of transportation, but to indicate the degree of similarity in commodity shipping densities. An important purpose of this commodity study was to find out if there were optimum levels in payload weights and gross combination weights that would satisfy a preponderance of the commodities transported by highway. The findings indicate that there are such levels which are within the limits of feasible automotive design. However, as the payload requirements of the freight do not, *per se*, provide the economic solution to the size and weight problem, the data of this report must not be used alone to forecast future size and weight limitations. The reported findings are intended primarily to define the areas of gross vehicle weights and dimensions that need to be considered in the economic solution of the problem, and to show the distribution of commodity shipping densities in the universe of highway freight.

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II. The Freight's the Weight

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• THE PLANNING of highways for the transportation of freight is concerned with the prediction of the size and weight of the line haul highway freight vehicles which may be encountered in the future. Before there can be any conclusive estimation of future vehicle weights there is a need for a study of certain features of the pattern of weight demands for highway freight transportation. Such a study of demand is in line with general commercial practices wherein the demand for a product influences the form, weight, and quantity to be produced.

The present study is one phase of a broader study being made by the Committee on Economics of Motor Vehicle Size and Weight of the Highway Research Board. An objective of this more comprehensive study is to develop data regarding the economic factors involved in the establishment of optimum size and weight specifications for highway freight vehicles and for correlated highway design and construction standards.

Previously there was not available a comprehensive study of the tonnages and shipping densities in pounds per cubic foot (pcf) of freight moved by highway. The present study, herein reported, is based on data for the calendar year 1954. The study analyzes the characteristics of commodities transported by line haul highway freight vehicles, in terms of shipping densities of goods as they move in commerce in the United States.

A first objective of this study was to find out the pattern of the shipping density characteristics of commodities moved by highway and the relationship of payloads of various commodities to the gross weights of practical highway freight vehicles. Another objective of the study was to determine if there are end points in payload weights beyond which there are no significant demands

for heavier weight allowances. This information also should indicate some of the reasons for loads in excess of legal limits.

The data of this report indicate the maximum limits and range of gross vehicle weights and sizes which should be considered by the committee in the parent study on the economics of motor vehicle size and weight. Also in the economic study, this pattern of freight tonnages and densities will be useful in estimating the extent of changes in vehicular operations and road usage for any given ceiling of gross vehicle weight. Such data will be needed in the development of comparative economic studies of vehicular operating costs, and the costs of highway facilities, that can be used to predict the sizes and weights of freight vehicles which will result in the optimum over-all cost of highway freight transportation.

To accomplish the objectives of this phase of the parent study, it was necessary to collect and analyze the tonnage and shipping density data concerning all commodities transported by highway. By use of shipping density data, potential payloads of various commodities for specific types and sizes of vehicles can be computed. Potential gross weights can be obtained by adding these potential payloads to the empty weights of the vehicles.

In the present report more emphasis has been given to the gross weights than has been given to the size of freight vehicles. Examples of potential gross weights have been limited to vehicles whose dimensions conform to the policy of the American Association of State Highway Officials (AASHO), which recommends a maximum width of 8 ft, a height of 12½ ft, with lengths of 50 ft for tractor semitrailers, and 60 ft for truck full trailer combinations.

TON-MILES

To develop ton-mile data by commodities, it is necessary to have valid average length-of-haul figures for all of the various commodities. Such average length-of-haul figures for highway freight are not available on a nation-wide basis. Starting with the calendar year 1956, the Interstate Commerce Commission (ICC) is requiring Class I interstate motor carriers of property to report certain detailed statistics regarding shipments handled. However, these statistics do not include the distances that shipments of commodities are hauled. For the reason that valid ton-mile data are not available for commodities moved by highway freight, this report does not include ton-mile information.

STUDY PROCEDURES

The 1954 edition of "Freight Commodity Statistics Classification" (*1*) is the commodity listing in widest use by the transportation industry. Its five principal groups of commodities are:

I. Products of agriculture.
II. Animals and products.
III. Products of mines.
IV. Products of forests.
V. Manufactures and miscellaneous.

These groups are subdivided into 262 commodity classes; for example, wheat is under products of agriculture, and industrial sand is under products of mines. Most of these classes are in turn subdivided; for example, industrial sand includes blast sand, filtering sand, glass sand, and 13 other kinds of sand.

With commodities thus defined in trade terms, the first step in determining the pattern of weight demand was to obtain data on the annual production of all commodities, both manufactured and not manufactured. Original sources of data were consulted, including the U. S. Department of Agriculture (*2*), the U. S. Bureau of Mines (*3*), the U. S. Bureau of the Census (*4*), the U. S. Interstate Commerce Commission (*5*), and statistical issues of various publications such as *Survey of Current Business*, *Iron Age*, and *Petroleum News*. Many of these sources reported, in addition to data on the tons of production, figures for the tons transported, sold, consumed, and imported. These commodity produc-

tion data did not, *per se,* indicate the amount of tonnage conveyed by any one or all five principal media of freight transportation in the United States — highway, railway, inland waterway, pipeline, and airway.

The second step was to identify the portion of total production which entered into transportation. At this point certain assumptions were made. It was considered conservative to assume that those portions of agricultural products which were reported as "sold" could be regarded as tonnage transported. Certain other commodities, such as pig iron, iron and steel ingots, various ores, and phosphate rock were found to be conveyed, to a considerable extent, from the place of initial production to points of manufacture, without resorting to public facilities for transportation. Estimates of the amounts of these commodities which were moved by line haul media of transportation were obtained from authorities in their fields.

The third step was to determine the tonnages carried by each of the five principal media of line haul transportation. Several sources of data were available for this purpose. The Interstate Commerce Commission, through its annual waybill analysis (*6*), determines a distribution of the annual tonnages of commodities hauled by railroads. The Office of Chief of Engineers, U. S. Army, publishes an annual report showing the tonnages of commodities transported by domestic waterway (*7*). A compilation of the annual reports filed by waterway carriers subject to the jurisdiction of the Interstate Commerce Commission (*8*) also was studied. The U. S. Bureau of Mines publishes data concerning commodity tonnages passing through pipelines (*9*). Figures showing tons of freight conveyed by air were obtained from the Civil Aeronautics Administration (CAA) (*10*). This air tonnage, although of high dollar value, represented only a small fraction of 1 percent of total tons conveyed by all transport media.

Data for the tonnages transported by private and for-hire carriers over public highways have been obtained from many sources. For instance, the U. S. Bureau of Mines, U. S. Bureau of the Census, and other governmental agencies, all have reported shipments of certain commodities classified by medium of transport. The introduction into commerce of agricultural products which had been sold, such as wheat and corn, was assumed to have been made by motor truck, as generally there are no rail sidings or water terminals convenient for initial farm transportation.

In other instances estimates of the tonnages line-hauled by truck were obtained by subtracting the subtotal of the tons hauled by railroad, inland waterway, and pipeline from the total tons moved. For example, food products in cans and packages, not frozen (Freight Commodity Statistics Classification No. 763), were produced during 1954 in the amount of 25,157,000 tons and shipped in the amount of 25,333,000 tons. From this latter figure were deducted the 11,052,000 tons which the ICC reported as being hauled by railroad and the 1,939,000 tons transported by inland waterway, leaving 12,342,000 tons which could only have been hauled by motor truck. This conclusion is based on the assumption that little, if any, of this commodity was consumed at the point of production, and that the amount shipped from inventories produced in previous years approximated the amount produced and added to inventory in 1954, but not shipped until 1955 or later. The data concerning these specific commodities were checked for validity by comparison with a U. S. Bureau of the Census report (*11*), which showed the tonnage of canned fruits and vegetables shipped by rail to be 45.5 percent, compared with 47.7 percent by truck and 6.8 percent by water and other means. The results of the method used in this study closely approximate the results obtained by the U. S. Bureau of the Census in that the rail haulage was found to be 43.6, the truck haulage 48.7, and water and other haulage 7.7 percent of the total.

At this point it should be noted that

there is a high probability that portions of the tonnage hauled by other media of transportation also were hauled short distances by motor truck. The highway figures reported herein should be representative of line haul carriage because the short trips to and from other transportation terminals have not been included.

Tons transported in line haul service by the five principal media of transportation for each group of commodities for the United States in 1954 are given in Table 1. In the data for each medium of transportation there is some duplication of tonnage that was hauled by more than one medium. The extent of this duplication is shown in the line "Hauled by more than one medium." Thus the total haulage is greater than that "Transported in commerce," which amounts to 3,470,754,000 tons of freight.

The fourth, and very important, step in this study was the determination of the shipping density of each commodity. Shipping density reflects the weight of a commodity as packaged for shipment and not its net weight, except in the case of commodities which may be shipped in bulk, such as wheat. As an example of shipping density and its relation to net weight, consider eggs. One dozen eggs weighs approximately 1.5 lb, or 45 lb for 30 dozen. The usual container, or crate, plus the 30 dozen of eggs packed for shipment, weighs 58 lb. This weight divided by the 2.23-cu ft size of the container results in a shipping density of 26 pcf. The most recent comprehensive study of commodity densities, containing thousands of measurements of volume and weight, was made by the Board of Investigation and Research (BIR) under the Transportation Act of 1940 during the period 1940 to 1943 (*12*). The "Stowage Red Book" (*13*) also contains commodity density data.

Initially it was thought that shipping densities might have changed since 1942, because of industry's program to reduce tare weights and cube dimensions. However, several studies revealed that there has not been any significant degree of change in shipping densities of the major commodities, insofar as the study objectives are concerned, in the 12-year period between 1942 and 1954. For example, one large packaging concern which distributes food in cans and packages furnished data of the outside measurements of cartons and the weights of canned fruits and vegetables packaged for shipment (*14*). The weighted average density computed from these data agreed closely with that in the BIR report for this commodity.

