Development of Weight-in-Motion Data Analysis Software

Rafiqul A. Tarefder and Md Amanul Hasan

Abstract While volumetric data were sufficient for roadway design in the past, weight data are needed for better design of roadways now-a-days. While weight and volume data are collected by the Weigh-in-Motion (WIM) devices installed along the roadside, there is no reliable software to analyze the abstract data from the WIM devices. To that end, this study has developed a Data Analysis Software (WIMDAS) in C# programming language. This software uses the data collected from WIM stations (class file and weight file) as inputs. Using some complicated mathematical formulas inputs are analyzed and software outputs the following parameters: traffic volume and distribution such as total traffic, monthly distribution, class distribution, hourly distribution; general traffic configuration such as number of axle per truck, axle spacing; and axle load spectra for different axles such as single, tandem, tridem and quad axles. The outputs are used as inputs in the new pavement mechanistic empirical (ME) design software for predicting performances of roadways pavements. This software is capable of bringing-in several benefits including design efficiency, time, system analysis, and accuracy, which are covered in this paper.

Keywords Software development · Traffic · Roadway design · Mathematical formula · System analysis · Accuracy

1 Introduction

Traffic is one of the primary inputs in pavement design as it represents the magnitude and frequency of the loading that is applied to a pavement. However, in past only volumetric data was used to determine pavement life. Later Equivalent

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Single-Axle Load (ESAL) method was used to determine the pavement life [1]. This approach is based on converting the pavement damage caused by an axle with a specific weight and configuration into an equivalent damage from a standard 18-kip (80-kN) single-axle load. Then, pavement life is accounted for by the ESALs that have accumulated during its life. However, this empirical method cannot give reliable result due to rapid growth of traffic, change of vehicle characteristics, and absence of weather consideration. Therefore, a new Mechanistic Empirical (ME) pavement design procedure is widely accepted as this method provides the capability to handle different axle configuration and other factors [1]. This method requires volumetric and weight data to calculate the pavement distresses.

The ME design procedure (ME design software) requires detailed traffic inputs to calculate the pavement life. These inputs are mentioned here:

i. Volumetric information:
   - Two-way annual average daily truck traffic (AADTT)
   - Number of lanes in the design direction
   - Percent trucks in design direction
   - Percent trucks in design lane
   - Monthly Adjustment Factor
   - Vehicle Class Distribution
   - Hourly Truck Distribution
   - Traffic Growth Factors.

ii. Weight information:
   - Axle Load Distribution Factors.

iii. General Traffic Inputs
   - Vehicle operational speed
   - Number of axles per truck
   - Axle configuration
   - Wheelbase distribution.

These volume and weight traffic data are collected by the Weigh-in-Motion (WIM) devices along roadside. These WIM devices store the volumetric raw data into "class" files (C-card) and axle load data into "weight file" (W-card). These raw data are too large to be handled manually or by simple spreadsheet. For this reason, software called TrafLoad was developed to abstract the raw WIM data. However, WIM data are sometimes questionable due to sensor error or other technical reasons. Past studies show that use of TrafLoad is not reliable because it only performs rudimentary checks for valid site IDs and lanes and direction values, and does not provide a sophisticated QC procedure [2]. Thus, several studies were conducted to introduce more sophisticated QC procedures in order to adjust the error. 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 [3, 4]. In addition, there is no efficient and user-friendly software available in the literature, which can effectively handle the WIM data. Therefore, this study has developed a Data Analysis Software (WIMDAS) in C# programming language. This software uses the data collected from WIM stations (class file and the weight file) as input outputs aforementioned data that can be directly used in the pavement ME design software. In addition, before processing this software performs a structured QC procedure to deal with the erroneous data.

2 WIM Data

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 and spacing between the axles. Raw data is stored into two special file formats. Volumetric data is stored in a class file which has an extension of *. CLA (C-card) and axle load data is stored in a weight file with an extension of *. WGT (W-card). In class files, each row contains the total information of volumetric data for 15 min. Where, in weight file, each vehicle information is stored in separated row. Detailed description of rows in class and weigh file are given in Tables 1 and 2 respectively.

