Methodology for Processing, Analyzing, and Storing Truck Weigh-in-Motion Data

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The use of high-speed weigh-in-motion (WIM) systems does eliminate the problems of high cost and slow static weight stations. However, another problem is usually generated—because it is easy to weigh all truck traffic with a WIM system, this type of system generates large amounts of data that require tremendous time and effort to convert into the appropriate formats. The work done to develop a common methodology for analyzing, storing, and reporting WIM data is documented. The evaluation of the various WIM systems used to collect the data, the identification of the needs of the various Pennsylvania Department of Transportation offices and bureaus, and the recommendations and development of five computer programs to analyze and report the WIM data are discussed. Among the unique features of the programs are the production of tables or graphs, or both; the ability of the user to specify time investments of hour, day, or month; and the ability of the user to request the analysis for any individual vehicle type or a combination of several vehicle types. In addition, all the variables of the analyses are kept in external files that could be modified at any time without accessing the actual programs. Finally, sample analysis for some recommendations for the implementation of this computer package is described.

Patterns of truck traffic and vehicle weights have undergone dramatic changes over the last 10 years. As a result, the engineers and personnel of the various offices and bureaus of state transportation agencies are faced with a continuing challenge to keep up with these rapidly changing conditions. The magnitudes and frequencies of truck traffic on pavements and bridges play important roles in the design requirements, long-term performance, and geometric design of these structures. Therefore, transportation engineers of all disciplines must be aware of the changes to respond with appropriate design, maintenance, construction, and weight enforcement recommendations. A major reason for the premature failure of pavement and bridge systems is the inaccurate prediction of traffic loads over the course of the system service life. Overloading of a bridge or pavement section beyond its design capacity will eventually lead to its failure. On the other hand, overcompensation on the design of a bridge or pavement section to account for an inaccurate load prediction would be a waste of resources.

One obvious way of keeping up with such traffic changes is to physically count and characterize every vehicle that passes over a section of bridge or highway in terms of its type, number of axles, and weight per axle. In the past, this information was collected by static scales and manual surveys; some of these static weight stations are still in operation. However, these methods are time-consuming and expensive to implement as a statewide network. Often the sample size has to be reduced to cut the actual cost, which jeopardizes the reliability of the observations. The Pennsylvania Department of Transportation (PennDOT) is responsible for the maintenance of more than 41,000 mi of state-owned highways. If each route were monitored by a static weigh and survey station, the aggregate cost would be prohibitively high. However, more recently sophisticated high-speed weigh-in-motion (WIM) instrumentation systems have been developed that can record the data in a traffic situation by means that are both unobtrusive and generally undetectable by drivers. Among the advantages of such a system are its ability to measure actual magnitudes of moving loads and a low implementation cost resulting from the system's applicability to highway speeds. (That is, traffic is not obstructed by trucks leaving the highway, and the trucks are weighed without any personnel requirement.)

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OBJECTIVE

The objective is to discuss the research done to develop a common methodology for extracting the needed data from the data collected by the PennDot WIM units (*1*). First, various methods of storing the large volume of data were investigated. Second, the data needs were identified through a survey questionnaire developed in this research and distributed to the various PennDOT bureaus and offices. Third, several computer programs were developed to generate the appropriate data summary and reports. The data storage investigations, survey questionnaire data, and characteristics of the specific computer programs are discussed.

REVIEW OF PENNDOT WIM CAPABILITIES

In order to develop recommendations, the researchers reviewed the capabilities of the WIM systems purchased by PennDOT. These systems can be divided into three categories based on their use of the following technologies: (a) bending plates; (b) hydraulic load cells; and (c) capacitive weighmats.

Bending-Plate WIM System

The PennDOT bending-plate WIM systems are supplied by the PAT Equipment Corporation. The weight sensor consists of strain gauges bonded to the underside of steel plates in such a way that the strain measured is proportional to the load applied. The plate is sealed in rubber to reduce environmental effects. There are no moving parts, improving the reliability of this device over some other WIM transducers.

The PAT bending-plate WIM system operates at vehicle speeds of 2.5 to 70 mph with moderate accuracy levels (i.e., a random error of 8 percent for axle loads). Speeds are measured with a random error of 3 percent. The nominal load rating for each WIM transducer is 22,000 lb. The operational temperature range for the weight sensors is −40°F to 175°F (−40°C to 80°C). The temperature range for the roadside data collection unit is −40°F to 140°F (−40°C to 60°C).

Hydraulic Load Cell WIM System

The hydraulic load cell WIM systems purchased by PennDOT were supplied by International Road Dynamics (IRD). The load-bearing surface of the weight sensor is a steel platform 5 ft 4 in. wide by 21 in. long by 9 in. deep. The load is transferred to a single oil-filled piston load cell by torsion arms. The weight sensor assembly is environmentally sealed. The hydraulic plate weighs 2,000 lb.

The IRD WIM system operates at 2.5 to 70 mph with accuracy levels similar to the PAT WIM system. The nominal load rating for each WIM transducer is 20,000 lb. The temperature range for the weight sensors is −50°F to 140°F (−45°C to 60°C).

