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Line-Haul Trucking Costs in Relation to Vehicle Gross Weights

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Preface

This study of the relationship between the operating costs of trucking equipment in line-haul, highway freight service and the gross weights and cargo weights of highway freight vehicles is the third in a series of reports prepared under the direction of the Committee on Economics of Motor Vehicle Size and Weight of the Department of Economics, Finance and Administration, Highway Research Board. The purpose of the study is to provide a representative schedule of vehicular operating costs, the differences between which are caused only by changes in vehicular gross weight, and/or changes in type of trailer combinations.

Such representative vehicular cost data later can be related to representative costs for highway facilities with different load-carrying capabilities. When the economic relationships between vehicular costs and highway costs are developed for different volumes of freight vehicle traffic, there will result indicators as to the optimum maximum gross vehicle weights that should be considered by highway officials, motor carriers, and vehicle manufacturers. This analysis will be the subject of another report.

The first report from the committee is entitled "Time and Gasoline Consumption in Motor Truck Operation as Affected by the Weight and Power of Vehicles and the Rise and Fall in Highways." This report was presented by Carl C. Saal at the 29th (1950) Annual Meeting of the Highway Research Board. The second report, entitled "The Freight's the Weight," was presented by Malcolm F. Kent at the 37th (1958) Annual Meeting of the Highway Research Board.

This study was made possible through the cooperation of several hundred motor carriers, both for-hire and private, the detailed records of which were made available to the committee; by the cooperation of the planning divisions of a number of State highway departments that provided field interviewers; by the assistance and facilities of regional and division offices of the Bureau of Public Roads; by data and information from the Bureau of Motor Carriers, Interstate Commerce Commission; by assistance from the American Trucking Association, Inc., and its affiliated State associations; by the Private Truck Council of America; by information from motor truck manufacturers and from truck trailer manufacturers; and by the assistance of other organizations that supplied references and addresses of motor carriers.

The study was directed and the report was prepared by Hoy Stevens, Secretary of the Committee on Economics of Motor Vehicle Size and Weight. The analyses of the field reports and the preparation of the data for machine tabulation were made by Malcolm F. Kent assisted by Miss Madeline M. Lappe, Miss Mildred M. Milazzo, and Mrs. Kathleen V. Toole of the Traffic Operations Division, Office of Research, Bureau of Public Roads, U.S. Department of Commerce. Special thanks are due Herbert S. Fairbank for his detailed review of the manuscript, and to the other members of the committee for their criticisms and encouragement. In addition, the assistance of numerous persons in the field and in the offices of the Bureau of Public Roads who contributed to the work is gratefully acknowledged.

Carl C. Saal, Chairman
Committee on Economics of
Motor Vehicles Size and Weight

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Line-Haul Trucking Costs in Relation to Vehicle Gross Weights

Report of Committee on Economics of Motor Vehicle Size and Weight

The main purpose of the study was to determine the changes in vehicle-mile costs and in payload ton-mile costs, as gross weights of trailer combinations are increased. In the second report of the committee (1), it was shown that there are many commodities with heavy shipping densities which could use to advantage higher permitted gross weights. The primary problem before the committee (and not solved in this report) is to determine the economic end point in gross weights beyond which savings in vehicular transport costs do not offset the increased costs of providing highways with additional axle and gross weight capabilities necessary to carry any increase in permitted gross weight above some specified level. Permitted gross weights now vary greatly between the States with much higher gross weights now allowed in double trailer combinations on certain toll roads.

The results of an extensive study of the operating costs of line-haul trailer combinations operating on rural roads are reported in this third report of the committee. The gross weights of the trailer combinations studied range from 22,500 lb to 192,000 lb. The types of trailer combinations range from 2-axle tractors with 1-axle semitrailers through multi-axle tractor semitrailers, truck full trailers, and tractor semitrailer and full trailer combinations.

The data were obtained from 611 motor carriers of property, including common carriers, contract carriers, exempt-for-hire carriers, and private carriers. Cost data were obtained for 17,737 gasoline engine powered trailer combinations, and 5,647 diesel engine powered trailer combinations.

The report describes how the different cost factors were adjusted for differences in prices paid for fuel, for wages, for fringe benefits, for depreciation and interest charges, and for new vehicles, so that the variations in costs by gross weights would reflect only differences caused by increases in vehicular gross weights. The cost data are reported under seven main headings: (a) repair, servicing and lubricant costs; (b) tire and tube costs; (c) fuel costs; (d) driver costs; (e) indirect and overhead costs; (f) depreciation and interest costs; and (g) gross operating costs. No road-user taxes, such as license fees, fuel taxes, and truck use fees, are included in the costs because these fees are considered payments for the highways; and the costs of providing highway facilities will be included in the next phase of the committee's project. The cost data cover only the line-haul operation of trailer combinations, and do not include any terminal costs, any city delivery and pickup costs, nor the many other costs that are incurred by for-hire carriers.

The data are reported in an extensive series of charts which show the variations in vehicle-mile costs by loaded gross weight for all the 23,384 trailer combinations, for all the gasoline engine powered trailer combinations, for all the diesel engine powered combinations, and by groups of types of trailer combinations using either gasoline or diesel engines. Other charts and tables show how unit costs are affected by body types, by type of terrain, by average daily travel mileage, by average road speeds, and by other operating variables.

The main conclusion to be obtained from the data is that after about 140,000-lb loaded gross weight, the reductions in unit payload ton-mile costs become less significant. Much other information about the effects of operating variables on unit costs can be obtained from the numerous tables and figures.

THE existing rapid and dependable highway freight transport industry in the United States has been made possible by the development and construction of both commercial motor vehicles and an extensive system of hard-surfaced, all-weather roads. These two technological developments have been used by the managements of motor freight carriers to create a mode of freight transport that can directly serve shippers and consignees in any road-connected area of the continental United States. Although the development and past construction of highways have made possible the present motor freight industry, there now is some question as to whether the past highway construction may not be preventing the development of the maximum utility and efficiency in the transportation of freight by highway.

In the early history of automotive highway freight transport the load capabilities of the hard-surfaced roads frequently exceeded the carrying capabilities of trucks. Today, this relationship is reversed because there are rubber-tired automotive freight vehicles with load-carrying capacities greatly in excess of the capacities being designed and built into new highways. This is not to say that roads with greater load capacity cannot be built, if it is deemed desirable to do so, because there now is increased knowledge of road building and materials which may be used to build roads with greater load-carrying capacity. But the higher load capacity can be achieved only at a cost of construction that is greater than that which has thus been deemed acceptable, and the question remains whether the advantages to be gained by the greater load capacity will outweigh the greater cost of attaining it.

The over-all research project on the economics of motor vehicle size and weight, of which this study is one phase, has the objectives of (a) establishing the trends in, and values of, the operating and maintenance costs of highway freight vehicles as the gross vehicle weights increase; (b) establishing trends and representative values for the construction and maintenance costs of roads and bridges of increasing levels of axle and gross load-carrying capacities; and (c) estimating the vehicle gross weight maxima at which the economies in vehicle operating costs fail to offset the increased costs of providing highways. The values established for these three objectives should provide economic end points in the controversy as to the optimum maximum size and weight limits for highway freight vehicles. These end-point weight limits should define the parameters for any contemplated consideration of new highway structural design specifications.

This report includes data from a considerable, but limited number of motor carriers operating in 1955 and 1956. The resulting information is believed to be generally typical of and in accordance with the trends of operating costs in line-haul freight service as loaded gross weights are increased. The purpose of the study was to develop the probable differences in operating costs for the line-haul operation of trailer combinations of an increasing series of loaded gross weights which would extend much above the gross weights currently allowed on public highways. Some assumptions and estimates were necessary to supplement the recorded and observed data, but the results are believed to be reasonably representative.

The increases in construction and maintenance costs of highways will be the subject of a later report. When the highway costs are available they may be related to these vehicular and shipping density data of highway freight to indicate the economic end points for maximum gross weights of various types of highway freight vehicles.

There is some disagreement on the part of certain segments of American business, with the principle that motor carriers with their large trailer combinations should be primary haulers of freight using to the utmost the State and interstate systems of highways. Some opinion holds that motor carriers and their vehicles should be relegated to the role of local and retail distributors of freight. If it may be postulated for this study that the public attitude and policy will continue to permit and enable the trucking industry to be primary and long distance haulers of freight in the competitive transportation field, then it may be argued that optimum sizes and weights of vehicles for freight service should be permitted, and that rural and urban highways should be constructed to carry such optimum sizes and weights of trucks and trailer combinations.

The problem of optimum size and weight limitations for commercial motor vehicles is, to a considerable degree, an economic rather than a technical one, because highway freight vehicle manufacturers have demonstrated that they can build vehicles with gross weight capacities greater than the legal weight limitations of any State, and highway engineers concede that highways of greater weight-supporting capabilities can be built, but at an increased cost. The many factors relating to trucking industry practices and to the industry's desires for increased size and weight allowances are discussed in the following sections. Vehicle operating costs in relation to gross weight are developed following the background information.

In the text of the report many trade and technical terms are used for brevity. A glossary of such terms is provided in an Appendix.

Over-All Problem and Related Factors

The problem of the optimum maximum size and weight limitations for commercial motor freight vehicles which will best serve the total volume of freight to be moved by highway, and hence result in the lowest over-all cost of highway freight transportation, including the costs of providing highways, has two phases:

1. The optimum maximum size and weight limitations for freight vehicles and highways, without consideration of any weight capacity inadequacies of existing highways.
2. The optimum maximum size and weight limitations for vehicles and highways taking into consideration existing new and older highways and the problems and additional costs of replacing those existing highways which would suffer reduced service life because of serious over-design weight allowances, and the costs of upgrading other existing highways to new standards.

Phase 2 is not within the primary scope of this study, but it is recognized as a practical and pressing problem on which enlightenment may be obtained from the results of the phase 1 study. The results of phase 1 may indicate that present or proposed size and weight limitations are nearly optimum and if such is the case any corrective actions may be simple. However, if the results of phase 1 indicate that much higher weight allowances would be optimum, there then arises a problem which requires a different approach than in this study to meet the exigencies of the foreseeable situation.

As a primary premise it may postulated that highways to carry higher axle and gross vehicle weights require heavier and costlier construction. The questions here concern the relationships between the annual costs of highways with increased load capacities, as axle and vehicle gross weights are increased. Can a large increase in load-carrying capacity with a small increase in annual highway costs be obtained, or do the annual highway costs increase faster than the savings that could be realized from the operation of larger and heavier vehicles?

The over-all cost of highway transportation, therefore, includes the vehicular operating costs of the line-haul freight vehicles, and the costs of providing and maintaining highways designed to carry any specified maximum loads. In considering the highway portion of the over-all freight transportation cost, it should be assumed that all the costs of providing additional pavement and base construction, and of providing greater load capacity in bridge structures, above the requirements of some basic level of highway gross weight structural capacity, are additional expenses occasioned only by the requirements of heavy freight vehicles. The weight requirements of large and heavy, single-trip, special-permit transporters of any category are not included in this study.

If only the largest regular freight vehicles with corresponding very heavy loads can use to advantage any increase in gross weight-supporting capacity, should not such vehicles and their cargos pay for the additional expense of providing additional structural capacity in the roads and bridges? Otherwise, the costs of providing the higher load-capacity roads must be distributed among all road users and will result in higher road-user fees for passenger cars and small trucks to which no additional benefits will accrue. The crux of these different interlocking conditions points up the question as to whether roads should be built with gross load-carrying capabilities greater than are now permitted in several States. If there are not sufficient total economic advantages for freight transport at any higher level of maximum permitted gross weights to offset the increased roadway costs, then there are no over-all economic advantages to all the road users and the public in higher maximum permitted gross weights.

The over-all problem has at least two parts. One phase is the possible and desirable payload capacities and operating economies of commercial motor vehicles, preponderantly multi-axle trailer combinations, of different gross weights and with different cargo weights. The second phase includes the costs of providing highway facilities, together with the establishment of load-carrying specifications for a basic practical minimum pavement structure that could adequately serve the people and the businesses of the United States.

POTENTIAL VEHICULAR CAPACITIES

To properly consider the scope of the size and weight problem, it is desirable to review the gross weights that could be obtained with practical automotive trailer combinations using only two common levels of axle weight limits. In the first series, it is assumed that the maximum allowed gross weights will depend on the number of axles with maximum axle load specifications of 18,000 lb for 4-tire single axles, and 32,000 lb for 8-tire dual or tandem axles. In Table 1, showing a schedule of possible maximum gross weights of vehicles, the 2-tire front axle weight is assumed as 50 percent of the 4-tire single axle weight allowance, or 9,000 lb.

Regarding the series of vehicles given in Table 1, evidence of the existence of a demand for the range of weights therein, is found in the fact that trailer combinations of gross weights approaching the heaviest of those listed are now legally permitted and are in use in one State. That they are practical from the standpoint of automotive design was further demonstrated in experiments conducted in 1959 on the New York Thruway. On the basis of these experiments the Thruway Authority has permitted the use of double trailer combinations as large as 98 ft in length and as heavy as 127,400 lb gross weight (with maximum permitted axle weights of 22,400-lb single axle and 36,000-lb tandem axles.) Subsequently, the Kansas Turnpike has allowed 130,000 lb gross weight for the tractor semitrailer and full trailer with maximum axle weight allowances of 18,000 lb and 32,000 lb in an over-all length of 105 ft. Operations on the Indiana, Massachusetts and Ohio Turnpikes have been at maximum gross weights of 127,400 lb.

The second series of combinations considered consists of vehicles having maximum weights of 22,000 lb on 4-tire single axles and 36,000 lb on 8-tire tandem axles. A schedule of possible gross weights obtainable by the use of various types of trailer combinations having these maximum axle weights is given in Table 2. In these combinations it is assumed that the 2-tire front axle weight is 50 percent of the 4-tire single-axle maximum of 22,000 lb, or 11,000 lb.

In both Tables 1 and 2 it is assumed that bridge structures would be adequate to carry the gross weights obtained from the sum of the axle weights. This assumption is not a practical one in many places at the present time. Capacities for the heaviest loads do not exist with respect to many bridges, especially the older bridges and those on the rural secondary roads.

From the standpoint of the practicality of vehicle design, the vehicles scheduled in Table 2 are no less practical than those scheduled in Table 1. Moreover, single axle

TABLE 1

SCHEDULE OF POSSIBLE GROSS WEIGHTS BY TYPE OF TRAILER COMBINATION
(18,000-Lb Single and 32,000-Lb Tandem Axles)

Vehicle Description	Axle Classification	Gross Weight (lb)
2-axle truck	2	27,000
3-axle truck	3	41,000
3-axle trailer combination	2-S1	45,000
4-axle trailer combination	2-S2	59,000
5-axle trailer combination	3-S2	73,000
5-axle trailer combination	2-S1-2	81,000
6-axle trailer combination	3-S1-2	95,000
7-axle trailer combination	3-S2-2	109,000
8-axle trailer combination	3-S2-3	123,000
9-axle trailer combination	3-S2-4	137,000

TABLE 2

SCHEDULE OF POSSIBLE GROSS WEIGHTS BY TYPE OF TRAILER COMBINATION
(22,000-Lb Single and 36,000-Lb Tandem Axles)

Vehicle Description	Axle Classification	Gross Weight (lb)
2-axle truck	2	33,000
3-axle truck	3	47,000
3-axle trailer combination	2-S1	55,000
4-axle trailer combination	2-S2	69,000
5-axle trailer combination	3-S2	83,000
5-axle trailer combination	2-S1-2	99,000
6-axle trailer combination	3-S1-2	113,000
7-axle trailer combination	3-S2-2	127,000
8-axle trailer combination	3-S2-3	141,000
9-axle trailer combination	3-S2-4	155,000

weights of the assumed 22,000 lb and more are now legally permitted in 12 States, and tandem axle weights of 36,000 lb and more are permitted in 17 States. There is, however, as yet no legal sanction of the operation on public highways of trailer combinations of the gross weights represented by the 8- and 9-axle trailer combinations scheduled in Table 2.

DEVELOPMENT OF HIGHWAY COSTS

Progress is being made in developing representative original and annual costs for those elements of geometric and structural designs of highways which are affected by changes in dimensions and gross weights of freight vehicles. These highway elements include pavement surface course, base and subbase courses, and bridge structures. These estimates of costs are being developed on the basis of a 4-lane divided and limited-access highway with geometric design characteristics similar to those of the Interstate System. Estimates of costs are being developed for three series of highways with capabilities of carrying different single- and tandem-axle weights; namely, 18,000 lb and 32,000 lb, 22,400 lb and 40,000 lb, and 30,000 lb and 48,000 lb, with correspondingly increased levels of gross weights. When these data are available the committee can use the highway cost information with its vehicular cost data to develop its answers to the committee's objective. The highway cost data are being developed by the Committee on Highway Costs of the Department of Economics, Finance and Administration of the Highway Research Board.

DESIRABLE MINIMUM HIGHWAY LOAD CAPABILITIES

The large freight trailer combinations are joint users of highways, and in developing highway costs that are chargeable only to trailer combinations, it is necessary to agree on some minimum level of highway load capabilities that will satisfy the freight needs of American business and the people.

The most important factor in determining the additional costs of highway construction for large and heavy freight vehicles is the establishment of the load capabilities to be assigned to the minimum level of pavements and bridges. As this study has to do with line-haul transportation, an approach may be made to this question by assuming that there exists no rural line-haul highway freight transportation; that is, that all line-haul freight moves by railroad, inland waterway, pipeline or airplane.

In this hypothetical situation trucks would be assigned only (a) to the work of moving freight from and to shippers and consignees and the nearest railroad, waterway, pipeline or airline terminals; and (b) to local transfer, delivery, construction and service work. The minimum vehicles to do such work would be 2-axle trucks similar to the different types and sizes now used in city and peddle work, such as single-unit trucks with express bodies, panel bodies, van bodies, tank bodies, platform bodies, dump bodies, utility bodies and various types of special purpose bodies. However, it is not reasonable to assume that small 2-axle trucks with only four tires, and with payload capacities little more than that of passenger cars, can be satisfactory for all local trucking services. These small trucks would be adequate for lightweight services such as retail deliveries, different kinds of utility and household services work and for some farm service. At the present time many such trucks are used in this work. However, such small vehicles would put freight deliveries almost back into the horse-and-wagon days, and would be too inefficient and most inadequate for today's American business activities.

To handle freight deliveries, other local heavy trucking work and agricultural transport, trucks the size of those now used in city and peddle pickup and delivery of freight should be considered. Such a typical city or peddle freight truck is a 2-axle, 6-tire truck capable of carrying a cargo body 14 to 16 ft long and 8 ft wide. Such a truck's cargo will average upwards of 1,000 lb in weight per ft of body length, or not less than 16,000 lb of payload when fully loaded. The chassis and body will weigh about 10,000 lb giving a gross vehicle weight loaded of 26,000-27,000 lb. This gross weight is distributed into about 8,000-9,000 lb on the front axle and 18,000 lb on the rear axle. Such trucks are the general type and size of present city and peddle trucks, and probably could do the job of distributing the freight carried line-haul by other modes of transportation, as was set up in the hypothetical situation. Undoubtedly there would need to be more of such trucks in use than at present, at least up to the number that would be required to make the local and near-local freight deliveries that now are made direct by line-haul trailer combinations and by large 3-axle trucks.

In considering efficient and economical freight pickup, delivery and transfer service to all businesses and the public, it appears reasonable that the 18,000-lb axle and 26,000- to 27,000-lb gross weights should be considered as the minimum pavement-axle design loads on rural primary and secondary roads and on city streets where there is a consistent and considerable amount of local truck traffic. The weight of 18,000 lb for single axles, which now is permitted in all States, establishes a minimum level of road design capacity above which can be developed the heavier pavement and bridge designs for large trucks and trailer combinations.

However, what does such a basic medium duty 2-axle truck mean in regard to the design load capacities for various categories of existing and contemplated roads, streets and bridges?

Pavement Situation

One of the difficult factors in pavement construction lies in the fact that the daily frequency of heavy axles and heavy vehicles, in addition to their weights, is a definite factor in determining the necessary design thickness of pavement and base courses regardless of the type of pavement material. For this reason, suburban and local streets and secondary rural roads of quite light construction will carry without distress a limited number of heavy vehicles a day for a satisfactory number of years. However, let the volume of truck traffic increase significantly and a lightly surfaced suburban street or rural road rapidly begins to need extensive and expensive repair, or even replacement.

Although suburban and local streets could be of low load-capacity design in hypothetical communities with no line-haul rural truck transportation, the arterial city and suburban streets and the rural roads leading to cities and towns not having railroad terminals would need to be capable of carrying a heavy daily volume of the 27,000-lb 2-axle trucks. Thus, even in the hypothetical community it is evident that design standards for arterial streets and primary roads cannot be much below the present design standards for 18,000-lb axle loads. The characteristics of suburban and local streets and secondary rural roads with low truck volumes, likewise, would not be changed from present practices.

Regardless of the basic design loads considered, there will continue to be differences in pavements which may appear confusing to the layman. These are due to differences in the terrain, soil, and climate of the various areas in which roads are constructed. Some parts of the country have excellent soil conditions and are able to obtain satisfactory load capacity in their roads with a minimum amount of construction material. In other areas the subsoil may be of a plastic or clay type which will require a greater amount of granular subbase material to properly distribute the imposed axle loads to the subsoil. Accepting the inevitability that differences in surface and subsoil conditions will require differences in pavement and subbase, it can be expected as a result of the knowledge gained from State road life studies and such accelerated tests as the AASHO Road Test, that for the different pavement design formulas, the design load capabilities will approach higher consistency between States than may have existed in the past. Also, the geometric characteristics of highways being constructed at the present time are approaching a higher degree of uniformity and consistency. This has been one of the major benefits of the Federal-aid program, and as more and more information is obtained about traffic and highway performance, it can be expected that geometric design characteristics will become more uniform.

As mentioned earlier, in one phase of the over-all study, original and annual costs are being developed for those elements of a highway facility that are affected by increases in maximum axle and vehicle gross weights. Other elements of a highway that are not affected by axle and gross weights, such as grading, roadside development, and signing, are not being evaluated in this study.

It is planned to develop these series of pertinent increments of costs around high-type pavement designs. As a matter of fact, the interest in this study is not in the absolute cost of either level of highway capacity, but is in the differences between the original and annual costs for one level of structural capacity as compared to the original and annual costs for a higher level of structural capacity. It is these differences, or increases in original and annual costs, that must be offset by economies in vehicular costs; otherwise the construction of highways with greater load capabilities at the higher costs would only result in an increase in the over-all cost of hauling freight, insofar as the general public is concerned.

Bridge Situation

The situation in regard to bridges is different from that of pavements. There are several distinct factors that enter into bridge designs and costs: length of crossing, foundation characteristics, length of spans, floor construction, frequency of heavy vehicles, and the spacing of vehicle axles. Whereas certain features and costs of bridges are determined by the bridge site, the designs of two of the elements of bridges are determined by the characteristics of the vehicles which are carried. For example, floor slabs are related to axle weights, whereas the main structural members are related to total gross weight and its distribution over the bridge structure. Thus, greater gross loads may be carried if the over-all length and the inter-axle spacings are generous. These factors are taken into account in the schedules of allowed gross weight of the so-called "bridge formulas."

A troublesome characteristic of most bridges is that an easy or economical method of upgrading for either increased axle loads or gross loads does not exist. This means that bridges, in general, have to be built originally to carry the maximum gross loads and wheel loads that will occur with consistent daily frequency. Hence, any existing bridges of low load capacity generally must be replaced if the gross weight allowances are to be increased on a road system which will have a considerable amount of daily truck traffic.

HYPOTHETICAL MINIMUM BASIC HIGHWAY DESIGN STANDARDS

At this point it is desirable to generalize regarding the several interlocking factors affecting highway construction and use (which include pavements, bridges, daily traffic volumes, sizes and weights of trucks and their daily frequency), and to make an assumption as to a minimum basic level of capabilities of pavements and bridges which could be considered adequate to serve the Nation if no line-haul trucking service existed. Under these circumstances it is reasonable to assume that the minimum basic level of pavements and bridges must provide for the carrying of a significant daily volume of 2-axle trucks with gross weights up to 27,000 lb and single axle weights up to 18,000 lb.

Considering the widespread use of trucks in the United States, and the present general level of development of highway systems, it also is reasonable to assume that practically all the highways essential to the Nation's economic life now are capable of carrying 2-axle, 27,000-lb gross weight trucks to the extent that the local traffic requires. As a matter of fact, the rural primary roads and the urban arterial streets currently are capable of carrying trailer combinations and trucks much heavier than 27,000-lb gross weight.

The purpose of this discussion of a hypothetical situation in regard to freight transport — that is, with no line-haul truck transportation — was to establish a basic minimum level of highway design on which could be calculated the increased costs of heavier load capability highways that are required for line-haul highway freight transport. Certainly it can be agreed that all the additional load-carrying capabilities built into a highway, above a basic minimum level of load capability, incur costs that are assignable to the heavier freight vehicles and trailer combinations, and to the heavier buses.

From this minimum basic highway design, it will be possible to evaluate each succeeding higher level of gross weights of trailer combinations in order to calculate at what point the vehicular economies in increased gross weights no longer completely offset the increased costs of building and maintaining higher load capability highways. Determining this balance point between vehicular economies and highway costs is the primary objective of the study. This balance point would be the economic end point in regard to commercial motor vehicle sizes and weights, until there may be some economic breakthrough in freight vehicle operating costs or in the costs of highways having a high frequency of heavy vehicles and axles.

Purpose and Background of Trucking Cost Study

OBJECTIVE

The objective of this study is to develop representative costs of moving freight in line-haul or over-the-road service from one terminus to another without any intermediate loading or unloading of cargo. The costs developed do not include any loading or unloading of the freight on or from the line-haul cargo vehicles, nor do the data include any costs of pickup and delivery service made by city trucks or rural peddle trucks. The starting point of the line-haul transport operation is stipulated as the time and place at which the cargo vehicles are closed and ready for the road trip, after having been loaded as fully as possible with the cargo available but not exceeding the legal gross weight limitations that control each carrier's operations. The end of the line-haul transport operation occurs when the cargo vehicles come to rest in the unloading area of the terminus of the line-haul run, and before the cargo is unloaded. The loading and unloading areas may be motor, railroad, or ship carrier terminals, shipper and consignee docks at manufacturing and mercantile plants, and various types of loading and unloading facilities found in rural areas, such as on farms, at elevators, mines, quarries, and logging operations.

SIZE AND WEIGHT TRENDS IN FREIGHT TRANSPORT

The trend in almost all media of freight transportation is toward the use of carrying units of larger capacity, up to some maximum limit that results from a combination of economic, engineering and operating factors. During the past 25 yr, technological advancement has resulted in the construction and use of carrying units of larger and larger capacity. For example, tank cargo ships of 45,000 tons dead weight capacity are in use, and still larger ones are on the drawing boards for petroleum hauls from foreign oil fields. Longer railroad freight trains are now being operated, frequently with as many as 150 to 175 freight cars. On inland waterways, the tug boats are more powerful and push bigger cargo loads than previously. The developments in the airplane industry have been prominently in the public eye with the development of more powerful jet engines and larger capacity airplanes. Even pipelines have grown in size and capacity, starting with the first "Big Inch" in the early years of World War II.

The situation in regard to increasing the size and load capacity of highway freight equipment is not as simple as that of some of the other types of carriers. Insofar as vehicle sizes are concerned, the widths of city streets and intersections, which are not expected to change greatly in the foreseeable future, do limit the geometric dimensions of trucks and trailer combinations to sizes which can be maneuvered through streets and intersections without unduly hampering other vehicles and traffic. Also highway systems have been built during the past 25 years to weight capacity specifications that are much less than the load capabilities now possible in automotive freight vehicles. This situation poses a difficult dilemma. Should limits be imposed on truck weights to fully protect existing roads and bridges; or should greater weight limits be permitted even though this may result in a reduced life of older portions of certain highway systems when the frequency of heavy vehicles significantly increases, resulting in premature necessity for extensive repair or reconstruction to higher standards? The answer to the last question is an economic one just as it is for the other types of carriers. The answer is related to the degree of increase in weight limits that will result in over-all economic advantages in highway freight transport, including vehicular costs and additional highway costs.

At the time of this report there exists an erratic and, in some instances, an illogical schedule of State size and weight limitations for highway freight vehicles. Some States restrict highway freight vehicles to single cargo-body vehicles, such as single-unit trucks and tractor and semitrailer combinations, whereas other States allow two cargo-body combinations composed of 2 or 3 vehicular units. Topographical conditions and population concentrations are not significantly different between these two groups of States. The States allowing the larger combinations are predominately in the West and do include large metropolitan cities along the Pacific Coast as well as much mountainous terrain, conditions that might be expected to militate against the use of the larger combinations.

Reasons for Demand for Greater Weight Allowances for Highway Freight

Insofar as the opitumum gross weights for highway freight are concerned, the end

TABLE 3

DISTRIBUTION OF HIGHWAY FREIGHT COMMODITY SHIPPING DENSITIES BY 5-LB WEIGHT INTERVALS AND BY GENERAL CLASS OF CARGO BODIES (1), UNITED STATES – 1954

Density (pcf)	Commodities Carried in Van-Type Cargo Bodies[a]			Commodities Carried in Other-Than-Van-Type Cargo Bodies[b]			Commodities Carried in Cargo Bodies of All Types		
	1,000 Tons	%	Cumulative %	1,000 Tons	%	Cumulative %	1,000 Tons	%	Cumulative %
5.0-9.99	15,017	0.90	0.90	14,239	0.86	0.86	29,256	1.76	1.76
10.0-14.99	46,231	2.80	3.70	13,955	0.85	1.71	60,186	3.65	5.41
15.0-19.99	15,337	0.93	4.63	-	-	-	15,337	0.93	6.34
20.0-24.99	42,986	2.60	7.23	5,959	0.36	2.07	48,945	2.96	9.30
25.0-29.99	86,368	5.23	12.46	7,788	0.47	2.54	94,156	5.70	15.00
30.0-34.99	70,254	4.26	16.72	-	-	-	70,254	4.26	19.26
35.0-39.99	69,491	4.21	20.93	15,189	0.92	3.46	84,680	5.13	24.39
40.0-44.99	36,080	2.19	23.12	122,102	7.41	10.87	158,182	9.60	33.99
45.0-49.99	129,165	7.83	30.95	109,510	6.63	17.50	238,675	14.46	48.45
50.0-54.99	9,782	0.59	31.54	104,401	6.32	23.82	114,183	6.91	55.36
55.0-59.99	6,456	0.37	31.91	85,517	5.18	29.00	91,973	5.55	60.91
60.0-94.99	23,368	1.42	33.33	55,803	3.38	32.38	79,171	4.80	65.71
100.0-104.99	-	-	-	469,337	28.44	60.82	469,337	28.44	94.15
105.0-254.99	9,520	0.58	33.91	86,970	5.27	66.09	96,490	5.85	100.00
Total tons	560,055			1,090,770			1,650,825		

[a]Includes closed, tarpaulin covered open-top, refrigerator, ventilated, and stock rack vans.
[b]Includes tank, hopper, dump, grain, platform, pole, logging, automobile transport, and other special bodies.

points in weight are dependent primarily on the commodities carried. The commodity density characteristics and tonnages carried by highway freight were reported in an earlier committee report (1). The commodity data given in that report are further subdivided in Table 3 as to general class of cargo body in which the various commodities are preponderantly hauled. This division is of necessity quite crude because in actual trucking practice specific commodities may be hauled in more than one type of cargo body, depending on size of the shipment, the shippers and consignees loading and unloading facilities, and the general climatic conditions of a given area. For example, in the Southwest, canned goods in cartons may be hauled on platform bodies, a practice not followed in the northern and eastern areas of the country. Also, considerable wheat flour now is transported by tank to large consumers, whereas other shipments are placed in bags and transported in vans.

In Table 3, cargo bodies are separated into two broad classes, defined as follows: (a) van-type bodies which include closed vans, tarpaulin covered open-top vans, refrigerator vans, ventilated vans, and stock racks; and (b) other-than-van-type bodies which include tank, hopper, dump, grain, platform, pole, logging, automobile transport, and other special types of cargo bodies. The cubic capacities of van-type cargo bodies are controlled by legal size regulations. Length and width regulations restrict the road-area size of other-than-van-type bodies, but height limits generally do not control the weight of the cargos because these types of vehicles are used extensively to haul the heavier commodities, and weight regulations become operative before the cargo can be piled to the height limits. In general, the payloads of commodities weighing less than

25 pcf are limited by size regulations which control the volume of a cargo body. Table 3 indicates that these lighter commodities comprise about 10 percent of the total freight moved by highway. On the other hand, the payloads of commodities weighing more than 25 pcf are limited by weight regulations.

Table 3 shows that dry freight and packaged commodities, which are transported in van-type bodies, constitute about 34 percent of the tonnage of all commodities transported by highway vehicles. Ninety-three percent of these dry freight commodities weigh less than 50 pcf, and this amount of dry freight comprises about 31 percent of the total tonnage of highway freight. These data further support the premise in the committee's report (2) that insofar as van-type bodies are concerned, payloads and gross weights developed with commodities weighing 50 pcf represent the maxima which need to be considered for the development of transport costs in relation to highway costs.

It is recognized that motor carriers do mix commodities of different densities in less-truck-load shipments, and thus may obtain lower average cargo densities than those given in Table 3. However, ICC statistics of freight moved by Class I common carriers, as given in Table 4, indicate that approximately 50 percent of their tonnage moved in truckload shipments. "Truckload" in this example means a volume-minimum shipment, or any shipment weighing more than 10,000 lb. Practically, this 10,000-lb minimum refers generally to commodities of such light density that the 10,000-lb shipments will essentially fill the cargo space of vans about 24 ft in length (common sizes of vans several years ago). Volume-minimum weights on other commodities are much higher, but still are related to the earlier body sizes and to earlier and lower gross weight restrictions.

TABLE 4

DISTRIBUTION BY TYPE OF SHIPMENT OF TONNAGE HAULED BY CLASS I COMMON CARRIERS (2)

Year	Tonnage Hauled (%) Truckload	LTL[a]
1958	48	52
1957	48	52
1956	49.5	50.5
1955	52	48

[a]Less than truckload.

It can also be assumed that private contract and exempt-for-hire carriers will haul consistently more truckload shipments than LTL shipments by reason of the nature of their businesses. Considering these factors, it is reasonable to assume that large shipments of single commodities constitute a high proportion of freight carriage on the Nation's highways. This assumption is true to an even greater degree with the second class of commodities, hauled in other-than-van-type bodies, because these are commodities usually handled in bulk.

Type of Freight Service Affects Need for Size and Weight

It is understandable that the broad range of trucking services can result in the great variety of sizes and types of single-unit trucks and trailer combinations that are found on American streets and rural highways.

Many of the 2-axle, 4-tire trucks are engaged in urban and rural retail delivery service, in utility service, and in farm work. Few vehicles in these classes are affected by truck size and weight limitations. The chief determinants for the sizes of these single-unit trucks are: (a) the number of deliveries or amount of goods a driver can handle in a working shift in the case of retail delivery; and (b) for service vehicles, the amount of equipment and supplies a service man needs for a day's work. The chief differences between such types of vehicles for city and rural service are their speed characteristics. City vehicles make many traffic stops and have little use for speeds more than 35 mph. Rural vehicles usually travel more miles in a day to make deliveries, and minimum speed capabilities should at least be consistent with that of other rural traffic.

Those city and rural delivery vehicles that are affected by size and weight limitations are engaged primarily in the movement of bulk commodities. The situation here is somewhat different in that bulk commodities usually can be loaded and unloaded faster than packaged commodities and require little manual labor on the part of the driver. Examples of this kind of freight service are gasoline deliveries to gasoline stations, coal and fuel oil deliveries to large buildings and manufacturing plants, delivery of construction materials and transit mix concrete to construction sites. Such services and vehicles are affected by truck size and weight limitations.

Household goods moving and transfer vehicles are affected by size limitations but are not affected by weight limitations inasmuch as the density of the commodity is low. A similar condition exists with regard to automobile transport vehicles. Both of these types of vehicles are used rather interchangeably in city, rural and line-haul services.

Dump trucks are a class of vehicle that is affected by weight limitations. However, where dump trucks are used for hauling waste material from an excavation, the conditions at a construction site may be limiting factors insofar as size and weight are concerned. In rural service, dump-type trailer combinations may be used for hauling such commodities as sand and gravel, coal, crushed stone, and the like. Such vehicles may not be used in excavation work but may travel almost all of their distance on hard-surfaced roads. In such cases the vehicles are, in effect, serving as freight trucks and are affected by size and weight limitations in a manner similar to that of other freight vehicles. In line-haul transport such vehicles are of large capacity and must have a speed capability equal to that of other traffic.

Vehicles in heavy-hauling service are affected by size and weight limitations. Much of heavy hauling may be within given levels of size and weight limits, but there is a limited amount of this type of service which will always travel under special permit. Such items as the transport of very large electrical generators, transformers, large machinery, and large steel structural pieces would fall into this category. Such loads and their special vehicles were not considered in this study.

Whereas all types of carriers of the heavier commodities can benefit from increases in gross weight limitations, it is evident that the line-haul over-the-road carriage of freight would benefit most significantly from increases in size and weight allowances. In this service, the driver does not handle freight enroute, and if the size of his vehicle and its engine power is properly proportioned, the driver exerts little more effort but more skill in handling a very large and heavy vehicle than he would in handling a lighter weight vehicle. In long-haul service a carrier is always interested in loading the vehicle as nearly visibly full as is possible, considering the densities of commodities and the allowed weight limitations. This is true whether the carrier hauls volume-minimum truckload shipments of LTL shipments.

TABLE 5

MOTOR VEHICLE REGISTRATIONS IN 1957 BY VISUAL TYPE (4)

Visual Type of Vehicle	Totals		
Automobiles			55,906,195
Buses: Intercity	19,259		
Transit	58,145		
School and non-revenue	179,221		
Subtotal, all buses			256,625
Single-unit trucks: 2-axle, 4-tire			6,929,488
Single-unit trucks: 2-axle, 6-tire	3,212,854		
3-axle	184,331		
Subtotal		3,397,185	
Trailer combinations, all type from 2-S1 to 8-axle or more		634,141	
Subtotal, trucks and trailer combinations which may be affected by increases in size and weight regulations		4,031,326	4,031,326
Total, all vehicles except trailers			67,123,634

To obtain an over-all perspective of the distribution of the various types of vehicles in the Nation's fleet, Table 5 gives a schedule of motor vehicle registrations in 1957 by visual type (4). This table shows the total number of powered vehicles and includes those owned by private and for-hire carriers, and by Federal, civilian, State, county and municipal governments. The table does not does not include trailers for reasons which are discussed in a later section entitled "Number of Vehicles in Line-Haul Fleet."

Present Sizes of Automotive Freight Vehicles

All but two States now permit trailers 40 ft in length, 12 ft 6 in. or more in height and 8 ft in width. Actually the present AASHO Policy does not impose a specific limit on semitrailer lengths but only on the over-all length of tractor and semitrailer. Under the AASHO Policy semitrailers as long as 42 ft could be used with cab-over-engine tractors and still be within the recommended 50-ft over-all length allowance for tractor and semitrailer.

Such being the situation, it appears logical to consider that 40 ft is practical and a desirable maximum length for trailers. Currently, the trailer manufacturers strive by ingenious engineering designs to make cargo bodies of maximum cubical capacity. Practical inside stowage dimensions are 92 in. wide and 96 in. high. Lengths inside are approximately 7 in. less than the external length of the cargo body. However, it cannot be assumed that the cubage indicated previously can be completely filled with freight. Cartons, cases and other freight do not nest together closely enough, nor can they be stowed high enough to eliminate all empty space. It is assumed that the average ullage of bodies loaded visibly full with dry freight merchandise will be about 10 percent. Under this assumption the maximum storage space in a 40-ft semitrailer would be 7.6 x 8.0 x 39.3 = 2,390 cu ft. Applying a 10 percent ullage factor gives a practical useful stowage capacity of 2,151 cu ft, or rounding 2,150 cu ft. The use of similar interior dimension factors to the cargo bodies of truck and full trailers and of tractor semitrailer and full trailers gives the possible maximum stowage capacities given in Table 6.

Table 7 gives corresponding payload weights for visibly full loadings on five different trailer combinations using a series of cargo densities from 10 to 50 pcf.

The maximum values obtained from dry freight commodities need to be considered next in relation to commodities hauled in other-than-van-type cargo bodies. The preponderance of the remaining freight includes bulk-type commodities where the size of the cargo body can and does control the payload. For example, with coal, sand, gravel, crushed stone, and ores, the height of the sides of the hopper body controls the cubic capacity and the total payload. With fluid materials like petroleum products, liquid chemicals, and bulk cement, the size of the cargo tank limits the payload. Other bulk materials such as metals and cut stone cannot be controlled by cargo body size, but their shipping densities are so high that they cannot be given consideration in regard to their maximum possible payloads. Such commodities will have to be limited by the gross weights allowed for other types of commodities.

TABLE 6

STOWAGE CAPACITY RELATED TO LENGTHS OF VAN TRAILER COMBINATIONS

Combination Type	Length (ft) Over-All	Length (ft) Total Cargo Body	Total Cargo Stowage Capacity (cu ft)
Tractor and semitrailer	45	35	1,880
Tractor and semitrailer	50	40	2,150
Truck and full trailer	60	50	2,660
Tractor semitrailer and full trailer	60	50	2,660
Tractor semitrailer and full trailer	65	54	2,870
Tractor semitrailer and full trailer	100	80	4,300

TABLE 7

PAYLOAD WEIGHTS RELATED TO STOWAGE CAPACITY OF VAN TRAILER COMBINATIONS[a]

Commod. Density (pcf)	Payload Weight (lb)					
	Ta-S 35 Ft	Ta-S 40 Ft	Tr-F 50 Ft	Ta-S-F 50 Ft	Ta-S-F 54 Ft	Ta-S-F 80 Ft
10	18,800	21,500	26,600	26,600	28,700	43,000
15	28,200	32,250	39,900	39,900	43,050	64,500
20	37,600	43,000	53,200	53,200	57,400	86,000
25	47,000	53,750	66,500	66,500	71,750	107,500
30	56,400	64,500	79,800	79,800	86,100	129,000
35	65,800	75,250	93,100	93,100	100,450	150,500
40	75,200	86,000	106,400	106,400	114,800	-
45	84,600	96,750	119,700	119,700	129,150	-
50	94,000	107,500	133,000	133,000	143,500	-

[a]Ta= tractor, Tr=truck, S=semitrailer and F=full trailer. Length is approximate length of cargo body.

The hauling of logs is an interesting example, in that the commodity is hauled on flat bed or bunker bed trailers, but the amount of the load is controlled by the over-all width and height allowed for van-type vehicles, namely, 8 ft wide by 12½ ft high. Within these dimensional limits, with logs 13 to 36 in. in diameter and 33 ft in length, approximately 8,500 scale bd ft of timber can be hauled in a single load. Using 10 lb per scale bd ft as an average weight for freshly cut timber, a payload allowance of approximately 85,000 lb would accommodate this commodity. Of course, there still remain in the West a considerable number of very large trees which are hauled in single logs. Such large single trees when cut into 33-ft logs may weigh more than 100,000 lb and may have to be hauled under special permit, or else the logs will have to be split at the logging site.

The data in Table 7 may be compared with that in Table 3 to reveal the type of commodities that produce the various payload weights. By adding appropriate vehicle tare weights to the various payload weights in Table 7, the resulting approximate gross weights may be compared with the possible vehicular gross weights given in Tables 1 and 2. From these comparisons it is obvious that certain commodities can use larger cargo bodies and carry more cargo before reaching the possible vehicular gross weights given in Tables 1 and 2. Conversely, there are many commodities which would obtain no benefits from increased sizes of cargo bodies, but would benefit from higher gross weights.

It may be said that practical sizes of trailer combinations with full cargo weights of various commodities prescribe the maximum end points of gross vehicle weights that need to be considered for regular highway freight transportation. These end points are useful guide lines in projecting the potentialities of future highway freight transportation. However, the immediate problem, which is the objective of the present study, is to establish the point at which increases in allowed gross weights do not result in any improvement in the total unit cost of transportation. Total unit transportation costs within this meaning include the costs of vehicular operation and the costs of providing highway facilities.

Trends Towards Uniformity in Sizes of Cargo Bodies

Recent extensive development of large cargo containers for transshipment of freight between trucks and steamships, and between trucks and railroads, exerts new forces towards a standardization of the exterior dimensions of trailer cargo bodies. It is possible that the different types of freight carriers are at the threshold of a new era in the joint transport of freight. The further evolution of the design of containers for dry or packaged freight is clearly indicated by relatively recent progress in this field. The final development will depend on the degree of standardization that can be agreed on by the different types of carriers. This standardization will require compromises by all three types of carriers both from the engineering and economic aspects.

Containerization can be defined as the technique of stowing together a number of packages or units of freight, with a common destination, into a large closed cargo body without running gear, that can be carried unopened from a point of origin to a destination over different types of carriage without the freight being restowed or handled piece-by-piece during the trip. The principle of containerization is not new, but the early attempts by the railroads were not notably successful, largely because the containers were so heavy as to discourage interchange of containers with other, and particularly highway, carriers. The development of the monocoque, stressed skin, automotive trailer cargo body appears to overcome two objections to earlier containers, namely their weight and size. The recent development began with the increase in trailer-on-flat-car (piggyback) service, and with roll-on-roll-off trailer (fishyback) service on ships. In both cases the light tare weight of the trailer and its running gear was attractive, together with the mobility of the trailer. There has been a considerable increase in these types of connecting line services since 1954, although both methods had been used to a limited extent before that year.

The handling of a complete semitrailer on either railcar or ship has involved considerable expenditure of time and labor in loading, supporting and tieing down the semitrailers to either the flatcar floors or the ship decks. On shipboard, in particular, the semitrailer landing and running gears were a considerable disadvantage because they took up valuable shiphold space and reduced the available tonnage capacity. In ferry boat operations where the lengths of the trips are short, this is not a serious disadvantage, but in either ocean or coastwise shipping the loss of capacity was appreciable. On some railroads the height of the usual semitrailer when mounted on a flatcar was too high for the clearance height of tunnels and structures on certain routes. Where such clearances were not easily corrected, the railroads have not been able to handle all types of trailers in piggyback service. Because of the advantages of the semitrailer cargo body and because of a demonstrated demand for the "back" type of intercarrier movements without restowage of freight, additional development work has been done on making the trailer body separable from its landing and running gear, thus leading to the principle of containers.

For maximum advantage in both ship operation and railcar operation as described, it is obvious that the length, width and height dimensions of the trailer body must be standardized. A 40-ft modular length for van containers has been selected tentatively by a standardization committee (3), because this length for semitrailers is now legal in all but two States. The 8-ft width was also selected because it is legal in all States. (This probable standardization of an 8-ft width for container cargo bodies does not obviate the desirability of an increase in width at the tires to 102 in. or more, which would enable the use of larger tires and engineering improvements in brakes, transverse stability and safety.) Although the 35-ft length van was used in much of the pioneering work, there is considerable question as to whether the 35-ft length is optimum for use with all three types of carriage.

Presently under the proposed basic modular van container length of 40 ft, the standardization committee (3) is proposing three shorter modular lengths, namely, 10, 20 and 30 ft. There is some demand in the western States where tractor, semitrailer and full trailers are used for modular lengths of 13¼ and 26½ ft for van containers. Within each series of lengths, groupings of different lengths of van containers may be made to produce the modular basic length of 40 ft.

Tractor semitrailer and full trailers (also called double trailer combinations) are permitted in 22 States. Seven of the western States permit over-all combination lengths of 65 ft. Seven other western States plus Ohio and Delaware permit over-all lengths of 60 ft; two eastern States permit lengths of 55 ft; and four other States permit 50-ft lengths. The seven western States which are leading the field in allowing 65 ft for double trailer combinations are Arizona, California, Idaho, Nevada, New Mexico, Oregon and Washington. These States include all types of terrain and all types of rural and urban developments. Within a 65-ft over-all length, two trailers or containers each 26½ ft long can be arranged and operated.

The tractor semitrailer and full trailer lends itself to the use of two trailers of equal length. As a matter of fact it is customary to have both trailers of the same construction — namely, semitrailers— but with a dolly converter gear and a fifth wheel placed under the rear semitrailer to make it a full trailer. The double trailer combination is a most excellent type of freight vehicle for the handling of dry and packaged freight. The two cargo bodies are easily separated from the expensive power units for loading and unloading at the carrier's terminal, or for movement to and from shippers or consignees platforms for loading or unloading.

