VOL. 29, NO. 5 DECEMBER 1956

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

PUBLISHED
BIMONTHLY BY THE
BUREAU OF
PUBLIC ROADS,
U. S. DEPARTMENT
OF COMMERCE,
WASHINGTON

The George Washington Memorial Bridge, New York City.
(An average of 98,000 vehicles used this bridge each day during 1955)

Public Roads

A JOURNAL OF HIGHWAY RESEARCH

Published Bimonthly

Vol. 29, No. 5 *December 1956*

C. M. Billingsley, *Editor*

BUREAU OF PUBLIC ROADS

Washington 25, D. C.

DIVISION OFFICES

No. 1. Delaware and Hudson Bldg., Albany 1, N. Y.
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont.

No. 2. 707 Earles Bldg., Hagerstown, Md.
Delaware, District of Columbia, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia.

No. 3. 50 Seventh St., NE., Atlanta 23, Ga.
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, and Puerto Rico.

No. 4. South Chicago Post Office, Chicago 17, Ill.
Illinois, Indiana, Kentucky, Michigan, and Wisconsin.

No. 5. Federal Office Bldg., Kansas City 6, Mo.
Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.

No. 6. 502 U. S. Courthouse, Fort Worth 2, Tex.
Arkansas, Louisiana, Oklahoma, and Texas.

No. 7. Old Mint Bldg., San Francisco 3, Calif.
Arizona, California, Nevada, and Hawaii.

No. 8. 753 Morgan Bldg., Portland 8, Oreg.
Idaho, Montana, Oregon, and Washington.

No. 9. Denver Federal Center, Bldg. 40, Denver 2, Colo.
Colorado, New Mexico, Utah, and Wyoming.

No. 10. Post Office Box 1961, Juneau, Alaska.
Alaska.

IN THIS ISSUE

PUBLIC ROADS is sold by the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at $1 per year (25 cents additional for foreign mailing) or 20 cents per single copy. Free distribution is limited to public officials actually engaged in planning or constructing highways, and to instructors of highway engineering. There are no vacancies in the free list at present.

Use of funds for printing this publication approved by the Director of the Bureau of the Budget, Mar. 17, 1955.

U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, Secretary

BUREAU OF PUBLIC ROADS
JOHN A. VOLPE, Administrator
CHARLES D. CURTISS, Commissioner

Traffic and Travel Trends, 1955

BY THE HIGHWAY TRANSPORT RESEARCH BRANCH
BUREAU OF PUBLIC ROADS

Reported by THOMAS B. DIMMICK
Head, Current Data Analysis Unit

The tremendous growth of the highway transportation industry is revealed in the considerable body of travel data presented in this article, which are collected by means of automatic traffic recorders installed at a large number of locations in all States, as well as from a number of loadometer or pitscale stations operated in 44 States for the purpose of studying vehicle types, weights, and loading practices.

From 1950 to 1955, travel on all roads and streets increased approximately 32 percent; travel on rural roads increased 40 percent, whereas urban travel increased almost 23 percent. During this same period, passenger-car travel increased 34 percent; trucks and truck combinations, 23 percent; and buses, 10 percent.

This aticle stresses primarily the travel trends and loading practices on the main rural roads of the country, which comprise about 12 percent of all rural mileage and carry 68 percent of all rural traffic. Approximately two-thirds of all truck travel in rural areas is performed on these roads, of which about one-third is by combination-type vehicles.

Average daily travel on the main rural roads totaled 595 million vehicle-miles in 1954, as compared with 625 million in 1955, a 5.1 percent increase. By principal geographical areas, the rate of increase in travel from 1954 to 1955 was 7.1 percent for the States in the eastern divisions, 5.4 percent for States in the western divisions, and 3.6 percent for States in the central divisions. The greatest increase in travel took place in States of the Middle Atlantic division, and was followed by the South Atlantic division.

Passenger-car and bus travel on main rural roads increased 147 percent between 1936 and 1955; 103 percent between 1940 and 1955; and 34 percent between 1950 and 1955. For single-unit trucks, the increases were 154 percent, 93 percent, and 18 percent; whereas truck combinations increased 455 percent, 248 percent, and 22 percent, respectively.

A special survey undertaken during the summer of 1955 indicated that 73 percent of the truck travel on main rural roads was performed by private haulers, and the remaining 27 percent was by for-hire carriers of which 18 percent had ICC authority numbers. Of the total truck travel on main rural roads, approximately 30 percent involved trips in more than one State; the remaining 70 percent were intrastate trips made largely by private haulers.

In 1955, 55 percent of all freight-carrying vehicles were loaded, and weighed an average of 24,336 pounds. The weight of empty vehicles averaged 9,426 pounds. For the period 1950–55, weights of loaded single-unit trucks increased 3 percent, whereas combinations increased over 6 percent.

Single-unit trucks in 1955 carried loads during 48 percent of their travel as compared with 60–65 percent during the prewar period 1936–41. Combinations in 1955 were found to be loaded during 68 percent of their travel as compared with 72 percent in 1936.

Average loads carried by single-unit trucks increased from 1.86 tons in 1936 to 2.47 tons in 1955 (33 percent increase), while combinations increased from 6.90 tons in 1936 to 11.07 tons in 1955 (60 percent increase).

Ton-mileage hauled in 1936 by single-unit trucks was 14.3 billion as compared with 38.5 billion in 1955; combinations in 1936 hauled 13.7 billion ton-miles as compared with 115.6 billion in 1955. The two-axle, six-tire trucks, the principal load-carrying single-unit trucks, accounted for 26 percent of all truck travel in 1955, and 17 percent of the ton-mileage hauled; truck-tractor and semitrailer combinations accounted for slightly less than 30 percent of the travel, but carried nearly 68 percent of the ton-mileage.

Frequencies of freight-carrying vehicles weighing 30,000, 40,000, and 50,000 pounds or more reached a new high in 1955. Since 1936 the number of trucks in each 1,000 loaded and empty vehicles weighing 30,000 pounds or more have increased almost 5 times; for 40,000 pounds or more, over 11 times; and 50,000 pounds or more, 25 times. From 1950 to 1955, the frequencies increased 10, 16, and 29 percent, respectively.

The frequencies of axles weighing 18,000, 20,000, and 22,000 pounds or more show an increase in 1955 over 1954, but for the period 1950–55, there has been a decrease of 9, 20, and 35 percent in the three respective axle-weight categories.

UNDER the greatly expanded highway program authorized by the Federal-Aid Highway Act of 1956, it is readily apparent that measurement of highway usage through traffic-counting and sampling procedures will play a significant role in the planning and design of traffic facilities. The huge program of completing within 13–15 years a 41,000-mile network of modern roads on the National System of Interstate and Defense Highways requires that traffic volumes must be determined as far in advance as 1975, in order that these highways be so designed that they will not become functionally obsolete before the surfaces wear out. Such future traffic demands can be estimated only on the basis of trends developed in the past under conditions that can be expected to be similar to those that will most likely be encountered in the future.

In the 5-year period beginning in 1936, 47 of the 48 States, in cooperation with the Bureau of Public Roads, conducted surveys for a 12-month period to collect data which would supply comprehensive information concerning vehicle characteristics and travel habits. The measuring of road mileages, the counting of traffic and classification by vehicle type, the weighing of trucks on rural roads, and the questioning of drivers concerning origin and destination of trips and mileage driven on different road systems during the preceding 12 months, supplied basic data from which a vast amount of information regarding travel habits, ton-miles hauled on rural highway systems, and vehicle-miles driven on all road systems could be determined for the period of the survey.

Shortly after the original surveys were completed, the States installed automatic traffic recorders at a large number of locations and adopted other continuing operations to provide data for estimating trends in traffic volumes. Such recorders were usually located on main rural roads, but in some instances they were located on the local roads and on city streets. Periodic weighing operations, combined with manual counts of all vehicles passing the weighing stations, have been made which provide information concerning vehicle types and weights as well as their loading habits. By means of these trends, annual estimates have been published, showing for each year the travel on rural roads and city streets from 1936 to 1954.[1] By combining carried load data with vehicle-mileage figures, the ton-mileage of freight hauled on main rural roads has been estimated for each year. Sufficient

[1] See previous articles on traffic in PUBLIC ROADS: vol. 28, No. 11; vol. 27, Nos. 6 and 11; vol. 26, Nos. 5 and 11; vol. 25, Nos. 3, 7, and 12; vol. 24, No. 10; and vol. 23, No. 9.

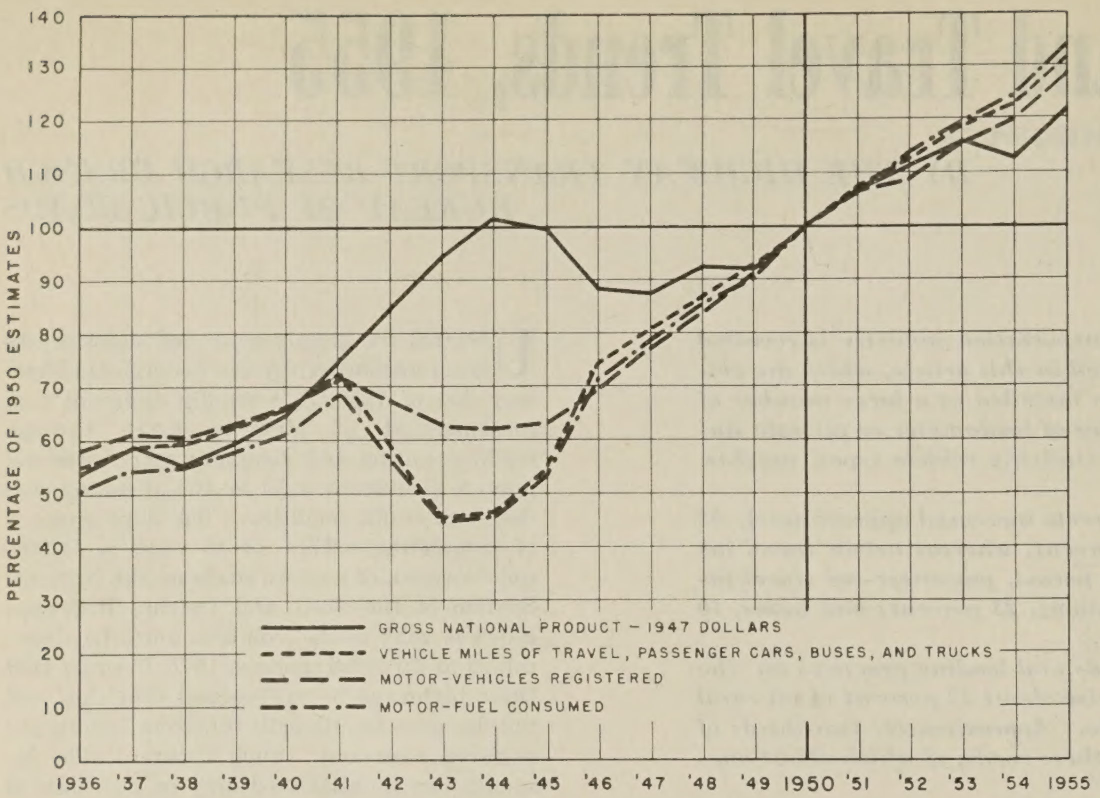

Figure 1.—Total travel, motor-vehicle registration, motor-fuel consumption, and Gross National Product, 1936–55, as a percentage of the respective amounts in 1950.

data are not available to permit the estimating of ton-mileage carried on local roads within reasonable limits of accuracy. No data are available concerning loads carried on city streets and no attempts have been made to estimate the amounts of this haulage.

Urban Travel Data Improve

In recent years many States have adopted some plan for observing trends in urban travel either by means of continuous or part-time traffic counts, and several States have made sufficient counts to enable them to estimate accurately the travel on streets of their key cities. Most States are now able to report the average daily travel on the urban extensions of State highway systems, and other arterial streets. While much is desired in the way of more complete urban travel data for these major thoroughfares, considerable progress is being made.

Although approximations may have to be made concerning the lightly traveled local streets, a large expenditure of funds to determine accurately the amount of travel on them is not always justifiable. Motor-vehicle-use surveys made in several States have provided some additional data concerning all urban travel.

One important result of State cooperation in the study of needs of the highway systems, required by the Federal-Aid Highway Act of 1954, was a complete estimate of vehicle-miles of travel in the previous year on all systems, urban as well as rural. These State estimates for 1953 made it possible to establish a new base period for estimating future traffic trends.

Table 1.—Estimate of motor-vehicle travel in the United States by vehicle types in the calendar year 1955

Vehicle type	Motor-vehicle travel: Main rural road travel	Motor-vehicle travel: Local rural road travel	Motor-vehicle travel: Total rural travel	Motor-vehicle travel: Urban travel	Motor-vehicle travel: Total travel	Number of registered vehicles [1]	Average travel per vehicle	Motor-fuel consumption: Total [2]	Motor-fuel consumption: Average per vehicle	Average travel per gallon of fuel consumed
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Thousands*	*Miles*	*Million gallons*	*Gallons*	*Miles/gal.*
Passenger cars [3]	178, 732	84, 356	263, 088	224, 452	487, 540	52, 092	9, 359	33, 548	644	14. 53
Buses:										
Commercial	1, 152	300	1, 452	1, 804	3, 256	96	34, 035	651	6, 807	5. 00
School and nonrevenue	623	504	1, 127	124	1, 251	159	7, 836	120	750	10. 45
All buses	1, 775	804	2, 579	1, 928	4, 507	255	17, 658	771	3, 021	5. 85
All passenger vehicles	180, 507	85, 160	265, 667	226, 380	492, 047	52, 347	9, 400	34, 319	656	14. 34
Trucks and combinations	47, 481	23, 005	70, 486	40, 901	111, 387	10, 413	10, 697	13, 308	1, 278	8. 37
All vehicles	227, 988	108, 165	336, 153	267, 281	603, 434	62, 760	9, 615	47, 627	759	12. 67

[1] Registration figures differ slightly from those in Bureau of Public Roads table MV–1 because of adjustments in classification in a few States of lightweight farm trucks.
[2] Total fuel consumed differs from that given in Bureau of Public Roads table G–21 because of adjustments to cover estimated amounts used by motorcycles.
[3] Includes taxicabs.

Traffic and Gross National Product

The travel on all rural roads and streets, motor-vehicle registrations, motor-fuel consumption, and the Gross National Product (in constant dollars) are shown in figure 1 for the years 1936–55, inclusive, as a percentage of the 1950 totals. This chart indicates that with the exception of the war years and a few years thereafter when traffic restrictions drastically curtailed travel, and while production was stimulated, the trend of total travel follows closely the economic trend as represented by the Gross National Product. In 1954 the Gross National Product decreased slightly but there was a lesser degree of leveling off in traffic, whereas in 1955, there was a parallel trend. The indexes of motor-vehicle registrations and motor-fuel consumption follow the same trend, which indicates that driving habits of the average car owner remain fairly constant in normal years.

Table 1 shows the estimated amounts of travel in 1955 on main rural roads, local rural roads, and urban streets for passenger cars, buses, and trucks together with the number of vehicles registered and quantity of motor fuel consumed on highways. The travel figures were obtained mainly by applying the available trends to the 1953 data which, as previously stated, were derived from the various State reports submitted for the nationwide highway study. Actual vehicle-mileage totals on the various turnpikes were obtained from reports of the turnpike authorities. Minor adjustments were made in the totals of local rural road and city street travel to include the generated or induced travel on improved or newly constructed sections of lightly traveled feeder roads and on streets in expanding fringe areas where traffic counts ordinarily are not made.

In addition, table 1 shows average miles of travel per vehicle, average consumption of motor fuel, and average travel per gallon of fuel consumed. These figures are included merely as checks on the reasonableness of the vehicle-mileage estimates when compared with other factual data.

Travel Continues Upward Trend

Available data indicate the following increases in travel from 1950 to 1955: rural areas, 40 percent; urban areas, almost 23 percent; and total travel, about 32 percent. Registrations have increased 28 percent and the quantity of motor fuel used on the highways has increased 34 percent. The miles traveled per vehicle and fuel consumed per vehicle increased about 3 and 4 percent, respectively, whereas the miles traveled per gallon of fuel consumed decreased about 2 percent.

A comparison of travel on all roads and streets in 1940, 1945, 1950, and 1955 is given in table 2. Probably the most significant relation is the greater long-range increase in travel by trucks and truck combinations in comparison with passenger cars and buses. This increase is particularly noticeable between 1940 and 1950. Travel by trucks and truck combinations in 1955 was more than

Table 2.—Comparison of estimated vehicle-miles of travel on all roads and streets in 1940, 1945, 1950, and 1955

Year	All vehicles, vehicle-miles	Passenger cars		Buses		Trucks and combinations	
		Percentage of all vehicles	Vehicle-miles	Percentage of all vehicles	Vehicle-miles	Percentage of all vehicles	Vehicle-miles
	Millions		*Millions*		*Millions*		*Millions*
1940	302,188	82.60	249,604	0.88	2,657	16.52	49,927
1945	250,173	80.02	200,199	1.53	3,832	18.45	46,142
1945: 1940 ratio	*.83*	*.97*	*.80*	*1.74*	*1.44*	*1.12*	*.92*
1950	458,246	79.35	363,613	.89	4,081	19.76	90,552
1950: 1945 ratio	*1.83*	*.99*	*1.82*	*.58*	*1.06*	*1.07*	*1.96*
1950: 1940 ratio	*1.52*	*.96*	*1.46*	*1.01*	*1.54*	*1.20*	*1.81*
1955	603,434	80.79	487,540	.75	4,507	18.46	111,387
1955: 1950 ratio	*1.32*	*1.02*	*1.34*	*.84*	*1.10*	*.93*	*1.23*
1955: 1945 ratio	*2.41*	*1.01*	*2.44*	*.49*	*1.18*	*1.00*	*2.41*
1955: 1940 ratio	*2.00*	*.98*	*1.95*	*.85*	*1.70*	*1.12*	*2.23*

twice the amount in 1940. The number of trucks and truck combinations in relation to all other vehicles increased from 16.52 percent in 1940 to 18.46 percent in 1955. Passenger-car travel during the period increased 95 percent. Bus travel leveled off considerably and only a 70-percent gain is indicated for this period. A more detailed study of the growth of bus travel shows that in the period 1940–55, commercial bus travel increased only 67 percent while travel by school and other nonrevenue buses increased 75 percent.

The largest portion of rural travel by trucks and combinations was found on the main roads. These main roads, which comprise only 12 percent of the mileage of all rural roads, actually carry over 67 percent of the truck travel. As would be expected, the larger portion of the heavier vehicles use the main rural roads. Approximately 32 percent of the truck traffic on these roads was made up of combination-type vehicles, but on the local rural roads these combinations accounted for only 10 percent of the traffic. To illustrate further the relation of truck traffic on the two classes of rural roads, the average daily number of trucks per mile of main rural roads in 1955 was 236 single-unit trucks and 112 truck combinations; on the local roads there were 21 and 2 vehicles, respectively.

Data have been collected concerning the loads carried on local roads, but such studies were limited in scope and therefore not as reliable as information on main roads. Local road mileage far exceeds that of the main roads, yet estimates indicate that truck travel on main roads was more than double and ton-mileage hauled was about four times the amount carried on local roads. Because of the limited data and the relative unimportance of the local road mileage from a freight-carrying standpoint, discussion in subsequent sections of this article is confined to the main rural roads.

Figure 2 shows the annual vehicle-miles of travel on main rural roads by 12-month periods ending each month (moving average) from the end of 1936, the first year of the planning surveys, to August 1956. This method of presentation reduces the seasonal fluctuations. The portion of the curve from the end of 1946 through 1950 indicates that the increase averaged over 10 percent each year. Since 1950 the annual increases have been somewhat smaller: 1951, about 9 percent; 1952, 7 percent; 1953, 5 percent; and 1954, 2 percent. Travel on the main rural roads increased at a slightly faster rate in 1955, being more than 5 percent above the 1954 total.

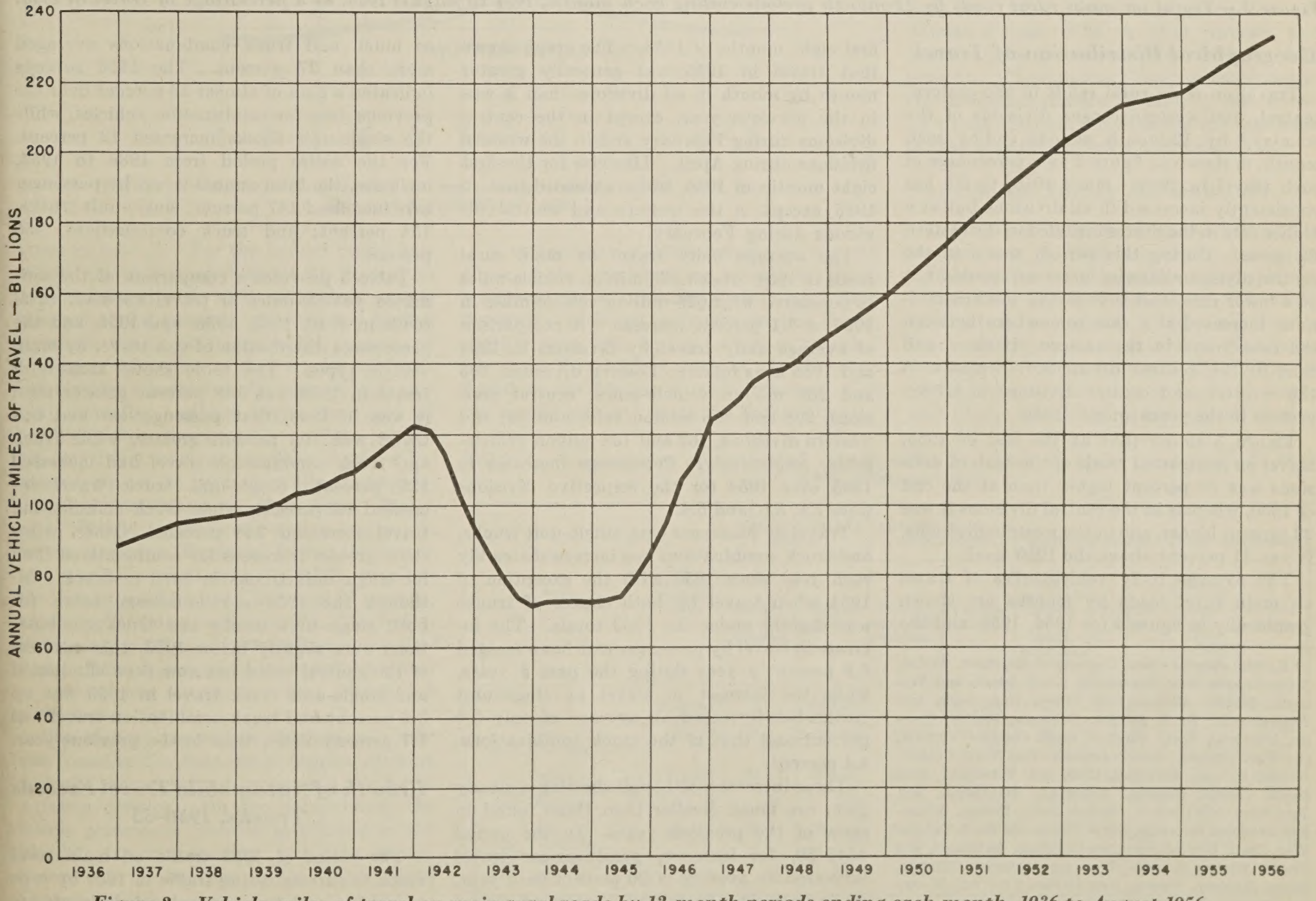

Figure 2.—Vehicle-miles of travel on main rural roads by 12-month periods ending each month, 1936 to August 1956.