Some of the commodities listed in the Freight Commodity Statistics Classification were not covered, however, in the BIR commodity density and packaging report. Extensive inquiry among personnel of the U. S. Bureau of Mines, com-

TABLE 1

TONS OF COMMODITIES CONVEYED BY 5 MEDIA OF TRANSPORTATION IN EACH GROUP OF COMMODITIES, UNITED STATES, 1954

Medium of Transportation	Haulage (1,000 tons)						Source
	Products of Agriculture	Animals and Products	Products of Mines	Products of Forests	Manufactures and Miscellaneous	Total	
Highway	178,084	106,621	630,648	153,796	581,676	1,650,825	Table 3
Railway [1]	134,841	13,528	649,724	80,783	349,580	1,228,456	Ref (*5*)
Inland waterway	10,821	20,992	337,175	25,389	259,337	653,714	Ref (*7, 8*)
Pipeline	—	—	290,303	—	88,404	378,707	Ref (*3*)
Airway	—	—	—	—	464	464	Ref (*10*)
Total	323,746	141,141	1,907,850	259,968	1,279,461	3,912,166	
Hauled by more than one medium	101,165	3,738	277,680	—	58,829	441,412	
Transported in commerce	222,581	137,403	1,630,170	259,968	1,220,632	3,470,754	

[1] The 55,297 (1,000) tons originating on Class II and III railroads, representing 4.5 percent of the Class I railroad tonnage, may or may not be included in the data used herein according to whether the tons involved in a given commodity class fell in tons originated or tons terminated used for that class, according to information given on page 3 of ICC Statement No. 570(5).

modity specialists in the U. S. Department of Agriculture, and the review of many publications, supplied shipping density data which were not available from conventional reference sources.

ARRANGEMENT OF DATA

The number of tons of each commodity produced and transported was tabulated by 5-lb shipping density class-intervals. In Table 2, which illustrates the method used, the combined tonnages for all media of transportation are listed opposite the name and density of each commodity, and also are arrayed under the appropriate density class-interval.

A summation of the tons shown in the same density class-interval for all of the five major groups of commodities gives the total tons in that class-interval for all media of transportation. For example, the 68,016,000 tons of products of forests in the 30- to 34.9-lb class-interval were added to 68,477,000 tons of two other groups of commodities (products of agriculture, and manufactures and miscellaneous) in this 30- to 34.9-lb class-interval, resulting in a total of 136,493,000 tons for all media of transportation. (There was no tonnage in this class-interval for animals and products, and products of mines.)

Figure 1 shows the distribution of the 3,470,754,000 tons of freight involved in transportation (by all five transport media) by shipping densities, for the United States in 1954. The main area where dry freight transportation utilizes van-type vehicles includes commodities with shipping densities of less than 50 pcf. The two 5-lb class-intervals between 50 and 60 pcf are composed mainly of flowable commodities, which require special purpose vehicles. These commodities are bituminous and anthracite coal, fuel, road and petroleum oils, crude petroleum, and acids.

DENSITY DISTRIBUTIONS OTHER THAN HIGHWAY

In a manner similar to that illustrated in Table 2, a distribution of tonnages by class-intervals was made for each medium of transportation, using data from the several transport agencies, such as ICC, CAA, Bureau of Mines, and other sources mentioned earlier. The distributions of tonnages by each medium of transportation are shown in the following series of charts. The entire compiled data regarding commodities moved by highway freight are given in Table 3, which is discussed later in the report. Tabulations of similar data for the other media of transportation are not included in this report, but are available for review by interested parties.

Figure 2, the first of five charts showing tonnage hauled by different media of transportation, portrays 1,228,456,000 tons of commodities transported by United States railroad during 1954, in-

TABLE 2

PRODUCTS OF FORESTS TRANSPORTED, DISTRIBUTED BY COMMODITY SHIPPING DENSITY, UNITED STATES, 1954

Product	Density, pcf	Total	Haulage (1,000 tons) 30-34.9 pcf	35-39.9 pcf	40-44.9 pcf	45-49.9 pcf	50-54.9 pcf
Logs, butts, and bolts	45	131,580	—	—	—	131,580	—
Posts, poles, and piling	40	4,375	—	—	4,375	—	—
Wood, fuel	40	5,600	—	—	5,600	—	—
Ties, railroad	50	2,800	—	—	—	—	2,800
Pulpwood	38	47,000	—	47,000	—	—	—
Lumber, shingles, and lath	31	51,961	51,961	—	—	—	—
Box, crate, and cooperage materials	31	3,436	3,436	—	—	—	—
Veneer, plywood, and built-up wood	30	5,991	5,991	—	—	—	—
Rosin and turpentine	38	597	—	597	—	—	—
Products of forests NOS.[1]	30	6,628	6,628	—	—	—	—
Total products of forests		259,968	68,016	47,597	9,975	131,580	2,800
Cumulation		—	68,016	115,613	125,588	257,168	259,968
Cumulative percent		—	26.2	44.5	48.3	98.9	100.0

[1] NOS = Not otherwise specified.

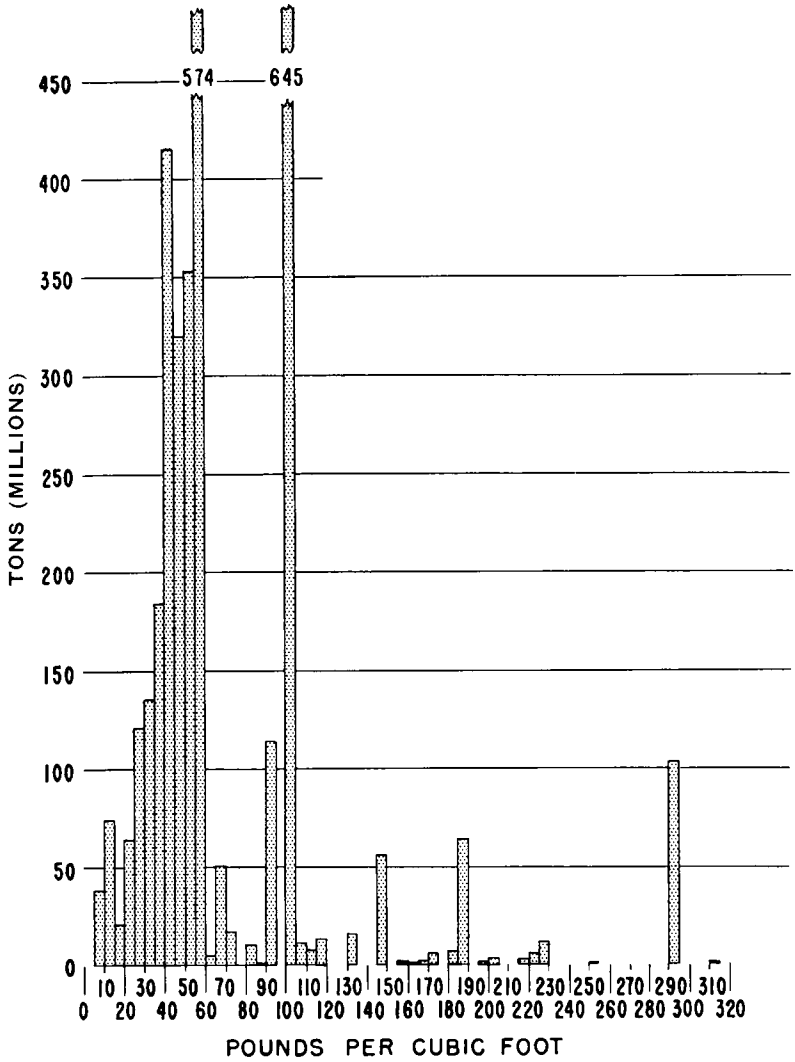

Figure 1. Freight tonnage involved in transportation, by shipping densities, United States, 1954.

cluding freight that also had been line hauled by some other medium of transport. The 50- to 54.9-lb class-interval contains bituminous and anthracite coal. Relatively little demand is shown for rail transportation of commodities weighing less than 30 pcf. A greater demand is indicated in the range between 30 to 55 pcf. The 55- to 59.9-lb class-interval shows little tonnage because pipelines carry so much crude petroleum and petroleum products, which are found in this weight interval.

Inland waterways in the United States carried 653,714,000 tons of freight in 1954. This freight consisted mainly of heavy-density commodities, as shown in Figure 3. The U. S. Corps of Engineers has its own classification of commodities, which corresponds to the Freight Commodity Statistics Classification in some cases but differs in many others. Correla-

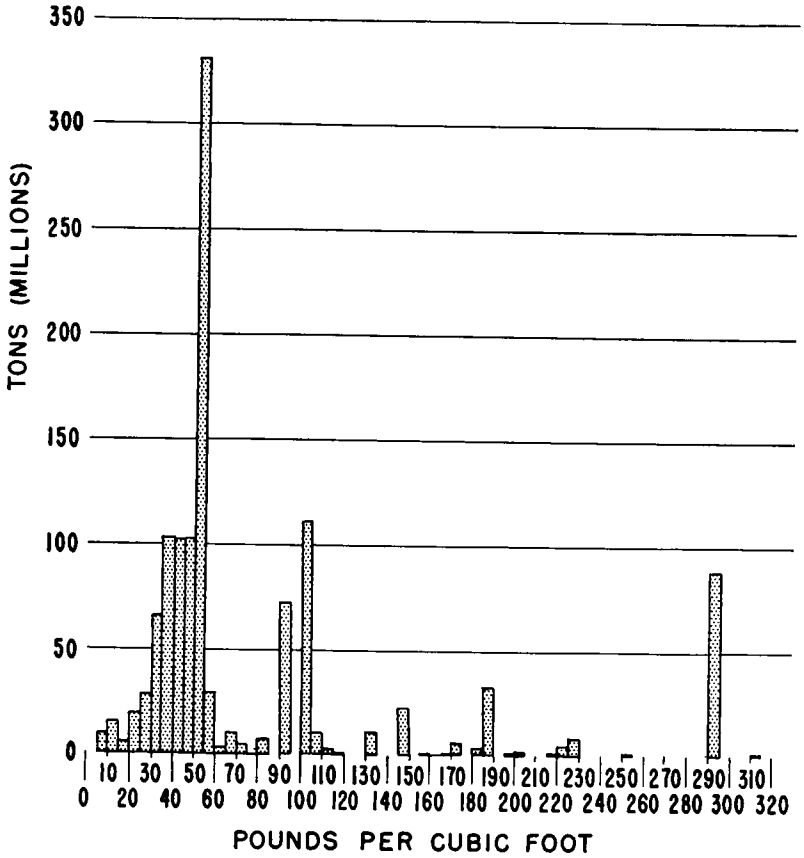

Figure 2. Railway freight tonnage, by shipping densities, United States, 1954.