Another size of double trailer combination has appeared on such limited-access roads as the Massachusetts, New York, and Kansas toll roads. These combinations may be made up of two 40-ft semitrailers, the over-all length approaching 100 ft. Such long double trailer combinations can be operated only on the toll roads, but for hauling on other roads each semitrailer is handled separately in a tractor semitrailer combination, conforming to the permitted size and weight limits.

From these several diverse vehicle combinations and size trends, there appears to be emerging a series of maximum practical lengths of cargo bodies and trailer combinations. For light density freight, these maximum lengths appear to afford optimum advantages in cargo space; whereas for freight of the heavier densities, the additional length of wheelbase of the trailer combinations would be an advantage to the highways, even though the cargo bodies could not be loaded visibly full because of the very heavy axle and gross weights that would result. With this possible reservation, the series of lengths for trailer combinations, semitrailers and modular-sized van containers given in Table 8 appear reasonable and practical, and conducive to a degree of uniformity desirable from the viewpoint of both motor carriers and State highway departments.

For the handling of many fluid commodities, the truck and full trailer has certain advantages and is used to a considerable extent. The 26½-ft length would appear to be a practical size for use on both the tractive truck and its full trailer.

This series of cargo-body and van-container lengths can be used as shown with four different types of trailer combinations. The over-all lengths of the combinations are found in the United States. The modular sizes of the cargo bodies or containers when combined with the over-all lengths would give desired uniformity in cargo bodies and sufficient diversification to meet the needs of the highway freight industry.

TABLE 8

LENGTHS OF TRAILER COMBINATIONS USING VARIOUS PROPOSED MODULAR SIZES OF CONTAINERS

Over-All Length (ft)	Combination Type	Basic Cargo Bodies		Modular Lengths of Van Containers (ft)
		No.	Length (ft)	
50	Tractor and semitrailer	1	40	10, 20, 30, 13¼[b] and 26½
65	Tractor semi-trailer and full trailer	2	26½[b]	13¼[b]
65	Truck and full trailer	2	26½[b]	13¼[b]
100[a]	Tractor semi-trailer and full trailer	2	40	10, 20, 30, 13½[b] and 26½[b]

[a]For use only on limited-access thruways.
[b]Sizes are not included in the standards now in progress for approval by the American Standards Association.

Number of Vehicles in Line-Haul Fleet

As previously stated, the objective of the present research is limited to the determination of the operating costs of trailer combinations engaged in line-haul service. What part of the total use of commercial motor trucks in the United States such line-hauls constitute is impossible to determine precisely because no one knows exactly the number of power vehicles and trailers, or the number of cargo-body vehicles that are used in line-haul highway freight service. The reasons for this lack of data are that motor vehicles are registered by size and type of vehicle and not by road use, although distinctions are recorded between for-hire, farm, private other-than-farm, and government (Federal, civilian, State, county and municipal) ownership. Also, there is a considerable amount of duplicate registration of trailers by various States, and furthermore, small cargo trailers used with passenger cars or small trucks, especially in agricultural regions, frequently are registered as commercial trailers. The latter obviously do not come within the scope of this research.

As is generally known, there is considerable use of trailer combinations in city services and rural peddle services, but single-unit trucks, on the other hand, are used to some extent in line-haul service. To develop an estimate of the number of vehicles in line-haul service, which might be affected by changes in maximum size and weight regulations, it may be acceptable to stipulate for this study that the number of single-unit trucks in line-haul service approximately equals the number of trailer combinations in local service. This stipulation permits the use of the data in Table 9 to approximate the number of commercial motor vehicles in line-haul freight service.

The trailer combinations reported in Table 9 are of the types and have the characteristics of vehicles the economies of which would be changed by increases in size and weight limitations. Also, the economies of these vehicles at increased levels of axle

TABLE 9

NUMBER OF POWER UNITS AND TRAILERS BY TYPE OF TRAILER COMBINATION AND OWNERSHIP – 1957

Combination Type	Private Carriers: No. of Power Units[a]	Private Carriers: No. of Attached Trailers	Private Carriers: No. of Attached Cargo Bodies	For-Hire Carriers: No. of Power Units[a]	For-Hire Carriers: No. of Attached Trailers	For-Hire Carriers: No. of Attached Cargo Bodies
Tractor and semitrailer						
2-S1 1-axle semi	128,066	128,066	128,066	99,163	99,163	99,163
2-S2 2-axle semi	122,990	122,990	122,990	136,510	136,510	136,510
3-S2 and over. 2 or more axle semi	22,630	22,630	22,630	31,245	31,245	31,245
Truck and full trailer						
2-1 1-axle full[b]	18,743	18,743	37,486	2,012	2,012	4,024
2-2 2-axle full	17,647	17,647	35,294	3,722	3,722	7,444
2-3 3-axle full	1,620	1,620	3,240	459	459	918
3-2 2-axle full	7,268	7,268	14,536	10,403	10,403	20,806
3-3 and over. 3 or more axle full	1,167	1,167	2,334	2,110	2,110	4,220
Tractor semi and full trailer						
2-S1-2 1-axle and 2-axle full	4,934	9,868	9,868	8,581	17,162	17,162
2-S1-3, 2-S2-s, 3-S1-2	1,248	2,496	2,496	2,036	4,072	4,072
2-S2-3, 3-S2-2	103	206	206	443	886	886
8 or more axles	41	82	82	89	178	178
Totals (less 2-1 combinations)	307,714	314,040	341,742	294,761	305,910	322,604
Totals, tractor only	280,012	-	-	278,063	-	-
Estimated extra trailers	-	15,702[c]	15,702	-	76,477[d]	76,477
Totals (less 2-1 combinations)	-	329,742	357,444	-	382,387	399,081
Summary (less 2-1 combinations)						
Private and for-hire carriers						
Power units	-	602,475	-	-	-	-
Trailers	-	712,129	-	-	-	-
Total vehicles	-	1,314,604	-	-	-	-
Total cargo bodies	-	756,525	-	-	-	-

[a]Number of combinations from third Progress Report (4).
[b]Deleted from totals because predominantly not in regular line-haul service.
[c]Estimated 5 percent extra trailers.
[d]Estimated 25 percent extra trailers.

and gross weight allowances will have to offset the increased costs of corresponding levels of pavement and bridge capabilities, if there are to over-all benefits to all users of highways.

Data regarding the number of trailer combinations registered in the United States in 1957 are given in Table 9 (4). The data represent registrations of complete trailer combinations. It should be noted that the numbers for truck and balanced 1-axle full trailers (axle code class 2-1) have been deleted from the totals. This deletion was made because it was assumed that this trailer combination is seldom used in regular line-haul freight hauling.

Many motor carriers own extra trailers, but the ratio of extra trailers to trailer combinations is known only for ICC Class I and II intercity carriers. Such carriers in 1956 owned 169 trailers for each 100 tractors (5). Using this factor to estimate the number of extra trailers resulted in a total number of trailers that was much greater than the total production of commercial civilian freight trailers during the previous 20 yr (6). For this reason and in order to distribute approximately 90 percent of the commercial trailers produced since 1940, an extra trailer factor of 5 percent was used for private carriers, and 25 percent for for-hire carriers.

In Table 9 there is developed the number of trailers that would be required to make up the complete trailer combinations reported. To these numbers are added the estimated number of extra trailers. Also developed in the table is the number of cargo bodies, which number includes the cargo bodies on the tractive trucks of the truck and full trailer combinations. Although these data are not precise, they do give a reasonable picture of the maximum number of large freight trailer combinations that may be in line-haul service.

It will be noted that 1,314,604 vehicles are required to keep the 602,475 trailer combinations in service. Of the total number of vehicles, 712,129 are trailers, either semitrailers or full trailers. The tractive trucks and the trailers in the total fleet provide 756,525 cargo bodies for the hauling of freight.

Another fact to be learned from the vehicle and trailer data is that the number of cargo vehicles in trailer combinations is 6.8 percent of the total fleet of private and for-hire commercial vehicles. Because of their extensive use in line-haul service, this 6.8 percent of commercial motor vehicles, representing the cargo vehicles of trailer combinations, runs 21.5 percent of the total commercial motor vehicle-miles.

The total fleet of freight vehicles includes:

Single-unit trucks (4)		9,841,777
Cargo vehicles in trailer combinations	756,525	
Tractors only	558,075	
Total tractors and cargo vehicles		1,314,600
Total vehicles		11,156,377

The 1957 mileage estimates (4) are:

	Miles	Percent
Trailer combinations	24,289,000,000	21.5
Single-unit trucks	88,916,000,000	78.5
Total	113,205,000,000	100.0

Length of Trucking Hauls

The lengths of haul made by line-haul highway freight vehicles provide one indication of the nature of demand for highway freight transport and may be useful in judging the effects of the National System of Interstate and Defense Highways in expending long-distance truck transport, as well as the degree to which truck freight transport may be diverted from the highways to "piggyback" on railroads, and "fishyback" on inland and coastal waterways. Both piggyback and fishyback are in operation with varying degrees of success and the advocates of each alternative method for carrying loaded trailers are actively promoting increased use of these facilities.

Data on lengths of haul by motor carriers are rather meager, but significant published data are reported in Tables 10-19. Table 10 gives a distribution of 310,200 shipments by mileage blocks which was made from a sample of 1947 data on ICC Class I motor carriers of general commodities. The data, as reported by ICC (7), showed the weights of shipments by mileage blocks but in Table 10 the data have been consolidated to show only the total number of shipments by mileage blocks.

In this sample it will be noted that 52 percent of the shipments were hauled 200 mi or less, whereas 89 percent were hauled 600 mi or less, leaving only 11 percent of the shipments to be hauled more than 600 mi.

The Interstate Commerce Commission, in its annual reports compiles "ton-miles per ton" from reports submitted by Class I and Class II Intercity Common and Contract Carriers (2). The value "ton-miles per ton" is approximately equal to the average length of haul. Table 11 gives data for 1955-58.

The data in Table 11 apply only to intercity for-hire carriers operating under ICC certificates. It will be noted that the Class I common carriers of general commodities have the longest average lengths of haul, more than 300 mi in recent years, whereas the other classes of for-hire carriers have average lengths of haul of less than 200 mi. The average lengths of haul of private carriers may be assumed to approximate those of the contract carriers, because, in general, contract carriage is in lieu of private carriage.

The average length of haul data in Table 11 do not give a clear picture of the overall services rendered by trucking equipment on the highways of the United States. Partial glimpses of the extent of trucking services are obtained from several studies of commodity movements made by the U.S. Bureau of the Census and by the U.S. Department of Agriculture, and are reported in Tables 12-19. In general, the data for these series of studies were obtained from shippers. A stratified sampling technique was used according to procedures developed by the Transportation Division of the Bureau of the Census.

The data in Tables 12 to 19 show the percentages of various commodities transported

TABLE 10

NUMBER OF SHIPMENTS BY MILEAGE BLOCKS (7) — 1947

Length of Haul (mi)	No. of Shipments	Shipments in Mileage Block (%)	Accumulative Percentage
0 - 50	30,967	10.0	10.0
51 - 100	55,427	17.8	27.8
101 - 150	42,867	13.8	41.6
151 - 200	34,568	11.1	52.7
201 - 300	49,745	16.0	68.7
301 - 400	29,075	9.4	78.1
401 - 500	20,745	6.7	84.8
501 - 600	12,991	4.2	89.0
601 - 800	15,047	4.9	93.9
801 - 1000	8,375	2.7	96.6
1001 - 1200	3,542	1.1	97.7
1201 - 1400	2,081	0.7	98.4
1401 - 1600	1,039	0.3	98.7
1601 - 2000	1,133	0.4	99.1
2001 - 2400	1,418	0.5	99.6
2401 - 2800	781	0.3	99.9
2800 +	399	0.1	100.0
Total	310,200	100.0	
Average 290			

by different modes of transportation and by mileage blocks. In this series of tables the distribution of the transportation of the specific commodities between railroad, highway and waterway for different lengths of haul can be seen. The lines of demarcation between hauls by railroad and by highway are not distinct except for one commodity which is hauled almost entirely by highway. The tables show that there is extensive overlapping of lengths of haul which probably results from faster deliveries and other features of highway transport. The data given in the series of tables were calculated from tables in each of the referenced reports.

Tables 12 to 19 do not completely cover the movement of all commodities, they may be considered together with the tonnage data given in the second committee report (1) to afford an approximate picture of truck transport. Some additional generalizations may be made about a few specific commodities, for example: (a) sand, gravel and crushed stone are hauled principally by truck for relatively short lengths of haul; (b) iron ore and limestone are hauled predominantly by rail and waterway for long hauls; and (c) industrial and export coal is hauled principally by rail and waterway. For the intercity transportation of other commodities, rail transport and highway transport are competitive under many circumstances as is indicated by the overlapping of the different modes of transport over the range of lengths of haul. Reasons for the selection of one or the other of the two modes of land transport depend on various factors, such

TABLE 11

AVERAGE LENGTHS OF HAUL BY INTERCITY FOR-HIRE MOTOR CARRIERS (2)

		1955	1956	1957	1958
Class	Type	Length (mi)			
I	Common carriers of general commodities	296	298	334	343
I	Common carriers other than general freight	160	149	173	172
I	Total common carriers	235	230	267	270
I	Total contract carriers	139	141	167	163
II	Common carriers of general freight	N.A.[a]	N.A.[a]	148	149
II	Common carriers other than general freight	N.A.[a]	N.A.[a]	131	128
II	Total common carriers	N.A.[a]	N.A.[a]	138	136
II	Total contract carriers	N.A.[a]	N.A.[a]	130	135

[a]Not available.

TABLE 12

INTERSTATE AND INTRASTATE TRANSPORTATION OF FROZEN FRUITS AND VEGETABLES, ALL REGIONS, 1957 (8)

Miles Transported	Rail and Truck (%)	Rail (%)	Truck (%)
Less than 250	24.6	0.3	24.3
251 - 500	13.4	0.7	12.7
501 - 750	5.5	0.1	5.4
751 - 1,000	7.0	1.9	5.1
1,001 - 1,500	7.6	2.4	5.2
More than 1,501	41.9	33.9	8.0
Total	100.0	39.3	60.7

TABLE 13

INTERSTATE TRANSPORTATION OF FRESH AND FROZEN POULTRY, 1956-57 (9)

Transport Mode and Mileage	Fresh Poultry (%)	Frozen Poultry (%)
By rail	1.0	13.0
By truck	99.0	87.0
By rail and truck	100.0	100.0
Less than 250	49.8	23.4
251 - 500	17.8	13.3
501 - 750	15.6	13.3
751 - 1,000	10.0	8.9
1,001 - 1,500	0.8	24.1
More than 1,501	6.0	17.0

as door-to-door freight rates, convenience, crating requirements, need for rapid transport, and other local circumstances. For the hauling of those commodities for which highway trucking can offer advantage, the trucking industry has been aggressive in searching out and obtaining the business. Whereas the tonnages transported in line-haul by highway and railroad are roughly equal (1), the ton-mileage of transport by railroad is more than twice that by line-haul highway (14). Any question as to whether these ratios would change with a significant increase in the levels of truck sizes and weights and with the development of the National System of Interstate and Defense Highways, only the future can answer. Although it may be assumed that any economies, resulting from the improvements of highways which are reflected in motor carrier freight rates, would have an

TABLE 14

TRANSPORTATION OF CANNED FOODS, JULY 1, 1957 TO JUNE 30, 1958 (10)

Miles Transported	All Modes (%)	Rail (%)	Highway (%)	Other[a] (%)
Less than 100	20.0	3.2	16.7	0.1
100 - 249	20.0	4.9	15.0	0.1
250 - 499	21.0	9.9	11.0	0.1
500 - 749	11.0	7.2	3.7	0.1
750 - 999	7.0	4.5	2.1	0.4
1,000 - 1,499	5.0	4.0	0.8	0.2
More than 1,500	16.0	11.3	0.7	4.0
Total	100.0	4.50	50.0	5.0

[a]Predominantly by waterway.

TABLE 15

TRANSPORTATION OF FRESH FRUITS AND VEGETABLES ORIGINATED BY ASSEMBLERS DURING 12 MONTHS ENDED JUNE 30, 1957 (11)

Miles Transported	All Modes (%)	Rail (%)	Highway (%)	Other[a] (%)
Less than 100	9.0	0.6	7.9	0.5
100 - 249	7.0	0.7	6.0	0.3
250 - 499	16.0	6.2	9.8	-
500 - 749	10.0	3.4	6.6	-
750 - 999	15.0	6.6	8.4	-
1,000 - 1,999	35.0	23.1	11.9	-
More than 2,000	8.0	7.4	0.4	0.2
Total	100.0	48.0	51.0	1.0

[a]Predominantly by waterway.

effect on the volume of motor carrier freight transportation, prognostications on these questions are not within the realm of the committee's study.

Influence of Railroad Piggyback Service

Even on the highway systems in their present condition, a great quantity of volume shipments is transported long distances by commercial motor vehicles. With the planned improvement of geometric features of the Interstate highway system, it can be expected that the amount of volume shipments will increase. The increasing development of railroad trailer-on-flatcar (TOFC) service may reduce the number of large trailer combinations operating on highways paralleling railroad routes, but there still will remain the necessity of transporting the freight and the trailers to and from the railroad terminals. These initial and final stages of TOFC transport will be over rural highways or city streets depending on the location of the shipper or consignee with reference to the railroad terminals. For maximum economy in transport, the first and last stages of TOFC deliveries must be made with the large trailers, because any transfer of volume freight at a railroad terminal from a large trailer (moved on a railcar) to small local delivery vehicles would eliminate the cost advantages of TOFC service. Thus, although the combination of railroad and truck service may reduce the amount of travel on certain long routes, it will not reduce the demand for heavy gross vehicle weights on highways feeding to railroad terminals. A reverse trend, a demand for higher gross weights, may develop on such feeder routes because the trailers are able to carry heavier payloads when transported on the railcars.

TABLE 16

TRANSPORTATION OF GRAIN, ORIGINS TO ELEVATORS, 1957 (12)

Miles Transported	All Modes (%)	Rail (%)	Highway (%)	Other[a] (%)
Less than 100	27.0	13.0	10.5	3.5
100 - 249	30.0	19.2	5.4	5.4
250 - 499	23.0	19.6	2.1	1.3
500 - 749	17.0	14.1	0.7	2.2
750 - 999	2.0	1.6	-	0.4
More than 1,000	1.0	0.6	-	0.4
Total	100.0	68.1	18.7	13.2

[a]Predominantly by waterway.

TABLE 17

TRANSPORTATION OF GRAIN, ELEVATORS TO DESTINATIONS, 1957 (12)

Miles Transported	All Modes (%)	Rail (%)	Highway (%)	Other[a] (%)
Less than 100	17.0	10.5	4.1	2.4
100 - 249	19.0	16.0	0.9	2.1
250 - 499	24.0	20.4	1.0	2.6
500 - 749	26.0	13.3	0.5	12.2
750 - 999	8.0	6.1	0.2	1.7
More than 1,000	6.0	4.3	0.1	1.6
Total	100.0	70.6	6.8	22.6

[a]Predominantly by waterway.

From the increasing use of TOFC service during the past few years, a pattern of parameters for this service is emerging. For hauls of 100 to 200 mi or less, it appears to be cheaper and faster to haul a trailer over the road rather than load it on a flatcar. About 300 to 400 mi appears to be the approximate break-even point above which there are economies in TOFC service which can attract haulage from intercity highways. The degree to which the railroads attract long-haul TOFC business will depend on the attractiveness of the TOFC rates, and the efficiency and rapidity with which the railroads accomplish their loading, attaching, travel, and unloading portions of the line-haul transport job. At the present time TOFC rail service is handling less than 20,000 trailer movements a week. This is less than 1 percent of all trailer movements and probably includes most of the movements that can make best use of TOFC service in the longer hauls.

The developments of fishyback services along the eastern and western coasts are too new to predict their ultimate size, although these systems may develop profitable

TABLE 18

TRANSPORTATION OF SELECTED EXPORT COMMODITIES, 1956 (13)

Miles Transported	All Modes (%)	Rail (%)	Highway (%)	Water and Combination (%)
Within port area[a]	32.0	-	-	-
Port area to 99	27.0	14.1	10.5	2.4
100 - 249	11.0	7.9	2.8	0.3
250 - 499	10.0	8.7	1.1	0.2
500 - 749	7.0	5.6	0.9	0.5
750 - 999	4.0	3.4	0.3	0.3
1,000 - 1,499	2.0	1.5	0.3	0.2
More than 1,500	1.0	0.8	0.1	0.1
Not reported[a]	6.0	-	-	-
Total	100.0	42.0	16.0	4.0

[a]Not classified by mode of transport.

TABLE 19

TRANSPORTATION OF SELECTED IMPORT COMMODITIES, 1956 (13)

Miles Transported	All Modes (%)	Rail (%)	Highway (%)	Water and Combination (%)
Within port area[a]	60.0	-	-	-
Port area to 99	13.0	4.0	5.7	3.3
100 - 249	7.0	3.5	3.1	0.4
250 - 499	5.0	3.2	1.7	0.1
500 - 749	3.0	1.5	0.7	0.8
750 - 999	1.0	0.6	0.2	0.2
1,000 - 1,499	1.0	0.6	0.3	0.1
More than 1,500	1.0	0.6	0.3	0.1
Not reported[a]	9.0	-	-	-
Total	100.0	14.0	12.0	5.0

[a]Not classified by mode of transport.

traffic, especially where they extend container or trailer service to areas north and south of the United States. The inland waterways now handle a considerable tonnage of volume shipments, such as coal, which have not been highway freight. Any great increase in trailer- or container-on-barge service of highway freight seems unlikely because of the loading, attaching, travel, and unloading problems, which are similar to those of the railroads, and which militate against short hauls except ferry hauls.

Because of the rather lengthy mileage break-even point between direct highway service and either TOFC or fishyback service it is unlikely that the preponderance of short- and medium-haul highway freight will shift to either of the "back" type of alternative transport, except to the extent that captive highway equipment may be coupled with freight rate advantages. For very long-haul freight, transfer to one or the other of the "back" services may be expected, but this transfer will not greatly reduce the truck traffic on highways because of the reasons mentioned earlier.

However, even if the railroads attain maximum efficiency in their TOFC service, and the ships do likewise in their fishyback service, and attract a significant portion of the very long-haul truck transport, there will result little difference in the demand for higher weight capabilities on highways, because the transported trailers must be hauled loaded to and from the transporter terminals. Further, with the completion of the Interstate System of controlled-access roads it is very possible that the mileage break-even point between all-road haulage and TOFC or fishyback haulage may become longer.

As TOFC and fishyback services increase, they may prove to be troublesome factors in the allocation of road-user charges to the large line-haul trailer combinations, because these transporter services may reduce the number of combinations and the vehicle mileage in very long-haul trucking service, without reducing the number of vehicles or the vehicle mileage in short and intermediate length line-haul trucking.

Long Double Trailer Combinations on Modern Controlled-Access Highways

It is feasible from the automotive viewpoint to allow long tractor semitrailer and full trailer combinations on modern controlled-access highways, such as the National System of Interstate and Defense Highways. This type of double trailer combination in making full use of the maximum vehicle-carrying capacity would consist of a 3-axle tractor, a 2-axle semitrailer and a 4-axle full trailer with trailers up to 40 ft in length. Such an arrangement would result in tandem axles at both ends of each trailer cargo body, a desirable vehicular design feature from the standpoint of spreading the extreme axles and reducing body overhang, but undesirable from the bridge standpoint because of the concentration of weight on the four center axles. The over-all lengths of such double trailer combinations with conventional tractors approach 100 ft.

Using the two levels of common axle weight allowances, without weight adjustments for bridge formulas, the maximum payloads and gross weights for such expressway double trailer combinations are as follows:

Maximum Axle Weight Allowance	Approx. Tare Weight (lb)	Approx. Payload Weight (lb)	Maximum Gross Combination Weight (lb)
18,000-lb single axle, 32,000-lb tandem axle	40,000	98,000	138,000
22,400-lb single axle, 36,000-lb tandem axle	42,000	113,000	155,000

The tractors for such expressway combinations would require power plants of about 335 and 375 horsepower in order to run 50 mph on level road, 20 mph on 3 percent grades and 12 mph on 5 percent grades. (These values are near the top limits of present automotive design.) At terminal yards near the interchanges on an expressway, the double trailer combinations would be assembled from or broken up into two 5-axle semitrailer combinations which could operate within the legal limits on many of the present conventional primary and secondary road systems. The extra powerful tractors and the 4-wheel conversion dollies used with the double trailer combinations usually would be used exclusively on the expressway to haul other trailers in double trailer combinations. The tractors used to haul the trailers in tractor semitrailer combinations on primary and secondary roads could be lighter tractors with about 180 horsepower engines. Such 5-axle tractor semitrailer combinations each could have a maximum gross combination weight of 74,000 lb with 32,000-lb tandem axles, and 10,000 lb on the front axle.

Although the practice of using a single 40-ft semitrailer with a tractor on primary and secondary roads, and then assembling the trailers into tractor semitrailer and full trailer combination for use on Interstate expressways, has some of the appearance of a classified system of highways with different weight allowances, such is not exactly the case, because the load capabilities of the individual cargo vehicles would not be changed whether operating on expressways or on conventional primary and secondary roads. The tandem axle weight limitations of 32,000 lb or 36,000 lb would be the same whether the vehicle was on a conventional road or on an expressway. The difference in gross weight results only from the combining of the two long semitrailers into one combination for use on those expressways which have the geometric characteristics permitting the use of such long double trailer combinations. Double trailer combinations of 127,000 lb to 130,000 lb currently are operating on several toll roads and warrant continued observations.

Study Variables

TYPES OF FREIGHT HAULING EQUIPMENT

For line-haul, over-the-road highway freight service, trailer combinations are the present predominant type of vehicle in use, and it is assumed that they will continue to predominate in the foreseeable future. Such vehicles range from 3-axle tractor and semitrailer, to 9-axle tractor semitrailer and full trailer. For the handling of dry and packaged freight, tractors and van trailers are generally used. For the handling of fluid commodities, tractive trucks and full trailers are used in addition to tractors and semitrailers. The trucks and full trailers appear to have a considerable degree of popularity in the West where two cargo-vehicle combinations are allowed. Where commodities can be quickly loaded and unloaded, as is the case with liquid and flowable commodities, the truck and full trailer is a convenient and efficient combination. This is not to say that the tractor semitrailer and full trailer is not used for the handling of fluid commodities in tanks or hoppers because there are some carriers that prefer this type of combination.

In addition to public highway trailer combinations, data were collected for large tractors and semitrailers operated on private roads where higher axle and gross weights were permitted. In the western logging industry, trailer combinations were found running on private roads with gross weights more than twice those allowed on most public highways, and with daily vehicle mileages comparable to line-haul service. There are several features which make these trucking operations somewhat different from those on public roads. Although the roads are surfaced with gravel or crushed rock, they generally are not all-weather roads. In fact, during wet or thawing weather there is very little log hauling on the private logging roads, and even when the roads are dry or frozen the loaded vehicle daily traffic volume is very low compared with the truck traffic on rural primary roads. However, as examples of trailer combinations of very heavy cargo capacity, cost data were obtained for logging trailer combinations. In addition to the operating cost data, a significant fact proved by these examples of special hauling by very heavy cargo vehicles is that the manufacturers of trucking equipment now are able to build reliable automotive freight vehicles with load-carrying capacities and gross combination weights much above the weights allowed in any State.

Because single-unit trucks are not extensively used in line-haul freight operations, operating cost data were collected on only a few such vehicles. Generally these vehicles were handling fluid commodities where loading and unloading times were short. In addition, some data were obtained on dump trucks of very large capacity used in the strip mining industry. Operations were found where such trucks averaged 150 to 200 mi a day over private roads. Forty- and 50-ton payloads in 3-axle dump trucks are common, with axle weights of 50,000 lb to 55,000 lb. The vehicles run over private roads which eventually are built to extreme thicknesses by the continual process of adding crushed rock and gravel to the soft places. Such rock roads are sprinkled in the dry season to prevent dusting away. They are kept free of large rocks that could punch holes in tires, but the roads are not as smooth as passenger car motorists demand. Even in those mines where high mileages are obtained, the travel is distributed over 24 hr, with the further advantages that the runs result in frequent stops for loading or unloading. Also, these large mine dump trucks run on large earth-mover types of tires and are wider than 8 ft at the tires. Although the strip mine operations appear different from line-haul public highway hauling, they further illustrate the point that freight automotive vehicles, with capacities much greater than those now permitted on public highways, are in regular use.

TYPES OF TRUCKING SERVICES

The transport of property by commercial motor vehicles in the United States includes all types of freight movements from the Interstate line-haul transport of volume shipments to the local retail delivery of single purchases. In addition to the transport of freight there are other trucking services which have come into increasing industrial use. Predominantly, these other trucking services are for the transport and storage of tools, equipment and supplies used to construct and maintain utility facilities, production machinery, buildings, and dwellings in urban and rural areas.

Although the maximum permitted sizes and weights of vehicles are of great importance in the business of transporting freight in line-haul service, they have much less effect on local retail delivery and the utility services field. The relatively small sizes of local pickup and delivery trucks are governed predominantly by the number of shipments that can be delivered or picked up by a driver during one working shift; and utility service trucks generally are small vehicles. On the other hand, such local service vehicles as transit-mix concrete trucks, construction supply trucks, dump trucks, and bulk delivery tank trucks could use to advantage higher weights than now are allowed in some States.

Between the extremes of local retail delivery and line-haul freight services, there are several types of trucking services which are identified partially in the following schedules to indicate the varied uses of trucking equipment.

Line-haul freight service includes:

1. Intercity carriage of volume shipments of finished goods from producer or manufacturer to warehouse or user.

2. Over-the-road carriage of volume shipments of raw materials and semifinished goods between producers and factories or consumers.

3. Over-the-road transport of products of agriculture, of animals, of forests and of mines in volume shipments from place of origin to processing plants or warehouses. These freight movements include farm-to-market movements, grain shipments, log and timber hauling, livestock hauling, coal hauling, sand, gravel and stone hauling and the hauling of certain petroleum materials.

4. Intercity carriage of less-truck-load shipments of finished goods.

5. Over-the-road moving of personal property, both household and industrial.

City pickup and delivery services, rural peddle services and utility services include:

1. Local retail delivery service, such as food deliveries and other retail deliveries to dwellings.

2. City pickup and delivery, and rural peddle pickup and delivery of freight shipments supplementray to line-haul movements. This service may be given by city trucks for small less-truck-load shipments, or by line-haul vehicles for volume shipments and large LTL shipments. This local truck service usually extends between a line-haul freight terminal, either motor carrier, railroad, airline or water carrier, and a warehouse or mercantile establishment.

3. Local delivery of bulk shipments of commodities, such as petroleum products, coal, concrete, building materials and local cartage deliveries of volume shipments from warehouses to manufacturing plants, mercantile establishments, or construction sites.

4. Local cartage of volume shipments of raw materials and semifinished goods between producers, factories, warehouses and consumers.

5. Local cartage of personal property, both household and industrial.

6. Vehicles used for the transport and storage of tools and equipment used to construct, install and maintain industrial facilities and utility facilities in commercial establishments, in dwellings, and on farms.

It will be noted that these various trucking services may be performed either by private carriers, exempt-for-hire carriers, or public-utility certificated for-hire carriers. It is characteristic of line-haul freight transport by land, that the initial movements of products and commodities occur predominantly in volume shipments from producer or manufacturer to warehouses or distribution centers. It is in the last stages of the transport movement that there are LTL shipments.

The descriptions of the various trucking services indicate that most trucking for both city delivery and rural peddle services has little need for any increase in size and weight limits. Preponderantly such vehicles are single-unit trucks and these trucks together with similar trucks used in farm service make up more than 90 percent of the nation's motor truck fleet. However, in certain city and peddle services, such as bulk fuel deliveries, construction supply deliveries, and deliveries from freight terminals or warehouses to stores, larger capacity trucks or trailer combinations are used, and these would benefit from higher weight allowances.

Machinery movers and heavy haulers constitute a class of trucking services that generally can use to advantage larger size and weight limits. However, the volume of this carriage, although important, is relatively small, and it is expected that such vehicles and loads will continue to have to move under special permit and on selected routes. Data on this type of trucking service are not included in the study.

TYPES OF CARRIERS

In this study no distinction has been made between classes of motor freight carriers by their legal classification as common carriers, exempt-for-hire carriers, contract carriers and private carriers. The study relates to the line-haul transport of commodities and freight, and the line-haul costs reported are a composite of the costs of practically all types of highway freight carriers except machinery and heavy haulers using special equipment and special transport techniques.

Data were obtained from carriers in each of the legal classifications, the only test being whether most of a carrier's regular services involved travel on rural roads, including operations on private roads where very heavy loads were the regular practice. Carriers were selected whose trips and runs were predominantly in excess of 150 mi. If the routes of such trips happened to include expressways through urban areas such routes were considered as the equivalent of rural roads for the purposes of the study. But data were not obtained from carriers whose routes were predominantly on local streets of built-up urban and suburban areas, such as exist around the largest metropolitan areas; for example, around New York City and northern New Jersey.

VARIABLES IN LINE-HAUL TRUCKING

In line-haul trucking services there are a number of factors that cause differences in operating costs within a given gross weight group of similar trailer combinations. A number of these different factors were explored in the processing of the data to learn their effects on operating costs. Some were found to be not significant and are not discussed further in this report.

The variable factors explored are discussed in the following paragraphs.

Types of Fuels and Engines

Three types of fuel and two types of engines currently are in use in the trucking industry. One type is the spark-ignited engine using either gasoline or liquefied petroleum gas. The other is the diesel-type engine which is compression-ignited and uses a less volatile grade of petroleum fuel. The two types of engines have different fuel consumption rates with resulting different fuel costs.

Types of Trailer Combinations

Fourteen types of trailer combinations, classified according to axle arrangements, were considered.

Types of Cargo Bodies

Ten types of cargo bodies were considered with the different vehicle types, although not all body types were found on all the vehicle types. Because of the smallness of the sample in several body types, costs were not developed for certain body types, but their costs are included in the gross weight cost data.

Types of Trucking Services

Three types of trucking services were studied, as follows:

1. Line-haul (terminal to terminal more than 100 mi length of haul).
2. Warehouse to retail outlet with 4 or less stops per trip and with total trip length more than 100 mi, predominantly over rural roads.
3. Private road operation, logging and mining with daily travel more than 100 mi.

Types of Carriers

Data were obtained from four types of carriers: private, exempt-for-hire, common, and contract.

Variables of Trip Cargos

One element of line-haul trucking that is troublesome to analyze and has an effect on certain cost factors is the degree to which a vehicle consistently may have payloads in both directions of round trips. In many classes of carriage, it is normal practice to have a payload in only one direction. This is typical of most liquid hauling in tanks and of much of the hauling of dry flowable material in tanks, hoppers, and dump bodies. Much exempt-for-hire carriage is loaded in one direction and empty on return trip.

Trailer combinations in warehouse-to-retail-outlet service, with over-the-road travel, start with a full load at the warehouse and have a lesser payload after each stop, with an empty cargo body from the last delivery stop to the warehouse. Under opportune circumstances, however, such vehicles may be dispatched to suppliers to pick up return loads for the warehouse. Typical of this over-the-road service are State or regional distribution truck fleets of the large grocery chain stores.

In common, contract, and private general merchandise hauling, the degree of loading ranges from full loads in both directions to full loads in one direction with empty return trips. To investigate the effects on costs of these different degrees of loading, the cost data were analyzed according to the following degrees of loading in line-haul service:

1. Full loads in both directions;
2. Full load in one direction, all vehicles empty on return;
3. Full load in one direction, 10-40 percent of vehicles empty on return;
4. Full load in one direction, 40-60 percent of vehicles empty on return;
5. Full load in one direction, 60-90 percent of vehicles empty on return; and
6. Terminal to intermediate-stop service of not more than 4 stops and with full load at start with diminishing load to last stop before return.

Days per Week Operated

It was found that the workweek in the trucking industry varies between 5, 6 and 7 days a week. The selection of a 5- or 6-day workweek depends largely on local practices of consignees and shippers as to when their establishments are open to receive or ship freight. This variation in number of working days a week applies to all classes of carriers. However, only among the very long distance for-hire carriers were operations conducted around the clock, 7 days a week. Such operations are predominantly either relay operations, in which the vehicles go through with different drivers, or sleeper-cab operations with two drivers.

Number of Trailers per Power Unit

Some carriers own and operate more trailers than they have power units. This practice is quite prevalent among the large common carriers of general freight. Common carriers serving industrial plants with volume shipments find it desirable to have extra trailers to permit convenient loading and unloading of cargo bodies at shippers' and consignees' plants without tying up power units during the loading and unloading periods. This practice is encountered in all parts of the country. It appears to be more prevalent where tractors and semitrailers are used than where trucks and full trailers are operated. The reason for this may lie in the fact that tractive trucks require as much time for loading and unloading as full trailers, hence extra full trailers do not help much in keeping the power unit running. Certain commodities, such as lumber, livestock, and petroleum products, are loaded and unloaded in much less time than dry freight, and for these services the tractive truck and full trailer has a considerable degree of popularity.

In fourteen western States and in four central States there appears to be an increasing use of double trailer combinations; that is, tractor semitrailer and full trailer. Also, as previously remarked, several toll roads are permitting such combinations. Carriers operating such double trailer combinations usually have additional extra trailers to serve their customers more conveniently.

Inasmuch as trailer mileage does not exceed tractor mileage within the conditions of this study, it appears that the direct costs for operation of the different types of trailer combinations are not affected by the number of extra trailers.

Average Daily Mileages of Vehicles

Daily mileages of line-haul vehicles on days operated were found to vary from a low figure of about 100 mi a day to a maximum of nearly 900 mi a day. Daily vehicle mileages ranging from 200 to 350 mi are common in the eastern part of the country where much of the line-haul operation is at night and between cities that are not more than one driving shift apart. For trips with daily mileages between 350 and 900 mi, either relay or sleeper-cab operation is used. Some turnaround operations conducted by means of 3 driving shifts per day can run 400 to 600 mi a day with the vehicle always returning to its home terminal at the end of each driving shift.

Average Road Speed when Running

Another characteristic of trucking operation which may have an effect on direct costs is the average road speed of the vehicle when running. Maximum road speeds appear to be somewhat higher in the prairie regions of the West and on expressways and turnpikes than on rural roads in the East where towns and villages are relatively close together. Average road speeds over different classes of highways appear to indicate a 15- to 20-mph differential between the faster and the slower rural roads. In the industrial East on 2-lane primary roads, 25 mph is a typical over-all travel speed with, of course, some periods of speed in the neighborhood of 50 mph. In the prairie regions and on the expressways, over-all travel speeds of 40 to 45 mph are attained with maximum speeds around 60 mph. In the field work of the study, driving times were obtained for representative trips and routes of carriers. From these data average scheduled running speeds were calculated.

Types of Gradient on Routes

Fuel consumption and travel time vary (15), and possibly maintenance and tire costs may vary, with the rise and fall of a route. In a broad study such as this, it was not possible to develop rise and fall factors for each route used by a carrier. However, an attempt was made to classify different trucking operations as occurring in terrain that could be crudely classified as flat, rolling, or mountainous. These terms which are not precisely defined have been used by the highway engineers and in road benefit studies.

Types of Road Surfaces

Differences in road surfaces may have an effect on tire wear and tire costs, but it was not possible to study this factor in this study.

Types of Commodities Hauled and Related Services

The characteristics of the commodities hauled affect both the type of cargo body used and the number of loaded versus empty trips. Some exploration of the commodity differences and their effect on operating costs was made, but the results are not conclusive. To illustrate the nature of these variables, brief descriptions of typical classes of commodities and typical types of cargo bodies are described in the following schedule.

Packaged Commodities. — Packaged commodities are those shipped in cartons, boxes, fibre drums, and bags. They usually are classified as general merchandise or dry freight. In general such commodities are carried in closed or open-top van bodies. In areas where there is little inclement weather, some of these commodities may be carried on platform bodies with tarpaulin covers.

Refrigerated Products. — (1) Refrigerated solid products, such as frozen foods, are carried in refrigerated vans, which can maintain near zero temperatures. (2) Refrigerated liquid products, such as milk, may be carried in insulated tank bodies or, if in small containers, in refrigerated vans. (3) Fresh meats and dairy products are carried in refrigerated vans at higher temperatures than those required for frozen foods.

Fresh Fruits and Vegetables. — Fresh fruits and vegetables generally are carried to market in closed vans. Some vegetables require a mild degree of refrigeration for long hauls, whereas others require only ventilation. On hauls to processing plants open-top bodies usually are used.

Livestock. — Livestock is carried in rack vans which provide ample ventilation. Certain agricultural commodities, such as feed and fertilizer in bags, are backhauled with such vehicles, but otherwise return trips are without payload.

Liquid Commodities. — Liquid commodities in bulk, such as petroleum products and chemicals, are carried in tank bodies. A rather consistent feature of this service is that the backhauls are without payload.

Dry Flowable Commodities. — Dry flowable commodities in bulk, such as portland cement, grains, flours, coal, ores, sand and gravel, are hauled in tank, hopper, grain, or dump bodies, frequently with built-in unloading equipment. Return trips are usually without payload.

Building Materials. — Dry building materials, such as lumber, sheet board, brick, concrete block, pipe, and plastering and cement materials in bags generally are carried on van or platform bodies. Return trips are frequently without payload.

Automobiles. — Special automobile transporter bodies are used to carry finished automobiles. Return trips are usually without payload.

Logs and Poles. — Long objects, such as logs and poles, predominantly are carried on tractor semitrailers equipped with U-shaped bunks to carry the cargo. In a few logging regions where short logs are cut, flatbed cargo bodies are used. For pulpwood logs, variations of flatbed bodies are used. Return trips are without payload.

Household Goods and Furniture. — Household goods, furniture, and appliances are carried in closed vans with low floors which provide increased storage space needed for such bulky commodities. In the long-distance household goods moving business, vehicles usually have full or partial payloads all the time.

Steel Products. — Structural steel, pipe, sheet steel in rolls, and similar products are carried on platform bodies or on special bodies.

Machinery. — Road construction equipment, oil well equipment, and other large machinery usually are hauled on low-bed trailers with built-in equipment for loading and unloading.

These 12 types of cargos and related services include the main types of freight hauled in the United States. For other special commodities that do not lend themselves to transport by conventional bodies, special bodies adapted to specific jobs are used. None of such special bodies is included in the study.

Trailer Interchange

The interchange of trailers between carriers is increasing in order to provide better through-service by connecting lines. Whenever an even exchange of trailers is not made, daily charges are paid for the use of trailers. However, it would appear that interchange of trailers does not significantly affect unit operating costs. The topic has not been explored in the study.

Trailer-On-Flatcar Service

The expenses connected with the loading and unloading of trailers to and from railcars are charged to transportation accounts that are not included in this study. Travel on railcars is not considered as trailer-operated miles, and does not affect the line-haul operating costs which are developed in this study.

UNIT COSTS OF TRANSPORT RELATED TO LENGTH OF HAUL AND TYPE OF COMMODITY

In addition to the variables mentioned previously there are variations in vehicular operating costs that are related to length of haul and type of commodity. To eliminate some of these variables, data were collected from carriers the vehicles of which ran predominantly more than 150 mi per day. This mileage selection was made after preliminary review of a number of economic studies of intrastate motor freight transportation in California (16), which showed that direct operating costs per vehicle-mile remained quite uniform for each commodity for trips greater than 150 mi in length. The engineering section of the Transportation Division of the California Public Utilities Commission (16) makes engineering economic studies of highway transport of various commodities for the consideration of the Commission in motor freight rate hearings. These data were not directly useful in the cost calculations, but are included to illustrate the effects of trip lengths and types of commodities in the establishment of motor freight rates.

In Figures 1 to 9 are curves indicating for nine different types of commodities the

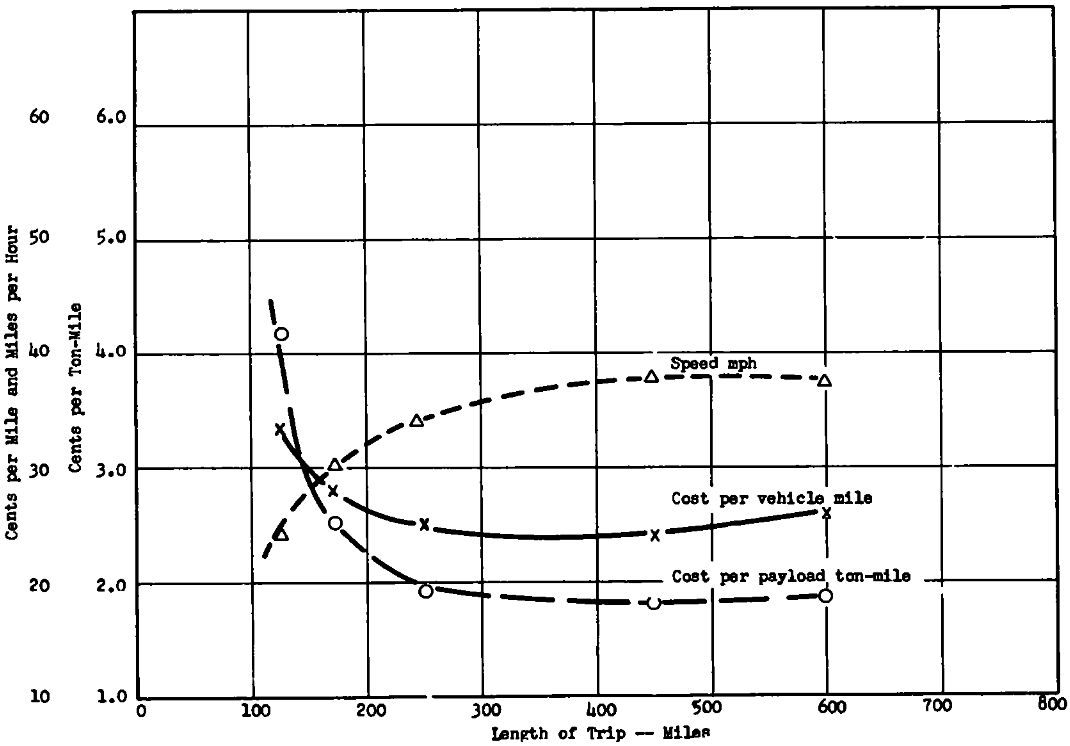

Figure 1. Line-haul trucking costs and average travel speeds for general freight in truck loads in California (16).

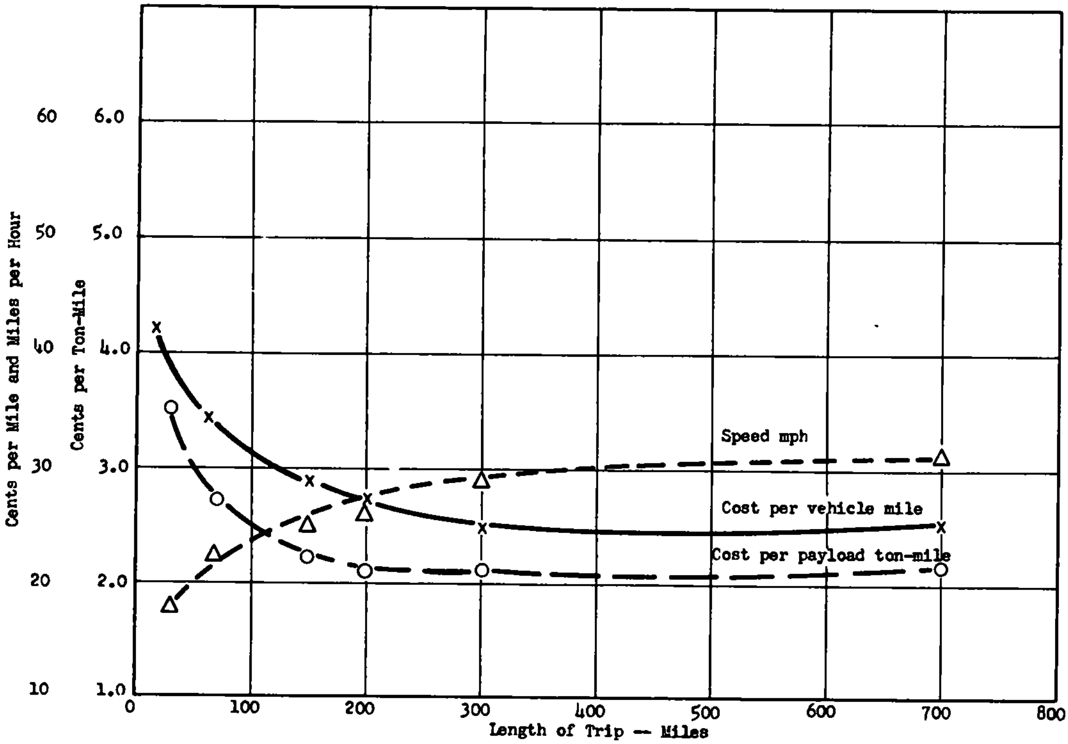

Figure 2. Line-haul trucking costs and average travel speeds for gasoline and petroleum products in truck loads in California (16).

