steps 1 ~ 3: straightforward
- The fourth step
  - Determine the number of trucks by class for each month
  - Calculate the normalized class distribution for each month
  - Compare the normalized class distribution for each month to determine if unexpected changes in vehicle mix had occurred (statistical procedure)

## Weight Data Check

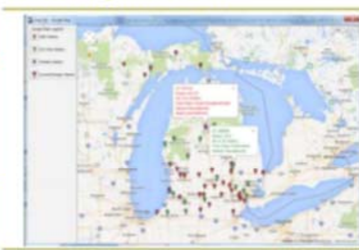
- Class 9 Truck only
- Check the Weight of Front Axle (10,000 ± 2,000 lb )
- Check the Fully Loaded Weight of Drive Tandem Axle (33,000 ± 3,000 lb )
  - Fully loaded Class 9 trucks: generally more than 72,000lb.

**2001 TMG Section 5 Appendix A**

## Weight Data Check

- Check the Gross Vehicle Weights (GVW)
  - GVW histogram at 4,000-lb. increment
  - Two peaks: 32,000 ± 4,000 lb (empty); 76,000 ± 4,000 lb (loaded)
    - Fluctuated Data: scale failed
    - Both peaks shifted: out of calibration
    - One peak shifted: should be reviewed with additional information
- Over-Weight Vehicles (<5%)

## Traffic Inputs for ME



## Traffic Inputs for ME

- Annual Average Daily Truck Traffic (AADTT): base year
- Monthly Adjustment Factors: 12 months, 10 vehicle classes
- Vehicle Class Distribution: 10 classes
- Hourly Truck Distribution: 24 hours
- Axle Load Distribution: 4 axle types (single, tandem, tridem, quad), 12 months, 10 classes
- Other Factors

## Traffic Inputs for ME

- Level 1: ideal if with site specific WIM data
- Level 3: if no data or not significant to performance
- Level 2: many research efforts based on sensitivity analysis, damage analysis, and/or cluster analysis
- **Dr. Haider: afternoon 1:00 – 1:20pm**

## ME Climate Module

## MDOT Climate Stations

## Material Inputs for ME

- Sensitivity Analysis for materials
  - Dynamic modulus (E*)
  - Coefficient of thermal expansion (CTE)
  - Resilient modulus (Mr)
- Material characterization & testing
  - Extensive efforts both at state and national level
  - Existing data: to establish state material library for Level 2 material inputs

## Material Data Import

## Material Data Import

## Prep-ME Overview

## Prep-ME Memory Lane

- Initially developed for AHTD in 2008
- Lead Agency: Louisiana Transportation Research Center (LTRC), LADOTD
- TPF-5(242) States: HI, KY, LA, MD, MI, NC, NH, WI, NV
- Additional Relevant Funding: AR, OK

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## Goals of Prep-ME

- Assist DOTs with data preparation
- Improve management and workflow of input data for Pavement ME Design in a production environment
- Provide high quality input data sets

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## Traffic Module of Prep-ME

- Import & process raw WIM data (2001 & 2013 TMG format) with TMAS checks
- Implement algorithms and check WIM data quality
- Generate loading spectra inputs for any design location with ME Design

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## Traffic Data Import

- Database: SQL server & LocalDB
- Computation efficiency
  - 12mins to import 5GB of MDOT WIM data with TMAS check
- Data type: WIM
  - W/C, short term counts
  - Data format: FHWA TMG 2003 & 2013
- TMAS check: implemented
  - Generate error log files

36

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## Traffic Data Import

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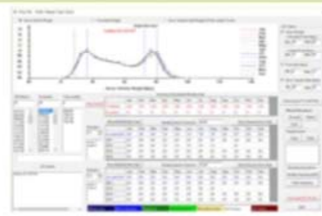
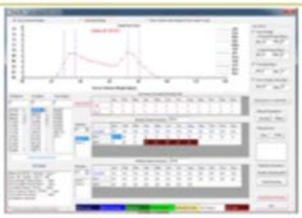
## QC Features



QC – Auto & Manual Operations

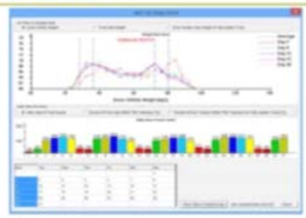
QC – by station, by direction, by lane

## QC Features



Review lanes for each month

## QC Features



Look for pattern change – by day & week

## Traffic QC Data Management

- TMG QC – automatically check data quality in batch mode
- Daily Sampling – select good days when a month has some invalid data
- Monthly Sampling – used when focusing on a particular time period
- Copy & Paste – borrow data from one month to represent a missing month
- Manual Accept/Reject – available if the standard QC is not suitable for a station

## Traffic Load Spectra

- Pavement ME Design: requires load spectra instead of ESALs
- Three input levels: depending on data availability and project criticality
  - Level 1 – site-specific (WIM, AVC etc)
  - Level 2 – intermediate
  - Level 3 – state, regional, or national average