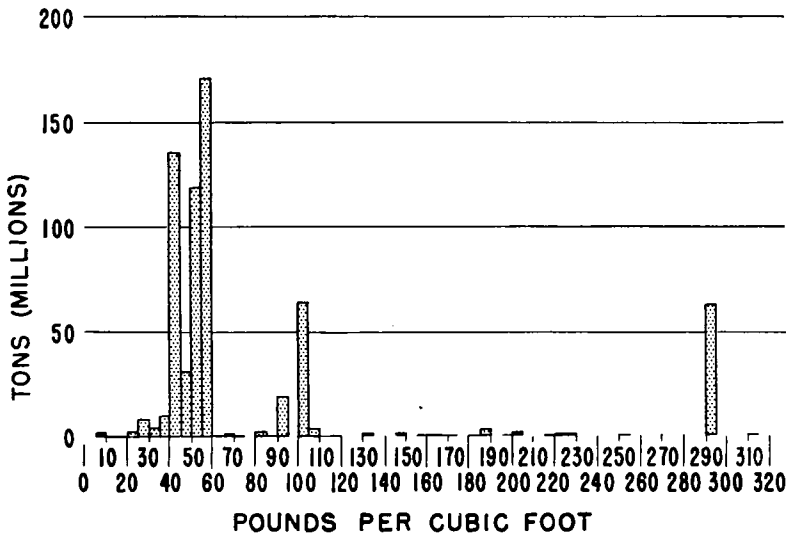

Figure 3. Inland waterway freight tonnage, by shipping densities, United States, 1954.

tion of statistical data between these two classifications was obtained through reference to a report entitled "Commodity Classification for Shipping Statistics — 1950" (*15*).

Pipelines in the United States, which carried 378,707,000 tons of commodities in 1954, are concerned with commodities found in only two density class-intervals; namely, 40- to 44.9-lb for gasoline, and 55- to 59.9-lb. for crude petroleum and residual oils. The distribution of the total tonnage to these class-intervals is shown in Figure 4.

The 464,000 tons of air freight transported in the United States in 1954 represented less than 0.02 percent of the total tons hauled. This means of carrying freight is increasing in favor, but does not now play a significant part in the total tonnage picture, as is evident from Figure 5.

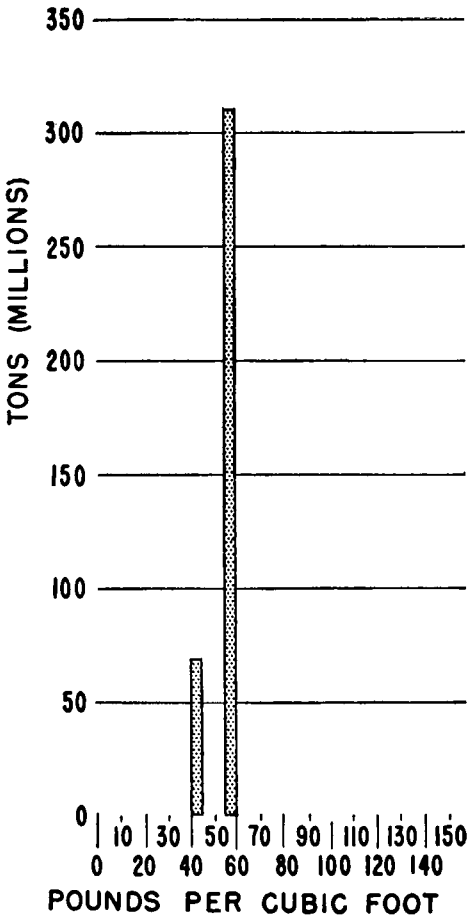

Figure 4. Pipeline freight tonnage, by shipping densities, United States, 1954.

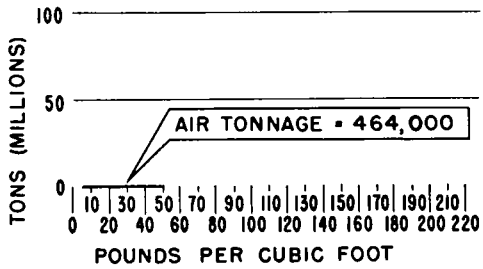

Figure 5. Airway freight tonnage, by shipping densities, United States, 1954.

DENSITY DISTRIBUTIONS OF HIGHWAY FREIGHT SHIPMENTS

In considering the tonnage of commodities which move by truck over the public highways, two types of carriage were examined: the extent to which this tonnage moves by "volume minimum" shipments, otherwise known as "truckload"; and the extent to which it moves by "less-than-truckload" (LTL) shipments. Generally "truckload" shipments are "volume minimum" shipments composed of one commodity. The Interstate Commerce Commission in its motor carriers statistical reports (*16*) defines a "truckload" as a shipment weighing 10,000 lb or more moving on a single bill of lading. The ICC (*16*) reports that in 1954, 723 Class I motor carriers of general freight hauled 58,199,274 tons of freight, or 53.7 percent of the total, in truckload shipments, whereas 50,279,475 tons, or 46.3 percent, were handled in LTL shipments. Line haul shipments by contract carriers and by private and exempt carriers, by their nature, are predominantly of the truckload variety. Because so much of the freight moves in truckload amounts, it is believed that the pattern of demand for payload weights can be estimated validly on a basis of truckloads of single commodities, rather than on any basis of cargo loads of LTL shipments of mixed freight.

Accordingly, it has been assumed in this study that freight moves predominantly in truckload shipments, and the tonnage distribution of commodities by shipping densities is used to estimate the demand pattern of transportation by the line haul trucking industry.

In line with the foregoing premise, the demand behavior for the highway transportation of 1,650,825,000 tons of freight is shown in Figure 6. Considerable demand will be noted in the three class-intervals between 25 and 40 lb, and much greater demand in the two class-intervals from 40 to 50 lb. Again, there is considerable demand shown in the two class-intervals between 50 and 60 lb, but above 60 lb there is little tonnage shown until the 100- to 104.9-lb class-interval is reached. This class-interval represents

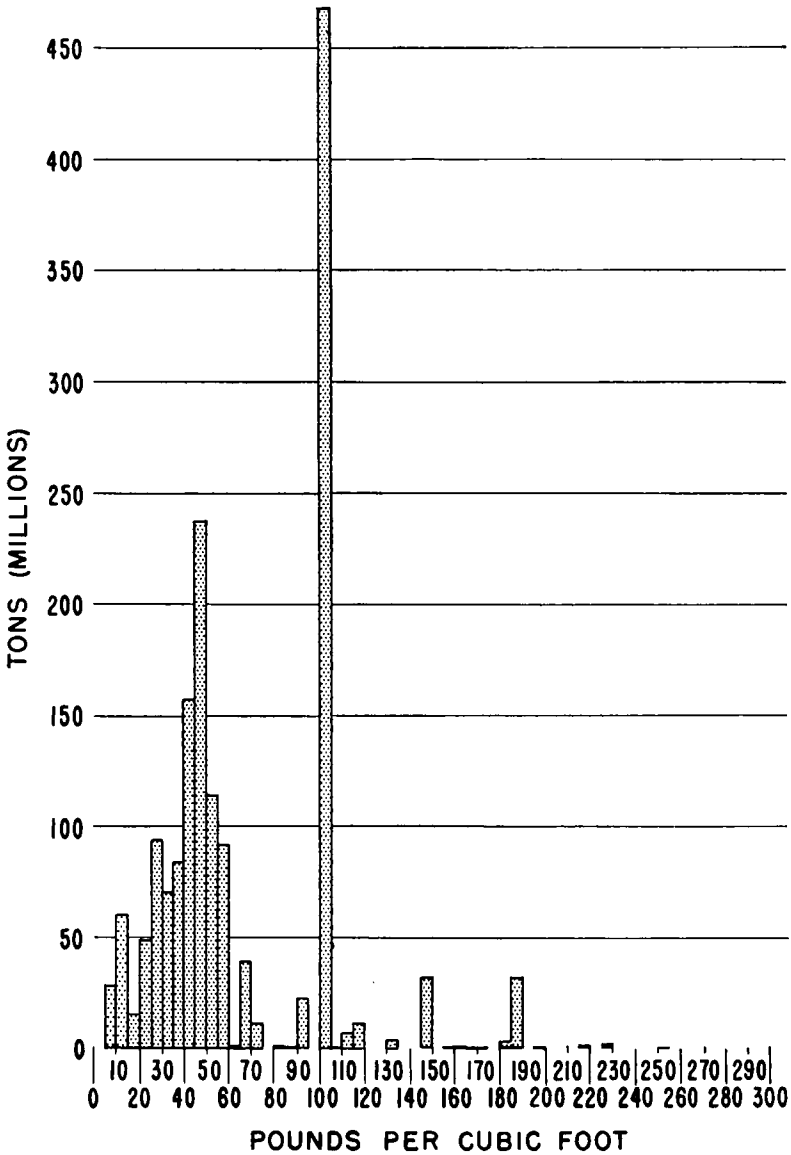

Figure 6. Highway freight tonnage, by shipping densities, United States, 1954.

the tonnage of crushed rock, gravel, and sand. Beyond the 105-pcf level there are two commodities of considerable magnitude — scrap iron and steel, and manufactured iron and steel.

