Weigh-in-Motion Data Analysis Software for Developing Traffic Data for Mechanistic Empirical Pavement Design

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Abstract—Currently, there are few user friendly Weigh-in-Motion (WIM) data analysis softwares available which can produce traffic input data for the recently developed AASHTOWare pavement Mechanistic-Empirical (ME) design software. However, these softwares have only rudimentary Quality Control (QC) processes. Therefore, they cannot properly deal with erroneous WIM data. As the pavement performance is highly sensible to the quality of WIM data, it is highly recommended to use more refined QC process on raw WIM data to get a good result. This study develops a user-friendly software, which can produce traffic input for the ME design software. This software takes the raw data (Class and Weight data) collected from the WIM station and processes it with a sophisticated QC procedure. Traffic data such as traffic volume, traffic distribution, axle load spectra, etc. can be obtained from this software; which can directly be used in the ME design software.

Keywords—Weigh-in-motion, software, axle load spectra, traffic distribution, AASHTOWare.

I. INTRODUCTION

TRAFFIC is one of the most important inputs required for the analysis and design of pavement. It represents the magnitude and frequency of the loading that is applied to a pavement. The new Mechanistic-Empirical (ME) pavement design software, AASHTOWare requires traffic data along with climate, and material properties for pavement design and analysis. Moreover, the software has default values for these traffic inputs. However, it was found that the site specific data significantly vary from the default values [1]. Therefore, Weigh-In-Motion (WIM) has gained popularity and is the most widely used equipment for collecting traffic counts and load spectra. However, WIM data are sometimes questionable due to sensor error or other technical reasons [2]. In addition, past studies have shown that pavement life is highly sensible to the quality of WIM data [3], [4]. Therefore, it is highly recommended to perform the quality control (QC) on the WIM data before using the data. In addition, WIM data is too large to be handled manually or by simple spreadsheet. For this reason, software called TrafLoad was developed to perform QC on the WIM data and convert these data into ME design

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input formats [5]. However, TrafLoad only performs rudimentary checks and does not provide a sophisticated QC procedure. Hence, several studies were conducted to introduce more sophisticated QC procedures in order to adjust the error [6]-[8]. These procedures were developed based on monitoring axle spacing, peak patterns of tandem axles and percentages of gross vehicle weight. These procedures can indicate whether WIM data is erroneous or not. However, these studies didn't describe how to handle the erroneous data. In addition, there is no efficient and user-friendly software available in the literature, which can effectively handle the WIM data. Therefore, the authors of this study develop software to analyze WIM data for mechanistic pavement design. In the current study, the authors demonstrate the developed WIM data analysis software called WIMDAS. This software can perform QC on the collected raw WIM data and generate the ME design traffic inputs.

II. WIMDAS

WIM station classifies each vehicle according to the Federal Highway Administration (FHWA) classification and stores the number of each type of vehicle in each lane for a specific period of time. It also stores the weight of each axle of a vehicle. Classification data is stored in a class file which has an extension of *.CLA and axle load data is stored in a weight file with an extension of *.WGT. These files are comma-separated text files, which cannot be used in the ME design software without further processing. In addition, these files are too large to process with simple spreadsheets. Moreover, sometimes WIM station records erroneous data. For these reasons, it is badly needed to develop data processing software for WIM data. WIMDAS is a highly efficient software written in *C*-sharp language, which can perform QC as well as generate the ME design inputs. The WIMDAS uses data collected from WIM stations as inputs. After analyzing the raw data, the software gives the following outputs:

i) Traffic volume adjustment factors such as monthly adjustment, vehicle class distribution, and hourly truck distribution.
ii) Axle load distribution spectra.
iii) General traffic inputs such as a number of axle per truck, axle configuration, and wheelbase/wheel wander.

These outputs can be used directly in the ME design software. Working methodology of WIMDAS is shown in Fig. 1. The details of the software and working procedure are described herein.

III. DETAILS OF THE SOFTWARE

The startup screen is shown in Fig. 2. It has three modules, which are mentioned below:

i)   Traffic Distribution (First Module)
ii) Weight Distribution (Second Module)
iii) Axle Load Spectra (Third Module)

The first module deals with the traffic classification and distribution. It analyzes the class file (.CLA) and calculates total vehicle, Annual Average Daily Truck Traffic (AADTT), directional distribution, hourly distribution, monthly distribution, average axle per truck and so on. The second module analyzes the weight distribution of the vehicle. The axle load spectra can be obtained from the third module.
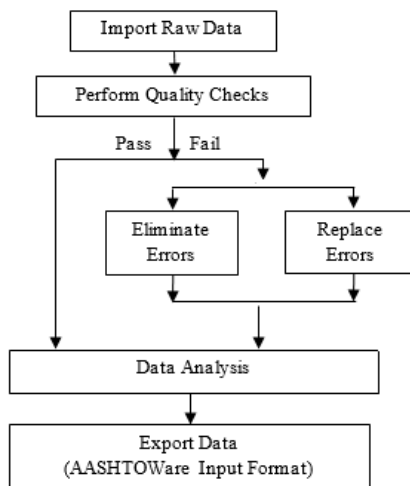

Fig. 1 Working methodology of WIMDAS

A. First Module (Traffic Distribution)

The first module generates the traffic volume adjustment factors.