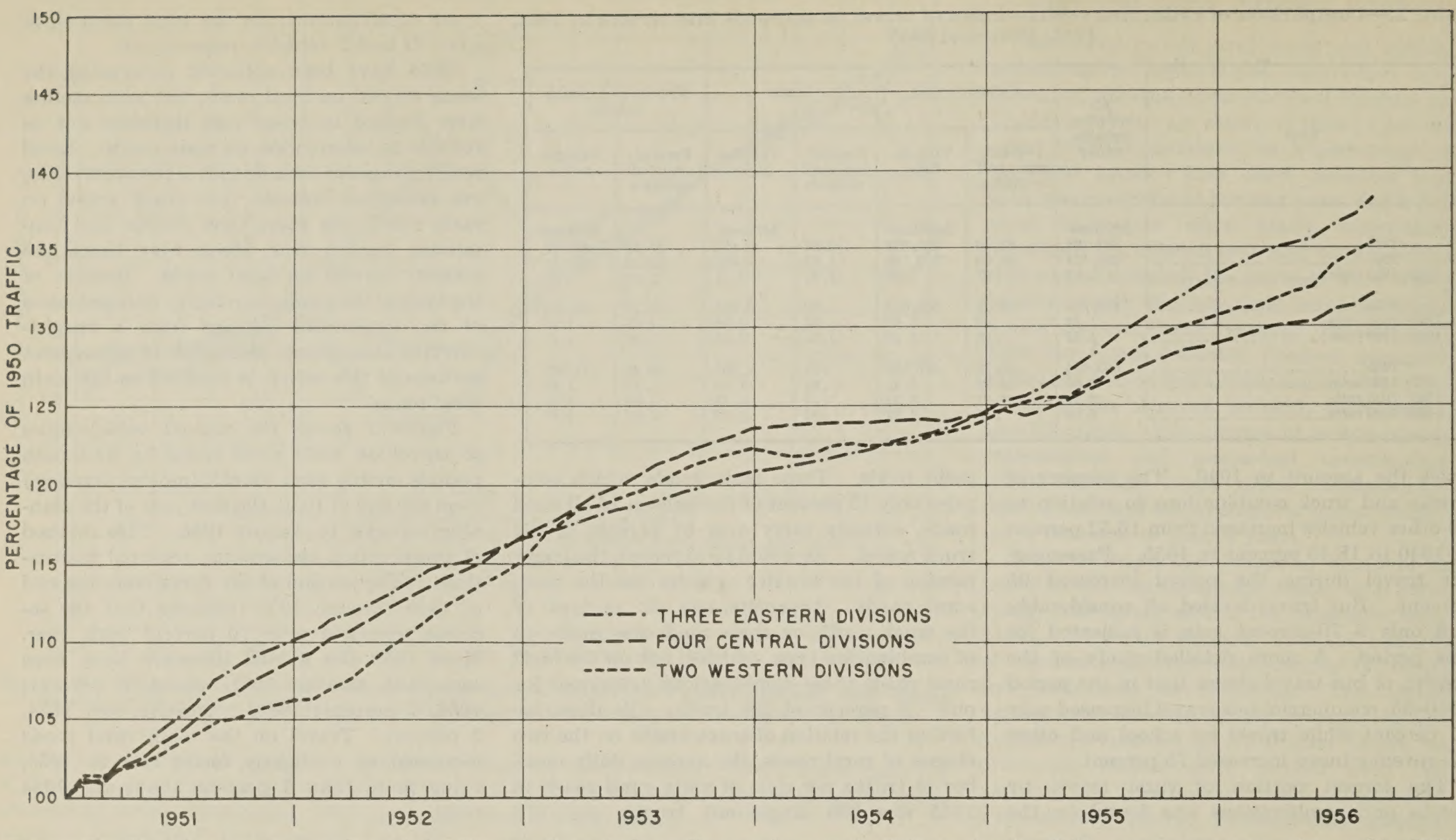

Figure 3.—Travel on main rural roads by 12-month periods ending each month, 1951 to August 1956, as a percentage of travel in 1950.

Geographical Distribution of Travel

Travel on main rural roads in the eastern, central, and western census divisions of the country,[2] by 12-month periods ending each month, is shown in figure 3 as a percentage of such travel in 1950. Since 1950, traffic has consistently increased in all divisions but at a higher rate in the States included in the eastern divisions. During this period, travel in the central divisions likewise increased steadily but at a lower rate, and that in the western divisions increased at a rate somewhere between the rate found in the eastern divisions and that in the central divisions. Increases in the western and central divisions had been greater in the years prior to 1950.

Figure 3 shows that at the end of 1955, travel on main rural roads of the eastern divisions was 33 percent higher than at the end of 1950, whereas in the central divisions it was 29 percent higher, and in the western divisions, it was 31 percent above the 1950 level.

The average daily vehicle-miles of travel on main rural roads by months are shown graphically in figure 4 for 1954, 1955, and the first eight months of 1956. The graph shows that travel in 1955 was generally greater month by month in all divisions than it was in the previous year, except in the central divisions during February and in the western divisions during April. Likewise for the first eight months of 1956, travel exceeded that in 1955 except in the western and central divisions during February.

The average daily travel on main rural roads in 1954 totaled 595 million vehicle-miles as compared with 625 million vehicle-miles in 1955, a 5.1 percent increase. A comparison of average daily travel by divisions in 1954 and 1955 is as follows: Eastern divisions, 195 and 209 million vehicle-miles; central divisions, 298 and 308 million vehicle-miles; and western divisions, 102 and 108 million vehicle-miles, respectively. Percentage increases in 1955 over 1954 for the respective divisions were 7.1, 3.6, and 5.4.

Travel by passenger cars, single-unit trucks, and truck combinations has increased steadily each year since 1950 with the exception of 1954 when travel by both classes of trucks was slightly under the 1953 totals. The increase in travel by passenger cars has averaged 6.8 percent a year during the past 5 years, while the increase in travel by single-unit trucks has increased an average of only 3.6 percent and that of the truck combinations, 4.4 percent.

These increases, although showing a steady gain, are much smaller than those found in some of the previous years. In the period 1945–50, for instance, passenger-car travel increased an average of 20 percent each year, while single-unit truck travel increased almost as much and truck combinations averaged more than 27 percent. The 1950 surveys indicated a gain of almost 33 percent over the previous year for combination vehicles, while the single-unit trucks increased 12 percent. For the entire period from 1936 to 1955, inclusive, the total annual travel by passenger cars increased 147 percent; single-unit trucks, 154 percent; and truck combinations, 455 percent.

Table 3 provides a comparison of the estimated vehicle-miles of travel on main rural roads in 1940, 1945, 1950, and 1955, and the percentage distribution of this travel by main vehicle types. The table shows that total travel in 1955 was 108 percent greater than it was in 1940, that passenger-car and bus travel was 103 percent greater, while truck and truck combination travel had increased 125 percent. Single-unit truck travel increased 93 percent, while truck combination travel increased 248 percent. Other ratios show greater increases for combinations than for single-unit trucks in each instance. Although the 1954 vehicle-mileage totals for both single-unit trucks and truck combinations were slightly below 1953, that reversal of the general trend has now been eliminated and single-unit truck travel in 1955 was up 3.6 percent and truck combination travel was 5.7 percent higher than in the previous year.

Growth of Automobile Travel Exceeds Trucks, 1950–55

The ratios of 1955 traffic on main rural roads to corresponding traffic in 1950 by type of vehicle and by geographical divisions are

[2] *Eastern divisions*—New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Middle Atlantic: New Jersey, New York, and Pennsylvania. South Atlantic: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. *Central divisions*—East North Central: Illinois, Indiana, Michigan, Ohio, and Wisconsin. East South Central: Alabama, Kentucky, Mississippi, and Tennessee. West North Central: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota. West South Central: Arkansas, Louisiana, Oklahoma, and Texas. *Western divisions*—Mountain: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Pacific: California, Oregon, and Washington.

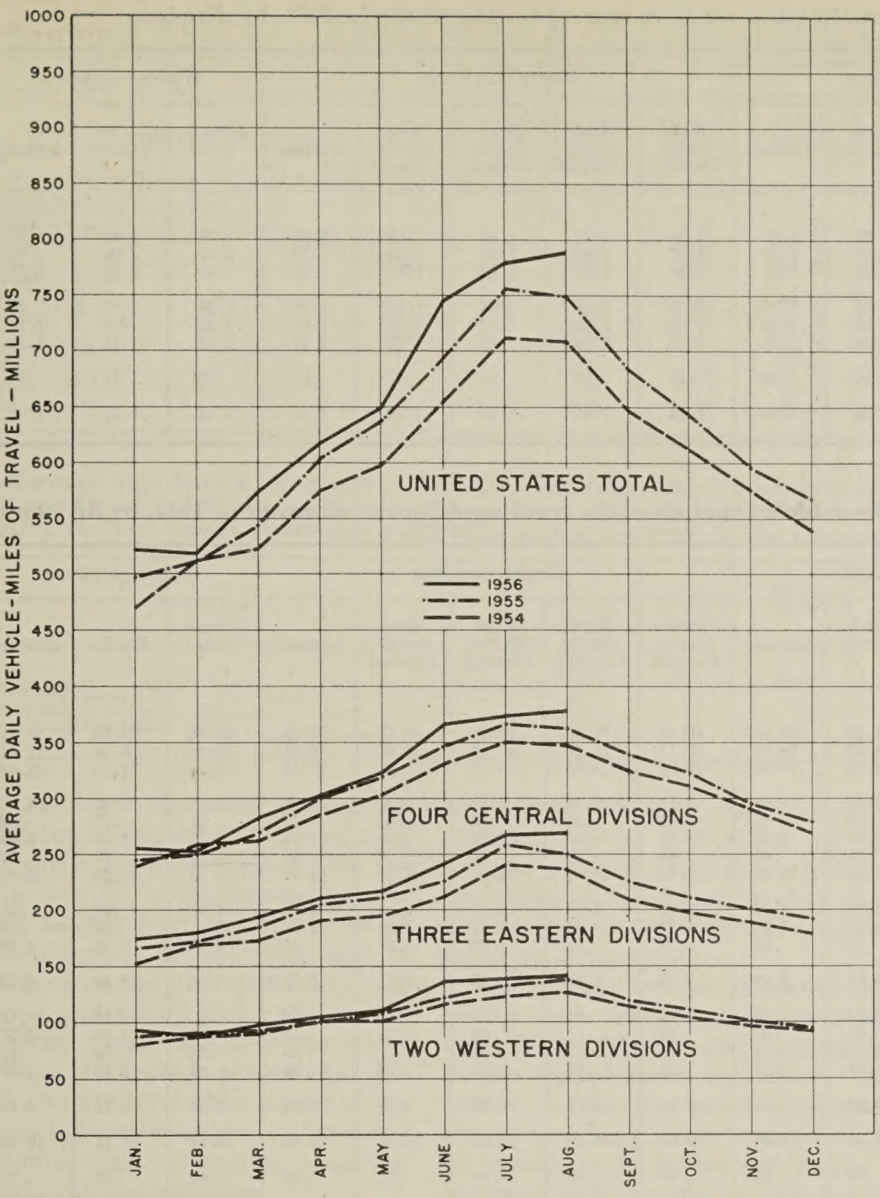

Figure 4.—Average daily travel on main rural roads in 1954, 1955, and in the first 8 months of 1956.

The large increase in travel found in the Middle Atlantic division was due, to a great extent, to an unusually large number of out-of-State vehicles traveling in that one division.

The percentage distribution of travel by vehicle types on main rural roads in the summer of 1955, according to geographical divisions, is given in table 5. The table shows that the largest percentage of passenger-car travel was in the Pacific division, with that in the New England division following closely. A comparison of truck travel shows that the West South Central division has the highest percentage of travel by all types of trucks and combinations, with the East South Central and Mountain divisions following in order. The lowest percentage for truck travel was found in the Pacific division with the New England division only slightly higher. Travel by all types of combinations in the East North Central division exceeded all others and was followed closely by the West South Central division. When the comparison is restricted to truck and trailer combinations, it can readily be seen that travel by this type is heavily concentrated in the Pacific, Mountain, and East North Central divisions.

When the percentage distribution of travel by types of motor vehicles given in table 5 is compared with a similar distribution previously published for 1950, it is found that during the 1950–55 period, the percentage of passenger-car travel to total travel increased from 76.15 to 78.50; that of single-unit trucks decreased from 15.63 to 14.11 percent; and combinations decreased from 7.21 to 6.72 percent. These figures show, as was noted in the discussion concerning table 4, that travel by trucks and combinations has not expanded as fast as passenger-car travel since 1950.

given in table 4. For the United States as a whole, travel increased about 31 percent in 1955 compared with 1950, an average annual increase of 6.2 percent. During this period, passenger-car travel increased 34 percent, an average of 6.8 percent a year; trucks and truck combinations increased 19 percent, 3.8 percent annually; and bus travel decreased 13 percent, 2.6 percent annually. Of the passenger-car travel, that of the local vehicles increased almost 34 percent, while the out-of-State vehicles increased at a slightly faster rate. Travel by the lighter weight single-unit trucks increased 18 percent during the 5-year period or 3.6 percent annually, while travel by the heavier combinations increased 22 percent, an average of 4.4 percent annually. The reduction in bus travel was mostly in the commercial-type vehicles, inasmuch as the travel by school or nonrevenue buses increased about 2.4 percent each year.

The highest percentage increase in traffic was found in the East South Central division with the second highest increase in the South Atlantic division. On the other hand, the lowest percentage increase was found in the Middle Atlantic division with the second lowest rate of increase in the West North Central division.

A comparison of 1955 travel figures with those of the previous year reveals that passenger-car travel increased slightly more than 5 percent; truck and truck combination travel, slightly more than 4 percent; and all travel, 5 percent. The highest rate of increase was found in the Middle Atlantic division, with the second highest rate in the South Atlantic.

Special Survey Made in 1955

Certain special information was gathered in the summer of 1955 concerning travel on main rural roads by freight-carrying vehicles. These data provided interesting and useful information concerning freight movements that ordinarily are not available. The information collected made possible the calculation of the percentage relation of travel by single-unit trucks and truck combinations; class of

Table 3.—Comparison of estimated vehicle-miles of travel on main rural roads in 1940, 1945, 1950, and 1955

Year	All vehicles, vehicle-miles	Passenger cars and buses		All trucks and truck combinations		Single-unit trucks		Truck combinations	
		Percentage of all vehicles	Vehicle-miles	Percentage of all vehicles	Vehicle-miles	Percentage of all trucks and truck combinations	Vehicle-miles	Percentage of all trucks and truck combinations	Vehicle-miles
	Millions		*Millions*		*Millions*		*Millions*		*Millions*
1940	109, 815	80. 8	88, 715	19. 2	21, 100	79. 1	16, 699	20. 9	4, 401
1945	85, 792	78. 0	66, 885	22. 0	18, 907	71. 9	13, 602	28. 1	5, 305
1945: 1940 ratio	*.78*	*.97*	*.75*	*1.15*	*.90*	*.91*	*.81*	*1.34*	*1.21*
1950	174, 349	77. 2	134, 527	22. 8	39, 822	68. 4	27, 257	31. 6	12, 565
1950: 1945 ratio	*2.03*	*.99*	*2.01*	*1.04*	*2.11*	*.95*	*2.00*	*1.12*	*2.37*
1950: 1940 ratio	*1.59*	*.96*	*1.52*	*1.19*	*1.90*	*.86*	*1.63*	*1.51*	*2.86*
1955	227, 988	79. 2	180, 507	20. 8	47, 481	67. 8	32, 173	32. 2	15, 308
1955: 1950 ratio	*1.31*	*1.03*	*1.34*	*.91*	*1.19*	*.99*	*1.18*	*1.02*	*1.22*
1955: 1945 ratio	*2.66*	*1.02*	*2.70*	*.95*	*2.51*	*.94*	*2.37*	*1.15*	*2.89*
1955: 1940 ratio	*2.08*	*.98*	*2.03*	*1.08*	*2.25*	*.86*	*1.93*	*1.54*	*3.48*

Table 4.—Ratio of 1955 traffic on main rural roads to corresponding traffic in 1950, by divisions

Vehicle type	Eastern divisions				Central divisions					Western divisions			United States average
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average	
Passenger cars:													
Local	1.61	1.12	1.50	1.35	1.28	1.73	1.19	1.32	1.32	1.29	1.40	1.37	1.34
Foreign	1.11	1.25	1.70	1.43	1.27	1.58	1.32	1.28	1.33	1.31	1.09	1.23	1.35
All passenger cars	1.46	1.15	1.55	1.37	1.28	1.68	1.21	1.31	1.32	1.30	1.36	1.34	1.34
Trucks and truck combinations:													
Single-unit trucks	1.24	1.20	1.34	1.27	1.09	1.11	1.03	1.26	1.13	1.38	1.16	1.26	1.18
Truck combinations	1.13	1.03	1.13	1.09	1.20	1.48	1.32	1.57	1.34	1.29	1.09	1.16	1.22
All trucks and combinations	1.21	1.15	1.28	1.20	1.13	1.19	1.12	1.32	1.17	1.35	1.13	1.22	1.19
Buses	.88	.87	.96	.92	.76	.80	.70	.97	.81	.70	1.14	.96	.87
All vehicles	1.40	1.15	1.48	1.33	1.24	1.51	1.19	1.32	1.29	1.31	1.32	1.32	1.31

Table 5.—Percentage distribution of travel by vehicle types on main rural roads in the summer of 1955, by divisions

Vehicle type	Eastern divisions				Central divisions					Western divisions			United States average
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average	
Passenger cars:													
Local	63.57	60.61	57.32	59.39	56.49	50.22	62.45	58.73	57.28	43.08	75.41	63.31	59.02
Foreign	19.33	17.70	21.62	19.90	23.17	23.83	17.34	14.47	19.86	32.68	8.53	17.57	19.48
All passenger cars	82.90	78.31	78.94	79.29	79.66	74.05	79.79	73.20	77.14	75.76	83.94	80.88	78.50
Single-unit trucks:													
Panel and pickup	3.87	5.98	7.40	6.38	5.15	9.79	6.22	11.31	7.69	10.64	6.95	8.33	7.37
Other 2-axle, 4-tire	1.48	3.86	.76	1.96	.17	.03	.40	.05	.17	.91	.77	.82	.88
Other 2-axle, 6-tire	5.87	4.99	5.69	5.47	5.18	8.02	5.82	5.69	5.91	6.13	1.91	3.49	5.34
3-axle	.40	.63	.76	.66	.45	.57	.42	.26	.41	.57	.57	.57	.52
All single-unit trucks	11.62	15.46	14.61	14.47	10.95	18.41	12.86	17.31	14.18	18.25	10.20	13.21	14.11
Truck tractor and semitrailer combinations:													
3-axle	3.53	4.31	2.27	3.17	3.16	4.16	2.21	3.15	3.12	1.41	.67	.95	2.77
4-axle	1.15	1.18	3.32	2.25	4.31	2.42	3.40	5.22	4.04	1.29	.59	.85	2.89
5-axle or more	.02	.01	.02	.02	.76	.07	1.00	.38	.60	1.85	1.30	1.50	.56
All truck-tractor and semitrailer combinations	4.70	5.50	5.61	5.44	8.23	6.65	6.61	8.75	7.76	4.55	2.56	3.30	6.22
Truck and trailer combinations:													
4-axle or less	.01	.13	.03	.06	.09	.01	.20	.03	.09	.22	.13	.16	.10
5-axle	--------	.01	.01	.01	.48		.04	--------	.19	.57	1.69	1.27	.31
6-axle or more	--------	--------	--------	--------	.11	--------	.01	--------	.04	.05	.63	.42	.09
All truck and trailer combinations	.01	.14	.04	.07	.68	.01	.25	.03	.32	.84	2.45	1.85	.50
All combinations	4.71	5.64	5.65	5.51	8.91	6.66	6.86	8.78	8.08	5.39	5.01	5.15	6.72
All trucks and truck combinations	16.33	21.10	20.26	19.98	19.86	25.07	19.72	26.09	22.26	23.64	15.21	18.36	20.83
Buses	.77	.59	.80	.73	.48	.88	.49	.71	.60	.60	.85	.76	.67
All vehicles	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

carrier (Interstate Commerce Commission authority, other for-hire, and private haulers); area of travel (interstate or intrastate trips); and road system traveled (Interstate system or other main roads). In addition, the average trip length of all vehicles sampled was tabulated according to major vehicle types and class of carrier. Since the samples were taken during the summer months, they represent the distribution of traffic in that season only and may not, in some respects, represent the annual distribution.

Table 6 shows the percentage of vehicle-miles of travel by trucks and truck combinations, according to class of carrier and type of trip (interstate or intrastate) in the summer of 1955. This table indicates, as might have been assumed, that the largest portion of travel was by private haulers making intrastate trips on main rural roads other than the Interstate system. The smallest amount of travel was performed by for-hire vehicles operating without ICC authority, and making interstate trips. About 73 percent of all truck travel was by private haulers, and the remaining 27 percent was by for-hire vehicles of which about 18 percent had ICC authority numbers. Slightly over 30 percent of the trips involved interstate travel, and the remainder had origins and destinations within a single State.

In a similar manner table 7 shows the percentage of ton-miles of freight hauled by trucks and truck combinations, according to class of carrier, and type of trip, in the summer of 1955. It is evident from a comparison of tables 6–7 that the heavier loads were carried generally on the Interstate system by vehicles operating with ICC authority numbers and especially, those vehicles engaged in interstate travel. Although vehicles traveling on the Interstate system with ICC authority numbers and making trips through more than one State accounted for 3.42 percent of the total main rural road travel, these vehicles carried 9.15 percent of all freight transported, a ratio of 1 to 2.68. On the other hand, private haulers using the main roads (other than Interstate system) and traveling within a single State accounted for about 45 percent of the travel but only 22 percent of the ton-mileage, or a ratio of 1 to 0.49. Common carriers frequently are able to obtain two-way loads whereas private haulers usually are limited to one-way loads, which may account for the larger proportion of freight transported by the common carriers.