It is desirable to note what commodities are predominant in each class-interval. The horizontal bars shown in Figure 7 are the same as those shown vertically in Figure 6. One might think that an automobile is heavy, but the cubic shipping size of the vehicle as it

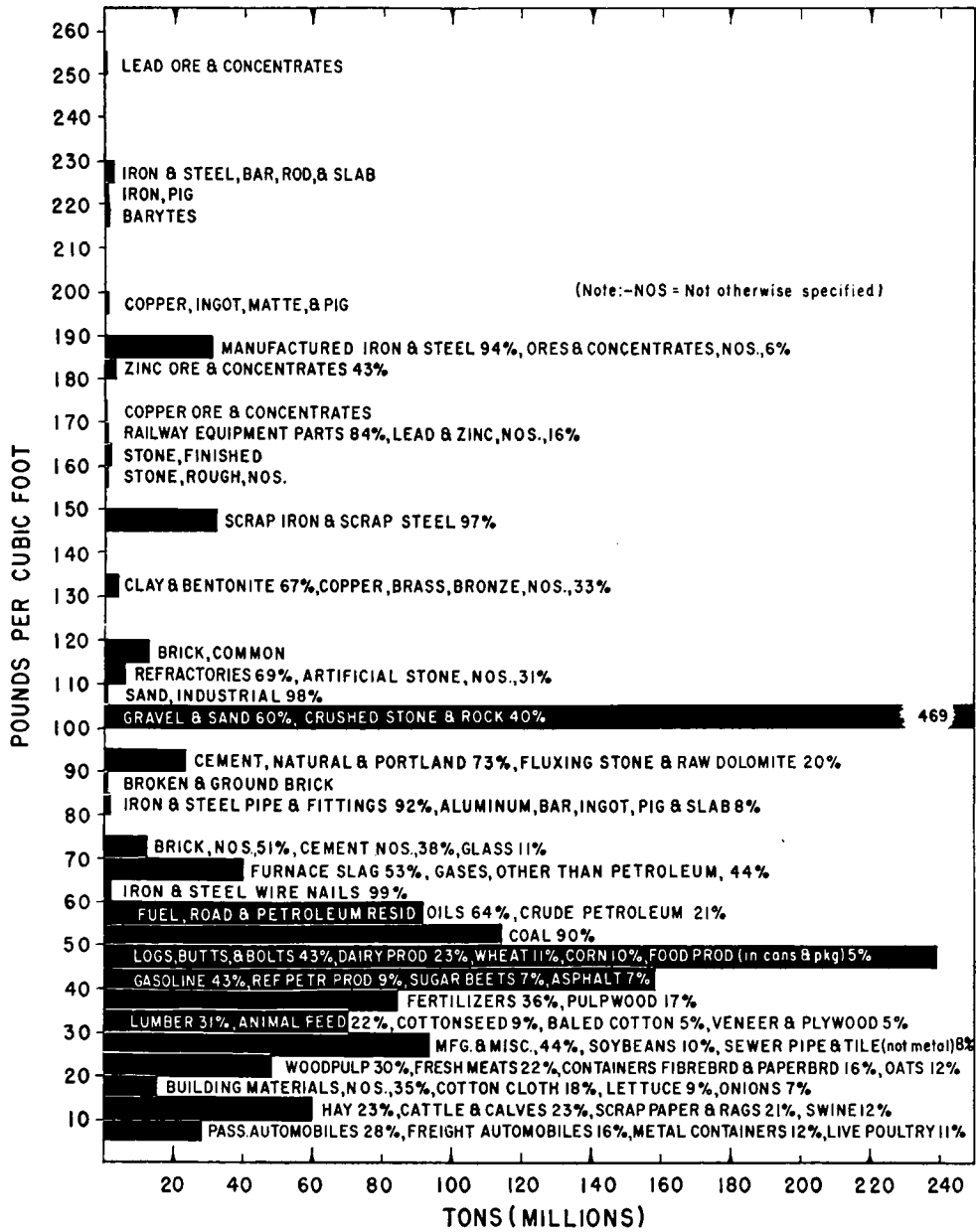

Figure 7. Highway freight tonnage, by shipping densities and predominant commodities, United States, 1954.

is transported results in a density of about 6 pcf. Other comparatively light commodities are hay and livestock. Other products in order of progression with shipping densities from 20 to 60 pcf are fresh meats, soybeans, lumber, fertilizers, gasoline, food products in cans and packages, coal, and fuel oil. Most of the commodities in the 50-54.9- and 55-59.9-lb class-intervals require special purpose vehicles (such as those with tanks or hopper bodies), whereas most of the commodities in the intervals between 25 and 50 lb, with the exception of gasoline in the 40-44.9-lb class-interval, are handled in van-type cargo vehicles. The tonnages of heavier commodities (slag, brick, iron and steel pipe, cement, gravel and sand, crushed rock, clay, scrap iron and steel, manufactured iron and steel, and various ores and concentrates) are shown in the upper part of Figure 7.

A listing of the estimated annual freight tonnage hauled by highway for each commodity classification is given in Table 3, and is arranged in the same

TABLE 3

TONNAGES OF COMMODITIES TRANSPORTED BY HIGHWAY, BY SHIPPING DENSITIES, UNITED STATES, 1954

Class — Interval, and Commodity [1]	ICC Class [2]	1,000 Tons
5.0-9.99 Pounds per Cubic Foot		
Automobiles, passenger	613	7,965
Automobiles, freight	615	4,524
Containers, metal	779	3,405
Poultry, live	223	3,002
Containers, wooden	781	2,350
Furniture, NOS	715	1,925
Iron and steel borings, turnings, etc.	791	1,750
Household goods, used	799	929
Vehicles, other than motor	611	816
Insulating materials, NOS	675	770
Sheep and goats	207-209	678
Airplanes, aircraft, and parts	625	421
Containers, NOS	785	338
Games and toys	743	197
Furniture parts	717	169
Luggage and handbags, NOS	739	17
Total		29,256
10.0-14.99 Pounds per Cubic Foot		
Hay	25	13,955
Cattle and calves	203-205	13,664
Scrap paper and rags	655	12,607
Swine	211-213	7,074
Tanks, NOS	589	4,848
Glass bottles, jars, and packing glasses	697	2,888
Building woodwork and millwork	677	2,254
Refrigerators, freezing apparatus, and parts	707	1,045
Glassware, NOS	695	467
Straw	27	250
Stoves, ranges, and parts	711	233
Bananas, fresh	51	226
Wool and mohair in grease	235	217
Tobacco siftings, sweepings, and waste	31	147
Wool and mohair, NOS	237	107
Household utensils	705	107
Horses, mules, ponies, and asses	201	97
Total		60,186
15.0-19.99 Pounds per Cubic Foot		
Building materials, NOS	679	5,392
Cotton cloth and cotton fabrics, NOS	727	2,749
Lettuce	81	1,407
Onions, dry	83	1,052
Buildings and houses, fab., and portable, NOS	681	998
Agriculture implements, NOS	591	814
Cotton linters, noils, and regins	35	684
Vehicles, motor, NOS	617	585
Tires and tubes, rubber	627	548
Laundry equipment	709	475
Bathroom and lavatory fixtures and sinks	689	414
Matches	771	110
Cotton factory products	729	109
Total		15,337
20.0-24.99 Pounds per Cubic Foot		
Woodpulp	653	14,571
Meats, fresh, NOS	215	10,882
Containers, fiberboard and paperboard, KD	783	7,903
Oats	7	5,959
Watermelons	67	1,437
Paper and paper articles, NOS	665	1,407
Cabbage	77	1,268
Tobacco, unmanufactured	29	1,122
Plastics	549	929
Cloth and fabrics, NOS	733	560
Paper bags	663	527
Peanuts	97	484
Floor covering	713	356
Cigarettes	777	324
Woodenware	703	296
Business and office machines, NOS	601	239
Chinaware, crockery, and earthenware	701	235
Boots, shoes and findings, NOS	737	229
Berries, fresh, NF	53	205
Cellulose articles, NOS	551	12
Total		48,945
25.0-29.99 Pounds per Cubic Foot		
Manufactures and miscellaneous, NOS	799	41,709
Soybeans	43	9,799
Sewer pipe and drain tile (not metal)	649	7,788
Vegetables, fresh, NOS, NF	89	6,092
Products of agriculture, NOS	199	5,812
Paperboard, fiberboard, and pulpboard	669	5,452
Eggs	227	5,242
Apples, fresh, NF	49	2,514
Poultry, dressed and frozen	225	1,419
Synthetic fiber and yarns (rayon or nylon)	731	1,328

TABLE 3—Continued

Class — Interval, and Commodity [1]	ICC Class [2]	1,000 Tons
Fruits, fresh, NOS, NF	69	1,222
Flaxseed	105	1,102
Cereal food preparations, NOS	21	1,021
Furnaces, heaters, radiators, and parts	687	876
Cantaloupes and melons, NOS	55	733
Celery	79	731
Rope, cordage, and binder twine, NOS	735	354
Leather, NOS	241	293
Vegetables, fresh, frozen	95	205
Coffee	75	184
Manufactured tobacco, NOS	775	182
Athletic, gym., playgrnd., and sportg. equip., NOS	741	85
Vegetables, dried, dehyd., and evap., NOS	93	13
Total		94,156
30.0-34.99 Pounds per Cubic Foot		
Lumber, shingles, and lath	411	21,536
Feed, animal and poultry, NOS	773	15,694
Cottonseed	37	6,330
Tomatoes	87	3,690
Cotton in bales	33	3,424
Veneer, plywood, and built-up wood	415	3,268
Automobiles and autotrucks, KD	621	3,041
Grapes, fresh	57	2,549
Products of forests, NOS	499	2,330
Box, crate, and cooperage materials	413	2,103
Peaches, fresh, NF	63	1,362
Cottonseed hulls and bran	41	1,278
Lemons, limes, and citrus fruits, NOS	59	560
Malt, NOS	103	551
Wallboard	671	543
Seeds, NOS	107	494
Meal, corn	17	480
Rubber goods, NOS	525	449
Bagging: burlap, cotton, gunny, and jute, NOS	723	311
Fruits and berries, fresh, frozen	73	261
Total		70,254
35.0-39.99 Pounds per Cubic Foot		
Fertilizers, NOS	539	30,355
Pulpwood	409	14,189
Potatoes other than sweet	85	8,870
Oranges and grapefruit	61	7,523
Barley and rye	9	6,307
Newsprint paper	657	1,512
Machinery and machines, NOS	595	1,507
Packinghouse products, edible, NOS	219	1,483
Electrical equipment and parts, NOS	685	1,404
Flour, wheat	15	1,262
Alcohol, NOS	535	1,213
Cottonseed oil cake and meal	39	1,144
Coke	307	1,000
Printed matter, NOS	667	962
Flour, edible, NOS	19	755
Rubber, crude, natural, and synthetic	523	701
Pears, fresh, NF	65	686
Soybean oil cake and meal	45	636
Liquors, alcoholic, NOS	745	496
Insecticides and fungicides, NOS	541	429
Sea foods, NOS	243	369
Vegetable and nut oils, NOS	517	318
Cheese	231	279
Wine	747	273
Abrasives, other than crude	721	200
Starch	767	145
Beans and peas, dried	91	144
Drugs, medicines and toilet preparations	553	135
Bags: burlap, cotton, gunny, and jute, NOS	725	125
Oils, NOS	519	100
Rosin and turpentine	417	89
Oil foots, sediment, and tank bottoms	521	38
Tanning materials, NOS	545	31
Total		84,680
40.0-44.99 Pounds per Cubic Foot		
Gasoline	501	68,319
Petroleum products, refined, NOS	507	14,493
Sugar beets	101	14,091
Asphalt	339	11,224
Liquors, malt	749	9,013
Products of mines, NOS	399	5,933
Beverages, NOS	751	5,587
Wood, fuel	405	5,034
Meats, cooked, cured, dried, and smoked	217	4,010
Vehicle parts, NOS	623	3,138
Rice	11	2,455
Waste materials, NOS	797	2,326
Sulphur	345	1,710
Soap and cleaning and washing compounds	769	1,486
Lubricating oils and greases	505	1,303
Posts, poles, and piling, wooden	403	1,298
Candy and confectionery	761	1,267
Wrapping paper	661	1,109
Animals and products, NOS	299	829
Margarine, NOS	221	623
Cottonseed oil	511	577
Butter	229	509
Mill products, NOS	23	418
Printing paper, NOS	659	343
Vegetable and nut oil cake and meal, NOS	47	307
Blacks, NOS	537	256
Fruits, dried, dehydrated and evaporated, NOS	71	240
Grain, NOS	13	131
Hides, skins, and pelts, NOS	239	98
Linseed oil	513	55
Total		158,182
45.0-49.99 Pounds per Cubic Foot		
Logs, butts, and bolts	401	102,532
Dairy products, NOS	233	55,746
Wheat	1	25,941
Corn	3	24,143
Food products, NOS, in cans and packages, NF	763	12,342
Sorghum grain	5	4,428
Sodium (soda) products	533	4,420
Tar, pitch, and creosote	543	4,171
Chemicals, NOS	527	2,432
Soybean oil	515	1,079
Machinery parts	597	644
Food products, NOS, frozen	765	422
Agriculture implement parts, NOS	593	375
Total		238,675