Capacitive Weighmat WIM System

Unlike the PAT and IRD WIM systems, the Golden River WIM equipment is designed for portable applications. The weight transducer is a capacitive weighmat. This device is 6 ft wide by 20 in. long by ⅜ in. thick. The capacitive weighmat weighs 80 lb. It comprises three parallel sheets of steel separated by sheets of rubber dielectric. An attached oscillator circuit treats the weighmat as a three-plate capacitor within a tuned circuit. Compression of the transducer by a wheel load causes a change in the oscillating frequency of the tuned circuit. This frequency shift is interpreted by microprocessor-based circuitry in the WIM unit.

The Golden River WIM system operates at between 20 and 70 mph with low accuracy levels (i.e., a random error of 12 percent for axle loads). The nominal load rating for the WIM transducer is 20,000 lb. The temperature range for the weight transducer is 32°F to 175°F (0°C to 80°C). The temperature range for the roadside data collection unit is −40°F to 175°F (−40°C to 80°C).

The PAT, IRD, and Golden River WIM systems collect and transmit the following information for each individual truck: vehicle sequence number; date; arrival time in hours, minutes, seconds, and 10ths of seconds; speed; TMG vehicle type; vehicle length; gross vehicle weight; axle weights; axle spacing; and total wheelbase.

WEIGH-IN-MOTION RECORDS

FHWA has requested that state highway agencies keep current data on traffic volumes, vehicle types, and truck weights for the various classes of roads under the jurisdiction of the state agencies. In order to keep a uniform data base among the various traffic monitoring sites within the states, FHWA developed the *Traffic Monitoring Guide* (TMG) in 1985 (*2*). The TMG provides standard procedures for the collection and analysis of traffic volume data, vehicle classification data, and truck weight data. It consists of five sections, each of which deals with a different part of the traffic monitoring process. Section 5 of the TMG was of great interest to this research because it describes the truck weighing and data collection procedures at truck weighing sites. Chapters 6–8 of Section 5 were especially pertinent, because they described the coding instructions for the FHWA truck weight survey, editing of truck weight data, and truck weight data summaries (FHWA *W*-tables).

The coding instructions provide details for coding the field data in the requested FHWA format. The coded field data can then be analyzed by the statistical computer programs that FHWA developed to produce the FHWA *W*-tables. Three different data records are required by the TMG guide; namely, the station description record (2-card), the vehicle classification record (4-card), and the truck weight record (7-card).

SURVEY OF PENNDOT NEEDS

Data Storage Requirements

The overall PennDOT WIM program consists of five permanent WIM units and three portable units. A total of 110 sites will be monitored, including 5 permanent, continuously monitored sites and 105 sites to be monitored with portable units for 48-hr periods. The data collected from the sites will be transferred to PennDOT's central office in Harrisburg for further analysis and reports generation. Figure 1 shows the general flowchart of the sites. In view of the number of sites and the expected levels of traffic on each site, it was clear that a large data storage medium would be required. The actual size of the data storage medium was established on the basis of the following estimates:

- Each vehicle that has five or fewer axles will be represented by one 7-card data entry, and vehicles that have more than five axles will need two 7-card entries. The maximum storage space that one card would require is about 64 bytes of memory.
- From the data that have been collected at the permanent site in Clearfield, Pennsylvania, an average of 2,000 vehicles per lane per day would be expected from the various sites. This volume requires a storage space of 2,000 × 64 = 128,000 bytes (128 KB) per lane per day.

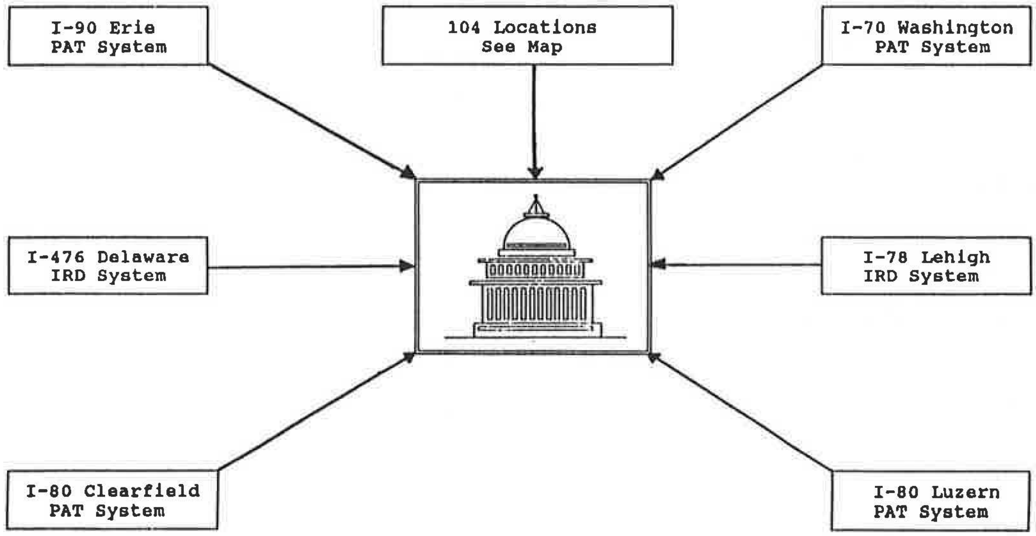

FIGURE 1 General flowchart of PennDOT WIM sites.

