Estimating Lanewise Traffic Loading on Multilane Highways from WIM Data

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ABSTRACT

A procedure for estimating the cumulative number of equivalent 18-kip single axle loads in each lane of a multilane highway is presented. The following sets of information are used: (a) weight data from a multilane weigh-in-motion (WIM) system, (b) an adequate sample of traffic classification (according to axle arrangement) data for each lane, and (c) modified and extended AASHTO axle load equivalency factors. Application of the procedure is illustrated with a 6-day data set from a four-lane WIM site in Texas. The significance of lanewise variability in traffic loading patterns with respect to time and location is emphasized by a 1983 data set from a Minnesota two-lane WIM site.

Highway pavements must withstand the combined stresses that result from internal volume changes in the pavement and subgrade materials and from external traffic loading. The cumulative damaging effects of stress variations over extended periods of time must also be accounted for in pavement design and performance evaluation processes; therefore adequate quantitative data on stress-causing conditions in pavements are essential.

Historically, routine traffic surveys have not supplied the kind of detailed statistical data about traffic loading that is needed, particularly for multilane highways. Traffic loads are generally channelized into each lane of the roadway and are applied to the pavement surface through the tires of moving or standing vehicles. The tire loads vary in magnitude, location, duration, frequency, and number of applications. To characterize these loads adequately, representative samples of data on vehicle speed, tire configurations and inflation pressures, wheel and axle weights, and number of repetitions of axles with different weights and spacings--all with respect to time and lane--are required. With static weighing and dimensioning techniques it has been impossible to stop and weigh vehicles on a lanewise basis. It has also been expensive, and sometimes hazardous, to attempt to weigh and measure the relatively large number of vehicles necessary for statistically representative samples, and data processing has been a problem. These techniques are manpower intensive, time consuming to road users, and often limited by environmental conditions. A better means of obtaining and processing the traffic loading data that are fundamental to all highway planning, financing, design, operation, maintenance, and management is long overdue.

A practicable technique for estimating the patterns of traffic loading in each lane of multilane highways is described. The essential statistical traffic data are obtained with a new weigh-in-motion (WIM) system that automatically measures vehicle speed and samples the dynamic tire forces of all, or selected, vehicles operating at normal road speeds in up to four highway lanes at a time. The system then instantaneously computes, displays, and records estimates of static wheel and axle weights and classifies each vehicle by type according to the total number of axles on the vehicle and to the spacing between axles in any group. Because the system can operate automatically over extended periods of time without interference or hazard to traffic, a sampling program can be designed to reflect any important timewise variations in traffic patterns at the site. The recorded digital data can be transported either manually on magnetic disks or via telecommunication linkages between computers at various locations.

The usual WIM data along with additional information concerning lanewise distribution of the traffic are arranged in a familiar format for conventional engineering and planning computations. The new four-lane WIM system was developed for the Texas Department of Highways and Public Transportation by Radian Corporation; Austin, Texas, as part of the FHWA-sponsored Texas WIM Demonstration Project, which is currently being conducted under the Rural Transportation Assistance Program (RTAP). The instrument system, which consists of a single rack of electronic gear, an IBM PC-XT computer, and a small printer, is transported between WIM sites and housed during data-taking sessions in an air-conditioned van. At each site, three inductance loop detectors and two wheel-force transducers are installed permanently in each lane. Active strain gauge load cells are inserted into the frames during operations. The instrument system and the load cells are rotated among several WIM sites in Texas.

A procedure for converting samples of WIM data to estimated numbers of equivalent 18-kip equivalent single axle loads (ESALs) in each highway lane is outlined and illustrated with a 6-day data set taken in June 1984 at a four-lane WIM site on I-10 near Seguin, Texas. The practicality of estimating ESALs from samples of truck classification data is also suggested, and steps for accomplishing this are included in a flow chart. A frequency distribution of axle weights on each class of truck must be assumed in this alternative method. To use the alternative method in practice, judgment must be exercised in selecting a reference WIM site that can be assumed to have trucks that are loaded comparably to those operating at the site for which only classification data are available. When this decision has been made, the ESAL computations are straightforward.

TRAFFIC SURVEYS

Traffic forecasting procedures usually project average daily vehicular traffic volumes for all lanes for both directions of travel on a highway. For pavement design and evaluation purposes, the truck traffic must be estimated and distributed by direction and by lane. Directional distribution factors are developed from directional traffic volume counts on various types or classes of highways and used to estimate the directional flows that are to be accommodated at specific sites. Some policies suggest assigning half the total traffic to each direction unless conditions justify another directional split. Manual vehicle classification counts, which categorize each vehicle by type, then serve as a basis for estimating percentages of different types of vehicles in each directional traffic stream.