Table 6.—Percentage of vehicle-miles of travel by trucks and truck combinations, by type of carrier and type of trip (interstate or intrastate), in the summer of 1955

System and trip type	ICC authority vehicles	Other for-hire vehicles	Private haulers	All vehicles
Interstate (rural) highway system:				
Interstate trips	3.42	0.62	4.28	8.32
Intrastate trips	1.70	1.25	11.83	14.78
Total	5.12	1.87	16.11	23.10
Other main rural roads:				
Interstate trips	8.49	1.83	11.69	22.01
Intrastate trips	4.77	4.72	45.40	54.89
Total	13.26	6.55	57.09	76.90
All main rural roads:				
Interstate trips	11.91	2.45	15.97	30.33
Intrastate trips	6.47	5.97	57.23	69.67
Total	18.38	8.42	73.20	100.00

Table 7.—Percentage of ton-miles of freight hauled by trucks and truck combinations, by type of carrier and type of trip (interstate and intrastate), in the summer of 1955

System and trip type	ICC authority vehicles	Other for-hire vehicles	Private haulers	All vehicles
Interstate (rural) highway system:				
Interstate trip	9.15	1.46	5.28	15.89
Intrastate trip	2.78	2.37	6.56	11.71
Total	11.93	3.83	11.84	27.60
Other main rural roads:				
Interstate trips	20.07	3.09	12.35	35.51
Intrastate trips	7.14	7.36	22.39	36.89
Total	27.21	10.45	34.74	72.40
All main rural roads:				
Interstate trips	29.22	4.55	17.63	51.40
Intrastate trips	9.92	9.73	28.95	48.60
Total	39.14	14.28	46.58	100.00

Table 8.—Average trip length (one way) of freight-carrying vehicles bearing Interstate Commerce Commission authority numbers, those without ICC authorization but engaged in for-hire travel, and those engaged in private hauling, in the summer of 1955

Vehicle type	ICC authority vehicles	Other for-hire vehicles	Private haulers	All vehicles
	Miles	*Miles*	*Miles*	*Miles*
Single-unit trucks	27	20	15	15
Truck combinations	120	77	75	91
All trucks and combinations	95	30	21	28

Possibly the most interesting information derived from the special study made in 1955 is the data given in table 8 concerning the average trip lengths of freight-carrying vehicles. Trip lengths have been adjusted to eliminate duplications in sampling due to length of trip, since the probability of a trip being recorded, under the method of sampling used, is in direct proportion to the length of the trip. From this table it is seen that the longest trips were made by truck combinations operating with ICC authorization; on the other hand, single-unit trucks in private operation generally made the shortest trips.

Weight Stations Operated

During the summer of 1955, a total of 519 loadometer or pitscale stations were operated in 44 States for the purpose of collecting data concerning vehicle types, weights, and loading practices. During this survey all vehicles (passenger cars, single-unit trucks, truck combinations, and buses) were counted and freight-carrying vehicles were classified according to the number of axles and tire equipment. Approximately 135,000 trucks and truck combinations were weighed, and a record was made of the type of vehicle, the weight of its axles, the spacing (in feet) between each pair of axles, and whether the vehicle was loaded or empty.

The stations used in the 1955 survey were located at the same points as in former years, most of them being at sites operated in the original surveys in the 1936–40 period. From comparable data collected at these locations, trends in travel, loading practices, and carried loads were obtained, which, when applied to former estimates derived from comprehensive surveys, gave current estimates of annual vehicle-miles traveled by loaded vehicles and the carried load. The product of these two factors is the ton-miles of carried load. Data concerning the frequency of overloading and of heavy axle and heavy gross weight occurrence also were made available. The remaining tables and charts in this article have been calculated by means of these trends, or by combining the actual data gathered in the summer survey with vehicle-mileage data developed from trends.

The average weights of loaded and empty trucks and truck combinations in 1955, according to vehicle types, are given in table 9 for the United States as a whole. From this table it is seen that about 55 percent of all freight-carrying vehicles were loaded, weighing an average of 24,336 pounds; empty vehicles averaged 9,426 pounds, and the average of all vehicles, loaded and empty, was 17,592 pounds. Data for 1955 compared with 1950 show that the weights of loaded single-unit trucks increased over 3 percent in the 5-year period; truck combinations, over 6 percent; and for all loaded vehicles, 5 percent. The weights of all empty vehicles increased 5 percent, although the weights of empty single-unit trucks decreased 2.5 percent and empty truck combinations increased over 9 percent.

The heaviest average weights of loaded single-unit trucks in 1955 were found in the South Atlantic division, with those in the New England division being slightly less. The heaviest average weights of truck combinations were found in the Pacific division, with those in the Mountain division being slightly smaller. The heaviest average weights for loaded trucks and truck combinations of all types were recorded in the Pacific division, with the average in the Mountain division slightly lower. At the other extreme, the lowest average weights for all types of loaded vehicles were in the East South Central division. Average empty weights of vehicles followed an area distribution pattern similar to that for the average loaded weights.

Relation of Payload to Total Weight

If it is assumed that the average empty weight of loaded vehicles of a given type is the same as the average weight of empty vehicles of the same type, then subtracting average empty weight from average loaded weight gives average carried load for the vehicle type. On this basis, the average loads carried in vehicles of different types and the relation of these loads to the average loaded weights of the vehicles are as shown in table 10. Thus, in general, the heavier the vehicle type the larger the proportion of the gross weight that consists of carried load or payload. The payload for trucks and combinations with three or more axles averages about one-half of the total weight of the loaded vehicle, whereas for two-axle vehicles it averages much less.

Travel by Loaded and Empty Trucks

The relation of travel by loaded and empty trucks and truck combinations has changed considerably since the prewar period. From 1936 to 1941, between 60 and 65 percent of the single-unit trucks were loaded. When war was declared and driving restrictions were invoked, many small truck owners found it advantageous to use their vehicles for general transportation purposes. Thus, it soon developed that the lighter weight trucks were being used more frequently for personal transportation than had previously been the case.

During the war period, the larger as well as the smaller single-unit trucks were used for the transportation of goods on less than half of their travel. Following World War II, the popularity of the lightweight trucks as a means of personal transportation continued, and in 1950 only about 47 percent of their travel involved carrying a load. The corresponding figure for 1955 was 48 percent. At no time since the war has travel by loaded single-unit trucks equaled that of empty vehicles of this type.

For truck combinations, the relation of

Table 9.—Average weight of loaded and empty trucks and truck combinations, by vehicle types, in the summer of 1955

Vehicle type	Weight loaded	Percentage loaded	Weight empty	Percentage empty	Weight loaded and empty
	Lbs.		*Lbs.*		*Lbs.*
Single-unit trucks:					
Panel and pickup	5,421	37.47	4,173	62.53	4,641
Other 2-axle, 4-tire	6,317	55.16	4,865	44.84	5,666
Other 2-axle, 6-tire	14,672	61.16	8,572	38.84	12,302
3-axle	30,471	60.05	14,765	39.95	24,196
Average	11,241	48.38	5,755	51.62	8,409
Truck combinations:					
Truck-tractor and semitrailer	42,695	68.24	21,482	31.76	35,959
Truck and trailer	62,428	67.82	27,232	32.18	51,101
Average	44,155	68.21	21,912	31.79	37,085
Average, all trucks and combinations	24,336	54.77	9,426	45.23	17,592

Table 10.—Average carried loads by trucks and truck combinations in the summer of 1955, in relation to the average loaded weights of such vehicles

Vehicle type	Average loaded weight	Average empty weight	Average carried load	Relation of carried load to loaded weight
	Lbs.	*Lbs.*	*Lbs.*	*Pct.*
Single-unit trucks:				
Panel and pickup	5,421	4,173	1,248	23.0
Other 2-axle, 4-tire	6,317	4,865	1,452	23.0
Other 2-axle, 6-tire	14,672	8,572	6,100	41.6
3-axle	30,471	14,765	15,706	51.5
Truck combinations:				
Truck-tractor and semitrailer	42,695	21,482	21,213	49.7
Truck and trailer	62,428	27,232	35,196	56.4

travel between loaded and empty vehicles has been fairly uniform throughout the entire period. In 1936, 72 percent of the travel by these vehicles involved the carrying of goods, as compared with 69 percent in 1950, and 68 percent in 1955.

Carried Loads Increase

Average loads carried by trucks and by truck combinations have increased slowly each year. The largest increase for single-unit trucks, 1.86 to 2.29 tons, took place between 1936 and 1941. Since that time average carried loads have not changed materially, being 2.31 tons in 1950 and 2.47 tons in 1955. From 1936 to 1955, the average carried loads hauled by single-unit trucks increased 33 percent. On the other hand, average loads for truck combinations increased rather steadily from 1936 to 1950, and at a reduced rate from that year to 1955. For 1936 the average carried load for combination-type vehicles was 6.90 tons; in 1950, it was 10.62 tons; and in 1955, it was 11.07 tons. The overall increase was 60 percent.

Due to the increased use of truck combinations, the average weight of loads carried by all trucks and truck combinations increased at a still faster rate than for either single-unit trucks or combinations considered separately. Loads hauled by all types of trucks averaged 2.90 tons in 1936, 5.64 tons in 1950, and 5.92 tons in 1955; thus the total increase was 104 percent.

Volume of Freight Hauled

Ton-mileage data provide a measure of the volume of freight hauled on any highway or system of highways. The actual volume of freight carried annually from 1936 to 1955, inclusive, by trucks and truck combinations on main rural roads is shown in figure 5. The chart shows the tremendous growth in ton-miles of freight transported by truck combinations since the beginning of the planning surveys. In 1936 an estimated 13.7 billion ton-miles were transported by combination-type vehicles, and slightly less than 14.3 billion ton-miles were transported by single-unit trucks. By 1940, the combination vehicles were hauling slightly more than the single-unit trucks, and in 1955 the ton-mileage hauled by combinations was three times that of single-unit trucks.

The growth in ton-mileage by single-unit trucks and truck combinations from 1936 to 1955 is illustrated in another manner in figure 6. Ton-mileage is the product of the vehicle-mileage traveled by loaded vehicles and the average tonnage carried by each vehicle. This chart shows the changes that have taken place in each of these factors. The horizontal scale measures the vehicle-mileage for loaded vehicles of each type, and the vertical scale measures the average carried load. Ton-mileage, the product of these two factors, is represented by the areas of the rectangles.

For single-unit trucks, the increase in ton-mileage from 14.3 billion in 1936 to 38.5 billion in 1955 came about mainly through an increase in the mileage traveled by loaded vehicles, since there was very little increase in the average carried load for this class of vehicles, especially from 1950 to 1955. For truck combinations, the increase in ton-mileage from 13.7 billion in 1936 to 115.6 billion in 1955 was the result of a substantial increase in the average carried load and a much greater proportional increase in mileage traveled by loaded vehicles.

It can be seen from figure 6 that almost the entire development of the movement of freight over the highways by the heavy combination-type vehicles has taken place since 1936. In that year, over one-half of the hauling, measured in ton-mileage, was performed by single-unit trucks; in 1955, about three-fourths of it was done by the heavy combination vehicles.

A comparison of the estimated percentage of trucks loaded, average carried load, and ton-miles of freight carried on main rural roads in 1940, 1945, 1950, and 1955 is given separately for single-unit trucks and truck combinations in table 11. The table shows the extent to which the ton-mileage gains were due to

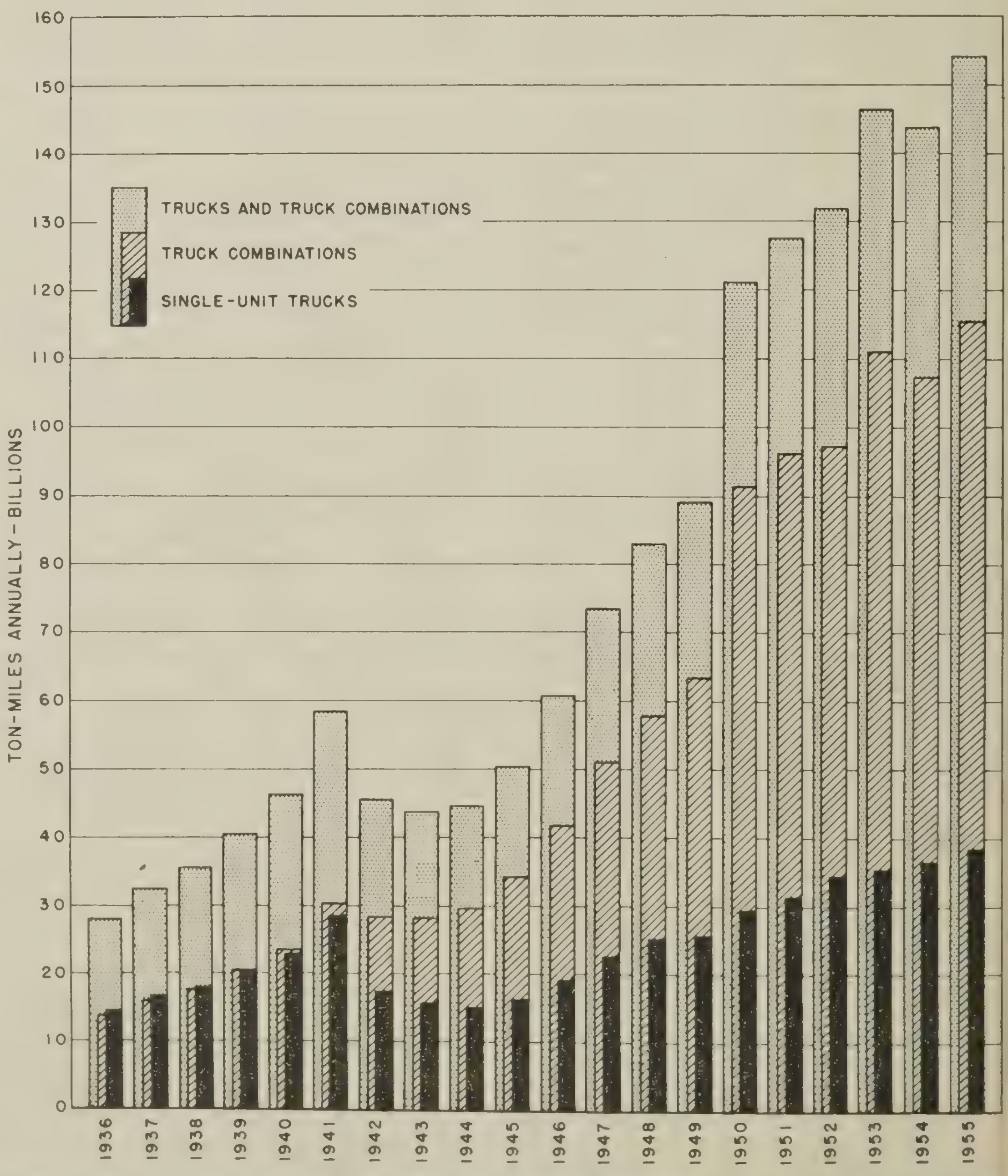

Figure 5.—Ton-miles carried by trucks and truck combinations on main rural roads, 1936–55.

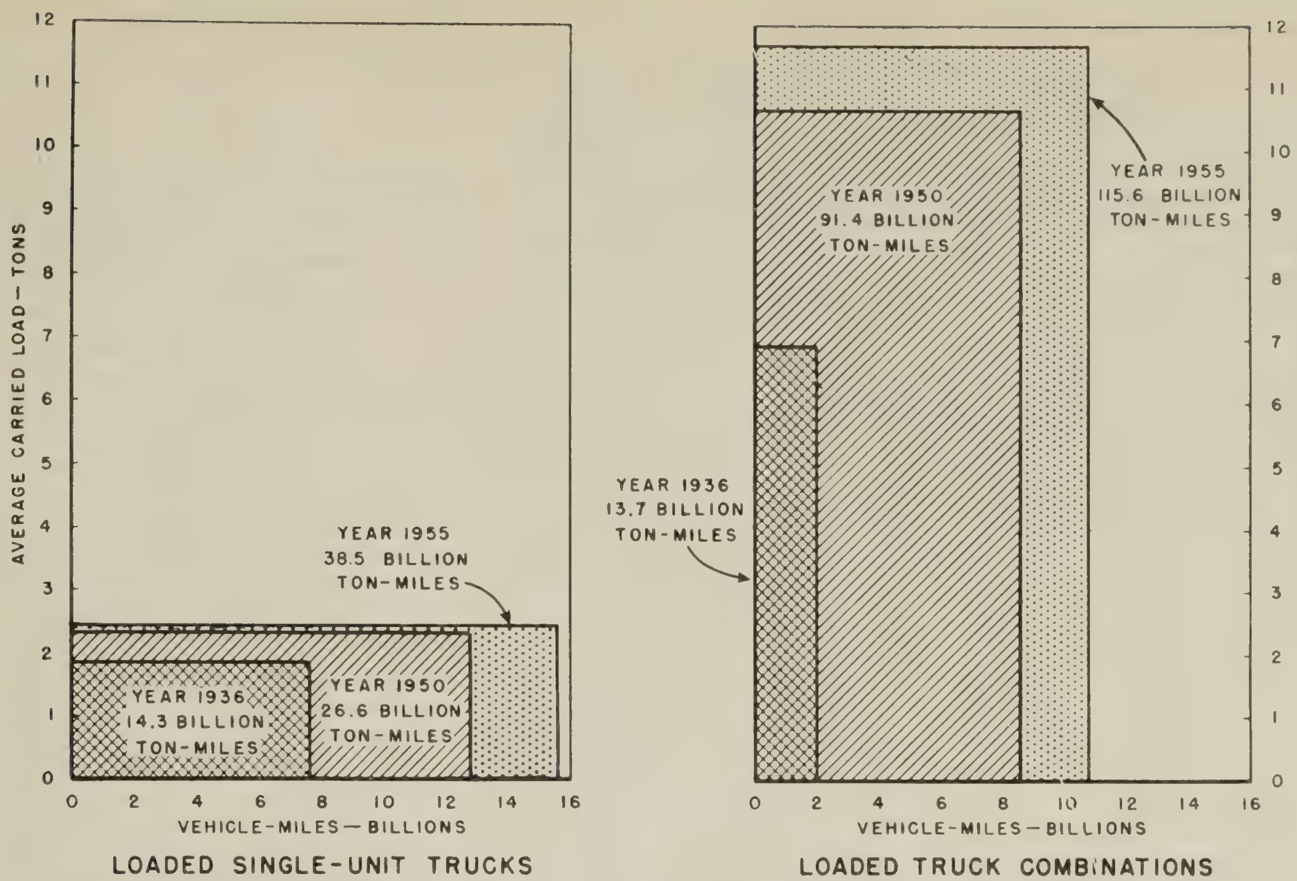

Figure 6.—Vehicle-miles of travel, average carried load, and ton-miles carried by trucks and truck combinations on main rural roads in 1955 compared with 1936 and 1950.

increased loading per vehicle. The increases beyond this point resulted, of course, from increased mileage by loaded vehicles.

In considering the 1955 : 1940 ratios shown in the final entry of the table, for example, it is observed that the ton-mileage hauled by combinations was almost five times as great at the end of this 15-year period as it was at the beginning, while the ratio for the average weight of carried load was 1.49, and the ratio for the percentage of vehicles loaded was 0.95. As shown in table 3, the corresponding ratio for the mileage traveled by all vehicles of the combination type, both loaded and empty, was 3.48, and when multiplied by 0.95 the ratio becomes 3.31 for loaded vehicles. Obviously, most of the enormous increase in ton-mileage was due to increased vehicle-mileage rather than to heavier loading, though the latter factor was of considerable importance in the case of the combination-type vehicle.

For single-unit trucks, the percentage of vehicles loaded decreased more than the average load increased during the period 1940–55. In other words, there was an actual decrease in the average load for vehicles of this type when both loaded and empty vehicles were included in computing the average. The 68-percent increase in ton-mileage carried by single-unit trucks was therefore smaller than the increase in vehicle-mileage, which was 93 percent, as shown by the ratio in table 3.