• The data from the six permanent sites will be collected in the following directions and number of lanes:

Site Name	*Direction of Travel*	*Number of Lanes*
Clearfield	East-west	4
Erie	West	2
Fountain Hill	West	2
N. Alexander	North	2
White Haven	West	2
Swarthmore	East-west	4

Therefore, for the two permanent sites with four lanes, the data will require (2 sites) × (4 lanes) × (128 KB per lane per day) = 1,024 KB per day, and for the four permanent sites with two lanes, the data will require (4 sites) × (2 lanes) × (128 KB per lane per day = 1,024 KB per day. In addition, if it is assumed that the portable units generate data equivalent to one of the permanent sites, the data from these units will require (3 units) × (1 lane) × (128 KB per lane per day) = 384 KB per day. A total storage space of 2,432 KB per day (2.5 MB per day) will be required. The required storage space for the entire year will be (2.5 MB per day) × (365 days per year) = 913 MB per year.

The following mass storage alternatives were investigated:

• Storing the data on 1.44-MB 3.5-in. diskettes; this procedure would require 634 diskettes per year.
• Storing the data on 30-MB tapes; this would require 30 tapes per year. In addition, the tapes can only provide sequential access to the data, which means that much operator time would be required to locate specific sets of data.
• Store the data on 650-MB magnetooptic disk; this procedure would require 1.4 disks per year. The magnetooptic disk drive allows direct access to any data set on the disk.

Because of the foregoing discussion, it was recommended that a 650-MB magnetooptic disk drive be installed on the IBM Personnel System II Model 80 computer. This procedure would allow the storage of the entire year of data on two disks, and direct access to the data. It was also recommended that PennDOT personnel perform a daily backup of the data from the various sites and a monthly backup of the hard disk. This backup procedure would ensure that a minimum amount (no more than 1 day) of data would be lost in the event of any computer malfunctioning.

Development of the Questionnaire

On the basis of the WIM system evaluations, all the PennDOT WIM systems would be capable of providing the following data for each vehicle:

• Functional classification of weighing site,
• Weighing site number,
• Direction of travel,
• Date and time,
• Vehicle class,
• Total weight of vehicle,
• Axle weights,
• Axle spacings, and
• Overall vehicle length.

With this kind of information on every vehicle, numerous data analyses and reports can be generated that will be useful to the various PennDOT operation units. The following data analyses can be performed:

• Number of vehicles weighed versus number counted;
• Average gross, loaded, and cargo weights;
• ESALs by truck type;
• Twenty-year ESAL estimates;
• Distribution of gross vehicle weights; and
• Number of trucks exceeding standard load limits.

On the basis of these recommendations, a survey questionnaire was developed and distributed to the various bureaus and offices. In addition to requesting information on the available data, the questionnaire also asks for any data requirements unique to a specific office or bureau. If more than one special data requirement is needed, the user is asked to list them in order of preference. Finally, the questionnaire solicits any comments or suggestions that the user might have about the use of the WIM data. The survey questionnaires were distributed as follows:

I. Total number of copies sent: 301

- Deputy secretaries (6): 1 copy each
- Directors of bureaus and centers (15): 5 copies each
- District engineers (11): 20 copies each

II. Total number of responses: 67

- Number of responses specifying a need for WIM data: 39
- Number of responses specifying unique data requirements: 19
- Number of responses specifying no need for WIM data: 28

Survey Analysis and Recommendation

In order to make sound recommendations concerning the needed data analysis and computer programs, the survey responses were analyzed and the various requests were weighed relative to each other. The objectives were to (a) develop a set of recommendations that satisfies the needs of the various bureaus and offices, and (b) avoid the replication of any data analysis programs that may be available through the FHWA WIM program, any other state agencies, or any WIM equipment manufacturer. As a first step in this analysis, the statistical distributions of the responses were evaluated as follows:

- How often would the respondents like to receive the data?

Period	*Percent of Respondents*
Annually	28
Semiannually	39
Quarterly	12
Monthly	12
Weekly	3

- Into what time increment should the data be divided?

Periods	*Percent of Respondents*
Months	50
Weeks	10
Days	19
Hours	21

- In what form would the respondents like to receive this information?

A majority would like to see both graphs and tables.
A majority would like hard copy of data.

On the basis of the above distributions, the following recommendations were made:

- Data should be distributed:

Monthly
Semiannually

- Data should be broken into (user-specified):

Hours
Days
Months

- Data should be presented in tables and graphs (user-specified).
- Data should be available in both hard copy and disk form (user-specified).

The distribution of data on monthly and semiannual bases would satisfy the needs of 97 percent of the respondents without overloading the offices with the burden of generating and distributing daily and weekly summaries. If the data were broken into hours, days, or months, the needs for the various time increments would be satisfied. For example, if the weekly summary were desired, the user would select the daily time increment for a period of 7 days. On the other hand, if the yearly summary were desired, the user would select the monthly time increment for a time period of 12 months. The user can also first look at the data for the entire year, then select the day increment option for a given month; the data could be further specified if, for example, a particular pattern were observed on a specific day of the month. Computer programs with these features would most likely satisfy the needs for the majority of PennDOT offices and bureaus.

On the basis of the analysis of the responses to the survey questionnaire and an investigation of the existing computer programs provided through FHWA, PAT, IRD, and Golden River, it was decided that the following computer programs should be developed (*2*):

- Average truck weights (gross, loaded, and cargo);
- ESALs by truck type;
- Number of trucks by weight range;
- Trucks exceeding standard weight limits; and
- Cumulative fatigue damage on bridge structure.

The development of the computer programs is discussed in the following section.