With regard to lane distribution, the objective is to further divide each directional flow and define the design traffic loading for each lane on a multilane highway. Design traffic loading needs to be described in terms of the cumulative number of wheel loads of given magnitude that can be expected in the lane during the design life of the pavement. Heavier wheel loads, which are usually associated with truck traffic, require stronger pavements, and each repetition of a heavy load causes relatively more damage than a lighter load; therefore consideration must be given to the practicability of designing and constructing the required pavement structure for each lane. To do this, the lanewise distribution of anticipated wheel loads is required along with the frequency distribution of wheel loads of various magnitudes in each lane.

In arriving at a descriptive lane distribution pattern for traffic loading on a section of roadway, it must be recognized that the lane placement that occurs at a given time and location results from each driver choosing to operate in a particular lane in response to a set of individual desires and to the constraints of the surrounding static and dynamic conditions. The basic tendency of most drivers appears to be to drive in the right lane while attempting to achieve and maintain comfortably the speed that is judged by the individual driver to be suitable for the roadway, terrain, and other prevailing conditions. When these desires can be realized more easily by traveling in another lane, an available lane to the left will usually be chosen. The decision by each individual driver to use a particular lane at any given time appears to be based on the momentary evaluation of a complex set of influencing factors, some tangible (e.g., legal speed limit, rough pavement surface, slower vehicles, other traffic, large vehicles, roadside obstructions) and some intangible (e.g., driver attitude, anxiety, frustration). The resulting pattern of lane distribution of vehicles on any selected highway section changes considerably with time. Both short-term and long-term fluctuations in this pattern must be recognized in estimating cumulative traffic loading in a lane over several future years.

The number of vehicles passing in each lane of a highway can be determined with conventional inductance loop detectors and recording traffic counters. Although this information is valuable, it is not sufficient for predicting the cumulative number of wheel loads of various magnitudes in a highway lane. The total number of wheels or axles must be estimated, and the magnitude of the load imposed on the pavement by each wheel or axle must be determined. Ideally, the wheel forces for each axle on every vehicle in each lane of a multilane highway would be measured, but this is neither feasible nor necessary for practical purposes. A suitable sampling process is required.

The weigh-in-motion (WIM) technology that has been developed during the past two decades now makes extensive sampling of wheel force, speed, and time feasible. The first operational WIM system in Texas incorporated one-lane weighing, dimensioning, and classifying (according to axle arrangement) capabilities about 1971 and was upgraded to two-lane capabilities some 10 years later. A new WIM system with four-lane weighing, dimensioning, and classifying capabilities was put into service by the Texas State Department of Highways and Public Transportation on June 26, 1984. This new WIM system, for the first time, provides a practical means of obtaining directly the type of detailed directional and lanewise traffic data that are needed for predicting design traffic loading on multilane highways. Representative samples of wheel and axle loads for selected classes of vehicles with respect to lane of operation and direction of travel can now be obtained periodically without interference with normal traffic flows.

With this site-specific weight information as a basis, lanewise vehicle counts and classification (according to axle arrangement) counts made at other comparable sites can be extrapolated to estimate the probable frequency of occurrence of wheel loads of given magnitudes in each highway lane over a period of time without actually measuring the loads. Although no easily installed portable vehicle counting and classifying equipment, which will function in a lane-by-lane mode on multilane highways for a few days at a time, is commercially available today, such equipment is in the final stages of development at the Center for Transportation Research, The University of Texas at Austin (1). Application of such portable vehicle counters and classifiers in a properly designed sampling program will extend the coverage of the WIM survey system and will also serve as a basis for identifying locations where truck traffic is significant and thus where additional WIM sites are needed. This concept, when implemented over a period of time that is sufficiently long to identify trends, will provide the type of detailed data on which projections of design traffic loading for multilane highways at specific locations must be based.

ESTIMATION OF TRAFFIC LOADING ON MULTILANE HIGHWAYS

Among the most important factors to be evaluated in the structural design of highway pavements is the cumulative effect of traffic loading. Traffic loading consists of numerous passes of various vehicle types, usually classified according to axle configuration, in a highway lane within a selected traffic analysis period (20 years is often used). Each particular vehicle class has a statistically definable pattern of axle configuration, number of tires, axle spacing, axle load, and tire pressure. Furthermore, the lateral placement of the vehicle within the lane follows a stochastic pattern.

Most of the pavement design procedures now in general use have been based on theoretical considerations coupled with a complementary evaluation of cumulative traffic loading effects. Many of these procedures define the design thickness of the pavement as a function of the number of applications of a standard single axle load. To use this concept, the damaging effect of each axle load in a mixed traffic stream must be expressed in terms of the equivalent number of repetitions of a selected standard axle load. The numerical factors that relate the number of passes of a standard single axle load that would be needed to cause pavement damage equivalent to that caused by one pass of a given axle load are called equivalent single axle load (ESAL) factors or traffic equivalency factors.