Comparative information concerning the percentage of vehicle-miles of travel, percentage of vehicles loaded, the average carried load, and percentage of total ton-miles hauled on main rural roads in 1955 and 1950 is given in table 12. Many interesting comparisons can be made from these data. For instance, two-axle, six-tire, single-unit trucks, which are the principal load-carrying single-unit vehicles, account for 26 percent of the total truck travel, yet carry only about 17 percent of the ton-mileage. On the other hand, truck-tractor and semitrailer combinations account for slightly less than 30 percent of the total

Table 11.—Comparison of estimated percentage of trucks loaded, average carried load, and ton-miles carried on main rural roads in 1940, 1945, 1950, and 1955

Year	All trucks and truck combinations			Single-unit trucks			Truck combinations		
	Percentage loaded	Average weight of carried load	Ton-miles carried	Percentage loaded	Average weight of carried load	Ton-miles carried	Percentage loaded	Average weight of carried load	Ton-miles carried
		Tons	*Millions*		*Tons*	*Millions*		*Tons*	*Millions*
1940	65.9	3.32	46,247	64.4	2.13	22,899	71.6	7.41	23,348
1945	55.1	4.84	50,365	49.6	2.40	16,187	69.2	9.31	34,178
1945: 1940 ratio	*.83*	*1.46*	*1.09*	*.77*	*1.13*	*.71*	*.97*	*1.26*	*1.46*
1950	53.9	5.64	121,091	47.2	2.31	29,645	68.5	10.62	91,446
1950: 1945 ratio	*.98*	*1.17*	*2.40*	*.95*	*.96*	*1.83*	*.99*	*1.14*	*2.68*
1950: 1940 ratio	*.82*	*1.70*	*2.62*	*.73*	*1.08*	*1.29*	*.96*	*1.43*	*3.92*
1955	54.8	5.92	154,050	48.4	2.47	38,487	68.2	11.07	115,563
1955: 1950 ratio	*1.02*	*1.05*	*1.27*	*1.03*	*1.07*	*1.30*	*.99*	*1.04*	*1.26*
1955: 1945 ratio	*.99*	*1.22*	*3.06*	*.98*	*1.03*	*2.38*	*.98*	*1.19*	*3.38*
1955: 1940 ratio	*.83*	*1.78*	*3.33*	*.75*	*1.16*	*1.68*	*.95*	*1.49*	*4.95*

Table 12.—Percentage of vehicle-miles of travel, percentage loaded, average carried load, and percentage of total ton-miles carried on main rural roads in 1955 compared with 1950

Vehicle type	Percentage of vehicle-miles of travel		Percentage loaded		Average carried load		Percentage of ton-miles carried	
	1955	1950	1955	1950	1955	1950	1955	1950
Single-unit trucks:					*Tons*	*Tons*		
Panel and pickup	35.37	31.35	37.5	37.4	0.75	0.69	3.05	2.65
Other 2-axle, 4-tire	4.22	2.79	55.2	52.4	1.01	.93	.72	.45
Other 2-axle, 6-tire	25.66	32.63	61.2	55.9	3.53	3.20	17.09	19.06
3-axle	2.51	1.68	60.1	58.3	8.85	7.23	4.12	2.32
All single-unit trucks	67.76	68.45	48.4	47.2	2.47	2.31	24.98	24.48
Truck combinations:								
Truck-tractor and semitrailer	29.86	29.43	68.2	68.9	10.75	10.32	67.53	68.87
Truck and trailer	2.38	2.12	67.8	62.3	15.04	15.32	7.49	6.65
All truck combinations	32.24	31.55	68.2	68.5	11.07	10.62	75.02	75.52
All trucks and combinations	100.00	100.00	54.8	53.9	5.92	5.64	100.00	100.00

405740—56——2

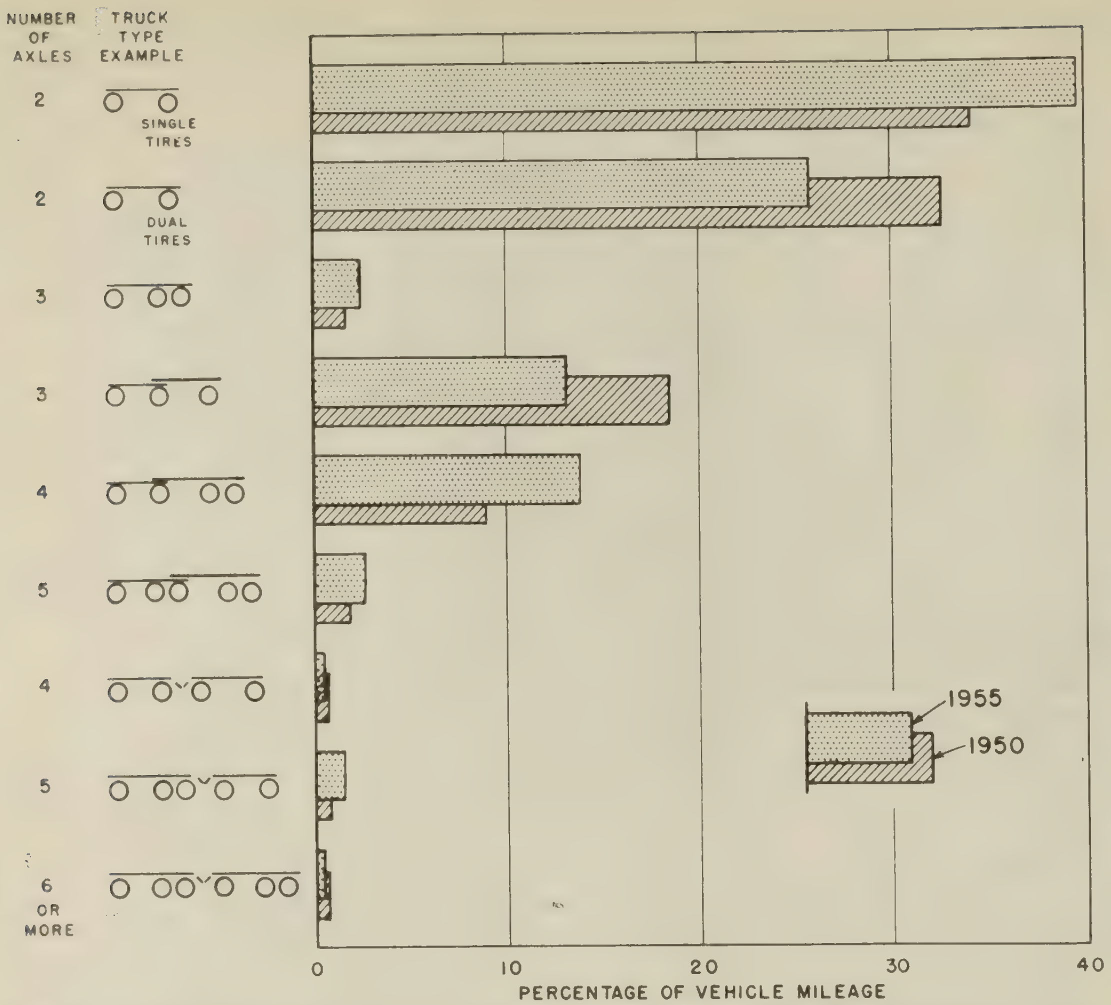

Figure 7.—Percentage of vehicle-miles traveled by various types of trucks and truck combinations on main rural roads in 1955 compared with 1950.

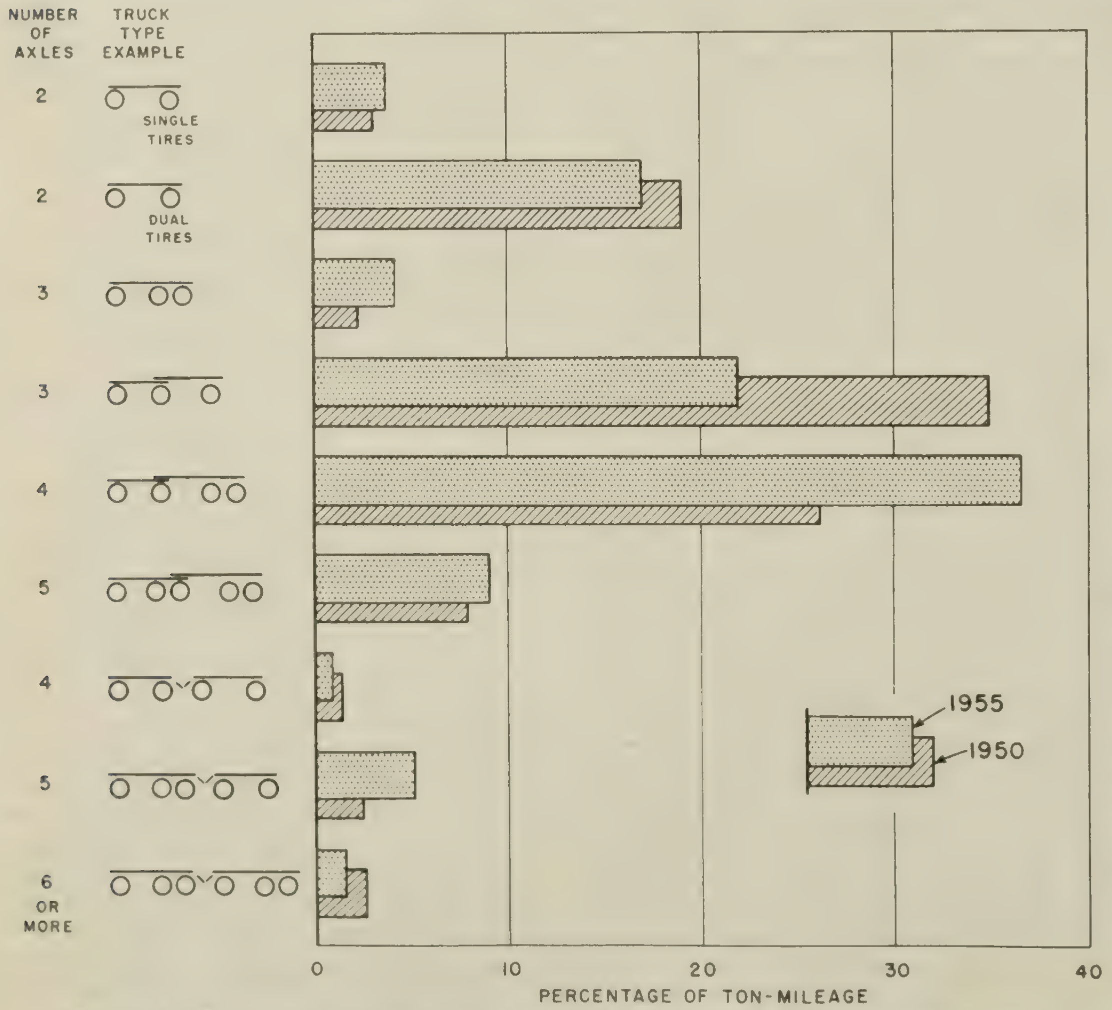

Figure 8.—Percentage of ton-miles hauled by various types of trucks and truck combinations on main rural roads in 1955 compared with 1950.

travel (only a little more than the two-axle, six-tire trucks), but carry almost 68 percent of the ton-mileage or almost four times the amount carried by the smaller vehicles.

The data concerning percentage of vehicles loaded and average carried load are also interesting. Panels and pickups, which carry loads of three-fourths of a ton or less, travel loaded less than 38 percent of the time. Assuming that there is a return trip with no load for each trip with a load, only 75 percent of the travel can be accounted for on the basis of the hauling of goods. Since vehicles are often loaded in both directions, the use of these vehicles as a substitute for passenger cars must be well in excess of 25 percent of their total travel.

The slightly larger two-axle trucks with single rear tires and carrying loads averaging around one ton are loaded about 55 percent of the time and surveys indicate little use for personal transportation. The same is true of the larger single-unit vehicles that operate with a load 60 to 61 percent of the time. Many of the truck combinations are common carriers which seldom are operated empty, inasmuch as they continually pick up and discharge freight. Combinations are found loaded, therefore, in greater proportion than the large single-unit trucks. Many of the latter type carry loads of a one-way variety, such as hauling building materials to construction projects, which tends to reduce the percentage loaded.

Shift to Two-Axle Semitrailers

The percentage of vehicle-mileage traveled by trucks of various types in 1955 compared with 1950 is shown in figure 7. An interesting fact shown by this chart is the great shift that took place in the 5-year period from single-axle semitrailers to those equipped with dual axles. In the earlier period, 18.5 percent of the truck and truck combination travel was performed by two-axle tractors pulling single-axle semitrailers, while travel by the same type of tractor with dual-axle semitrailers amounted to only 9.0 percent.

The 1954 and 1955 survey figures indicated that this relation has changed materially, and the percentage for the dual-axle semitrailers now exceeds the percentage for the single-axle semitrailers. Considerable expansion in the use of three-axle tractors pulling semitrailers equipped with dual axles likewise may be noted, though the percentage for this vehicle type is still relatively low for the country as a whole. These vehicles are found principally in the western divisions, although more are being used elsewhere, especially in the north central divisions. This shift from one-axle to two-axle semitrailers apparently has taken place in order that maximum possible payload can be carried under the weight restrictions in effect in some States.

The percentage of ton-miles hauled by various truck types in 1955 compared with 1950 is shown in figure 8. This chart emphasizes, even more so than figure 7, the shift between 1950 and 1955 from three-axle tractor-semitrailer combinations to four- and five-axle combinations. In 1955 the four-axle combina-

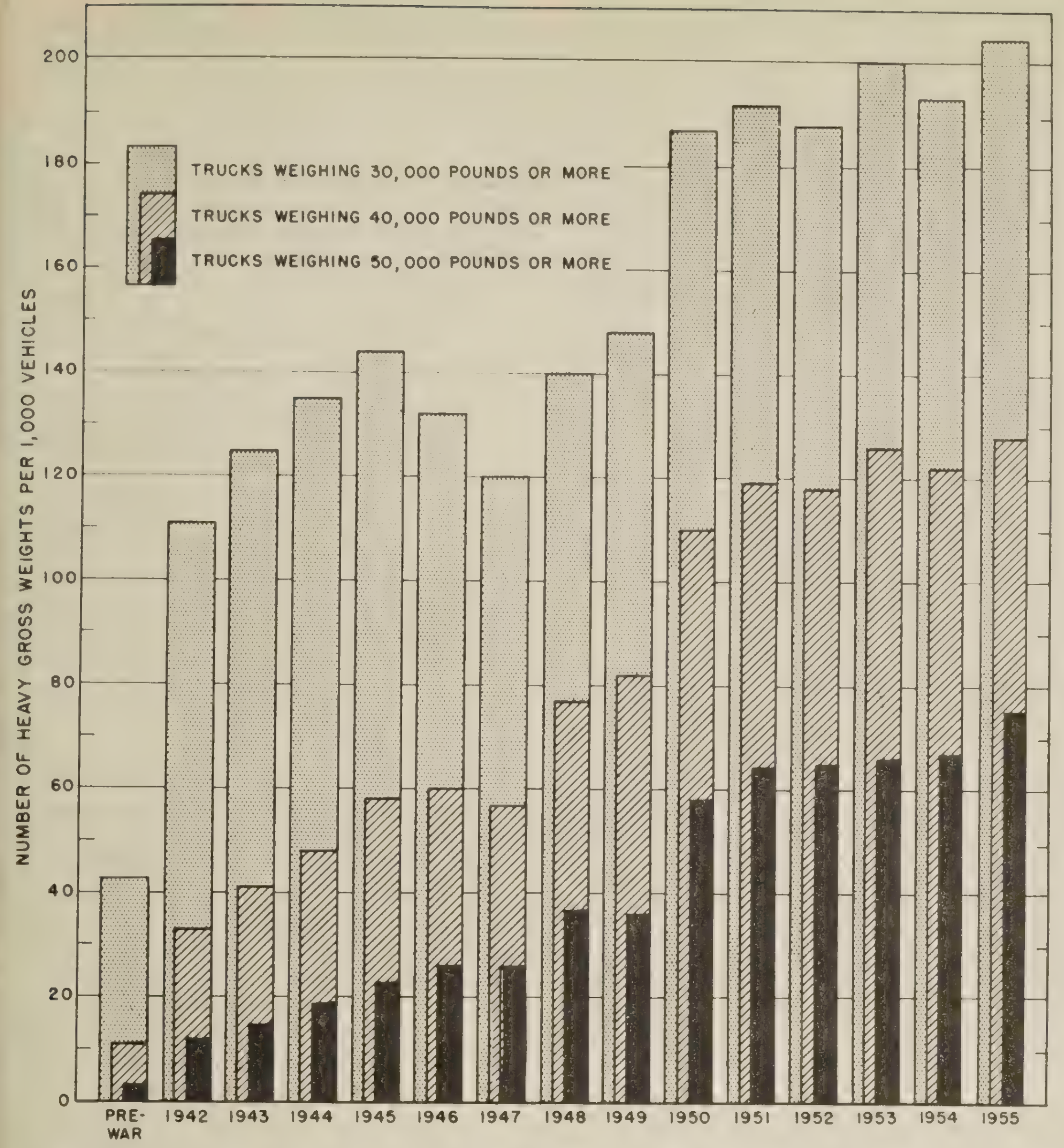

Figure 9.—Number of gross loads of 30,000, 40,000, and 50,000 pounds or more, per 1,000 loaded and empty trucks and truck combinations, on main rural roads in the summers of 1942–55 and a prewar year.

tions accounted for a larger portion of the ton-mileage than any other single vehicle type, whereas in 1950 the three-axle combinations predominated.

Heavy Gross-Load Frequencies

The frequencies of gross loads of 30,000, 40,000, and 50,000 pounds or more per 1,000 trucks and truck combinations on main rural roads in the summers of 1942 to 1955, and in a prewar period (1936–37) are shown in figure 9. During this period of about 19 years the trend of the frequency of vehicles weighing 50,000 pounds or more was consistently upward, although at a generally lower rate of increase from 1951 to 1954, and the frequency of those weighing 40,000 pounds or more was generally upward with temporary drops in 1947, 1952, and 1954. The long-range trend in frequency of weights of 30,000 pounds or more was also upward, but there was a substantial decline from 1945 to 1947 and temporary declines in 1952 and 1954. The 1945 to 1947 decline was quite temporary and was followed by a rapid rise in 1950.

Since 1950 the frequency of weights of 30,000 pounds or more has fluctuated up and down within comparatively narrow limits. While the frequencies of vehicles weighing 30,000 pounds or more and those weighing 40,000 pounds or more were slightly lower in 1954 than in 1953, the 1955 frequencies in each case reached an all-time high. In 1955 the frequency of vehicles weighing 50,000 pounds or more likewise reached a peak. Since the beginning of the planning surveys in the 1936–37 period, the frequency of loads of 30,000 pounds or more increased almost 5 times, those of 40,000 pounds or more increased over 11 times, and those of 50,000 pounds or more increased 25 times.

The 1955 gross-weight frequency data, by vehicle types, are presented in table 13. Since no panels, pickups, or other two-axle, four-tire, single-unit trucks were found in the survey weighing as much as 30,000 pounds, there is no entry for these vehicles in the table. They are included, however, in the total number of vehicles weighed in computing the frequencies for all single-unit trucks and for all trucks and combinations.

In addition to the gross-weight frequencies of vehicles traveling on main rural roads, the variation of these frequencies among the several geographical divisions is interesting. The highest frequency of vehicles weighing 30,000 pounds or more (286 in 1955) was found in the East North Central division, with the Pacific division having the second highest frequency (246). The lowest frequency (158) was in the East South Central division. Similarly, the highest frequency of vehicles weighing 40,000 pounds or more (191) was found in the East North Central division, with the second highest frequency (188) in the Pacific division. On the other hand, the highest frequency of vehicles weighing 50,000 pounds or more (162) was found in the Pacific division, with the second highest frequency (114) in the East North Central division. The lowest frequency for this weight group (22) was found in the East South Central division.

Table 13 shows that the frequency of heavy vehicles is increasing. In the last 5 years the frequency of vehicles weighing 30,000 pounds or more increased 10 percent, vehicles weighing 40,000 pounds or more increased 16 percent, and those weighing 50,000 pounds or more increased 29 percent.

Combining the increases in the frequencies of heavy vehicles with the increases in travel by trucks and truck combinations, the mileage traveled in 1955 compared with 1950 by vehicles weighing 30,000, 40,000, and 50,000 pounds or more increased 31, 39, and 54 percent, respectively.

Heavy Axle-Load Frequencies

The number of axles weighing 18,000, 20,000, and 22,000 pounds or more, per 1,000 trucks and truck combinations, found on main

Table 13.—Frequency of heavy vehicles of 30,000, 40,000, and 50,000 pounds or more, per 1,000 loaded and empty trucks and truck combinations, on main rural roads in the summer of 1955 by main vehicle types

Vehicle type	Number of vehicles, per 1,000 trucks and truck combinations, weighing—		
	30,000 pounds or more	40,000 pounds or more	50,000 pounds or more
Single-unit trucks:			
2-axle, 6 tire	6	(1)	(1)
3-axle	332	102	10
Average	14	4	(1)
Truck combinations:			
Truck-tractor and semitrailer	606	411	231
Truck and trailer	646	518	474
Average	609	419	249
Average, all trucks and combinations	205	128	75
Comparative average, 1954	193	122	67
Comparative average, 1950	187	110	58

[1] Less than 5 per 10,000.

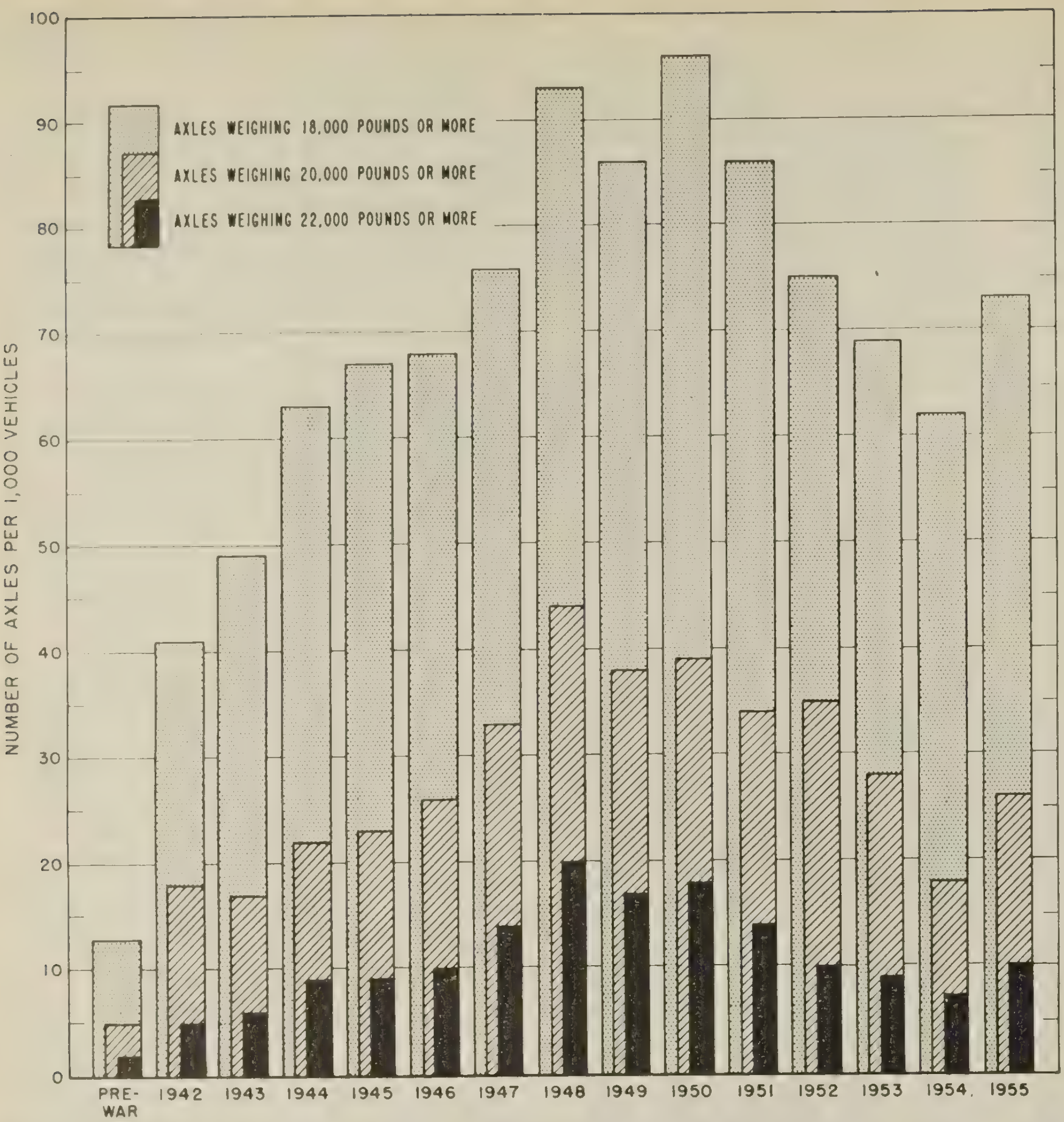

Figure 10.—Number of axles weighing 18,000, 20,000, and 22,000 pounds or more, per 1,000 trucks and truck combinations, on main rural roads in the summers of 1942–55 and a prewar year.

rural roads during the period 1942–55, and a prewar year are shown in figure 10. A most important finding indicated in the chart is the reversal in trend that began in 1951 and continued each year to 1954. The 1955 frequencies show an increase over 1954 for the three weight groups, and in the case of axles weighing 22,000 pounds or more were equal to the 1952 frequency. The number of axles weighing 18,000 pounds in 1950 was more than seven times that in the prewar year, but from the 1950 high there was a drop of 24 percent by 1955. Likewise, the frequency of 20,000-pound axles in 1950 was almost eight times that in the prewar year, but by 1955 the number in this category was two-thirds of that in 1950. The number of axle loads of 22,000 pounds or more increased ninefold from the prewar year to 1950, but dropped 45 percent below that peak in 1955.