Table 1 Description of a row in class file

Field	Position	Size	Description
1	1	1	Record type
2	2	2	FIPS state code
3	4	6	Station ID
4	10	1	Direction of travel code
5	11	1	Lane of travel
6	12	2	Year of data
7	14	2	Month of data
8	16	2	Day of data
9	18	2	Hour of data
10	20	5	Total volume
11	25	5	Class 1 count
12	30	5	Class 2 count
13	35	5	Class 3 count
14	40	5	Class 4 count
15	45	5	Class 5 count

(continued)

Table 1 (continued)

Field	Position	Size	Description
16	50	5	Class 6 count
17	55	5	Class 7 count
18	60	5	Class 8 count
19	65	5	Class 9 count
20	70	5	Class 10 count
21	75	5	Class 11 count
22	80	5	Class 12 count
23	85	5	Class 13 count
24	90	5	Class 14 count
25	95	5	Class 15 count

Table 2 Description of a row in weight file

Field	Position	Size	Description
1	1	1	Record type
2	2	2	FIPS state code
3	4	6	Station ID
4	10	1	Direction of travel code
5	11	1	Lane of travel
6	12	2	Year of data
7	14	2	Month of data
8	16	2	Day of data
9	18	2	Hour of data
10	20	2	Vehicle class
11	22	7	Total weight of vehicle
12	29	2	Number of axles
13	31	3	Axle weight 1
14	34	3	Axles 1–2 spacing
15	37	3	Axle weight 2
16	40	3	Axles 2–3 spacing
17	43	3	Axle Weight 3
18	46	3	Axles 3–4 spacing
19	49	3	Axle weight 4
20	52	3	Axles 4–5 spacing
21	55	3	Axle weight 5
22	58	3	Axles 5–6 spacing
23	61	3	Axle weight 6
24	64	3	Axles 6–7 spacing
25	67	3	Axle weight 7

(continued)

Table 2 (continued)

Field	Position	Size	Description
26	70	3	Axles 7–8 spacing
27	73	3	Axle weight 8
28	76	3	Axles 8–9 spacing
29	79	3	Axle weight 9
30	82	3	Axles 9–10 spacing
31	85	3	Axle weight 10
32	88	3	Axles 10–11 spacing
33	91	3	Axle weight 11
34	94	3	Axles 11–12 spacing
35	97	3	Axle weight 12
36	100	3	Axles 12–13 spacing
37	103	3	Axle weight 13

3 Weigh-in-Motion Data Analysis Software (WIMDAS)

3.1 Description

The raw WIM files are 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. Therefore, it is badly needed to develop a data processing software to process the raw data. WIMDAS is a highly efficient software written in C-sharp (C#) 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 outputs that can be directly used in ME design software.

The main interface of WIMDAS is shown in Fig. 1. It has three modules, which are mentioned below:

(i) Traffic Distribution (First Module): The first module deals with the traffic classification and distribution. It analyzes the class file and calculates total vehicle, Annual Average Daily Truck Traffic (AADTT), directional distribution, hourly distribution, monthly distribution, average axle per truck and so on.

(ii) Weight Distribution (Second Module): The second module analyzes the weight distribution of the vehicle.

(iii) Axle Load Spectra (Third Module): The third module generates the axle load spectra, axle per truck, axle spacing, and wheelbase distribution.

Fig. 1 Startup screen of WIM Data Analysis Software (WIMDAS)

3.2 *Working Methodology*

WIM data are stored in text file. Therefore, WIMDAS is developed such a way that it can read the raw text messages and extract the key information using some complicated mathematical formulas. It also can detect the errors in the WIM raw data. Moreover, WIMDAS can eliminate the error data for simplification. In addition, it can also replace the error data by averaging adjacent rows. Thus, it minimize the chance to reduce total volume of traffic/load. Finally, it can able to generate outputs for in text and xml format. These format can be directly imported by the ME design software. The working methodology of WIMDAS is shown in Fig. 2.