In many parts of the world, a legal axle load limit has been imposed. Thus the maximum axle loads on highways have probably not increased as much with time as they would have if no such limits had existed. In the United States, the 18-kip (80-kN) single axle load was the maximum legal load permitted in most states for many years; therefore this axle load has been selected for general use as a standard axle load. Axle loads for mixed traffic are frequently converted to equivalent 18-kip (80-kN) single axle loads (18-kip ESALs) for use in structural design of highways. Because the equivalency factors that were derived from the AASHO Road Test (2) will be used in the following procedure, they are reviewed briefly.

AASHO Equivalency Factors

Perhaps the most commonly used equivalency factors for pavement design and analysis are those derived from a statistical analysis of the AASHO (now AASHTO) Road Test data (3). As stated earlier, these factors are used to convert various axle loads to a common denominator by expressing the cumulative effect of the axle loads applied by mixed traffic as the sum of the effects that would be caused by a computed number of applications of a standard axle load. The standard axle load used by AASHO is an 18-kip (80-kN) single axle load. Analysis of the AASHO Road Test (4) design equations permits the determination of equivalency factors for both flexible and rigid pavements.

Traffic Equivalency Factors for Flexible Pavements

The design equations for flexible pavements presented in the AASHTO Interim Guide (4) are

$$\log W_t = 5.93 + 9.36 \log(\overline{SN} + 1) - 4.79 \log (L_1 + L_2) + 4.331 \log L_2 + G_t/\beta \quad (1)$$

$$\beta = 0.40 + \{[0.081 (L_1 + L_2)^{3.23}] / [(\overline{SN} + 1)^{5.19} L_2^{3.23}]\} \quad (2)$$

where

W_t = number of axle load applications at the end of time t for axle sets with dual tires;
$\overline{SN}$ = structural number, an index number derived from an analysis of traffic, roadbed conditions, and a regional factor that may be converted to a thickness of flexible pavement layer coefficient that is related to the type of material being used in each layer of the pavement structure;
L_1 = load on one single axle or on one tandem axle set for dual tires (kips);
L_2 = axle code (one for single axle and two for tandem axle sets);
G_t = a function (the logarithm) of the ratio of loss in serviceability at time t to the potential loss taken to a point at which

$P_t = 1.5$, $G_t = \log[(4.2 - P_t)/(4.2 - 1.5)]$

β = a function of design and load variables that influences the shape of the p-versus-W serviceability curve; and
P_t = serviceability at the end of time t (serviceability is the ability of a pavement at the time of observation to serve high-speed, high-volume automobile and truck traffic).

As indicated, for this design method the number of axle load repetitions to failure is expressed in terms of a pavement stiffness or rigidity value that is represented by structural number ($\overline{SN}$), load characteristics denoted by L_1 and L_2, and the terminal value of serviceability selected as the pavement failure points (P_t). Values commonly used to define terminal serviceability (P_t) are 2.0 and 2.5.

The relationship between the number of applications of an 18-kip (80-kN) single axle load (standard axle) (W_{t18}) and the number of applications of any axle load i, single or tandem (W_{ti}), to cause the same potential damage can be found from the following equation:

$$E_i = (W_{t18}/W_{ti}) = [(L_i + L_2)^{4.79}/(18 + 1)^{4.79}] \times [10^{G_t/\beta_{18}}/(10^{G_t/\beta_i})L_2^{4.331}] \quad (3)$$

The ratio shown is defined as an equivalency factor and is evaluated by solving Equation 3 for any value i. Because the term β is a function of $\overline{SN}$ as well as of L_i, the equivalence factor varies with $\overline{SN}$.

Traffic Equivalency Factors for Rigid Pavements

The basic equations for rigid pavements developed from the AASHO Road Test (4) are

$$\log W_t = 5.85 + 7.35 (\log D + 1) - 4.62 \log(L_1 + L_2) + 3.28 \log L_2 + G_t/\beta \quad (4)$$

and

$$\beta = 1.0 + \{[3.63(L_1 + L_2)^{5.20}] / [(D + 1)^{8.46} L_2^{3.52}]\} \quad (5)$$

where D is thickness of rigid pavement slab (in.), G_t is $\log[(4.5 - P_t)/(4.5 - 1.5)]$, and all other terms are as defined previously.

As can be seen from analyzing Equations 4 and 5, the pavement rigidity or stiffness value is expressed by the pavement thickness (D).