Load Distribution Improves

The number of axles weighing 18,000, 20,000, and 22,000 pounds or more for each 1,000 loaded and empty trucks and truck combinations in 1955 are given in table 14 for the main vehicle types. Since none of the two-axle, single-unit trucks with single rear tires was found to have axles weighing as much as 18,000 pounds, that type is not shown in the table. The number of such vehicles counted is included, however, in obtaining the total frequencies for all single-unit trucks and for all trucks and combinations.

In order to give a clearer indication of what is happening on the roads, travel by vehicles with axles weighing 18,000, 20,000, and 22,000 pounds or more was calculated for the period 1950–55. These calculations show that when vehicle-mileage trends are considered, there was an overall downward trend in heavy axle-weight frequencies, notwithstanding the general upward trend in travel and heavy gross-load frequencies that prevailed during the period; decreases in the 18,000-, 20,000-, and 22,000-pound axle-weight categories were 9 percent, 20 percent, and 35 percent, respectively. By a shift to vehicles with a larger number of axles, trucks are hauling more and heavier loads over the highways and yet subjecting them to less frequent applications of heavy and destructive axle loads.

Loads Exceeding Legal Limits

The number of trucks and truck combinations in 1955, per 1,000 loaded and empty vehicles, that exceeded the axle, axle-group, or gross-weight limits in effect in the States or recommended by the AASHO, with comparative figures for the summer of 1950, are given in table 15. The 1955 frequencies, which are generally lower than those for 1950, are also lower than the 1953 figures but somewhat higher than those for 1951, 1952, and 1954. This comparison is similar to the variations in heavy axle-load and heavy gross-load frequencies found in the 5-year period (1950–55) as shown in figures 9–10.

Detailed estimates concerning the overload frequencies in the various geographical areas show that the highest frequency of loads in excess of State legal weight limits in 1955 was in the Pacific division where 71 vehicles in each 1,000 were overloaded to some extent, and 2 vehicles in each 1,000 were overloaded by 20 percent or more. The second highest frequency was found in the West North Central division where 67 vehicles in each 1,000 were overloaded and 3 vehicles in each 1,000 were overloaded by 20 percent or more.

A comparison of frequencies of vehicles loaded in excess of the recommendations of the AASHO shows that the highest frequency of heavy loads was likewise in the Pacific division where 162 vehicles in each 1,000 exceeded the recommended weight limits, and 7 in each 1,000 exceeded these limits by 20 percent or more. The second highest frequency, however, was found in the New England division where 109 vehicles in each 1,000 exceeded the recommendations and 49 in each 1,000 exceeded them by 20 percent or more. The high frequencies of loads exceeding the recommendations in the New England division, are caused by the higher legal axle-load limits in effect in that area. Although

Table 14.—Frequency of axle loads of 18,000, 20,000, and 22,000 pounds or more, per 1,000 loaded and empty trucks and truck combinations, on main rural roads in the summer of 1955 by main vehicle types

Vehicle type	Number of axles, per 1,000 trucks and truck combinations, weighing—		
	18,000 pounds or more	20,000 pounds or more	22,000 pounds or more
Single-unit trucks:			
2-axle, 6 tire	32	12	4
3-axle	83	37	23
Average	15	6	2
Truck combinations:			
Truck-tractor and semitrailer	195	73	29
Truck and trailer	184	21	2
Average	194	69	27
Average, all trucks and combinations	73	26	10
Comparative average, 1954	64	20	8
Comparative average, 1950	96	39	18

Table 15.—Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded any of the axle, axle-group, or gross-weight limits in effect in the States or recommended by the AASHO, in the summer of 1955 and the corresponding comparative figures in 1950

Vehicle type	Vehicles exceeding State legal limits						Vehicles exceeding AASHO recommendations					
	Number per 1,000 over-loaded	Number per 1,000 overloaded more than—					Number per 1,000 over-loaded	Number per 1,000 overloaded more than—				
		5 percent	10 percent	20 percent	30 percent	50 percent		5 percent	10 percent	20 percent	30 percent	50 percent
Vehicles over Limits in 1955												
2-axle, 6-tire truck	18	9	5	2	(1)	(1)	27	18	12	5	2	(1)
3-axle truck	64	34	19	11	5	2	98	65	39	15	9	3
Average, single-unit trucks	9	5	3	1	(1)	(1)	14	9	6	2	1	(1)
Truck-tractor and semitrailer	148	83	46	14	5	1	216	152	98	38	16	2
Truck and trailer	209	73	24	7	4	------	442	345	224	59	22	6
Average, truck combinations	153	82	44	13	5	1	233	167	108	39	16	3
Average, all trucks and combinations	55	30	16	5	2	(1)	84	60	39	14	6	1
Vehicles over Limits in 1950												
2-axle, 6-tire truck	20	14	9	4	1	(1)	28	20	15	8	3	1
3-axle truck	70	55	38	13	7	4	77	50	41	18	10	4
Average, single-unit trucks	11	8	5	2	1	(1)	15	11	8	4	2	1
Truck-tractor and semitrailer	187	121	75	30	12	2	249	183	125	56	26	6
Truck and trailer	224	143	92	52	30	4	359	280	191	72	33	10
Average, truck combinations	189	122	76	31	13	2	256	190	129	57	26	6
Average, all trucks and combinations	67	44	27	11	5	1	91	68	46	21	10	3

[1] Less than 5 per 10,000.

the maximum axle-load limit recommended by the AASHO and permitted in most States is 18,000 pounds, the legal limits in States of the New England division range from 20,000 to 22,400 pounds. Consequently, a considerable number of vehicles carrying loads within the State limits may exceed the recommendations of the AASHO by as much as 24 percent.

Experience in Application of Statistical Method to Traffic Counting

BY THE HIGHWAY TRANSPORT RESEARCH BRANCH
BUREAU OF PUBLIC ROADS

Reported by BORIS B. PETROFF
Head, Sampling Techniques Unit

The average daily volume of traffic moving over a particular highway during the year, commonly called the ADT, is a measure of service of that highway to its users. From traffic-counting experience it is known that volumes vary from day to day and month to month, but it is the average daily traffic throughout the year and certain peak volumes to which the highway administrator primarily directs his attention.

To obtain true values of ADT, it would be necessary to count traffic continuously for a year on every section of road between intersections which would be prohibitive from a cost standpoint. On the other hand, a rough estimate of traffic could be made by an experienced traffic engineer, but this method would prove to be too inaccurate. Thus a compromise must be made between accuracy and cost in accordance with need.

The usual practice is to take samples of traffic. Counts of 24- or 48-hour duration are adjusted and expanded into estimates of ADT. The problem is to develop improved procedures for sampling and expanding traffic counts that will produce estimates of acceptable accuracy for design and administrative purposes at minimum cost.

It has been observed in recent years that monthly traffic variations form patterns which tend to persist from year to year on the same road sections. Similarities among patterns permit grouping of rural road sections accordingly, and it has been found that groups thus formed remain substantially intact for several years. This relatively new concept and its application are discussed in this article.

There are about 1,000 continuous-count stations in the United States where traffic-counting machines are permanently installed. The basis for measuring the errors or differences between the estimated ADT and true ADT is provided by the data from these installations. The measure used for evaluating these errors is the standard deviation. That generalizations can be made about traffic volumes on the basis of the standard deviation has been established by the Chi square test of goodness of fit used in this study. The test shows that the errors of ADT estimates follow the normal distribution curve.

Although the application of statistical method in establishing traffic-counting programs, as described in this article, is new, its use in several States has resulted in either a savings in manpower or the obtaining of more accurate and additional information for the same cost.

THE only reason for spending money on counting traffic is to obtain estimates of traffic volumes of acceptable accuracy to be used in establishing structural design and administrative requirements. The efficiency of traffic-counting procedures is then directly related to the degree of accuracy of estimates. Statistical method provides the means of measuring the accuracy of different procedures, thus showing the way to the most efficient one.

Concept of Error of Estimate

One can guess the average daily traffic (subsequently referred to as ADT) at a particular point on a road. But such a guess would not ordinarily be considered acceptable either by those who are responsible for the traffic information or by its users. The reason for the rejection of a guess, of course, is the belief that were the true ADT known it could be considerably different from the guess. If this difference is called an error, then it could be said that a guess may result in too great an error.

It is impractical to obtain true ADT at all points on the road system of a State where such information is needed. It then becomes necessary to arrive at some such value of ADT that in the judgment of the administrator would have error within an acceptable degree of accuracy; thus it is conceded that an estimate of ADT which is based on factual observations, is better than a guess.

Then the task is to find ways of measuring the errors in the estimates of ADT when the estimates are derived by different methods of sampling traffic volumes. In the determination of the ADT, any traffic count for a period of less than one year is considered a sample. The least costly sample from which a sufficiently accurate estimate of ADT can be produced is the most desirable. No single standard exists for the permissible error in estimates of ADT. This decision is usually the responsibility of the administrator.

Sampling of Traffic Volumes

A sample of traffic volume is the number of vehicles passing a particular point on the road during a specific period of time. Samples are obtained by traffic counts. Nowadays machines are used almost exclusively for traffic counts to obtain the total number of vehicles without classification by type.

This discussion deals primarily with traffic counting on rural roads which carry traffic volumes of 500 or more vehicles per day. The cost analysis of a machine traffic count usually reveals that more than 90 percent of such cost is attributed to the wages of the man who installs and removes the machines and the cost of mileage traveled between the places where the machines are located. The places on the road where traffic-counting machines are located will be referred to as stations which may be coverage stations or control stations depending on their purpose.

At a coverage station the traffic is usually counted for 24 or 48 consecutive hours once a year. Here the ADT is estimated by application of factors obtained from control stations. The bulk of traffic-counting stations are of the coverage type. Control stations are of two types: Continuous-count stations where traffic is counted and recorded continuously for a year or several years (about 1,000 stations of this type in the United States), and seasonal control stations where several sample counts are taken in such a manner that the relation between the seasonal or monthly volume of traffic and the ADT can be established. Control stations of both types are used in determining expansion factors for adjusting counts at coverage stations to estimates of ADT.

Traffic counts of 24-hour duration or multiples of 24 hours, such as 48 hours, 72 hours, and so forth, are economical units from which estimates of ADT can be made. Furthermore, such periods of traffic counting are administratively convenient in scheduling the travel of the man who works with the machines. Thus only traffic counts in multiples of 24 hours are considered here. These samples of traffic volumes can be taken once during the year at a particular station or be repeated several times.

Both the duration of traffic counts and the frequency of repetitions have been studied in several States. Only studies of general and fundamental interest are presented in this article. Other studies have been conducted but are not mentioned because they are primarily of local interest.

Use of Statistical Method

Since opinions concerning the accuracy of traffic counts are personal matters and subject to disagreements, it was considered desirable to develop procedures which would permit the measurement of the error in the estimate of ADT and thus appraise it objectively.

The error of estimate of ADT due to a specific method of sampling can be determined only at a few stations where there are permanent machine installations because only there is the true ADT known. Even at permanent installations, the ADT is not absolutely true because of machine failures; the error is comparatively small, however, and is ignored. The ultimate goal is to determine the error at all stations. This cannot be done directly without continuous counts, but the theory of probability in statistical methodology can serve this purpose.

The statistical method, as it has been applied in several States, does not determine the error at a particular station where a traffic volume sample is taken. It does evaluate the size of the error which can be expected at a number of stations without identifying the stations. This means that when traffic counts are made at thousands of stations on the rural roads of a State, it is possible to determine how many stations will have errors of a particular size.

The application of statistical method to a statewide traffic-counting program is relatively new.[1] Only the major sources of errors have been investigated, and means of measuring them have been devised. When these measures were applied to the design of traffic-counting programs, the result was a savings in manpower, or in expenditures, or the obtaining of more accurate information for the same money.

There are, however, yet unexplored sources of error, the evaluation of which can be expected to increase the efficiency of traffic-counting operations even further. It is believed that the discoveries already made do account for the bulk of possible improvements.

Conclusions

All average daily traffic volumes based on samples of traffic counts are estimates. As such they all have errors of estimate. The size of the error depends on the sampling procedure. The cost of obtaining traffic volume information depends on the method of sampling. Statistical method provides the means for measuring these errors in the bulk of rural ADT and vehicle-mileage determinations. It is possible, therefore, to select a procedure for sampling which produces results commensurate with cost.

Experience shows that the estimates of ADT with errors measured by standard deviation of about 10–12 percent for high-volume (over 500 vehicles per day) roads are satisfactory to the users of the data. For this purpose procedures have been developed which are more efficient than the old procedures. The new procedures involve grouping of stations and the predominant majority of road sections on the basis of statistical probabilities of errors of estimates, rather than judgment used in the old procedures. In practical application it means either savings in costs or obtaining more information for the same annual expenditures and yet usually providing more accurate data.

Grouping based on statistical probabilities permits the reduction of both coverage and control operations. Even further improvement in efficiency can be expected in the future when the number and location of continuous-count stations are determined more scientifically for this purpose, and when grouping of road sections according to similarity of seasonal expansion factors will be even better supported by additionally gathered facts.

Fundamental Historical Observations

Persons who deal with traffic counting observed a long time ago that traffic volumes vary in accordance with certain patterns. For instance, at a particular station in a given week, there are about the same number of vehicles counted on each weekday, Monday through Friday, but quite different volumes of traffic appear on Saturday and Sunday. Yet these differences are fairly consistent from one week to another within a month. The traffic volumes will vary from one month to another but the relation of each monthly volume to the yearly volume is about the same over the period of years (data shown in table 9 on page 117 are an example). The recurrence and comparative stability of these elements of pattern gave rise to the idea that if a sample traffic count is adjusted for the variations of pattern, then the sample can be expanded into an estimate of ADT.

The fundamental reasoning which supports the idea of application of statistical method, in the manner here described, to the analysis of traffic-volume patterns and their variations may be enhanced by the understanding of the Gestalt concept and organismic theory which were originally developed in psychological studies.[2]

The idea of expansion of a sample traffic count into an estimate of ADT has been universally accepted and used in this country. There were and still are considerable differences in sampling methods and in the methods of expansion.

As already explained, whether the sample is for a 24- or 48-hour period or even a continuous 7-day count has relatively little effect on cost although the results vary significantly in accuracy. The really big difference in cost of obtaining ADT estimates by several methods lies then in the methods of expansion of counts at individual stations into ADT estimates.

An observation of the greatest importance is that on rural roads where ADT is 500 vehicles or more the pattern of monthly variation of traffic volumes remains pretty much the same for great lengths of consecutive road sections which may or may not be on routes carrying the same route number.

Usual Method of Expanding Samples

The usual procedure for expanding sample traffic counts to ADT has required seasonal control stations which supply the data necessary for computation of expansion factors. The number of seasonal control stations and the schedules of their operations have varied greatly among States. For instance, in one State there are 96 seasonal control stations in rural areas where traffic is counted for 7 consecutive days, 4 times a year, 3 months apart; another State has 560 control stations, each of which is operated for at least 4 consecutive days including a Saturday and a Sunday, 4 times a year, 3 months apart.

In two States the sample counts at coverage stations (operated only once a year and not necessarily every year) are taken simultaneously with control-station counts and each coverage count is then expanded in accordance with the relation of ADT to the traffic volume at the control station on the date of coverage count. The administrator exercises his judgment in relating traffic counts at coverage and control stations. Sometimes slight modifications of this method are used.

In the majority of States composite expansion factors are computed from control-station data. These are grouped on the basis of geographical areas, routes using descriptive correlations such as intercity, recreational, commercial, farm-to-market, and so forth, or routes having similar patterns in the judgment of the administrator. The grouping is usually done without the benefit of statistical evaluation.

The usual procedure is to compute at each seasonal control station the estimated ADT by averaging the traffic volumes during each operation, giving proper weight to weekdays, Saturdays, and Sundays. Then the factors are computed by taking the ratio of ADT to the similar period of coverage-station counts which is generally a weekday. Each such ratio is considered an expansion factor for a particular month. In each group the data from the control stations are used in computing the factors for each month or each season

[1] *Improving traffic-count procedures by application of statistical method*, by Boris B. Petroff and Robert C. Blensly. Proceedings of the Highway Research Board, vol. 33, 1954, pp. 362–375.

[2] The Gestalt concept can be interpreted as configuration of the whole, the behavior of which can be established by measurement of configuration rather than measurement of the individuals that comprise the whole. In traffic a time pattern (hourly, daily, monthly, etc.) at a point of observation (a station, a road, a State, etc.) may be regarded as configuration of the total (the whole) of the traffic volume. The measurement of these patterns can be obtained from traffic counts at that point but could not be obtained by the study of time-travel patterns of each individual driver who passes that point during the given time period.

Table 1.—Percentage relation of 1954 average daily traffic volumes to average weekday volumes at 25 continuous-count stations in Minnesota

Station number	Group symbol [1]	April	May	June	July	August	September	October	November
152	Ib	102.8	102.1	93.3	90.0	86.3	92.0	102.0	114.3
156	II	97.0	102.2	95.2	99.7	90.0	95.6	102.4	107.1
157	II	103.4	103.3	92.5	95.1	93.0	95.0	101.5	107.0
164	Ia	116.0	105.4	86.7	74.2	74.7	91.8	109.2	120.8
166	Ia	108.8	98.9	87.1	80.1	80.6	92.0	102.0	113.9
170	IV	131.5	106.3	81.4	65.6	68.1	90.6	111.8	129.9
172	Ia	[2] 127.3	105.7	81.9	75.8	81.0	86.7	95.1	107.2
175	Ia	113.3	103.0	85.6	75.9	80.3	89.6	103.6	115.0
179	Ia	105.8	97.5	92.2	91.1	87.1	82.7	99.9	110.4
187	Ia	[2] 124.3	114.4	89.0	72.7	80.5	86.9	114.5	114.6
189	Ib	117.6	103.0	94.2	92.3	93.8	94.4	110.6	119.9
190	Ia	[2] 130.3	105.3	92.0	74.6	85.3	97.9	113.8	118.9
192	Ia	122.5	108.9	101.3	84.9	87.0	96.0	113.3	113.3
193	II	101.5	100.7	96.2	92.8	93.4	97.3	108.5	103.4
194	II	101.4	98.9	87.9	89.1	85.9	95.8	116.1	114.6
195	Ia	112.5	108.8	92.9	84.0	83.4	92.1	107.3	118.6
196	Ia	107.2	101.3	87.2	75.9	76.4	90.5	99.1	114.2
197	Ib	103.9	101.9	91.2	89.6	86.4	92.5	101.2	107.3
198	Ib	105.3	100.5	91.5	86.6	88.3	90.8	99.9	107.3
199	Ia	[2] 132.3	96.1	86.1	85.9	81.1	92.6	103.3	107.1
201	Ia	111.0	103.4	91.6	80.6	86.1	94.2	105.1	112.2
202	IV	131.2	119.6	89.0	64.4	61.3	84.9	109.6	129.5
204	III	188.5	94.9	83.9	73.1	78.6	94.9	140.9	145.1
205	Ib	108.6	105.6	91.4	83.7	81.7	91.9	106.2	108.7
206	II	117.6	106.1	92.5	92.3	85.8	99.6	104.7	109.4

[1] A ±10 percent range of variation among factors in each month was used as a criterion for assigning the group symbol.
[2] Values for various reasons were found unacceptable.

and averaged, thus a mean factor for a month or a season is obtained. This mean factor is then used for the expansion of coverage counts assigned to the group. A number of minor variations of this basic method are also used. Continuous-count recorder data sometimes are included with the seasonal control-station data.

It should be noted in all these methods that judgment rather than objective measurement is exercised in either combining factors or assigning the ratios between coverage and control stations.

New Concept of Objectivity

The important observation that similar patterns of monthly variations of weekday traffic in relation to ADT exist on many road sections already has been mentioned. The practical use of this observation is as follows:

1. Continuous-count station data are obtained from machines located on high-volume highways (ADT, 500 vehicles or more) which are usually on the State designated system. At each such station monthly expansion factors are computed. These factors are the percentages or ratios of the ADT to the average weekday volume of each month.

A ±10-percent range of variation among factors in each month is used as a criterion for the grouping of stations.[3] Since the ultimate objective is the determination of expansion factors for coverage counts, only months during which coverage stations are operated are included in the grouping at continuous-count stations. If during these months the factors between two continuous-count stations do not differ by more than ±10 percent, these two stations are put into the same group.

To expedite this rather tedious process of comparing all the continuous-count stations with each other, the approximation method is used: One station selected by cursory examination as being representative serves as a standard and all other stations are compared with it; all stations having monthly patterns within ±10 percent of the standard are grouped together. Occasionally a station may be put in two different groups. Since in either case it will fall within the ±10-percent range criterion, it makes little difference how it is grouped. Other considerations, such as continuity of route of similar pattern, are then taken into account. For each group for each month compared, a mean factor is computed. Thus, if the mean factor were used for expanding the sample instead of the factor for each of the stations in the group, the error introduced due to this substitution would not be greater than ±10 percent. On rare occasions stations having factors beyond the ±10-percent range in only one month have been included in the group.

For example, tables 1 and 2 show the grouping of 25 continuous-count stations in Minnesota. Only the months April through November were used because these are the months when coverage stations were operated. Although 17 stations fell into the original group I, it was conveniently possible to subdivide it into groups I–a and I–b, in each of which the deviations of individual factors from their respective means were even less than the allowed ±10 percent, thus making the mean factors even more accurate.

2. On the State highway map all stations are indicated with colored pencils in the color

[3] "Student's" t tests (a measure of significance of the differences of sample means) indicated that this range tends to produce group mean factors that are significantly different.

