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EQUIVALENT AXLELOADS FOR PAVEMENT DESIGN

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INTRODUCTION

Proper structural design of highway pavements requires an evaluation of the destructive effects of the anticipated vehicular loading. The concept of load equivalency provides a means for expressing these destructive effects in terms of a single measure, the equivalent axleloads[1] (EAL's). The design EAL's represents the equivalent number of applications of a standard or base axleload anticipated during the design life.

The concept of load equivalency is rooted in an early work of Bradbury (2) which was devoted in part to consideration of flexural fatigue in portland cement concrete pavements. Grumm (1) proposed the first workable design tool

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[1] Historically, this measure has been called equivalent wheel loads (EWL's) since the base load was typically a wheel load (1). This distinction has little practical significance, however.

based on this concept and the earlier work of Bradbury. Subsequently, California (3), Kentucky (4, 5), and others (6) have used the load equivalency concept as an integral element of their flexible pavement design procedures. A nationwide resurgence of interest in the load equivalency concept followed analyses of the AASHO Road Test results (7-10). These analyses focused attention on the validity of expressing many of the destructive effects of mixed traffic in terms of equivalent loadings, at least insofar as empirical design procedures are concerned.

Kentucky has been estimating design EAL's since adopting the load equivalency concept in the mid-1940's (4). Average estimates obtained at several locations had been found to agree remarkably well with the actual average EAL's that had been accumulated. However, when EAL estimates at specific locations were compared with actual accumulations, an unacceptably large variation was often found, illustrating the need for a more proper determination of the effects of local conditions on significant parameters of the traffic stream.

The objectives of this study are (1) to establish a proper methodology for obtaining estimates of design EAL's, (2) to identify those characteristics of a particular route or locale which affect the composition and weights of traffic, and (3) to provide a means for relating significant traffic parameters to local conditions. The study is limited to analyses of data obtained in predominantly rural areas and assumes that accurate estimates of average daily traffic (ADT) are available to the pavement designer.

CURRENT METHODS FOR PREDICTING DESIGN EAL'S

The procedure used in Kentucky for estimating design EAL's is based upon analyses of four traffic parameters--ADT, average percent trucks, average number of axles per truck, and average load distribution of truck axles (composite axleload distribution) (5). Initial estimates of these parameters are based on data gleaned from traffic volume counts, vehicle classification counts, and weight studies at loadometer stations. A series of additive and multiplicative adjustments are applied to convert these initial estimates to averages for the design period (11). Proper manipulation of these averages yields predictions of the number of applications of truck axleloads falling within designated axleload intervals. Application of load equivalency factors and subsequent summation produce the design estimate.

The prime deficiency in this technique is the manner of relating initial estimates of the four pertinent parameters to local conditions. This is currently accomplished through the judgment of the designer who normally considers one of the following as the basis for the estimates: (1) a nearby loadometer station, (2) a loadometer station having similar characteristics, or (3) statewide averages for all loadometer stations in the designated traffic-volume group. This method has been relatively unsuccessful in the past; it ignors a wealth of available, classification data; and it affords no basis for predictions if unusual or changing traffic conditions are anticipated.

California (3, 12) separates the problem of estimating the composition of the traffic stream (percentages of the various vehicle types) from the problem of estimating the axleload distributions. This is advantageous since much more data are commonly available for composition (classification counts) than for weights (loadometer surveys). Furthermore, California simplifies the computations by expressing the axleload distributions in terms of unit EAL's, defined as the average EAL's per vehicle. The parameters used in the California procedure are, then, the vehicle-type percentages and the corresponding unit EAL's.

Design estimates are thus obtained by first multiplying design volumes by the vehicle-type fractions. The resulting volumes (classified by vehicle type) are multiplied by the corresponding unit EAL's and the results summed to obtain the design EAL's. Local conditions enter the analysis primarily in the estimation of vehicle-type percentages on the basis of vehicle classification counts at similar locations. Some consistency is assumed in the average unit EAL's among the many types of highways within the state though modifications can be made at the discretion of the designer.

Two rather recent investigations conducted in Texas shed additional light on both methodology and the effects of local conditions. The first of these (13) was concerned primarily with methodology. Pertinent parameters of the traffic stream include ADT, percent trucks, numbers of single and tandem axles per 100 vehicles, and composite axleload distributions for both single and tandem axles. Estimates of percent trucks are based on an analysis of historical data which relates the percentage of trucks to ADT. The numbers of both single and tandem axles per 100 vehicles are obtained from a cross-classification tabulation based on volume group, percent trucks, and highway classification. Finally, the composite axleload distributions are related to percent trucks on the basis of historical data. Proper manipulation of the estimated parameters yields the numbers of each type of axle in each load category. These serve as the basis for estimates of design EAL's. The local conditions which enter the analysis are traffic volume and highway classification.

The second investigation (14) employed a slightly different methodology but focused attention on the estimation of axleload distributions at one location on the basis of those obtained at other locations. It was concluded that design axleload distributions should be obtained from measurements at a nearby loadometer station if such measurements are available and if design and traffic conditions are nearly identical. If not, the statewide average distributions should be used. For highways approaching interstate design

Standards, average axleload distributions for stations of this high-type design are recommended.

