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PROCEDURES FOR ESTIMATING THE TOTAL LOAD EXPERIENCE OF A HIGHWAY AS CONTRIBUTED BY CARGO VEHICLES

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Procedures for Estimating the Total Load Experience of a Highway as Contributed by Cargo Vehicles

by

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Introduction

In September 1967, the Texas Transportation Institute in cooperation with the Texas Highway Department and the U. S. Bureau of Public Roads began a study entitled "Studies of Truck Characteristics Relating to Highway Use and Taxation in Texas."

During the first year of the study, research efforts were directed toward determining fuel tax differentials of Texas cargo vehicles. The results were published during 1968 in Research Report 131-1 and summarized in Summary Report 131-1(S), both entitled "Fuel Tax Differentials of Texas Cargo Vehicles."

During the last two years of the study, the research efforts have dealt with the development of procedures to estimate the total load experience (measured in 18-kip axle equivalents) generated on a highway by cargo vehicles and to determine the adequacy of the vehicle weight and count samples used in the above calculations. The results were published during 1970 in Research Report 131-2 entitled "Procedures for Estimating the Total Load Experience of a Highway as Contributed by Cargo Vehicles."

An accurate estimate of a highway's total load experience for the design period is needed to help determine the design requirements of the roadbed. An underestimate will result in an underdesigned facility, giving it a shorter physical life than planned for. Thus, road replacement and repairs would be needed much sooner than expected.

Historical cargo vehicle weight and count data collected at 21 permanent loadometer stations were used in the various analyses. Also, limited data from a weigh-in-motion station were analyzed.

Estimating the Total Load Experience of a Highway

If accurate base period axle weights and annual average daily traffic (AADT) counts of cargo vehicles are used, then an accurate estimate of the total experience (measured in 18-kip axle equivalents) of an existing or future highway can be made to assist in determining the design requirements of the roadbed.

Procedures developed for making such estimates are summarized below.

Two alternative procedures were developed and tested for making an estimate of the total load experience in 18-kip axle equivalents for a highway. One procedure used multiple regression models in which the "dummy" variables represent various characteristics of the vehicles weighed. The sets of variables entered into the models included vehicle type, body type, fuel type, time of weighing (night, day of week, summer and year) and load status. The other procedure used percentage frequency sets generated from corresponding actual weight frequency distribution composed of one kip weight classes, 40 for single axles and 50 for tandem axles. The percentage frequency

TABLE 1

PERCENTAGE ESTIMATING ERRORS OF TWO ALTERNATIVE PROCEDURES USED TO ESTIMATE THE TOTAL 18-KIP AXLE EQUIVALENTS GENERATED BY TEXAS CARGO VEHICLES WEIGHED AT EACH LOADOMETER STATION DURING ONE YEAR (1967) VERSUS SEVERAL YEARS (1964-68)

Loadometer Station by Highway System	Percentage Estimating Errors			
	One-Year Data		Multi-Year Data	
	Frequency Set 5	Regression Model 2	Frequency Set 5	Regression Model 2
Interstate Rural				
10-1	21.3	20.5	14.4	13.7
10-2	9.1	— 0.1	1.3	— 8.4
20-1	— 2.0	— 1.8	— 1.7	— 2.2
20-2	1.4	— 0.1	3.4	— 0.2
20-3	— 4.6	— 5.7	— 1.8	— 4.6
30-1	8.0	7.6	6.6	1.9
35-1	— 0.4	— 14.7	— 1.6	— 12.7
37-1	10.8	5.8	14.5	3.1
45-2	— 9.9	— 8.9	— 9.8	— 11.5
Other Rural				
7	21.7	30.7	27.3	29.0
16	22.1	26.5	19.8	23.4
20	— 1.6	10.2	5.3	16.5
42	— 0.8	12.3	— 8.2	— 2.0
72	— 1.5	— 4.3	— 1.6	0.7
81	— 25.4	— 18.5	— 30.1	— 21.7
88	— 13.1	— 15.0	— 13.9	— 15.1
145	14.4	15.8	10.3	12.5
147	— 18.6	— 5.3	— 0.1	5.2
149	10.6	19.8	9.0	16.3
Urban				
3	0.8	30.9	— 0.1	5.0
4	— 1.6	38.0	0.1	20.8
All Stations				
Total[1]	199.7	292.5	177.6	226.1
Average[1]	9.5	13.9	8.5	10.8