3.3 *Quality Checks*

WIM data are sometimes questionable due to sensor error or other technical reasons. In addition, past studies revealed that predicted pavement life is highly sensible to the quality of WIM data [5, 6]. Thus researchers recommend to perform quality checks in order to get good result. There are 14 quality checks for class data and 15 quality checks for weight data. Table 3 lists the quality checks for class data used in this software.

Table 4 lists the quality checks for weight data used in this software.

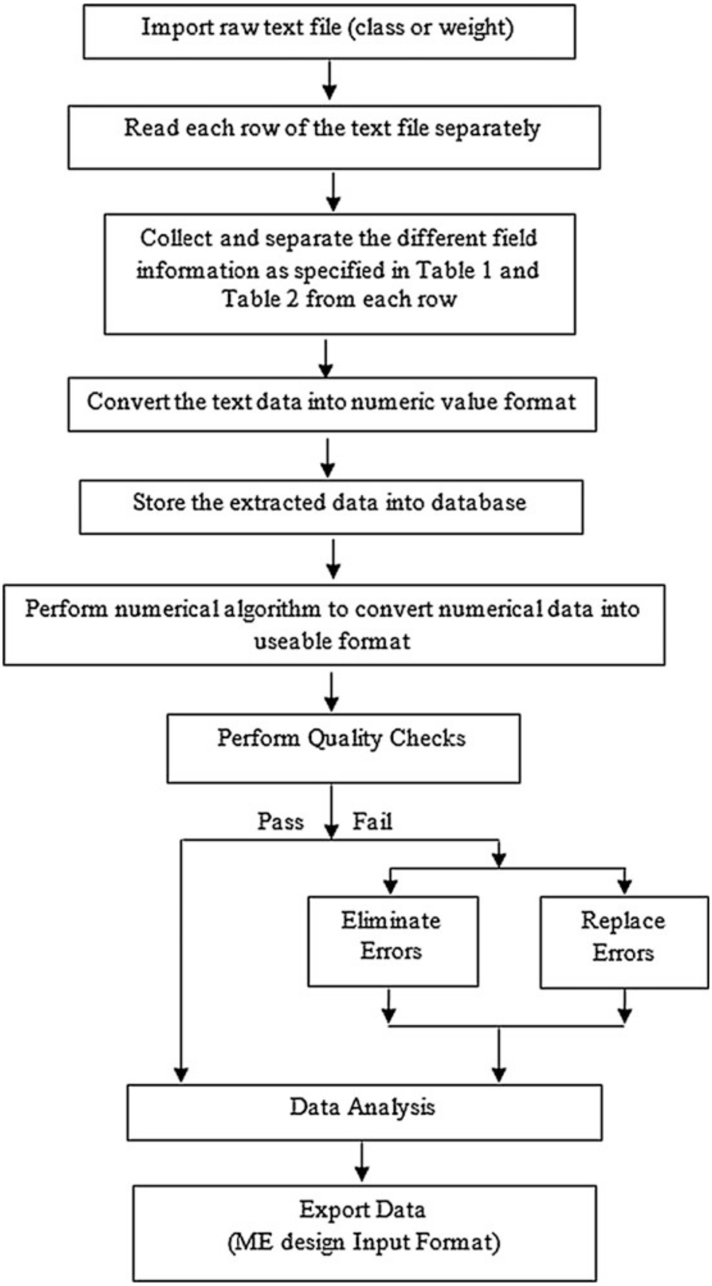

Fig. 2 Startup screen of WIM Data Analysis Software (WIMDAS)

Table 3 Quality checks for class data

Check No.	Descriptions
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 a.m. and 2 a.m. does not exceed the same volume collected from 1 p.m. to 2 p.m., 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"

Table 4 Quality checks for weight data

Check No.	Descriptions
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"

(continued)

Table 4 (continued)

Check No.	Descriptions
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"

4 Conclusion

The new ME design software requires the volume and weight data collected by the Weigh-in-Motion (WIM) devices installed along the roadside for predict the pavement life. However, there is no reliable software to analyze the abstract data from the WIM devices. To that end, this study has developed a Data Analysis Software (WIMDAS) in C# programming language. 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.

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