Recently, Ulbricht (15) devised an approximate method for estimating design EAL's based on two parameters of the traffic stream, namely, ADT and an equivalency coefficient. The equivalency coefficient is the average EAL's per vehicle and considers the proportions and weights of all vehicle types in the traffic stream. To estimate design EAL's, it is recommended that vehicle weight and classification data be used directly. Only if such data are unavailable should an estimate be made by taking the product of average ADT, the equivalency coefficient, the number of years, and 365. Local conditions are considered through a relationship between the equivalency coefficient and a three-cell classification of highway type by truck usage.

Other organizations (16-18) have also sought appropriate means for estimating EAL's for pavement-design purposes. Still others (19, 20) have been concerned with related aspects of the problem including sampling procedures, methods for obtaining measurements, and so forth. Apparently, there has been very little in-depth study of the effects of local conditions on the pertinent traffic parameters, and there has been little agreement on the proper traffic parameters and methodology to accomplish the desired objectives.

PROPOSED PROCEDURES

Review of the Kentucky procedure suggested that deficiencies existed not only in the method for relating the traffic parameters to local conditions but also in the methodology and specification of the relevant traffic parameters. A semi-theoretical approach of the type alluded to by Larson (19) was first suggested as an alternate to the Kentucky procedure. Such an approach would be based on postulations of intercity interactions (21) extended to encompass the necessary range of vehicle types. While such an approach is intuitively appealing, development of the procedures and characterization of the system seemed to be rather monumental tasks. It was decided to adopt an empirical approach which relied on correlations of significant parameters of the traffic stream with those local conditions of potential importance which could be identified and evaluated rather easily.

Parameters and Methodology

Since it was desirable to maximize use of all available, relevant data, two types of parameters were considered; one dependent on vehicle classification counts for which extensive data were available and the other dependent on loadometer surveys for which more limited data were available. Percentages of the various vehicle types were chosen as parameters to represent the classification data. These seemed to offer significant advantages over the percentage of trucks and the number of axles per truck since they (1) allowed consideration of vehicle types such as buses which heretofore had been excluded, (2) maximized the amount of information available for other than pavement-design purposes, (3) lent more insight into the basic characteristics of the traffic stream, and (4) were felt to be more sensitive to changing local conditions. The vehicle types selected for investigation included cars; buses; single-unit, two-axle, four-tired (SU-2A-4T) trucks; single-unit, two-axle, six-tired (SU-2A-6T) trucks; single-unit, three-axle, (SU-3A) trucks; combination, three-axle (C-3A) trucks; combination, four-axle (C-4A) trucks; and combination, five-axle (C-5A) trucks. These represented all major vehicle types for which data had been accumulated in Kentucky during the 17-year study period of 1950-1966.

The parameters selected to represent the vehicle weight data were the unit EAL's or the average EAL's per vehicle for each vehicle type. This selection was based primarily on the criterion of simplicity since alternate parameters such as axleload distributions are much more difficult to treat statistically and handle computationally. Unfortunately, some information is lost by collapsing the axleload distributions into a single measure and some flexibility is sacrificed due to the necessity for preselecting the set of equivalency factors.

Given these parameters of the traffic stream and the ADT, the design EAL's can be computed rather simply as follows:

$$\text{Design EAL's} = 365 \sum_j (\text{ADT}_j) \sum_i (P_i)(D_i)(L_i)(\text{UEAL}_i) \tag{1}$$

in which ADT_j = the average daily traffic in the jth year, P_i = the predicted fraction of the total traffic stream which is of vehicle type i, D_i = the annual average fraction of type i vehicles which travel in the critical direction, L_i = the annual average fraction of type i vehicles traveling in the critical direction in the design lane, and UEAL_i = the predicted average unit EAL's for vehicle type i. Equation 1 provides a convenient method for computing design EAL's and considers possible differential effects of lane and directional distributions. It can be simplified somewhat when an average or effective ADT can be estimated and when the basis for design is the total accumulation of EAL's in both directions and all lanes. Equation 1 then reduces to:

$$\text{Design EAL's} = 365(N)(\text{ADT}_{\text{eff}}) \sum_i (P_i)(\text{UEAL}_i) \tag{2}$$

in which N = the design period in years and ADT_{eff} = the average or effective ADT during the design period. Equation 2 provides valid estimates for use with Kentucky's current flexible-pavement design procedure.

Local Conditions

Having established the proposed methodology and identified the traffic parameters of interest, it was then necessary to identify those local conditions thought to be significantly related to the composition of the traffic stream and the weights of the vehicles included therein. These local conditions were to serve as the basic independent variables from which estimates of the dependent variables of vehicle-type percentages and unit EAL's could be made.

Several general guidelines were available to aid in this selection. Any apparently relevant local condition would have to be amenable to analysis for purposes of enabling future preditions and analyzing historical data. Some rationale would have to be formulated to tentatively substantiate the relationships between the traffic parameters and the local conditions. Finally, it would be desirable to exclude from the set of local conditions any predictive characteristics of the traffic stream itself except ADT. Extensive review of available data in light of the above guidelines led to establishment of that set of local conditions identified in Table 1.