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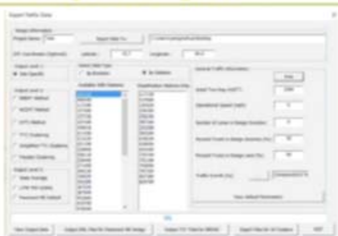
## Load Spectra Export

- Prep-ME: provide 3 levels of outputs
- Level 2 Clustering Methods
  - Michigan DOT method
  - NCDOT method
  - Kentucky method
  - TTC method
  - Simplified TTC method: low volume road
  - Flexible method: manual clusters
  - Modified TPF-5(004) method

## Load Spectra Export

- Fully implemented C++ Ward-based hierarchical clustering algorithm
  - Allow users to evaluate existing clusters and define new clusters if necessary
- Allow mixed three levels of traffic outputs
- Generate traffic input files for MEPDG (text files) and Pavement ME Design software (xml files)

## Load Spectra Export



## Michigan Method

Discriminant equations; Freight data

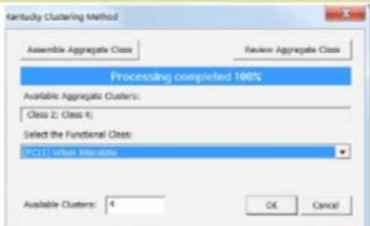
## Setup Clusters

Compare new data and new stations to research groups and identify new patterns

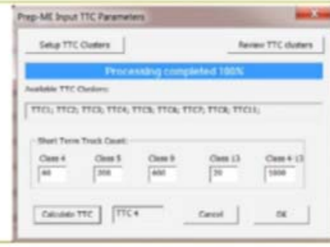
## NCDOT Method

Project specific VCD; Designer selects ALDF

## KYTC Method



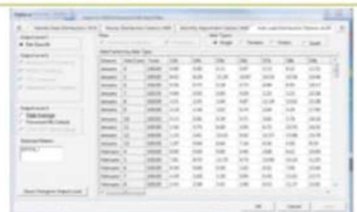
## TTC Method



## Simplified TTC Method

Low volume road without site-specific data

## View Load Spectra Output



Mixed output levels - can save user inputs

## Traffic Module Summary

- Targeted QC – evaluates weight measures that are relatively consistent
- Manage Data – able to select the data used to generate statistics
- Clustering – able to cluster data to identify patterns for each input with multiple methodologies

## Other Capability: Climate

- Import climate data
  - Any climate data that comply with Pavement ME Design Hourly Climate Data (HCD) format
- Conduct preliminary data checks
- Interpolate ICM file for MEPDG and XML file for Pavement ME Design

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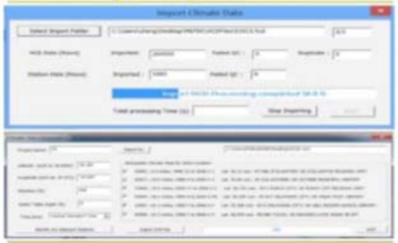
## Other Capability: Climate



55

## Other Capability: Materials

- Retrieve dynamic modulus (E*) data for HMA materials from statewide material library
- Retrieve Coefficient of Thermal Expansion (CTE) data for PCC materials from statewide material library
- Retrieve NCHRP 9-23A subgrade soil map data

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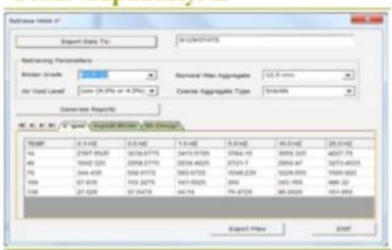
## Other Capability: E*



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## Other Capability: CTE

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## Other Capability: Soil Map

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## Other Capability: Soil Map

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## Other Capability: FWD

- Import raw FWD F25 data into Prep-ME database
- Output summary report for back-calculation software
- Generate FWD XML file for Pavement ME Design

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## Other Capability: FWD

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## Other Capability: Google Map

**Google Map v3.22 API** 63

## Portable Prep-ME Software

- For portable WIM and short term count programs
- To check traffic data in the field: Identify data issues in the field & taken on-site correction activities
  - Save participating states' time and costs
  - Assure DOTs to collect high quality data that can be used for ME Design and many others
  - Help engineers view WIM data and conduct relevant analysis and comparisons during WIM calibration process

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## Portable WIM

## Portable WIM

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## Prep-ME Future Development

- Assist participating states implementing Prep-ME
- Develop new module for local calibration: Required since the models in ME were developed using national inputs

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## Prep-ME Software Demo

## Prep-ME Software Demo Outline

- Traffic data import with TMAS check
- Weight & classification data check
  - Automatic TMG data check
  - Monthly & daily data review
  - Data sampling and replacement
- Traffic data export
  - Setup clusters
  - Identify traffic clusters
  - Generate/view output data

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## Prep-ME Software Demo Outline

- Climate module: data import and output
- Material module: E*, CTE, soil map, FWD
- Portable Prep-ME

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## Thank you for your time & support

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