Table 2.—Monthly expansion factors computed for the 25 continuous-count stations in Minnesota, grouped according to a ±10 percent range of variation of individual factors from their respective group means

Station number	April	May	June	July	August	September	October	November
Group Ia								
164	1.16	1.05	0.87	0.74	0.75	0.92	1.09	1.21
166	1.09	.99	.87	.80	.81	.92	1.02	1.14
172	(1)	1.06	.82	.76	.81	.87	.95	1.07
175	1.13	1.03	.86	.76	.80	.90	1.04	1.15
179	1.06	.98	.92	.91	.87	.83	1.00	1.10
187	(1)	1.14	.89	.73	.81	.87	1.15	1.15
190	(1)	1.05	.92	.75	.85	.98	1.14	1.19
192	1.23	1.09	1.01	.85	.87	.96	1.13	1.13
195	1.13	1.09	.93	.84	.83	.92	1.07	1.19
196	1.07	1.01	.87	.76	.76	.91	.99	1.14
199	(1)	.96	.86	.86	.81	.93	1.03	1.07
201	1.11	1.03	.92	.81	.86	.94	1.05	1.12
Mean	1.12	1.04	.90	.80	.82	.91	1.06	1.14
Group Ib								
152	1.03	1.02	0.93	0.90	0.86	0.92	1.02	1.14
189	1.18	1.03	.94	.92	.94	.94	1.11	1.20
197	1.04	1.02	.91	.90	.86	.93	1.01	1.07
198	1.05	1.01	.92	.87	.88	.91	1.00	1.07
205	1.09	1.06	.91	.84	.82	.92	1.06	1.09
Mean	1.08	1.03	.92	.89	.87	.92	1.04	1.11
Group II								
156	0.97	1.02	0.95	1.00	0.90	0.96	1.02	1.07
157	1.03	1.03	.93	.95	.93	.95	1.02	1.07
193	1.02	1.01	.96	.93	.93	.97	1.09	1.03
194	1.01	.99	.88	.89	.86	.96	1.16	1.15
206	1.18	1.06	.93	.92	.86	1.00	1.05	1.09
Mean	1.04	1.02	.93	.94	.90	.97	1.07	1.08
Group III								
204	1.89	0.95	0.84	0.73	0.79	0.95	1.41	1.45
Group IV								
170	1.32	1.06	0.81	0.66	0.68	0.91	1.12	1.30
202	1.31	1.20	.89	.64	.61	.85	1.10	1.30
Mean	1.31	1.13	.85	.65	.65	.88	1.11	1.30

[1] Values for various reasons were found unacceptable.

assigned to the group to which the stations belong.

3. The ratios of ADT to the weekday of the month are also computed for other types of control stations.

4. These control stations are then marked in colored pencil on the same map in accordance with the group to which the control stations appear to belong on the basis of the available expansion factors (usually up to four or six factors per station).

5. When the distribution of continuous-count and seasonal control stations was studied on the map in Florida, New Mexico, Colorado, Idaho, and West Virginia, it was found that the predominant majority in each group fall along continuous road sections which often follow the same route number but not necessarily so. Frequently the consecutive road sections between two continuous-count stations, both belonging to the same group of monthly expansion factors, are along the same route number. However, the route number per se is not necessarily an indication that all of its sections will fall into the same group. Thus, it has been observed that the route of similar traffic-habit pattern is often coincident with a route number but does not have to be. On the other hand, large sections of routes with different numbers very often fall into the same expansion-factor group.

When all stations belonging to the same group are connected by drawing a line of the color chosen for the group, the resultant picture shows the distribution of these highways into groups of monthly patterns, each of which is characterized by the criterion of ±10-percent range of variation of monthly factors at the points of observation. Experience shows that most of the highways in a State distribute themselves by the groups of stations located on them, but usually there is a small mileage of roads that does not seem to fall into any known group either because of the lack of information or for a special reason such as a unique scenic or recreational attraction.

It has been observed that within a few miles of built-up areas of large cities the seasonal factors vary considerably from those of the rural sections of the same road. These factors tend to be closer to the urban factors, which as a rule come closer to unity, than rural for the corresponding months. Since this article deals with the bulk of rural ADT estimates of 500 or more vehicles per day, the rural sections with suburban characteristics are not included in the numerical data presented.

Only continuous-count stations are used in these analyses for the computing of group mean factors since all months are not usually represented at seasonal control stations. The reason why control stations other than continuous-count stations are not used in computing the mean group factors is that they were not properly scheduled originally for that purpose. When distributed by groups, the counts during some of the months predominate, whereas some of the months may not be represented at all. General observations, however, point to the fact that when adequate representation of control counts is available for certain months, then the mean factors for these months are very close to the means based on continuous-count station data alone. Group mean expansion factors could be obtained from properly located seasonal control stations. The continuous-count stations are already in existence, and new installations appear economical in the long run. Furthermore, continuous-count stations serve other purposes for which seasonal control stations are not considered suitable.

Quite frequently a single continuous-count station or the mean pattern of a fewer number of stations than the total number in a group produces practically the same pattern of monthly expansion factors as all stations in the group. This observation gives rise to the possibility of more efficient use of continuous-count stations by moving the excess machines to new locations where the need for information is greater. Seasonal control stations can also be temporarily established for the purpose of proper allocation of a road section to a group. In making these decisions it should be remembered, however, that there are other uses of the continuous-count station data, such as the study of long-range traffic trends. Therefore the machine should be kept at its location unless other considerations show there is no need for it, although it may be superfluous for the purpose of obtaining expansion factors.

The discussion that follows pertains to those roads which can be grouped. These roads represent the great majority. Those few that cannot be grouped require special consideration. Also, as already mentioned, expansion of traffic counts in the suburban developments of larger cities sometimes requires special treatment.

Statistical Significance of Objective Grouping

To make practical use of this objective grouping it is necessary to make the following assumption: That the monthly factors on road sections between two stations falling within the same group, also fall within the same ±10-percent range of variation from the mean factor. This assumption is necessary because the ultimate objective of the grouping is the identification of coverage stations by groups for the purpose of selecting proper expansion factors. In other words, every coverage station should be expanded by the mean-group factor of the group to which its road section has been assigned on the basis of continuous-count and seasonal control stations. This assumption is not arbitrary. The reasoning behind it follows.

For a complete traffic-volume survey of the primary highways in a State the needed number of points in each group at which ADT estimates should be obtained can be assumed to be equal to the number of road sections between intersections—one point for each road section. Thus in each group a total of several thousand stations, either coverage or control, can be expected. This possible total number of stations constitutes the statistical population or universe of stations in each group. In order to obtain such information as the mean monthly expansion factors of a population and the difference between the individual station factors and the mean of the population, it is not necessary to have the data for all the stations in the population. Instead, reasonable approximation can be obtained from a random sample of stations.

From the point of view of statistical theory the sample would be considered to have been selected at random if every one of the thousands of stations in the population had an equal chance of being selected. The continuous-count and the seasonal control stations can be considered a sample taken from the population of stations in the group. However, they were not consciously selected at random. With respect to the concept of random selection these stations can be described as having been selected haphazardly. In locating these stations the primary purpose was to select such places along the highways as were, in the judgment of the administrator, representative of the largest mileage of primary highways. No numerical measures described the meaning of the word representative in the sense of monthly expansion factors.

For this reason there is no awareness of this bias being injected in the selection of stations. Although at times some bias might have been injected accidentally, as observed in the fact that the number of control stations selected does not seem to have any definite relation to the total number of stations under consideration. Thus the sample sizes vary in different pattern groups. It is observed, however, that because the distribution of selected control stations is fairly uniform throughout a State, the sample in each group is approximately proportional to its population. This, however, is not considered too important because each group represents its own statistical population.

In the statistically haphazard distribution of the continuous-count and seasonal control stations there is no knowledge of any bias that could have an effect on the mean values of the monthly factors. Thus these haphazard selections are in effect random. In a random sample of continuous-count stations (of the same number) so selected from the same statistical population, each such sample would produce monthly group mean expansion factors that would not be significantly different from those obtained from the existing selection. The fact that seasonal control stations fall into the same pattern of monthly factors and are along the same habit-pattern routes, as established by grouping of continuous-count stations, tends to demonstrate the validity of the group mean factors.

Understanding of this discussion is necessary because it introduces the theoretical basis for considering the coverage stations as belonging to the same statistical population as the continuous-count and seasonal control stations. This concept, in turn, then justifies the application for expansion of the group mean factors computed from continuous-count and/or seasonal control stations to the coverage counts along the route of similar habit pattern (similar monthly expansion factors). This discussion of theory also may

Table 3.—Standard deviation of the differences (errors) between estimated ADT and true ADT on primary rural systems in eight States [1]

State	Number of stations	Period of count	Number of counts in sample N	Standard deviation, in percent S	Number of counts within one S [2]		Number of counts within two S [3]		Indicated equivalent annual savings due to adoption of new procedure
					Theoretical	Actual	Theoretical	Actual	
		Hours							
Georgia	(4)	24	142	10.1	97	95	135	136	Incomplete analysis.
Idaho	9	48	44	7.2	30	28	42	44	$12,000–20,000.
Minnesota	22	48	199	10.8	136	146	189	190	(5)
Montana [6]	12	48	120	9.6	82	85	114	112	(7)
Montana	12	48	123	9.2	-----	(4)	-----	(4)	
Montana	12	48	122	9.9	-----	(4)	-----	(4)	
New Mexico	27	48	175	9.5	119	125	166	170	Possible 50-percent savings.
Oregon	17	24	119	12.6	81	78	113	116	(8)
Washington	12	48	84	9.4	57	62	80	78	$20,000–40,000.
West Virginia	(4)	48	106	12.1	72	82	101	100	(5)

[1] Data for West Virginia are for 1953; all other States, 1954.
[2] Theoretical frequency is 68 percent of N.
[3] Theoretical frequency is 95 percent of N.
[4] Data are not readily available.
[5] Predominant number of control-count stations and a few continuous-count stations can be eliminated on roads carrying 500 or more vehicles per day.
[6] Three independent random samples were used in Montana.
[7] Present studies indicate that urban and local rural road counts can now be taken in addition to rural primary highway counts at no extra cost.
[8] Additional rural and urban vehicle-mileage data and average daily traffic volumes on extensions of the urban system can be determined at no extra cost.

be a cogent stimulus for better appreciation of the significance of the statistical measures used.

It has been found that the standard deviations are significant measures of errors of estimates of ADT that can be expected at coverage stations. These errors distribute themselves normally at the conglomerate of locations. It has been demonstrated by Chi square tests that there is no significant bias that results from this assumption.

The foregoing paragraph indicates that with the aid of continuous-count and other control stations the allocation of road sections to groups of similar monthly expansion-factor patterns can be accomplished. Also the experience with seasonal control stations supports the hypothesis that the continuous-count stations are representative of the population so far as monthly expansion factors are concerned. Where it has been properly demonstrated that the expansion of coverage counts can be made on the basis of continuous-count data alone, then the seasonal control stations or any control stations other than continuous-count stations are ordinarily no longer necessary for development of ADT expansion factors. This means a savings in money or effort which can be used elsewhere.

As pointed out before, there can be unevaluated or unusual situations requiring special treatments. Among such special situations are the following: An isolated road leading to a resort area which has no counterpart in the State; a certain area in the State may temporarily attract unusual volumes of traffic during the hunting season and thus appreciably affect the traffic volumes on a relatively small number of roads; the occurrence of such events as football games which may have a brief but pronounced effect on traffic volumes in some localities; and other situations causing instantaneous variations in traffic volumes or patterns. In these relatively few cases special control stations other than continuous-count stations can and should be used.

Standard Deviation

The error that can be expected in the estimates of ADT at the coverage stations is measured from the data at continuous-count stations by taking random samples of counts of 24- or 48-hour duration, or for any period that may be considered by the State. Each sample is expanded into an estimate of ADT by application of the appropriate group mean factor. At the continuous-count stations the true ADT is always known. The difference between the estimated and the true ADT value is termed the error.

Since the continuous-count stations, when grouped, are considered to represent the population of the group, their standard deviation is also the measure of the errors at the coverage stations—the latter being also samples taken out of the same population. The advantage of the standard deviation [4] as a measure of errors is that it gives the size of the error, and also the expectation of how often an error of that size or smaller may occur. The formula of the standard deviation is as follows:

$$S=\pm\sqrt{\frac{\Sigma E^2}{N-1}}$$

Where:

N=number of random units in sample.
E=percent error of estimate of ADT.

$$E=\frac{X_1-X}{X}\times 100$$

Where:

X_1=estimated ADT.
X=true ADT.

Table 3 shows the results of a study of errors of estimate of traffic volumes in eight States. The last column of the table indicates the extent of annual savings due to the adoption of new procedures. In compiling table 3 all estimates of ADT were based on each unit in the sample expanded by its appropriate group mean factor. Only weekdays were used in the samples.

In some States, standard deviations were computed for counts of different durations. Computations were made either for data expanded to estimates of ADT, or for unexpanded samples which are individual weekday samples compared with the average weekday of the month. Results are shown in table 4.

In table 5 the standard deviations were determined for differences between the individual monthly weekday expansion factors at each continuous-count station and the respective group mean factor.

The effect of repetition of counts at approximately equal intervals during the year was investigated in several States. The results are shown in table 6. The more frequently the counts are repeated during the year, the more accurate are the estimates of ADT, but because each repetition costs as much as the first count, repeated counts usually are considered prohibitive.

A few studies have been made of single samples of 7-day counts and these indicate a

Table 4.—Standard deviation of the differences (errors) between estimated ADT and true ADT on primary rural systems in eight States [1]

State	Period of count	Number of counts in sample N	Standard deviation, in percent S	Number of counts within one S [2]		Number of counts within two S [3]	
				Theoretical	Actual	Theoretical	Actual
Arizona	24 hours	105	8.3	-------	(4)	-------	(4)
Idaho	7 days	44	6.1	30	27	42	42
Montana	7 days	114	8.2	-------	(4)	-------	(4)
Nevada	24 hours	178	11.0	-------	(4)	-------	(4)
Nevada	7 days	191	7.3	-------	(4)	-------	(4)
New Mexico	7 days	172	8.0	-------	(4)	-------	(4)
Oregon	24 hours	119	9.6	81	83	113	112
West Virginia	48 hours	222	8.6	151	154	211	210
Wyoming [5]	7 days	114	12.3	-------	(4)	-------	(4)
Wyoming [6]	7 days	114	8.8	-------	(4)	-------	(4)

[1] In Idaho, Montana, New Mexico, and Wyoming, computations were made from data expanded to estimates of ADT. In Arizona, Nevada, Oregon, and West Virginia, standard deviations were computed from unexpanded samples.
[2] Theoretical frequency is 68 percent of N.
[3] Theoretical frequency is 95 percent of N.
[4] Data are not readily available.
[5] Group mean monthly expansion factors were used.
[6] Group mean weekly expansion factors were used.

[4] Standard deviation is a measure of dispersion of individual items about their mean value. In estimates of ADT the mean value of errors approaches zero. The numerical value of error computed by this measure means that approximately 68 percent of all individual errors included in the computation can be expected to have values as large or smaller than one standard deviation; approximately 95 percent of all individual errors to have values as large or smaller than two standard deviations. The percent of all individual errors can be obtained for any multiple of the standard deviation.

Table 5.—Standard deviation determined for the differences between the individual monthly weekday expansion factors at each continuous-count station on primary rural systems and the respective group mean factor

State	Number of counts in sample N	Standard deviation, in percent S	Number of counts within one S [1]		Number of counts within two S [2]	
			Theoretical	Actual	Theoretical	Actual
Montana	110	6.5	75	72	105	107
New Mexico:						
Group 1	84	5.2	57	62	80	80
Group 2	105	6.6	-------	(3)	-------	(3)
Group 3	48	5.6	-------	(3)	-------	(3)
All groups	237	5.9	-------	(3)	-------	(3)
Oregon	336	7.3	228	256	319	323
West Virginia, 1952	144	6.2	98	110	137	134
West Virginia, 1953	144	9.2	98	108	137	135

[1] Theoretical frequency is 68 percent of N.
[2] Theoretical frequency is 95 percent of N.
[3] Data are not readily available.

Table 6.—The effect of repetition of counts on the standard deviation of the differences (errors) between estimated ADT and true ADT on primary rural systems in six States [1]

State	Frequency of count	Period of count	Number of counts in sample N	Standard deviation, in percent S	Number of counts within one S [2]		Number of counts within two S [3]	
					Theoretical	Actual	Theoretical	Actual
Arizona	Quarterly	24 hours	27	4.6	------	(4)	------	(4)
Colorado	do	7 days	63	4.1	43	42	60	60
Florida	do	24 hours	(4)	7.6	------	(4)	------	(4)
Florida	do	48 hours	(4)	6.1	------	(4)	------	(4)
Idaho	do	4 days [5]	21	4.3	------	(4)	------	(4)
Montana	Semiannually	48 hours	109	7.3	73	80	103	104
Washington	Quarterly	7 days	36	4.2	25	25	34	33
Washington	Bimonthly	7 days	48	3.6	33	36	46	46
Washington	Monthly	7 days	24	1.9	16	17	23	22

[1] In Arizona, Florida, and Montana, Saturday, Sunday, and holiday counts were not included; therefore the 24-hour count means were compared with the true average annual weekday traffic volumes.
[2] Theoretical frequency is 68 percent of N.
[3] Theoretical frequency is 95 percent of N.
[4] Data are not readily available.
[5] Saturday, Sunday, and two weekdays.

possibility of their practical use when higher accuracy is desired than that provided by single 48-hour counts. The results are shown in table 4 for Idaho, Montana, Nevada, New Mexico, and Wyoming. In Wyoming it was decided to use the weekly rather than the monthly expansion factors, since the difference in the cost of analysis is negligible. It is possible that with additional data improvement in grouping could reduce the errors in Wyoming.

An inspection of standard deviations shown in tables 3–6 reveals how similar are the values for similar tests and how small are the standard errors of the means. Both observations give strength to the soundness of procedure used in measuring the error of estimates of ADT and to the reliability of the results.

Chi Square Test

The Chi square test is used to provide a measure of the "goodness of fit" of observed distribution of units in the sample as compared with the theoretical distribution. If the fit is good then for practical purposes it may be expected that the characteristics of observed distribution bear similarity to the characteristics of theoretical distribution, the latter characteristics always being known. The numerical expression for goodness of fit is given in terms of P (probability). Again from a practical standpoint the fit may be construed to be reasonably good if P is somewhere between 0.05 and 0.95 as obtained from tables of Chi square values.

In the preceding discussion almost every standard deviation shown was accompanied by the theoretical and the observed number of units having errors no greater than one and two standard deviations, respectively. The consistently close agreement between the theoretical and observed values gave impetus to further investigation of the meaning of this agreement. Within recent months a number of Chi square tests were run leading to the conclusion that the errors in estimates of ADT and expansion factors distribute themselves satisfactorily in accordance with the normal curve. The normal curve of distribution of observed values has the familiar bell shape. Its distinctive feature is that the frequency of occurence of either extremely small or extremely large values is relatively small as compared with the bulk of values which are distributed close to the mean value of observations. Some of these observations are shown in table 7.

All the Chi square tests have indicated good fit or a high degree of probability, and if other similar samples had been taken, good fits could also be expected for them. In a practical sense, the importance of this test is that the empirical data follow closely the normal distribution, thus it can be expected that statistical measures which are based on normal distribution are applicable to traffic characteristics which were tested. The conclusion of special importance is that the standard deviations can be used reliably as a tool for the measurement of the size of the error and the frequency of its distribution.

A sample computation of Chi square is given in table 8 and the values obtained are presented graphically in figure 1.

Persistence of Same Group Mean Factors

If, in two or more succeeding years, the same group mean expansion factors from the same stations are obtained and if all such stations fall within the ±10-percent range from the mean, then it appears that the same grouping of road sections can be extended for a number of years. This is probably true of the majority of road sections belonging to a particular group. It is advisable, however, to watch for any local development that may affect some sections.

Recently a few studies were made concerning the perpetuation of the monthly expansion factors and their relation to estimating the ADT.

In Montana, using only 1954 data, the estimated ADT based on weekday 48-hour

Table 7.—Comparison of the results of Chi square tests of the percentage errors in various sampling techniques

State	Year of data	Number of stations	Number of counts in sample N	Standard deviation, in percent S	Values of Chi square x^2	Probability P
Montana [1]	1954	10	110	6.5	5.81	0.30–.50
Montana [2]	1954	10	120	9.6	2.22	.80–.90
Oregon [1]	1954	38	336	7.3	(3)	.10
Washington [4]	1953	12	86	6.9	13.93	.20–.30
Washington [5]	1953	12	88	7.8	9.22	.60–.70
Washington [4]	1954	12	87	8.7	19.32	.10–.20
Washington [5]	1954	12	84	9.4	13.26	.30–.40
West Virginia [1]	1953	16	144	9.2	16.32	.30–.40

[1] Distribution of percentage differences between monthly expansion factors for individual stations and their respective group means.
[2] Distribution of percentage differences between estimates of ADT based on 48-hour counts and true ADT.
[3] Data are not readily available.
[4] Distribution of percentage differences between estimates of ADT based on 48-hour counts and true ADT. Weekday traffic volumes with Friday p. m. counts excluded.
[5] Distribution of percentage differences between estimates of ADT based on 48-hour counts and true ADT. All weekdays included.

Table 8.—Chi square test distribution of errors in 1953 ADT estimates based on 48-hour counts at 12 continuous-count stations in Washington

Class interval	$\frac{X}{S}$	Cumulative frequency observed	f_o	Cumulative frequency theoretical	f_t	f_o-f_t	$(f_o-f_t)^2$	$\frac{(f_o-f_t)^2}{f_t}$
0–1	0.129	11	11	9.2	9.2	1.8	3.2	0.348
1–2	.258	22	11	18.2	9.0	2.0	4.0	.444
2–3	.3877	27	5	26.9	8.7	−3.7	13.69	1.571
3–4	.516	39	12	35.1	8.2	3.8	14.44	1.761
4–5	.645	47	8	42.8	7.7	.3	.09	.012
5–6	.775	55	8	50.0	7.2	.8	.64	.089
6–7	.904	59	4	56.4	6.4	−2.4	5.76	.900
7–8	1.032	63	4	62.0	5.6	−1.6	2.56	.457
8–9	1.161	70	7	67.2	5.2	1.8	3.24	.623
9–10	1.289	72	2	71.5	4.3	−2.3	5.29	1.230
10–11	1.420	75	3	75.1	3.6	−.6	.36	.100
11–12	1.548	80	5	78.2	3.1	1.9	3.61	1.169
12–13	1.678	80	0	80.8	2.6			
13–14	1.807	82	2	82.6	1.8			
14–15	1.938	83	1	84.2	1.6			
15–16	2.064	84	1	85.5	1.3			
16–17	2.196	86	2	86.7	1.2	2.3	5.29	.514
17–18	2.324	87	1	87.2	.5			
18–19	2.456	87	0	87.7	.5			
19–20	2.580	87	0	88.1	.5			
20–21	2.710	88	1	88.4	.3			
$n=13-2=11$; $P<0.70$								$x^2=9.218$

counts had a standard deviation of ±9.2 percent. From continuous-count stations the average rate of change in traffic volumes between 1953 and 1954 was determined. In terms of 1954 volumes, the average rate of change was −3.44 percent. This reduction factor was applied to the 1954 sample of 48-hour counts, bringing them to an estimate of the 1953 sample. The group mean monthly expansion factors were computed from the 1953 data. These factors were then applied to the estimated 1953 sample. The estimates of ADT for 1953 were then compared with the true ADT for 1953. The differences (errors of estimate) thus obtained indicated a standard deviation of ±10.5 percent.