SOFTWARE DEVELOPMENT

On the basis of the recommendations of survey questionnaire data, it was decided that a total of five computer programs should be developed to satisfy the needs of the various offices and bureaus of PennDOT. This task was undertaken with the assumption that the potential users of these programs may not have a strong background in the usage of computers and are not familiar with the various computer programming languages. Therefore, a number of requirements were set for the computer programs to be developed. Specifically, it was determined that the programs should be

- User-friendly,
- PC-based,
- Menu-driven,
- Capable of automatic report generation,
- Able to generate both tables and graphs, and
- Able to display data by hour, day, and month.

All the computer programs were written in the Fortran 77 standard programming language. The graphics conform to the Graphical Kernel System standard established by the International Standards Organization.

The vehicle classes used in the computer programs are based on the PennDOT vehicle classification system, which consists of 11 different classes as presented in Table 1. Table 1 also indicates the equivalent FHWA vehicle classification system.

Each of the five computer programs addresses unique objectives and uses specific methods of data analysis. However, various steps are common to all five programs, namely selection of WIM site, selection of time increment, and selection of time interval. Therefore, these common steps are discussed first; then the objectives and methods of data analysis particular to each program are presented.

Selection of WIM Site

As discussed earlier, the overall PennDOT WIM program currently consists of a total of 110 monitoring sites; this number may be increased in the future. The specific characteristics of each of the sites are compiled in a site information file. Once the user selects the site to be analyzed, the computer program will access the site information file and extract the appropriate data pertaining to each specific analysis.

Currently, the site information file contains information about each of the 110 sites while allowing for the option of future expansion or adjustment of existing site information. This feature is extremely helpful and necessary because the majority of the sites will at some point be subjected to certain maintenance or rehabilitation activities that could change the corresponding pavement type, structural number, slab thickness, and so on. In addition, the population of the areas around the sites could change, which might also affect their classifications. In such cases, PennDOT personnel will not have to assign multiple site numbers for the same location.

TABLE 1 PENNDOT AND FHWA VEHICLE CLASSIFICATION SYSTEMS

Type of Vehicle	PennDOT Class	FHWA Class
Passenger Car	1	2
Motorcycle	1	1
Pickup or Panel Truck	1	NA
2 Axles, 4 Tires, Single-Unit Truck	2	3
2 Axles, 6 Tires, Single-Unit Truck	2	5
3 Axles, Single-Unit Truck	3	6
4 Axles or More, Single-Unit Truck	5	7
3 Axles, Single-Trailer Truck	4	8
4 Axles, Single-Trailer Truck	6	8
5 Axles, Single-Trailer Truck	7	9
6 or More Axles, Single-Trailer Truck	9	10
5 Axles, Multi-Trailer Truck	8	11
6 Axles, Multi-Trailer Truck	10	12
7 Axles or More, Multi-Trailer Truck	11	13
Bus	4	2

Selection of Time Increment and Time Interval

The time increment in which the data will be presented is selected by the user and consists of one of the three options: hour, day, or month. Each time increment must be accompanied by a time interval. The following combinations of time increment and interval are allowed:

Time Increment	*Maximum Time Interval*
Hour	24-hr period
Day	31-day period
Month	12-month period

The time interval can spread over two consecutive days, months, or years. The programs assume that a continuous set of data exists between the beginning and end of the time interval. If some data are missing, then the time interval should not be extended to include such data. For example, if WIM data are available for the periods from January 1 to January 10 and from January 12 to January 31, but the WIM data from January 11 are missing, it is the responsibility of the user to either provide a statistical estimate of the WIM data for January 11 or break the time interval of the analysis into two time intervals.

WIM COMPUTER PROGRAMS

The following discussion describes each program in terms of its methods of analysis and report generation capabilities.

Average Truck Weights: Gross, Loaded, and Cargo Weights

This program is intended for use with planning and highway design activities. It provides the average gross weight for all vehicles, the average gross weight for the loaded vehicles, and the average cargo weight carried by the loaded vehicles. These average weights are referred to as gross weight, loaded weight, and cargo weight, respectively. The average gross weight is obtained by summing the gross weights for all the weighed vehicles and dividing the sum by the number of vehicles. The average loaded weight is determined by first identifying the loaded vehicles. This is accomplished by comparing the actual gross weight for each vehicle to a set of standard empty weights provided by the PennDOT weights enforcement office. The software provides the option of changing the standard empty weights on the basis of any future observations. The weights of the identified loaded vehicles are summed and divided by the corresponding number of loaded vehicles. The average cargo weight is obtained by comparing each vehicle weight to its corresponding empty weight, and the excess weight is considered cargo. Finally, the total cargo weight is divided by the number of loaded vehicles to obtain the average cargo weight. The number of weighed vehicles is also provided, along with the sample size on which the data are based.

Equivalent Single-Axle Loads

This program generates the ESAL data to be used with pavement design, maintenance, and rehabilitation activities. It provides ESALs for the WIM site, for standard flexible pavement, and for standard rigid pavement. The equivalency factors are based on the AASHTO Design Guide (*3*). The AASHTO factors require the axle type, axle load, terminal serviceability, pavement type, structural number (for flexible pavements), and slab thickness (for rigid pavements). All of the AASHTO factors have been incorporated into the program. Once these parameters for each WIM site and individual axle or axle group have been identified, the program will access the AASHTO factors data base and assign the appropriate equivalency factor. The total equivalency factor for each vehicle is obtained by summing the equivalencies for the individual axles and axle groups for the entire vehicle. The pavement data, which include pavement type, terminal serviceability, and structural number or slab thickness, are obtained from the site information file, as discussed earlier. The unique features of this program compared with the other available ESAL programs (FHWA, PAT, Golden River, etc.) include its capability to both analyze each vehicle individually (whereas the other programs combine all vehicles in weight ranges), and provide the ESALs for individual sites on the basis of site-specific information in addition to ESALs for standard flexible and rigid pavements.