Table 1

The road-type category was established to provide an indication of the percentage of through trucks in the traffic stream. Categorization by the manner in which the route was numbered simplified the process of analysis. The direction category reflects a geographical situation in which the bulk of interstate truck traffic in Kentucky travels on primarily north-south routes. Accordingly a two-cell classification was used to represent direction, the importance of which was felt to diminish as the local-service nature of the route increased. The significance of the availability and quality of alternate routes became apparent when traffic parameters on certain routes were studied during time periods in which alternate routes having superior geometric design standards were opened to traffic.

A large number of routes in Kentucky provide access to areas in which rather unusual types of traffic are generated. Most notable are those mining areas in which the bulk of coal is carried over some segment of the highway system. To enable proper estimates of EAL's in these areas, the service-provided category was established. Traffic volume has long been associated with other significant parameters of the traffic stream and, since it must be independently projected, was included in the set of relevant local conditions. Equally as significant was the legal maximum allowable gross weight. Kentucky has had four different maximum allowable gross weights during the study period and increases in this legal limit have invariably led to an increase in the percentages of the larger combination vehicles. So significant is the effect that much of the variability in the traffic parameters, which has in the past been attributed to the time factor, is in reality a reflection of the changing legal weight limitations.

Traffic characteristics, particularly for primarily local-service routes, were felt to reflect in part the social and economic characteristics of the residents in an area. To consider this factor in the analysis, the state was divided into four major geographical areas, each of which is relatively homogenous with respect to socio-economic environment. Past procedures have considered year as a major independent variable and it was retained in the analysis primarily for this reason. Season is known to have a significant effect on the composition of the traffic stream (for example, percent trucks) and had to be included in the set of local conditions to enable correlations with historical data.

CORRELATION OF TRAFFIC PARAMETERS WITH LOCAL CONDITIONS

The nine local conditions served as the independent variables with which the traffic parameters (dependent variables) were correlated. Extensive analysis verified the significance of these local conditions though the relative importance of each varied according to the particular parameter under evaluation.

It was implicitly assumed that the relationships ovserved in the past would remain sufficiently stable to permit valid future predictions. Criteria for assessing the suitability of various meaningful relationships included those of accuracy, simplicity, reasonableness, and predictability. In addition, the relationships had to be amenable to predicting traffic parameters for combinations of local conditions for which little or no data had been obtained in the past.

Data Sources

Vehicle weight data were available from the operation of loadometer stations throughout the state. Two types of loadometer surveys included routine coverage at the permanent loadometer stations and two special weight surveys. Approximately 10 permanent loadometer stations have been operated each year since 1942 (11). These provided the bulk of weight data for the higher volume and more important routes. The two special weight surveys were conducted during the spring and summer months of 1957 and 1964 and provided the bulk of available weight data for low-volume facilities. During the study period, the number of different rural locations at which vehicles were weighed was 51. The total number of vehicles weighed at these locations was approximately 69,000.

Vehicle classification data were available from the loadometer surveys, from automatic-traffic-recording stations, from special classification surveys, and from origin-and-destination studies. Such data were available for approximately 730 different rural locations. A total of 1871 counts were taken at these locations and approximately 6,100,000 vehicles were counted.

All vehicle classification and weight data available from these sources during the study period were incorporated into the data bank. For convenience in storing and processing these data, the summarized weight data were placed on magnetic tape and the classification data on punched cards.

Methods

The dependent variables in the analysis (vehicle-type percentages and unit EAL's) were treated as continuous variables. The independent variables (the local conditions) were treated as classification sets. Because of this method for data representation and because of the plausibility of strong interactions existing among many of the local conditions, a combinatorial analysis or cross-classification tabulation was immediately suggested as having relevance to the problem. Using such a method, the available data would be grouped into categories representative of each feasible combination of the independent variables and the averages of the dependent variables within each combination would then serve as the best estimates of future traffic characteristics. Since the number of possible combinations of the local conditions, excluding year and season, exceeds 30,000, the combinatorial analysis was judged to be unsuitable.

The most convenient method for estimating the traffic parameters would be to compute statewide gross means without regard to local conditions. This is basically the approach chosen by California in their unit EAL tabulations. However, since the effects of local conditions can be considered only by modifying the gross means based on intuition and judgment, this approach was not considered further.

The first method which was seriously considered included evaluation of the effects of the local conditions through a series of correction or adjustment factors applied to the gross means. There is one correction factor for each local condition and its value is determined by the local-condition code. To apply this procedure, the gross means are first computed. The average residuals between the actual parameter values and the gross means are then computed for each value of one preselected local condition. The process is repeated for the second and subsequent local conditions by computing average residuals between observed values and those predicted from previously analyzed local conditions. The entire process is iterated to eliminate possible effects of the chosen sequence of local conditions.

Interactions among a limited number of local conditions can be considered by a slight modification of the above procedure. Combinatorial means computed for various combinations of the interacting local conditions are substituted for the gross means and the process continued as enumerated above.

The basis of these two correction-factor techniques is one of intuition and judgment. Of somewhat more appeal are multiple regression techniques which are supported by sound mathematical and statistical theory. The first multiple regression technique considered is basically one of obtaining weighted averages. Thus average estimates of each parameter are obtained for each different local condition. Multiple regression techniques are used to assign weights or importance to each local condition for the purpose of obtaining weighted averages for final predictions.