This experiment could be interpreted as follows: If in 1953 there was a comprehensive coverage of all primary highways in Montana, but in 1954 all coverage count stations were eliminated and only continuous-count stations were in operation, then an estimate could be made of 1954 traffic volumes at all stations which were operated in 1953. These estimates then could be expected to lose accuracy to the extent of 1.3 percent (10.5−9.2=1.3). All expenditures made for coverage counts could have been eliminated, were it not for special counts that are always needed.

Comparison of monthly group mean factors in Oregon disclosed that approximately two-thirds were either identical for the 2 years or varied by one percent. A few varied by 2 percent. Table 9 shows the comparison of 1954 and 1953 data in Minnesota.

In Washington, 24 weekday samples taken in 1954 were expanded by group mean monthly factors for 1954 and for 1953. The standard deviations of the errors of estimate of 1954 ADT were as follows:

	Standard deviation
Using 1954 factors____	± 7.6 percent
Using 1953 factors____	± 7.5 percent

The comparison shows that if in 1954 there were no control stations from which the expansion factors could be obtained, then the 1953 expansion factors could be applied to the 1954 coverage counts without any practical change in the accuracy of the ADT estimates.

In West Virginia, a comparison of group mean monthly expansion factors for the years 1954 and 1953 showed that they were practically the same.

From these studies the observation is made that the distribution by groups is quite stable. It is also indicated that even if there are or were in these States seasonal control stations in operation, such operations could be discontinued for a period of at least one year. Also, at least one observation measures the effect of discontinuation of coverage counts for one year on the ADT estimates. The discontinuation of coverage counts for periods as long as 5 years has been practiced before. But the effect of such practice has not been measured statistically.

Seasonal Control Stations

In some States there is not enough information for grouping road sections by patterns of monthly group mean factors. For the purpose of such grouping and also for obtaining group mean factors at the end of the first year of operation of the plan, the following procedure has been devised and used:

Highways are grouped in what is expected to be similar patterns of monthly expansion factors. The continuous-count stations provide the basic information. In each group a series of seasonal control stations are estab-

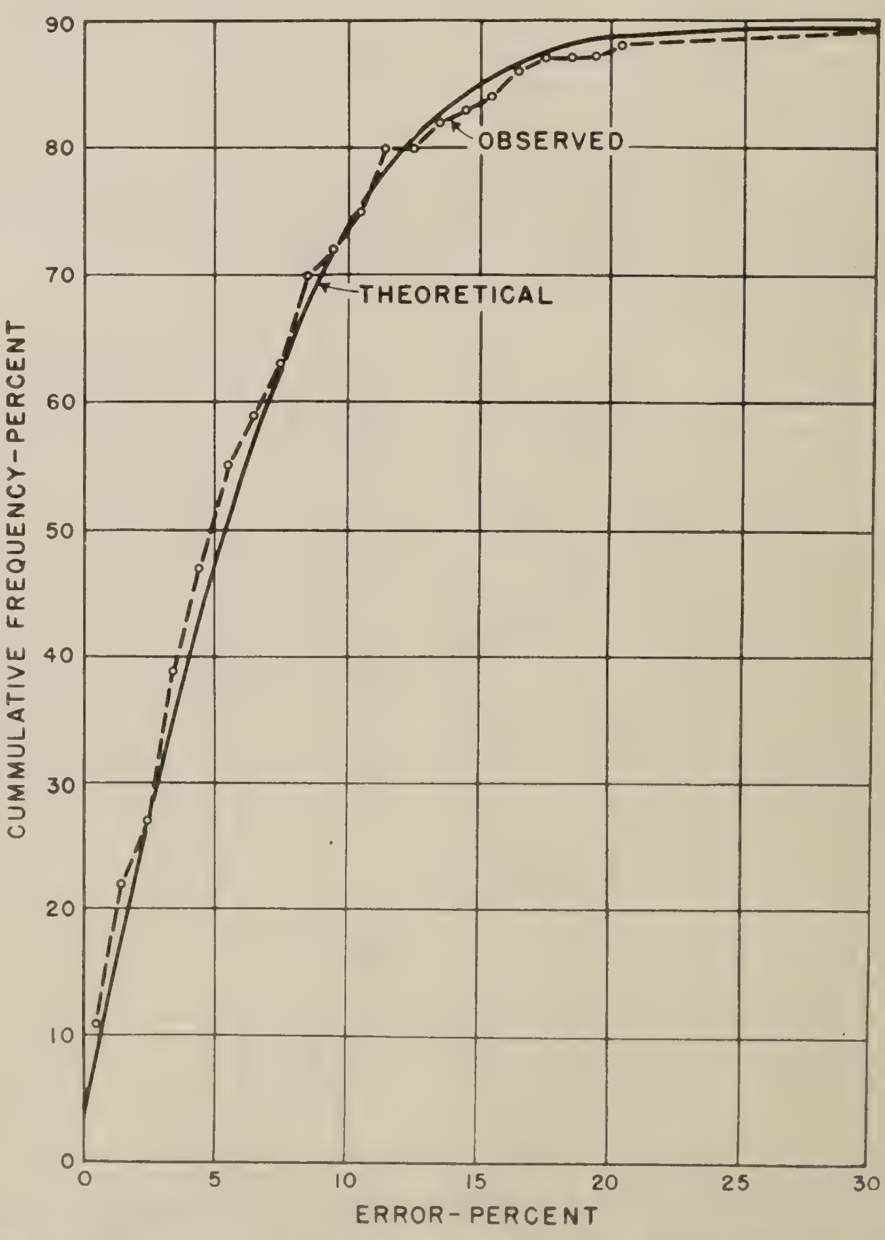

Figure 1.—Comparison of observed and theoretical distribution of errors of ADT estimates, based on 48-hour counts at 12 continuous-count stations in Washington during 1953.

Table 9.—Comparison of the group mean monthly expansion factors for Minnesota and the ranges of variation of individual stations within groups, for the years 1953 and 1954

Number of Stations	Year of traffic count	April		May		June		July		August		September		October		November	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
GROUP Ia																	
12	1954	1.12	1.06–1.23	1.04	0.96–1.14	0.90	0.82–1.01	0.80	0.73–.91	0.82	0.75–.87	0.91	0.83–.98	1.06	0.95–1.15	1.14	1.07–1.21
12	1953	1.19	1.06–1.32	1.03	.96–1.11	.88	.81–.95	.80	.74–.90	.83	.74–.89	.91	.84–.97	1.04	.92–1.15	1.14	1.06–1.22
GROUP Ib																	
5	1954	1.08	1.03–1.18	1.03	1.01–1.06	0.92	0.91–.94	0.89	0.84–.92	0.87	0.82–.94	0.92	0.91–.94	1.04	1.00–1.11	1.11	1.07–1.20
5	1953	1.07	.98–1.19	1.00	.94–1.02	.90	.89–.92	.88	.86–.93	.86	.80–.94	.92	.90–.94	1.00	.96–1.06	1.09	1.04–1.15
GROUP II																	
5	1954	1.04	0.97–1.18	1.02	0.99–1.06	0.93	0.88–.96	0.94	0.89–1.00	0.90	0.86–.93	0.97	0.95–1.00	1.07	1.02–1.16	1.08	1.03–1.15
6	1953	1.08	.93–1.22	.99	.90–1.06	.91	.87–.94	.89	.87–.95	.89	.85–.94	.93	.89–.97	1.05	1.01–1.11	1.11	1.06–1.15

lished. It was found that the most practical way is to operate each station for about 1 week, 6 times a year, 2 months apart.

The absolute minimum size sample for obtaining a mean of some statistical significance, in the opinion of many statisticians, is five units in a sample. Five counts per month in each group are then used as a guide. If factors are needed for all 12 months, then the number of such stations in each group is computed thus: 12 months times 5 counts per month divided by 6 counts per station per year equals 10 seasonal control stations per group.

In actually determining the locations of these stations, it is important to select them at random so that the group mean pattern would be representative of the population. In actual experience systematic sampling was used. For this purpose the total mileage of highways in the group was divided by the number of stations which gave the spacing in miles between seasonal control stations. For actual location on the map, the road sections were arranged in a contiguous manner according to section numbers, route numbers, or by adding sections as they appear by moving on the map from east to west or north to south, and so on. The continuous-count stations were included in the control setup. The beginning of the mileage count for locating successive stations was selected at a continuous-count station.

After the first year of operation the correctness of grouping is verified. If need be, for the second year of operations, the seasonal control station setup should be modified by rearranging the grouping and redistributing the seasonal control stations. Ultimately when grouping is completed, the bulk of seasonal control stations can be eliminated.

With some local modification, this general principle was applied in 1951 in Oregon and soon after in Wyoming and Michigan. A considerable number, about 25 percent of the road sections, had to be regrouped after the first year of operation in Oregon. But after 3 years of operation the grouping has been satisfactorily stabilized. The method of seasonal control stations was used at that time, not so much because of the lack of historical information, but because statistical methods and considerations which are discussed in this article had not yet been fully developed.

Table 10.—Standard deviations of the differences (errors) between 1938 estimates of ADT and true ADT for different periods of traffic counts on low-traffic volume roads in Minnesota [1]

Station number	Annual average daily traffic	Σd^2 by stations			
		24-hour count	48-hour count	72-hour count	7-day count
178	118	5,962.5	2,213.6	1,195.1	2,240.3
169	153	1,386.8	904.3	1,287.4	225.4
183	184	436.7	398.4	176.0	190.7
158	220	521.9	1,010.7	861.2	218.9
173	235	2,091.2	507.2	242.7	161.5
151	250	2,618.7	829.0	320.4	388.4
181	275	1,655.5	1,022.7	938.9	952.4
171	278	1,172.2	799.5	460.5	281.4
Σd^2		15,845.5	7,685.4	5,482.2	4,659.0
Standard deviation, S		18.36	14.41	11.45	9.96

[1] ADT estimates based on data for May through October.

Low-Volume Roads

For the same period of traffic counts once the daily traffic volume drops below 500 vehicles, the ADT estimates on such low-volume roads become rapidly less accurate, particularly so on roads carrying less than 300 vehicles per day. The roads with daily volumes below 500 vehicles comprise the great bulk of the mileage of rural roads. To obtain estimates of ADT as accurate as on the high-volume roads, much larger samples would be required at each coverage station. Since there are many more miles of such roads, comprehensive and accurate data would be very costly. In reality, however, it is seldom that data as accurate as on primary roads are necessary for the low-volume roads and, therefore, 24- or 48-hour weekday counts have usually been accepted by the administrators as satisfactory for both high- and low-volume roads.

In table 10 the standard deviations of random samples from their respective monthly means are shown for various time periods. The data are for low-volume roads (less than 300 ADT) in Minnesota for the year 1938. It is observed that these dispersions are much larger than for the higher volume roads.

In designing the procedure for a comprehensive traffic volume survey of low-volume roads, the procedures developed for higher volume roads cannot be used because in some States there are no continuous-count stations or only a very few located on low-volume roads. Thus, grouping by road sections is impracticable.

Since greater errors are permissible on low-volume roads, the recent experience of grouping by geographical areas appears to be satisfactory. In several States the areas were designated on the basis of economic areas established by the U. S. Bureau of the Census. In each area the seasonal control station system is established, except that locations are selected at random in each area rather than systematically on the mileage basis.

An interesting observation was made in Oregon. The mean monthly expansion factors were almost identical in the several areas, although the economic and climatic characteristics were quite different. Also it was observed that although the differences between individual station factors and area mean factors were great, standard deviations ranging from 20 to 25 percent, the group mean factors were quite similar. The result of this observation indicated the possibility of considering the whole State as a single area for computing expansion factors, thus eliminating the cost of operating several seasonal control station systems.

It is felt, however, that existing experience is not sufficiently conclusive to arrive at the decision that a single set of expansion factors for all low-volume roads would be satisfactory in any given State.

A Laboratory Test to Evaluate the Shape and Surface Texture of Fine Aggregate Particles

BY THE PHYSICAL RESEARCH BRANCH
BUREAU OF PUBLIC ROADS

Reported by HARRY M. REX and ROBERT A. PECK
Highway Physical Research Engineers

ONE of the most widely specified characteristics of sand particles comprising the finer fractions of aggregate used in bituminous paving mixtures pertains to the shape of those particles. Thus, specifications usually require that this fine material consist of natural or manufactured sand having sharp, angular grains. It has long been held that materials of such nature are very important to the development of high resistance to deformation in bituminous paving mixtures, and also to the development of a high degree of resistance to skidding in pavement surfaces composed of such mixtures. The development of these properties in the sand fraction is believed to be especially desirable when coarse aggregate materials, having rounded shape and smooth texture, are to be used.

There has been no satisfactory laboratory test for evaluating sands with respect to angularity and texture. Comparison can be made, of course, by means of microscopic examination, but this method is too time consuming for routine analysis, and in addition, the results are obtained by visual observation only.

Measuring Angularity and Texture of Sand

Recently a simple, direct test was developed in the laboratories of the Bureau of Public Roads. It is based upon the principle that smooth textured, rounded sand particles offer less resistance to free flow than do rough textured angular particles.

In this test a specified amount of one-size sand is allowed to flow freely through an orifice and the rate, in terms of seconds per 100 cubic centimeters, is determined. This rate of flow compared with that of Ottawa sand of the same size is taken as a measure of the relative angularity and surface roughness of the sand.

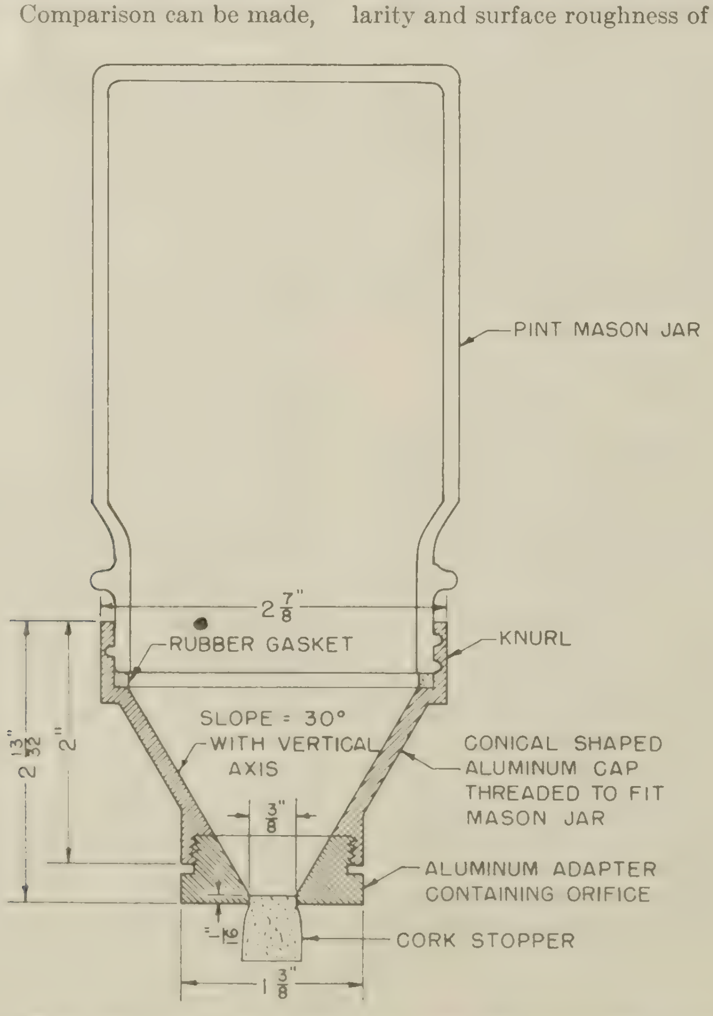

Figure 1.—Cross section of sand angularity test apparatus equipped with ⅜-inch diameter orifice.

The equipment used in making the test consists of a one-pint Mason jar and an aluminum cap in the shape of a frustum of a cone, with a base threaded to fit the jar. An accurately dimensioned orifice is threaded into the center of the top of the cap and is fitted with a cork stopper of suitable size. The apparatus is shown in figures 1 and 2.

Test Procedure

In making the test, 500 grams of dry washed sand, which passes a No. 20 sieve and is retained on a No. 30 sieve, are placed in the glass jar and the aluminum cap is screwed into place. The cork stopper is then inserted, after which the jar is inverted and positioned in a ring stand immediately above a receptacle of a suitable size. The stopper is then removed and the time required for the 500-gram sample of sand to flow through the orifice is measured with a stop watch. Figure 3 shows the test in operation.

The nine different sands tested are as follows:

1.—Standard Ottawa sand (No. 20–30 sieve size).
2.—Potomac River, Virginia (river sand).
3.—Red Hill granite, Virginia (manufactured sand).
4.—Natchez Trace, Mississippi (bank sand).
5.—College Creek, Virginia (creek sand).
6.—Bar Harbor, Maine (pit sand).
7.—St. Catherine Creek, Mississippi (creek sand).
8.—Canadian River, Oklahoma (river sand).
9.—Black Mountain, North Carolina (creek sand).

The Ottawa sand tested was from the regular laboratory stock of that material. The other sands tested consisted of the No. 20–30 sieve-size fractions of samples that had been sent to the laboratory from time to time. Photomicrographs of small samples of all nine sands, magnified approximately 11 times, are shown in figure 4.

The bulk specific gravity of the sands was determined, using the method described in ASTM Designation C128–42. The results of these determinations are given in table 1.

In the test, the rate of flow is assumed to be a function of the weight of the sample and the

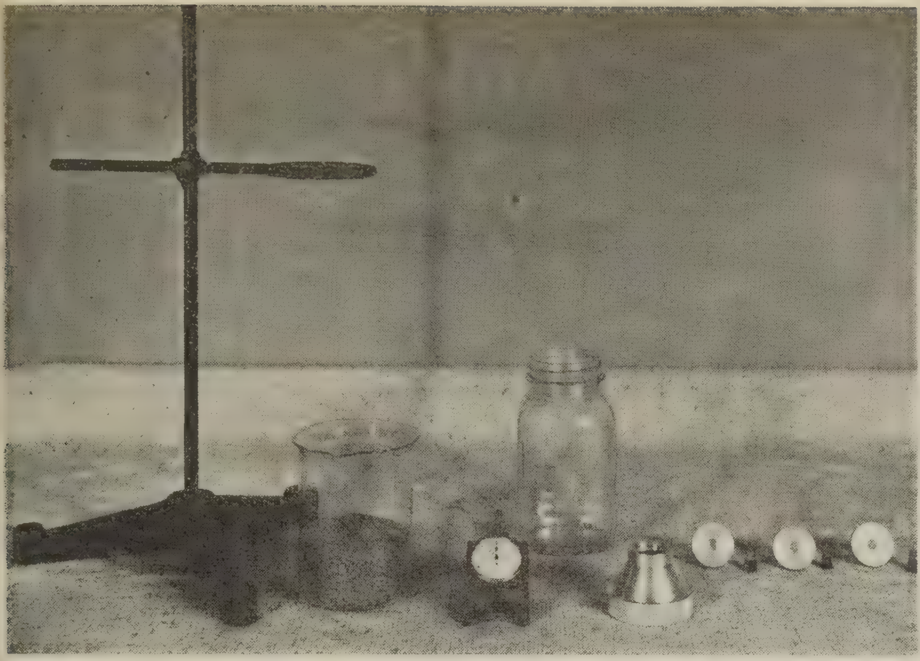

Figure 2.—Sand angularity test apparatus with the three different size orifices shown on the right.

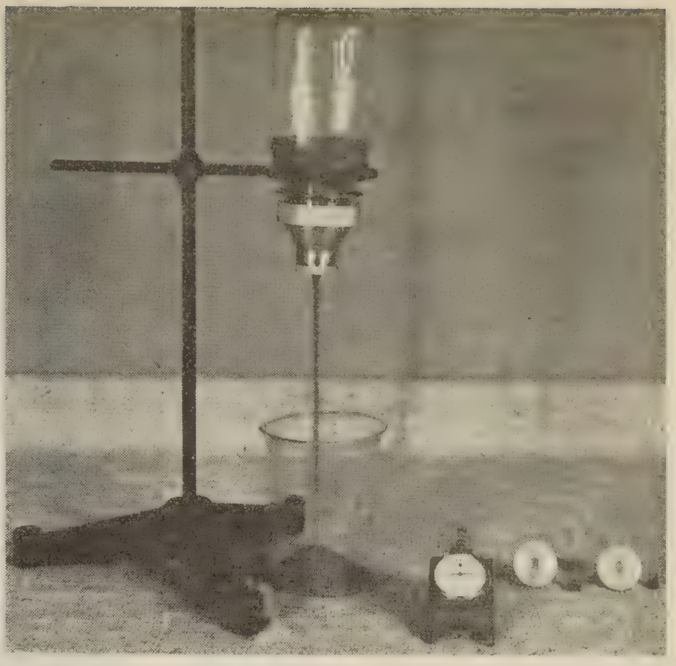

Figure 3.—Sand angularity test in operation.

shape and texture of the particles. If the weight of the test samples is the same in all cases, then the differences in time required for a unit volume of sand to flow through an orifice will reflect directly the differences in particle shape and texture for various sands.

Evaluating Test Results

Calculations required to convert the test results into readily usable units for evaluating sands are simple. The number of particles of two or more sands of a single size in a unit of weight is roughly proportional to their specific gravities. Therefore, in comparing the time required for a unit volume of an unknown sand to flow through the orifice with that required for the same volume of a standard sand (in this study the Ottawa sand), a correction for differences in specific gravity must be made.

For example, as shown in table 1, it was found that 25 seconds was required for 500 grams of Ottawa sand to flow through the ⅜-inch orifice. The bulk specific gravity of this sand had previously been found to be 2.66, so there were 188 cubic centimeters of sand solids in the test sample ($500 \div 2.66 = 188$). The rate of flow expressed in terms of seconds per 100 cubic centimeters was, therefore, $(25 \div 188) \times 100 = 13.3$. The Potomac River sand (No. 2 in table 1) had a bulk specific gravity of 2.60, so there were 192.3 cubic centimeters of sand solids in the 500-gram sample. It was found that it required 33 seconds for the sample to flow through the orifice. The rate of flow of this sand expressed in terms of seconds per 100 cubic centimeters was 17.2. The ratio of these two rates of flow is taken as a measure for comparing the surface characteristics of these two sands, and is expressed as a time index with the standard of comparison taken as unity. Thus, the time index of the Potomac River sand is 1.29 ($17.2 \div 13.3 = 1.29$). The rougher and more angular the sand particles, the larger will be the numerical value for the time index.

The time index values for each of the test sands are given in table 1 and figure 4. These values correlate very well with the discernible surface characteristics of the sand particles.