Number of Trucks by Weight Range

This program generates the distribution of gross vehicle weights. The gross weights are divided into eight ranges from 20,000 to over 90,000 lb. The cumulative number of each vehicle class for every weight range is presented for every time increment of the data. The distribution of these data is based on the gross vehicle weight as reported by the 7-card data. The weight data in the summary tables are expressed in terms of pounds. This summary of data can be used with the weight enforcement activities. Therefore, if the summary is requested for an individual vehicle class, the standard gross weight limit of the vehicle class is presented in the heading of the summary table. The gross weight distribution is then compared to the actual standard limit and any vehicles in the weight ranges above the standard weight limit are considered to exceed the standard limits.

Trucks Exceeding Standard Weight Limits

This program generates the summary of the vehicles that have one or more excesses of the standard weight limits. It is intended for use with the weight enforcement activities. The summary data consist of the number of trucks weighed; number of trucks exceeding standard limits; number of single-axle units exceeding standard limits; number of tandem-axle units exceeding standard limits; number of gross weights exceeding standard limits; number of trucks exceeding bridge formula limits; number of excesses below a certain prespecified percentage; and number of excesses above a certain prespecified percentage. The number of trucks weighed includes all trucks, whether they exceed the standard limits or not. A truck is considered to exceed the standard limits if it has one or more excesses. For example, if a truck exceeds the standard limits for gross weight, single-axle weight, and the bridge formula, this truck is only counted as having one excess, and only the highest percentage excess is used to classify it relative to the prespecified percentages. The standard limits were provided by PennDOT personnel and are stored in an external parameters file; this allows the user to change the limits at any time without having to interact with the actual program. The prespecified percentages can also be changed through the external parameter files, a unique feature of this program that allows the user to account for the level of confidence in the dynamic weights collected from the WIM system.

Cumulative Fatigue Damage on Bridge Structure

The objective of this program is to evaluate the cumulative fatigue damage on bridge structures generated by a set of WIM data. The responses of the survey questionnaire indicated that two types of tables are of primary interest: the gross vehicle weight distribution and the cumulative damage by truck type tables. The fatigue analysis is conducted according to the AASHTO *Standard Specifications for Highway Bridges* (*4*).

SAMPLE ANALYSIS

As mentioned earlier, the computer programs are all PC based and menu driven. The following represents typical analysis from each of the five programs.

The report generation of the average truck weight program involves the production of tables, graphs, or both. The type of information and the number of tables and graphs produced depend on the specific user request. Figure 2 shows the graph generated when the user requested the analysis of the WIM data from the Clearfield site for the period between 3 a.m. and 9 p.m. on December 1, 1989, with the hourly time increment. The information on the table also indicates that the user requested the program to combine Classes 4, 5, and 7. If the user had not requested the combined class arrangement, the program would have generated a separate table for each class requested.

The report generation of the equivalent single-axle loads program is very similar to that of the average weights program. Each table contains data for the specific site, standard flexible design, and standard rigid design. The standard flexible design consists of an SN value of 5.0 and a terminal serviceability index (TSI) value of 2.5. The standard rigid design consists of a slab thickness of 9.0 in. and a TSI of 2.5. Figure 3 shows the graph generated when the user requested the analysis of the WIM data from the Clearfield site for the time period between December 20 and December 31, 1989, with the daily time increment. In this case, the user requested combining the ESALs generated by vehicle Classes 2 to 11.