The relationship between the number of passes of an 18-kip (80-kN) single axle load and the number of passes of any axle load i, single or tandem, to cause equivalent damage to a rigid pavement can be found from the following equation:

$$E_i = (W_{t18}/W_{ti}) = [(L_i + L_2)^{4.62}/(18 + 1)^{4.62}] \times [10^{G_t/\beta_{18}}/(10^{G_t/\beta_i})L_2^{3.28}] \quad (6)$$

The ratio is defined as an equivalency factor and is evaluated by solving Equation 6 for any value i. Because the term β is a function of D as well as of L_i, the equivalency factor varies with D.

Procedure for Estimating Traffic Loading on Multilane Highways

In this section a detailed procedure for using traffic survey data to estimate traffic loading in terms of the number of 18-kip (80-kN) single axle load applications that will occur in each lane of a multilane highway in each direction is outlined. It uses the following sets of information:

1. Frequency distributions for the weight of each axle on each class of truck in each lane from weight survey data,

2. Truck volume and classification (according to axle arrangement) data by lanes from vehicle classification surveys, and
3. Modified and extended AASHO axle load equivalency factors as described later.

Representative frequency distributions for the weight of each axle on each class (according to axle arrangement) of truck in each direction by lanes can be developed from WIM data or from any other adequate weight survey data that are obtained at representative weighing sites. Lanewise weight data can best be obtained with a multilane WIM system.

Statistical data related to the frequency with which various classes of vehicles operate on each lane of multilane highways can be obtained by sampling the operational patterns of various types of trucks. Manual observation and enumeration can be used to collect these data, or a technique for automatically classifying trucks can be used.

Appropriate equivalency factors can be applied to convert the numerical data on trucks and axles into estimates of the cumulative number of equivalent 18-kip (80-kN) single axle loads in each lane in each direction on multilane facilities for a selected period of time. With regard to suitable equivalency factors, the usual procedure for calculating equivalency factors for single axle and tandem axle sets from the AASHO Road Test data was summarized previously. The values that will be used in the outlined procedure have been calculated for 1,000-lb (4.45-kN) axle load increments.

A separate set of equivalency factors for steering axle loads greater than 12 kips on flexible pavements that was developed recently (5) will also be used. This is appropriate because the data collection and analysis techniques employed at the AASHO Road Test (2,3) combined the damage caused by the single-tired steering axle loadings of up to 12 kips with the damage caused by the associated dual-tired axles in deriving equivalency factors. Carmichael et al. (5) developed equations, using Minor's hypothesis, that provide a means of separating such damage. They used a concept of pavement surface curvature and the resulting tensile strains in the asphalt mixture as a basis for computing equivalency factors for flexible pavements. In their analysis, single tire loadings generally produced somewhat more damage than the same loads on dual tires. This was also substantiated by Deacon's theoretical work (6). He reported that axles with single tires are three times more damaging to flexible pavements than are dual-tired axles with the same load. Because it is possible for steering axle loads to exceed those that were on the test trucks at the AASHO Road Test (2 through 12 kips), their additional damaging effects should be assessed. The values calculated by Carmichael et al., given in Table 1, are applicable for this purpose.

In developing equivalency factors for tridem axles, Carmichael et al. (5) used the same curvature concept that had given good agreement with the AASHO factors for single and tandem axles on flexible pavements. A set of equivalency factors for tridem axles that agrees quite closely with those derived by Carmichael et al. was calculated by setting $L_2 = 3$ in Equation 3. The results of these calculations are given as a rather complete set of equivalency factors for tridem axles on flexible pavements in Appendix B of Lee et al. (1). They can also be computed directly from Equation 3.

When applying the curvature concept to rigid pavements, Carmichael et al. found that the derived equivalency factors for single and tandem axle sets differed from the AASHO values by a factor of two or more. They concluded that the curvature concept as they had used it was not applicable for this pur-

TABLE 1 18-kip Equivalency Factors for Steering Axle Loads Greater than 12 kips for Flexible Pavements [adapted from Carmichael III et al. *(5)*]