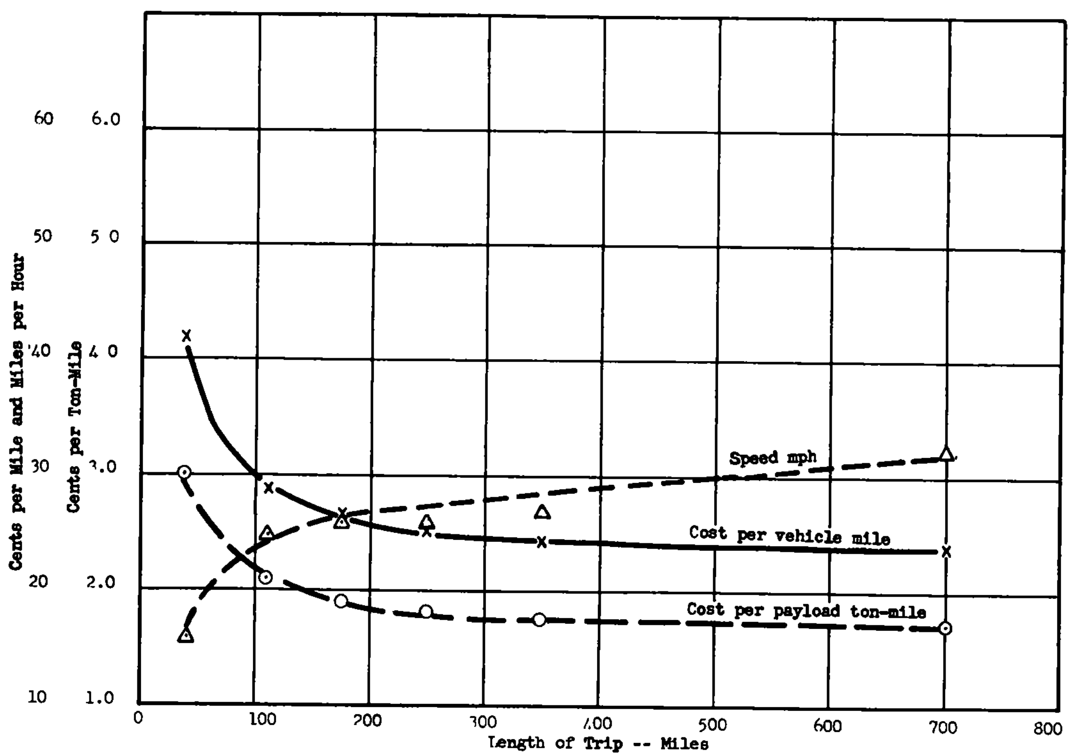

Figure 3. Line-haul trucking costs and average travel speeds for beer in bottles and cans in California (16).

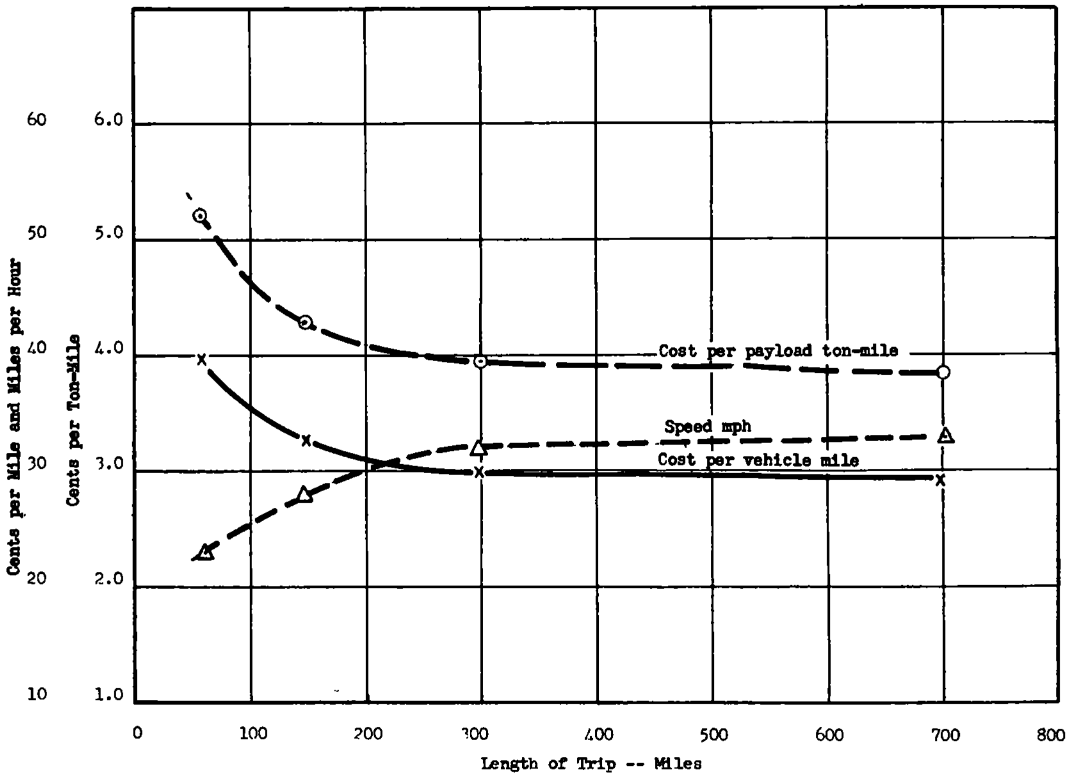

Figure 4. Line-haul trucking costs and average travel speeds for cattle in California (16).

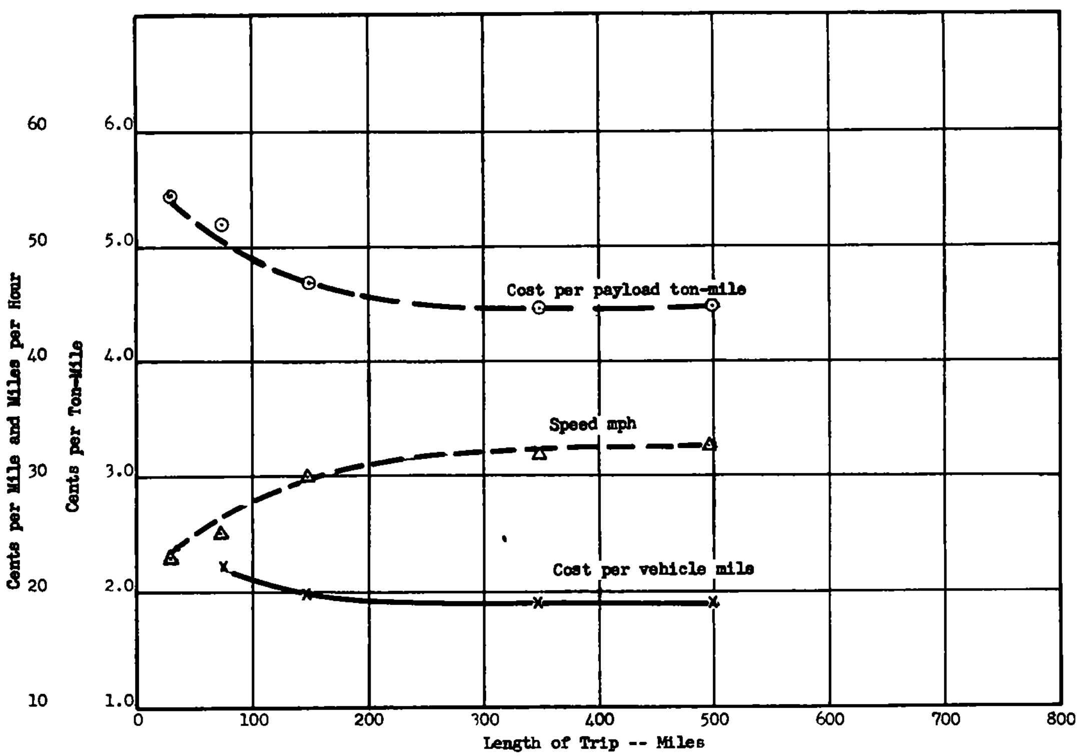

Figure 5. Line-haul trucking costs and average travel speeds for automobiles in California (16).

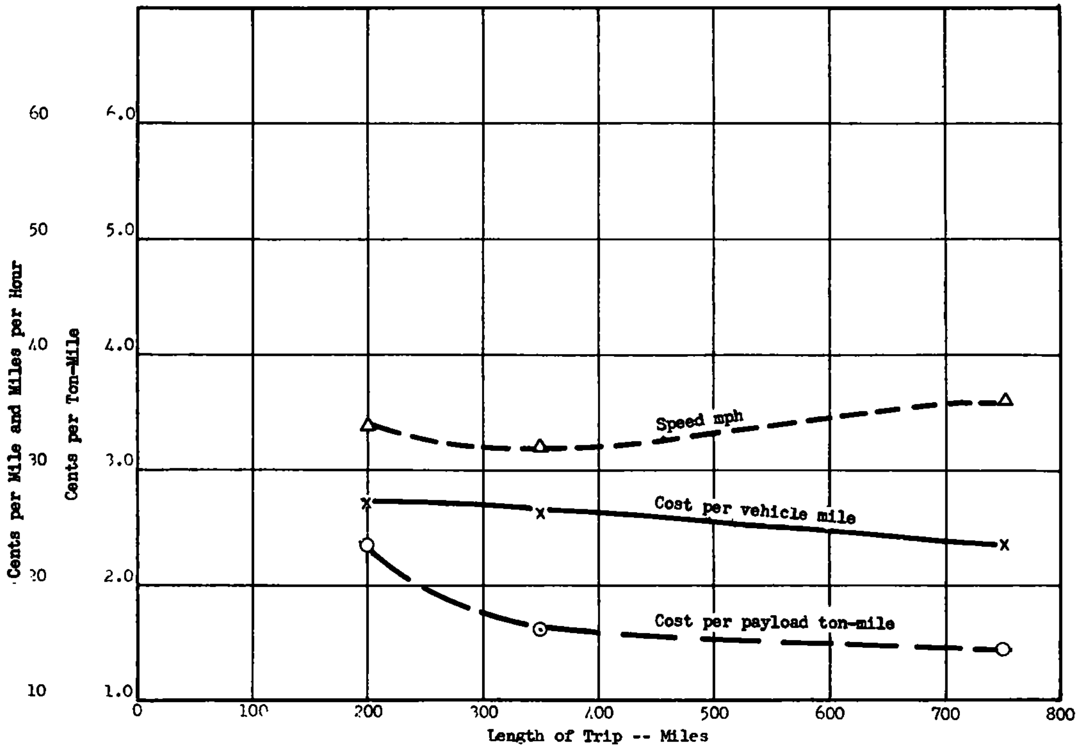

Figure 6. Line-haul trucking costs and average travel speeds for lumber in California (16).

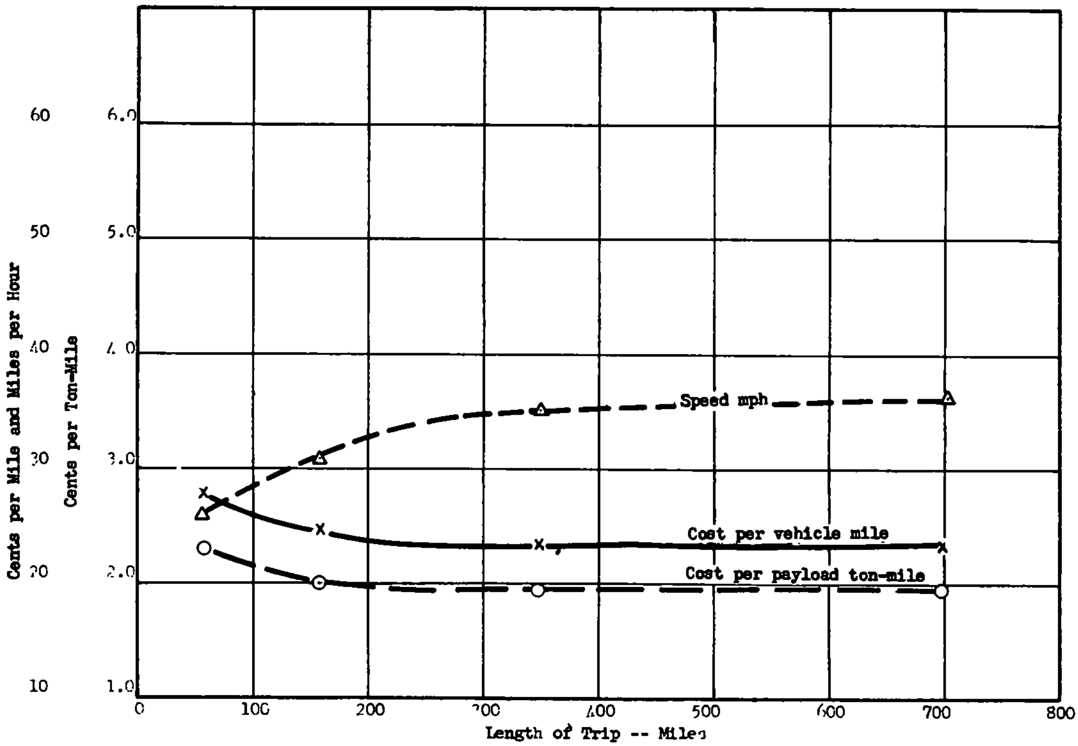

Figure 7. Line-haul trucking costs and average travel speeds for bulk cement in California (16).

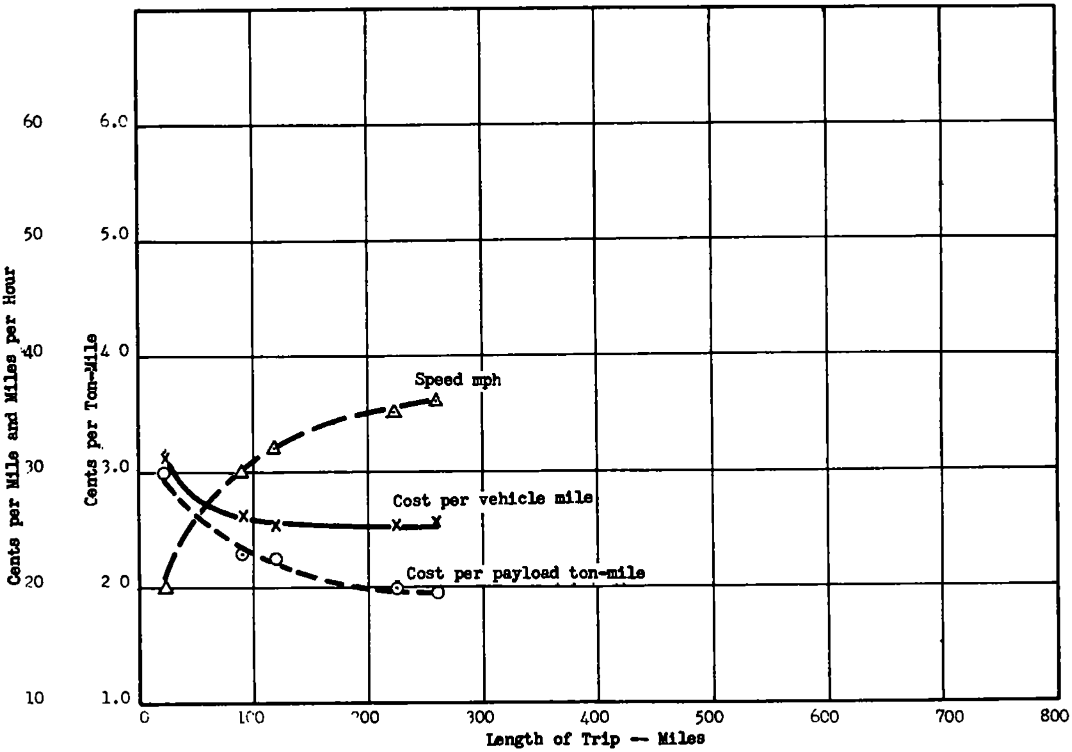

Figure 8. Line-haul trucking costs and average travel speeds for citrus fruits in California (16).

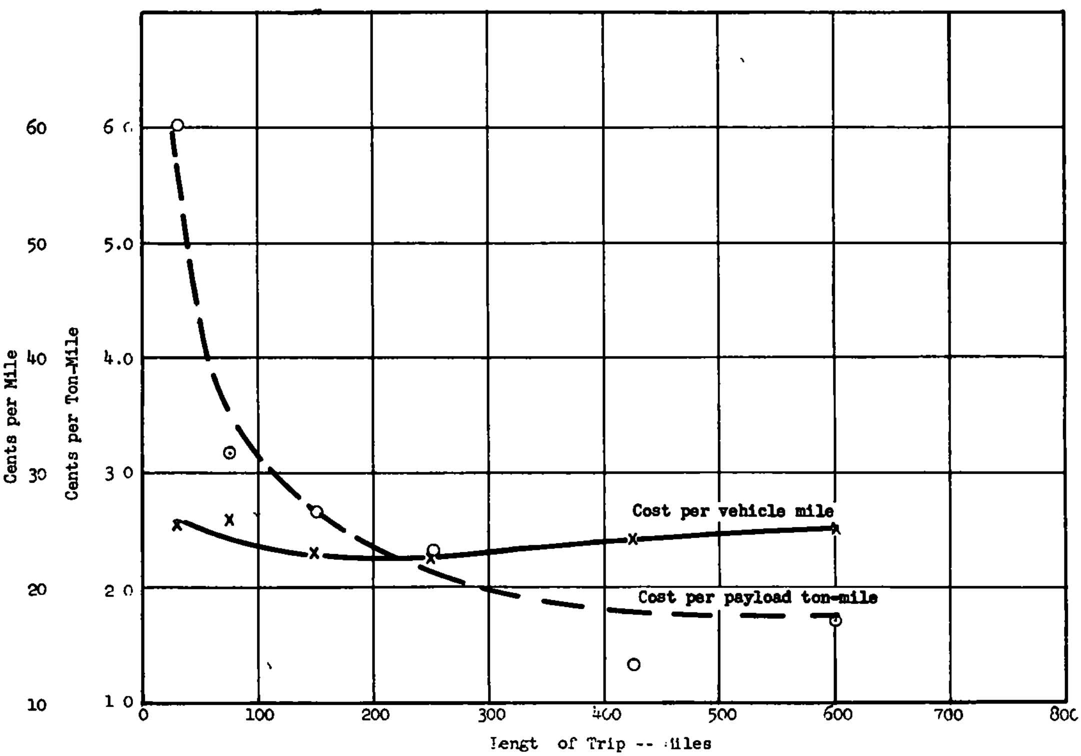

Figure 9. Line-haul trucking costs for fruits and vegetables in California (16).

variations in line-haul operating costs per vehicle-mile, in costs per payload ton-mile, and in average vehicle speeds for different lengths of haul. The costs shown reflect one-way costs for commodities which have revenue backhauls, and round-trip costs where the return trip is without revenue payload. The average speed data are calculated for either the one-way trips or the round trips whichever are used to determine the unit costs. Although there are differences in unit costs between commodities at different lengths of haul, it will be noted that the unit vehicle costs for each type of commodity begin to level off at lengths of haul greater than 150 mi.

By using line-haul data from carriers, the vehicle operations of which were preponderantly greater than 150 mi a day, the many irregular variables in short-haul service, that are difficult to adjust or to compensate for, were avoided and resulted in a better consistency in the line-haul data.

Boundaries of Trucking Cost Study

PROBLEM OF VEHICLE SIZES

From the preceding discussion and background information, it is evident that the solutions to the two problems of maximum vehicle sizes and maximum vehicle (and axle) weights will require different approaches. For a given vehicle width, such as the present 8-ft width on a 12-ft pavement lane, an increasing scale of axle and vehicle gross weights can be related costwise to the initial and annual costs of highways, and thus will provide an economic measure of the benefits of any greater weight allowance.

Insofar as vehicle dimensions are concerned, the economic measurements are much more difficult, because the different dimensions have different effects, and the benefits of size do not apply to all freight. Also it must be assumed that carriers would prefer uniformity in freight vehicle sizes in all the States, and that this uniformity must be feasible in both urban and rural areas. Single trip, overlength and overwidth vehicles for the handling of special loads would continue to travel under special permit, and their maximum sizes and weights are not a part of the study.

Maximum vehicle lengths are governed by the maneuverability of vehicles and trailer combinations in the streets and roads over which they may travel. For a general maximum length of a single vehicle, the present predominant allowed length of 40 ft for a trailer appears to be a feasible limit. As discussed earlier, this length of semitrailer in a single trailer combination can be maneuvered with care through existing city streets so as not to hamper other traffic. For double trailer combinations in city streets, shorter trailers are necessary, whereas two 40-ft trailers can be used in double trailer combinations on major rural roads with geometric design features similar to those of the toll roads and the new Interstate System. Trailer length affects the cubic capacity of a trailer and may result in greater payload and greater gross weight, but does not require any increase in pavement lane width.

Permissive heights are dependent on bridge and tunnel clearances, whereas desirable heights are dependent on the height to which freight packages may be stowed one upon another, and on the transverse stability of the loaded vehicle. The present height of 13 ft 6 in. allowed in 23 States appears about optimum for present width allowances of 8 ft.

Width is a dimension that does not have strong economic advantages, but does have good engineering justification. Additional width would permit larger tires, improved brake and spring construction, improved transverse stability, and additional cargo capacity for light density freight and freight with one standard dimension of 8 ft such as building board. Haulers of freight with densities less than 25 pcf could gain additional revenue from additional payload and still have their weights under present weight limits. Only about 10 percent of highway freight weighs less than 25 pcf. Carriers of heavier commodities could gain in payload and revenue from additional width, only if gross weight allowances are increased, because they currently cannot load cargo bodies visibly full without exceeding permitted axle and gross weights. In the study, it was found that differences in trailer sizes, per se, were not as significant in their effects on operating costs as were differences in gross weights; hence, operating costs by sizes of vehicle could not be evaluated. This does not imply that the desirable engineering features obtainable with a greater width are not sufficient justification for a 6-in. increase in width. The engineering advantages may override the last of economic data in regard to width effects.

For these reasons, the following discussion and the remainder of the report are concerned primarily with the gross weight of trailer combinations, and secondarily with such variables as axle weight, vehicle type, and cargo capacity. The last three variables are closely associated with gross vehicle weight which can be related costwise to the original and annual costs of highways and bridges designed to carry the vehicles. By stipulating that vehicle sizes cannot be evaluated costwise, either with regard to vehicular or highway costs, the committee's task is somewhat simplified as only the cost effects of axle and gross weights on pavements and bridges need be considered.

As a matter of information, the following schedule gives the maximum sizes allowed in various States in continental United States.

Height		13 ft 6 in.	23 States
Height	more than	13 ft 6 in.	4 States
Width		8 ft	46 States
Width		8 ft 6 in.	2 States
Length, trailers		40 ft	46 States
Length, tractor semitrailer		55 ft	16 States
Length, truck full trailer		65 ft	7 States
Length, tractor semitrailer and full trailer		65 ft	7 States
Length, tractor semitrailer and full trailer		98 - 105 ft	5 toll roads

As indicated by the schedule many of the States do not now permit these maximum sizes. Accordingly there does exist the problem of selecting maximum sizes which will be universally acceptable to all the States and all the carriers. This size problem can be approached primarily from the standpoint of a given vehicle's demonstrated use and practicality, and the geometrics of modern highways and streets.

WEIGHT STUDY

In the study of the effect of weight, the first concern was to be sure that the differences in operating cost, as reported, were the result of differences in gross weight or factors closely related thereto, and not of other variables in the observed data wholly unrelated to vehicle weight. Such extraneous variables had to be eliminated or reduced in their effects as far as possible. This requirement necessitated adjustments in the raw data, adjustments which it is believed are not unreasonable when it is considered that the original operating cost data were obtained from all types of motor carriers operating a variety of vehicles under different local levels of wages and prices in different parts of the nation.

The stipulations previously made — that is, the decision to eliminate consideration of local delivery and pickup operations and the conclusion that size of vehicle, per se, is not a significant determinant of operating cost — simplified the problem and enabled the development of vehicular costs which, it is reasonable to presume, are affected in their differences only, or at least mainly, by the differences in axle and gross vehicle weights.

LINE-HAUL TRUCKING COSTS

The vehicular costs derived in this study relate only to the line-haul transport of freight. The line-haul costs are developed in such manner as to bring out the differences in vehicular costs that result from differences in the primary factor of gross vehicle weight and in the secondary factors of vehicle type, vehicle cargo-carrying capability, and other operating factors. The reported costs are not comparable with freight rates charged for transporting any specific commodity in any specific part of the United States, because the data are a composite of line-haul costs observed in many types of motor freight carriage in all parts of the country. Nor do the costs reported reflect completely every facet of for-hire or private trucking operations. They relate, as stated, only to the line-haul phase of the operation of freight trailer combinations, including the operations of private, exempt-for-hire, and certificated for-hire carriers. Accordingly the costs to not include: (a) pickup and delivery services, (b) terminal expenses (loading and unloading of cargo), (c) sales solicitation expenses, (d) accounting and revenue billing expenses, (e) legal expenses, (f) communication expenses, (g) freight claim loss and damage expenses, (h) road-user fees and taxes (fuel and registration), and (i) expenses and fees for doing business as for-hire carrier. Although these listed costs are important in the development of freight rates, they are not applicable to the vehicle-road economics of line-haul freight transportation.

As discussed earlier, a length of 150 mi was considered as the minimum length of daily travel for which operating costs would be collected in the study. Most of the travel by the vehicles studied considerably exceeded this minimum, but data were collected for a small number of vehicles operating as few as 100 mi per day.

Comprehensive data were obtained for trailer combinations ranging in gross weight from 30,000 to 75,000 lb. A lesser amount of data relating to gross weights between 75,000 and 192,000 lb were obtained from trucking operations on public and on private roads where the daily travel met the study criteria.

Study Data

METHOD OF OBTAINING DATA

The field data for this study were obtained by interviewers who called on the individual motor carriers and asked for their voluntary participation in the study. It was presumed at the start and later confirmed that the degree of detail derived could not possibly have been obtained by a mail questionnaire.

In addition to obtaining operating cost data it was also necessary to obtain considerable information regarding the horsepower and tare weights of power units, the payload usually carried, the degree of empty operation, characteristics of the commodities carried, and other operating detail. These types of data, together with considerable other detail regarding the vehicles themselves, were not obtainable from carrier reports, such as those made to the Interstate Commerce Commission or to State public utility commissions. Also, information regarding the retirement of vehicles, types of fuel, actual prices paid for fuel, wage rates, hours of work, and operating practices, which are not available from published reports, were obtained from each carrier.

It was found that a number of carriers operated two distinct types of combinations for which they kept individual or group cost data. Each of these groups of similar vehicles could be considered and was reported as a separate case for this study, a thing which would not have been possible from the carrier's reports to regulatory commissions. Also, as there was no interest in city delivery operation, it was possible by calling on the carriers to obtain a better separation of costs of line-haul operation from the costs of city pickup and delivery and rural peddle service.

Some 4,500 carriers were contacted in 36 States. Of this number approximately 15 percent had records which would supply data useful for the study. The work of collecting the field data was a cooperative research project carried out with the assistance of the planning divisions of the State highway departments in 33 States. A pilot study in three States was conducted by the Bureau of Public Roads' staff to obtain information and develop the techniques of collecting the detailed data.

One of the real difficulties in the study was the fact that only a limited number of the carriers kept cost records by groups of similar vehicles, even though they operated more than one type or capacity of trailer combination. The accounting information, which was kept by many carriers, was such as would reveal the position of the business as a whole for top management, but would not show vehicular cost data. In those cases where a carrier's records could not be related to specific groups of similar vehicles, the interview was quickly terminated.

ADJUSTMENTS NECESSARY IN TRUCKING COST DATA

The actual cost data obtained from carriers involved unit prices of materials and wage rates which varied in different parts of the country. Because it was desired that the operating costs obtained from the widely scattered carriers should vary, as nearly as possible, only with the gross weight and type of the trailer combinations, it was necessary to make adjustments in the cost data obtained from different carriers to compensate for regional differences in prices and wages. Such variations occurred in wage rates, driver subsistence costs, fuel prices, property taxes, insurance costs, garage costs, employee fringe benefits, and other items.

The bases of adjustment of such irregular prices are given in detail in sections of the report descriptive of the several cost accounts which follow. In general, the prices and values used for the adjustments approximate either the median or the mode of the prices and values reported by the carriers or determined from other sources. In certain elements of indirect and overhead costs, the variations were so great between the carriers that the costs of such functions were developed around a schedule of factors which were representative of best carrier practice. Moreover, these adjusted prices and values were not developed by elaborate statistical methods, nor was such a refinement deemed essential for purposes of the study. The adjusted prices and values selected can be considered as representative of the general levels of prices and values prevailing in the United States in 1956. Anyone desiring to use the data of the report in a specific situation can do so by comparing the prices and values existing in the situation in question with the values and prices used herein and then making appropriate adjustments in the several cost accounts.

ARRANGEMENT OF CUMULATIVE ACCOUNTS IN REPORT

Thirty cost accounts in the ICC Uniform System of Accounts (17) are related to line-haul trucking operations. These accounts were used as a guide in assembling and analyzing the cost data of the study. The descriptive context of these accounts is not included in this text, because the details may be read from the ICC booklet (17). The titles of the expense accounts are descriptive and generally will suffice for many readers. However, for those readers who need more precise understanding of the accounts, the appropriate account numbers are shown after the account titles.

The ICC Uniform System of Accounts was not an ideal schedule of accounts for this cost study, but it was available in printed form and was used by many carriers. Generally, the data were collected from carriers according to the ICC system, but for certain accounts the carrier data were inadequate and other methods of developing the costs were used. Where such different procedures were used, they are described in appropriate sections. In all instances, however, the developed cost data are in line with the ICC account descriptions as they apply to line-haul operations.

To indicate the trends in vehicle-mile costs, it was expedient to group and accumulate the individual expense accounts under six general descriptive headings. Cumulative unit cost curves also are developed under these general headings.

The general headings of these groups of vehicle-mile costs are arranged in cumulative order, as follows:

1. Repair and servicing costs;
2. Direct maintenance costs;
3. Direct vehicular costs;
4. Direct running costs;
5. Total running costs; and
6. Gross operating costs.

The vehicle-mile costs that are accumulated under these general headings include data described by the expense accounts shown in the following schedule. The numbers following the name of the account are the ICC account numbers.

1. Repair and servicing costs include: repairs and servicing, line-haul equipment (4131); and oil for revenue equipment, line-haul equipment (4261).

2. Direct maintenance costs include all the foregoing accounts plus: tires and tubes, line-haul equipment (4161).

3. Direct vehicular costs include all the foregoing accounts plus: fuel for revenue equipment, line-haul (4251).

4. Direct running costs include all the foregoing accounts plus: drivers and helpers, line-haul equipment (4231); and other transportation expenses (4280).

5. Total running costs include all the foregoing accounts plus indirect and overhead costs which include: maintenance supervision (4110); maintenance office and other expenses (4120); other maintenance expenses (4180); transportation supervision (4210); transportation office and other expenses (4220); insurance and safety supervision (4510); insurance and safety office and other expenses (4520); other insurance and safety department expenses (4580); public liability and property damage insurance (4530); fire, theft and collision insurance (4560); workmen's compensation insurance (4540); Social Security taxes (5240); employees' welfare expenses (4645); real estate and personal property taxes (5230); salaries — general officers (4611); salaries — other general office employees (4613); expenses — general officers (4621); expenses — general office employees (4622); and other general office expenses (4623).

6. Gross operating costs include all the foregoing accounts plus: depreciation of structures (5010); depreciation of service cars and equipment (5030); depreciation of shop and garage equipment (5040); depreciation of revenue equipment, line-haul (5020); and interest (7100).

The unit vehicle-mile costs reported in the study are costs for complete trailer combinations. Useful carrier data were found in two forms. Some carriers kept cost records of individual vehicles. In such cases the records of similar vehicles were grouped together during analysis and calculated with the total annual mileage of the group of vehicles to obtain average unit costs. Other carriers kept their records on the basis of groups of similar vehicles, and these group data were calculated with the group mileage to obtain average costs. These average data from the numerous fleets were then arrayed by type of combination and by levels of gross combination weights using the least-squares method.

There are a variety of differences between the different vehicles that make up trailer combinations. Power units were classified as similar when they were uniform with regard to the following criteria: type of fuel used; engine displacement within an increment of approximately 100 cu in.; whether tractive truck or tractor; and whether with 2 or 3 axles. Trailers were classified by semitrailer or full trailer, by number of axles, and by cargo body type. Complete trailer combinations were classified by type of power unit, axle arrangement, arrangement and number of cargo bodies, and typical gross weight when loaded for road trips.

The unit costs were further analyzed to learn the effects of items, such as average travel speed when running, terrain, degree of loading on outbound and return trips, number of days operated per week, and commodities hauled.

REPAIR AND SERVICING COSTS

Due to the fact that engine oil consumption is primarily related to engine condition and wear, and because other studies (18) have shown that oil costs are small and have almost no correlation with gross weight, engine oil was included as one of the lubricants used in repairing and servicing vehicles. Thus engine oil costs are summarized with repair and servicing costs. Engine oil costs were obtained from carriers' records and were adjusted to an average price of $0.675 per gallon, less Federal tax. The actual prices paid for engine oil ranged from $0.42 to $1.31 a gallon, less Federal tax.

In compiling repairs and servicing costs there were two types of extraneous variables which required adjustment. One was the great range of wage rates paid mechanics. The second was the ownership of the shop and garage facilities used to maintain the fleet. Where a carrier company owned its shop and garage facilities, it had an investment in real and personal property for which there were the costs of depreciation, interest on investment, and local property taxes. Such a company also had supervisory expenses which are reported in the appropriate expense accounts. On the other hand, if a carrier farmed out its repair and servicing work to dealers or independent garages, these same investment and supervisory expenses were included in the invoices from the dealers.

For the purposes of the study, it was desirable to have all the repair and servicing costs computed on the same basis. The basis selected was that the work be done in company-owned garage facilities. This plan made it possible to set up investment costs and other overhead costs on a comparable basis. To do this required the adjustment of the repair and servicing costs of those carriers that did not own and operate shops. It was found that the usual practice among truck dealers was to bill a customer for labor at a rate which included a 100 percent overhead for plant costs and supervision. Parts and supplies were billed at list prices, which were reasonably constant throughout the country. It was also found that dealers' billings were about evenly divided between costs of parts, and costs of billed labor. In other words, the make-up of outside shop invoices was approximately 50 percent parts, 25 percent labor wages, and 25 percent dealer's overhead and profit.

To make costs from company-owned shops and from dealers' shops comparable it was necessary to adjust the costs from dealers' shops. The costs from carriers with company-owned garage facilities were used as recorded. Where a carrier used outside shops extensively, its costs were reduced 25 percent which approximately eliminated the dealers' overhead charges and made the labor and material costs comparable with those obtained in company shops.

This first adjustment, however, still left the variable of mechanics' wage rates to be adjusted. The field interviewers obtained from each carrier the local wage rates paid journeyman mechanics, either in the company's shop or at local dealer shops. The reported wage rates varied from $1.25 to $3.10 an hour. The average of the rates encountered was $2.17 an hour.

To adjust for differences in wage rates, one-third of the adjusted costs of repairs and servicing was assumed as the cost of labor. This labor cost was adjusted up or down according to the ratio by which the reported journeyman rate in a given case was above or below the average rate of $2.17 an hour. The adjusted labor cost then was added to the parts cost to obtain adjusted repair and servicing costs. The adjusted costs then were arrayed by type of combination, gross combination weight, and engine type by the least-squares method to show the trends in these costs.

TIRE AND TUBE COSTS

Data for tire and tube expense were collected from motor carriers' records for line-haul vehicles. In general, the tire costs are partially related to vehicle gross weights by reason of the practice of using tire sizes that are appropriate to the axle weights. Thus the low gross weight trailer combinations, those under 30,000 to 35,000 lb, use smaller tires than the heavier vehicles. Preponderantly, the tires used in the line-haul service are of the 10.00 and 11.00 sizes for 18,000- and 22,400-lb axles, respectively.

Tire sizes and axle weights are not the entire explanation of differences in tire costs. Purchase discounts vary somewhat among carriers; and the condition of road surfaces predominantly traveled also affects costs. Even though tires with rayon fabric and an increasing proportion of nylon fabric were in use during the period of the field work, there still existed a considerable difference in tire recapping practices among carriers. All of these factors combine to make the tire cost data less precise than the ideal. However, the tire costs do represent a general over-all average of existing tire use. The number of tires and the loads on a given type of trailer combination may account for most of the differences in tire costs. It was not possible to develop any relationships with pavement surface types.

Inasmuch as the tire cost data collected were for three different years, the tire costs were adjusted to a 1956 level of net tire prices to large carriers. A separate side study was made of tire prices and of representative fleet discounts. The multiplying ratios used in adjusting tire costs are given in the following schedule:

Year	Multiplying Ratio
1956	1.00
1955	1.06
1954	1.14

These index ratios are based on the assumption that the fleet tire discounts, representative of 1956, were a chain of six 10 percents. For example, a 10.00 x 20 rayon tire with a list price of $181.55 costs the carriers approximately $96.40, less tube and taxes.

Tire costs were segregated and analyzed according to the differences in operating and vehicular factors discussed earlier in order to obtain unit costs by gross vehicle weights.

FUEL COSTS

Fuel cost data were collected from carriers' records. The fuel costs reported are less Federal and State fuel taxes. The fuel taxes are not included in fuel costs because these are road-user taxes and represent the carriers' payments for the use of the highways. The committee's complete study contemplates developing vehicle-mile cost differentials for highways of different load capabilities, and these highway unit costs will be combined with vehicular costs to develop over-all transportation costs by gross vehicle weights. Hence, to include road-user fuel tax fees with vehicular costs would result in a dual charge for highway facilities in the over-all transportation cost figures.

Net prices for fuel varied considerably among the carriers interviewed. These variations were caused by differences in volume purchases, in discounts, and in tank wagon prices which generally are related to distance from a refinery. During interviews the cooperating carriers were asked for their predominant net prices paid for gasoline, diesel fuel, and LP-Gas.

To eliminate the variable of different net prices, the fuel costs of the individual carriers were adjusted to a modal price for each type of fuel. The modal prices used are as follows:

Gasoline	$0.151 per gal
Diesel fuel	$0.131 per gal
LP-Gas	$0.090 per gal

Each carrier's fuel costs were adjusted by the percentage difference between the carrier's net price and the modal price.

Fuel costs were segregated and analyzed by type of fuel and according to the differences in operating and vehicular factors discussed earlier in order to obtain unit costs by gross vehicle weights. Because of the relatively few vehicles encountered which used LP-Gas, fuel costs were not developed separately for vehicles with LP-Gas engines; their costs are included with gasoline engine vehicles.

DRIVERS' PAY COSTS

In the trucking cost study it was essential to develop mileage cost figures for line-haul drivers' work that would indicate how driver costs are affected by changes in the gross weights of the various combinations. Because of the great differences in industry practices in regard to the work assignments of drivers, and because of extraneous cost elements (vacations, overtime, etc.) included in the typical accounts for drivers' wages, it was not feasible to develop the drivers' costs, while driving, from the accounts of carriers. It was found that drivers' wages for line-haul service were accumulated in an account which generally conforms to ICC account No. 4231, "Drivers and Helpers—Line-Haul Equipment" (17), in which bonuses, vacation pay, and all wages paid the drivers, whether driving or not, were included. Thus the account included pay for any loading and unloading of cargo enroute, pay for waiting to be dispatched on a run, pay for delay time caused by mechanical or other reasons, pay for deadheading time, bonus for certain commodities, overtime when paid, and paid time for paperwork at the start or end of a trip. Most of these extraneous elements are not related either to driving performance, or to the gross weight of a combination. The effect of these various payments to drivers for work other than driving may be to inflate driver mileage costs to the level of $0.20 per mile. Obviously such a variety of costs is not useful in a study to determine differences in costs resulting from variations in gross vehicle weights.

Motor carriers compute drivers' payrolls by different methods using a variety of pay rates. The different methods of calculating drivers' pay include payment for miles driven, payment for hours worked, payment for days worked, payment for units of commodity carried, and agreed on pay for specific runs and payloads. Line-haul drivers under ICC jurisdiction are not under Wage and Hour Administration regulations, and generally are paid on a straight performance basis, but some contracts do carry overtime provisions.

In addition to the variety of computation methods, there are considerable variations in unit rates for similar types of vehicles between different parts of the country. For example, hourly wage rates for truck drivers were found to vary from $1.20 per hour to $3.09 per hour. The unit rates reflect differences in local living costs and in traffic conditions which may affect the distance that can be traveled in an average hour. Also owner-operators, driving their own power units to haul carriers' trailers, frequently are paid on a percentage of revenue basis.

It was found impracticable in the field interview work to obtain sufficient detail of all of the variations in pay methods and pay rates. Hence, a satisfactory statistical adjustment could not be made of these many variables to obtain driver wage costs per mile that would reflect changes in drivers' pay resulting only from changes in gross vehicle weights. For this reason, after a review of the field data, representative mileage wage rates were developed from the study of a number of labor contracts which specified different mileage rates for different sizes of trailer combinations. The advantage of developing and using specific mileage wage rates is that any reader may readily adjust this element of cost for a specific situation by comparing the assumed mileage wage rates with the rates prevailing in a given local situation.

In 23 States, mileage rates were the prime basis for paying line-haul drivers. These States were Alabama, Arkansas, Colorado (in which different rates are specified for north and south of Denver), Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, Tennessee, Texas, and Wisconsin. These mileage rates increase with increases in the size of the vehicle or combination when measured either by the type of combination or number of axles. An analysis of the contract mileage rates in these 23 States produced the following average rates in 1956 for various combinations: 3-axle tractor semitrailers, \$0.07534; 4-axle tractor semitrailers, \$0.07784; 5-axle tractor semitrailers, \$0.07961; and double cargo vehicle combinations (truck full trailer, or tractor semitrailer and full trailer), \$0.08719.

In addition to the straight pay based on mileage rates, it can be expected that, in the normal run of line-haul trucking operations, drivers will regularly receive a certain amount of pay for such nonproductive time as that spent in waiting for dispatch and preparing daily reports. (Vacation and holiday pay in this study is assumed to be a fringe benefit and is not included in drivers' cost but is in fringe benefits expense.) Preponderantly such nonproductive time is paid on an hourly basis. The effect of these nonproductive costs is to increase the average cost per mile of operation, because the drivers receive additional pay without driving additional miles.

To estimate the amount of such nonproductive pay, a sample study was made to compare driver's wage costs per mile, calculated from payrolls, with modal mileage rates from labor contracts. As might be expected the calculated costs per mile varied greatly between different operations and different scheduled runs. The increased cost varied from 20 to 50 percent above contract rates. These actual additional costs included pay for sleeper-cab driving, delay time on the road, waiting time at terminals, deadheading time, overtime, vacations and holidays, as well as an allowance for drivers' paperwork at start and end of trips. The drivers' paperwork includes completion of ICC drivers' log, equipment defect reports, handling of manifests and freight bills, and making out daily pay tickets. These last duties are a regular part of the line-haul driver's job, whereas the other payments for road delay time, etc., are not a function of mileage driven nor are they related to type and gross weight of vehicle.

To eliminate the extraneous costs and still include a reasonable drivers' terminal time, it was assumed that a driver's daily paperwork and terminal time would not require more than ½ hr daily. Although this nonproductive time would be paid on an hourly basis, it was assumed that the hourly rates are proportional to the mileage rates; hence, the mileage rates may be increased proportionally as developed hereinafter.

Not all line-haul runs require the full 10 hr of driving permitted by the ICC Motor Carrier Safety Regulations (19). It was assumed that a representative line-haul driver's time, while driving, averages 8.5 hr per working shift. Some nonpay time is required during a working shift for meals and personal requirements which with the terminal time will make up a representative shift time of 10 hr daily. Under these assumptions the driver's make-ready time approximates 5.6 percent of the pay time. As an estimate to cover such make-ready time the contract mileage rates were increased by 5.6 percent. Mileage rates adjusted to include drivers' make-ready pay are as follows:

3-axle tractor semitrailers, $0.0796; 4-axle tractor semitrailers, $0.0822; 5-axle tractor semitrailers, $0.0841; and double cargo vehicle combinations (truck full trailer, or tractor semitrailer and full trailer), $0.0921.

This schedule of contract mileage rates indicates an increase in rates with an increase in the size of the combination. To evaluate the ratio of pay increase to gross weight, practical gross combination weights were assigned to the different trailer combinations as follows:

Description	Gross Weight, lb
3-axle tractor semitrailers	38,000
4-axle tractor semitrailers	52,000
5-axle tractor semitrailers	66,000
Double cargo vehicle combinations	74,000

These data are plotted in Figure 10. It will be noted that the three mileage rates for drivers of tractor semitrailers lie approximately on a straight line. This line projected indicates a reasonable trend of drivers' costs for these types of trailer combinations at the higher gross weights that would result if axle and gross weight allowances were increased.

The one mileage rate for double cargo vehicle combinations, either truck and full trailer or tractor semitrailer and full trailer, is $0.0063 above the rate for the same gross weight of tractor and semitrailer. This differential may be a payment for the additional skill required to drive the double trailer combinations. It was assumed that the slope of the curve for the double cargo vehicle combinations will parallel the one for the tractor semitrailers, and that it can be extrapolated for gross weights much above those now permitted. Such an extrapolation is shown in Figure 10.

Mileage wage rates do not change with weight increments of only a few pounds, and

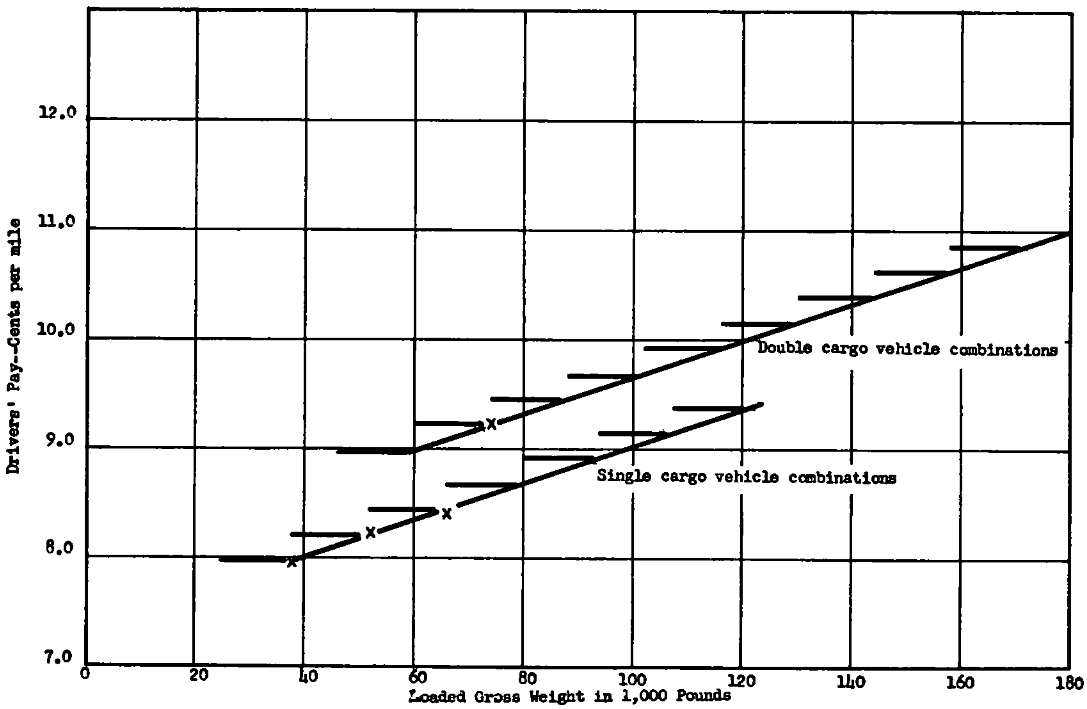

Figure 10. Drivers' wage rates per mile by gross weight of trailer combination.

hence should not be picked directly from the curves in Figure 10 for such small increments of weight. From inspection of the data, it was evident that the mileage wage rates would be constant over weight increments of approximately 14,000 lb of carried gross weights as the vehicles are customarily loaded. Consequently a 14,000-lb increment between pay steps was assumed to apply along both curves. Return trips with no load are assumed to pay the same rate as for the initial loaded trip. Table 20 gives wage rates for 14,000-lb increments of gross vehicle weights for both single cargo vehicle and double cargo vehicle combinations. The mileage wage rates given are assumed for the purposes of this study to apply to the appropriate types of combinations of the listed gross weights. In any given situation, such as an improvement benefit study where the actual drivers' mileage rates may be obtainable, the drivers' cost per mile may be adjusted by the ratio between actual local rates and the assumed rates.