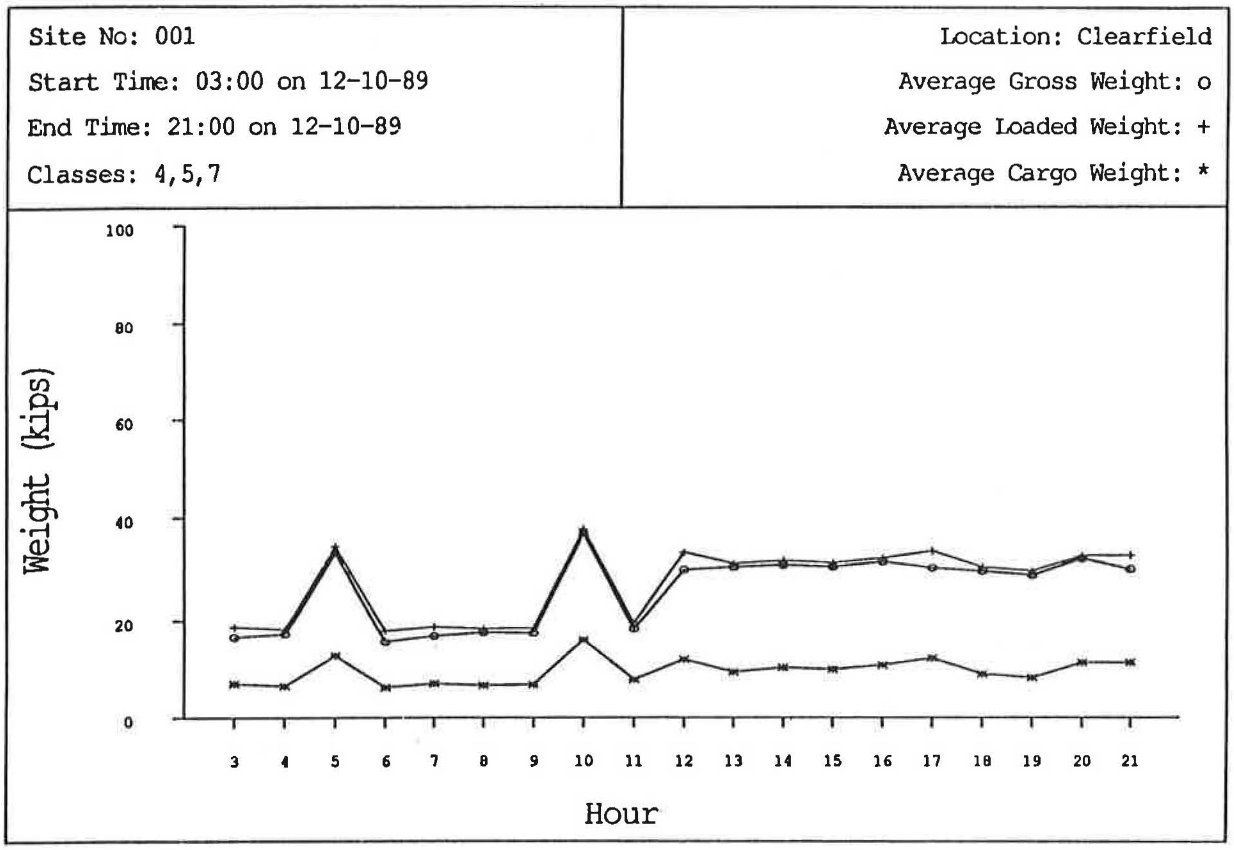

FIGURE 2 Graph from the average truck weights analysis for Classes 4, 5, and 7, combined.

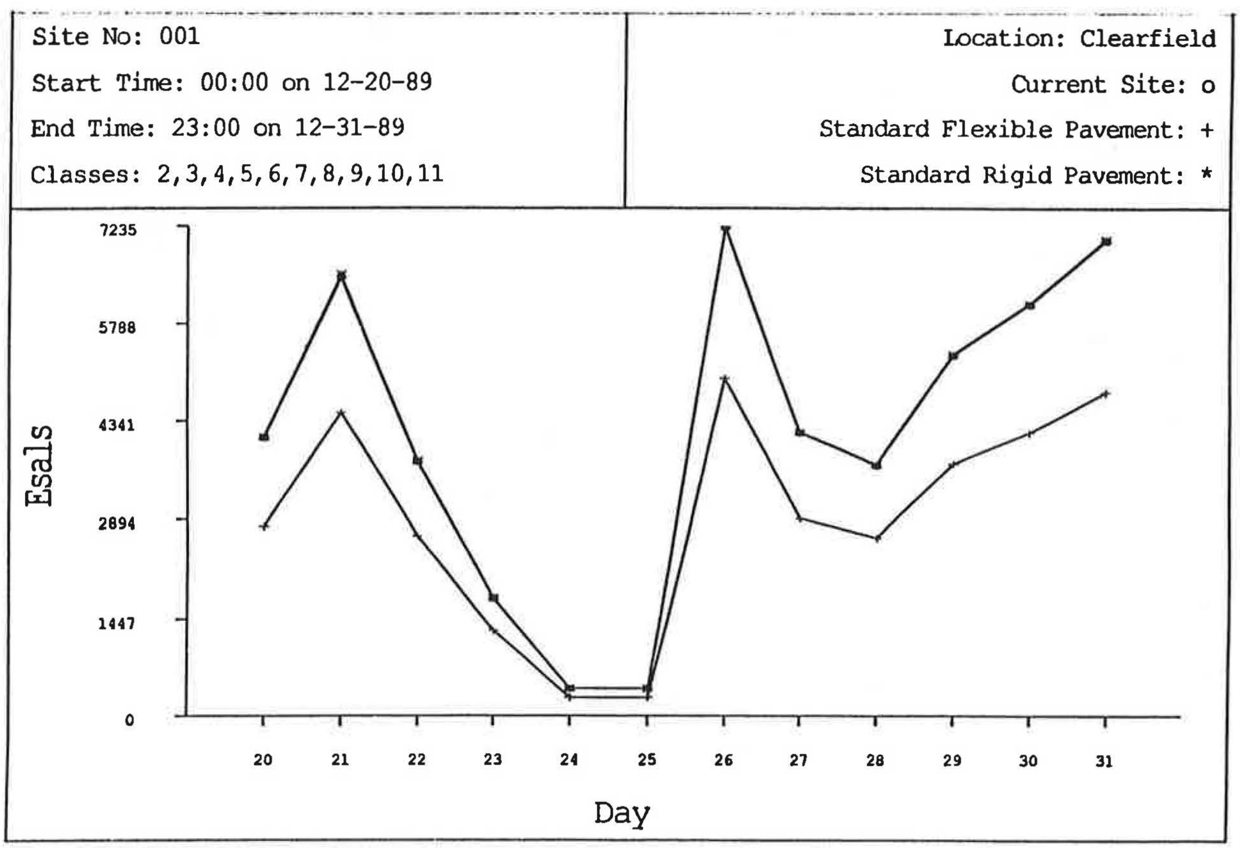

FIGURE 3 Graph from the ESAL analysis for Classes 2–11, combined.