The second multiple regression technique makes use of dummy variables and is designed specifically for independent variables which are treated as classification sets (22). The number of dummy variables, which assume values of either zero or one, required to represent each local condition is the number of classification sets for that condition less one. Thus, 40 dummy variables are required to represent the nine local conditions of Table 1. Theoretically, the procedures can be generalized to include interactions among two or more of the local conditions by redefining the dummy variables so that each variable corresponds to one combination of the interacting local conditions. Practically, this greatly increases the number of dummy variables and was not attempted due to computer program limitations which restricted the number of dummy variables to 50 (23).

The above methods for correlating the traffic parameters with local conditions are summarized in Table 2. For all practical purposes, FACT1, MULTRA, and MULTRD were found to yield results of comparable accuracy. MULTRD offers certain advantages, however, of simplicity and a more appealing basis for development. Where a limited number of interactions are important, however, FACT2 was adjudged to be the only feasible approach.

Table 2

Vehicle-Type Percentages

Extensive analyses showed that FACT2 was the superior of the techniques investigated for relating the vehicle-type percentages to the local conditions. Multiplicative correction factors were chosen since their use precludes the estimation of negative percentages. Based on the number of possible combinations of the various local conditions and the number of available data sets, the number of interacting local conditions was limited to three. Eight of the most promising combinations of three local conditions were selected intuitively and analyzed jointly on the basis of relative accuracy and predictability. As a result of this analysis, road type, maximum allowable gross weight, and traffic volume were adjudged to exhibit the most significant interactions among those investigated.

Problems were soon apparent in treatment of the time variable, year. Prior work indicated that additive correction factors for the C-4A trucks were influenced randomly by year during the 17-year study period and this did not furnish a reasonable basis from which to predict the possible effects of future years. The same disturbing tendencies were observed for other vehicle types and for multiplicative correction factors as well. Accordingly, year was excluded from the set of local conditions with an average reduction in accuracy as measured by the correlation coefficient of about 5 percent.

The criterion of reasonableness dictates that the sum of the predicted percentages must equal 100 percent. Since the percentage of each vehicle type is predicted independently, the initial estimates will rarely total 100 percent. A simple adjustment procedure, whereby each initial estimate is multiplied by 100 and divided by the sum of the initial predictions, was adopted.

Th procedures described above were used to estimate vehicle-type percentages for comparison with the actual percentages obtained from past vehicle classification counts. The results of this accuracy comparison are summarized in Table 3. Despite the relative inaccuracy of the technique, it was found superior to others of those investigated on the basis of the four criteria of accuracy, simplicity, reasonableness, and predictability.

Table 3

Unit EAL's

One of the major disadvantages of the unit-EAL parameter is that the particular set of load equivalency factors must be preselected. This shortcoming was partially alleviated by considering three types of unit EAL's--Kentucky, AASHO, and modified AASHO. The modified AASHO EAL's were computed using AASHO load equivalency factors without distinguishing between single and tandem axles.

Because of the limited amount of vehicle weight data, consideration of interactions among even a limited number of local conditions was felt to be unwarranted. In spite of this, preliminary analyses indicated that an approach such as gross means would be inappropriate since the local conditions did measurably affect the average unit EAL's. Consideration was limited to multiple regression techniques since the residual techniques offered no known additional advantages.

MULTRD proved to be simpler and slightly more accurate than MULTRA. Additive factors were chosen instead of multiplicative factors on the basis of their superior accuracy and because they are slightly easier to derive and use. Some reasonableness was sacrificed, however, because of the possibility of predicting negative unit EAL's.

The method finally selected for relating unit EAL's with local conditions made use of additive factors derived using multiple regression with dummy variables. Three of the local conditions had to be excluded from the analysis. Season was omitted because all available weight data had been limited to the late spring or summer months. Service provided was eliminated because of the relative scarcity of weight data representative of each of the service-provided categories. Unfortunately this caused a significant reduction in accuracy (a reduction in the correlation coefficients of about 15 percent) and suggests that more accurate future estimates may be partially dependent on the weighing of vehicles on roads representing each of the service-provided categories. The variable, year, also had to be eliminated from the analysis. Data again indicated that it would be extremely difficult, if not impossible, to estimate the correction factors for future years. Furthermore, because of the interrelationships between year and maximum allowable gross weight, the correction factors for maximum allowable gross weight appeared incongruous when year was included as an independent variable.

The procedures described above were used to estimate unit EAL's for comparison with actual unit EAL's obtained from past weight data. The results of this accuracy comparison are summarized in Table 4. A brief glance at the tabulated correlation coefficients is sufficient to reveal that the accuracy of the estimates leaves much to be desired. However, no other technique yielded superior accuracies as long as it was stipulated that the technique had to represent a valid, predictive procedure. It is apparent from Table 4 that this method of accounting for the effects of local conditions is superior

Table 4

to the gross means approach. The best accuracy was generally achieved for those vehicle types which contribute most significantly to the EAL accumulations.

Changes in Maximum Allowable Gross Weight

With one exception, the local conditions were defined and coded so as to be equally as relevant to future as to past conditions. Of special importance is maximum allowable gross weight since it is such a vital determinant of traffic composition and weights and since future changes in this legal limit will doubtlessly fall outside the realm of historical experience in Kentucky. Despite the failure of preliminary attempts to successfully establish relationships between maximum allowable gross weights and the traffic parameters of interest, it was felt that a procedure is required for demonstrating the effects of changing legal weight limits.