TABLE 3—Continued

Class — Interval, and Commodity [1]	ICC Class [2]	1,000 Tons
50.0-54.99 Pounds per Cubic Foot		
Bituminous coal	305	95,700
Anthracite coal	301-303	7,284
Paint, paint material, putty, and varnish	547	3,940
Salt	341	2,522
Sugar	759	1,936
Ties, railroad	407	1,417
Tools and parts, NOS	719	753
Ammunition and explosives	631	371
Asbestos articles, NOS	683	260
Total		114,183
55.0-59.99 Pounds per Cubic Foot		
Fuel, road, and petroleum residual oils, NOS	503	58,970
Petroleum, crude	337	19,644
Sulphuric acid	529	3,565
Lime, NOS	645	3,318
Aluminum, NOS	557	1,678
Plaster: stucco and wall	647	1,447
Cast-iron pipe and fittings	585	1,044
Molasses residual	757	818
Ice	753	744
Bldg. paper and prepared roofing materials	673	718
Syrup and molasses, refined	755	27
Total		91,973
60.0-64.99 Pounds per Cubic Foot		
Iron and steel nails and wire (woven and not woven), NOS	581	1,680
Railway equip., SU, not moved on own wheels	605	19
Total		1,699
65.0-69.99 Pounds per Cubic Foot		
Furnace slag	793	20,720
Gases, other than petroleum, NOS	509	17,641
Hardware, NOS	691	1,354
Total		39,715
70.0-74.99 Pounds per Cubic Foot		
Brick, NOS, and building tile	639	6,173
Cement, NOS	635	4,533
Glass	693	1,341
Total		12,047
80.0-84.99 Pounds per Cubic Foot		
Iron and steel pipe and fittings, NOS	587	1,352
Aluminum: bar, ingot, pig, and slab	555	123
Total		1,475
85.0-89.99 Pounds per Cubic Foot		
Broken or ground brick, blocks, crockery, and glass	651	569
Total		569
90.0-94.99 Pounds per Cubic Foot		
Cement: natural and portland	633	17,210
Fluxing stone and raw dolomite	331	4,806
Phosphate rock	343	1,650
Total		23,666
100.0-104.99 Pounds per Cubic Foot		
Gravel and sand, NOS	327	283,821
Stone and rock: broken, ground, and crushed	329	185,516
Total		469,337
105.0-109.99 Pounds per Cubic Foot		
Sand, industrial	325	1,345
Magnesium metal and alloy	567	26
Total		1,371
110.0-114.99 Pounds per Cubic Foot		
Refractories	641	4,294
Artificial stone, NOS	643	1,895
Total		6,189
115.0-119.99 Pounds per Cubic Foot		
Brick, common	637	12,176
Total		12,176
130.0-134.99 Pounds per Cubic Foot		
Clay and bentonite	323	3,109
Copper, brass, and bronze, NOS	561	1,417
Total		4,526
145.0-149.99 Pounds per Cubic Foot		
Scrap iron and scrap steel	789	29,959
Waste materials for remelting, NOS	795	2,047
Total		32,006
155.0-159.99 Pounds per Cubic Foot		
Stone, rough, NOS	333	330
Total		330
160.0-164.99 Pounds per Cubic Foot		
Stone, finished	335	903
Total		903
165.0-169.99 Pounds per Cubic Foot		
Railway equipment parts	607	569
Lead and zinc, NOS	565	108
Total		677
170.0-174.99 Pounds per Cubic Foot		
Copper ore and concentrates	313	58
Total		58
180.0-184.99 Pounds per Cubic Foot		
Zinc ore and concentrates	317	1,095
Alloys for steel manufacture	569	639
Metals and alloys, NOS	571	572
Rails and rwy., track material, iron and steel	609	255
Total		2,561
185.0-189.99 Pounds per Cubic Foot		
Manufactured iron and steel	583	28,751
Ores and concentrates, NOS	319	2,000
Total		30,751
195.0-199.99 Pounds per Cubic Foot		
Copper: ingot, matte, and pig	559	294
Total		294

TABLE 3 —Continued

Class — Interval, and Commodity [1]	ICC Class [2]	1,000 Tons	Class — Interval, and Commodity [1]	ICC Class [2]	1,000 Tons
215.0-219.99 Pounds per Cubic Foot			225.0-229.99 Pounds per Cubic Foot		
Barytes	217	913	Iron and steel: bar, rod, and slab	577	2,970
Total		913	Total		2,970
220.0-224.99 Pounds per Cubic Foot			250.0-254.99 Pounds per Cubic Foot		
Iron, pig	573	680	Lead ore and concentrates	315	85
Total		680	Total		85
			Grand total		1,650,825

[1] NOS = Not otherwise specified; KD = Knocked down; NF = Not frozen; SU = Set up.
[2] Interstate Commerce Commission freight commodity statistics classification.

5-lb class-intervals of density as are used in Figures 6 and 7. The 45-49.9-lb class-interval of Table 3, containing 238,675,000 tons, corresponds to the second tallest bar in Figure 6. The tonnage of commodities represented by this bar includes logs, dairy products, wheat, corn, food products in cans and packages frozen and not frozen, and seven other commodity classes. The tallest bar includes 469,337,000 tons of sand, gravel, and crushed stone, which, although they are commodities of importance, are generally moved relatively short distances in line haul service.

The five groups of commodities have different patterns of distribution of tonnages by shipping densities. Figure 8 presents the tonnage distribution by density class-intervals for each of the five

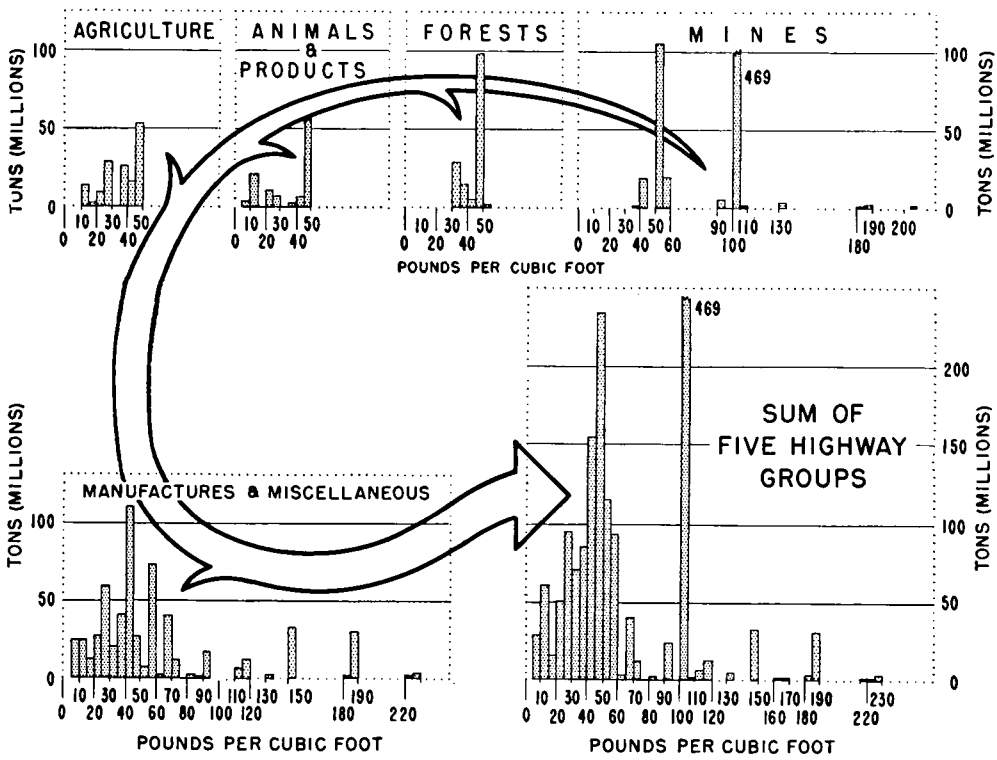

Figure 8. Highway freight tonnage by group of commodity and shipping density, United States, 1954.

commodity groups. In the lower right-hand corner of Figure 8 is shown a summary distribution of the combined tonnage, which is the same as Figure 6. Most of the commodities in three of the five groups — products of agriculture, animals and products, and products of forests — mainly include commodities with densities below 50 pcf, although there are a few tons of forest products in the 50-54.9-lb class-interval. All three of these groups have considerable tonnage in the range of densities from 30 to 50 lb, with special emphasis on the 45-49.9-lb class-interval. Products of mines generally have densities of over 50 pcf, although there is some tonnage in the 40-44.9-lb class-interval. Manufactures and miscellaneous commodities are found in practically all weight intervals up to 95 pcf and in some higher density intervals. The height of the bar in the 40-44.9-lb class-interval is due to the tonnage of gasoline hauled.