DRIVERS' SUBSISTENCE COSTS

In long-distance line-haul freight hauling there are additional drivers' costs which are accumulated in carriers' accounts similar to ICC account 4280 "Other Transportation Expense." Included in this ICC account are driver subsistence expenses for meals and lodging when away from home terminal, which expenses should be included in the line-haul trucking costs, as well as carrier costs for badges and uniforms, fines, bridge and highway tolls, weighing charges, and extra labor hired by a driver when away from the carrier's terminals. Also included in this account are similar expenses of city delivery drivers. Applicability of these expenses varied greatly among carriers, some having almost none, whereas others had considerable amounts. For these reasons, it was not feasible to develop representative costs from available carrier data; instead, a representative cost for drivers' away-from-home subsistence was developed as discussed hereinafter.

TABLE 20

DRIVERS' MILEAGE WAGE RATES BY GROSS COMBINATION WEIGHTS

Single Cargo Vehicle		Double Cargo Vehicle	
Gross Wt. (lb)	Pay Rate ($ per mi)	Gross Wt. (lb)	Pay Rate ($ per mi)
24,000 - 38,000	0.0796	46,000 - 60,000	0.0898
38,001 - 52,000	0.0819	60,001 - 74,000	0.0921
52,001 - 66,000	0.0842	74,001 - 88,000	0.0944
66,001 - 80,000	0.0866	88,001 - 102,000	0.0968
80,001 - 94,000	0.0890	102,001 - 116,000	0.0992
94,001 - 108,000	0.0914	116,001 - 130,000	0.1016
108,001 - 122,000	0.0938	130,001 - 144,000	0.1040
		144,001 - 158,000	0.1064
		158,001 - 172,000	0.1088
		172,001 - 186,000	0.1112
		186,001 - 200,000	0.1136

In line-haul trucking, there are three general patterns for scheduling the work and rest periods of drivers. These are as follows:

1. Trips and vehicle movements are scheduled so that the driver returns to his home for rest at the end of the day. Such trips generally are called "turnaround" trips and may be made with one vehicle in certain situations, or may be accomplished by an exchange of vehicles at some midway point which will permit each driver to return to his home within one driving shift. Turnaround runs are the usual type of service where

the lengths of haul are less than approximately 125 mi. Drivers are at the home terminal at the end of each working shift; hence, they receive no allowance for lodging and meals.

2. "Layover" or "relay" runs are those on which the driver drives for one shift and takes his rest at a designated place at the end of his driving shift. Layover runs are the usual practice where lengths of haul are between approximately 150 and 325 mi. In such cases, the layover driver takes his rest at a hotel near the foreign terminal while his cargo vehicle is being unloaded and reloaded. He then returns the next day to his home terminal, usually with the same tractor and frequently with the same trailer.

For very long runs, more than approximately 350 mi, the cargo vehicles predominantly are operated on either a relay or a 2-man sleeper-cab schedule. On some relay runs, the power unit will go along with the trailers to be driven by successive drivers. On other relay runs, the tractors may be turned around at division points for maintenance control, or to permit tractors with large engines and extra braking capacity to be used in mountain service and tractors with smaller engines to be used in level areas. Relay drivers on such runs usually operate on a layover basis with the division, or turnaround points, spaced one driving shift apart. In such scheduling the driver drives to a division point from his home terminal, then takes his required rest at a hotel and hauls another trailer back to his home terminal the next day. In either the layover or relay methods of operation, a driver is away from home for his rest period every other day in a 6-day week, and he is reimbursed for the cost of lodging and one or two meals for each such period away from home.

3. There are two types of sleeper-cab operations: two-man sleeper-cab operation, and one-man sleeper-cab operation.

Two-man sleeper-cab operation is used in certain freight operations, and in such operations the drivers alternate between driving and resting in the sleeper berth, with time out for meals, personal needs, and servicing of power unit, until the destination is reached. For long hauls, more than 350 mi, considerable use is made of two-man sleeper-cab operations. This type of operation results in the fastest service and, within the regulations regarding driving time, two drivers can cross the continent in a week's time. Sleeper-cab wage rates are approximately 19 percent higher than single driver rates and, in addition, drivers get certain lodging and meals allowance for time at foreign terminals awaiting dispatch.

One-man sleeper-cab operation is used considerably by household-goods movers. In such operation the driver drives for the allowed driving hours, and then parks his vehicle at a truck stop and sleeps in the sleeper berth. At the end of the prescribed rest period, he prepares for a new day and continues on his trip. This routine is repeated until the scheduled destination is reached. The arrangement is a matter of convenience as it provides the driver with a bed whenever he wishes to sleep. Drivers usually work one shift a day and, in addition, help load and unload their cargo. Compensation plans for away-from-home subsistence expenses vary in the industry and are not reported here.

Other combinations of vehicle and driver scheduling can be found in the trucking industry, but the predominant types of scheduling are covered in the foregoing descriptions.

For the purposes of this study, it was desirable to select one type of driver scheduling, develop the driver's expenses in such an operation, and use this cost as a constant factor for all vehicle types and weights. Because the study has to do with line-haul operation, the layover or relay type of driver scheduling was assumed as the most representative of long-distance highway freight operations with lengths of haul of such distances that the drivers cannot return to their home terminals within the prescribed 10 hr of daily driving time. It was assumed that the drivers regularly lay over at a foreign terminal at the end of one driving shift, return to their home terminal the next day after a rest period, and work not more than 60 hr in a 6-day week. This schedule results in three layovers away from home each week, for each of which drivers are paid lodging and meals allowance.

To determine the average length of a layover run, considerable data were collected from carriers as to the average road speeds while driving for representative regular runs. The average road speeds, while driving, varied considerably from around 16 mph in mountainous country and on heavily traveled rural roads, to as much as 45 mph on level roads with few traffic impediments. Inspection of the data indicates that 31 mph for a driving time of 8.5 hr, or an average of 263 mi per working shift, is representative of layover operations in the industry.

A brief review of several labor contracts indicated that $6.00 a day for lodging and subsistence was a representative allowance during 1956. A driver making three such layover runs a week would receive $18.00 for approximately 1,578 mi of driving. These values calculate to $0.0114 per mile, and this cost is applied to all types and sizes of combinations.

The other elements of cost in ICC account 4280 — namely, badges and uniforms, bridge and highway tolls, and other incidental driver expenses — are not included in drivers' expenses in this study. They are omitted for the following reasons:

1. Practices in regard to the purchase of badges and uniforms are not consistent, and if they were the amount would be small.

2. Bridge and highway tolls, as well as fines, are not consistent throughout the country and on all routes. Although there are numerous toll bridges, the miles of toll highway are relatively few, even though they may be used extensively. In the interest of consistency, it appeared best to omit such tolls from the cost data. Other incidental drivers' expenses are omitted for the same reason.

INDIRECT AND OVERHEAD COSTS

Although the methods of separation and accumulation of direct expenses, such as fuel, tires and maintenance costs of line-haul trailer combinations, were quite consistent among the motor carriers interviewed, there was much less consistency regarding the accounting of indirect expenses. The ICC Class I motor carriers showed good consistency because of their use of the ICC system of accounts (17), but the other classes

TABLE 21

LINE-HAUL, INDIRECT EXPENSES, COST PER TRAILER COMBINATION MILE (2)

Indirect Expense Account	Total Amount ($)	Vehicle-Mile Cost ($)
Maintenance supervision (4110)	5,257,228	0.0031
Maintenance office and other expenses (4120)	345,582	0.0002
Other maintenance expenses (4180)	6,252,057	0.0037
Transportation supervision (4210)	16,529,453	0.0096
Transportation office and other expenses (4220)	956,650	0.0006
Insurance and safety supervision (4510)	5,533,097	0.0032
Insurance and safety office and other expenses (4520)	1,899,737	0.0011
Insurance and safety other department expenses (4570 and 4580)	1,053,479	0.0006
Salaries — general officers (4611)	21,545,570	0.0126
Salaries — other general office employees (4613)	17,348,313	0.0101
Expenses — general officers (4621)	3,897,369	0.0023
Expenses — general office employees (4622)	711,290	0.0004
Other general office expenses (4623)	7,557,720	0.0044
	88,887,545	0.0519

Note: The ICC Class I common carriers of general freight engaged in intercity service with owned equipment principally (2) operated in 1956 a total of 1,712,129,225 power unit vehicle-miles in intercity highway service.

of carriers interviewed showed no such consistency. There were several reasons for this, including the lumping of overhead expenses and differences in staff organization.

From observation it became apparent that the ICC Class I motor common carriers of general freight, engaged in intercity service and operating with owned equipment principally, had the staff organization and operating divisions which were representative of the best practice in line-haul trucking operations. These Class I common carriers generally have adequate maintenance departments, transportation departments, and safety departments, the indirect and overhead expenses of which are kept separate from other overhead expenses that are not involved in the line-haul transport operation. Further, these Class I motor carriers have general offices, general office employees and general office expenses which are an essential part of the management and administration of a trucking company. These factors were not always distinct in private and exempt operations. Admittedly, some of these general office expenses cover more than strictly line-haul operations and it was not possible to separate these expenses between line-haul and city delivery services; but, in order that the study data should include costs for general offices and general office expense, it was necessary to use the costs of the ICC Class I common carriers (2). In 1956, these Class I common carrier fleets had an average of 57 power units and 92 trailers in intercity service, and the average annual mileage of the power units was 51,200 mi.

For these reasons, vehicle-mile unit costs for indirect expenses were developed from these ICC data (2). Further, because the overhead expenses are generally proportional to fleet size and are about the same for each trailer combination, the unit vehicle-mile indirect costs can be applied equally to the different types of trailer combinations. Developed on these assumptions, the unit trailer combination mileage costs for the various indirect expenses included in the study are given in Table 21.

Admittedly, there are other indirect expense accounts listed in the ICC classification of accounts (17), but on examination it was found that the expenses included in these other indirect accounts relate primarily to variations in methods of doing business, to items that are not related to line-haul operation, or to fringe benefits that are proportional to certain direct costs which are discussed later. For example, in ICC accout 4280, "Other Transportation Expense," the main items of expense are bridge, ferry, tunnel and road tolls, uniforms and badges for drivers, and extra labor hired by drivers for loading and unloading freight. None of these expenses is affected by changes in size and weight limitations and for that reason these expenses are not included in the study. "Purchased Transportation," account 4270, likewise is not included in the study. Nor are legal fees, outside auditing, communication service, outside management and consultant fees, uncollected revenues, regulatory expenses, operating rents, revenue accounting salaries, other general expenses, and loss and damage claims which are not related to vehicle size and weight.

INSURANCE COSTS

All motor carriers provide for financial protection against liability resulting from accidents and against losses from other forms of damage, either by the purchase of insurance protection or by approved self-insurance plans. Although there is a consistency in the types of coverage, the amount of financial protection varies greatly among carriers, and the rates vary in different parts of the country. For the purposes of the trucking cost study it was believed desirable to establish a schedule of insurance coverage and rates that could be applied consistently to the various sizes and classes of vehicle combinations. The carriers interviewed were asked to report the dollar values and costs of the various types of insurance carried. These insurance data were summarized and modal values and rates were developed that are applied uniformly in the calculation of insurance costs.

The variations in types of insurance carried, as reported by carriers interviewed, are as follows:

1. All carriers have automobile public liability insurance.
2. All carriers have automobile property damage liability insurance.
3. Approximately 30 percent of the carriers have excess liability insurance; however,

a cost for excess liability insurance is not included in the insurance costs in this study.

4. Approximately 50 percent of the carriers do not carry collision insurance. Although 50 percent of the carriers interviewed reported that they carried collision insurance, it was found that such insurance primarily was carried only when vehicles were new and generally while the vehicles would have some unpaid balance due on the original purchase. Further, collision insurance is quite expensive, and when a vehicle becomes several years old the purchase of collision insurance on such old but useful vehicles was found to be rare. For these reasons, a mileage cost for collision insurance was not developed and is not included.

5. Approximately 3 percent of the carriers reported that they did not carry fire and theft insurance on vehicles.

6. Practically all carriers carry fire, theft and windstorm insurance on buildings and shop equipment.

7. Approximately 2 percent of the carriers reported that all of their liability and damage insurances were included in a single comprehensive policy, the payments for which were calculated on a percentage of revenue and a retrospective basis. However, because the single comprehensive type of insurance contract was relatively new in the industry, and because relatively few carriers had such coverage at the time of the field work, only conventional types of insurance coverage and guaranteed rates are used in this study.

8. No data were collected on cargo loss and damage insurance because this liability was not considered a function of vehicle size and weight. Also, this type of insurance frequently is not carried by private carriers.

An analysis of the replies received from the motor carriers interviewed gave the following modal amounts of coverage for purchased insurance protection:

Public liability : one person	$100,000
one accident	$500,000
Property damage liability (no cargo damage)	$100,000
Fire, windstorm and theft on revenue vehicles	actual value
Fire, windstorm and extended coverage on property used for maintenance and transportation	actual value
Collision insurance on revenue vehicles	(not included)
Cargo insurance	(not included)

To determine representative insurance rates and costs, it was necessary to set up a "model" of trucking service operating conditions for the information of the insurance underwriters that were consulted. The characteristics assumed for the fleet model are given in the following table. The mileage and revenue data of the fleet model were developed from data for ICC Class I common carriers of property in intercity service operating owned equipment principally for the year 1956 (2).

Fleet Model Assumptions	
Number of line-haul power units	100
Number of line-haul trailers, approximate	160
Average annual miles per line-haul power unit, approximately	51,200
Annual tons of freight hauled per power unit, approximately	1,964
Average annual revenue per intercity power unit	$37,600
Estimated carrier gross revenue (100 power units)	$3,760,000

Costs of Insurance on Revenue Vehicles

For the assumed model of a representative line-haul trucking fleet the schedule of insurances (supra) was evaluated by representatives of large fleet insurance underwriters. Table 22 gives the guaranteed (manual) rates for each of the types of insurance that are considered in the trucking cost study. These rates are assumed to apply to all types of line-haul trucking in order to eliminate any variables except the variables of gross vehicle weight, type of engine, and type of trailer combination. The average annual mileage per trailer combination used in developing mileage costs for insurance was 51,200 mi (supra).

The insurance rates given in Table 22 apply to long-distance hauling (Class CB, more than 150 miles) in commercial motor vehicles including trucks, tractors, and van trailers. The rates are representative of the manual rates that apply in average eastern industrial areas exclusive of Boston, Chicago, New York and Philadelphia. The rates are those which would apply to a fleet of 100 or more tractors and 100 or more trailers, which numbers of vehicles would give a carrier the maximum fleet discount. It must be recognized that these rates are higher than would be obtained with retrospective comprehensive plans. Obviously the assumptions are not completely realistic as to many actual operations, but the method does provide consistency in calculation, and does provide base values which can be adjusted to fit any different and specific circumstances.

Public liability and property damage insurances on vehicles relate to damage or injury to the other party in an accident, and hence are affected but slightly by vehicle size and weight. For this reason only one rate each for public liabiltiy and property damage for combinations is listed. These rates and mileage costs are assumed to apply to all sizes and types of trailer combinations for the amounts of insurance listed earlier.

Fire, theft and windstorm insurance costs are calculated on the actual values of the vehicles. The higher capacity tractors and trailers cost more than lesser capacity vehicles; so there is a relation between gross weight and these three types of insurance. It was assumed that the average values of the vehicles in a fleet at any time (original price less depreciation) were 50 percent of the original price. This premise on the average value of a fleet at any time is developed in the section on depreciation. The prices of vehicles as related to gross weights are developed in the section on investment.

TABLE 22

INSURANCE RATES

Type	Annual Cost per Tractor Semitrailer Combination ($)	Cost per Vehicle-Mile ($)
1. Public liability insurance	891.00	0.0174
2. Property damage insurance	286.00	0.0056
Total PL and PD insurance.		0.0230
3. Fire, theft and windstorm insurance	Rate per $100 Value	
Fire and windstorm:		
Gasoline tractor.	1.05	
Diesel tractor.	0.90	
Trailers.	1.05	
Theft insurance on tractors	0.10	
Theft insurance on trailers	0.10	
4. Fire, windstorm and extended coverage on garage and garage equipment (actual value)	0.15	0.0002

Costs of Insurance on Garage and Garage Facilities

The value of the insurable property in the fleet model garage was estimated at $514,000. The details of this value are given in the section on investment. To the total value was applied the fire, windstorm and extended insurance rate of $0.15 per $100 of value, giving a total annual insurance bill of $772. Reducing this amount to the total annual mileage of the fleet model and rounding the answer, resulted in a cost for this insurance of $0.0002 per vehicle-mile. This cost is used with all types of vehicles and combinations.

EMPLOYEES' FRINGE BENEFITS

There are several kinds of employee benefits that now are offered to industrial employees and to motor carrier employees. These employee benefits generally are known as fringe benefits and include such forms of additional compensation as life and health insurance plans, pensions, and vacations that are paid for by the employer. Not all motor carriers offer the complete scale of benefits and insurances, but certain of the benefits are mandatory; that is, required by State or Federal legislation. Frequently the costs of these mandatory insurances are classed as taxes. However, because the benefits are paid to the employees in case of certain eventualities, they are similar to, and may be classified as, fringe benefits. In addition to the mandatory insurance programs there are other fringe benefits that are offered by many employers. These voluntary fringe benefits are frequently written into labor contracts or otherwise are a part of the employment agreement.

In this study, the following company-employee voluntary benefits and mandatory benefit insurances have been assumed as reasonably typical fringe benefits in the trucking industry during 1956.

Mandatory benefit insurances are: (a) State workmen's compensation insurance, (b) Federal old age and survivor insurance (employer pays half), (c) Federal unemployment compensation insurance, and (d) State unemployment insurance.

Voluntary fringe benefits are: (a) hospitalization and surgical service insurance (Blue Cross Plan), (b) life insurance with nonoccupational death and dismemberment provisions, (c) pension plan, (d) paid vacation, and (e) paid holidays.

Some of these benefits are paid as a percentage of payroll, whereas others are on a flat fee basis. Certain field questionnaire items sampled the rates paid by carriers. From other sources, there were obtained estimates of fringe benefits paid by various types of industry. From these several sources, a series of fringe benefits was selected which is assumed to be representative of good practice in the trucking industry during 1956. These benefits are discussed in detail later.

In the case of these fringe benefits that are paid on a flat fee basis, it was necessary to relate the amounts paid to some assumed representative annual wage in order to enable the development of a percentage-of-payroll rate.

From the field data, the following modal wage rates were obtained: over-the-road drivers, $2.08 an hour; and first-class mechanics, $2.17 an hour. From statistics published by the U.S. Department of Labor (20), it was found that a typical number of hours per workweek for truck drivers was 45.5 hr. Combining the modal wage rate for drivers with the typical hours per workweek for 52 weeks results in an annual wage of approximately $4,900. Line-haul drivers, in general, are under ICC jurisdiction as to hours of work and not under Fair Labor Standards Act, and are not paid overtime rates. The first-class mechanics' wage rate is slightly higher than the drivers' wage rate, and predominantly mechanics are paid time and one-half for work in excess of 40 hr per week. The field data indicate that frequently overtime is paid to mechanics. Also, for 1956, a report by the U.S. Department of Commerce (21) shows $5,346 as the average annual wages of full-time employees in "highway freight transportation and warehousing." Considering the trends of these several sources of information it was not thought necessary to expand the field work further to determine, for fringe benefit costs, precisely the average annual wages of employees of carriers interviewed. Instead, a figure of $5,200 was assumed as the average annual wages of those motor carrier employees whose wages are included in the line-haul trucking cost study.

Salaries of general officers are assumed to be higher and corresponding adjustments are made in such accounts.

State Workmen's Compensation Insurance

In the ICC Uniform System of Accounts for Class I Motor Carriers of Property, workmen's compensation expense is charged to account 4540. Workmen's compensation insurance usually is paid as a percentage of payroll for wages and salaries up to $5,200 a year, and the cost percentage varies from State to State, and from carrier to carrier depending on each carrier's actual experience. The rates for workmen's compensation insurance also vary with the type of work and the degree of risk. For example, rates for drivers and mechanics are higher than those for clerical help. However, because drivers constitute the preponderant group of employees whose wages are covered by the study, the workmen's compensation rate for drivers is applied uniformly to all the labor expenses that are included in the study.

In the field interviews the cooperating carriers were asked to report their current workmen's compensation insurance rates. Analysis of these replies gave a modal value of 2.0 percent of payroll, which is assumed as a representative rate in this study. Because workmen's compensation insurance rates generally apply to the first $5,200 of annual wages received by an employee, that portion of a given expense account to which the workmen's compensation fee percentage is applied varies, depending on the amount of expense other than wages that is included in the account and on the proportion of employees included in an account whose wages are greater than $5,200 a year. A small corollary study of the field data indicated that the assumptions in Schedule A (following table) regarding the portion of the total of each expense account to which the workmen's compensation rate should be applied, would give reasonable and consistent workmen's compensation costs.

Schedule A	Percent of Account Used in Calculating Cost
Repairs and servicing — line-haul equipment (4131)	35
Drivers wages — line-haul equipment (4231)	100
Maintenance supervision (4110)	100
Transportation supervision (4210)	100
Insurance and safety supervision (4510)	100
Salaries — general officers (4611)	35
Salaries — other general office employees (4613)	100

Federal Old Age and Survivor Insurance

The employer's portion of the Federal old age and survivor insurance (Social Security) is charged to ICC account 5240. These employer contributions are considered a fringe benefit. In 1956, the employer's portion was 2 percent of the first $4,200 of wages paid. The percentage applicable to the assumed average annual wage of $5,200 is 1.62 percent of payroll, which is assumed as applying to the costs of labor as given in the accounts in Schedule A in the section on workmen's compensation.

Federal Unemployment Insurance

The Federal unemployment insurance fee which the employer pays to the Internal Revenue Service amounts to 0.3 percent of payroll up to $3,000. It is charged to account 5240 in the ICC classification of accounts. For application to the assumed annual wage of $5,200 this would be equivalent to a rate of 0.17 percent, which is applied to the costs of labor as given in the accounts in Schedule A in the section on workmen's compensation.

State Unemployment Compensation Insurance

In the ICC classification of accounts, State unemployment compensation insurance fees are charged to account 5240. State unemployment compensation insurance fees vary from State to State, and from carrier to carrier. An employer's contribution rate for unemployment compensation insurance varies with the past employment record of the company. In the field interviews, cooperating carriers were asked to report their current unemployment compensation insurance rate. An analysis of these replies gave a modal value of 1.0 percent of the first $3,000 of wages of each employee. For application to the assumed annual wage of $5,200, this would be equivalent to a rate of 0.58 percent of payroll which is assumed as applying to costs of labor as shown in the accounts in Schedule A in the section on workmen's compensation.

Among the voluntary fringe benefits offered by carriers, there are differences in amounts of benefit, as well as in method of payment (22). Some benefit programs are paid entirely by the employer, whereas other programs are partially paid for by employees' contributions which are collected through payroll deductions. In this study, it is assumed that the costs of all voluntary fringe benefits are paid directly by the employer. The employer-paid fringe benefits are generally classed as employees' welfare expenses and are charged to ICC account 4645, but vacations and paid holidays are charged in carrier's books to the same ICC labor expense account as employees' wages.

Hospitalization and Surgical Service Insurance

Hospitalization and surgical service insurance plans generally are on a group basis. Some plans, such as the Blue Cross Plan, are cooperative arrangements and are usually found in the larger cities. In smaller communities the plan may be on an indemnity basis with the subscribers being reimbursed according to a schedule of stipulated fees. Payment of the membership fees in such plans varies throughout the industry from full payment by the employer, to full payment by the employee. However, in this study it is assumed that the entire cost of this benefit is paid by the employer as a fringe benefit.

In this study, the 1956 annual cost for a family type of coverage is assumed to be $82.80. This was the cost of the standard Blue Cross Group Plan offered in Washington, D.C., by Group Hospitalization, Inc. On the basis of the assumed average annual wage of $5,200, this assumed cost represents a rate of 1.59 percent of the average annual wages for hospitalization and surgical service insurance, and is applied to the accounts in Schedule A in the section on workmen's compensation.

Life Insurance

Most company life insurance plans include nonoccupational death and dismemberment features and are related to the average annual wages, with the amount of life insurance in even thousands of dollars approximately equal to the annual wage. Such insurance plans are term insurance on a group basis with various arrangements for continuing or converting the insurance after the employee leaves a company's employ. Payments for the insurance vary from full company payment to full payment by the employees through a payroll deduction plan. In this study it is assumed that the carrier pays all costs of the life insurance plan, which are charged to account 4645.

The rates paid for the life insurance group plan offered Federal employees are assumed in this study. The employee pays $0.25 per $1,000 of insurance at each 2-week pay period. The Federal Government contributes one-half as much as each employee. Assuming 26 periods a year, these two fees amount to an annual fee of $9.75 per $1,000 of insurance, or 0.975 percent of annual payroll. This percentage is applied to the accounts including labor costs according to the following Schedule B.

Schedule B	Percent of Account Used in Calculating Cost
Repairs and servicing — line-haul equipment (4131)	35
Drivers wages — line-haul equipment (4231)	100
Maintenance supervision (4110)	100
Transportation supervision (4210)	100
Insurance and safety supervision (4510)	100
Salaries — general officers (4611)	100
Salaries — other general office employees (4613)	100

Pensions

Industry pension plans generally are arranged to augment Federal old age and survivor insurance, but are charged to account 4645. The inclusion of pension costs in this study does not imply that pension plans are offered by all motor carriers. However, because pension plans appear to be a coming feature in industrial work, a cost for pensions is included in the trucking costs. In this study, it is assumed that the carrier pays all costs of a pension plan regardless of the method of managing the plan. Some sparse data from motor carriers indicate that carriers offering pension plans are contributing about 2.5 percent of payroll, approximately $0.05 an hour, for pension plan costs. This amount is close to the average figure of 2.8 percent for manufacturing industries which was reported in a 1955 report by the U.S. Chamber of Commerce (22). A pension premium rate of 2.5 percent of annual wage is assumed in this study, and is applied to the expense accounts as given in Schedule B in the section on life insurance.

Paid Vacations

Two weeks of paid vacation are assumed in the study. The cost amounts to 3.85 percent of annual wages, and is applied to the expense accounts as given in Schedule B in the section on life insurance.

Paid Holidays

Six paid holidays are assumed during a year. Frequently employees work on the designated holidays but at a bonus rate. The cost of six paid holidays is assumed in the study as 1.92 percent of payroll, and is applied to the expense accounts as given in Schedule B in the section on life insurance.

Summary of Employer-Paid Benefit Costs

The various percentages for the different types of fringe benefits and the schedule of wage and salary accounts to which thev are applied are summarized as follows:

Name of Employee Benefits	Account No.	Wages and Salaries Accounts	
		Percent	Schedule
Workmen's compensation	4540	2.0	A
Social security fees			
Federal old age and survivor insurance	5240	1.62	A
Federal unemployment insurance	5240	0.17	A
State unemployment insurance	5240	0.58	A
Employees welfare benefits			
Hospital and surgical insurance	4645	1.59	A
Group life insurance	4645	0.975	B
Pension plan	4645	2.50	B
Paid vacations	Wage and salary accounts	3.85	B
Paid holidays		1.92	B
Total percentage		15.205	

LOCAL TAXES

Motor carriers are subject to a variety of taxes all of which are an expense to them, but not all are properly chargeable as vehicular operating costs. Certain local taxes can be considered as payments for State, county and municipal functions and services that benefit businesses and communities. These local functions include police and fire protection, sanitary services, schools, and general government functions. Some of these taxes are chargeable as operating expenses. Federal and State fuel taxes were discussed earlier and are not included with vehicular costs.

The multitude of taxes can be grouped generally in five types, and the application of each type is outlined hereinafter. In general, the different types of taxes and fees are accumulated according to the system of accounts prescribed by the Interstate Commerce Commission (17), but there are certain exceptions that are described in appropriate sections. There is no perfect distinction between the local community service taxes and road-user fees, but the instructions of the ICC Classification of Accounts and the analysis of the data did permit a reasonable separation of taxes into different general types.

Real and Personal Property Taxes, Other Than Personal Property Taxes on Vehicles

Real and personal property taxes, other than personal property taxes on vehicles, are imposed to pay for local governmental services such as fire and police protection, water and sewerage service, schools, and general governmental functions. Such taxes are paid, directly or indirectly, by private, exempt, and for-hire carriers in accordance with the amount of real and personal property used by the carrier. In this study these taxes are calculated on the basis of representative real and personal property tax rates applied to the fleet model garage.

The real and personal property investments in garage facilities and supplies vary greatly among carriers. This topic is developed in the section on property investments in which, for the purpose of developing vehicle-mile costs, there was postulated a fleet model of 100 tractors and 160 trailers. The original costs for the garage and garage equipment which were developed in the section on investments are used in the calculations of real and personal property taxes. Terminal and general office property are not included because they are assumed to be unaffected by changes in vehicular size and weight.

The methods of assessing real and personal property for local tax purposes vary greatly among the various States and cities. Likewise the tax rates per $1,000 of assessed value vary greatly. A study was made of real and personal property tax formulas of various States and cities as reported by one of the nationwide tax reporting services (23). Averages of representative tax formulas selected from this source and assumed for use in the trucking cost study are:

Real property is assessed at 55 percent of appriased value.
Personal property is assessed at 59 percent of appriased value.
Tax rate per $1,000 assessed value is $58.32.

The original prices of the different types of property in the postulated fleet model garage, together with appraisal and assessment practices that were assumed for the development of annual local tax costs are as follows:

1. Land for garage, parking and service area, original price $69,000, appraised at 100 percent of purchase price and assessed at 55 percent of appraised value;
2. Garage building and appurtenances, original price $394,000, estimated life 35 yr, age estimated for tax purposes at 10 yr, appraised at 72 percent of value new and assessed at 55 percent of appraised value;
3. Garage equipment, original price $78,000, estimated life 10 yr, age estimated for tax purposes at 5 yr, appraised at 50 percent of value new and assessed at 59 percent of appraised value; and
4. Parts and supplies in stock, original price $44,500, appraised at 100 percent of purchase price and assessed at 59 percent of appraised price.

SUMMARY OF ANNUAL REAL AND PERSONAL PROPERTY TAXES

Item	Price New ($)	Appraised Value ($)	Assessed Value ($)	Annual Taxes ($)
Land	69,000	69,000	37,950	2,213
Building and fixtures	394,000	283,680	156,024	9,099
Machines and equipment	78,000	39,000	23,010	1,342
Parts and supplies in stock	44,500	44,500	26,255	1,531
Total taxes				14,185

Total annual vehicle-miles estimated for the fleet model was 5,120,000 mi as reported in the section on insurance costs. Dividing this mileage into the annual real and personal property taxes of $14,185 gives a tax cost of $0.0027 per vehicle-mile. This tax cost of $0.0027 per vehicle-mile for garage facilities and supplies is applied uniformly to all types and sizes of combinations.

Employee Benefit Taxes

Federal and State laws impose four employee benefit taxes on employers; namely, State workmens' compensation insurance, Federal and State unemployment compensation insurance, and Federal old age and survivors insurance. In this report these taxes are included in employee fringe benefits and are not considered as taxes.

Excise and Sales Taxes

There are a variety of State and Federal sales and excise taxes imposed on materials purchased by motor carriers. Such taxes include sales and excise taxes on complete vehicles, parts, supplies, tires and tire repair materials. Although certain of these taxes are in effect road-user fees, they usually cannot be separated from the materials purchase costs because of the accounting rules of the ICC classification of accounts. The handling of these taxes for different accounts is indicated as follows:

ICC Account 1180: Materials and Supplies in Stock (except motor fuel and engine oil). — Sales and excise taxes are included in this account for parts, materials and shop supplies. As a result these taxes are charged to expense when the materials are used and charged to Account 4131, Repairs and Servicing — Like-Haul Revenue Equipment.

ICC Account 1220: Tangible Property — Revenue Equipment. — Although excise and sales taxes are in some respects road-user fees, they are included in the purchase prices of revenue equipment and are capitalized. In this way, these taxes are included in the investment values of revenue equipment. In the study, a schedule of stipulated prices for revenue equipment was developed based on list prices less a discount and plus excise taxes. This procedure was necessary because fleet prices, fleet discounts, freight charges, and year of purchase varied so greatly between carriers and regions that comparable investments in revenue equipments by gross weight capacity could not be developed statistically from the field data.

ICC Account 4161: Tires and Tubes — Line-Haul Revenue Equipment. — Because of accounting rules, sales and excise taxes, even though they have the nature of road-user taxes, are included in the prices paid for tires, tubes, and recapping camelback, and hence do appear in tire and tube costs.

TAXES AND FEES NOT INCLUDED IN COST STUDY

Motor Vehicle Road-User Taxes

The following series of taxes are considered as predominantly road-user fees, and because of the accounting rules for their accumulation, it was possible to omit them from the operating expenses and they were so omitted:

1. Motor-fuel taxes in ICC account 5211;
2. Motor-oil taxes in ICC account 5211;
3. Vehicle registration and license fees based on various criteria such as empty weight, declared gross weight, etc., and including any plate or tag identification fee, in ICC account 5221;
4. Mileage taxes in ICC account 5221;
5. Ton-mile taxes in ICC account 5221;
6. Weight-distance taxes in ICC account 5221;
7. Axle-mile taxes in ICC account 5221;
8. Gross receipts taxes paid by for-hire carriers as a measure of highway use in ICC account 5221;
9. Federal motor-vehicle-use tax in ICC account 5221; and
10. Personal property taxes on vehicles, or vehicle taxes in lieu of personal property taxes — these taxes are reported in ICC account 5230 but in this study they have been considered as a part of the vehicle registration fee and are not included as operating expenses.

In general, most of the listed taxes are considered as road-user taxes, and as such they are methods of paying for the construction and maintenance of highways. Certain of the taxes are for the administration of the registration and licensing system. Although these taxes are an expense to the carriers, such taxes are not directly a part of the operation and maintenance of trucking equipment. Further reasons for not including the road-user taxes in vehicular costs are that these taxes are not applied uniformly in the different States, and are not applied uniformly among private, exempt-for-hire, and certified-for-hire carriers.

Fees for Doing Business as a Carrier

There are a variety of fees, taxes and licenses, local, State and Federal which are required for doing business as a company and/or carrier. Such fees are for various purposes, including that of raising revenue for general government purposes. These fees have no relation to vehicular operation or road use, even though they are an expense to a carrier. Included are public utility fees and local business license fees. These fees vary from State to State and do not apply consistently among private, exempt-for-hire, and certificated for-hire carriers. For these reasons, none of these types of taxes or fees is included in the trucking costs reported in this study. Federal and State income taxes likewise have no direct relation to vehicle operating costs, and hence are not included in this cost study.

PROPERTY INVESTMENTS

The property employed in trucking operations can be divided into four general classes:

1. Real property, such as land and buildings;
2. Personal property, such as shop equipment, service equipment, repair parts and supplies in stock;
3. Automotive revenue freight vehicles, such as trucks, tractors and trailers; and
4. Automotive service vehicles, such as service trucks and safety patrol cars.

These elements of property and investment are used in different degrees by all classes of highway freight carriers; that is, common carriers, contract carriers, exempt-for-hire carriers, and private carriers. In regard to real and personal property, the amounts owned and used by carriers vary greatly between classes of motor carriers and between carriers. Common carriers have the greatest investment in real property, which includes terminal docks, terminal yards, and buildings for housing office facilities for dispatching, rating, billing, and accounting, and for safety and management functions. Maintenance garage buildings and servicing areas usually are a part of a common carrier's property. Contract carriers have no need for dock facilities because they primarily haul direct from a shipper's dock to a consignee's receiving station. Maintenance garage buildings and servicing areas usually are included in a contract carrier's property. Private carriers, providing their own haulage service, frequently do not consider their shipping and receiving platforms as a part of their trucking operations. Maintenance buildings and service areas are included in their property. Exempt-for-hire carriers seldom have terminal dock facilities for the transfer of freight. Maintenance facilities needed for the vehicles may not be included in the property because such work may be performed at public garages or by truck dealers.

It is evident from these different practices and circumstances that the one type of real property used by all types of carriers is garage and servicing facilities for revenue vehicles. An inherent feature of automotive freight vehicles is that they all require periodic maintenance, repair, overhaul, and daily servicing for which shop and servicing facilities must be provided. To eliminate the variables of the other kinds of trucking facilities, only the property used for maintenance, repair, overhaul and servicing of revenue equipment is included in the real property investment for line-haul service.

The property included in garage and servicing facilities consists of (a) garage building and appurtenances, (b) garage machinery and equipment, and (c) repair parts and supplies in stock.

Garage Building and Appurtenances

Garage and servicing facilities for line-haul revenue equipment vary greatly between carriers. The size of a fleet has an effect on the extent of carrier-owned maintenance and repair equipment. The very large fleets have shops completely equipped with many machine tools and carry a sizeable stock of parts, supplies and tires; whereas the small fleets make use of the machinery, tools and stocks of local automotive dealers. In either case, however, there is an investment to provide the required facilities the costs of which must be brought into the vehicle operating costs.

Vehicle maintenance and servicing facilities are provided by one of several means in the trucking industry, such as (a) in carrier wholly owned and operated garages, (b) in leased garage buildings equipped by the carrier, (c) in public garages or truck dealer shops which furnish the facilities and do the maintenance and repair work, or (d) in mixtures of these plans. Even in the last three examples, the carriers usually will have fuel storage tanks, pumps, and minor servicing facilities on their own property.

Whatever the ownership arrangement, there is an investment in shop and service equipment, and in supplies to repair, maintain and service the revenue vehicles. The manner in which these facilities are paid for depends on the ownership of the facilities. When the work is done at a dealer shop the cost of the facilities is included in the overhead charged on the service invoices and so appears in maintenance expense. Where the shop facilities are wholly carrier-owned, the price of the facilities appears in the property account and shows an investment of the carrier's capital. If the shop facilities are leased, the rental charges would be a rental expense.

In all cases, however, there necessarily exists an investment in garage facilities, equipment, and supplies, the costs of which are to be included in the vehicle operating costs. The range and scope of machine tools and supplies required to repair, maintain, overhaul and service a fleet of line-haul vehicles is about the same for a small fleet as for a large fleet, even though the ownership of the garage equipment and supplies may vary as previously discussed. Also the range and scope of machine tools and shop equipment are about the same for the lighter capacity combinations as for the heavy capacity combinations.

In the collection of field data, all types of carriers were interviewed with the resulting variety of data as outlined previously. It was not possible to obtain enough detailed data of individual company practices to make a statistical development of the investment costs of garage and service facilities. Instead, by assuming a hypothetical fleet model garage, consistent investment costs for building, equipping and supplying garage and service facilities could be estimated.

A hypothetical garage and servicing area was postulated for the maintaining and servicing of a fleet model consisting of 100 tractors and approximately 160 semitrailers doing about the amount of business that was done, on the average, by ICC Class I intercity common carriers of general freight using owned equipment principally (2). It also was postulated that the garage was quite completely equipped to do practically all repair and maintenance work with very little recourse to the machine tool equipment of outside shops. Admittedly, not all fleets will have the complete range of machine tools on their property, but they will make use of the entire range of machine tools through jobs sent to outside automotive shops. Thus it is logical to have the investment in garage equipment reflect a complete line of machine tools and garage equipment.

The number of vehicles in a fleet hauling a given total amount of freight will vary with the sizes and payload capacities of the vehicles. Although the extent of the garage facilities may vary in different situations, the average amount of garage facilities and shop equipment needed per vehicle is not greatly affected by the size and payload capacity of the vehicles. Thus the unit costs of garage facilities and shop equipment that are developed for the fleet model can be used for any size of vehicle.

The hypothetical garage was postulated on information reported by the largest carriers entered in several trucking shop contests conducted in the industry (24). A 39,000-sq ft building was assumed to be located on a plot 69,000 sq ft in size. It was assumed that this area will provide sufficient parking space for revenue equipment awaiting entry to the shop, and will include the fueling and outbound servicing area. The shop area does not include parking space for vehicles under the control of the transportation or terminal departments of a carrier.

The hypothetical shop plant does not contain any facilities for the transportation, terminal, traffic, or general office departments. It is assumed that these non-shop

TABLE 23

FLEET MODEL GARAGE BUILDING AND EQUIPMENT

This plant is to provide complete repair, maintenance and service facilities for a fleet model of 100 tractors and approximately 160 semitrailers.

1. One story building — fire resistant, garage construction. Building stands by itself, fronts on street with other sides facing paved service and parking area of 30,000 sq ft
2. Building floor area 39,000 sq ft
3. Walls, concrete block, brick and glass
4. Height to under sides of roof 20 ft
5. Roof framing and structure made of steel
6. Roofing, composition over lightweight concrete decking
7. Skylights, standard
8. Floor, concrete
9. Exterior doors, 11 ft wide by 14 ft high
10. Radiant heating in floor, oil fired boiler
11. Building divided into 6 or 7 rooms with largest room having approximately 10,000 sq ft of floor area
12. Separate paint spray room, 20 ft by 60 ft, with ventilating exhaust fan
13. Eight repair and service pits with built-in lighting and ventilation
14. Overhead fluorescent light
15. Sprinkler system, not including central alarm station connection
16. Fire hydrant within 600 ft, public fire protection within 4 mi
17. Building in use 24 hr a day, no watchman, number of employees approximately 40

Cost new of building and building appurtenances	$390,000
Cost of land, 69,000 sq ft at $1.00 a sq ft	69,000
Cost of paving in parking area, 1,100 sq yd at $4.00 a sq yd	4,400
	$463,400

facilities of a carrier would not be altered significantly with any changes in vehicle size and weight allowances, and the costs of facilities for such other departments of a carrier are not included in the line-haul trucking costs.

Other reasons for differences in garage building costs lie in the location of the facility. Fleets located in the northern regions of the country have buildings adequate for the rigors of winter weather. In southern regions the buildings may be of simpler construction. In the study, the fleet model garage was assumed to be located in a Middle Atlantic industrial area, specifically in or near Baltimore, Md. This arbitrary selection of a specific location enables a consistent estimation of building costs and other costs related to the facility which will permit the adjustment of these costs to fit other locations. The garage facilities are estimated to be sufficient for trailer combinations, the average annual mileages of which are 51,200 mi, which, as previously stated, was the average annual vehicle mileage reported in 1956 by ICC Class I intercity common carriers of general freight using owned equipment principally (2).

A tabular description of the hypothetical garage building, its land and surroundings is given in Table 23.

Garage Machinery and Equipment

A schedule of machine tools, shop equipment, storage bins and lockers is not included in the report, but estimates of the cost new of comprehensive garage equipment for the repair, maintenance, overhaul and servicing of the fleet model were developed from data reported in Truck Shop Excellence contests conducted in the industry (24). In these contests a number of companies were entered that had very comprehensive shop facilities and equipment for the complete repair, maintenance, overhaul and servicing of line-haul revenue equipment. These major shops were the basis for an estimate of $78,000 for the investment in garage machinery and equipment.

Repair Parts and Supplies in Stock

The amount of parts and supplies carried in stock for immediate use in a large garage will vary with the proximity of vendors. In a major shop, such as was assumed in the study, a sizeable stock of parts and supplies would be carried on hand. The values assumed for such materials are:

Parts, components and supplies	$34,000
Tires and tubes	10,000
Motor fuel	2,000
Oil and lubricants	500
	$46,500

Summary of Garage Investments

A summary of the investment values of garage real and personal property is given in Table 24.

Automotive Revenue Vehicles

The investment in automotive revenue equipment is the predominant portion of the invested funds required to operate a motor freight business. According to 1956 data reported by the Interstate Commerce Commission (2) for Class I, common carriers of general freight engaged in intercity service with owned equipment principally, the depreciated value of the revenue equipment used by 642 common carriers amounted to approximately 72 percent of the depreciated value of all tangible property owned and used by the carriers.

The ICC depreciated value for revenue equipment includes the value of city delivery and pickup trucks, which by definition are not included in the study of line-haul trucking costs. Also, these investment data are based on different prices paid in various years for equivalent equipment. In addition, there is some use of leased equipment, the values of which do not appear in the asset account.

TABLE 24

INVESTMENT VALUES OF GARAGE REAL AND PERSONAL PROPERTY

Real property:		
Land, garage building 39,000 sq ft	$ 39,000	
Land, garage parking and servicing area 30,000 sq ft	30,000	
Subtotal, land values		$ 69,000
Garage building and appurtenances, new	390,000	
Paving, parking and service are 1,100 sq yrds at $4,00 a sq yd	4,400	
Subtotal, building		394,400
Personal property:		
Machines, tools, lockers, etc.	$ 78,000	78,000
Parts and supplies in stock:		
Parts, components and supplies	34,000	
Tires and tubes	10,000	
Motor fuel	2,000	
Oil and lubricants	500	
Subtotal, parts and supplies		46,500
Total, garage facility		$587,900

The revenue equipment investment data collected from the field for the cost study had all of the deficiencies in respect to the identification of prices with vehicles that exist in the published data. For this reason it was not possible to calculate, from either published data or from the data collected from interviewed carriers, a schedule of investments in line-haul vehicles of different size and weight capabilities.

The objective of this portion of the study was to develop consistent investment data related to trailer combinations of different types and different levels of payload capacity and gross vehicle weight. The vehicles of higher payload capacity cost more than do the smaller vehicles, but fewer large vehicles are required to carry a given tonnage. As a basis for a consistent evaluation of equipment investments, the prices new for a series of both power units and trailers of different types and carrying capacities were developed by consultation with manufacturing members on the committee.

The prices new of line-haul freight vehicles, both tractors and trailers, of equivalent capacities built by different manufacturers are reasonably consistent, but the differences in price between different levels of capacity are not related directly to either payload or gross weight capacities. Differences in manufacturing processes cause much of the variation in costs. The small power vehicles may be volume produced, whereas the larger power vehicles are practically made on a job-shop basis. Other factors affecting prices paid by a carrier are size of fleet, the number of vehicles purchased in a given lot or in a year, and the local competitive market. Obviously, in a study to determine the degree to which line-haul trucking investment costs vary with different levels of gross combination weights, it was necessary to eliminate such extraneous variations in original prices.

Price quotations for 4 x 2 and 6 x 4 tractors equipped with either gasoline or diesel engines were obtained from selected truck manufacturers. These tractors were rated according to their gross combination weight-hauling capacity. The prices developed into the smoothed curves shown in Figure 11. The prices represented in this figure are base prices less tires, less two 10 percents, plus a 5th wheel lower assembly, and plus excise taxes. (Excise taxes previous to the 1956 Highway Act were general fund taxes and for that reason were capitalized in the original purchase price, whereas since then a portion of these taxes have been converted by law into highway use taxes and put into the Highway Trust Fund.) For pricing tractive trucks, the same net prices were used without the 5th wheel and plus the cost of the cargo body mounted on the truck chassis.