A simplified procedure was suggested based on obtaining estimates of the EAL's per 1,000 vehicles at each of the four weight limits for which data are available. These estimates would then be plotted as illustrated by Figure 1 and the curve extrapolated to the future maximum allowable gross weight. The extrapolated EAL's per 1,000 vehicles would then be multiplied by the total traffic volume expressed in thousands to obtain the final estimate. Figure 1

ACCURACY VERIFICATION

Several empirical methods were investigated for predicting the pertinent traffic parameters. Optimal methods were proposed considering the criteria of accuracy, simplicity, reasonableness, and predictability. The true validity of the proposed model could not be assessed solely on the basis of estimates of the individual traffic parameters. Of considerably more significance is the accuracy of estimates of design EAL's or of estimates of pavement thickness resulting therefrom.

To enable such a determination, EAL's were estimated and compared to actual EAL's for all stations at which both vehicle classification and weight data had been obtained. There were 51 such stations representing a total of 225 counts for an average of approximately four annual counts per station. Of these, nine were stations for which 11 or more years of data were available and 18 for which seven or more years were available. Thirty-one of the stations were represented by only one or two years of data.

Table 5

Figure 2

The first comparisons were made on the basis of EAL's per 1,000 vehicles for the 225 individual counts and are summarized in Table 5. The correlation coefficients are relatively small, which indicates that a large portion of variability in EAL's per 1,000 vehicles for individual counts remains unexplained. This was felt to be due in large part to the extreme variability in the actual EAL's that are accumulated at individual stations from year to year. Such variability is depicted in Figure 2a for Station 8, for which 14 years of data were available. This figure suggests that if the daily EAL's were accumulated over a period of years, the actual and predicted accumulations might tend to converge. Figure 2b shows that, following a six-year period of initial instability, the percent error between actual and predicted EAL's at Station 8 did tend to become reduced as the number of years increased. By extrapolation, the percent error at the end of a 20-year design period would be about 6 percent, certainly a tolerable error.

Similar curves for six of the remaining eight stations for which 11 or more years of data had been accumulated are also shown in Figure 2. These curves verify that the percent errors tend to become reduced and stabilized as time increases. This is of extreme significance since flexible pavement designs in Kentucky are usually based on a 20-year period.

As a further means for validating the proposed methodology, the influence of the accuracy of the EAL estimates on the accuracy of the design pavement thicknesses was also investigated. First the actual and estimated EAL's for each of the 51 locations were extrapolated to 20-year accumulations. Then the combined flexible pavement thicknesses including base and pavement were determined for a design CBR of 5 (5). Figure 3 summarizes the results of these determinations. Differences in the thicknesses based on estimated actual and predicted EAL's seem rather large at first glance. However, it should be recalled that actual data were available for periods of only one or two years for 1 of the 51 stations represented in Figure 3. This would, of course, decrease the reliability of the estimates of 20-year accumulations of EAL's. Figure 3 shows 27 overdesigns, 16 balanced designs and eight underdesigns.

Figure
3

CONCLUSIONS

This search for a technique to estimate EAL accumulations for pavement-design purposes which is responsive to the influence of local conditions required extensive data compilations and the development of many relevant summaries. Only limited data are presented herein, however, due to space limitations and the fact that most of the data are valid only for Kentucky conditions. The interested reader will find the complete data tabulations elsewhere (24). The significant conclusions of this study are:

1. The best basis for predicting EAL's for pavement-design purposes remains data taken from a nearby reference station if that station has similar characteristics to the location in question, at least three or four years of data are available, and due consideration is given to possible future effects of changing local conditions.

2. The alternate predictive methodology recommended when no suitable reference data are available contains a set of traffic parameters which enter the design computations directly, a set of local conditions which can be con-

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TABLE 1

IDENTIFICATION OF LOCAL CONDITIONS

Local Condition	Code	Description
Road Type	1	Interstate-numbered
	2	US-numbered
	3	KY-numbered
	4	Other
Direction	1	North-south
	2	East-west
Alternate Route	1	Alternate route is inferior
	2	No alternate or alternate of same quality
	3	Alternate route is superior
Service Provided	1	Primary service to major recreation
	2	Significant service to major recreation
	3	Some service to recreation
	4	Ordinary
	5	Some service to mining
	6	Significant service to major mining
	7	Primary service to major mining
	8	Some service to industry
	9	Primary service to industry
Volume (ADT)	1	0- 499
	2	500- 999
	3	1000- 1999
	4	2000- 2999
	5	3000- 3999
	6	4000- 5999
	7	6000- 7999
	8	8000- 9999
	9	10000-13999
	10	14000 or more
Maximum Allowable Gross Weight	1	30,000 lbs
	2	42,000 lbs
	3	59,640 lbs
	4	73,280 lbs
Geographical Area	1	Western Kentucky
	2	South Central Kentucky
	3	North Central Kentucky
	4	Eastern Kentucky

TABLE 1 (Cont'd.)