[1]The signs of the errors were ignored.

sets developed were as follows: (1) combined stations, (2) combined stations by vehicle type, (3) combined stations by fuel type, (4) combined stations by load status, (5) combined stations by highway and vehicle type, and (6) combined stations by highway systems.

Two sets of loadometer data, one-year (1967) and multi-year (1964-68) were applied to the above procedures. Of the regression models developed, Model 2 (which included the loaded vehicle variable) was the most accurate in estimating total station 18-kip axle equivalents for both sets of data. Of the frequency sets, Set 5 was the most accurate for both sets of data. Of the two procedures, Frequency Set 5 was more accurate than Regression Model 2. The station by station results for each procedure are shown in Table 1. It shows that the over-all average percentage errors for Frequency Set 5 are less than those for Regression Model 2. Also, the former has few stations with percentage errors of over 10 percent. The estimates for multi-year data were more accurate than those for single-year data.

Determining the Adequacy of Cargo Vehicle Weight and Classification Count Samples

Another purpose of this research study was to determine the adequacy of cargo vehicle weight and classification count samples taken at the loadometer stations. Samples taken during 1964-68 were tested for representativeness of the vehicle traffic and reliableness of statistics generated therefrom. To determine the above, the weighing and counting schedules and sample sizes were evaluated. Also data collected at conventional stations were compared with data collected on a continuous basis at a special weigh-in-motion station. The weight and count sample size requirements were established through the use of a statistical formula which utilizes sample averages and variances with 10 percent error and 95 percent probability level criteria.

It was found that a considerable amount of station to station variation in the sample statistics was due to differences in the weighing and counting schedules and sample sizes. Combining stations and/or years made the data more representative and increased the reliability of the sample statistics. Hence, Table 2 shows the weight sample size requirements for the major vehicle types. Table 3 shows the count sample requirements of a major vehicle type at each station using multi-year data.

Conclusions

A primary use of vehicle (axle) weight and count sample data collected at the various stations over the state is for estimating the total design period load experience of a proposed highway so that its roadbed design requirements can be met.

TABLE 2

NUMBER OF SINGLE AND TANDEM AXLES ACTUALLY WEIGHED AND NECESSARY TO WEIGHT OF EACH MAJOR VEHICLE TYPE TO OBTAIN AN AVERAGE AXLE WEIGHT IN 18-KIP AXLE EQUIVALENTS WITHIN 10 PERCENT OF THE POPULATION AVERAGE FOR ALL STATIONS COMBINED[1]

Vehicle Type	Number of Axles		Number of Vehicles		18-Kip Axle Equivalents Per Axle		
	Actually Weighed	Necessary to Weigh	Actually Weighed[2]	Necessary to Weigh[2]	Average	10 Percent of Average	Variance from Average
Single-Unit							
2-Axle 6-Tire							
Single	21,084	384	10,542	192	0.099	0.010	0.100
Tandem	*	*	*	*	*	*	*
3-Axle							
Single	1,791	3,000	1,791	3,000	0.076	0.008	0.050
Tandem	1,791	1,260			0.221	0.022	0.160
Multi-Unit							
2-S1							
Single	11,213	1,110	3,738	370	0.164	0.016	0.074
Tandem	*	*	*	*	*	*	*
2-S2							
Single	14,961	1,565	7,480	888	0.199	0.020	0.163
Tandem	7,480	888			0.175	0.018	0.071
3-S2							
Single	23,603	1,688	23,603	1,688	0.080	0.008	0.028
Tandem	47,206	526			0.261	0.026	0.093
Miscellaneous							
Single	3,825	2,257	2,013	2,049	0.207	0.021	0.259
Tandem	712	725			0.201	0.020	0.091
All Types							
Single	76,477	2,279	48,272	1,442	0.127	0.013	0.096
Tandem	57,189	583			0.248	0.025	0.093

[1]Based on 1966-68 data from the 21 conventional loadometer stations and using the standard formula shown in the text of the final report.
[2]Controlled by the axle type requiring the largest number of vehicles of that type.
*Not applicable.