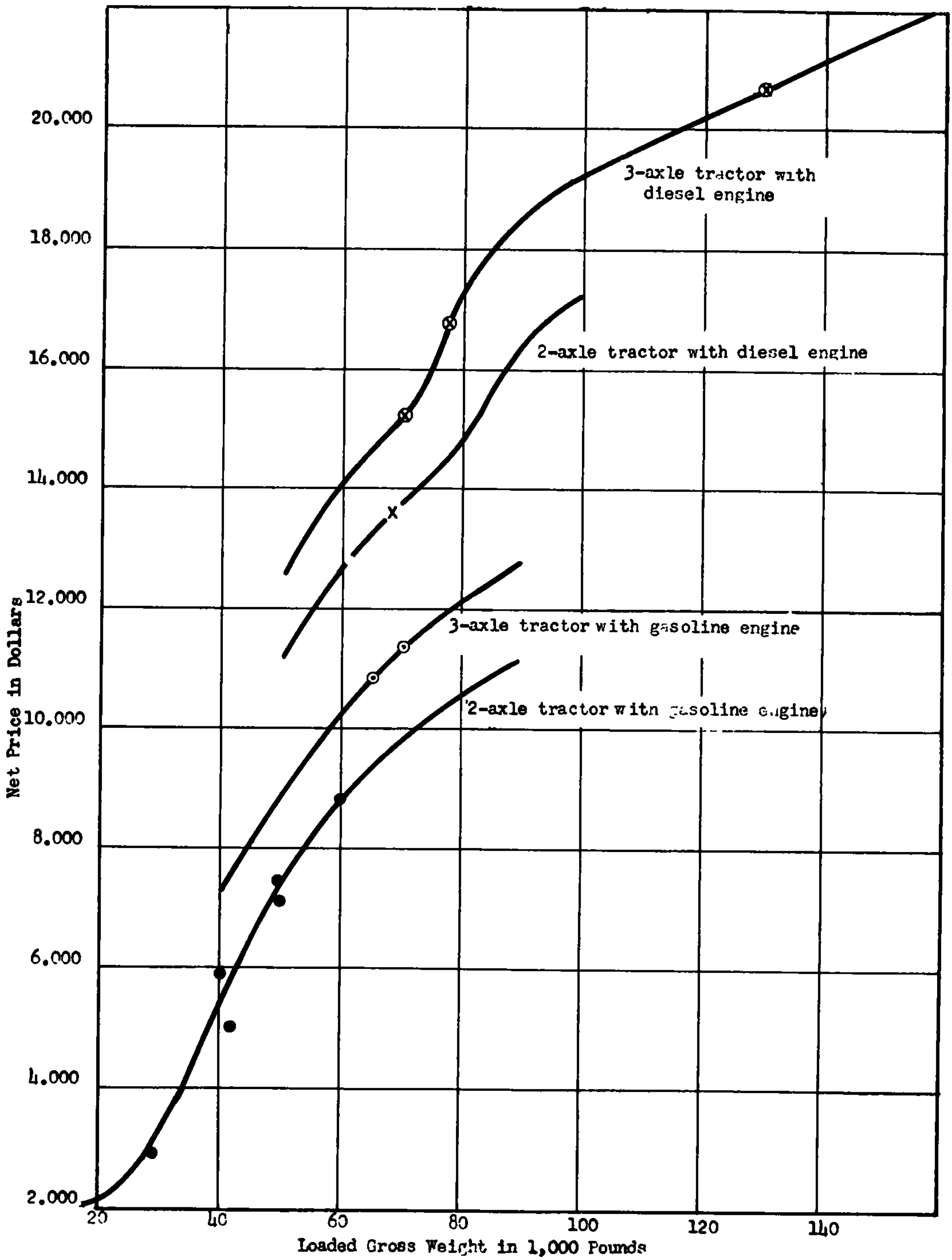

Figure 11. Net prices of tractors by gross combination weight rating. Manufacturer's list price less tires and discount, plus 5th wheel.

Prices for 1- and 2-axle semitrailers and 2-axle full trailers with either closed van or tank cargo bodies were obtained from trailer manufacturers and were similarily developed into the curves shown in Figure 12. These trailer prices are base prices less tires, less one 10 percent, and plus excise taxes. Prices for 1- and 2-axle dolly converter gears also were obtained. Vehicle prices are less tires because under ICC

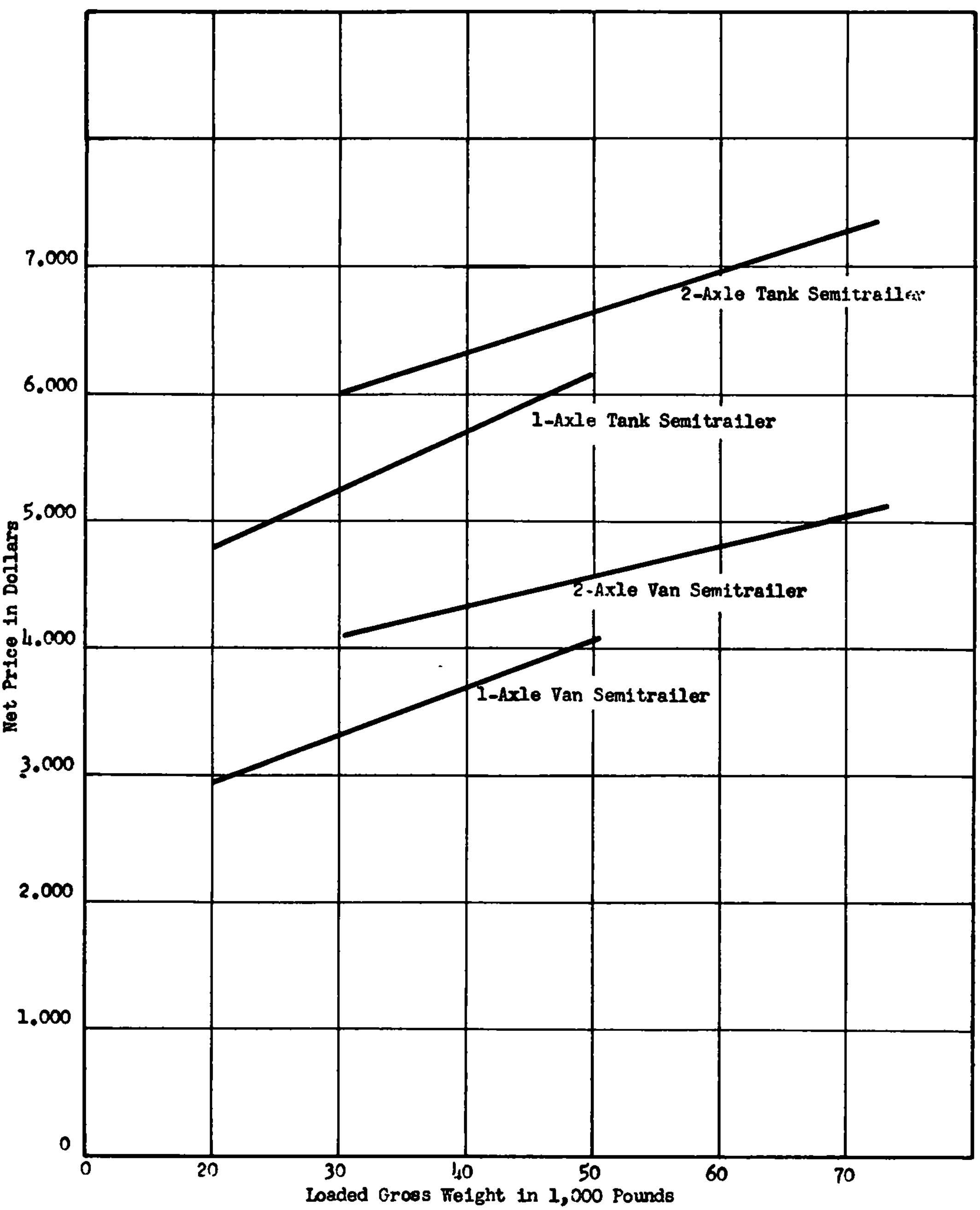

Figure 12. Semitrailer net prices by gross weight of trailer. Manufacturer's list price less tires and discount.

accounting rules original equipment tires are not capitalized but are charged to tire expense. The discounts were assumed as representative of those offered to large fleets.

From these price data, the types and capacities of trailer combinations used by reporting carriers were priced. Vehicles were priced in 5,000-lb increments of gross weight using the price at the midpoint of the increment. Trailer combinations were priced by adding together the prices of the individual vehicles used in a combination.

These prices were used to calculate annual depreciation costs for specific vehicles in the different carriers' reports, using the depreciation rates that are developed in the section on depreciation expenses.

Depreciated Investment in Revenue Equipment

Revenue line-haul equipment is a type of property that has a relatively high wear rate and relatively short life compared with real property, such as buildings. Because of the rapid retirement and replacement of line-haul vehicles it was necessary to develop a method of analysis which would give a consistent relationship between the average value of depreciated investment per vehicle and the reserve for depreciation per line-haul vehicle. In a going company which has been in business for a number of years, the depreciated investment may be assumed to represent the outside funds, usually stockholders money or long-term debt, that are invested in the business. These are funds for which the money owners expect payments, either as interest on loans or dividends to stockholders. The reserve for depreciation includes the annual depreciation costs that have been charged against income during the previous several years of life of each piece of equipment. Such reserve funds are used in the purchase of replacement equipment.

To develop an average depreciated investment value of line-haul equipment which could be consistently related to gross vehicle weights, it was necessary to use several assumptions to make a model of a retirement and depreciation program. The following conditions were stipulated for the model: (a) the number and types of vehicles in a fleet are to remain constant; (b) the individual capacities of the various vehicles are to remain constant; (c) the replacement prices of equivalent vehicles are to remain constant at selected original purchase prices throughout the service lives of the vehicles; (d) the straightline method of computing annual depreciation charges is to be used; (e) all vehicles are to run out their useful lives in one carrier's service; (f) the retirement life in years for each different type and size of vehicle is to be used in calculating annual depreciation charges; (g) the salvage value of any vehicle at normal retirement is a junk or zero value; (h) 1956 prices are to be used as original prices in order to be comparable with other cost data. These assumptions are discussed further in the section on Depreciation Expenses.

In the retirement model program, it was assumed that all line-haul vehicles were regularily retired and replaced at a uniform rate each year. The retirement cycles for different types and sizes of vehicles may vary, as discussed in the section on Depreciation Expenses, but in the retirement model, vehicles of each type and size are regularly and uniformly replaced at their established rate each year. Under these stipulations of regular and uniform retirement and replacement of vehicles, a mature fleet will be 50 percent depreciated at any time, with some vehicles being just new and some just ready for retirement, and the balance of the fleet spread uniformly between the two extremes.

Under these conditions, the depreciated investment in an average vehicle in a fleet or a group of similar vehicles may be assumed as 50 percent of the original new price. This 50 percent of original price of vehicles was used as the investment base for calculating annual vehicle-mile interest charges which are discussed further in the section on Interest Paid for Investment Funds.

Investments in Fleets of Equivalent Payload Capacities with Vehicles of Different Gross Weights

The effects of different maximum gross vehicle and axle weights on the number of trailer combinations and on the investment in revenue vehicles for transporting a given tonnage of freight are given in Table 25. In compiling this table it was assumed that freight was available to produce the possible payloads listed for the different vehicles. Tables 3 and 6 support this premise. The maximum vehicle weights given are calculated from axle weights without reference to any type of "bridge formula" calculation of gross weight allowances.

To show the effects of different weight limits, a specific task of moving 1,000 tons of freight oneway in one day, a distance of 200 to 400 mi was postulated. This distance was assumed as allowing each trailer combination only one trip a day. This assumption that all trips are loaded is not realistic because not all line-haul trips are with payload, as discussed earlier. To accommodate empty trips will require a percentage increase in the number of vehicles and in the investment, but the relative relationships between these factors will not be changed. For trailer combinations with 4 or more axles, the payloads and prices for each are calculated on two bases, (a) 18,000-lb single axles with 32,000-lb tandem axles, and (b) 22,400-lb single axles with 40,000-lb tandem axles.

From the investment standpoint, it is apparent that the 22,400-lb single axle and the 40,000-lb tandem axle maximum limits provide more economical vehicles than do the 18,000-lb and the 32,000-lb limits. Obviously, the number of trailer combinations required for a specific tonnage diminishes with the increase in payload capacities, but this effect on costs can be measured only by including the different operating costs of the various vehicles. This comparison is made later in the report.

The net horsepowers listed in Table 25 are estimated as those required to move each trailer combination weight at a speed of 50 mph on level road at sea level. A road speed of 50 mph was assumed because the vehicles are intended for line-haul freight service and should have at least this road speed capability. This level road speed capability will provide for a hill-climbing ability of a little better than 20 mph on a 3 percent grade. The net horsepower figures listed were estimated, using the SAE Truck Ability

TABLE 25

CHARACTERISTICS AND PRICES OF TRACTOR AND TRAILER COMBINATIONS FOR RANGE OF AXLE AND GROSS WEIGHTS[a]

1	Type of combination	Tractor semi	Tractor semi	Tractor semi	Tractor semi	Tractor semi	Tractor semi	Tr semi & full	Tr semi & full	Tr semi & full	Tr semi & full	Tr semi & full	Tr semi & full	Tr semi & full	Tr semi & full
2	Axle code classification	2-S1	2-S1	2-S2	2-S2	3-S2	3-S2	2-S1-2	2-S1-2	3-S2-2	3-S2-2	3-S2-3	3-S2-3	3-S2-4	3-S2-4
3	Number of axles on power unit	2	2	2	2	3	3	2	2	3	3	3	3	3	3
4	No of axles on 1st trailer	1	1	2	2	2	2	1	1	2	2	2	2	2	2
5	No of axles on 2nd trailer	-	-	-	-	-	-	2	2	2	2	3	3	4	4
6	Rating single axles (4-tires), lb	12,000	18,000	18,000	22,400	-	-	18,000	22,400	18,000	22,400	18,000	22,400	-	-
7	Rating of tandem axles, lb	-	-	32,000	40,000	32,000	40,000	-	-	32,000	40,000	32,000	40,000	32,000	40,000
8	Gross combination weight, gvw	30,000	42,000	57,000	71,400	73,000	91,000	81,000	100,600	109,000	135,800	123,000	153,400	137,000	171,000
9	Tare weight of combination, lb	12,600	16,500	21,500	22,500	26,000	27,000	28,500	31,000	36,000	39,500	42,500	43,000	44,500	46,000
10	Payload capacity, lb	17,400	25,500	35,500	48,900	47,000	64,000	52,500	69,600	73,000	96,300	80,500	110,400	92,500	125,000
11	Type of engine in power unit	Gas	Gas	Gas	Gas	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
12	Net engine horsepower, approx	132	156	184	212	216	250	230	269	288	337	312	370	340	403
13	Price of power unit, $	3,140	5,400	8,100	9,800	16,100	18,640	14,600	17,280	19,780	20,960	20,490	21,800	20,960	22,600
14	Price of 1st trailer, $	3,140	3,520	4,450	4,810	4,810	5,180	3,520	3,880	4 810	5,050	4,700	4,940	4,810	5,180
15	Price of 2nd trailer, $	-	-	-	-	-	-	3,520	3,880	3,520	4,070	4,700	4,940	4,810	5,180
16	Price of converter dolly, $	-	-	-	-	-	-	1,250	1,250	1,250	1,250	1,250	1,250	2,100	2,100
17	Price of combination, $	6,280	8,920	12,550	14,610	20,910	23,820	23,090	26,290	29,360	31,330	31,140	32,930	32,680	35,060
18	Price per 1,000 lb gvw, $	209	212	220	205	286	262	285	261	269	231	254	215	239	205
19	Price per 1,000 lb payload, $	361	349	354	299	445	372	440	378	402	325	387	299	353	280
20	No of combinations to move 1,000 tons per day, one way	115	79	57	41	43	32	38	29	28	21	25	19	22	16
21	Investment to move 1,000 tons per day, one way, $	722,200	704,680	715,350	599,010	899,130	762,240	877,420	762,410	822,080	657,930	778,500	625,670	718,960	560,960
22	Tare weight tractor, lb	5,800	8,500	10,500	11,000	14,500	15,000	12,000	12,500	15,000	16,500	16,500	17,000	16,500	17,500
23	Tare weight 1st trailer, lb	6,800	8,000	11,000	11,500	11,500	12,000	7,000	8,000	11,500	12,000	12,000	12,000	12,000	12,500
24	Tare weight 2nd trailer, lb	-	-	-	-	-	-	7,000	8,000	7,000	8,500	11,500	11,500	11,500	11,500
25	Tare weight converter dolly, lb	-	-	-	-	-	-	2,500	2,500	2,500	2,500	2,500	2,500	4,500	4,500
26	Tare weight, combination, lb	12,600	16,500	21,500	22,500	26,000	27,000	28,500	31,000	36,000	39,500	42,500	43,000	44,500	46,000

[a] Prices less tires and with closed van cargo bodies

Prediction Procedures (25). It will be noted that the use of 269 hp in the hauling of a 100,000-lb trailer combination has been assumed as the practical limit for 4 x 2 tractive vehicles. Where grades exceed 3 percent, or where snow-covered roads are encountered, it is not likely that a single drive axle will pull satisfactorily this amount of gross weight. In such circumstances, tractive vehicles with two drive axles must be used, either 4 x 4 or 6 x 4 powered vehicles.

Automotive Service Vehicles

All types of carriers have some need for road service trucks, whether owned by the carrier or operated by public garages. Likewise all types of carriers have need for safety departments and safety patrol cars, whether they be carrier-owned or supplied by others with inspection service for a fee. It was not practical to develop adequate automotive service truck and car investment data from the variety of carriers interviewed, and for this reason the investment data reported by the ICC under its account 1230, "Service Cars and Equipment," for Class I common carriers of general freight with owned equipment principally (2) have been used. These data provide a reasonable level of investment in such equipment and can be applied to any type of line-haul service. From ICC data the average fleet investment in service trucks and cars and equipment was $19,442 in 1956.

Property Not Included in Study

It was assumed that a change in size and weight limitations would cause no change in the following types of properties: terminals, docks and terminal yards; dock equipment; general office buildings; general office equipment; salesmen and official's cars; and city pickup and delivery trucks. For this reason, investments in and depreciation of these types of properties are not included in the trucking cost study.

DEPRECIATION EXPENSES

Depreciation charges represent an estimate of the reduction in the value of property that is caused by the factors of deterioration and obsolescence, and charges for these factors are properly included in the cost study. Deterioration and obsolescence, however, do not affect uniformly the different types of properties used by highway freight carriers. In usual accounting practices, the depreciation charges are intended only to accumulate in a reserve account, during the estimated life of a property, the number of dollars spent in the original investment in the property. In a period of rising prices this practice does not accumulate a sufficient reserve fund to purchase the replacement property, and the additional funds needed for the purchase of the replacement property are usually taken from earnings retained by the company. Although these practices are satisfactory for financial management, they do not suffice in a cost study because the total cost of the replacement property may not be recovered in the depreciation charges, and there was no convenient means for determining and distributing annually the additional funds taken from surplus earnings for the purchase of the replacement property. As a result, in order to have depreciation charges reflect current costs, the major properties included in the cost study were priced at 1956 levels, and the depreciation rates applied were those which would recover all of the 1956 purchase prices. Certain other low value properties were handled as was expedient with the available data. The types of properties that are depreciated are those which have been described previously in the section on Property Investments, and the depreciation methods used for each type of property are described in the following sections.

Land

Because the fleet model garage facility was assumed to be located on industrial property, no depreciation was calculated on the land investment.

Garage Building and Building Appurtenances

The estimated new value of the fleet model garage building and building appurtenances including the paved service and parking area was $943,400 at 1956 prices. The estimated life of the facility was assumed as 35 yr, giving an annual straightline depreciation charge of $11,260. This facility was assumed to be adequate for 100 trailer combinations with average annual mileages of 51,200 mi. For the assumed annual fleet mileage of 5,120,000 mi, as reported in the section on Insurance, the depreciation charge resulting is $0.0022 per vehicle-mile. This charge for garage facilities is applied to all types and sizes of vehicles and trailer combinations.

Garage Machinery and Equipment

The estimated value of the shop machinery and shop equipment in the fleet model garage facility was assumed at $78,000. The average composite life of this equipment was assumed at 10 yr. On this basis the straightline annual depreciation charge is $7,800. Distributing this expense to vehicle-miles, as was done for the garage building, gives a shop machinery and equipment depreciation expense of $0.0015 per vehicle-mile. This expense is applied equally to all types and sizes of trailer combinations.

Parts and Supplies in Stock

Because parts and supplies in stock are considered as active and current stock which is being frequently turned over, no depreciation expense is calculated for this material.

Automotive Service Vehicles

The estimated value of $19,442 for service vehicles for an average line-haul fleet was developed from data reported by ICC Class I common carriers of general freight (2). This value of service trucks was for an average fleet of 57 trailer combinations averaging 51,200 mi per yr. An average life of 6 yr was assumed as the useful life of service trucks and equipment. On this basis the straightline annual depreciation expense was $3,240. Distributing this expense to the vehicle mileage of the 57 trailer combinations gave a service trucks and equipment depreciation charge of $0.0011 per vehicle-mile. This expense is applied equally to all types and sizes of trailer combinations.

Line-Haul Revenue Vehicles

Motor carriers' depreciation charges for line-haul vehicles necessarily are based on past prices. This is the result of the recognized methods for depreciation accounting as mentioned earlier. In addition, it was found from the field study that carriers used widely different depreciation rates and methods for equivalent vehicles, and that the rates used for accounting purposes seldom represented the actual physical life and use of the vehicles because vehicles were continued in use after being fully depreciated. For these reasons neither the field data nor other published data were useful in estimating 1956 annual depreciation charges that would accumulate sufficient reserve funds to purchase new replacement vehicles at 1956 prices.

In addition to depreciation data, the carriers were queried as to the actual periods at which they retired vehicles from line-haul service. Although these retirement times also had a wide range, it was thought that these data were more valid for the purposes of the study than were the reported depreciation rates. The handling of these retirement data is discussed in the following sections on power units and trailers.

Power Units

Vehicle retirement practices in the line-haul part of the trucking industry differ from those of passenger car owners, as well as from those of city truck operators. Passenger cars predominantly pass through several ownerships during their service lives from factory to junk yard. This situation prevails because there is a market for used cars of different ages and varying conditions in the United States.

City trucks include pickup trucks, panel trucks, utility service trucks, and various freight trucks, such as those with van bodies, tank bodies, and dump bodies. The resale market for some city trucks is good and for others, fair to poor. Panel trucks and van trucks do descend rather easily down the economic scale from the first owners, who regularly replace their trucks rather early because of style changes, appearance, and anticipation of repairs, to second and subsequent owners who primarily desire service with low capital investment. Such vehicles may progress from owner to owner because their general utility makes them readily marketable. Some of these trucks may even enter the farm market where the annual mileage may be even below that of city trucks.

The resale market for large high-powered tractors, built for line-haul service, is much more limited than the market for other vehicles. The large number of users of smaller capacity trucks have no need for large, heavy-duty vehicles. In the past, obsolescence, caused by changes in size and weight regulations, has been the frequent cause of the early retirement, by first owners, of medium-size line-haul tractors. Tractors of specific payload capabilities, which thus have become obsolete in one State, frequently would find a market in other States retaining lower weight limits. Of course, there does exist a used-tractor market relationship between those carriers, who wish to keep the appraisal value of their rolling equipment relatively high, and those carriers who desire lower capital investment in rolling equipment and hence preferably purchase used tractors. A second resale market for still older tractors is relatively small.

Under these circumstances, many line-haul carriers run their line-haul tractors to the end of their useful life. This long usage is especially the case with the large heavy-duty line-haul tractors. In the study, many cases were found where heavy-duty line-haul tractors and tractive trucks were more than 10 yr old, with individual vehicle mileage of 1,000,000 or more miles.

The intricacies and variations that occur in the actual purchase, ownership, and disposal of line-haul power vehicles in the trucking industry reflect, primarily, differences in the management and local circumstances of a given company, and, as such, have little or no relation to the basic depreciation and replacement costs that are needed to compare different levels of types and capacities of vehicles. For these reasons the following methods were used in calculating depreciation and replacement charges for different sizes and types of power vehicles.

It first was assumed that early obsolescence, which might be caused by a change in permitted size and weight limits, would not be considered. Instead, it was assumed that vehicles would be retired from line-haul service when worn to the extent that it was more practical to replace and junk a vehicle, than to rebuild it completely for continued line-haul service. This retirement age would be the maximum useful life in line-haul service, whether run out by one or more than one owner. Also, inasmuch as the study is to determine costs for specific levels of gross weight capacities, a replacement vehicle is to be the equivalent of the one retired, with no upgrading as to capacity or purchase price. Further, because the vehicles are assumed to run out their useful line-haul life, they are salvagable only at scrap values; although the scrap values are approximately one percent of the original prices, for expediency in calculation, they are considered to be zero.

It was assumed in the study that an equal proportion of the vehicles in a fleet is retired and replaced each month of each year during their service life. For example, where the service life of a series of similar vehicles is stated as 8 yr, it is assumed that 12½ percent of the vehicles are replaced each year. In this way, the average age of the vehicles in the fleet is kept constant at one-half of the stated service life, or in the 8-yr example the average age of the vehicles in the fleet would be 4 yr at any time.

Under these conditions of retirement and replacement the annual depreciation charge for a power unit would be $\frac{1}{\text{years of service life}}$ X original price. For consistency in distributing this annual depreciation charge, all power vehicles were assumed to run 51,200 mi per year (average annual line-haul vehicle-miles for trailer combinations of Class I common carriers) (2).

The carriers' data regarding retirement of power vehicles from line-haul service were segregated by engine type, engine size, and gross combination weight capacities. These classes are shown in the following schedule:

Gasoline Engine		Diesel Engine	
Engine Displacement (cu in.)	Gross Combination Weight (lb)	Engine Displacement (cu in.)	Gross Combination Weight (lb)
250-350	25,000-45,000	250-500	25,000-60,000
351-500	45,000-60,000	501-700	60,000-70,000
over 501	60,000-80,000	over 700	70,000-80,000

As would be expected, the range in number of years of service life showed considerable variation. In Figure 13, cumulative percentage curves show the distribution of vehicle retirement ages among 595 carriers using gasoline engine power units. Figure 14 shows similar data for 163 carriers using diesel engine power units. These curves are manually smoothed.

In each figure, the 80 percentile line was selected as a level at which a preponderance of power units in regular line-haul service would be retired and replaced. The values picked off at this 80 percentile level were used in calculating depreciation charges for different capacity power units, as given in Table 26.

Trailers

Like large heavy-duty line-haul tractors, the resale market for used, large line-haul trailers is limited. Changes in exterior styling are not a factor in obsolesence, but changes in legal length limitations have been a factor in causing early replacement of trailers. Significant changes in permitted lengths have occurred during the past

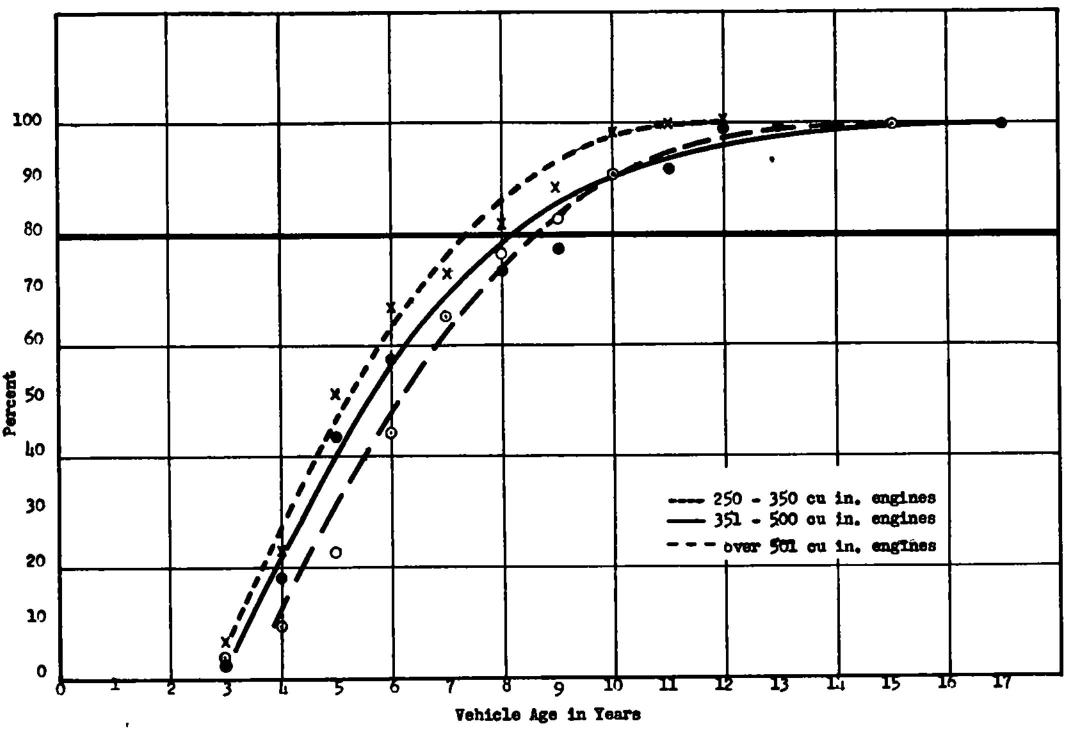

Figure 13. Gasoline engine power units. Age in years when replaced.

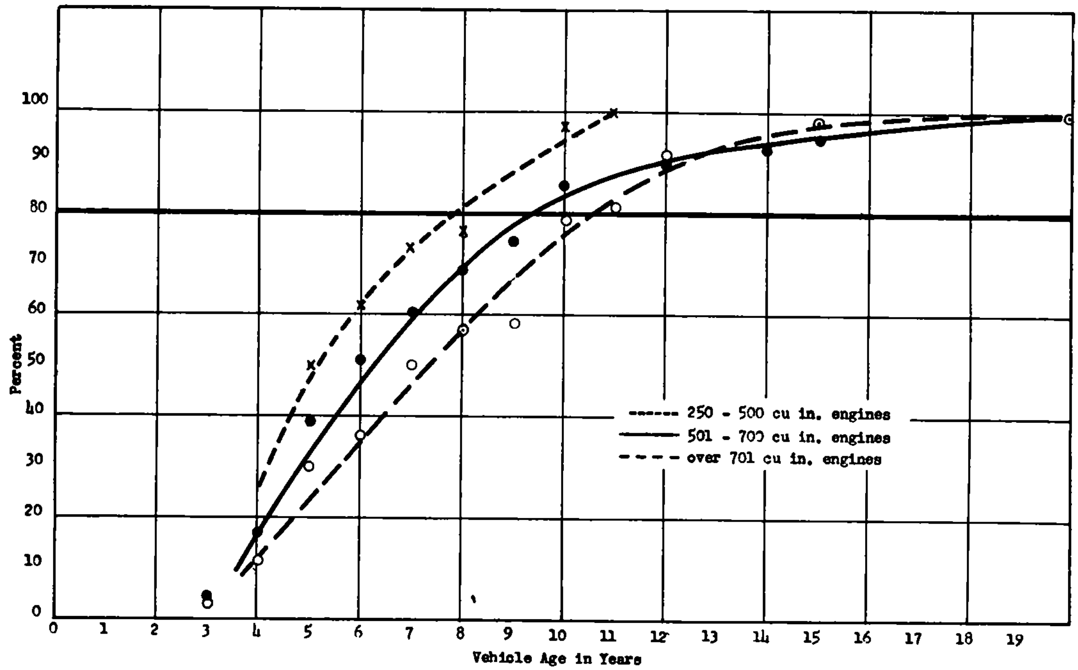

Figure 14. Diesel engine power units. Age in years when replaced.

4 yr in previous barrier States which held lengths of trailers to a maximum of 35 ft. Currently (1960) only two States, Pennsylvania and West Virginia, do not permit trailers as long as 40 ft. Some obsolescense has resulted from increased use of light metals in trailer construction which reduces tare weight and permits greater payload with the same gross weight.

The field work of the study was conducted just before the recent upsurge of length increases, and at a time when the 35-ft length of trailers was the prevailing useful maximum length. The range of service lives of trailers as reported by the carriers varied from 6 to 14 yr.' Undoubtedly, some of the short lives were a result of obsolescence resulting from changes in length limits. The distribution of retirement ages was

TABLE 26

RETIREMENT DEPRECIATION RATES OF POWER UNITS BY GROSS COMBINATION WEIGHTS

Gasoline Engine		Diesel Engine	
Gross Combination Weight (lb)	Life (yr)	Gross Combination Weight (lb)	Life (yr)
25,000-45,000	7.4	25,000-60,000	7.9
45,000-60,000	8.1	60,000-70,000	9.3
60,000-80,000	8.5	70,000-80,000	10.6
over 80,000	8.5[a]	over 80,000	10.6[a]

[a]Because of inadequate information, service lives of power vehicles with gross combination weights above 80,000 lb were assumed as the same as for the 80,000-lb vehicles.

fairly uniform, between 6 and 14 yr, and for that reason an arithmetical average of retirement ages was calculated for the seven types of trailers given in Table 27. These average retirement ages are probably on the low side for modern trailers, but they furnish specific values which can be used in making adjustments in depreciation costs to fit different circumstances. The retirement ages are comparable with a 10-yr life factor developed by the California Public Utility Commission (16) more than 10 yr ago.

From the field data, it was not possible to develop retirement rates in relation to gross weights, except to the extent that 2-axle semitrailers are expected to carry greater payloads than 1-axle semitrailers. This effect may be noted in the shorter useful lives of the 2-axle semitrailers compared with the average lives of the 1-axle semitrailers.

TABLE 27

RETIREMENT DEPRECIATION RATES OF TRAILERS

Type	No. of Axles	Life (yr)
Van semitrailer	1	9.5
" "	2	8.8
Van full trailer	2	10.0
Tank semitrailer	1	10.8
" "	2	9.5
Tank full trailer	2	9.4
" "	3	10.0

INTEREST PAID FOR INVESTMENT FUNDS

The interest paid for capital funds varied considerably among carriers interviewed. Revenue equipment is purchased under several different plans which are briefly: (a) cash purchases with funds from depreciation reserves and from retained earnings, (b) bank loan financing of all or part of the purchase price, and (c) factory or dealer installment financing plan.

The range of interest rates reported for revenue equipment purchase funds was from 4 to 7 percent. A preponderance of the carriers reported that they paid 6 percent for equipment funds, and for that reason a 6 percent annual rate is used in the study in calculating interest charges on revenue equipment investments.

For funds invested in buildings and land, a lesser rate of 4.5 percent was predominant and was representative of bank loan rates on industrial property at the time of the field interviews. This rate is used in the study.

Although it is true that not all of the trucking industry's property is purchased with bank loan funds, nevertheless those who supply the funds want some return, whether they be stockholders, banks, finance companies or individual owners. The element of profit is a recognized cost in American industry; and in an attempt to avoid controversy as to a reasonable amount of profit, the interest rates previously mentioned were applied to the depreciated value of revenue equipment and, for convenience, to the reported values of other types of property to determine the interest costs chargeable to line-haul operations.

RATIOS OF PAYLOADS TO GROSS COMBINATION WEIGHTS

Table 25 lists the maximum payload capabilities of the various types of trailer combinations when equipped with conventional closed van cargo bodies, and when loaded to the specified axle weight limits. These payload values are those which could be obtained if the cargo bodies were always fully loaded to the extent that would give a gross combination weight equal to the sum of the specified axle weights. This condition would be a 100 percent use of the vehicle capabilities; a condition that does not exist in practical trucking operations because of differences in weight characteristics of shipments, and because of empty or part empty backhauls.

From the data in Table 25, Figure 15 was developed. This figure shows the maximum payload capabilities of various trailer combinations with closed van bodies for an increasing scale of gross combination weights. The ascending curve shows the maximum payload in 1,000 lb for given gross combination weights. The second curve shows the payload in percentage of gross combination weight. It will be noted that the payload ratio improves from 60 percent at 30,000 lb gross to 69 percent at 100,000 lb gross, whereas at 160,000 lb and above gross the payload ratio approximates 73 percent.

CALCULATION OF GROSS WEIGHTS

The loaded gross weights used in developing vehicle-mile costs and shown in the abscissas of the cost curves are the sums of the tare weights of the trailer combinations plus the predominantly carried payloads. These weights were obtained from each carrier by the following procedures:

1. For each group of similar vehicles for which cost and operating data were available, the interviewer obtained the tare weights of both power units and trailers. At the same time cargo body type, body dimensions, tire sizes and other vehicular data were recorded.
2. Several days of each carrier's daily pullout reports, which are compiled by line-haul dispatchers and which list payload weights for each outgoing trailer, were analyzed by the interviewers to determine the mode of the payload weights on fully loaded trailers. The pullout reports of several days were discussed with the line-haul dispatcher, or the transportation superintendent, to further check on the validity of each carrier's predominantly carried payload. During these interviews with transportation supervisors, estimates were obtained carrier-system-wise as to the percentage of empty trips of trailers when no backhaul freight was available.

For example, with liquid commodity haulers it was simple to calculate the normal full payload by multiplying the cubic capacity of the tank or hopper by the shipping density of the commodity in lb per gal, or pcf. Predominantly, with such commodities the backhauls would be empty.

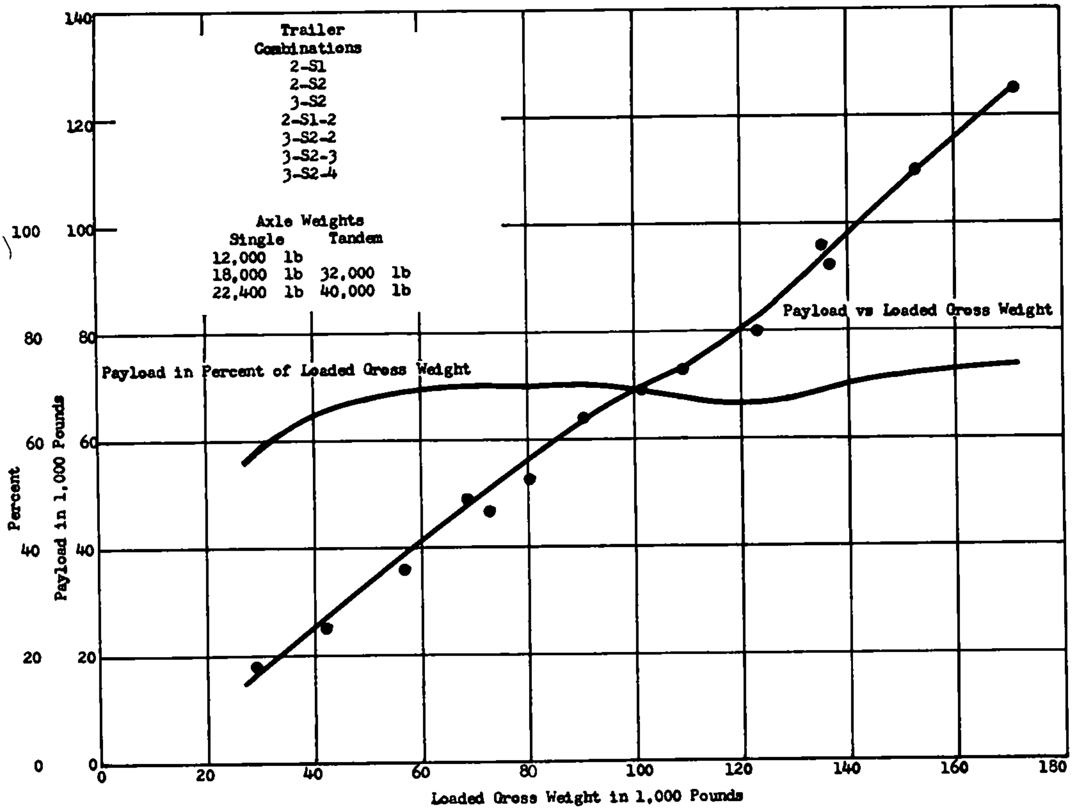

Figure 15. Maximum payload capability vs maximum gross combination weight for various trailer combinations with van cargo bodies.

For the different types of dry freight, the procedure was not as simple, but good estimates as to degree of loading were obtained from the daily pullout records and by the interviews with dispatchers.

A number of the carriers interviewed had more than one group of similar trailer combinations in their fleets, and had cost data for the vehicles in each group of similar trailer combinations. For example, a carrier might have a fleet of 2-S1 van trailer combinations for that part of the carrier's service (with light density commodities) in which such a trailer combination was optimum, whereas another part of the carrier's service (with heavier commodities) might require 3-2 trailer combinations. Cost and payload data would be different for these two groups of similar vehicles, and the data of each fleet was recorded and analyzed separately, even though from the same carrier. For this reason there are data for more groups of similar trailer combinations in the analysis than the number of carriers. Of course, where a carrier's fleet was composed entirely of the same type and capacity of trailer combination, the fleet was considered as a single group of similar trailer combinations, and was analyzed accordingly.

3. In the office analysis, the average tare weight of the vehicles in each group of similar trailer combinations in a carrier's fleet was added to the predominant weight in the payloads carried by each group of similar trailer combination to make the loaded gross weight that was used with the corresponding cost data. (See definition 44 in Glossary of Terms in Appendix for further detailed explanation of loaded gross weight.)

It is believed that this loaded gross weight value for trailer combinations is, for the study, the most realistic of the various methods of determining the gross vehicle weights to be used in calculating unit costs. Further, the loaded gross weights of the various sizes and weights of trailer combinations can be related to the costs of providing highway facilities at different levels of load-carrying capabilities.

TABLE 28

GROUPING OF TYPES OF TRAILER COMBINATIONS

Gasoline Engine		Diesel Engine	
(a)	2-S1	(f)	2-S1
(b)	2-S2	(g)	2-S2
(c)	3-S2	(h)	3-S2
(d)	2-2	(i)	2-2
	3-2		2-3
			3-2
			3-3
(e)	2-S1-2	(j)	2-S1-2
	2-S2-2		2-S2-2
	3-S2-3		3-S1-2
			3-S2-3

All methods of developing gross weight values produce different degrees of error in gross weights as a result of differences in the characteristics of different types of operation, but the use of the loaded gross weight values is thought to be best for the study for the following reasons:

1. Repair, servicing, and lubricant costs are related primarily to mileage. They are also affected to a lesser extent by payload, highway conditions and grades, vehicle designs, and type of operation.

2. Tire and tube costs are primarily related to mileage, but may be affected by payload carried. However, there were no data available on this effect.

3. Fuel costs are affected by payload; but the difference between the fuel consumption of vehicles loaded on both outbound and inbound trips and the fuel consumption of vehicles loaded in one direction with empty return is but a small portion of the gross operating cost.

4. Driver costs in this study are related entirely to mileage and loaded gross weight, regardless of degree of payload.

5. Indirect and overhead costs are largely time costs with little or no relation to degree of payload.

6. Depreciation and interest costs are time costs with no relation to degree of payload.

GROUPING OF TYPES OF TRAILER COMBINATIONS FOR ANALYSIS

As can be expected from the numerical distribution of trailer combinations as given in Table 5, the observed data do not encompass a uniform number of trailer combinations of each type. An adequate sample was obtained for certain of the most popular types of combinations, but for the less frequently occurring and larger vehicles the number of cases was too small to permit the development of statistically smoothed curves. For this reason the data of the less frequently occuring types of combinations were grouped together into logical family groups of vehicles for statistical processing. These family groupings by axle classification and fuel type result in 10 groups of trailer combinations which are listed in Table 28. In addition, other analyses are made by body type, average road speeds, etc., but such subdivisions also are made about the family groups by axle classification and fuel type given in Table 28.

Cost Trends

QUANTITY OF DATA

The field data, after review to determine completeness and consistency of each case report, were found to consist of reports from 611 highway freight carriers which involved a total of 23,384 trailer combinations. The trailer combinations were sorted into 743 groups of vehicles of similar characteristics with each group operating in identical or similar services. The operations of these 743 groups of similar vehicles were distributed among the different types of motor carriers as follows: common carriers, 408; private carriers, 246; contract carriers, 79; and exempt-for-hire carriers, 10. The analyzed data for each of the 743 groups of similar vehicles were punched on punch cards for machine tabulation and development of smoothed trend curves by the method of least squares. The data punched on the cards consisted of the following items and average unit costs for each group of similar vehicles.

1. Case code number;
2. Type of motor carrier;
3. Type of trucking service;
4. Type of vehicle or trailer combination by axle classification;
5. Type of fuel used;
6. Type of cargo body;
7. Number of power units;
8. Average gross weight of combination loaded;
9. Average daily miles per power unit on regular working days;
10. Number of days line-haul service operated per week;
11. Average annual miles operated by power units;
12. Type of terrain (terrain of road);
13. Typical average road speed when running;
14. Characteristics of payloads;
15. Characteristics of line-haul cargo loadings;
16. Commodities predominantly carried;
17. Ownership of repair and maintenance facilities;
18. Average costs per power unit vehicle-mile for: (a) repairs, servicing and lubricants, (b) tires and tubes, (c) fuel, (d) driver wage and subsistence, (e) indirect and overhead costs, and (f) depreciation and interest costs;
19. Cumulative subtotals of the foregoing average costs under the following headings: (a) repair, servicing, and lubricant costs (18a), (b) direct maintenance costs (19a plus 18b), (c) direct vehicular costs (19b plus 18c), (d) direct running costs (19c plus 18d), (e) total running costs (19d plus 18e), and (f) gross operating cost (19e plus 18f).

Additional supplementary data:

20. Ratio of power units to trailers;
21. Tare weight of combination;
22. Engine size — cu in. displacement;
23. Gross weight lb per net horsepower; and
24. Average fuel consumption in gal per mile.

It is obvious that the variety of details of these data will permit studies of the effects of different factors on operating characteristics and on operating costs. Not all of these factors affect the problem of sizes and weights, but their consideration may indicate the degree of significance, if any, of certain factors for use in other studies.

SCATTER OF OBSERVED DATA

To show the degree of variance that exists in the study data, inasmuch as considerable variance can be expected in studies of this type, scattergrams of the gross operating costs by vehicle gross weight are shown for gasoline engine trailer combinations in Figure 16, and in Figure 17 for diesel engine trailer combinations. These gross operating cost data include all types of combinations, all types of terrain and all types of service.

In Figure 16 are shown the gross operating costs for 531 groups of similar trailer combinations with gasoline engine power units. These 531 groups included 17,737 trailer combinations. In Figure 17 are similar data for 212 groups of trailer combinations with diesel engine power units which include a total of 5,647 trailer combinations.

These scattergrams merely indicate that the spread of the data is not excessive (there are a few mavericks in the higher weight groups), and that trends of the means of the values in the different gross weight intervals are consistent. The data for the trailer combinations with very high loaded gross weights (most of those above 100,000 lb) relate primarily to private road operations which are the main source of such information. The private roads all were graded and had a degree of hard surfacing which varied from compacted gravel to bitumem-treated surfaces.

ANALYSIS OF DATA

The data cards were initially sorted into groups of vehicles by axle classification and by type of engine. Following this the punch cards of each group of vehicles were arranged in an ascending order of loaded gross weight. For analytical processing, the cards were further sorted and assembled into class-intervals of 5,000-lb loaded

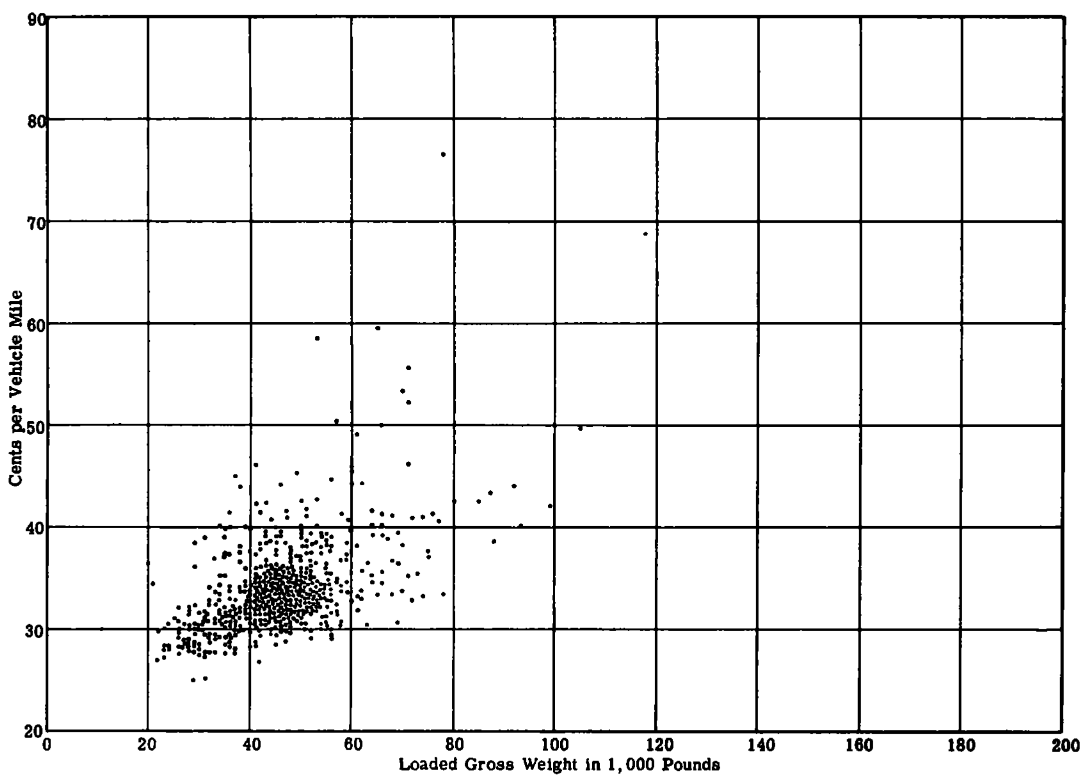

Figure 16. Scattergram showing range and spread of gross operating costs of 531 groups of gasoline engine powered trailer combinations.