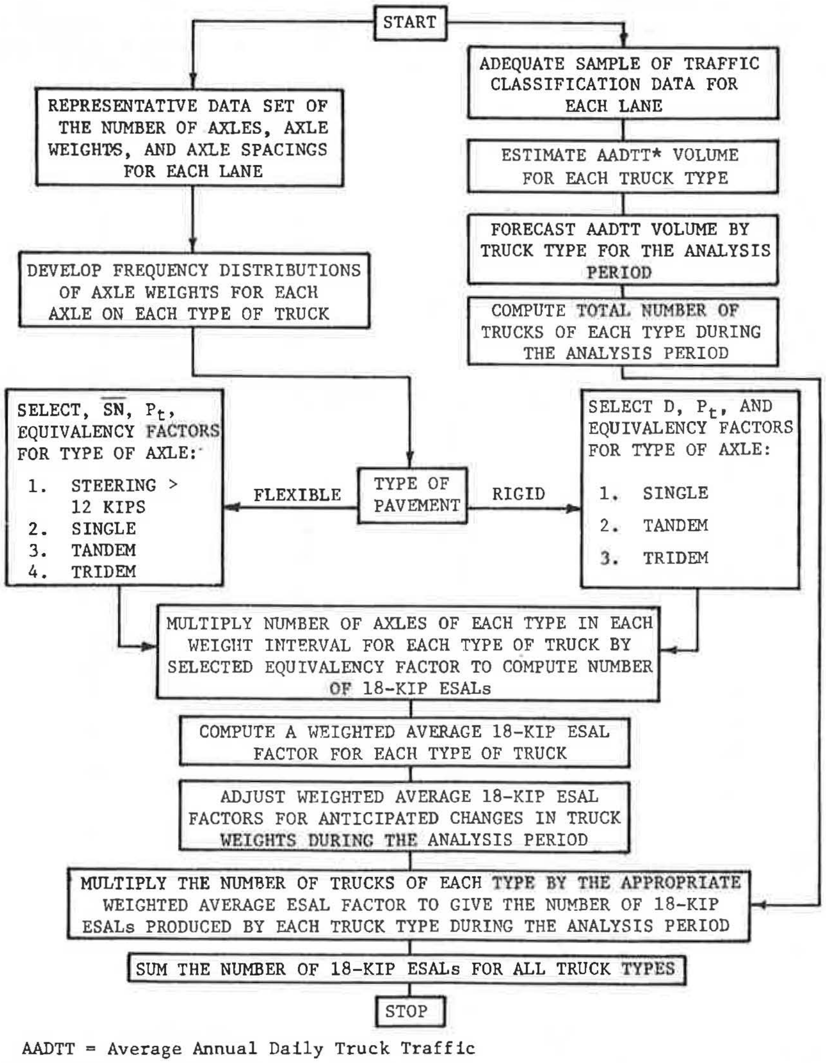
Steering Axle Load		Terminal Present Serviceability Index, P_t			
kips	kN	1.5	2.0	2.5	3.0
2	8.9	Damaging Effects of Steering Axles Less than 12 Kips are Combined Into AASHO Dual-Tire Equivalency Factors			
4	17.8				
6	26.7				
8	35.6				
10	44.5				
12	53.4				
14	62.3	0.92	0.86	0.93	0.94
16	71.2	1.42	1.31	1.33	1.28
18	80.1	2.12	1.94	1.90	1.74
20	89.1	2.95	2.52	2.44	2.16
22	97.9	4.02	3.35	3.15	2.70
24	106.8	5.29	4.40	3.95	3.28
26	115.7	6.73	5.49	4.82	3.89
28	124.6	8.31	6.67	5.83	4.59
30	133.4	10.19	8.05	6.80	5.23

pose. A set of equivalency factors for tridem axles on rigid pavements has been calculated by setting $L_2 = 3$ in Equation 6. These values are shown in Appendix B of Lee et al. (1). They appear to be reasonable, but they have not been validated through experimental work.

A procedure for estimating the truck traffic loading on multilane highways is outlined hereafter in sequential order. The flowchart in Figure 1 shows schematically the order in which the traffic calculations proceed in order to estimate the total number of equivalent 18-kip (80-kN) single axle loads in each lane during a selected period of time.

STEPS IN ESTIMATING LANEWISE TRAFFIC LOADING

1. Obtain representative truck weight data from a selected weigh station or stations at which the patterns of truck traffic are similar to those at the location being analyzed.
2. Develop a separate frequency distribution of axle weights for steering (heavier than 12 kips on flexible pavements), single, tandem, and tridem axles for each type of truck for each lane by determining the number of axle weights that falls into either 1-kip (4.45-kN) or 2-kip (8.9-kN) intervals.
3. Multiply the number of axles of each type in each load interval for each type of truck by the appropriate equivalency factor to give the number of 18-kip equivalent single axle loads (18-kip ESALs).
4. Sum the number of equivalent 18-kip single axle loads over all weight intervals for each type of truck and then divide these sums by the respective number of trucks of each type to obtain a series of weighted-average 18-kip ESAL factors.
5. Adjust the weighted-average 18-kip ESAL factors for anticipated changes in truck weights during the analysis period. Use available prediction models (e.g., trend analysis, time series analysis) or engineering judgment as appropriate.
6. Obtain an adequate sample of traffic classification data for each lane at a site where traffic loading is to be estimated.
7. Estimate the average annual daily truck traffic (AADTT) count of each truck type from the traffic classification data.
8. Forecast AADTT volume of each truck type for the analysis period.
9. Compute the total number of trucks of each type for the analysis period.
10. Multiply the number of trucks of each type by the appropriate adjusted, weighted-average ESAL factors to give the number of equivalent 18-kip (80-kN) single axle loads produced by each truck type during the analysis period.