TABLE 3

ESTIMATED NUMBER OF COUNTS NECESSARY TO MAKE OF FIVE-AXLE SEMITRAILER VEHICLES BASED ON THE AVERAGES AND VARIANCES COMPUTED FROM VARYING NUMBERS OF ACTUAL COUNTS TAKEN AT THE 21 LOADOMETER STATIONS DURING 1965-68

Loadometer Stations by Highway System	Actual Counts[1]			Number of Counts	
	Average	Variance[2]	10 Per-cent of Average	Actual[3]	Necessary
Interstate Rural					
10-1	162	518	16	12	10
10-2	477	1,846	48	12	4
20-1	736	1,428	74	12	2
20-2	808	3,868	81	11	3
20-3	679	10,885	68	10	13
30-1	658	1,321	66	12	2
35-1	701	2,183	70	12	3
37-1	288	684	29	12	4
45-2	1,154	12,338	115	12	5
Other Rural					
7	150	164	15	12	4
16	280	1,008	28	11	7
20	520	2,212	52	12	4
42	123	338	12	11	12
72	519	4,728	52	12	9
81	259	2,912	26	12	21
88	122	215	12	12	7
145	418	2,067	42	12	6
147	110	773	11	12	31
149	253	1,003	25	11	8
Urban					
3	159	2,332	16	8	52
4	51	168	5	8	37
All Stations					
Total	8,627	52,991	863	238	244
Average	411	2,523	41	12	12

[1]These counts are adjusted for trend, using the linear equation presented in the text of the final report.

[2]This is the variance used in the sample size formula shown in the text of the final report.

[3]All stations have counts for spring, summer, and fall, except the urban stations which have only summer counts.

A considerable amount of such data was used to establish the accuracy of two estimating procedures. The procedure employing the multiple regression technique was not as accurate as the procedure using percentage frequencies generated from single and tandem axle weight distribution sets. The most accurate set was one which divided the sample data on a highway system and vehicle type basis.

The findings of this research study indicate that as long as the present weighing schedule is followed, the system should combine data collections from all 21 of the conventional loadometer stations to obtain representative input data. To assure reliable outputs, the minimum quantity of combined station data should be about that collected during one summer. However, if the data are broken down on a station or highway system basis, the quantity of data collections should be increased, especially in the case of the urban system. The same thing could be accomplished by combining enough data collected during previous years or summers.

The findings tend to indicate that fewer stations could be used to obtain the necessary input data to produce reliable statistics or estimates of the population parameters. Thus, continuous seven-day weighing periods during each season of the year are recommended to be conducted at several stations. Perhaps two or three stations would be enough. However, a final decision should not be made until more data are generated with the weigh-in-motion scales at several conventional station locations on each highway system. Then, it could be determined whether true station to station differences in vehicle or axle weights actually exist.

The findings indicate that several 24-hour volume counts per year for three or four years should be made at each manual count station to estimate the base year AADT for each vehicle type. Also, a more accurate estimate of a cargo vehicle type AADT is obtained if the estimating method uses only the 24-hour volume counts of that vehicle type.

Future loadometer data collections should be periodically tested for adequacy, that is, tested for representativeness and reliableness. The procedures used in this study are recommended for such determinations. Also, the same tests should be performed on the manual count data. The continuous need for adequate data to support future research in this area should always be kept in mind.

The published version of this report may be obtained by addressing your request as follows:

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