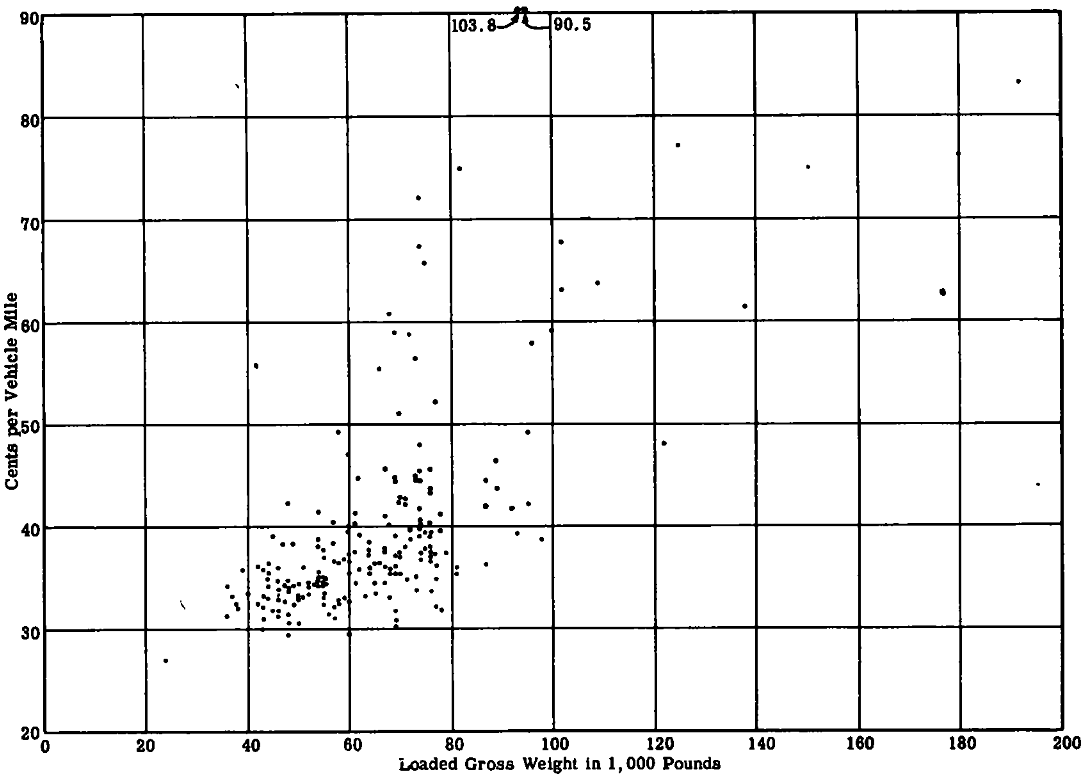

Figure 17. Scattergram showing range and spread of gross operating costs of 212 groups of diesel engine powered trailer combinations.

gross weight, with the midpoint of each 5,000-lb class-interval being used as the plotting ordinate. After these sortings, the mean of each of the several cost elements of each class-interval of vehicles, together with the number of vehicles in the class-interval, were tabulated from the cards. From these tabular sheets were taken the appropriate data relating to each operational characteristic to be studied. The selected data were then processed on an electronic computer by a least-squares program to develop the general characteristics of a best-fit curve for a specific group of data. The same process was used in making analyses of finer subdivisions of the cost data, such as by axle-classification, by body type, and by type of terrain, in addition to loaded gross weight values. In a few of these substudy analyses the data were sparse at the ends of the curves so that it was necessary to make adjustments at the extreme ends of certain curves to make them conform to the logic of trucking operations. Especially in these subdivision studies, the cost trend curves should not be extrapolated beyond the data shown.

COST RESULTS

The costs developed from the data are reported in the figures and tables in the following portions of the report. One feature of many of the figures is small circles, or other code marks, near the curves which indicate the mean of the values in a given 5,000-lb class-interval of loaded gross weight. (An explanation of the range of the data making up the means is given in the Appendix.) The selected best-fit curve is drawn through the scatter of these mean value points. In addition, on the charts relating to "Repair, Servicing and Lubricant Costs," a numeral is printed adjacent to each mean value point. This numeral is the number of trailer combinations the costs of which make up the adjacent mean value. The number and distribution of vehicles are the same in each of the charts grouped together under a single figure number, but this vehicular information is shown only on the "Repair, Servicing and Lubricant Costs" charts.

From the mean values shown, and the number of vehicles included in the mean, together with the trend curves and their equations, the reader can see at a glance the spread and amount of data in a specific series of curves. Because all the data are shown on the charts, these data are not repeated in tabular form in the text.

Gross Operating, Payload Ton-Mile, and Gross Ton-Mile Costs for All Trailer Combinations

The following three charts (Figs. 18, 19 and 20) reflect the over-all results of the trucking cost study. These three charts show how gross operating costs of trailer combinations increase with increases in loaded gross weight; show the extent to which payload ton-mile costs and gross ton-mile costs decrease with increases in gross weight; and indicate the region of maximum gross weight above which further increases in loaded gross weight do not produce significant reductions in payload ton-mile costs and in gross ton-mile costs with vehicles and power plants available in 1956.

Immediately following these three charts are an extensive series of cost charts of various subdivisions of the data which show how the elements of unit operating costs vary with different types of trailer combinations, and with different operating conditions. These series of charts are the supporting data for the three over-all charts described in the following paragraphs. The nature and data of the supporting charts are discussed later.

Figure 18 shows the trend of gross operating costs developed from the data of all the trailer combinations included in the study. Data from 23,384 trailer combinations are reflected in the curves in Figure 18. It will be noted that these data extend over a range

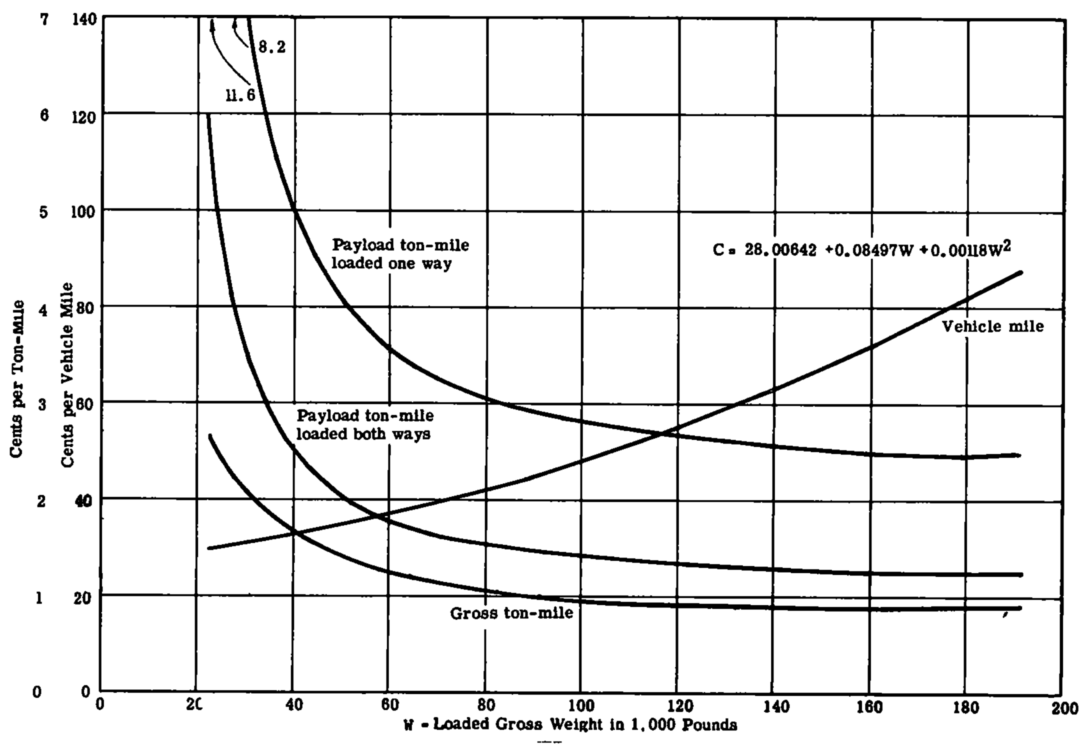

Figure 18. Gross operating costs for all trailer combinations, showing gross ton-mile costs, payload ton-mile costs for operations loaded both ways, and payload ton-mile costs when loaded one way with empty return trips.

of loaded gross weights from 22,500 lb to 192,000 lb. The gross operating costs per vehicle-mile increase from $0.30 at 22,500 lb to $0.88 at 192,000 lb loaded gross weight.

In the equation of the curve of vehicle-mile costs: "C" means cost in cents per vehicle-mile, and "W" means loaded gross weight in 1,000 lb.

Two additional curves shown in Figure 18 reflect payload ton-mile costs under two operating conditions: (a) with full payloads in both outbound and return directions, and (b) full payload in one direction with no cargo on the return trip. The third additional curve shows changes in gross ton-mile costs.

With all mobile transportation equipment it is necessary for the conveyance to be returned ultimately to its original starting point for further cargo carrying. In line-haul trucking, the return trip of the conveyance frequently is more direct and immediate than is the case with other freight conveyances, such as railcars and ocean steamships. In the case of certain highway freight carriers, many return trips are made without cargo (Table 35). Empty return trips are inherent in the truck transport of commodities, such as sand, crushed stone, coal, petroleum products, flour and portland cement in bulk, fluid chemicals, and automobiles. Empty return trips are encountered less frequently by carriers of merchandise and dry freight.

When a freight vehicle is empty on its return trip, the payload ton-mile cost of delivering the payload to its destination must include the cost of the empty return trip, hence the unit payload ton-mile cost for the delivery trip is closely equivalent to twice the unit payload ton-mile cost when an equivalent vehicle is loaded in both directions. The slight differences between the vehicle-mile costs of a vehicle loaded in both directions, and the vehicle-mile cost of a vehicle loaded in one direction with an empty return trip, are discussed later in the report. In Figures 18, 19 and 20, the unit ton-mile costs for vehicles loaded in one direction with empty return trips are assumed as twice the unit ton-mile costs of vehicles loaded in both directions. These two curves define the payload ton-mile costs for the two extremes of operating circumstances; namely, loaded in both directions versus loaded in one direction with empty return trip. Unit payload ton-mile costs for loads in one direction with different degrees of loading on backhauls will lie between these two extremes.

In Figure 18 the lower payload ton-mile cost curve is for loads in both directions, while the upper payload ton-mile cost curve is for loads in one direction with empty return trip. The payloads used in calculating the payload ton-mile costs for loads in

TABLE 29

PAYLOAD TON-MILE AND GROSS TON-MILE COSTS BY LOADED GROSS WEIGHT — ALL TRAILER COMBINATIONS

Loaded Gross Weight (lb)	Payload Ton-Mile Costs: Loaded in Both Directions ($)	Payload Ton-Mile Costs: Loaded in One Direction With Empty Return ($)	Gross Ton-Mile Costs ($)
27,500	0.0410	0.0820	0.0227
44,000	0.0230	0.0460	0.0155
58,000	0.0183	0.0366	0.0127
65,000	0.0170	0.0340	0.0118
73,000	0.0160	0.0320	0.0111
82,000	0.0152	0.0304	0.0105
91,000	0.0147	0.0294	0.0100
100,600	0.0142	0.0284	0.0096
123,000	0.0133	0.0266	0.0091
137,000	0.0129	0.0258	0.0090
171,000	0.0124	0.0248	0.0090

both directions are the representative possible payloads in relation to loaded gross weights which are developed in Figure 15.

The payload ton-mile costs are taken from Figure 18 and tabulated in Table 29 in a series of hypothetical maximum gross weights that are representative of: (a) loaded gross weights developed with cargos of certain light density commodities; (b) loaded gross weights that are the average of the permitted gross weights of different axle classifications of vehicles in certain States; and (c) loaded gross weights that would be attainable with different axle weights and with different numbers of axles in a trailer combination. This arrangement of loaded gross weights shows directly the reduction in unit costs that corresponds to the increments of maximum gross weights that would result from changes in axle weights and axle arrangements. The general characteristics of the trailer combinations and permitted gross weights related to the loaded gross weights listed in Table 29 are described as follows:

27,500 lb: 2-S1 trailer combinations of about this gross weight are found in the transport of household goods, automobiles and other light and bulky commodities.

44,000 lb: a gross weight predominantly permitted for 2-S1 trailer combinations.

58,000 lb: a gross weight representative of permitted weights for 2-S2 trailer combinations in a number of States.

65,000 lb: a gross weight limit for 4-, 5- and 6-axle trailer combinations in several States.

73,000 lb: a gross weight limit representative of permitted weights for 5- and 6-axle trailer combinations in several States.

82,000 lb: a gross weight possible with a 2-S1-2 double trailer combination with 18,000-lb load-carrying axles.

91,000 lb: a gross weight possible with a 3-S2 tractor semitrailer with 40,000-lb tandem axles.

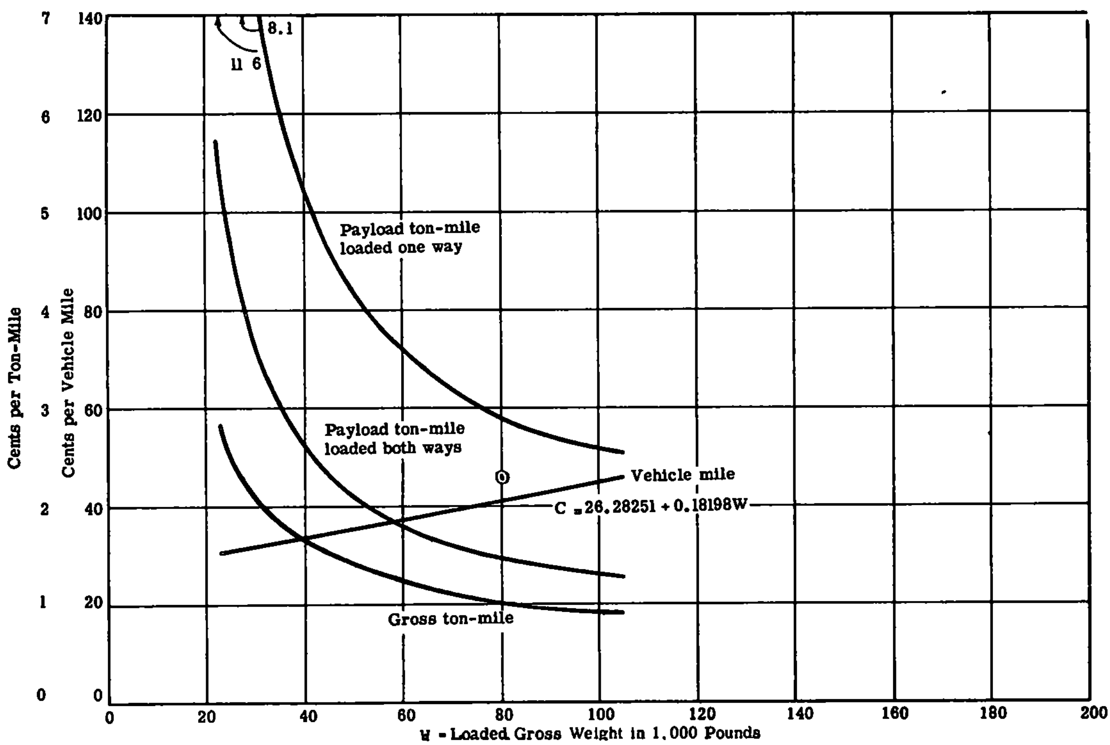

Figure 19. Gross operating costs for gasoline engine powered trailer combinations, showing gross ton-mile costs, payload ton-mile costs for operations loaded both ways, and payload ton-mile costs when loaded one way with empty return trips.

100,600 lb: a gross weight possible with a 2-S1-2 double trailer combination with 22,400-lb single axles.

123,000 lb: a gross weight possible with a 3-S2-3 double trailer combination with 18,000-lb single axles and 32,000-lb tandem axles.

137,000 lb: a gross weight possible with a 3-S2-4 double trailer combination with 32,000-lb tandem axles.

171,000 lb: a gross weight possible with a 3-S2-4 double trailer combination with 40,000-lb tandem axles.

The lowest curve in Figure 18 shows how gross ton-mile costs are reduced as gross weights are increased. The gross ton-mile costs reduce from $0.0267 at 22,500-lb gross weight to a low point of $0.0090 at 140,000 to 160,000 lb after which it rises slightly to $0.0092 at 192,000-lb gross weight. These gross ton-mile costs were obtained by dividing the vehicle-mile costs by the appropriate loaded gross weight. The gross ton-mile costs from Figure 18 also are given in Table 29 using the same increments of loaded gross weight that were used for the payload ton-mile costs.

Gross Operating, Payload Ton-Mile, and Gross Ton-Mile Costs for Gasoline Engine Powered and Diesel Engine Powered Trailer Combinations

The data shown in Figure 18 and Table 29 for all trailer combinations are broken down by type of engine in Figures 19 and 20, and Tables 30 and 31.

Figure 19 shows the gross operating costs per vehicle-mile, the two payload ton-mile costs, and the gross ton-mile costs for trailer combinations using gasoline engines. The data of 17,737 trailer combinations are included in these curves. The payload ton-mile costs, and the gross ton-mile costs were calculated in the same manner as in Figure 18. Table 30 gives the same three series of data as in Table 29, except that the values go up only to 100,600 lb, which amount was near the highest gross weights encountered in gasoline engine equipment.

Figure 20 and Table 31 show similar information for 5,647 diesel engine equipped trailer combinations.

Referring to Figures 18, 19 and 20, it will be noted that, for gasoline engine vehicles, the payload ton-mile costs appear to be still declining at 105,000-lb loaded gross weight, but data regarding heavier vehicles of this type were not available.

For the diesel engine trailer combinations, the payload ton-mile costs level off at about 160,000 lb. The reduction in payload ton-mile costs becomes insignificant above about 140,000-lb loaded gross weight.

TABLE 30

PAYLOAD TON-MILE AND GROSS TON-MILE COSTS BY LOADED GROSS WEIGHT — GASOLINE ENGINE POWERED TRAILER COMBINATIONS

	Payload Ton-Mile Costs		
Loaded Gross Weight (lb)	Loaded in Both Directions ($)	Loaded in One Direction With Empty Return ($)	Gross Ton-Mile Costs ($)
27,500	0.0405	0.0810	0.0228
44,000	0.0237	0.0474	0.0156
58,000	0.0184	0.0368	0.0127
65,000	0.0168	0.0336	0.0117
73,000	0.0155	0.0310	0.0108
82,000	0.0144	0.0288	0.0100
91,000	0.0137	0.0274	0.0094
100,600	0.0129	0.0258	0.0089

The combined data for all trailer combinations (Fig. 18) show a leveling off of payload ton-mile costs at about 140,000 lb. Hence, for this study, a limit of 140,000-lb loaded gross weight was selected as the point above which reductions in unit payload

TABLE 31

PAYLOAD TON-MILE AND GROSS TON-MILE COSTS BY LOADED GROSS WEIGHT — DIESEL ENGINE POWERED TRAILER COMBINATIONS

Loaded Gross Weight (lb)	Payload Ton-Mile Costs: Loaded in Both Directions ($)	Payload Ton-Mile Costs: Loaded in One Direction With Empty Return ($)	Gross Ton-Mile Costs ($)
37,500	0.0259	0.0518	0.0166
44,000	0.0222	0.0444	0.0149
58,000	0.0182	0.0364	0.0121
65,000	0.0170	0.0340	0.0118
73,000	0.0160	0.0320	0.0112
82,000	0.0154	0.0308	0.0106
91,000	0.0149	0.0298	0.0102
100,600	0.0146	0.0292	0.0099
123,000	0.0137	0.0274	0.0095
137,000	0.0133	0.0266	0.0093
171,000	0.0128	0.0254	0.0093

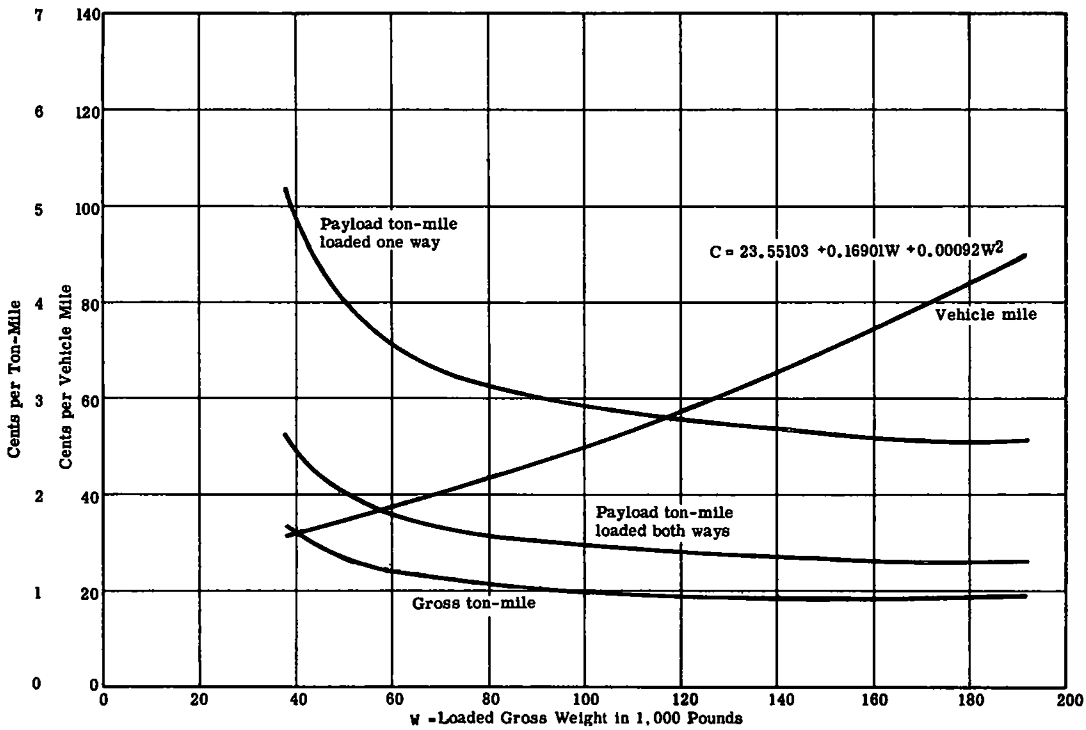

Figure 20. Gross operating costs for diesel engine powered trailer combinations, showing gross ton-mile costs, payload ton-mile costs for operations loaded both ways, and payload ton-mile costs when loaded one way with empty return trips.

ton-mile costs become less significant. Whether this limit is the over-all transport economic optimum will depend on the costs of building and maintaining roads and bridges to carry such loads in automotive freight vehicles. (This last question is the next phase of the Committee's study.)

Amounts of Reduction in Payload Ton-Mile Costs

Tables 29, 30, and 31 indicate the payload ton-mile reductions that can result from specific increases in levels of permitted gross weights. The extents of these savings

TABLE 32

AMOUNT OF COST REDUCTION PER PAYLOAD TON-MILE FOR INCREMENTS OF LOADED GROSS WEIGHT — ALL TRAILER COMBINATIONS

Increase in Loaded Gross Weight (lb)		Reduction in Payload Ton-Mile Cost: Loaded in Both Directions ($)		Reduction in Payload Ton-Mile Cost: Loaded in One Direction With Empty Return ($)	
From	To	Each Increment	Accumulated Amount	Each Increment	Accumulated Amount
27,500	44,000	0.0180	0.0180	0.0360	0.0360
44,000	58,000	0.0047	0.0227	0.0094	0.0454
58,000	65,000	0.0013	0.0240	0.0026	0.0480
65,000	73,000	0.0010	0.0250	0.0020	0.0500
73,000	82,000	0.0008	0.0258	0.0016	0.0516
82,000	91,000	0.0005	0.0263	0.0010	0.0526
91,000	100,600	0.0005	0.0268	0.0010	0.0536
100,600	123,000	0.0009	0.0277	0.0018	0.0554
123,000	137,000	0.0004	0.0281	0.0008	0.0562
137,000	171,000	0.0005	0.0286	0.0010	0.0572

TABLE 33

AMOUNT OF COST REDUCTION PER PAYLOAD TON-MILE FOR INCREMENTS OF LOADED GROSS WEIGHT — GASOLINE ENGINE POWERED TRAILER COMBINATIONS

Increase in Loaded Gross Weight (lb)		Reduction in Payload Ton-Mile Cost: Loaded in Both Directions ($)		Reduction in Payload Ton-Mile Cost: Loaded in One Direction With Empty Return ($)	
From	To	Each Increment	Accumulated Amount	Each Increment	Accumulated Amount
27,500	44,000	0.0168	0.0168	0.0336	0.0336
44,000	58,000	0.0053	0.0221	0.0106	0.0442
58,000	65,000	0.0016	0.0237	0.0032	0.0474
65,000	73,000	0.0013	0.0250	0.0026	0.0500
73,000	82,000	0.0011	0.0261	0.0022	0.0522
82,000	91,000	0.0007	0.0268	0.0014	0.0536
91,000	100,600	0.0008	0.0276	0.0016	0.0552

TABLE 34

AMOUNT OF COST REDUCTION PER PAYLOAD TON-MILE FOR INCREMENTS OF LOADED GROSS WEIGHT – DIESEL ENGINE POWERED TRAILER COMBINATIONS

Increase in Loaded Gross Weight (lb)		Reduction in Payload Ton-Mile Cost			
		Loaded in Both Directions ($)		Loaded in One Direction With Empty Return ($)	
From	To	Each Increment	Accumulated Amount	Each Increment	Accumulated Amount
37,500	44,000	0.0037	0.0037	0.0074	0.0074
44,000	58,000	0.0040	0.0077	0.0080	0.0154
58,000	65,000	0.0012	0.0089	0.0024	0.0178
65,000	73,000	0.0010	0.0099	0.0020	0.0198
73,000	82,000	0.0006	0.0105	0.0012	0.0210
82,000	91,000	0.0005	0.0110	0.0010	0.0220
91,000	100,600	0.0003	0.0113	0.0006	0.0226
100,600	123,000	0.0009	0.0122	0.0018	0.0244
123,000	137,000	0.0004	0.0126	0.0008	0.0252
137,000	171,000	0.0005	0.0131	0.0010	0.0262

are given in Tables 32, 33 and 34. These tables start at 27,500 lb because it can be assumed that the very light density commodities can be transported in visibly full body loads within this loaded gross weight. The higher ton-mile costs for the light commodities are a result of their light weight and not a result of low gross weight limitations. Further, the ton-mile costs of the light commodities would not be improved by increases in permitted gross weights. Only the heavier commodities that now are transported in less-than-visible full body loads could gain a cost advantage in higher permitted gross weights.

Table 32 gives the amount of cost reduction per payload ton-mile for different increments of loaded gross weight for all trailer combinations. The cost reductions for all trailer combinations (Table 32) are broken down into two tables. Table 33 pertains to trailer combinations with gasoline engines and Table 34 pertains to those with diesel engines.

Cost Elements of Gross Operating Costs

The gross operating costs shown in Figures 18, 19 and 20 are broken down into the six elements of operating costs which are shown in Figures 21, 22, and 23, each containing seven small charts. The six small charts in each figure show, for the specific classes of trailer combinations, the variations in vehicle-mile cost for the following elements of operating expenses: repair, servicing, and lubricant costs; tire and tube costs; fuel costs; driver wage and subsistence costs; indirect and overhead costs; and depreciation and interest costs.

The seventh chart in each figure accumulates the different cost elements for the type of trailer combination in a strata-type chart, whereby successive levels of operating costs are shown, ending with the gross operating cost. On this chart, the cumulative curves indicate the following costs: lowest curve is "repair, servicing and lubricant costs;" second from bottom is "direct maintenance costs;" third from bottom is "direct vehicular costs;" fourth from bottom is "direct running costs;" fifth from bottom is "total running costs;" and the top curve is "gross operating costs."

The costs in this series are over-all average costs without adjustment as to the type of terrain or the degree of loading of cargo bodies. The effects of terrain and degree of loading on certain elements of costs are investigated in later sections.

Figure 21 shows the values of the six cost elements for all the trailer combinations, and the gross operating cost curve shown in the strata-type chart is the same as the gross operating cost curve shown in Figure 18.

Figure 22 shows similar data for gasoline engine powered trailer combinations and is the breakdown of the gross operating cost curve in Figure 19.

Figure 23 shows similar data for diesel engine powered trailer combinations (See Fig. 20).

VEHICLE-MILE COSTS BY AXLE CLASSIFICATION OF TRAILER COMBINATIONS

The variations in operating costs of the ten groups of trailer combinations segregated by engine type and axle classification (Table 28) are reported in Figures 24 through 33, in each of which the different operating costs described in the previous section are shown. This further subdivision of the cost data into several axle classifications stratifies the data in a manner that may introduce irregular variables in operating circumstances that undoubtedly account for irregularities appearing in certain of the vehicle classes. The data of the charts have been progressively summarized through the previous sections to develop Figures 18, 19 and 20.

VEHICLE-MILE COSTS BY TYPE OF CARGO BODY

To investigate the effects of type of cargo body on the various elements of operating costs, the data of the gasoline engine powered trailer combinations and the data of the diesel engine powered trailer combinations were each sorted by two broad classifications of cargo body. The two cargo-body classifications studied were van-type bodies: including closed van, open-top van, refrigerated van, ventilated van, and rack van; and tank- or hopper-type bodies. The costs were not developed by axle classification of trailer combination, but were developed by loaded gross weight. The other types of cargo bodies were not analyzed because their numbers were too sparse and the range of types, from automobile transporters to logging rigs, was too great to give useful values.

Vehicle-mile costs for the four body classifications of trailer combinations (gasoline engine van, diesel engine van, gasoline engine tank or hopper, and diesel engine tank or hopper) were developed for the same six elements of costs, such as "Repair, Servicing, and Lubricant Costs," "Tire and Tube Costs," etc., similar to the six elements of cost that were reported by axle classification in Figures 21 to 33, including a "Summation of Costs" for each vehicle type in a strata-type chart.

The data in Figure 34 include 13,489 gasoline engine powered van-type trailer combinations, whereas the data in Figure 35 include 4,065 diesel engine powered van-type trailers within a loaded gross weight range from 22,500 lb to 77,500 lb. In comparing the data on these two charts it will be noted that the values of four of the cost elements are quite close together, but the fuel costs for diesel engine vehicles are consistently less than those of gasoline engine vehicles, whereas the depreciation and interest costs for diesel engine vehicles are higher than those for the gasoline engine vehicles. The differences in these two costs roughly offset each other, so that the gross operating costs, shown on the summation charts, are nearly equal for both types of van cargo body vehicles.

The data in Figure 36 include 1,776 gasoline engine powered tank- or hopper-type trailer combinations, whereas the data in Figure 37 include 1,215 diesel engine powered tank- or hopper-type trailer combinations. The range of loaded gross weights for these types of cargo vehicles is much higher than for the van vehicles, with the diesel engine trailer combinations, running up to 192,000 lb, and the gasoline engine vehicles reaching 105,000 lb. The reason for this difference is that some large tractor semi-trailers with dump hopper bodies, used in strip mine operations, are included in the diesel group. Only diesel engines were found in this mining service, primarily because of the horsepower required in such service. The strip mine vehicles included are those whose daily mileages conformed to the mileage criteria of the study. Vehicles making only short trips (less than 1 or 2 mi) were not included. However, if the gross operating costs of the diesel engine tank or hopper vehicles are compared with similar

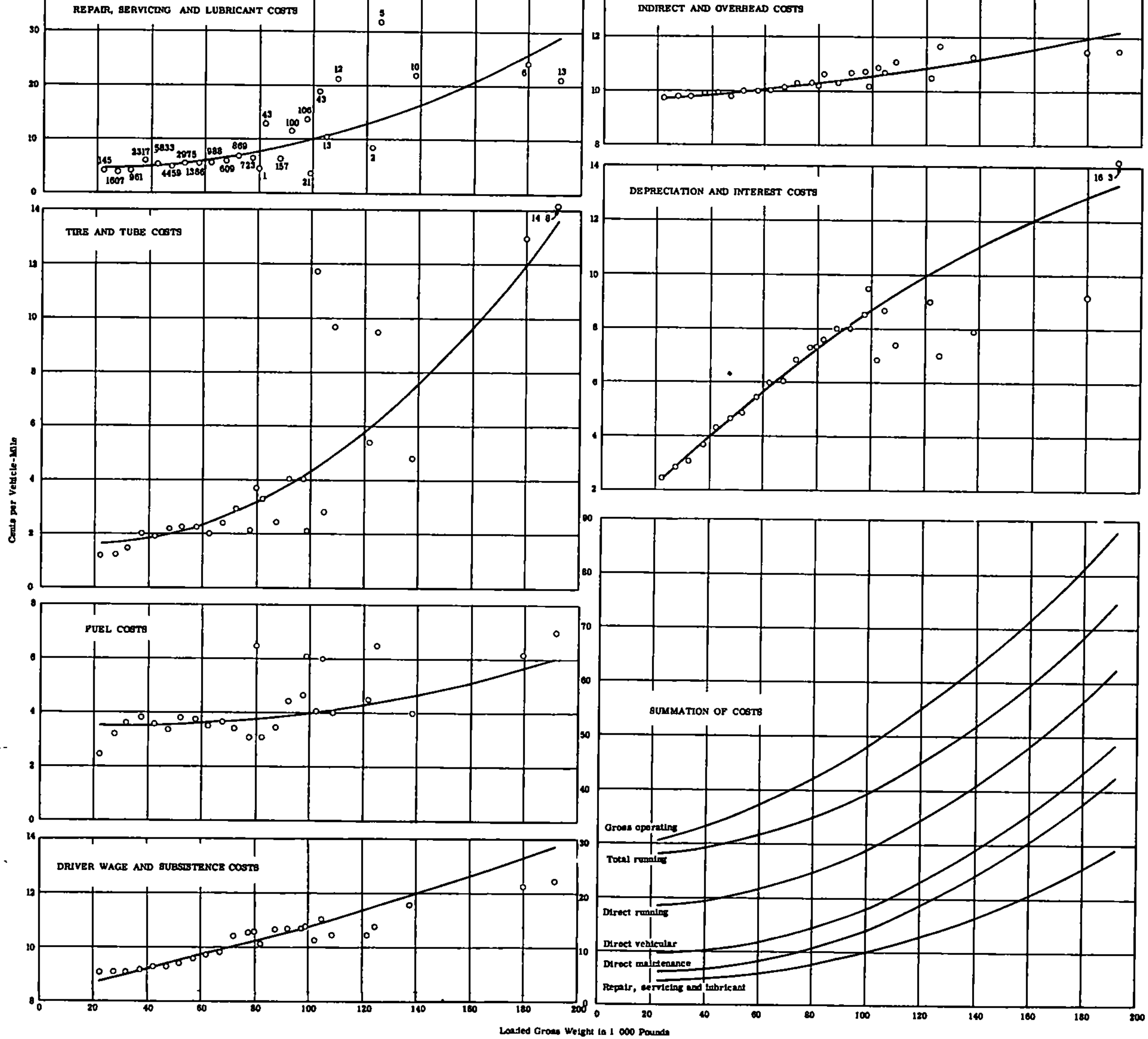

Figure 21. Various costs per vehicle-mile for gasoline and diesel engine powered trailer combinations, by loaded gross weight.

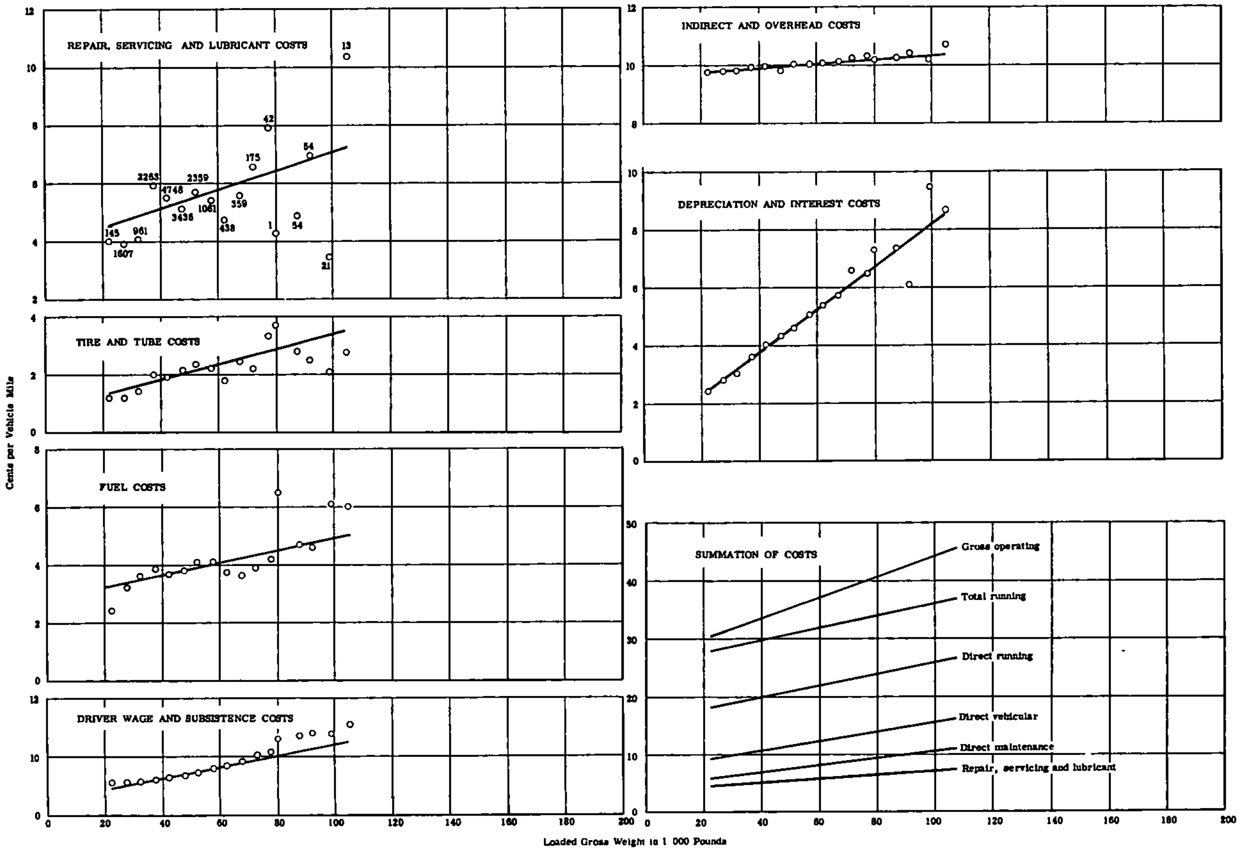

Figure 22. Various costs per vehicle-mile for gasoline engine powered trailer combinations, by loaded gross weight.

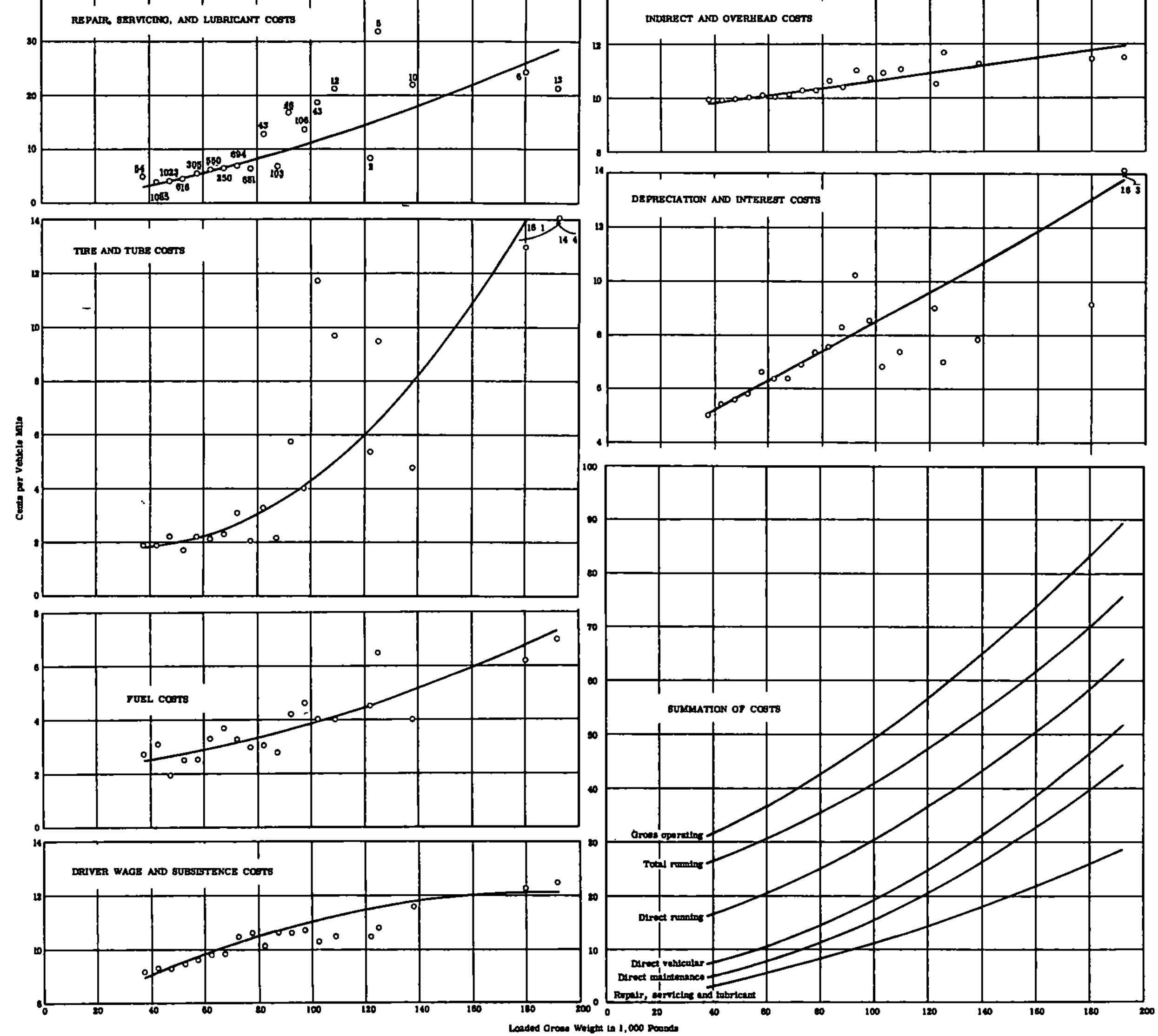

Figure 23. Various costs per vehicle-mile for diesel engine powered trailer combinations, by loaded gross weight.

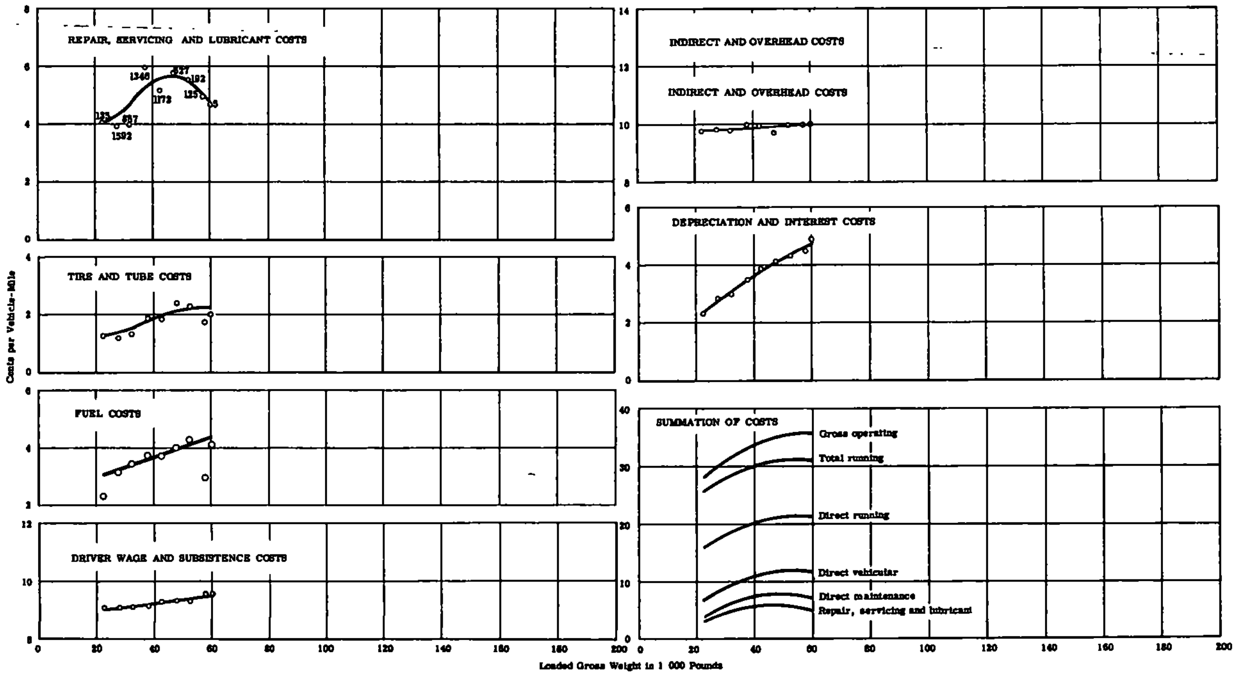

Figure 24. Various costs per vehicle-mile for gasoline engine powered 2-S1 trailer combinations, by loaded gross weight.

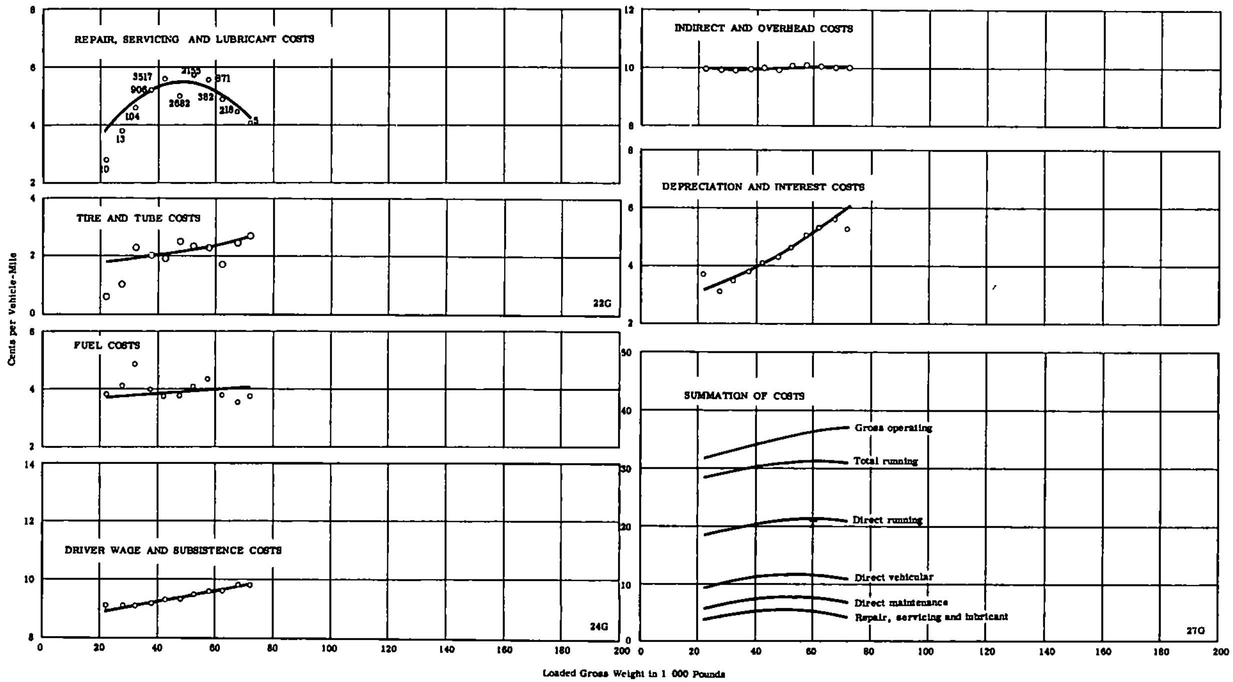

Figure 25. Various costs per vehicle-mile for gasoline engine powered 2-S2 trailer combinations, by loaded gross weight.