Local Condition	Code	Description
Year	1	1950-1951
	2	1952-1953
	3	1954-1955
	4	1956-1957
	5	1958-1959
	6	1960-1961
	7	1962-1963
	8	1964-1965
	9	1966
Season	1	Winter (Jan-Mar)
	2	Spring (Apr-June)
	3	Summer (July-Sept)
	4	Fall (Oct-Dec)

TABLE 2

METHODS FOR CORRELATION OF TRAFFIC PARAMETERS WITH LOCAL CONDITIONS

Description	Nomenclature
Combinatorial means, full interaction	None
Gross means, no consideration of local conditions	None
Correction factor based on gross means, no interaction, iterative	FACT1
Correction factor based on classified means, limited interaction, iterative	FACT2
Multiple regression, averages, no interaction	MULTRA
Multiple regression, dummy variables, no interaction	MULTRD

TABLE 3

ACCURACY OF VEHICLE-TYPE PERCENTAGE ESTIMATES

Vehicle Type	Mean Percent	Standard Deviation	Standard Error		Correlation Coefficient		Number of Vehicles Counted
			Uncorrected	Corrected[a]	Uncorrected	Corrected[a]	
Cars	71.6718	7.1262	5.7059	5.6479	0.5984	0.6098	4,159,168
Buses	0.8592	0.6164	0.4842	0.4843	0.6187	0.6186	46,953
SU-2A-4T	9.0922	3.8732	2.6203	2.5744	0.7364	0.7471	474,626
SU-2A-6T	8.5095	3.8990	3.2277	3.2297	0.5610	0.5602	456,745
SU-3A	1.0016	2.3819	2.1307	2.1244	0.4470	0.4522	52,264
C-3A	3.9378	4.1526	2.6852	2.6831	0.7628	0.7632	239,123
C-4A	4.1038	4.3735	2.6848	2.6772	0.7894	0.7907	263,847
C-5A	0.8230	2.1582	1.5584	1.5448	0.6918	0.6983	56,805

[a] Estimates of vehicle-type percentages were corrected to a total of 100 percent.

TABLE 4

ACCURACY OF UNIT EAL ESTIMATES[a]

Vehicle Type	EAL Type	Mean Unit EAL	Standard Deviation	Standard Error		Correlation Coefficient		Number of Vehicles Weighed
				Uncorrected	Corrected[b]	Uncorrected	Corrected[b]	
SU-2A-4T	KY	0.0415	0.644	0.632	0.630	0.192	0.212	12,349
	AASHO	0.0061	0.030	0.030	0.030	0.190	0.198	
	MAASHO[c]	0.0061	0.030	0.030	0.030	0.190	0.198	
SU-2A-6T	KY	3.1945	4.121	3.758	3.752	0.411	0.414	23,389
	AASHO	0.1787	0.088	0.081	0.081	0.377	0.377	
	MAASHO	0.1787	0.088	0.081	0.081	0.377	0.377	
SU-3A	KY	10.0445	16.129	12.973	12.867	0.594	0.603	2,180
	AASHO	0.3391	0.289	0.235	0.234	0.578	0.583	
	MAASHO	0.5290	0.440	0.363	0.362	0.564	0.568	
C-3A	KY	8.8944	6.560	6.109	6.106	0.364	0.366	12,143
	AASHO	0.6071	0.270	0.253	0.253	0.351	0.351	
	MAASHO	0.6071	0.270	0.253	0.253	0.351	0.351	
C-4A	KY	15.2519	9.848	7.766	7.759	0.615	0.615	14,321
	AASHO	0.8076	0.328	0.227	0.226	0.723	0.723	
	MAASHO	0.9872	0.435	0.302	0.301	0.721	0.721	
C-5A	KY	18.3338	15.225	11.478	11.471	0.658	0.658	4,302
	AASHO	0.7865	0.452	0.347	0.347	0.639	0.639	
	MAASHO	1.2088	0.705	0.530	0.530	0.659	0.659	

[a] No weight data were available for cars or buses.

[b] Negative estimates were transformed to zero.

[c] Modified AASHO procedures were used.

TABLE 5

ACCURACY OF ESTIMATES OF EAL'S PER 1,000 VEHICLES FOR 225 INDIVIDUAL COUNTS

Type of EAL	Actual Mean	Standard Deviation	Standard Error	Correlation Coefficient
Kentucky (EWL's/1,000 vehicles)	1535.4	1405.3	1173.1	0.55
AASHO (EAL's/1,000 vehicles)	82.4	54.5	42.4	0.63
Modified AASHO (EAL's/1,000 vehicles)	96.9	70.8	52.2	0.68