In the development stage, orifices of ¼-, 5/16-, and ⅜-inch diameters were used. Orifices of 7/16- and ½-inch were considered but not used, because the time of flow for either of these two sizes would be so short that any error in reading the time of flow would appreciably effect the time index. The close agreement between the time index values shown in table 1 indicates that for this particular size of sand the size of the orifice is not critical in respect to ability to differentiate between sands. Since it requires about one-half minute to make the test with a ⅜-inch orifice, any small error in reading the time of flow would not effect the time index, and a longer time would be unnecessary. It is therefore suggested that ⅜-inch orifice be used for the test.

Table 1.—Results of tests made with 500-gram sand using orifices of different diameters

Test procedure	Sand designation								
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
⅜-Inch Diameter Orifice									
Total time of flow [1] ... sec	25	33	37	30	32	35	29	28	37
Bulk specific gravity of sand	2.66	2.60	2.76	2.65	2.63	2.58	2.63	2.64	2.72
Solid volume of sand ... cc	188.0	192.3	181.2	188.7	190.1	193.8	190.1	189.4	183.8
Flow rate ... sec/100 cc	13.3	17.2	20.4	15.9	16.8	18.1	15.3	14.9	20.1
Time index	1.00	1.29	1.53	1.19	1.26	1.36	1.15	1.12	1.51
5/16-Inch Diameter Orifice									
Total time of flow [1] ... sec	43	58	63	50	55	60	48	49	61.7
Flow rate ... sec/100 cc	22.9	30.2	34.8	26.5	28.9	31.0	25.8	25.9	33.6
Time index	1.00	1.32	1.51	1.16	1.26	1.35	1.13	1.13	1.47
¼-Inch Diameter Orifice									
Total time of flow [1] ... sec	84	115	128	99.5	112	120	96	95.5	126.5
Flow rate ... sec/100 cc	44.7	59.8	70.6	52.7	58.9	61.9	50.5	50.4	68.8
Time index	1.00	1.34	1.58	1.18	1.32	1.38	1.13	1.13	1.54

[1] Average of three determinations.

Recommended Test Procedure

The following test procedure is suggested:

1. Obtain by careful sieving at least 500 grams of the No. 20–30 size sand. Wash and dry this sample.

2. Determine bulk specific gravity of the sample and compute the solid volume for a 500-gram weight of the sample.

3. Place 500 grams of the dry sample in a clean dry Mason jar of pint size. Assemble jar and aluminum cap containing a ⅜-inch orifice fitted with a stopper. Invert assembly and place in a ring stand over a large glass beaker.

4. Begin the determination of flow time by removing the stopper and starting the stop watch simultaneously. Determine the time between the removal of the stopper and the passage of the last sand particles through the orifice. Make a minimum of three determinations and report the average as the time of flow. Individual test results should not vary from the average by more than 2 seconds.

5. Compute the flow rate in terms of seconds per 100 cubic centimeters of solid volume.

6. Determine the flow rate for standard Ottawa sand which has been carefully sieved to remove all oversized and undersized material. This shall be the standard flow rate with which all other flow rates are to be compared.

7. Compute the time index of the sand under study by dividing its flow rate by the flow rate of Ottawa sand.

Summary

It is believed that this test will be of value in laboratory studies of bituminous mixtures and in evaluating the surface characteristics of sands in the field with respect to specified requirements. The equipment is simple, the operation is practically free from the personal element, and the results obtained by different operators are highly reproducible as indicated in table 2.

Table 2.—Comparison of tests made by two operators using 500-gram sand and orifices of different diameters

Test sequence	Sand designation		
	No. 1	No. 2	No. 3
TIME (IN SECONDS) OF FLOW: 3/8-INCH ORIFICE			
Technician A:			
Test 1	26	33	36
Test 2	25	33	37
Test 3	25	34	37
Technician B:			
Test 1	26	33	37
Test 2	26	33	37
Test 3	26	33	37
TIME (IN SECONDS) OF FLOW: 5/16-INCH ORIFICE			
Technician A:			
Test 1	43	58	63
Test 2	43	58	63
Test 3	43	58	63
Technician B:			
Test 1	43	57	62
Test 2	43	57	62
Test 3	43	57	62
TIME (IN SECONDS) OF FLOW: 1/4-INCH ORIFICE			
Technician A:			
Test 1	83	115	128
Test 2	84	115	128
Test 3	84	115	129
Technician B:			
Test 1	83	114	127
Test 2	83	114	126
Test 3	83	114	127

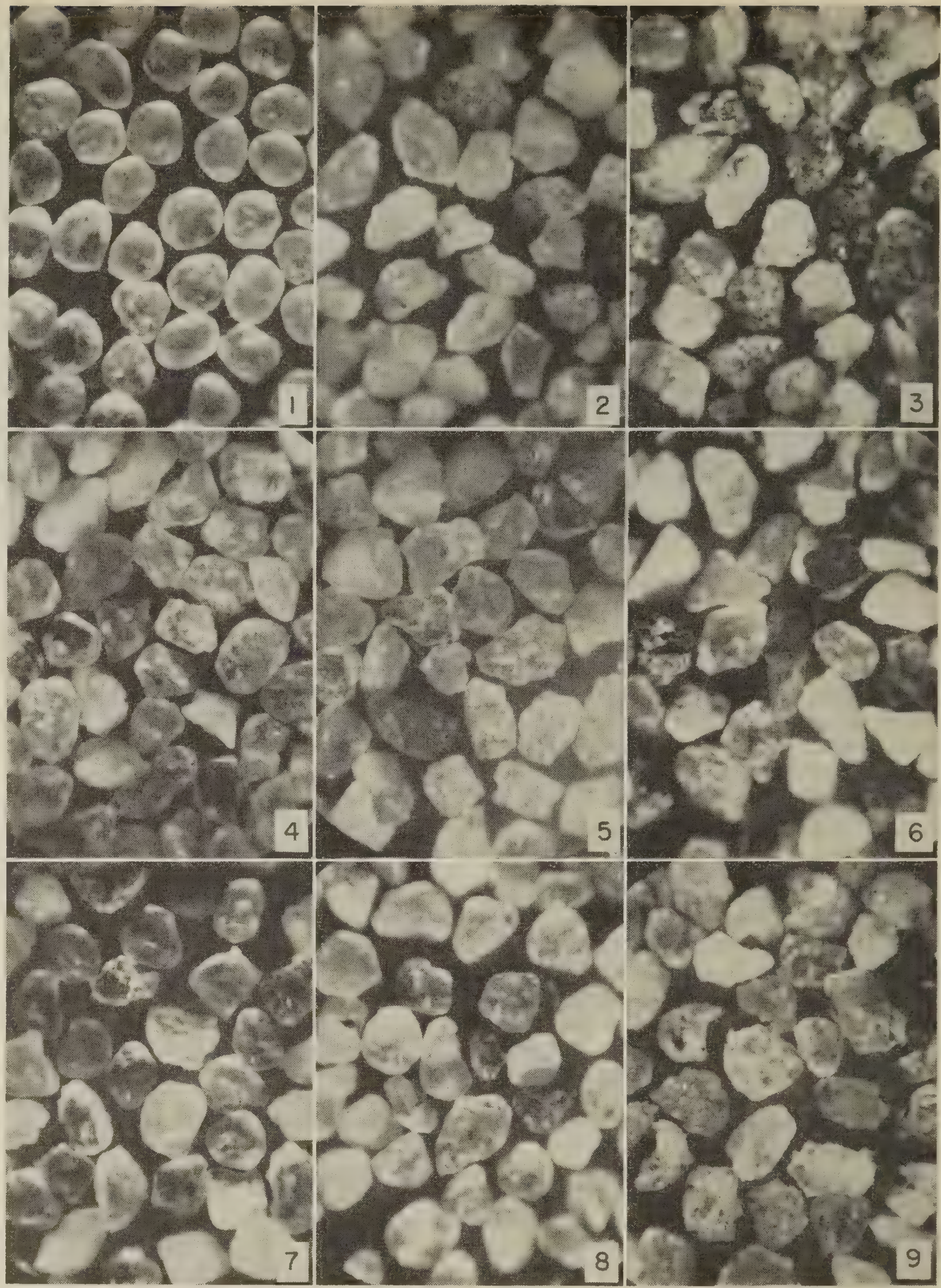

Figure 4.—Photomicrographs of samples of nine sands (X 11.4) having time index values as follows: No. 1, 1.00; No. 2, 1.29; No. 3, 1.53; No. 4, 1.19; No. 5, 1.26; No. 6, 1.36; No. 7, 1.15; No. 8, 1.12; and No. 9, 1.51.

New Publication

The Bureau's *Parking Guide for Cities*, a study of travel habits and parking problems of motorists in urban areas and the characteristics of parking facilities, is now available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 55 cents a copy.

A considerable volume of information has been assembled from these travel-habit and parking studies, and from many other reference sources. Experience and information which have been studied were obtained largely from the medium- and small-size cities, but many of the facts and principles are equally applicable to larger cities.

Collected material on the subject was first published by the Bureau of Public Roads in 1947 in a processed pamphlet, *Factual Guide on Automobile Parking for the Smaller Cities* (now out of print). The text of that pamphlet has now been thoroughly revised and expanded in the new publication, and an entirely new section on parking and travel habits has been added.

U. S. GOVERNMENT PRINTING OFFICE: 1956

A list of the more important articles in PUBLIC ROADS may be obtained upon request addressed to Bureau of Public Roads, Washington 25, D. C.

PUBLICATIONS of the Bureau of Public Roads

The following publications are sold by the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Orders should be sent direct to the Superintendent of Documents. Prepayment is required.

ANNUAL REPORTS

Work of the Public Roads Administration:
- 1941, 15 cents. 1948, 20 cents.
- 1942, 10 cents. 1949, 25 cents.

Public Roads Administration Annual Reports:
- 1943; 1944; 1945; 1946; 1947.
- (*Free from Bureau of Public Roads*)

Annual Reports of the Bureau of Public Roads:
- 1950, 25 cents. 1952, 25 cents. 1954 (out of print).
- 1951, 35 cents. 1953, 25 cents. 1955, 25 cents.

PUBLICATIONS

Bibliography of Highway Planning Reports (1950). 30 cents.
Braking Performance of Motor Vehicles (1954). 55 cents.
Construction of Private Driveways, No. 272MP (1937). 15 cents.
Criteria for Prestressed Concrete Bridges (1954). 15 cents.
Design Capacity Charts for Signalized Street and Highway Intersections (reprint from PUBLIC ROADS, Feb. 1951). 25 cents.
Electrical Equipment on Movable Bridges, No. 265T (1931). 40 cents.
Factual Discussion of Motortruck Operation, Regulation, and Taxation (1951). 30 cents.
Federal Legislation and Regulations Relating to Highway Construction (1948). Out of print.
Financing of Highways by Counties and Local Rural Governments: 1931–41, 45 cents; 1942–51, 75 cents.
General Location of the National System of Interstate Highways, Including All Additional Routes at Urban Areas Designated in September 1955. 55 cents.
Highway Bond Calculations (1936). 10 cents.
Highway Bridge Location No. 1486D (1927). 15 cents.
Highway Capacity Manual (1950). $1.00.
Highway Needs of the National Defense, House Document No. 249 (1949). 50 cents.
Highway Practice in the United States of America (1949). 75 cents.
Highway Statistics (annual):

1945 (out of print).	1949, 55 cents.	1953, $1.00.
1946, 50 cents.	1950 (out of print).	1954, 75 cents.
1947, 45 cents.	1951, 60 cents.	
1948, 65 cents.	1952, 75 cents.	

Highway Statistics, Summary to 1945. 40 cents.
Highways in the United States, *nontechnical* (1954). 20 cents.
Highways of History (1939). 25 cents.
Identification of Rock Types (reprint from PUBLIC ROADS, June 1950). 15 cents.
Interregional Highways, House Document No. 379 (1944). 75 cents.
Legal Aspects of Controlling Highway Access (1945). 15 cents.
Local Rural Road Problem (1950). 20 cents.
Manual on Uniform Traffic Control Devices for Streets and Highways (1948) (*including 1954 revisions supplement*). $1.00.
Revisions to the Manual on Uniform Traffic Control Devices for Streets and Highways (1954). *Separate,* 15 cents.

PUBLICATIONS (Continued)

Mathematical Theory of Vibration in Suspension Bridges (1950). $1.25.
Model Traffic Ordinance (revised 1953). Out of print.
Needs of the Highway Systems, 1955–84, House Document No. 120 (1955). 15 cents.
Opportunities in the Bureau of Public Roads for Young Engineers (1955). 25 cents.
Parking Guide for Cities (1956). 55 cents.
Principles of Highway Construction as Applied to Airports, Flight Strips, and Other Landing Areas for Aircraft (1943). $2.00.
Progress and Feasibility of Toll Roads and Their Relation to the Federal-Aid Program, House Document No. 139 (1955). 15 cents.
Public Control of Highway Access and Roadside Development (1947). 35 cents.
Public Land Acquisition for Highway Purposes (1943). 10 cents.
Public Utility Relocation Incident to Highway Improvement, House Document No. 127 (1955). 25 cents.
Results of Physical Tests of Road-Building Aggregate (1953). $1.00.
Roadside Improvement, No. 191MP (1934). 10 cents.
Selected Bibliography on Highway Finance (1951). 60 cents.
Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1956: a reference guide outline. 55 cents.
Specifications for Construction of Roads and Bridges in National Forests and National Parks, FP-41 (1948). $1.50.
Standard Plans for Highway Bridge Superstructures (1953). $1.25.
Taxation of Motor Vehicles in 1932. 35 cents.
Tire Wear and Tire Failures on Various Road Surfaces (1943). 10 cents.
Transition Curves for Highways (1940). $1.75.

MAPS

State Transportation Map series (available for 39 States). Uniform sheets 26 by 36 inches, scale 1 inch equals 4 miles. Shows in colors Federal-aid and State highways with surface types, principal connecting roads, railroads, airports, waterways, National and State forests, parks, and other reservations. Prices and number of sheets for each State vary—see Superintendent of Documents price list 53.
United States System of Numbered Highways. 28 by 42 inches, scale 1 inch equals 78 miles. 20 cents.

Single copies of the following publications are available to highway engineers and administrators for official use, and may be obtained by those so qualified upon request addressed to the Bureau of Public Roads. They are not sold by the Superintendent of Documents.

Bibliography on Automobile Parking in the United States (1946).
Bibliography on Highway Lighting (1937).
Bibliography on Highway Safety (1938).
Bibliography on Land Acquisition for Public Roads (1947).
Bibliography on Roadside Control (1949).
Express Highways in the United States: a Bibliography (1945).
Indexes to PUBLIC ROADS, volumes 17–19 and 23.
Title Sheets for PUBLIC ROADS, volumes 24–28.

DEPARTMENT OF COMMERCE - BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL-AID HIGHWAY PROGRAM

AS OF OCTOBER 31, 1956

(Thousand Dollars)

STATE	UNPROGRAMMED BALANCES	ACTIVE PROGRAM											
		PROGRAMMED ONLY			PLANS APPROVED, CONSTRUCTION NOT STARTED			CONSTRUCTION UNDER WAY			TOTAL		
		Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles
Alabama	$41,831	$42,502	$30,814	515.2	$5,813	$3,726	41.5	$52,423	$30,439	535.4	$100,738	$64,979	1,092.1
Arizona	36,387	7,038	5,788	69.5	5,608	4,108	39.5	9,785	7,255	101.8	22,431	17,151	210.8
Arkansas	47,261	16,540	8,717	454.6	6,372	3,184	86.0	32,317	19,757	445.1	55,229	31,658	985.7
California	145,287	65,195	39,645	274.4	39,872	31,534	41.5	139,769	71,839	203.4	244,836	143,018	519.3
Colorado	50,391	9,265	5,192	107.1	3,111	1,863	19.7	26,203	17,245	152.4	38,579	24,300	279.2
Connecticut	47,488	10,799	8,344	12.9	641	369	.6	9,944	5,154	17.8	21,384	13,867	31.3
Delaware	23,691	1,850	1,005	14.8	1,249	645	12.2	8,761	4,327	50.2	11,860	5,977	77.2
Florida	57,915	15,526	7,926	311.5	11,851	6,385	39.9	44,679	23,016	334.3	72,056	37,327	685.7
Georgia	85,940	37,792	20,494	560.0	7,168	3,430	41.2	60,236	29,489	845.6	105,196	53,413	1,446.8
Idaho	36,168	4,796	3,174	46.2	5,901	4,213	31.4	10,964	7,124	160.8	21,661	14,511	238.4
Illinois	131,226	63,234	41,827	506.7	23,139	13,946	68.3	111,304	63,387	681.1	197,677	119,160	1,256.1
Indiana	102,852	22,123	12,020	90.4	7,603	4,101	48.8	39,653	21,758	242.2	69,379	37,879	381.4
Iowa	58,245	28,120	20,222	377.3	11,905	7,766	51.9	32,384	18,710	1,035.3	72,409	46,698	1,464.5
Kansas	53,597	19,760	13,495	702.6	3,908	2,134	59.5	39,421	22,257	1,068.9	63,089	37,886	1,831.0
Kentucky	71,932	6,336	3,259	99.1	3,459	1,749	15.4	40,844	22,047	448.6	50,639	27,055	563.1
Louisiana	54,098	35,231	15,621	141.5	10,427	5,308	10.1	39,308	19,259	305.6	84,966	40,188	457.2
Maine	30,235	7,123	3,572	60.9	1,019	655	5.1	17,550	9,097	112.6	25,692	13,324	178.6
Maryland	20,456	29,504	20,109	99.6	20,203	13,500	19.8	31,537	17,844	130.3	81,244	51,453	249.7
Massachusetts	65,445	32,303	19,808	25.8	13,919	7,666	15.9	51,011	28,382	57.2	97,233	55,856	98.9
Michigan	96,534	56,191	35,418	410.9	15,342	8,802	41.0	75,543	43,542	596.2	147,076	87,762	1,048.1
Minnesota	58,384	22,421	15,505	341.5	7,376	4,837	73.0	54,819	31,116	1,149.3	84,616	51,458	1,563.8
Mississippi	55,191	16,788	8,940	519.6	6,648	4,366	78.3	25,707	13,812	592.0	49,143	27,118	1,189.9
Missouri	81,608	31,451	16,883	1,269.0	6,210	3,801	38.5	80,305	45,084	983.7	117,966	65,768	2,291.2
Montana	57,892	6,698	4,135	141.4	6,148	3,604	74.7	28,184	17,751	425.4	41,030	25,490	641.5
Nebraska	64,006	4,397	2,397	185.7	5,355	3,210	63.7	31,557	16,346	1,000.6	41,309	21,953	1,250.0
Nevada	39,828	3,413	2,849	71.8	1,051	948	.6	11,233	9,511	119.6	15,697	13,308	192.0
New Hampshire	22,019	4,516	2,606	22.6	81	40		11,418	6,770	49.3	16,015	9,416	71.9
New Jersey	92,800	7,206	3,603	55.0	3,901	1,950	1.6	35,892	17,544	50.9	46,999	23,097	107.5
New Mexico	31,165	13,207	11,438	58.2	5,224	3,363	41.7	15,620	10,525	211.6	34,051	25,326	311.5
New York	230,207	35,008	21,367	62.0	47,741	29,659	28.3	274,800	133,030	412.6	357,549	184,056	502.9
North Carolina	92,906	13,401	7,017	171.6	4,865	2,476	33.1	56,294	27,748	706.8	74,560	37,241	911.5
North Dakota	41,993	6,701	3,404	758.7	3,320	1,777	302.5	14,343	7,347	694.0	24,364	12,528	1,755.2
Ohio	102,262	75,258	52,961	196.7	31,640	23,730	44.6	101,537	55,798	143.2	208,435	132,489	384.5
Oklahoma	43,919	46,221	29,213	508.0	6,971	3,567	49.7	50,470	28,319	504.7	103,662	61,099	1,062.4
Oregon	34,139	11,282	8,181	66.1	3,585	3,045	21.8	34,282	22,880	223.3	49,149	34,106	311.2
Pennsylvania	167,286	86,205	52,265	147.6	14,831	7,692	24.7	117,986	59,901	365.3	219,022	119,858	537.6
Rhode Island	20,098	4,497	2,949	5.2	890	717	.1	20,907	11,087	23.9	26,294	14,753	29.2
South Carolina	50,404	17,162	9,383	410.0	3,567	1,965	18.0	24,752	13,363	491.8	45,481	24,711	919.8
South Dakota	42,165	10,327	5,959	358.7	671	376	35.1	17,920	10,330	545.7	28,918	16,665	939.5
Tennessee	81,981	18,123	8,312	299.0	15,366	7,683	60.3	47,107	21,829	450.5	80,596	37,824	809.8
Texas	176,691	19,914	10,914	395.7	45,349	29,978	267.5	121,731	67,051	1,391.5	186,994	107,943	2,054.7
Utah	33,177	6,443	4,697	72.1	664	492	1.9	8,722	6,809	119.9	15,829	11,998	193.9
Vermont	22,684	1,191	596	17.8	381	190	2.1	11,007	6,238	71.1	12,579	7,024	91.0
Virginia	75,538	17,365	9,661	170.1	3,590	2,021	17.7	34,114	17,378	350.2	55,069	29,060	538.0
Washington	56,087	9,260	5,399	105.5	5,867	3,490	63.8	32,007	18,056	211.5	47,134	26,945	380.8
West Virginia	49,164	15,415	8,130	58.3	6,722	3,370	31.6	20,780	10,528	56.7	42,917	22,028	146.6
Wisconsin	83,588	12,675	6,424	118.9	7,751	3,994	50.0	44,578	22,582	339.0	65,004	33,000	507.9
Wyoming	16,013	21,958	18,060	162.3	2,974	1,871	29.8	18,693	13,393	228.4	43,625	33,324	420.5
Hawaii	7,507	1,448	714	3.4	3,701	1,844	6.7	3,298	1,533	2.4	8,447	4,091	12.5
District of Columbia	25,769	11,801	6,931	3.7	111	48		8,458	4,245	1.9	20,370	11,224	5.6
Puerto Rico	11,887	7,825	3,381	26.6	1,148	459	.7	18,973	8,888	56.6	27,946	12,728	83.9
Alaska	15,074												
TOTAL	3,240,411	1,070,805	660,724	11,663.8	452,209	281,647	2,151.4	2,251,130	1,218,720	19,498.2	3,774,144	2,161,091	33,313.4

UNITED STATES
GOVERNMENT PRINTING OFFICE
DIVISION OF PUBLIC DOCUMENTS
WASHINGTON 25, D. C.

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE TO AVOID
PAYMENT OF POSTAGE, $300
(GPO)

If you do not desire to continue to receive this publication, please CHECK HERE ☐; tear off this label and return it to the above address. Your name will then be promptly removed from the appropriate mailing list.