AADTT = Average Annual Daily Truck Traffic

FIGURE 1 Flow chart of lanewise traffic load estimating procedure.

11. Sum the number of equivalent 18-kip single axle loads over all types of trucks for each lane.

EXAMPLE

To illustrate the results of applying the procedure for calculating lanewise traffic loading on a multilane highway, a 6-day WIM data set, which was taken from June 26 through July 1, 1984 on I-10 at milepost 602 near Seguin, Texas, is used. This survey site is located on a four-lane rural freeway between Houston and San Antonio where trucks comprise some 35 percent of the total weekday traffic volume during daylight hours. From 1976 until the summer of 1984, WIM scales had been installed only in the right-hand westbound lane, and data samples had been taken periodically. WIM scales were added in the remaining three lanes in May 1984 in preparation for the new four-lane instrument system. The new system was operated continuously for 7 days; however, due to an operator error, data for the last day of the data-taking session were eradicated. The recorded data for 6 days are used for illustration.

Table 2 gives the results of applying the first four steps in the procedure to the observed data for all two-axle, single-unit trucks in one lane. The total number of equivalent 18-kip single axle loads in the right-hand westbound lane during the 6-day period in June 1984 is calculated and a weighted-average ESAL factor for this truck type at this site is determined. These steps were also carried out for each truck type included in the data set.

The truck volumes of each type were averaged to obtain an estimated daily volume of trucks of each type in each lane. These volumes are tabulated in Table 3 along with the weighted-average ESAL factors for an 8-in. rigid pavement taken to a terminal serviceability index of 3.0 at this site. The number of 18-kip equivalent single axle loads that are attributable to each truck type in each lane during an average day in June 1984 is given in Table 4 along with the overall lanewise totals and the percentage of loads in each lane.

The directional distribution of truck traffic volumes at this site was remarkably near equality; however, the loading was about 9 percent heavier in the eastbound direction. Approximately 80 percent of

TABLE 2 Frequency Distributions of Observed Axle Weights, Numbers of 18-kip ESALs, and Weighted Average Equivalency Factors for Two-Axle Single-Unit Trucks in Right-Hand Westbound Lane

Axle Load Group, Kips	Axle Load, Kips	Equivalency Factor	Number of Axles	Number of Equivalent 18-Kip Single Axles
Steering Axles, Rigid Pavement, P_t=2.5, D=8.0 inches				
.5 - 1.5	1	.0000	0	0
1.5 - 2.5	2	.0002	2.	.00
2.5 - 3.5	3	.0008	10.	.01
3.5 - 4.5	4	.0022	52.	.11
4.5 - 5.5	5	.0051	83.	.42
5.5 - 6.5	6	.0104	82.	.85
6.5 - 7.5	7	.0193	46.	.89
7.5 - 8.5	8	.0332	31.	1.03
8.5 - 9.5	9	.0540	23.	1.24
9.5 - 10.5	10	.0838	11.	.92
10.5 - 11.5	11	.1250	0	0
TOTAL =			340	5.48
WEIGHTED-AVERAGE EQUIVALENCY FACTOR = 5.48/340 = 0.016				
Drive Single Axles, Rigid Pavement, P_t=2.5, D=8.0 inches				
.5 - 1.5	1	.0000	0	0
1.5 - 2.5	2	.0002	0	0
2.5 - 3.5	3	.0008	4.	.00
3.5 - 4.5	4	.0022	7.	.02
4.5 - 5.5	5	.0051	18.	.09
5.5 - 6.5	6	.0104	34.	.35
6.5 - 7.5	7	.0193	39.	.75
7.5 - 8.5	8	.0332	45.	1.50
8.5 - 9.5	9	.0540	35.	1.89
9.5 - 10.5	10	.0838	30.	2.51
10.5 - 11.5	11	.1250	19.	2.38
11.5 - 12.5	12	.1805	20.	3.61
12.5 - 13.5	13	.2533	16.	4.05
13.5 - 14.5	14	.3468	20.	6.94
14.5 - 15.5	15	.4646	8.	3.72
15.5 - 16.5	16	.6102	7.	4.27
16.5 - 17.5	17	.7875	10.	7.87
17.5 - 18.5	18	1.0000	8.	8.00
18.5 - 19.5	19	1.2515	6.	7.51
19.5 - 20.5	20	1.5454	6.	9.27
20.5 - 21.5	21	1.8854	3.	5.66
21.5 - 22.5	22	2.2751	2.	4.55
22.5 - 23.5	23	2.7186	1.	2.72
23.5 - 24.5	24	3.2202	1.	3.22
24.5 - 25.5	25	3.7849	0	0
25.5 - 26.5	26	4.4187	1.	4.42
26.5 - 27.5	27	5.1280	0	0
TOTAL =			340	85.30
WEIGHTED-AVERAGE EQUIVALENCY FACTOR = 85.30/340 = 0.251				
WEIGHTED-AVERAGE EQUIVALENCY FACTOR FOR TRUCK TYPE = 0.016 + 0.251 = 0.27				