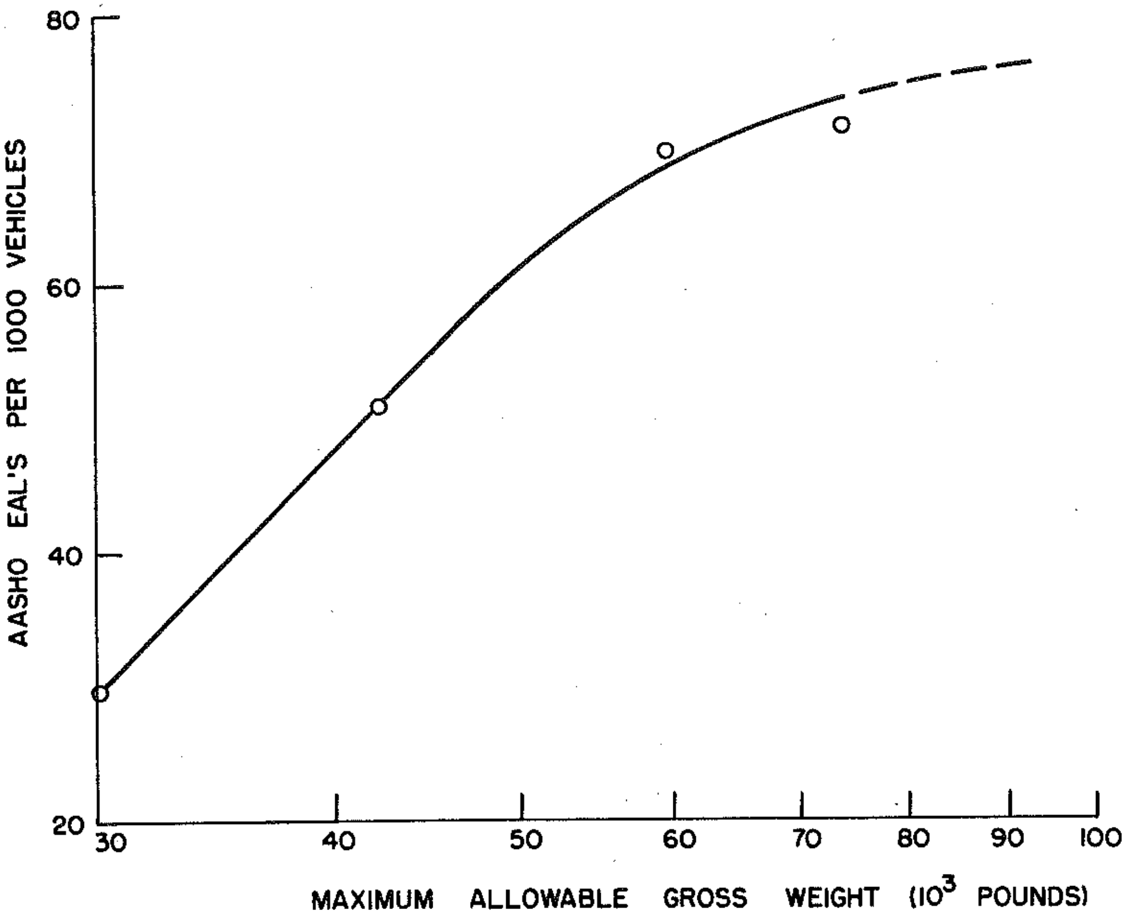

FIGURE 1. EXAMPLE EFFECT OF MAXIMUM ALLOWABLE GROSS WEIGHT ON AASHO EAL'S PER 1000 VEHICLES.