DENSITY RELATED TO CARGO CAPACITY

To demonstrate what these various class-intervals of density mean in relation to gross vehicle loads, let the weight possibilities of a 5-axle, tractor semitrailer combination with a 35-ft van cargo body of 2,000-cu ft stowage capacity be considered. When loaded visibly full of a commodity weighing 24 pcf, it would contain a payload of 48,000 lb. Addition of tare or empty weights of a 14,000-lb tractor and an 11,000-lb trailer would result in a gross load of 73,000 lb, which closely approximates the gross weight limitation of 73,280 lb declared in the Highway Act of 1956.

Commodities having shipping weights of 25 lb or less per cubic foot (such as cigarettes, which weigh 22 pcf) would visibly fill the trailer, as shown in the upper left-hand corner of Figure 9. Heavier commodities, such as veneer and plywood, weighing 30 pcf would fill 80 percent of the stowage space of the trailer when loaded to the gross weight limit of 73,000 lb. Similarly, van loads of oranges and grapefruit could legally be loaded to 69 percent of the 2,000-cu ft available stowage space, soap to 60 percent, canned and frozen food to 53 percent, and paint to 48 percent.

Using a different approach, a combination vehicle 45 ft in length, within the over-all length restrictions of all states,

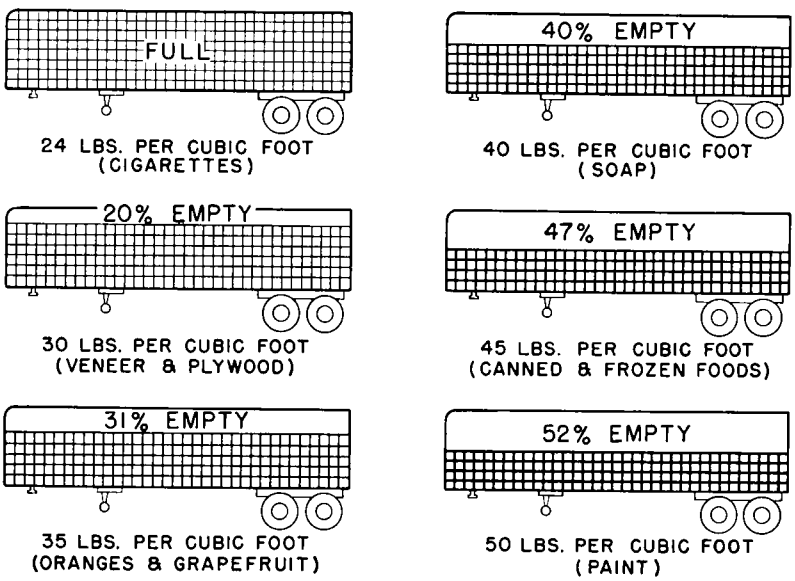

Figure 9. 73,000-lb gross loadings in 35-ft semitrailers of 2,000-cu ft capacity; tare weight of tractor 14,000 lb, trailer 11,000 lb.

would measure about 41 ft between extreme axles and could be equipped with a 35-ft cargo body of approximately 2,000-cu ft stowage capacity. The gross weight limit recommended for this combination under the 1946 policy of the American Association of State Highway Officials (AASHO) is 61,580 lb. Subtracting from this gross weight the tare weights of the 14,000-lb tractor and the 11,000-lb semitrailer would leave a maximum allowed payload of 36,580 lb. Division of this payload by the 2,000-cu ft capacity gives a density of 18.3 pcf, the highest density of commodities under the AASHO weight policy that can be loaded to visibly fill the cargo body of the combination described.

DENSITIES CONSIDERED FOR VISIBLY FULL LOADS

Just how far can highway supporting abilities be increased economically to satisfy the demand for heavier loads? The answer to this basic question is one of the objectives of the Committee on Economics of Motor Vehicle Size and Weight. Data concerning the payload part of this question are the substance of this report.

To point out certain of the implications which can be made from the data herein developed, two different ceiling levels of commodity densities have been selected for discussion. This selection of a cut-off point suggests the principle of diminishing returns, which is not new to roadbuilding. There is a generally accepted rule in highway planning that a design to accommodate a traffic volume greater than that estimated to occur during the 30th highest hour of the design year to which the projection is made, usually is not warranted. This means that during 29 hours of the year for which the design is made drivers will be inconvenienced by traffic congestion or restriction in freedom to maneuver to a greater degree than they normally consider reasonable under the prevailing roadway conditions. This cut-off point has been selected on the reasoning that the additional expense of providing highway facilities with practical capacities for the highest annual 29 hours of traffic demand generally is not justified.

In the first discussion it will be assumed that commodities with shipping densities of 100 lb or more per cubic foot must move in less-than-visibly full body loads when handled in cargo bodies of approximately 2,000-cu ft capacity. In the second discussion it will be assumed that commodities with shipping densities of 50 lb or more per cubic foot must be similarly limited. These two ceiling levels of commodity density were selected from Figure 6 as being logical division points in the 1954 highway freight traffic pattern.

Considering a freight vehicle with 2,000 cu ft of stowage space and the carrying of freight weighing 100 pcf, the maximum gross vehicle weight would be on the order of 250,000 to 260,000 lb. Where the freight carried weighs 50 pcf the maximum gross weight for this vehicle would be approximately 130,000 lb, and where freight weighs 25 pcf the maximum gross weight would be approximately 75,000 lb.

In addition to tractor semitrailer 2-unit combinations with 2,000-cu ft capacity, there also can be considered the potentials of "double-bottom rigs:" either the truck full trailer combination of two units, or the tractor semitrailer and full trailer combination of three units. In a "double-bottom" combination, which has two cargo bodies with an over-all length of 60 ft, the stowage space is 2,700 to 2,900 cu ft. Carrying commodities weighing 50 pcf, the gross weights of such combinations would approximate 180,000 lb, with the payload divided between two separate cargo-carrying vehicles. Such larger volume vehicles are adapted to the hauling of lighter density commodities when equipped with van bodies.

In Figure 10 all commodities with shipping weight of 100 lb of more per cubic foot have been deleted from consideration in regard to visibly full cargo body loading. There remain 1,084,069,000 tons of commodities with densities below 100 pcf, or 65.7 percent of the total

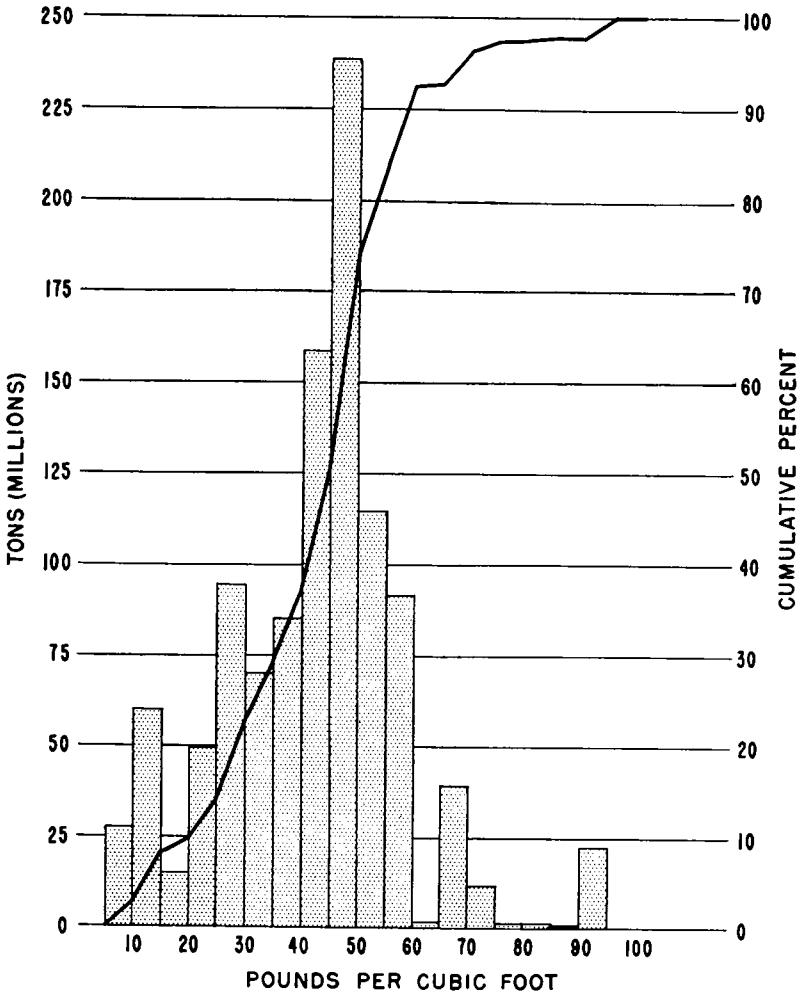

Figure 10. Highway freight tonnage under 100 pcf, by shipping densities and cumulative percentage, United States, 1954.

highway tonnage of 1,650,825,000. The bars shown in Figure 10 are the same as those shown in Figure 6 up to the 100-pcf classification.