Step 1. To start analyzing the traffic classification, click on 'Traffic Distribution' button shown in Fig. 2.

Step 2. Then, the user interface of the first module will appear in the screen space (Fig. 3). It will give the user an option to import the raw data. Click on the 'Browse' button to import the input file (*.CLA). Then, click on the 'Fill Table' button so that the input table of the first module gets updated with the input values. If previous data are present in the input table, click on 'Clear Table' button. When the loading of input put file is completed, the first module gives the number of records, positive directional code, negative directional code, lane code, WIM station code, year and month of data recorded. Raw data can be exported to an excel file by clicking on 'Export data" button

Step 3. There might be some anomaly in the data for unavoidable reasons. The next step is to perform the Quality Control (QC) check of the raw data. The QC can be performed by clicking on 'QC Check' button. There are fourteen QC checks for the class data, which are given in Table I. After the QC check if there is any erroneous data in a row, it puts an 'Error' mark beside that row. Check result for QC checks can be exported to an excel file by clicking on 'Export Data' button. It also shows the total number of error data in the text box named 'No of Error'. After performing QC, the data can be exported in excel file. The error record can be exported by clicking on 'Error Records' and then 'Export Data' button. This will export only the error data.

Step 4. The error data can be deleted by clicking 'Delete Error' button. This eliminates the error data from the raw traffic data. Then, the total number of error records will be zero. Deleting errors mean deleting the whole record for that period. It may underestimate the total traffic. Another option is kept in the software which is replacing the errors by taking the average value of the previous and the next good values. Then, the total number of error records will be zero.

Step 5. After fixing the error data, click on 'Calculate Distributions' button. It will show the outputs, AADTT, directional distribution, percent truck in design lane and hourly truck distribution etc. 'Export Data' button exports the data in both text and XLM format.

Fig. 2 Startup screen of WIM Data Analysis Software (WIMDAS)

B. Second Module (Weight Distribution)

The second module analyzes the weight distribution of vehicle and output the gross vehicle weight (GVW) and Steering Axle Weight (SAW) distributions.

Step 1. In the startup screen (Fig. 1), Click on 'Weight Distribution' button.

Step 2. Then, the user interface of the second module will appear (Fig. 4). Click on the 'Browse' button to import the input file (*.WGT). Then, click on the 'Fill Table' button so that the input table of the second module gets updated with input values. If previous data are present in the input table, click on 'Clear Table' button. When the loading of input put file is completed, the second module gives the number of records.

Step 3. Clicking on 'QC Check' button to perform the quality control checks. There are fifteen QC checks for class

data given in Table II. If there is any erroneous data in a row it puts an 'Error' mark beside that row. It also shows the total number of error data in the text box named 'No of Error'. Description of these specific checks can be found by clicking on 'Help' button. QC Check result can be exported to an excel file by clicking on 'Export Data' button. Only error data can export by clicking on 'Error records' and then 'Export data' button

Step 4. Error data can be fixed by clicking 'Delete Error' button or 'Replace Error' button. 'Delete Errors' method eliminates the error data for input tables, then the total number of error records will be zero. After pressing 'Delete Errors' button number of the error, records becomes zero. 'Replace Errors' method fixes the error data by averaging using the values from adjacent rows.

Step 5. After fixing the error data, click on 'FHWA Truck Class' button. Then, a new window will appear. Then truck class distribution, directional distribution, lane distribution will be shown in the respective table in that window. Truck class distribution, directional distribution, and lane distribution can be plotted by pressing on 'Show TCD', 'ShowDD' and 'ShowLD' button respectively.

Step 6. Front axle wheel load and Gross vehicle weight can be found by clicking on 'Class 4-8_GVW and SAW' and 'Class 9-13_GVW and SAW' button for class 4 to 8 and class 9 to 13 vehicle respectively. After pressing one of those buttons, a new window will pop up. Press 'Clear table' button and then 'FHWA Truck Class Distribution button'. It will generate SAW and GVW data. This output data can be exported to an excel file by clicking on 'Export data' button.

C. Third Module (Axle Load Spectra)

The third module deals with the axle load spectra for single, tandem and tridem axles. The output from this phase can be used in AASHTOWare Pavement ME Design software.

Step 1. The startup screen is shown in Fig. 1, Click on 'Axle Load Spectra' button.

Step 2. Then the user interface of the third module will appear (Fig. 5). Click on the 'Browse' button to find the source file directory and select the input file (*.WGT) and then click on the 'Fill Table' button so that the input table of module three gets updated with input values. If previous data are present in the input table, click on 'Clear Table' button to clear the existing values in the table. When the loading of the input file is completed, the third module gives the number of records.