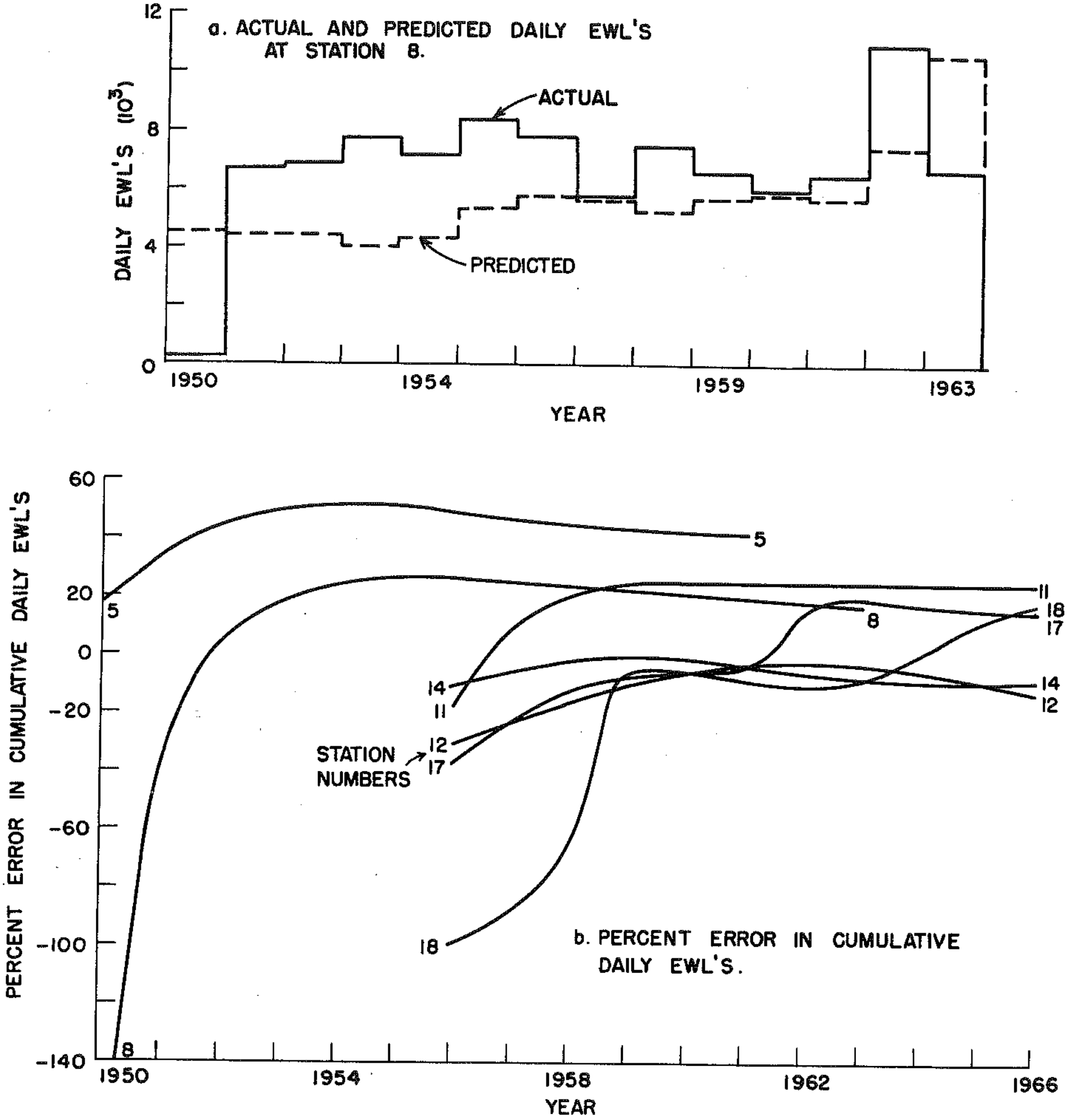

FIGURE 2. VARIABILITY IN KENTUCKY DAILY EWL'S.

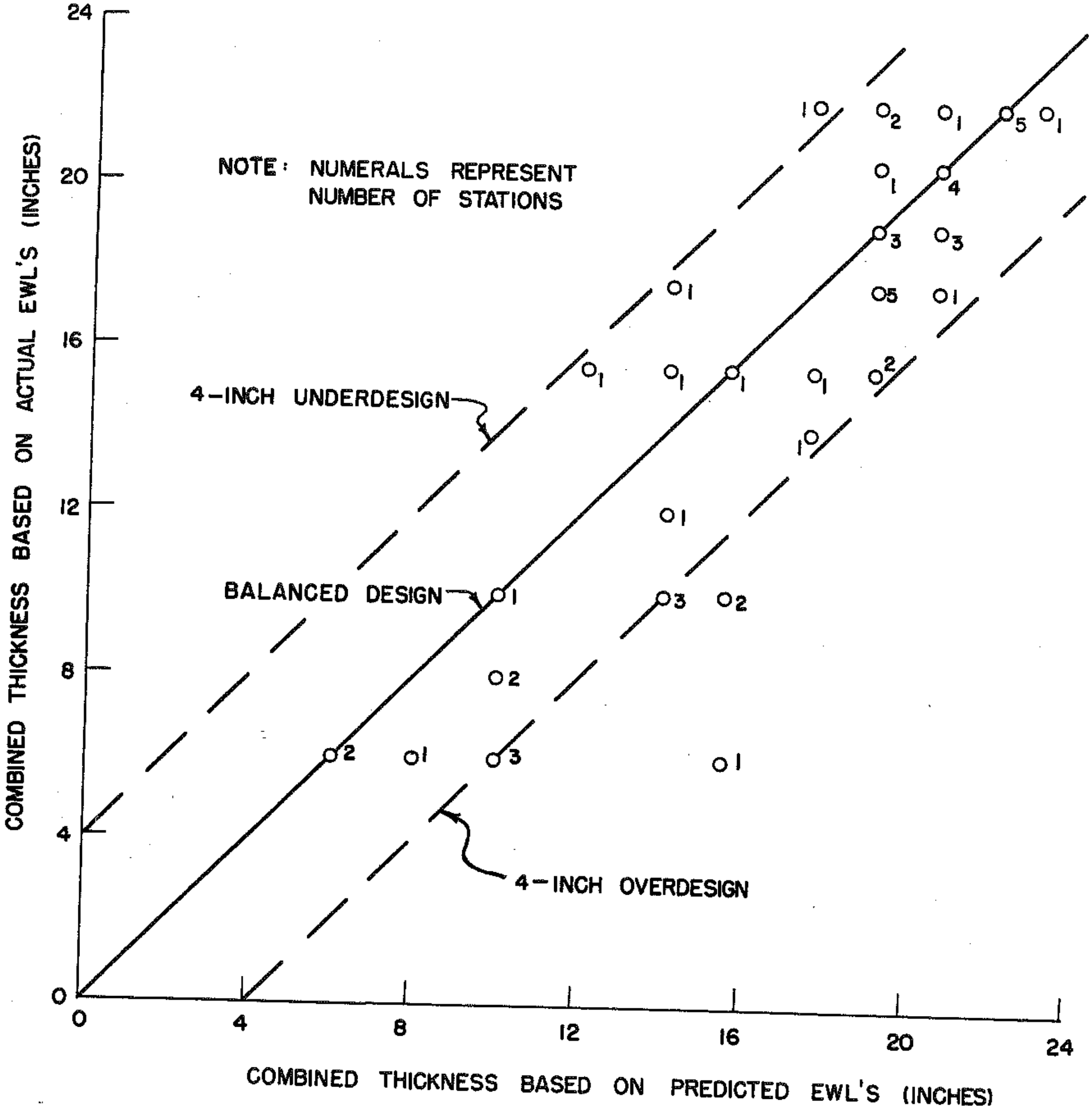

FIGURE 3. FLEXIBLE PAVEMENT THICKNESS BASED ON ACTUAL AND PREDICTED 20-YEAR EWL ACCUMULATIONS.