TABLE 3 Average Daily Truck Volume and Weighted 18-kip ESAL Factors by Truck Type, June 1984, I-10, Milepost 602, Seguin, Texas

Truck Type	Average Daily Truck Volume in June 1984				Weighted 18-kip ESAL Factors for an Average Day in June 1984 (Rigid Pavement)			
	Westbound		Eastbound		Westbound		Eastbound	
	Lane 1(R)	Lane 2(L)	Lane 3(L)	Lane 4(R)	Lane 1	Lane 2	Lane 3	Lane 4
2A (6 tire)	57	10	11	64	0.27	0.26	0.23	0.23
3A	21	7	4	23	0.38	0.22	0.67	0.60
2-S1	14	2	2	12	0.56	0.18	1.01	0.68
2-S2	38	5	5	35	0.77	0.63	1.04	0.83
3-S1	8	2	4	6	0.15	0.09	0.09	0.20
3-S2	496	119	117	497	1.53	1.62	1.70	1.68
3-S3	7	2	1	5	1.28	1.54	1.07	1.81
2-S1-2	14	1	1	12	1.42	3.33	1.22	2.16
3-S1-2	4	<1	1	4	1.36	1.13	0.93	0.92
TOTAL	659	149	146	658				

TABLE 4 18-kip ESALs of Each Truck Type on Each Lane and Their Total Percentages, June 1984, Seguin, Texas

Truck Type	18-Kip ESALs for an Average Day in June 1984 (Rigid Pavement, P_t=3.0, D=8 inches)			
	Westbound		Eastbound	
	Lane 1 (R)	Lane 2 (L)	Lane 3 (L)	Lane 4 (R)
2A (6 tire)	15.39	2.60	2.53	14.72
3A	7.98	1.54	2.68	13.80
2S1	7.84	0.36	2.02	8.16
2S2	29.26	3.15	5.20	29.05
3S1	1.20	0.18	0.36	1.20
3S2	758.88	192.78	198.90	834.96
3S3	8.96	3.08	1.07	9.05
2S1-2	19.88	3.33	1.22	25.92
3S1-2	5.44	1.13	0.93	3.68
TOTAL	854.83	208.15	214.91	940.54
% ESALs	38.5	9.4	9.7	42.4

the traffic loading was in the right-hand lane in both directions. The predominant truck type at this site was the five-axle combination tractor-semitrailer (3-S2). This type constituted about 76 percent of all trucks and accounted for approximately 90 percent of the total traffic loading at this site.

The lanewise distribution of truck traffic volumes and traffic loading at the rural Texas site in June 1984 was somewhat different than that observed at a site in Minnesota in June 1983 (7) where WIM scales operated all year in the two eastbound lanes of a rural-urban portion of I-494 in Bloomington. The average daily truck traffic volume there in June 1983 was 2.5 times greater than at the Texas site with 1,455 trucks (72 percent) in the right-hand lane and 579 trucks (28 percent) in the left-hand lane. Approximately 66 percent of the traffic loading was in the right-hand lane. On an annual basis (Table 5), the average lanewise distribution of loading was the same as in June with 66 percent of the average daily rigid pavement 18-kip ESALs in the right-hand lane. The 3-S2 truck type was also predominant at the Minnesota site; it comprised 42 percent of the truck traffic volume and contributed 82

TABLE 5 Average Daily Truck Traffic and Traffic Loading in 1983 at Minnesota WIM Site [after MnDOT *(7)*]

Truck Type	1983 AADTT*		ESAL Factors for the Average Day of the Year 1983 (Rigid Pavement)		18-Kip ESALs for an Average Day, 1983	
	Eastbound		Eastbound		Eastbound	
	Lane 1 (R)	Lane 2 (L)	Lane 1 (R)	Lane 2 (L)	Lane 1 (R)	Lane 2 (L)
2A	485	122	0.14	0.24	67.90	29.28
3A	124	43	0.74	0.49	91.76	21.07
2S1	53	12	0.19	0.25	10.07	3.00
4-Axle Semi	72	29	0.41	0.33	29.52	9.57
3S2	437	289	2.07	1.79	904.59	517.31
3S3	22	13	0.94	0.67	20.68	8.71
7-Axle Semi	1	1	2.05	0.94	2.05	0.94
2S1-2	1	1	1.11	0.88	1.11	0.88
other	15	7	1.14	1.18	17.11	8.26
TOTAL	1210	517			1144.79	599.02
PERCENT	70%	30%			66%	34%