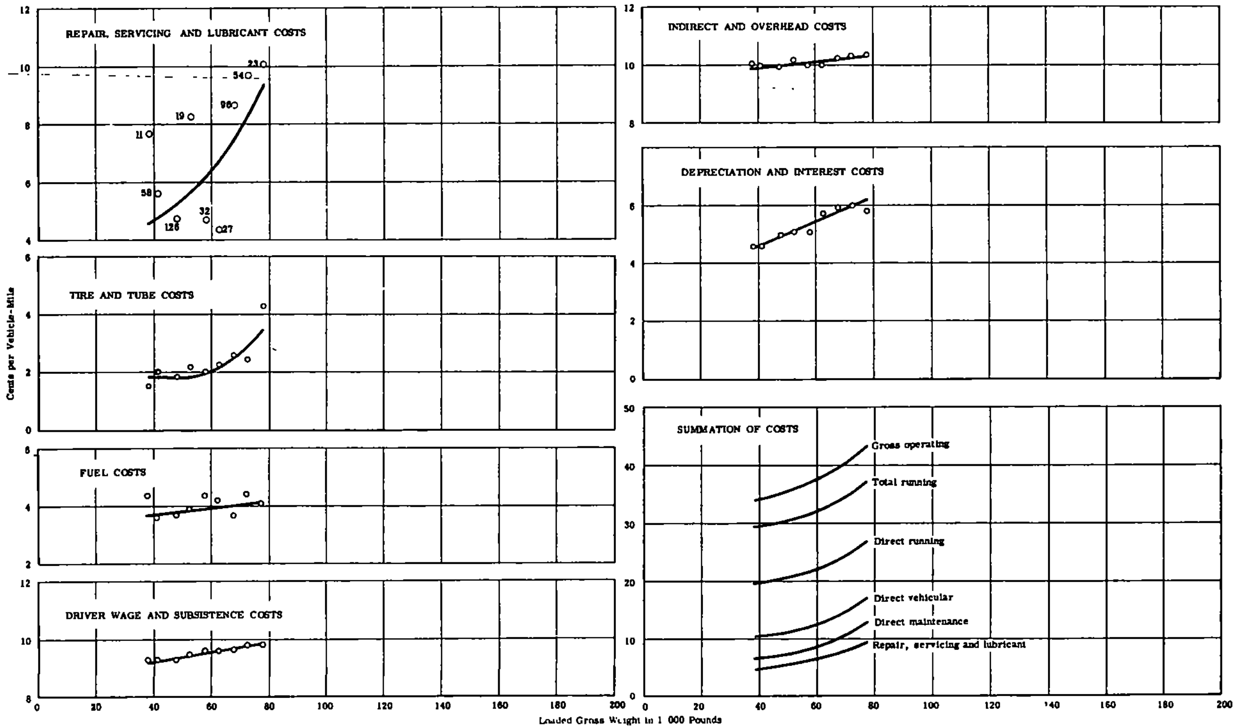

Figure 26. Various costs per vehicle-mile for gasoline engine powered 3-S2 trailer combinations, by loaded gross weight.

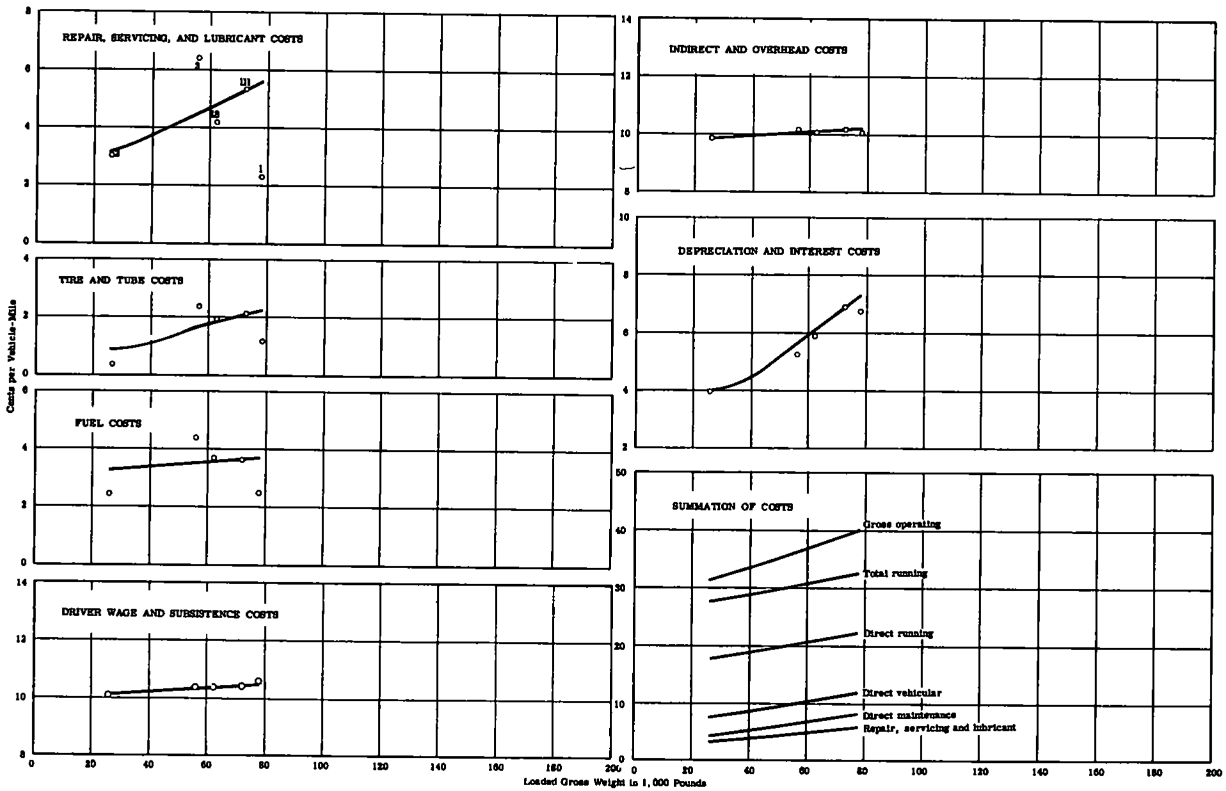

Figure 27. Various costs per vehicle-mile for gasoline engine powered 2-2 and 3-2 trailer combinations, by loaded gross weight.

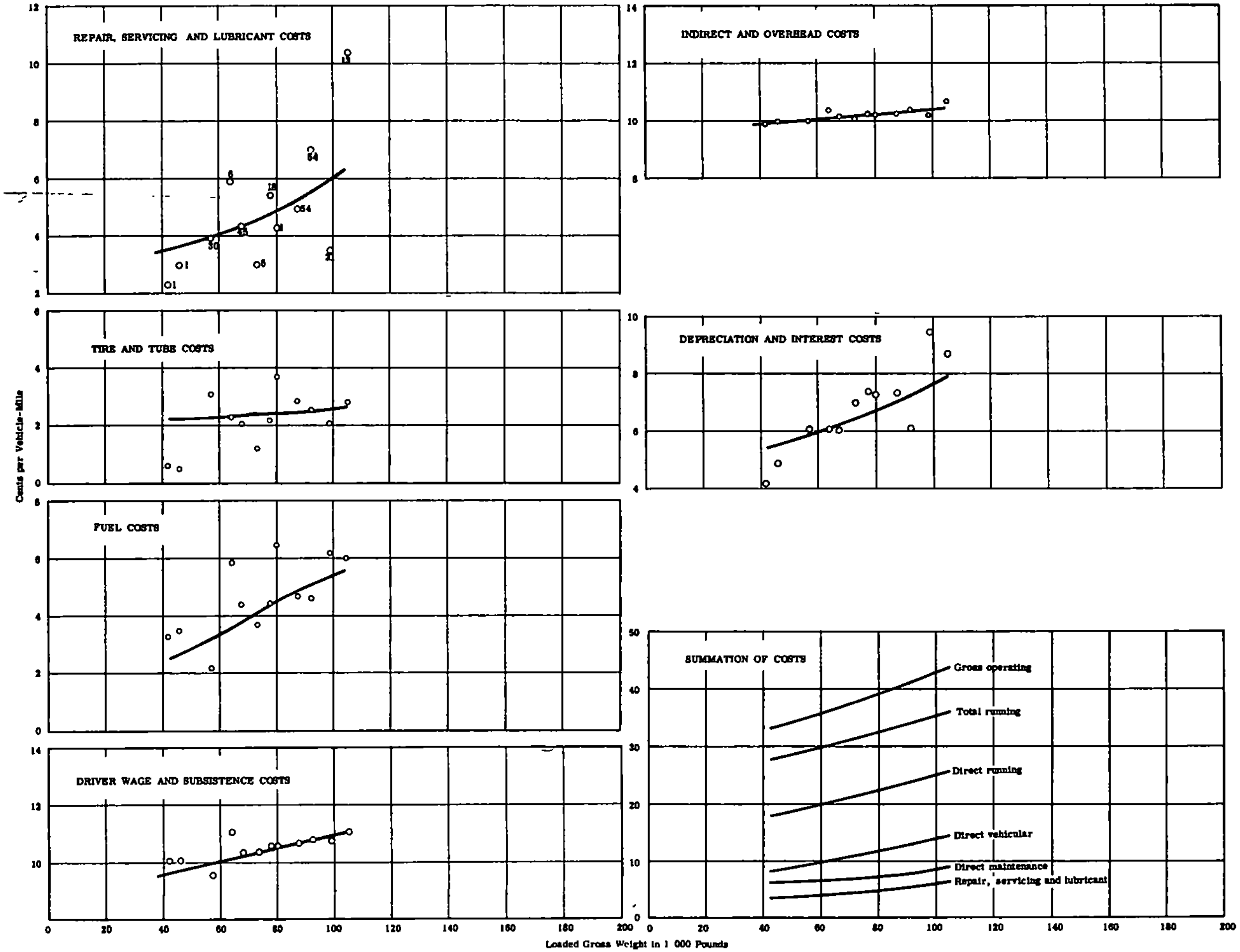

Figure 28. Various costs per vehicle-mile for gasoline engine powered 2-S1-2, 2-S2-2, and 3-S2-3 trailer combinations, by loaded gross weight.

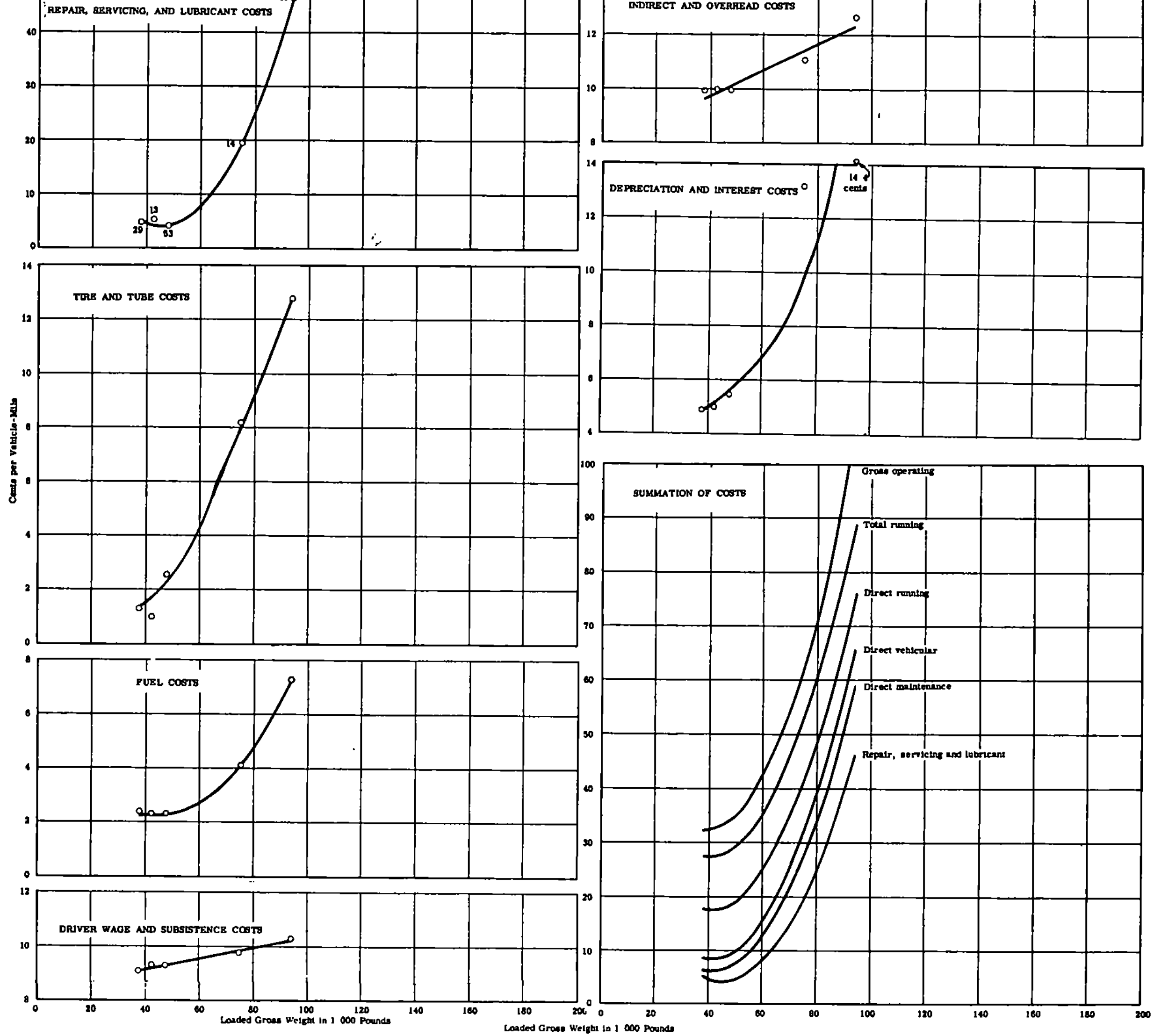

Figure 29. Various costs per vehicle-mile for diesel engine powered 2-S1 trailer combinations, by loaded gross weight.

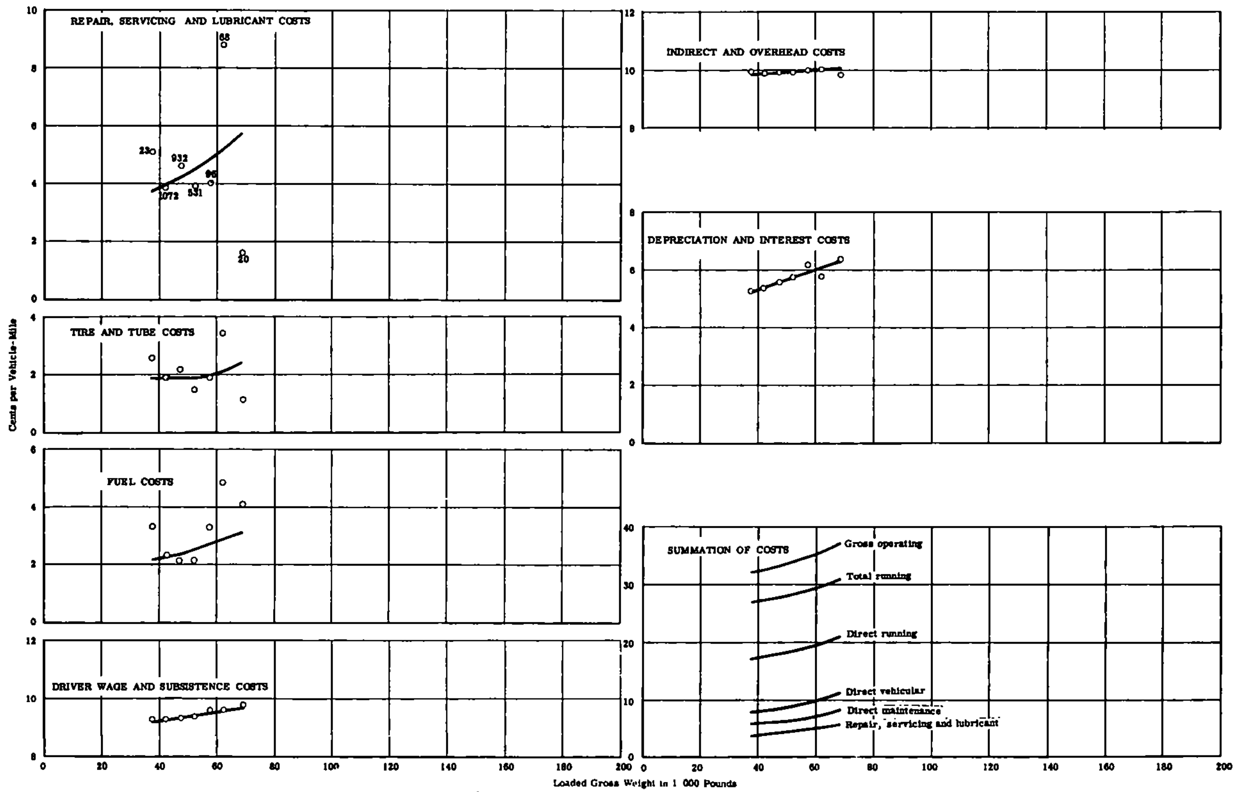

Figure 30. Various costs per vehicle-mile for diesel engine powered 2-S2 trailer combinations, by loaded gross weight.

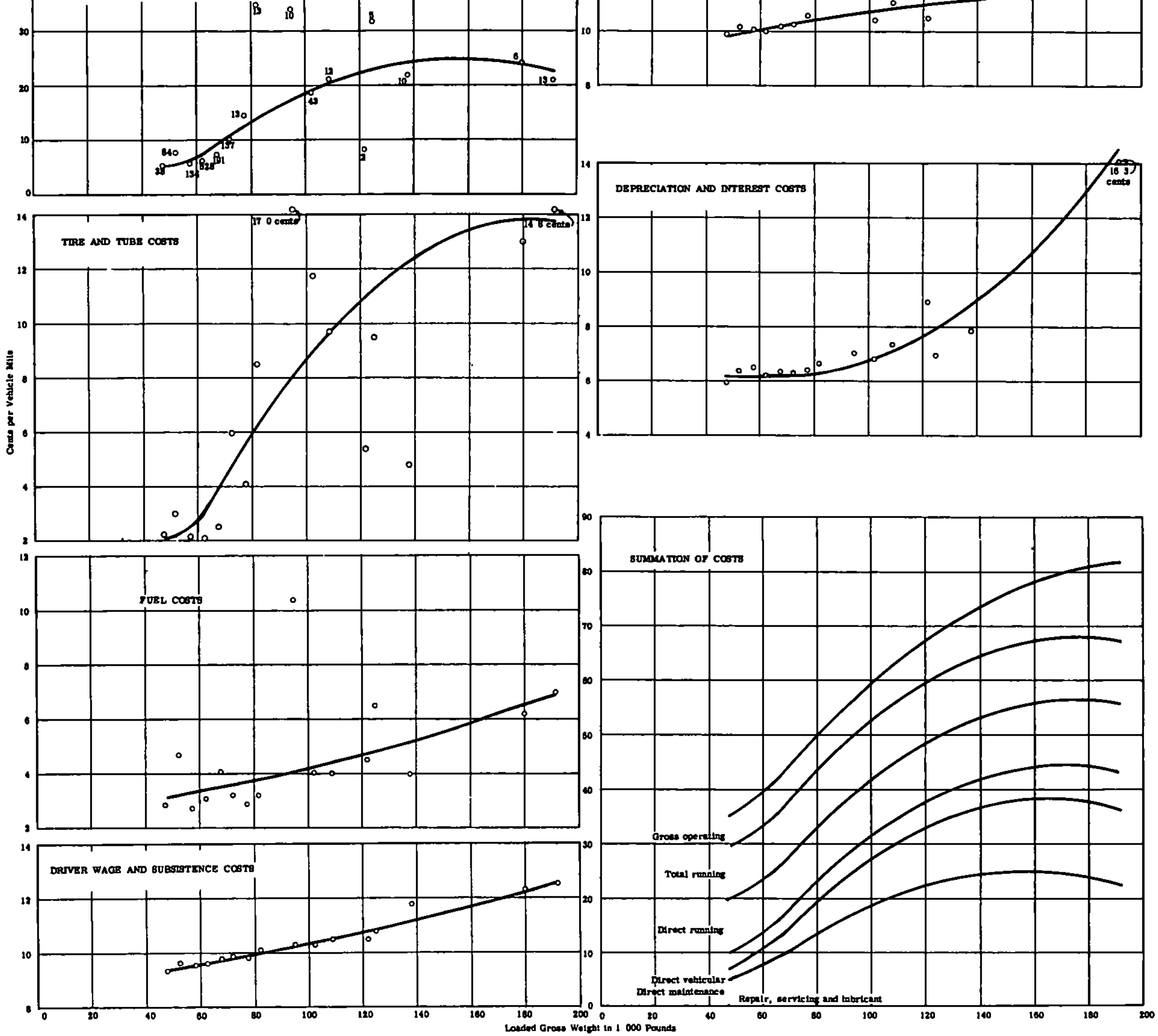

Figure 31. Various costs per vehicle-mile for diesel engine powered 3-S2 trailer combinations, by loaded gross weight.

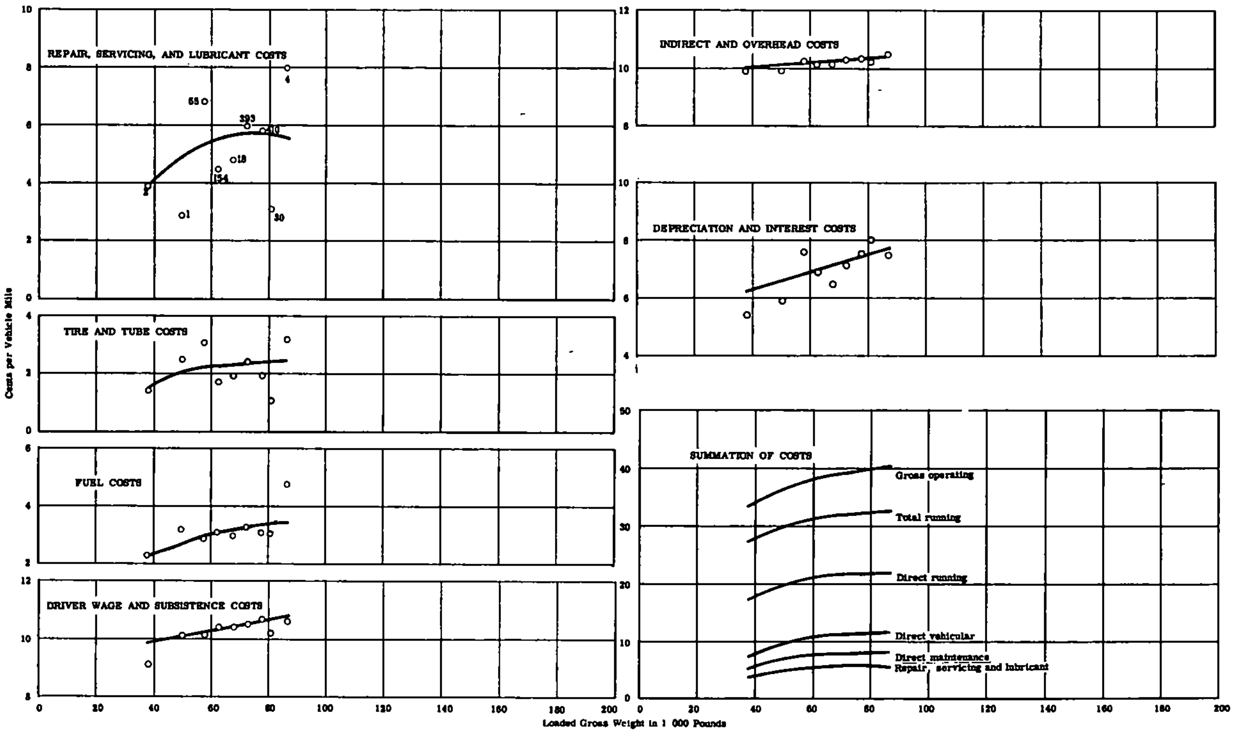

Figure 32. Various costs per vehicle-mile for diesel engine powered 2-2, 2-3, 3-2, and 3-3 trailer combinations, by loaded gross weight.

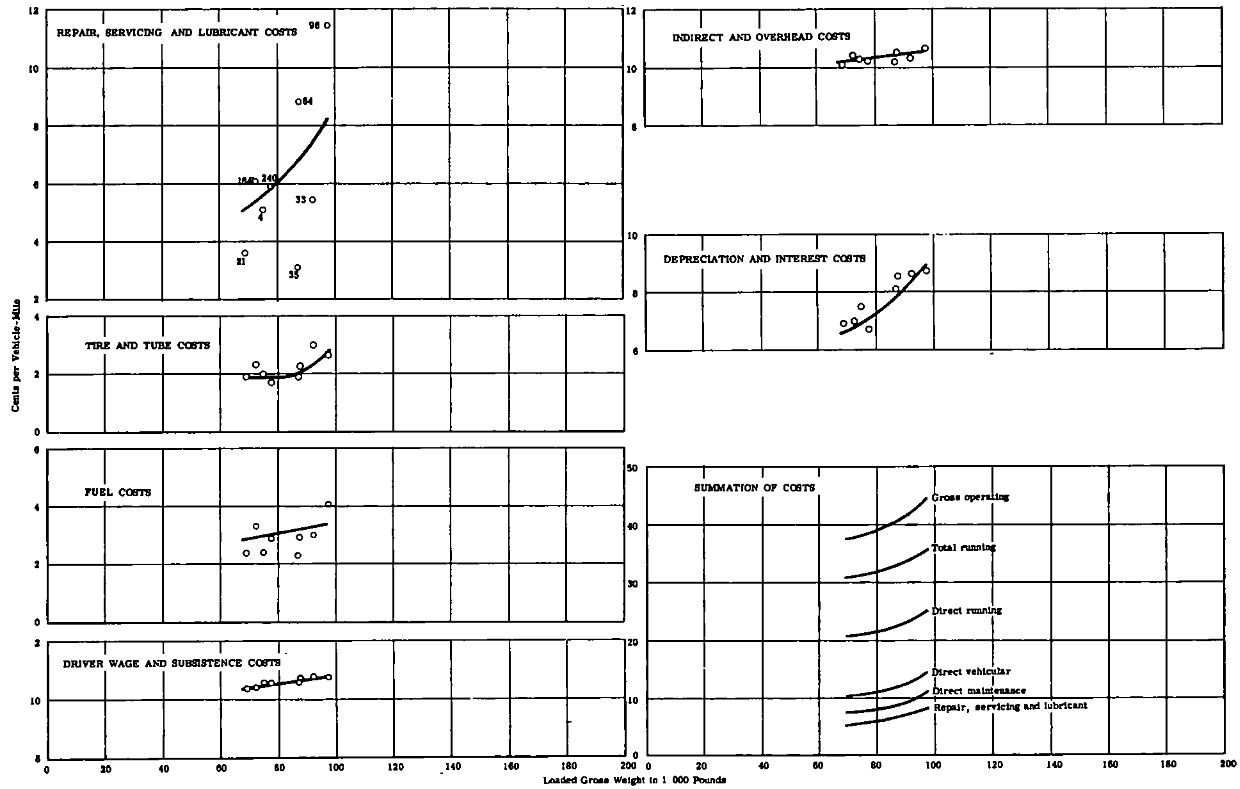

Figure 33. Various costs per vehicle-mile for diesel engine powered 2-S1-2, 2-S2-2, 3-S1-2, and 3-S2-3 trailer combinations, by loaded gross weight.

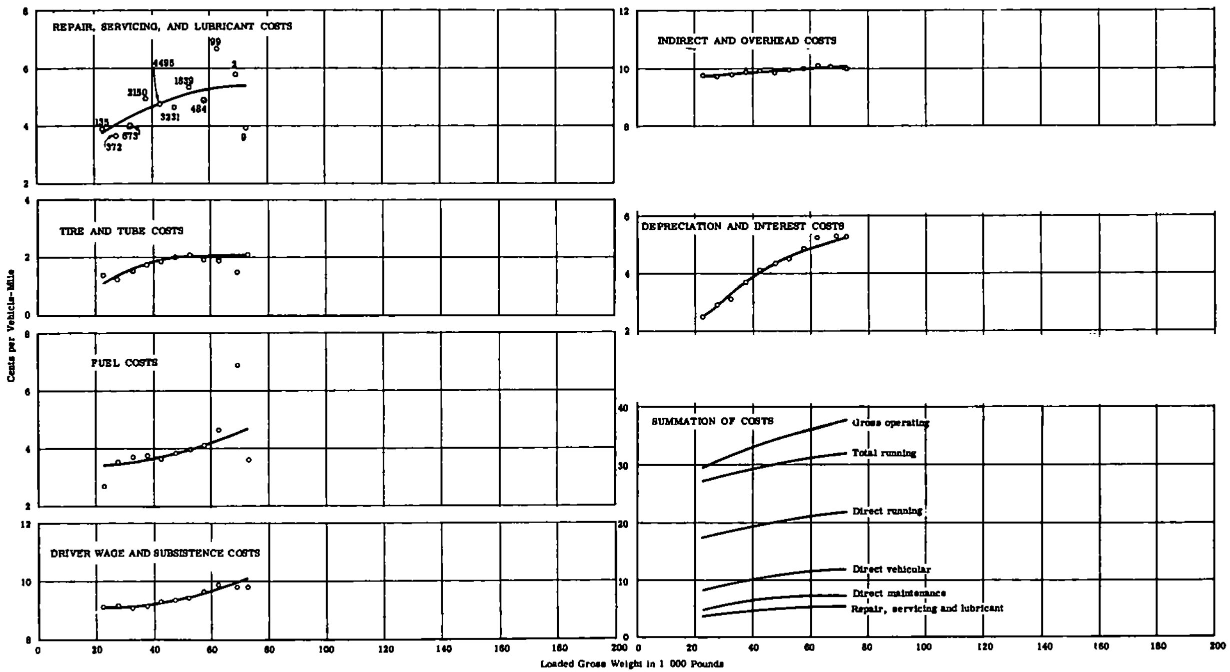

Figure 34. Various costs per vehicle-mile for gasoline engine powered van-type trailer combinations, by loaded gross weight.

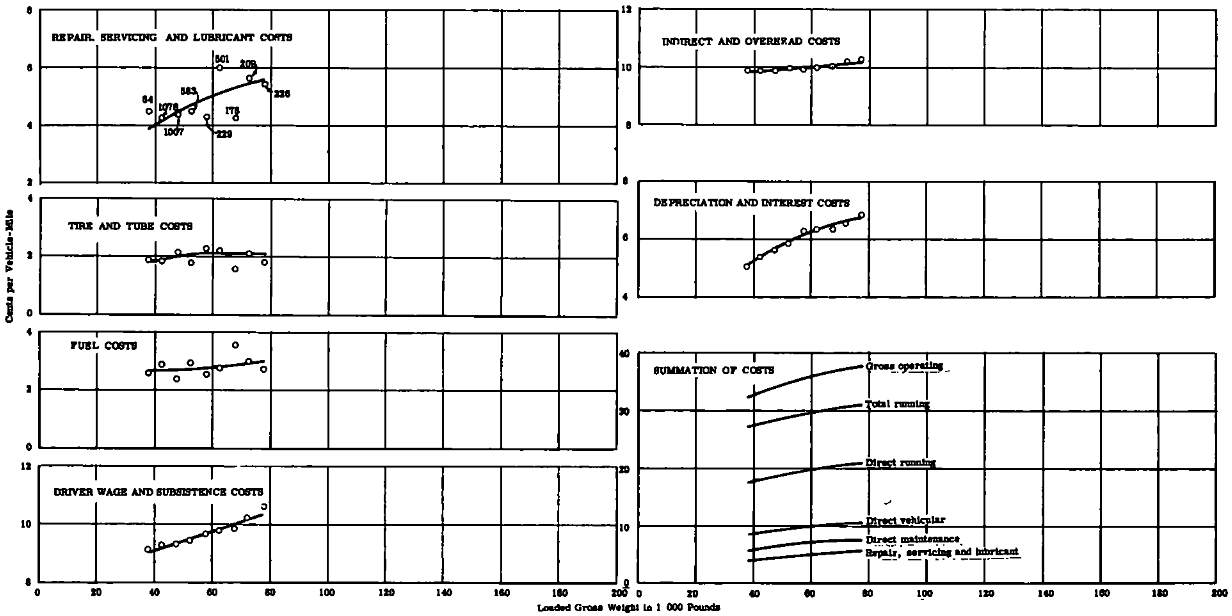

Figure 35. Various costs per vehicle-mile for diesel engine powered van-type trailer combinations, by loaded gross weight.

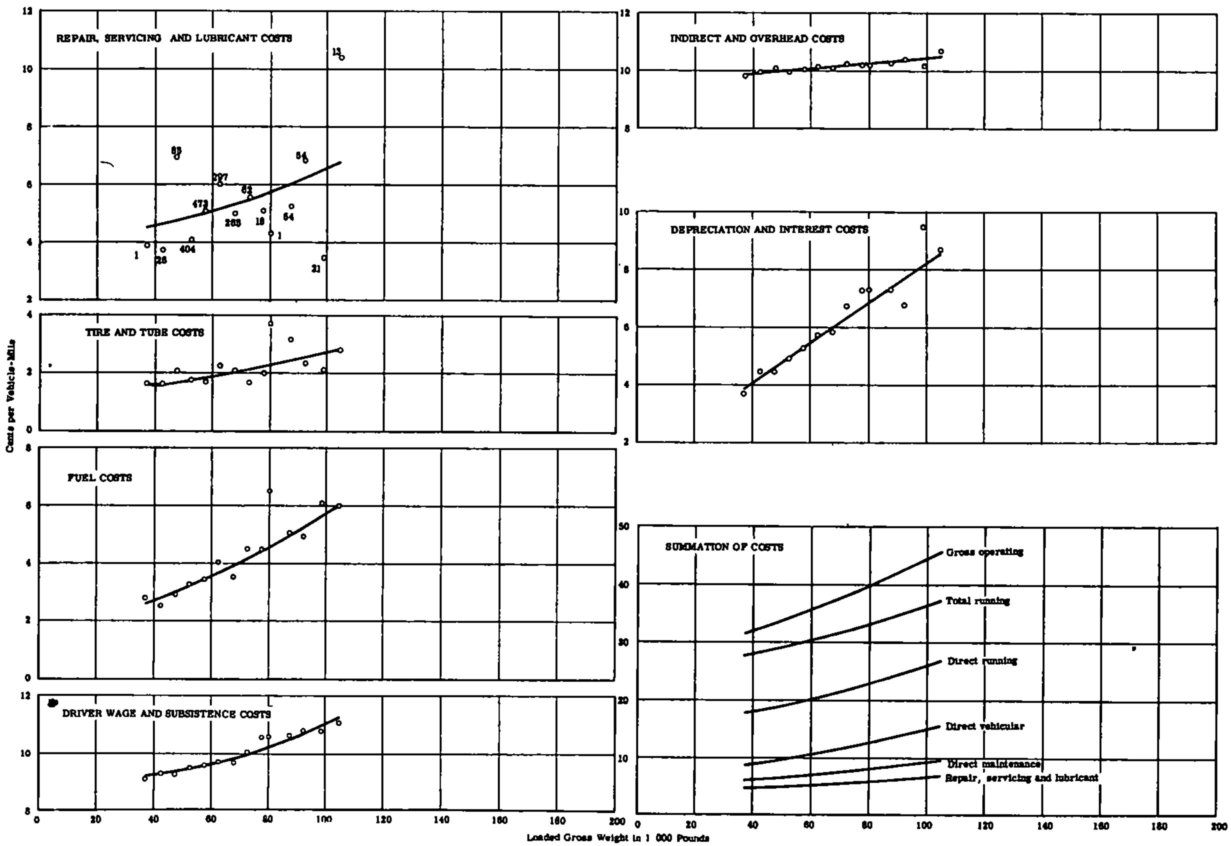

Figure 36. Various costs per vehicle-mile for gasoline engine powered tank- and hopper-type trailer combinations, by loaded gross weight.

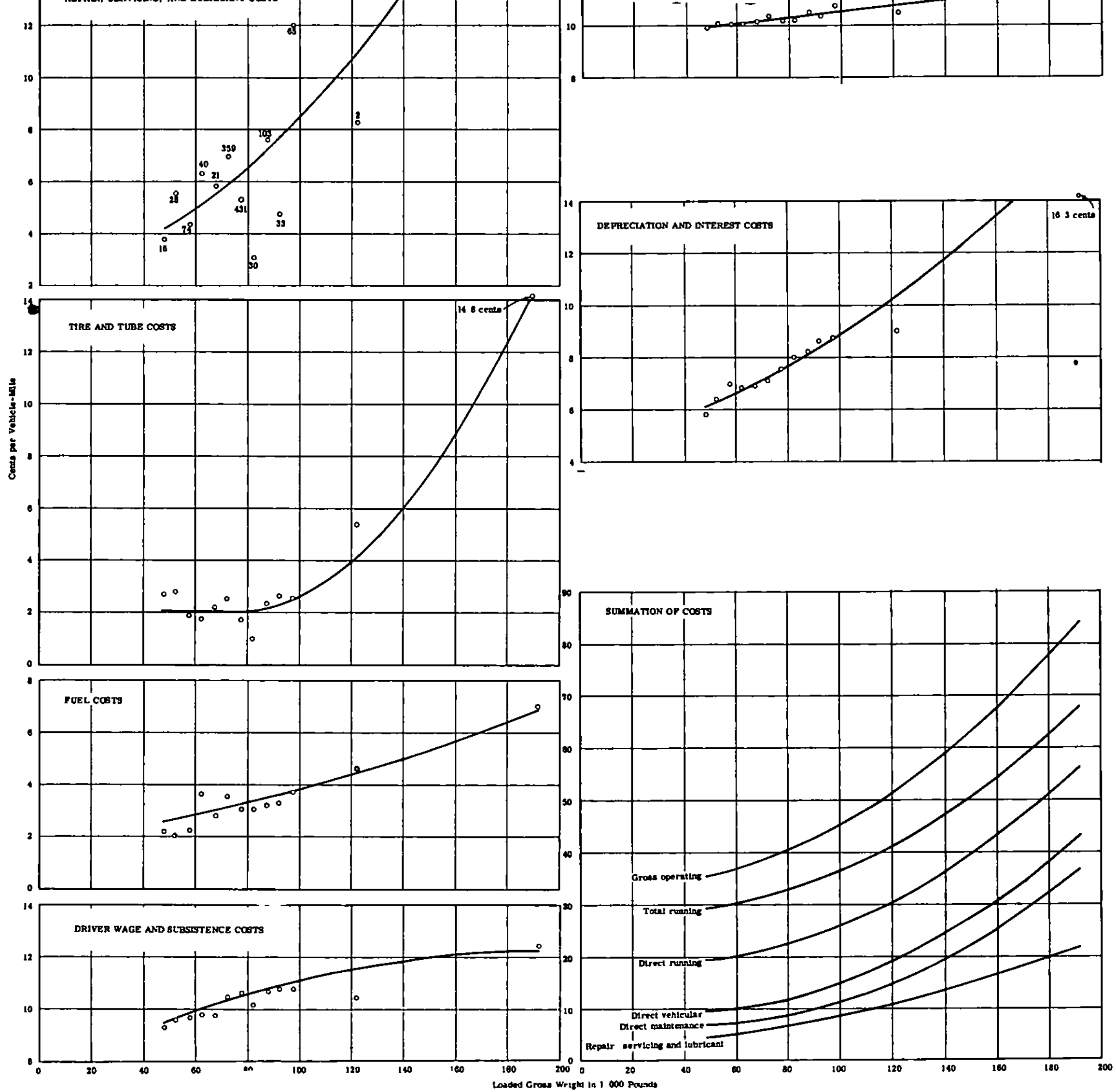

Figure 37. Various costs per vehicle-mile for diesel engine powered tank- and hopper-type trailer combinations, by loaded gross weight

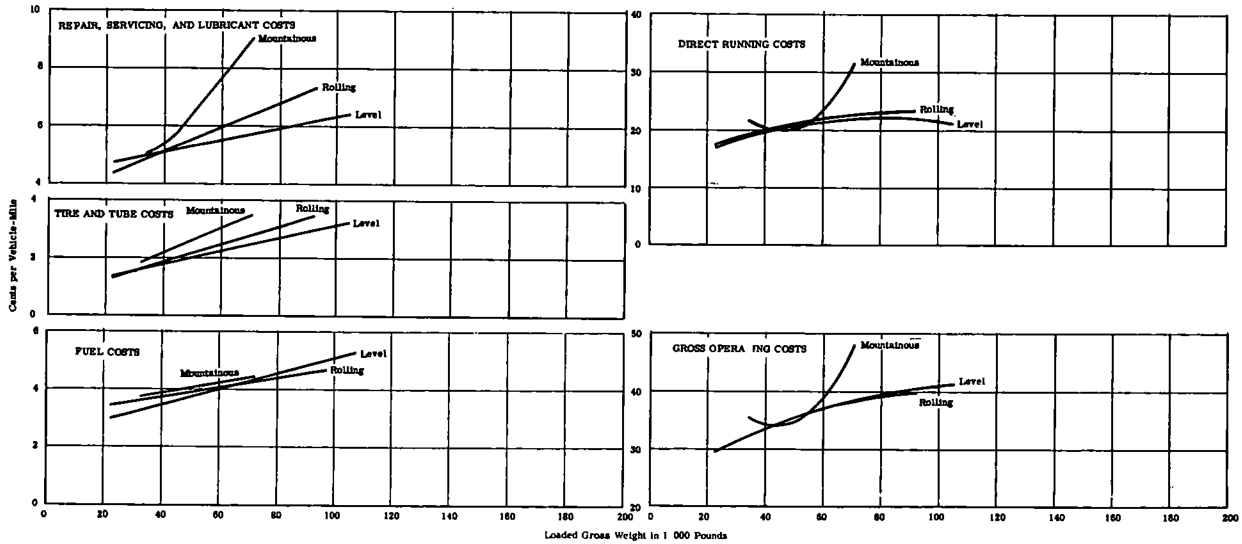

Figure 38. Various costs per vehicle-mile by type of terrain for gasoline engine powered trailer combinations, by loaded gross weight.

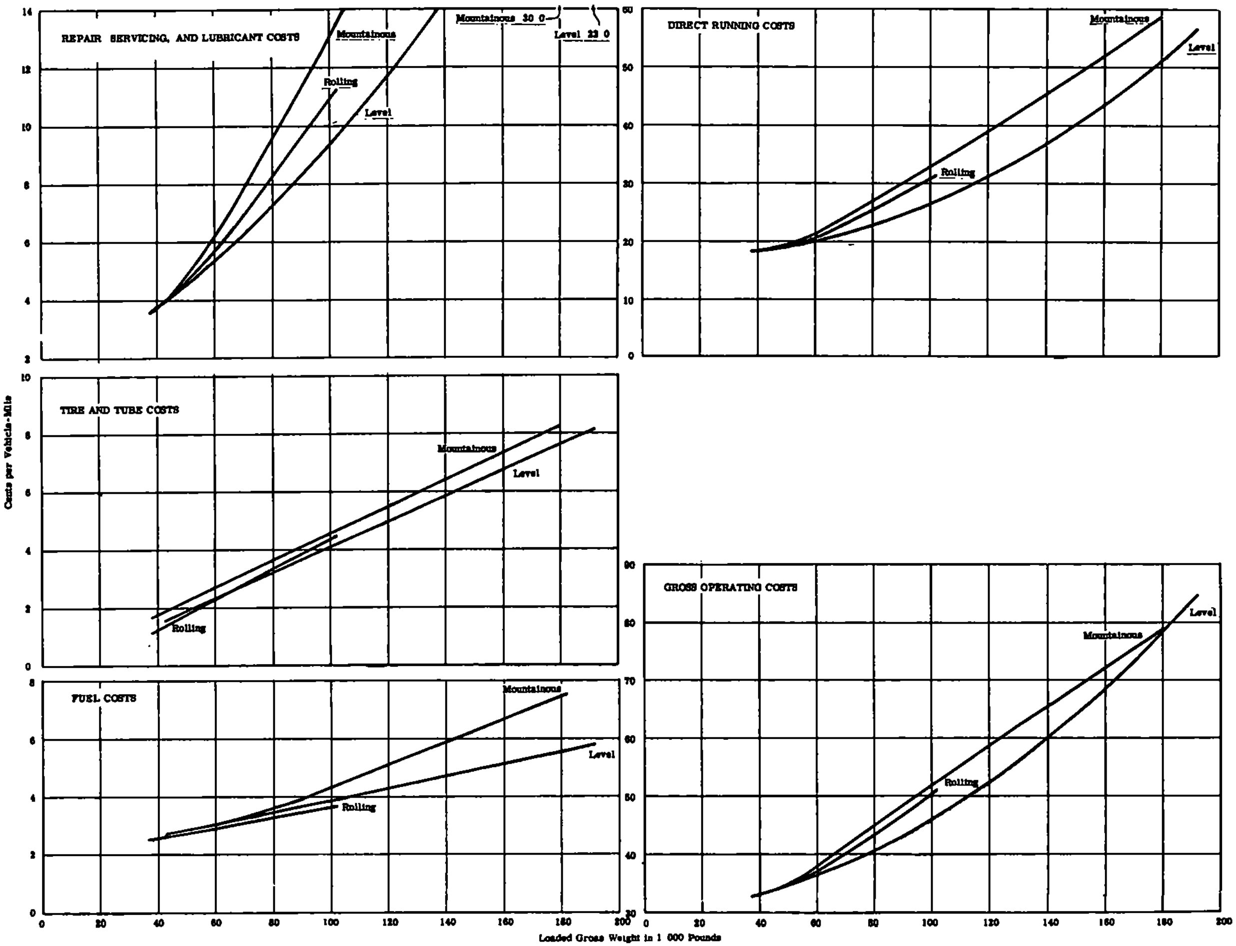

Figure 39. Various costs per vehicle-mile by type of terrain for diesel engine powered trailer combinations, by loaded gross weight.

gasoline engine vehicles up to about 105,000-lb loaded gross weight, the heaviest weight of the gasoline engine vehicles, it is found that the cost variations are similar to those found with van vehicles; that is, diesel fuel costs are less per mile, but the other costs offset this saving with the result that gross operating costs are not significantly different.

For the very heavy tank or hopper vehicles, with weights up to 192,000 lb, only diesel engines were encountered, and no comparisons with gasoline engine vehicles can be made.

A comparison of the gross operating costs per vehicle-mile for van combinations with that for tank or hopper combinations at 70,000-lb loaded gross weight indicates that the tank or hopper combinations cost about $0.011 per vehicle-mile more to run than the van vehicles, or about 3 percent more. This margin of cost difference varies slightly over the range of gross weights, but the factor of about $0.01 differential between van vehicles and tank or hopper vehicles appears compatible with the data.

VARIOUS OPERATING COSTS BY TYPE OF TERRAIN

As stated earlier, the field interviewers reported estimates of the type of terrain over which each carrier's vehicles predominantly operated. The descriptive names of the three types of terrain reported were level, rolling and mountainous. It was intended that these terms should apply to the characteristics of the roads rather than to the general nature of the area. For example, improved roads with mild grades would be considered rolling if they went through low passes in mountains. On the other hand, there exist roads through high mountain passes that are definitely mountainous. However, long truck routes which may include mountainous sections also may have long sections of level or rolling roads. These discordant circumstances should be borne in mind in considering the following series of cost data related to the type of terrain. The five sets of costs give general information relating to the effects of terrain on costs, and thus indicate the relative degree of vehicular economies that can be attained through road terrain improvements. However, these data are not precise enough to be used in the specific evaluation of short grades. Methods of evaluating time and fuel consumption on specific grades are discussed in a following section concerning fuel costs.

The five series of costs (gross operating; direct running; fuel; tire and tube; and repair, servicing, and lubricant) which are developed by terrain factors were defined earlier. (Detailed charts are not shown for driver wage and subsistence costs, indirect and overhead costs, and depreciation and interest costs, because in the study data these costs are not affected by differences in terrain.)

These costs are developed for gasoline engine powered trailer combinations (Fig. 38), for diesel engine powered trailer combinations (Fig. 39).

Gross Operating Costs by Type of Terrain

The gross operating costs of all trailer combinations were segregated by type of engine, by type of terrain, and arrayed by loaded gross weight. The variations in these costs as related to loaded gross weight are shown in Figure 38 for gasoline engine powered trailer combinations, and in Figure 39 for diesel engine powered trailer combinations.

In both of the Gross Operating Costs charts the costs appear in the expected order with the level road costs the lowest, and the mountainous roads the highest. It must be pointed out, however, that the increase in costs for mountainous roads undoubtedly is greater than that shown in these two figures because of the slower vehicle speeds that can be expected on heavy grades. The sources of these increases are discussed in the following sections.