The first bar, representing commodities with densities of 5-9.9-pcf, indicates 28,327,000 tons in this classification. This tonnage represented 1.7 percent of the total tonnage having densities below 100 pcf. Likewise, each succeeding bar represents certain tonnage and the percentage relationship of each bar is cumulated with preceding bars as shown by the cumulative percent curve. This gives a handy means of calculating the range of commodities that could be accommodated by roads built to carry visibly full loads of any given gross weight. For instance, reading from the right side of the 20-24.9-lb bar where it is crossed by the cumulative percent curve, and using the scale at the right, it will be seen that 14 percent of the total highway tonnage with shipping densities under 100 pcf would be accommodated if commodities weighing up to 25 pcf could be legally loaded to visibly fill the cargo space of the vehicle. In any consideration of

changes in weight allowances, this method of analysis can be used to show what increased percentage of demand would be satisfied by any increased weight allowance.

In Figure 11 commodities with shipping weights of 50 lb or more per cubic foot have been deleted from consideration as far as visibly full body loading is concerned. There were 799,671,000 tons of commodities with densities below 50 pcf, or 48.4 percent of the 1,650,825,000 total highway tons. Comparing the percentages of the total highway freight that could be feasibly carried with either of the foregoing density ceilings, it is found that a ceiling of 100 pcf would include 65 percent of the 1,650,825,000 tons, whereas a ceiling of 50 pcf would include 48 percent. It is significant that this 50-pcf reduction in densities from 100 to 50 pcf affects only 17 percent of the total highway freight tonnage. It is also significant that the tonnage with shipping densities found between 25 and 49.9 pcf represents 39 percent of the total highway freight tonnage, whereas only 9 percent of the tonnage has shipping densities below 25 pcf.

The bars shown in Figure 11 are for

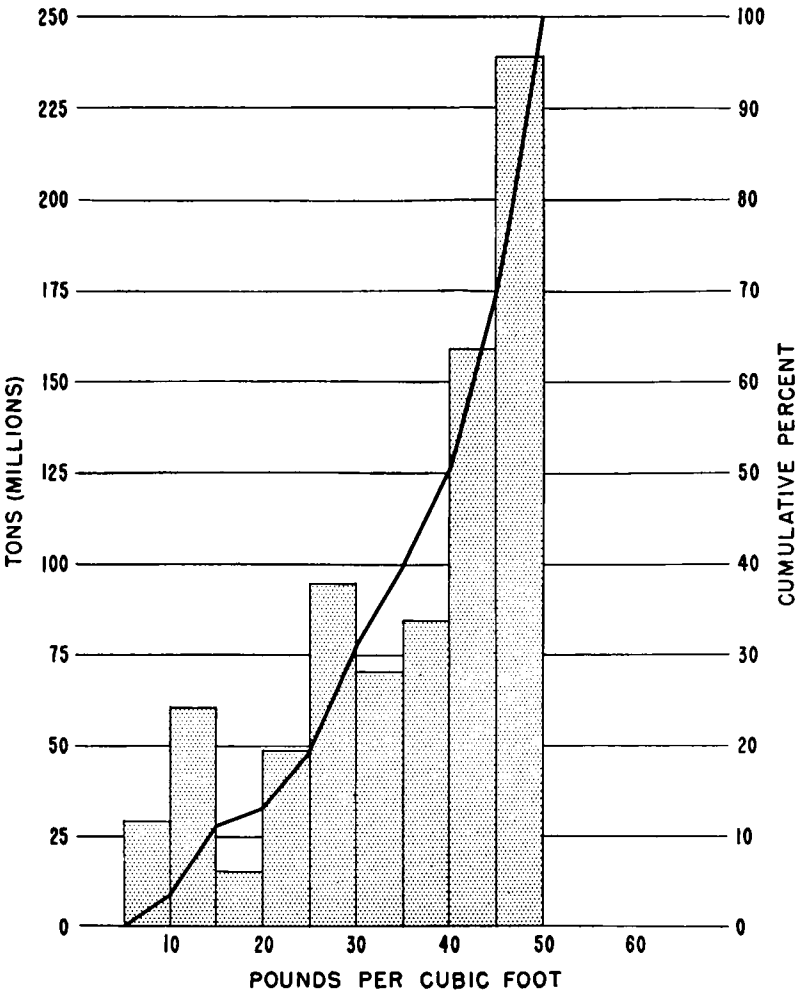

Figure 11. Highway freight tonnage under 50 pcf, by shipping densities and cumulative percentage, United States, 1954.

the same amount as those shown in Figure 6 for commodities up to 50 pcf. Each bar length represents the tonnage in its class-interval and the percentage relationship of each bar is cumulated with those of preceding bars, as shown by the cumulative percent curve. Reading from the right side of each bar where it is crossed by the cumulative percent curve and using the scale at the right, the cumulative tonnage up to or including any weight interval may be read. This chart indicates, for instance, that of the tonnage of all commodities weighing less than 50 pcf, the tonnage weighing less than 25 pcf represents 19.9 percent. Thus, only about one-fifth of the commodities weighing less than 50 pcf can be hauled in visibly full loaded cargo bodies under the 73,000-lb gross loading described in Figure 9. The portion of commodities with densities below 50 pcf which could be accommodated in visibly full body loads can be computed from this chart for any designated weight ceiling.

LOADOMETER WEIGHTS INDICATE GROSS WEIGHT DEMANDS

Loadometer studies made in 1955 (*17*) have provided evidence that there are pressures for gross combination weights above the limits recommended in the AASHO Size and Weight Policy. Examples of this evidence are illustrated by analyses of the recorded gross vehicle weights of loaded combinations in Missouri, Washington, and Michigan.

Figure 12 shows the range of observed weights of loaded vehicles for the three types of combinations weighed in Missouri. Although other types of combinations are permitted in Missouri, almost none were used because of the length limitation of 45 ft. The bars indicate the percentage of loaded combinations observed in each of the several 5,000-lb class-intervals of gross vehicle weight. The arrows indicate legal maximum gross weights for each combination shown. In some instances the loads above the prescribed limits may have been authorized under special permits. It will be noted that the preponderance of gross weights for the three-axle tractor semitrailer combination is well below the permitted limit, indicating that this combination generally is used for the lighter density commodities. However, it will be observed that the 4- and 5-axle combinations, with their correspondingly greater

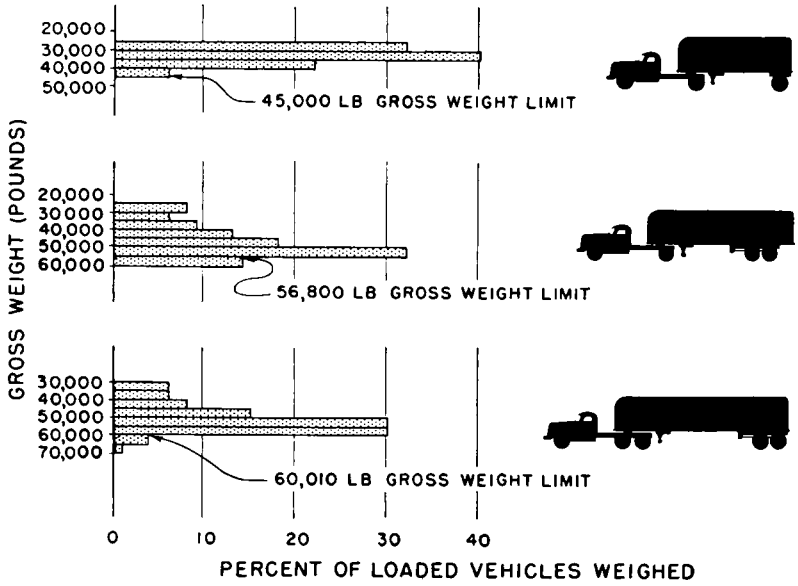

Figure 12. Gross loaded vehicle weight distribution, by type of combination, Missouri, 1955 (*17*).

weight allowances, tend to approach and exceed the prescribed weight limits.

Figure 13 shows similar data for loaded combinations weighed in the State of Washington, where the over-all length limitation of combinations is 60 ft. There is a marked similarity in gross weight trends with those of Missouri, except for the added feature that 2-cargo body combinations were observed in Washington. The 3-axle tractor semitrailer gross weights observed were generally below the permitted limit, whereas the 4- and 5-axle combination gross weights approached and exceeded the permitted weight limits. The 2-cargo body combinations observed in Washington also had gross weights which approached and exceeded the legal weight limits for the vehicles in regular operation.

In Michigan, the gross weights of freight vehicles are computed by adding the permitted weights of all axles, there being different limitations for axles spaced more than and less than 9 ft apart, and different limitations for one pair of tandem axles and for tandem axles in excess of one pair on the same combination. The permitted gross weights assumed in Figure 14 for each combination are the sum of the axle weights

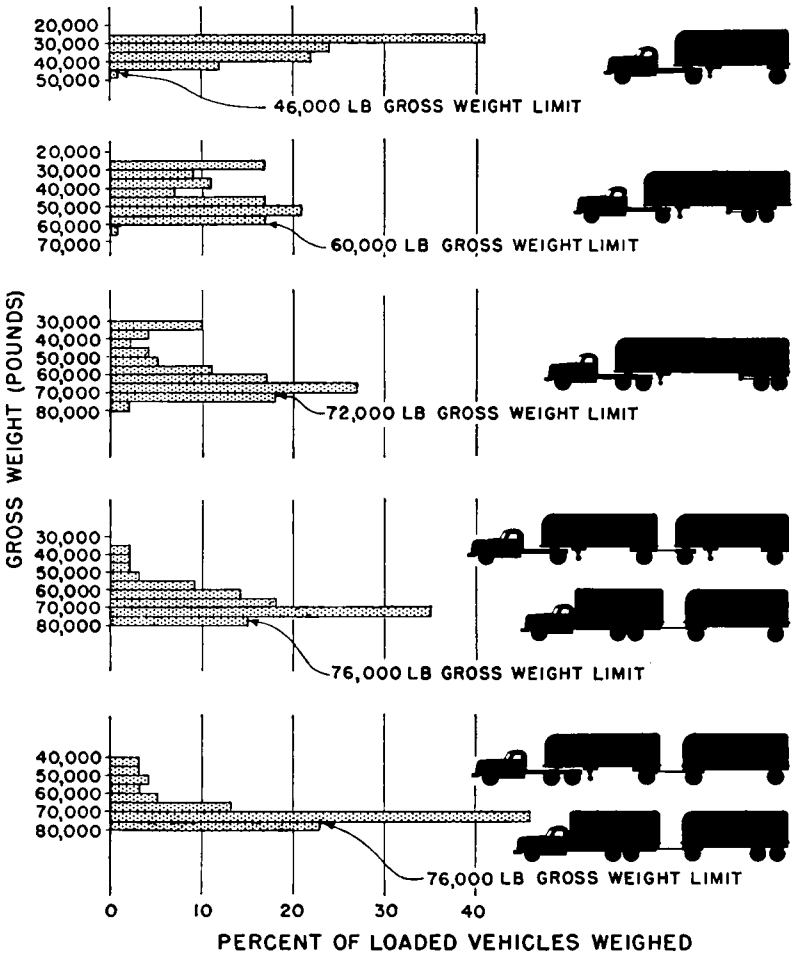

Figure 13. Gross loaded vehicle weight distribution, by type of combination, Washington, 1955 (17).