* AADTT = Average Annual Daily Truck Traffic, Number of Trucks per Day

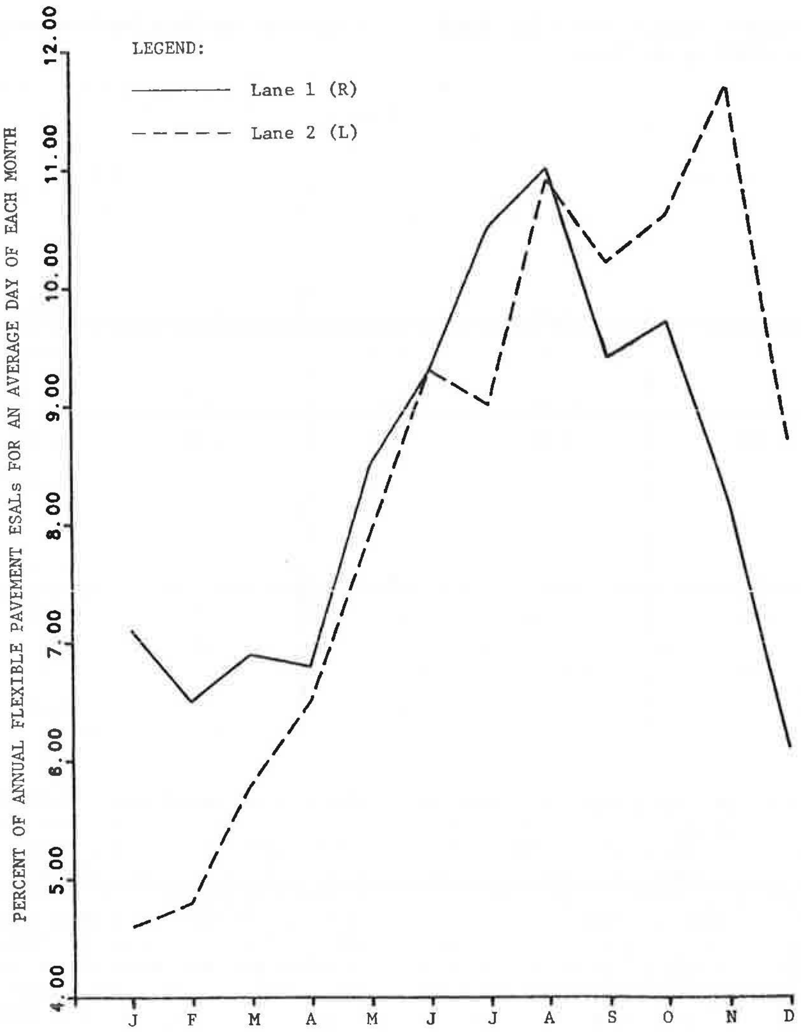


FIGURE 2 Monthly variation of flexible pavement ESALs for an average day of each month [after MnDOT *(7)*].

percent of the traffic loads. Two-axle and three-axle single-unit trucks accounted for 32 percent and 9 percent of the total truck traffic volume, respectively. These types each contributed 6 percent of the average annual daily truck traffic loads. The Minnesota data for 1983 have been used to plot the values shown in Figure 2. These data emphasize the seasonal variability in truck traffic loading.

SUMMARY

A step-by-step procedure for using data from a multilane WIM system as the basis for estimating lanewise traffic loading, in terms of the number of equivalent 18-kip single axle loads, has been outlined and illustrated with a 6-day data set. The procedure also suggests the practicability of using a site-specific WIM data set to extrapolate lanewise vehicle and classification counts into estimates of the probable occurrence of loads of given magnitudes at sites where vehicle types are counted but not actually weighed. The continuing need for a portable, automatic vehicle classifier that will function on a lanewise basis is pointed out, and reference is made to such a device now under development.

The timewise variability in traffic loading patterns is illustrated. Traffic surveys, including weigh-in-motion studies, must be scheduled and conducted in such a way that data-taking sessions reflect all significant variations adequately. Care must be taken to assure that seasonal, day and night, day-of-the-week, and lane-distribution variations are included in the sampling program.

New WIM systems have the capability of sensing, calculating, displaying, and recording an extensive variety of traffic data on a lanewise basis including traffic volume by vehicle type, number of axles per vehicle, wheel and axle weights, axle spacings, speed, and time automatically, safely, and economically. These data are essential for forecasting the future traffic loading patterns that directly affect all decisions concerning the planning, financing, design, operation, maintenance, and management of highways.

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