The report generation capabilities of the number of trucks by weight range program involves the production of a summary table that indicates the distribution of the gross weights for the various weight ranges as a function of time increment. Figure 4 shows the table generated when the user requested the analysis of the WIM data from the Clearfield site for the time period between 12 a.m. and 12 p.m. on December 21, 1989, with the hourly time increment. In this case, the user requested to combine the weight ranges of Classes 4, 5, 7, 9, and 10.

The report generation feature of the trucks exceeding standard weight limits program involves the production of tables, graphs, or both. Figure 5 shows the graph generated when the user requested the analysis of the WIM data from the

Site No: 001 SR: 0080 FCC: 01 Segment: 1160/1161 Area Type: Rural

County Name: Clearfield Dir: Both Location: Clearfield

Start Time: 00:00 on 12-21-89 End Time: 23:00 on 12-21-89

Class Arangement: Combined Classes: 4,5,7,9,10

Hour	20,000 to 29,999	30,000 to 39,999	40,000 to 49,999	50,000 to 59,999	60,000 to 69,999	70,000 to 79,999	80,000 to 89,999	90,000 and Over
00:00	25	38	41	41	113	7	0	0
01:00	19	37	40	48	99	12	1	0
02:00	21	42	37	42	62	7	1	0
03:00	16	25	28	29	78	6	0	1
04:00	15	24	32	25	57	5	0	0
05:00	16	36	30	46	57	7	0	0
06:00	20	34	48	37	67	7	0	0
07:00	17	32	36	36	91	9	0	0
08:00	32	52	38	60	85	16	0	1
09:00	34	46	34	42	80	10	0	0
10:00	37	44	34	38	78	8	3	1
11:00	49	59	40	42	89	14	0	0
12:00	40	65	40	41	85	18	0	0
13:00	49	57	31	35	85	11	0	1
14:00	50	48	37	37	86	7	1	1
15:00	59	51	46	54	85	2	0	0
16:00	52	65	52	57	110	11	1	0
17:00	68	63	52	64	103	6	0	0
18:00	67	51	48	49	97	7	0	0
19:00	45	51	53	61	128	5	0	0
20:00	45	40	59	58	103	4	0	0
21:00	47	57	44	60	98	7	0	0
22:00	40	62	57	43	96	5	1	0
23:00	35	51	32	66	96	1	0	0

FIGURE 4 Table from the number of trucks by weight range for Classes 4, 5, 7, 9, and 10, combined.