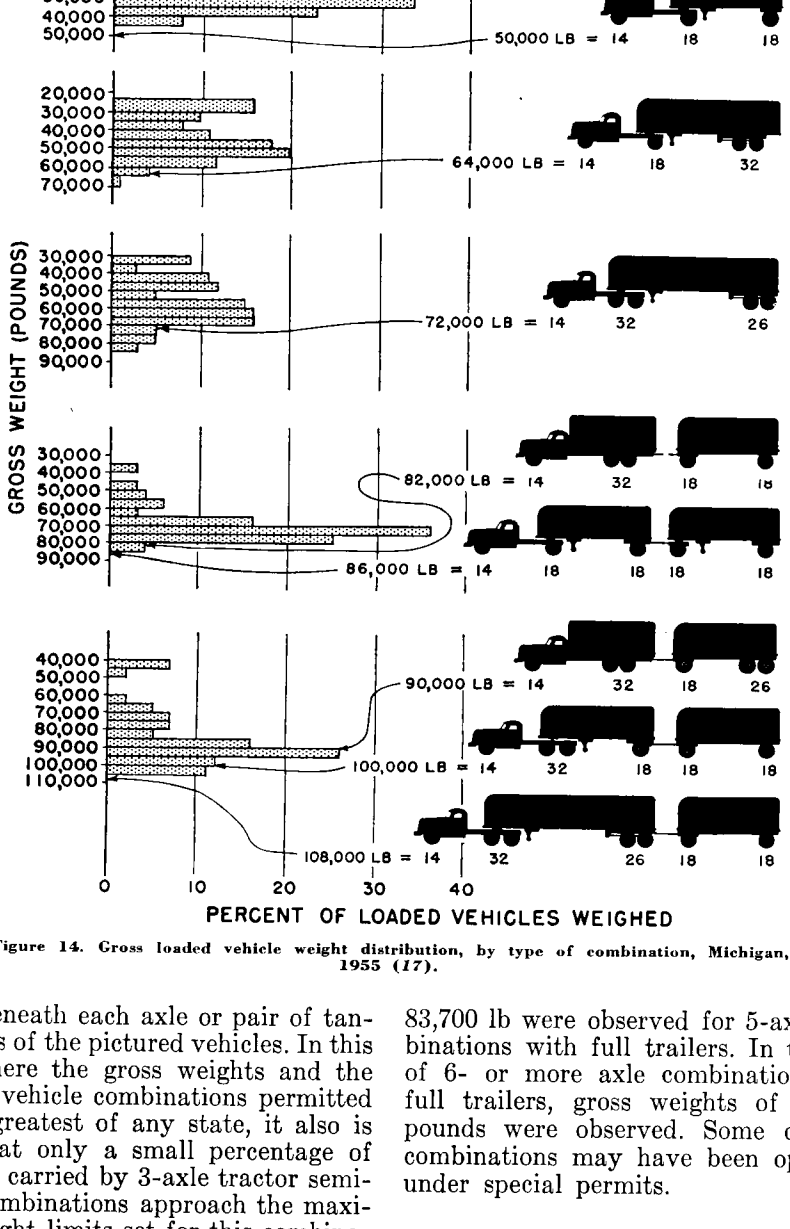

Figure 14. Gross loaded vehicle weight distribution, by type of combination, Michigan, 1955 (*17*).

shown beneath each axle or pair of tandem axles of the pictured vehicles. In this state, where the gross weights and the range of vehicle combinations permitted are the greatest of any state, it also is found that only a small percentage of the loads carried by 3-axle tractor semitrailer combinations approach the maximum weight limits set for this combination. However, it will be observed that the 4-, 5-, 6-, and 7-axle combinations, with their correspondingly greater weight allowances, tend to approach and exceed the legal weight limits. Gross weights of 83,700 lb were observed for 5-axle combinations with full trailers. In the case of 6- or more axle combinations with full trailers, gross weights of 105,000 pounds were observed. Some of these combinations may have been operating under special permits.

SUMMARY

The foregoing analysis has presented data from which may be determined the proportion of commodities that may be hauled in visibly full body loads under

various gross weight limitations. This information will be used in the economic phases of the parent study to determine the degree of vehicle loading and the number of vehicle trips required to haul a given volume of freight under any assumed level of gross vehicle weight.

The pattern of shipping densities indicates that a commodity shipping density of 50 pcf provides a reasonable top limit for the calculation of maximum payloads in the development of the combined costs of trucking operations and highway facilities. Maximum gross vehicle weight for one-cargo vehicle combinations with approximately 2,000 cu ft of stowage space is indicated to be on the order of 130,000 lb. For the 2-cargo vehicle combinations with stowage space ranging from 2,700 to 2,900 cu ft the maximum weight would be on the order of 180,000 lb under a shipping density ceiling of 50 pcf.

The analysis shows that only commodities weighing 24 lb or less per cubic foot may be hauled in visibly full body loads under the gross weight limitation of 73,280 lb as set forth in the Federal-Aid Highway Act of 1956. Also, the data show that of the total tonnage having densities up to 50 pcf, 80 percent have densities in excess of 25 pcf.

This report of this phase of the parent study must not be interpreted as recommending any optimum economic specifications for motor vehicle sizes and weights. Instead, the data primarily present a clearer understanding of the pattern of the 1954 highway freight commodity movements, for use by the committee when other phases of the study are being considered.

GLOSSARY OF TERMS

For the year 1954, an interstate for-hire motor carrier of property operating under a certificate from the Interstate Commerce Commission, was classed by the ICC as a Class I motor carrier if the carrier had an average annual gross revenue of $200,000 or more from motor carrier operations.

Demand means a seeking or state of being sought after; an expressed desire for ownership or use, as of a commodity; as, in great demand socially, an increased demand for labor. (Webster's New International Dictionary — Unabridged — 1953.) In the report the amount of freight moved by highway is assumed to be an expressed desire for use of highway freight, *ergo,* demand.

General freight includes those commodities which are capable of being transported together in mixed cargo and do not require special types of equipment or special handling and protection.

Line haul service means highway freight transportation service in which, preponderantly, the payload is not varied between the starting and end points of a trip, and the service is performed (a) between cities and towns and their contiguous suburban areas, (b) to or from rural locations and cities and towns with their contiguous suburban areas, or (c) between one rural area and another rural area. Line haul service does not include city pickup and delivery service, local cartage service, or rural pickup and delivery (frequently known as peddle) service.

A *shipment* is a lot of freight received from one shipper at one point at one time for one consignee at one destination and covered by one bill of lading.

Supporting ability refers to the structural capacity or load carrying ability of both roads and bridges.

The term *truckload* has three meanings in the motor freight business:

1. In a general sense, *truckload* means a quantity of freight which visibly fills the cargo space of a vehicle, or which equals the legal allowed payload of a vehicle.

2. In a freight rate tariff sense, a *truckload* shipment means a definite weight of a commodity, as specified in the Motor Freight Classification and the carrier's tariff schedule, which is handled as a single shipment, known also as "volume minimum weight."

3. According to a definition prescribed

by the Interstate Commerce Commission for use in part of the statistics of the annual reports of common carriers of general freight engaged in intercity service, the term *truckload* means any shipment which moves on a single bill of lading and weighs 10,000 lb or more, billed weight.

A *less than truckload* (LTL) rating for a shipment is a rating other than a "volume" or "truckload" rating applying on an article for which a "volume" or "truckload" rating is provided.

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DISCUSSION

E. R. FELDMAN, *Highway Engineer, Competitive Transportation Division, Association of American Railroads.* — As Mr. Kent stated in the beginning of his paper, the Committee on Economics of Motor Vehicle Size and Weight of the Highway Research Board has as its objective the development of data regarding the economic factors involved in the establishment of optimum size and weight specifications for highway freight vehicles and for correlated highway design and construction standards. From this statement of objective, the work of the committee is clearly economic in nature.

Shipping density data developed by the author are of interest and should prove useful in determining possible movements of various commodities by the line haul trucking industry. Both Mr. Stevens' introduction and Mr. Kent's paper admonish that the data should not be used alone to forecast future size and weight limitations or as a recommendation of optimum economic specifications for motor vehicle sizes and weights. Their warning properly foresees the need for correlating the data with other material not now available.

Throughout the paper the word *demand* appears; for example, "demands for heavier weight allowances," and "the demand pattern of transportation by the line haul trucking industry." In the "Glossary of Terms," the paper defines *demand* as a seeking of or an expressed desire for something and in context the amount of freight moved by highway is said to be an expressed desire (demand) for use of highway freight. It is unfortunate that demand, defined in such general terms, is used in a paper addressed to economic factors.

In an economic sense demand has meaning only when related to prices or costs; in this case the costs that would have to be incurred in supplying the desired highway facilities. It is significant that the paper does not, and at present probably cannot, include any information regarding either highway or operating costs at the various weight levels which are described as "demands." A two-cargo vehicle combination may have a gross weight of 180,000 lb and although there may be those who would desire to operate such vehicles, at the present stage of the work of this committee there is no basis for suggesting that there is a demand, in the economic sense, for such operations. The important test road project being conducted under the direction of the Highway Research Board, in cooperation with the Bureau of Public Roads and other interested parties, has as one of its purposes the determination of highway cost factors attributable to various types of vehicles. Until the related costs of highways to carry such loads have been determined and properly assessed, the essential data for determining whether there is an economic demand for such facilities is lacking.