Step 3. Clicking on 'QC Check' button to perform the quality control checks. If there is any erroneous data in a row, it puts an 'Error' mark beside that row. It also shows the total number of error data in the text box named 'Total Records with Error'.

Step 4. Error data can be fixed by clicking 'Delete Error' button or 'Replace Error' button. 'Delete Errors' method eliminates the error data for traffic input tables, then the total number of error records will be zero.

Step 5. After fixing the error, data click on 'Fill Table' and then 'Load Table' button, it will classify the axles into single, tandem, tridem or quad axle. This result can be exported by clicking on 'Export Data' button.

Step 6. After fixing the error data click on 'Single Axle Load', a new window will popup Click on 'Clear table' button and then 'Single axle' button to generate load spectra shown. The data can be export by clicking on 'Export data'. Other axle load spectra can be found in a similar way.

Fig. 3 Interface of the first module

TABLE I
QUALITY CHECKS FOR CLASS DATA [3]

Check No.	Description
1	The record belongs to a C-file, e.g. if Record Type ≠ C then "ERROR".
2	The record belongs to New Mexico, e.g. if State Code ≠ 35 then "ERROR".
3	The WIM site ID is unique, otherwise show "ERROR".
4	The direction is correct, e.g. if Direction ≠ 1 or 5 then "ERROR".
5	The lane number is correct, e.g. if Lane Number ≠ 1 to 4 then "ERROR".
6	The year is unique and correct, e.g. if Year ≠ 10 then "ERROR".
7	The month is correct, e.g. if Month ≠ 1 to 12 then "ERROR".
8	The day is correct, e.g. if Day ≠ 1 to 31 then "ERROR".
9	The time is correct, e.g. if Hour ≠ 0 to 23 then "ERROR".
10	The total hourly volume per lane does not exceed the maximum limit, e.g. if Total Hourly Lane Volume > 3000 then "ERROR".
11	The total volume in the outside lanes collected between 1 am and 2 am does not exceed the same volume collected from 1 pm to 2 pm, e.g. if Hour 1 Total Lane Volume > Hour 13 Total Lane Volume then "ERROR".
12	The total outside lanes volume is not constant for four consecutive hours, e.g. if Hour X Total Lane Volume = Hour X+1 Total Lane Volume = Hour X+2 Total Lane Volume = Hour X+3 Total Lane Volume then "ERROR".
13	The percentage of motorcycles is less than 5%, e.g. if % Motorcycles > 5 then "ERROR".
14	The percentage of unclassified vehicles (classes 14 and 15) is less than 5%, e.g. if Percentage of Unclassified Vehicles > 5 then "ERROR"

IV. CONCLUSIONS

The developed software can be used to process the WIM data. The output from the software can be directly exported to the AASHTOWare pavement ME design software. The authors of this study highly expect that this software may be useful to analyze WIM data and use it in the pavement design.

TABLE II
QC CRITERIA ADOPTED FOR WEIGHT DATA [3]

Check no	Description
1	The year is unique; otherwise show "ERROR".
2	The month is correct, e.g. if Month ≠ 1 to 12 then "ERROR".
3	The day is correct, e.g. if Day ≠ 1 to 31 then "ERROR".
4	The time is correct, e.g. if Hour ≠ 0 to 23 then "ERROR".
5	The WIM site ID is unique, otherwise show "ERROR".
6	The direction is correct, e.g. if Direction ≠ 1 or 5 then "ERROR".
7	The lane number is correct, e.g. if Lane Number ≠ 1 to 4 then "ERROR".
8	The vehicle class is correct, e.g. if Vehicle Class ≠ 4 to 13 then "ERROR".
9	The number of axles is consistent with the number of axle spaces, e.g. if Number of Axles ≠ Number of Axle Spaces + 1 then "ERROR".
10	The number of axles is consistent with the number of axle weights, e.g. if Number of Axles ≠ Number of Axle Weights then "ERROR".
11	The gross vehicle weight is consistent with the sum of axle weights, e.g. if Sum of Axle Weights ≠ GVW then "ERROR".
12	The number of axles is consistent with the vehicle class, e.g. if Number of Axles ≠ Range of Axles for that vehicle class then "ERROR".
13	The sum of axle spaces is consistent with the maximum length, e.g. if Sum of Axle Spaces > 115 ft (35 m) then "ERROR".
14	The axle weights are within acceptable range, e.g. if Axle Weight ≠ 440 lbs (200 kg) to 33,000 lbs (15,000 kg) then "ERROR".
15	The axle spaces are within acceptable range, e.g. if Axle Spacing ≠ 2 ft (0.6 m) to 50 ft (15 m) then "ERROR".

Fig. 4 Interface of the second module

Fig. 5 Interface of the third module

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