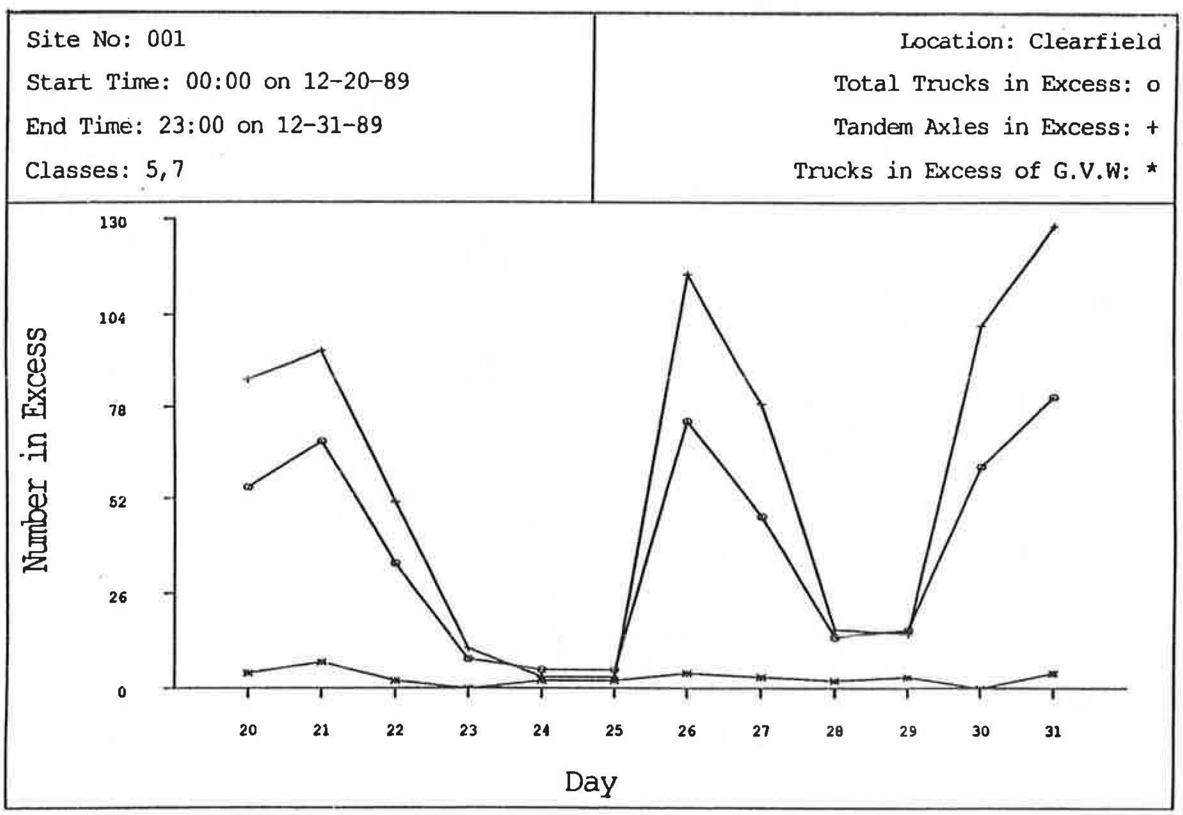

FIGURE 5 Graph from the trucks exceeding standard weight limits analysis for Classes 5 and 7, combined.

Site No: 001 SR: 0080 FCC: 01 Segment: 1160/1161 Area Type: Rural

County Name: Clearfield Dir: Both Location: Clearfield

Start Time: 00:00 on 12-20-89 End Time: 23:00 on 12-31-89

Class Arrangement:Mixed Classes: 2,3,4,5,6,7-11

Gross Vehicle Weight (kips)	Phi	PhiCube	Class of Vehicle Gamma*PhiCube					
			2	3	4	5	6	7 plus
20- 29.9	0.347	0.042	0.03851	0.02362	0.02408	0.00067	0.01765	0.00479
30- 39.9	0.486	0.115	0.00873	0.03418	0.03326	0.00311	0.04286	0.01830
40- 49.9	0.625	0.244	0.00100	0.03037	0.03111	0.02103	0.03892	0.03680
50- 59.9	0.764	0.446	0.00000	0.00399	0.00344	0.27797	0.01752	0.08289
60- 69.9	0.903	0.736	0.00000	0.00060	0.00000	0.18189	0.00473	0.25636
70- 79.9	1.042	1.130	0.00000	0.00000	0.00000	0.00000	0.00000	0.04451
80- 89.9	1.181	1.645	0.00000	0.00000	0.00000	0.00000	0.00000	0.00184
90- 99.9	1.319	2.297	0.00000	0.00187	0.00000	0.00000	0.00000	0.00041
100-109.9	1.458	3.101	0.00000	0.00000	0.00000	0.00000	0.00000	0.00075
110-119.9	1.597	4.075	0.00000	0.00000	0.00000	0.00000	0.00000	0.00033
120-129.9	1.736	5.233	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010
130-139.9	1.875	6.592	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
140 plus	2.014	8.168	0.00000	0.02656	0.00000	0.00000	0.00000	0.00033
Sum of Gamma*PhiCube			0.04824	0.12118	0.09190	0.48467	0.12169	0.44741

Total Cumulative Damage:
Sum of Gamma*PhiCube =
Sum of (Percentage of Truck-Type) * (Sum of Gamma*PhiCube by Truck-Type)
= 0.427

The quantity, Sum of Gamma*PhiCube, shown for each truck type represents the cumulative fatigue damage caused by the distribution of trucks in each truck type as a percentage of that caused by like number of vehicles, all of the design gross vehicle weight.

FIGURE 6 Table from the cumulative fatigue damage on bridge structure analysis.

Clearfield site for the time period between December 20 and December 31, 1989, with the daily time increment. In this case, the user has requested the analysis for the individual Class 7 (five-axle semitrailer).

The report generation for the cumulative fatigue damage on bridge structure program consists of producing two tables for the entire time period of the analysis. Figure 6 shows a typical table generated from this analysis.

SUMMARY AND RECOMMENDATIONS

This computer package will be helpful to the various bureaus and offices of any department of transportation agency and should be distributed to all personnel who will be dealing with the WIM data collected from various sites. Two ways of handling the WIM data analyses are recommended. First, the computer package may be installed in the central office in conjunction with the data extraction programs from the field locations and the 7-card format conversion programs. All of the programs must be set up in a batch operation that is capable of conducting the following tasks at a prespecified time of the day:

- Extraction of the data from the WIM system and convert into 7-card,
- Analysis of the data using the five analyses,
- At the end of each month, presentation of a monthly summary with the day and time increment for all five analyses, and
- Distribution of the monthly summary for the potential users.

This batch operation would be perfect for the permanent WIM systems that collect data for 24-hr periods year round. However, for the portable (Golden River) system, this operation must be done interactively by the potential users. The second approach consists of having the central office personnel extract the WIM data from the field, convert the raw data into 7-card format, preprocess the data using the preprocessing program developed in this research, and then distribute the preprocessed WIM data to the potential users. The users would then produce their own summaries using the programs developed in this research. The latter approach will relieve some of the pressure on central office personnel; however, it will require extensive training of the potential users so that they can handle the production of the desired summaries.

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REFERENCES

1. P. E. Sebaaly, W. Cunigan, and T. Chizewick. *Truck Weight Data Processing, Storage, and Reporting*. PennDOT Report FHWA-PA-89-040+89-11, Harrisburg, Pa., 1990.
2. *Traffic Monitoring Guide*. FHWA, U.S. Department of Transportation, June 1985.
3. *AASHTO Guide for Design of Pavement Structures*. AASHTO, Washington, D.C., 1986.
4. *Standards Specifications for Highway Bridges*. 13th ed. AASHTO, Washington, D.C., 1983.

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