Direct Running Costs by Type of Terrain

To show further the effects of terrain on certain vehicle operating costs, the direct running costs of all trailer combinations were segregated by type of engine and by type of terrain. Direct running costs include repair and servicing costs, tire and tube costs, fuel costs, and drivers wage and subsistence costs. The changes in these costs as related to gross vehicle weight are shown in the Direct Running Costs charts in Figure 38 for gasoline engine powered trailer combinations, and in Figure 39 for diesel engine powered combinations.

In both of these Direct Running Costs charts, the costs appear in the expected order with level road costs the lowest, and mountainous road the highest. It must be pointed out, however, that the increase in costs for mountainous roads undoubtedly is greater than that shown in these two charts, because the slower vehicle speeds on grades would result in higher driver costs. Where the drivers are paid on an hourly basis, or where there may be agreed-upon extra pay for mountainous routes, the actual driver costs would be higher than the mileage pay rates that are used in the study. No attempt was made to estimate these additional driver costs on mountainous routes, because such data were not pertinent to the study. For specific routes where driver costs are determinable, such known costs can be used instead of the driver costs shown in Figure 10 and Table 20.

The variations in the other three cost elements in direct running costs (other than driver costs) are discussed in the following sections. The range of gross weights is the same in each series of charts.

Fuel Costs by Type of Terrain

To investigate the relative effects of terrain on fuel costs, the fuel cost data of all combinations regardless of type, were sorted by type of engine, by gross vehicle weight and by the three types of terrain — level, rolling and mountainous. The fuel costs are less Federal and State fuel taxes. These data were smoothed by statistical methods and the results are plotted in the Fuel Costs charts in Figure 38 for gasoline engine trailer combinations. It will be noted that the costs for level and rolling terrain are close together with a portion of the level operation slightly but not significantly higher. These close results indicate that roads in rolling country with relatively short momentum grades may not increase fuel consumption. However, in mountainous terrain the fuel consumption is consistently greater.

Similar results are indicated for diesel engine trailer combinations in the Fuel Costs charts in Figure 39, except that at the high gross weights the increase in fuel costs becomes significant. The results shown are not precise measures of the additional fuel consumption on specific long and relatively steep upgrades, because the data on the charts are average route data and are affected by the extent to which grades constitute a major or minor portion of a given mileage of route.

All of these data are composite fuel data and are related crudely to type of terrain, but they do show that over long distances the increases in fuel costs because of terrain are not a large factor in gross operating costs. Fuel consumption on specific grades and on specific lengths of routes is related to the rise and fall characteristics of the specific routes. To determine the probable road-user benefits in reduced gasoline fuel costs for specific grades on specific routes it is necessary and desirable to use the rise and fall data reported in HRB Research Report 9-A (15), which is the first report issued by the Committee and gives comprehensive data regarding the user benefits in time and gasoline fuel consumption that can be obtained by reducing the rise and fall factors on specific sections of a road.

For routes in very mountainous country with many long, steep grades the fuel benefits would be much greater than shown in the Fuel Costs charts of Figures 38 and 39. In addition to benefits in fuel savings, there also are benefits in time consumption which are not measured in this report. Grade reductions on long grades also improve general road speeds, reduce vehicular congestion on the grades to the advantage of all highway users, and reduce the problems encountered in winter weather operation of commercial vehicles.

Tire and Tube Costs by Type of Terrain

Another element of direct running costs which was investigated was the effects of terrain on tire costs. These cost data are shown in Figure 38 for the gasoline engine vehicles and in Figure 39 for the diesel engine vehicles.

In the Tire and Tube Costs chart in Figure 38 it will be noticed that the vehicle-mile tire costs tend to approach a common value at the lowest gross weight, but diverge significantly at the higher gross weights with the different types of terrain.

In the Tire and Tube Costs chart in Figure 39, where the gross weights start higher and go much higher with diesel engine vehicles, the costs on mountainous roads are consistently above those for flat terrain.

Although the data in these two figures are consistent in that both show that mountainous roads result in higher tire costs than do level roads, the unit values overlap to such an extent that it can only be concluded that an average of the tire cost values by vehicle type would probably provide better vehicle-mile costs. There appears no reason why engine types should affect tire costs. However, as these charts were intended primarily to indicate that differences in costs result from terrain, no attempt was made to develop such average costs. The over-all average cost data shown previously by axle classifications of vehicles provide more useful tire cost data, which, if desired in studies of mountainous routes, could be adjusted to some degree by the factors reported in the tire charts in Figures 38 and 39.

Repair, Servicing, and Lubricant Costs by Type of Terrain

The last cost element to be explored in this analysis of direct running costs and the effects of terrain is Repair, Servicing and Lubricant Costs. This cost element is one in which there is a considerable divergence of industry practice, and such differences may be irregularily distributed in the data. For example, certain sizes and classes of vehicles may be overhauled quite inexpensively at relatively short mileages, whereas the heavier capacity vehicles may run longer mileages between overhauls, but the overhauls may be relatively expensive and with a view to rebuilding the unit to a like-new condition. All of these variables have an effect on repair costs. The two charts of Repair, Servicing and Lubricant Costs in Figures 38 and 39 show clearly that repair costs are affected by differences in terrain, and that reduction in grades are of benefit in this cost element.

The chart in Figure 38 shows for gasoline engine combinations that at the lighter gross weights, terrain has little effect on repair costs. At the higher gross weights there are significant differences in costs between operation on level, rolling, or mountainous terrain.

Figure 39 shows that for diesel engine vehicles there is a similar convergence of repair costs at the lower gross weights with divergence at the higher gross weights between the three different classes of terrain.

Appendix

In addition to the cost information presented, the field data of the study contained other operational data which give additional information about various trucking practices and some indications of their effects on different operating costs. These various topics are discussed in the several following sections.

DIRECTIONAL CHARACTERISTICS OF LINE-HAUL LOADINGS

Estimates regarding the relative extent of possible full payloads on both outbound and inbound trips were reported by the carriers interviewed. Analyses of these data (Tables 35 and 36) indicate that the over-all average of trips with payloads was 78 percent of the possible full payload trips in both directions. The unused and empty capacity amounted to 22 percent of the full load capability in both directions. This 22 percent empty capacity gives a factor of 1.28 that can be used to calculate the additional number of any series of trailer combinations that will be required to move a given tonnage of freight in a day under the usual conditions of loading that occur in the trucking industry.

These percentage figures cannot be used to estimate an average payload weight and an average gross combination weight from the standpoint of required pavement and bridge capability, because vehicle weights range from the tare weights of combinations to the maximum gross weights permitted by axle limitations and bridge formula gross weight limitations. Highway facilities must be built for the maximum permitted weights regardless of the fact that carriers may not always use such maximum weights.

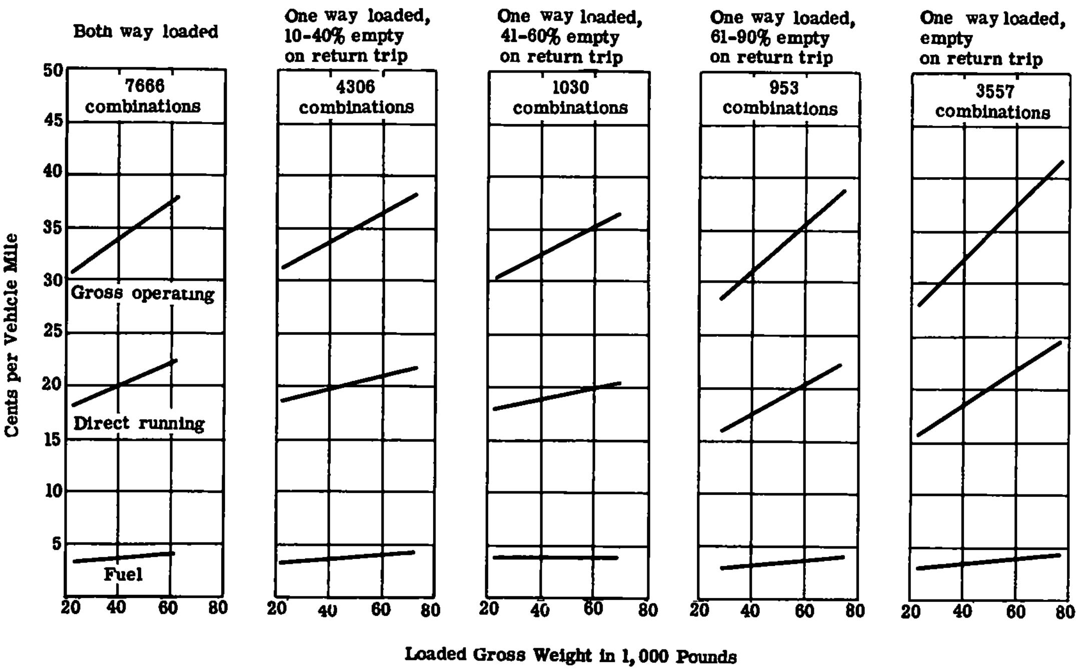

Figure 40. Various costs of line-haul gasoline engine powered trailer combinations, by degree of loading and by loaded gross weight.

EFFECTS OF EMPTY TRIPS ON OPERATING COSTS

The haulage of certain types of commodities always includes an empty return trip. Other types of carriers have different degrees of empty or partial load return trips. During the field interviews, the carriers were asked to classify their regular hauling operations into one of the five following categories of loading and hauling:

1. Full loads in both directions; that is both outbound and return trips;
2. Full loads in one direction with 10-40 percent of return trips empty;
3. Full loads in one direction with 41-60 percent of return trips empty;
4. Full loads in one direction with 61-90 percent of return trips empty; and
5. Full loads in one direction with return trip empty.

The full load category means either a visibly full body load, or a payload which would give the permitted maximum gross weight allowed in the carrier's territory. The other categories are self-explanatory.

To investigate the effects of empty, partial and full loads on different operating costs, the data of all the trailer combinations were segregated by type of engine, and by the foregoing five categories of loading and hauling. Values were then developed for the following costs: fuel cost, direct running cost, and gross operating cost, by 5,000-lb class-intervals of loaded gross weights.

The resulting cost data are shown in Figure 40 for gasoline engine powered trailer combinations, and in Figure 41 for diesel engine powered trailer combinations. It must be borne in mind in reviewing the data that these costs do not show a comparison between full-loaded vehicles and vehicles without payload, but show the relation in costs between vehicles with full payload on both legs of a round trip, and vehicles with a full load on one leg of a round trip and an empty or partial payload on the return leg of a round trip.

The results of these analyses are disappointing in that they do not consistently show reductions in costs on round trips with reductions of payload on return trips. These results support a premise made earlier that vehicular operating costs were related primarily to loaded gross weights, and that the chief effect of partial

TABLE 35

DIRECTIONAL CHARACTERISTICS OF LINE-HAUL LOADINGS BY CARGO BODY TYPE

Directions and Loadings	Closed Van No	Closed Van %	Refer Van No	Refer Van %	Vent Van No	Vent Van %	Open Top Van No.	Open Top Van %	Low Side Open No.	Low Side Open %	Rack Van No	Rack Van %	Flat Bed No	Flat Bed %	Stake No	Stake %	Log Bunks No	Log Bunks %	Tank No	Tank %	Hopper No.	Hopper %	Auto Transport No	Auto Transport %	Dump No	Dump %	Other No.	Other %
Full loads in both directions	9,566	59.2	78	13.6	171	94.0	356	69.1	56	69.2	91	58.3	9	1.7	-	-	-	-	23	0.8	1	0.4	-	-	6	2.5	-	-
Full load in one direction and empty on return	530	3.3	162	28.1	-	-	23	4.5	24	29.6	32	20.5	267	49.6	32	100	423	100	2,183	78.9	199	84.3	957	60.3	217	90.0	113	100
Full load in one direction and 10-40% of trips empty on return	5,032	31.1	177	30.7	6	3.3	115	22.3	1	1.2	17	10.9	161	29.9	-	-	-	-	90	3.3	1	0.4	213	13.4	-	-	-	-
Full load in one direction and 41-60% of trips empty on return	478	3.0	101	17.5	5	2.7	6	1.2	-	-	-	-	52	9.7	-	-	-	-	222	8.0	-	-	257	16.2	-	-	-	-
Full load in one direction and 61-90% of trips empty on return	549	3.4	58	10.1	-	-	15	2.9	-	-	16	10.3	49	9.1	-	-	-	-	250	9.0	35	14.9	160	10.1	18	7.5	-	-
Full load at start with diminishing load to last stop before return	7	(0.04)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	16,162	100.0	576	100.0	182	100.0	515	100.0	81	100.0	156	100.0	538	100.0	32	100.0	423	100.0	2,768	100.0	236	100.0	1,587	100.0	241	100.0	113	100.0

TABLE 36

DIRECTIONAL CHARACTERISTICS OF LINE-HAUL LOADINGS BY TYPE OF CARRIER

Directions and Loadings	Type of Carrier										Percent of Trips Loaded	Equivalent Loaded Vehicle Trips
	Private		Exempt		Common		Contract		Total			
	No	%	No	%	No.	%	No	%	No	%		
Full loads in both directions	196	7 3	3	5 2	10,019	52.4	139	7.9	10,357	43.9	100.0	10,357
Full load in one direction and empty on return	1,529	57.0	29	50 0	2,653	13 9	951	53 8	5,162	21.9	50.0	2,581
Full load in one direction and 10-40% of trips empty on return	364	13.6	21	36 2	4,814	25 2	614	34 7	5,813	24.6	62.5	3,633
Full load in one direction and 41-60% of trips empty on return	203	7.6	5	8 6	889	4.7	24	1 4	1,121	4.7	75 0	841
Full load in one direction and 61-90% of trips empty on return	381	14.2	-	-	730	3.8	39	2.2	1,150	4.9	87 5	1,006
Full load at start with diminishing load to last stop before return	7	0.3	-	-	-	-	-	-	7	0.0	50 0	4
Total	2,680	100 0	58	100.0	19,105	100.0	1,767	100 0	23,610	100.0	-	18,422

$\frac{18,422}{23,610}$ - 78 percent of vehicles operated with payloads

$\frac{1}{0.78}$ - 1.28 vehicle factor for computing vehicle requirement for a given tonnage

loadings would occur in fuel costs. However, the fuel cost data on these charts do not significantly support the premise that round trip fuel costs would be lower with empty or partial loads on return trips. Such results may result from faster speeds when running empty, may be the result of different operating conditions that were not sufficiently detailed in the field data, or may be the result of an insufficient number of cases in the series of round trips with empty or partial load return trips. These assumptions are borne out by the curves in the empty return trip chart. The vehicles in the lower weights of this chart were primarily tank or hopper vehicles, and some reductions in costs appear for the empty return trip. The vehicles in the higher weights include vehicles in logging and strip mine operations, where conditions are different from those in the other four categories which were predominately van or dry freight vehicles.

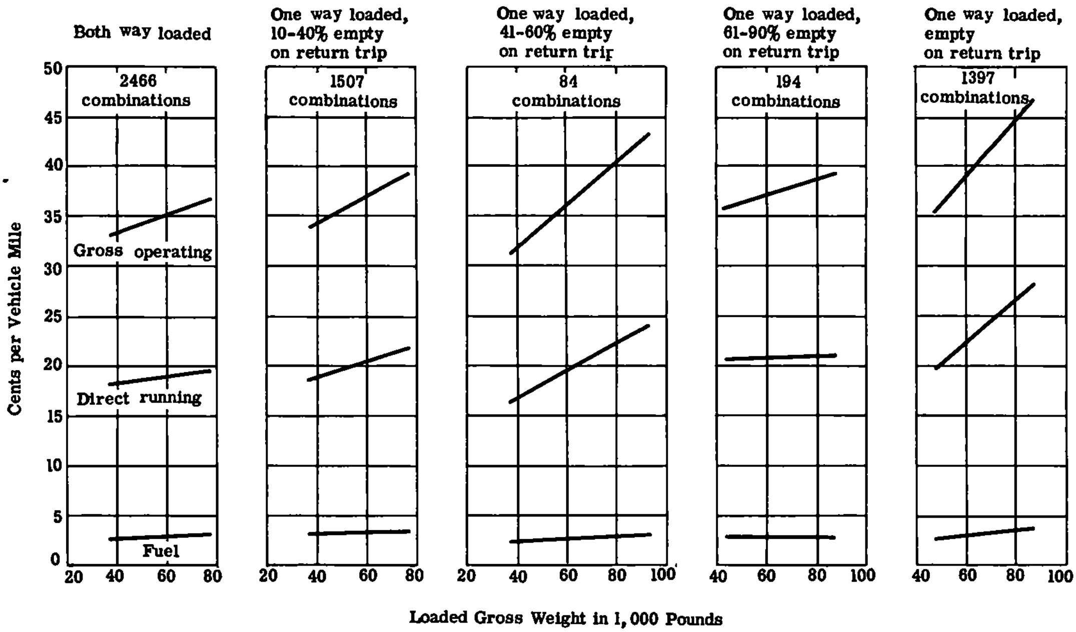

Figure 41. Various costs of line-haul diesel engine powered trailer combinations, by degree of loading and by loaded gross weight.

ROAD SPEEDS AND EFFECTS ON GROSS OPERATING COSTS

During the interviews with cooperating carriers, data were obtained as to the mileages of a number of representative trip-routes of each carrier, together with the usual time for driving each specific trip. This time while driving did not include rest stops or any delays other than normal traffic stops. The over-all time to make a trip, including rest stops, etc., was called trip time, and the time when driving was always less than the trip time. Dividing the trip mileage by the time when driving gave an average road speed when running. The modes of the average road speeds when running of the different trip routes was determined for each carrier and this modal road speed was used with the carrier's cost data to determine the effects of road speed on gross operating costs.

Table 37 distributes into 5-mph speed-blocks and by type of trailer combination, the number of gasoline engine powered trailer combinations and the number of diesel engine powered trailer combinations.

It will be noted that the modal speed for both gasoline engine and diesel engine powered trailer combinations is 30 to 35 mph, which is a considerable increase above the average level road speed of about 25 mph, typical 20 yr ago. The median speeds also are in the 30- to 35-mph speed-blocks, which further indicate that many trailer combinations regularly travel faster than 30 to 35 mph. A preponderance of the power plants of the trailer combinations reported had sufficient power to enable a level road speed of 50 mph or slightly faster. From these data it may be concluded that with improved and divided-lane highways, typical average road speeds of trucks will continue to increase and more of the trailer combinations will keep up with other traffic on level roads.

The gross operating cost data of all the trailer combinations were segregated into their average road speeds when running (as discussed previously), and the gross operating costs per vehicle-mile were plotted against loaded gross weight in Figure 42.

TABLE 37

AVERAGE ROAD SPEEDS WHEN RUNNING FOR VARIOUS TYPES OF TRAILER COMBINATIONS BY 5-MPH SPEED-BLOCKS (611 CARRIERS)

MPH	No. of Trailer Combinations by Axle Classification: 2-S1	2-S2	3-S2	Truck Full Trailer	Tractor Semi-Trailer and Full Trailer	Total	Percent of Total
(a) Gasoline Engine Vehicles							
Under - 14.9	102	96	7	15	17	237	1.3
15 - 19.9	176	71	-	3	20	270	1.5
20 - 24.9	735	675	46	40	97	1,593	9.0
25 - 29.9	1,446	1,967	51	54	25	3,543	20.0
30 - 34.9	2,172	4,770	189	-	80	7,211	40.7
35 - 39.9	978	2,198	120	18	10	3,324	18.7
40 - 44.9	414	1,015	6	5	-	1,440	8.1
45 and over	28	71	20	-	-	119	0.7
Total	6,051	10,863	439	135	249	17,737	100.0
(b) Diesel Engine Vehicles							
Under - 14.9	13	-	107	-	79	199	3.5
15 - 19.9	14	-	59	6	31	110	2.0
20 - 24.9	-	-	49	108	37	194	3.4
25 - 29.9	53	226	63	244	220	806	14.3
30 - 34.9	13	1,056	239	420	124	1,852	32.8
35 - 39.9	11	901	388	222	54	1,576	27.9
40 - 44.9	4	558	151	51	112	876	15.5
45 and over	15	-	3	16	-	34	0.6
Total	123	2,741	1,059	1,067	657	5,647	100.0

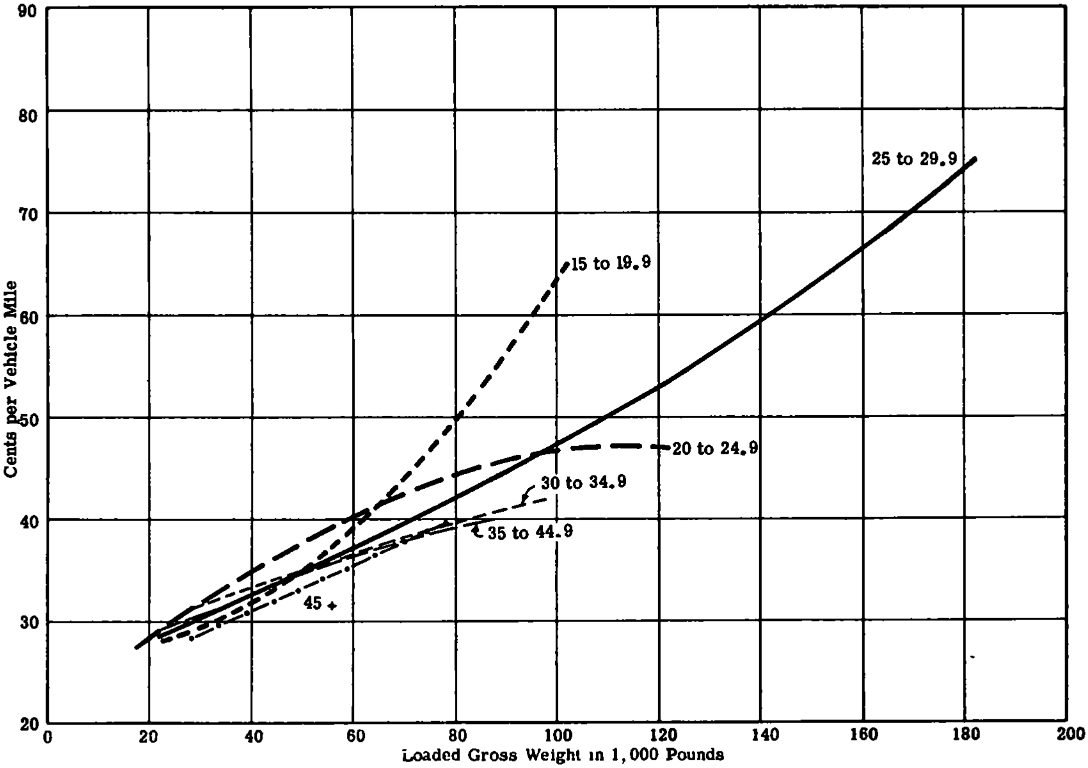

Figure 42. The effects of road speeds on gross operating costs of trailer combinations, by loaded gross weight.

The spread between costs at different speeds is considerable and is not entirely consistent. However, the data do indicate clearly that higher average road speeds, at least up to 45 mph, do not increase gross operating costs, but in general result in lower gross costs.

ROAD SPEEDS AFFECT FUEL COSTS

To investigate the effects of average road speeds on fuel costs and to compare the trends in fuel costs with those of gross operating costs (Fig. 42), the fuel cost data were analyzed in the same manner as were the gross operating costs. The fuel costs at the various average speed-blocks are shown in Figure 43 for gasoline engine powered trailer combinations, and in Figure 44 for diesel engine powered trailer combinations.

For gasoline engine powered trailer combinations it will be noted (Fig. 43) that travel at the lowest rate of speed — 10 to 14.9 mph — resulted in the highest fuel costs. Lower fuel costs occurred at progressively higher rates of speed until a reverse trend was evidenced at speeds between 35 and 39.9 mph above which fuel costs increased as speeds increased.

Figure 44 shows similar cost relationships for diesel engine powered combinations. Again, the slower speeds resulted in the highest fuel costs. Fuel costs gradually decreased as speed increased up to approximately 25 to 29.9 mph above which speed fuel costs tended to increase as speed increased.

The data in both figures support the findings of others; that there is an optimum speed for minimum fuel costs, which speed is considerably below the usual cruising speed of line-haul vehicles. The data also indicate that higher fuel costs can be expected as a result of the higher speeds which will be possible on controlled-access and multilane divided highways.

AVERAGE MILES TRAVELED DAILY BY MILEAGE BLOCKS

The average number of miles traveled daily by line-haul equipment is the average distance traveled in one 24-hr period by a vehicle which may include one or more driving shifts. This term "miles traveled daily" has a different meaning than the common transportation term "length of haul." "Length of haul" means the total distance a shipment may travel from shipper to consignee regardless of the number of days of travel.

In the study, data were collected regarding the various routes, and the mileage between route termini that was accomplished in one working day without regard to the number of drivers that may have driven the vehicle during the 24 hr. The observed data do not reveal the number of drivers required on the longer runs, but from the modes of the data it may be concluded that the modal daily mileage of a trailer combination driven by a single driver during one working shift is between 100 and 300 mi. The longer mileages reported undoubtedly required two or more drivers, either in a relay operation, or in a sleeper-cab operation.

During the carrier interviews, very few operations were found where the daily mileages were between 700 and 900 mi. Unfortunately, the cost records of these carriers were not in such order that they could be used in the study, and hence these few exceptional cases are not reported in the cost data or in Table 38. Such long daily mileages were found on roads in the Rocky Mountain and southwestern regions where towns and villages were few and far between and daily traffic volume was low. Such long daily mileages likely are representative of the maximum daily mileages that will be attained on the Interstate System of Highways, assuming that the weight/power ratios of line-haul trailer combinations remain at values which will produce level road speeds of 50 to 55 mph, with combination loaded to rated gross weight.

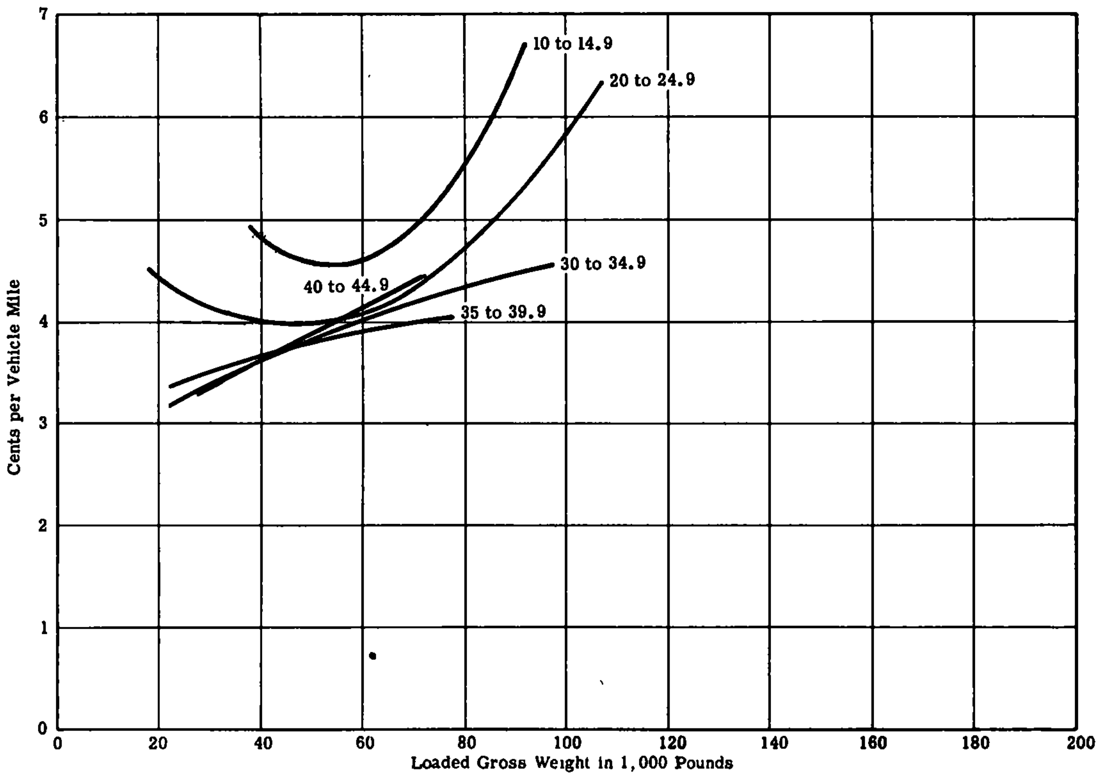

Figure 43. The effects of road speeds on fuel costs of gasoline engine powered trailer combinations, by loaded gross weight.

TABLE 38

AVERAGE MILES TRAVELED DAILY BY TRAILER COMBINATIONS OF VARIOUS AXLE CLASSIFICATIONS IN 100-MI MILEAGE BLOCKS (611 CARRIERS)

Mileage Bocks (mi)	No. of Trailer Combinations by Axle Classification						Percent of Total
	2-S1	2-S2	3-S2	Truck Full Trailer	Tractor Semi-Trailer and Full Trailer	Total	
(a) Gasoline Engine Vehicles							
80 - 100	1,087	691	4	36	67	1,885	10.6
100 - 199	3,066	6,087	199	78	137	9,567	54.0
200 - 299	1,819	3,352	175	3	28	5,377	30.3
300 - 399	76	726	56	18	14	890	5.0
400 - 499	3	7	-	-	3	13	0.1
500 - 599	-	-	5	-	-	5	0.0
Gasoline subtotal	6,051	10,863	439	135	249	17,737	100.0
(b) Diesel Engine Vehicles							
80 - 100	27	12	143	-	18	200	3.5
100 - 199	38	630	186	372	387	1,613	28.6
200 - 299	42	1,188	306	521	235	2,292	40.6
300 - 399	16	476	126	78	17	713	12.6
400 - 499	-	177	290	10	-	477	8.5
500 - 599	-	250	8	77	-	335	5.9
600 - 699	-	8	-	9	-	17	0.3
Diesel subtotal	123	2,741	1,059	1,067	657	5,647	100.0
All Vehicle Total	6,174	13,604	1,498	1,202	906	23,384	

AVERAGE DAILY MILEAGES AFFECT GROSS OPERATING COSTS

To investigate the effects of longer daily travel distances on gross operating costs, the data were sorted by the daily mileage blocks (discussed in the previous section), and the costs in each mileage block were then arrayed by loaded gross weights of the combinations. The results are shown in Figure 45.

It is interesting to note that with the longer average daily mileages, the gross operating costs are reduced. This effect roughly parallels the effects of increased average running speeds shown in Figure 42.

It may be concluded from Figures 42 and 45 that the greater speeds and the longer daily mileages, which may be possible on controlled-access roads, will result in cost benefits to line-haul motor carriers. The specific cost elements in which such benefits occur have not been developed for this report.

AVERAGE MILES TRAVELED ANNUALLY

The average number of miles traveled annually by the different types of trailer combinations observed in the study are reported in Table 39. The trailer combinations are segregated by the five axle classification groups and by the two engine types that are used elsewhere in the study. The data in Table 39 include vehicles operated by all four types of motor carriers: common, contract, exempt-for-hire, and private.

The average annual mileages of the trailer combinations segregated by the four types of carriers are given in Table 40. In comparison with the data in this table, the average annual mileage of the line-haul power vehicles operated by 642 ICC Class I common carriers of general freight engaged in intercity service with owned equipment principally, was 51,209 mi in 1956.

DAYS OPERATED PER WEEK AND EFFECTS ON GROSS OPERATING COSTS

In the trucking industry the number of days operated per week depends on several

TABLE 39

AVERAGE MILES TRAVELED ANNUALLY BY TRAILER COMBINATIONS OF VARIOUS AXLE CLASSIFICATIONS (611 CARRIERS)

Axle Class of Vehicle	With Gasoline Engine		With Diesel Engine		Total	
	Vehicles Number	Average Annual Miles	Vehicles Number	Average Annual Miles	Vehicles Number	Average Annual Miles
2-S1	6,051	47,600	123	56,100	6,174	48,100
2-S2	10,863	57,000	2,741	83,400	13,604	61,500
3-S2	439	64,200	1,059	74,500	1,498	71,300
Truck full trailer	135	52,500	1,067	85,500	1,202	78,700
Tractor semitrailer and full trailer	249	59,600	657	65,800	906	63,000
Total	17,737	54,200	5,647	77,400	23,384	60,600

factors, such as, length of haul, length of trips, type of commodity and desires of the customers. Many manufacturing and processing plants, which are predominantly shippers, work only five days a week. Without discussing further the idiosyncracies of shippers and consignees, the variations in carriers' operations can be reported within the limits of the study.

Table 41 gives the distribution of the four types of carriers by number of days worked per week. It will be noted that the 6-day workweek is predominant, but that there is an extensive proportion of 7-day workweeks. Carriers with 7-day workweeks are the longer haul carriers, and to such carriers, travel on Sunday is very useful in advancing long-haul freight by a day where it otherwise would stand idle.

TABLE 40

AVERAGE ANNUAL MILES OPERATED BY TRAILER COMBINATIONS BY CLASS OF CARRIER (611 CARRIERS)

Class of Carrier	Number of Combinations	Average Annual Miles
Private	2,466	59,000
Exempt-for-hire	58	73,300
Common	19,104	64,000
Contract	1,756	46,700
Total	23,384	60,600

Figure 46 shows how the number of days worked per week affects the gross operating costs of the study. The relatively insignificant differences in costs between the different operating schedules are not entirely realistic because of the manner in which indirect and overhead costs, and depreciation and interest costs were developed. Much of each of these two costs is related to time, and hence the greater annual mileage, made possible because of vehicle operation on a seventh day, would reduce the vehicle-

TABLE 41

DAYS OPERATED PER WEEK BY 611 MOTOR CARRIERS BY CLASS OF CARRIER

	Days Operated Per Week							
	5		6		7		Total	
	No.	%	No.	%	No.	%	No.	%
Private	76	38.2	94	47.2	29	14.6	199	100.0
Exempt-for-hire	-	-	2	22.2	7	77.8	9	100.0
Common	89	26.3	159	47.1	90	26.6	388	100.0
Contract	33	50.8	22	33.8	10	15.4	65	100.0
Total	198	32.4	277	45.3	136	22.3	611	100.0

mile costs of these two cost elements. It was not possible to make such an analysis, and still keep all other factors constant so as to conform to the study's purpose; namely, the differences in operating costs resulting from changes in gross weights.

FUEL CONSUMPTION RATES

Although all the carriers interviewed kept fuel cost records, only approximately 40 percent of them had fuel consumption records by individual power units, or by groups

TABLE 42

RATIOS OF TRAILERS TO POWER UNITS OF 611 MOTOR CARRIERS INTERVIEWED

Ratio of Trailers to Power Units	No. of Power Units and Trailers									
	Private		Exempt-for-Hire		Common Carrier		Contract Carrier		Totals	
	Power Units	Trailers	Power Units	Trailers	Power Units	Trailers	Power Units	Trailers	Power Units	Trailers
1 0 - 1.0	1,295	1,295	28	28	3,770	3,770	1,034	1,034	6,127	6,127
1.0 - 1.25	439	494	17	19	2,343	2,637	215	242	3,014	3,392
1 0 - 1.50	203	279	10	14	3,089	4,247	98	135	3,400	4,675
1.0 - 1 75	232	377	3	5	2,407	3,911	112	182	2,754	4,475
1 0 - 2 0	202	379	-	-	2,564	4,808	124	233	2,890	5,420
1.0 - 2 5	69	155	-	-	2,143	4,822	28	63	2,240	5,040
1.0 - 3 0	22	61	-	-	869	2,390	75	206	966	2,657
1.0 - 3 5	-	-	-	-	995	3,234	5	16	1,004	3,263
1.0 - 4 0 and over	-	-	-	-	924	3,465	65	244	989	3,709
Totals	2,466	3,053	58	66	19,104	33,284	1,756	2,355	23,384	38,758
No. of extra trailers	-	587	-	8	-	14,179	-	599	-	15,373
Average percentage of extra trailers	-	23 8	-	13.8	-	74.2	-	34 1	-	65.7

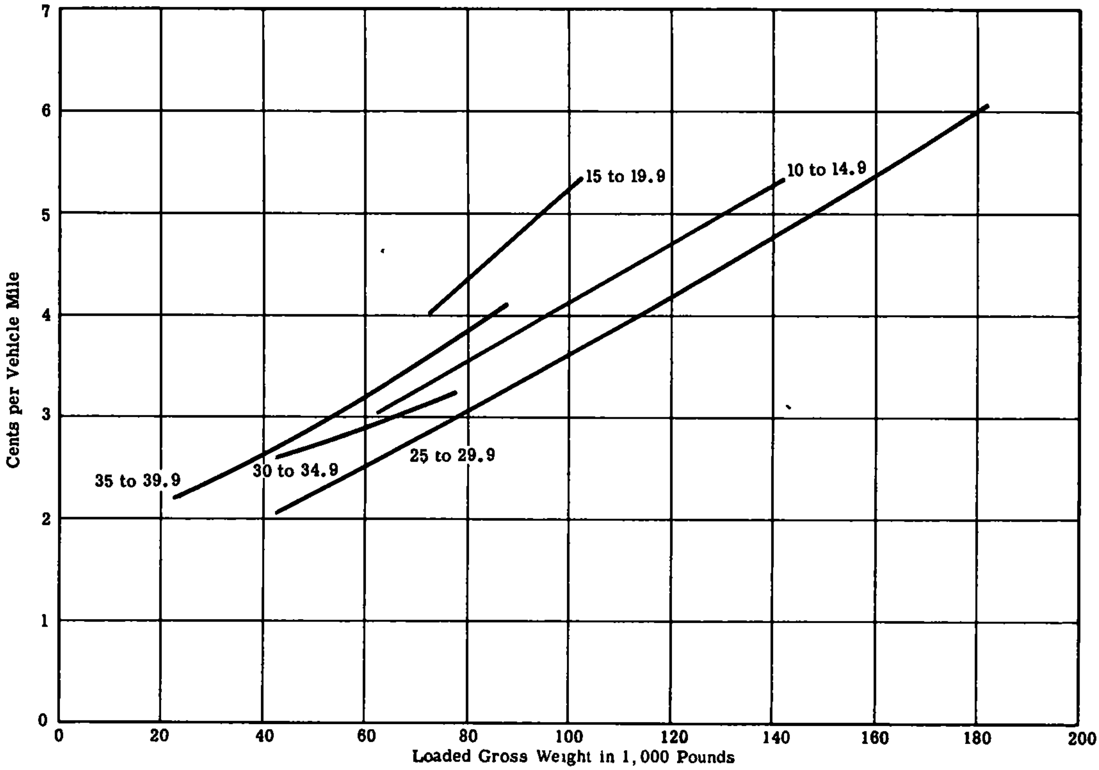

Figure 44. The effects of road speeds on fuel costs of diesel engine powered trailer combinations, by loaded gross weight.

of similar power units, which could be related to trailer combinations and their respective loaded gross weights. Such fuel consumption data did not need to be adjusted for purchase price as was done for the cost data, but could be used directly in terms of gallons per vehicle-mile. However, although the fuel consumption data relate to only a portion of the vehicles for which cost data were obtained the observed data are reported in Fig. 47 as an addition to the existing fund of information regarding the in-

TABLE 43

VEHICLE-MILE AND PAYLOAD TON-MILE COSTS OF OPERATING VARIOUS GASOLINE ENGINE POWERED STRAIGHT TRUCKS ON RURAL HIGHWAYS

Item	Concrete Mixers		Closed Vans					Open-Top Van	Dump		Tank
Commodity	Transit mix	Transit mix	Groc's	Meat	Bakery goods	Meat	Bakery goods	Feed	Sand rock	Sand cement	Bulk ammonia
No of axles	3	3	2	2	2	2	2	3	2	3	3
Aver length of run, mi	9	50	72	200	387	191	95	-	128	-	450
Aver daily mileage	-100	-100	-100	200	150	150	250	250	150	-100	150
Aver annual mileage	6,500	11,000	24,000	43,000	62,000	43,000	87,000	69,000	43,000	13,000	31,000
Tare weight, lb	18,000	23,000	8,000	9,000	10,000	10,000	11,000	15,000	9,000	17,000	22,000
Payload weight, tons	10 0	10 0	5 5	5 0	5 0	5 0	6 0	12 5	9 0	14 0	6 0
Loaded gross weight, lb	38,000	43,000	19,000	19,000	20,000	20,000	23,000	40,000	27,000	45,000	34,000
No of vehicles	16	80	7	12	5	9	1	2	10	3	2
Vehicle-Mile Costs ($)											
Repair, serv and lubricant	0 561	0 186	0 047	0 033	0 024	0 025	0 016	0 037	0 040	0 100	0 064
Tire and tube	0 016	0 044	0 011	0 007	0 006	0 006	0 005	0 011	0 008	0 032	0 008
Fuel	0 108	0 060	0 033	0 018	0 021	0 027	0 023	0 024	0 013	0 046	0 028
Driver wage and subsist	0 093	0 093	0 091	0 091	0 091	0 091	0 091	0 093	0 091	0 093	0 091
Direct running	0 778	0 383	0 182	0 149	0 142	0 149	0 135	0 165	0 152	0 271	0 191
Indirect and overhead	0 126	0 107	0 098	0 097	0 097	0 097	0 096	0 099	0 098	0 102	0 100
Depreciation and interest	0 038	0 047	0 023	0 023	0 018	0 023	0 022	0 038	0 028	0 047	0 041
Gross operating	0 942	0 537	0 303	0 269	0 257	0 269	0 253	0 302	0 278	0 420	0 332
Payload Ton-Mile Costs ($)											
Repair, serv and lubricant	0 0561	0 0186	0 0085	0 0066	0 0048	0 0050	0 0027	0 0030	0 0045	0 0071	0 0106
Tire and tube	0 0016	0 0044	0 0020	0 0014	0 0012	0 0012	0 0008	0 0009	0 0009	0 0023	0.0013
Fuel	0 0108	0 0060	0 0060	0 0036	0 0042	0 0054	0 0038	0 0019	0 0014	0 0033	0 0047
Driver wage and subsist	0 0093	0 0093	0 0166	0 0182	0 0182	0 0182	0 0152	0 0074	0 0101	0 0067	0 0152
Direct running	0 0778	0 0383	0 0331	0 0298	0 0284	0 0298	0 0225	0 0132	0 0169	0 0194	0 0318
Indirect and overhead	0 0126	0 0107	0 0178	0 0194	0 0194	0 0194	0 0160	0 0079	0 0109	0 0073	0 0167
Depreciation and interest	0 0038	0 0047	0 0042	0 0046	0 0036	0 0046	0 0037	0 0031	0 0031	0 0033	0 0068
Gross operating	0 0942	0 0537	0 0551	0 0538	0 0514	0 0538	0 0422	0 0242	0 0309	0 0300	0 0553

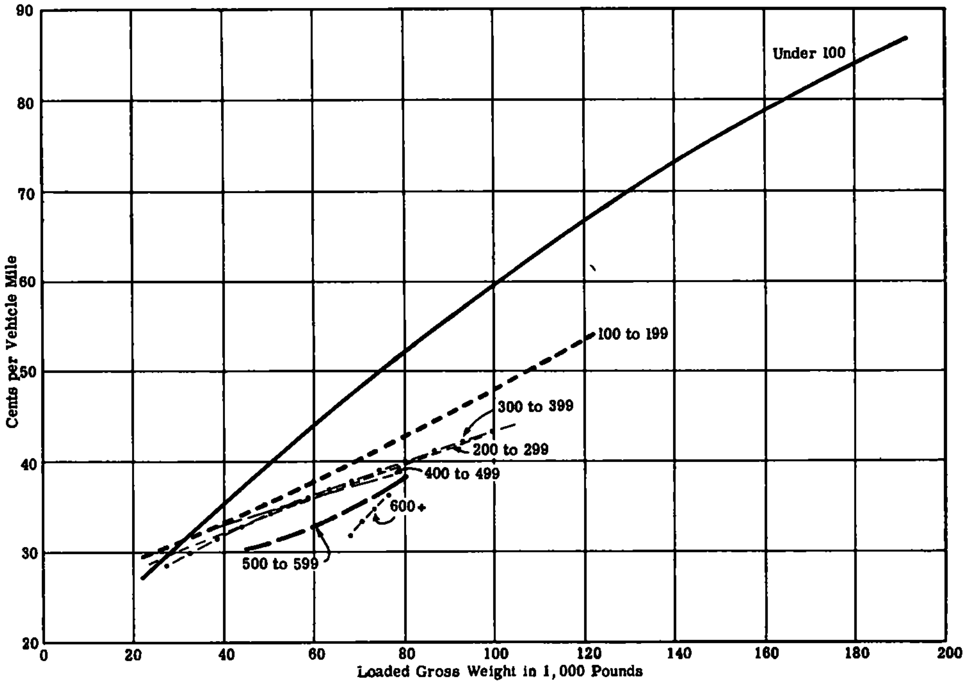

Figure 45. Gross operating costs of all trailer combinations related to average daily mileage and to loaded-gross weight.

constant and not firmly established ratios of fuel consumption between freight vehicles equipped with gasoline or diesel engines. Additional data on relative fuel consumption, which further illustrate the variability of this ratio, are reported elsewhere (18, 28, 29, 30, 31, 32, 33).

TABLE 44

VEHICLE-MILE AND PAYLOAD TON-MILE COSTS OF OPERATING VARIOUS DIESEL ENGINE POWERED TRAILER COMBINATIONS AND STRAIGHT TRUCKS ON PRIVATE ROADS

Item	3-Axle Tractor Semitrailers			5-Axle Tractor Semitrailers					3-Axle Straight Trucks	
Body type	Dump	Hopper	Dump	L Bunk	L Bunk	L Bunk	L Bunk	L Bunk	Dump	Dump
Commodity	Coal	Coal	Coal	Logs	Logs	Logs	Logs	Lumber	Copper ore	Copper ore
Average length of run, mi	4 4	4 0	4 6	42 0	28 0	25 0	16.0	13 0	7 6	7 2
Average daily mileage	-100	-100	150	-100	-100	-100	-100	-100	150	150
Average annual mileage	19,000	19,000	57,000	24,000	12,000	18,000	16,000	7,000	46,000	39,000
Tare weight, lb	45,400	48,000	75,000	31,000	29,000	37,000	44,000	55,000	68,000	110,000
Payload weight, tons	32 8	50 0	55.0	40 5	45.0	45 0	75.0	83.0	36.5	54 5
Loaded gross weight, lb	111,000	148,000	185,000	112,000	119,000	127,000	194,000	221,000	141,000	219,000
Number of vehicles	12	11	8	9	11	7	20	5	21	4
Vehicle-Mile Costs ($)										
Repair, serv and lubricant	0 271	0.493	0 228	0 320	0 388	0 447	0 435	1 228	0 977	1 071
Tire and tube	0 133	0 166	0 086	0 241	0 206	0 122	0 191	0 551	0 381	0 821
Fuel	0 051	0 100	0 056	0 090	0 096	0 044	0 085	0.106	0 191	0 399
Driver wage and subsist	0 105	0 105	0 105	0 105	0 105	0 108	0 125	0 130	0 116	0 130
Direct running	0 560	0 864	0 475	0 756	0 795	0 721	0.836	2 015	1.665	2 421
Indirect and overhead	0.118	0 124	0.116	0 134	0 120	0 124	0 126	0 168	0 210	0 165
Depreciation and interest	0 156	0 132	0 180	0 095	0 077	0 082	0 092	0 088	0 128	0 137
Gross operating	0 834	1 120	0.771	0 985	0 992	0 927	1 054	2 271	2 003	2 723
Payload Ton-Mile Costs										
Repair, serv. and lubricant	0 0083	0 0099	0.0041	0 0079	0 0086	0.0099	0 0058	0 0148	0 0268	0 0196
Tire and tube	0 0041	0.0033	0 0016	0 0060	0 0046	0 0027	0 0026	0 0066	0 0104	0 0151
Fuel	0 0015	0 0020	0 0010	0 0022	0 0021	0 0010	0 0011	0 0013	0 0052	0 0073
Driver wage and subsist	0 0032	0 0021	0 0019	0 0026	0 0024	0 0024	0 0017	0 0016	0 0032	0 0024
Direct running	0.0171	0 0173	0 0086	0 0187	0 0177	0 0160	0 0112	0 0243	0.0456	0 0444
Indirect and overhead	0 0036	0 0025	0 0021	0 0033	0 0026	0 0028	0 0017	0 0020	0 0058	0 0030
Depreciation and interest	0 0047	0 0026	0 0033	0 0023	0.0017	0 0018	0 0012	0 0011	0 0035	0 0025
Gross operating	0 0254	0 0224	0 0140	0 0243	0 0220	0 0206	0 0141	0 0274	0 0549	0.0499

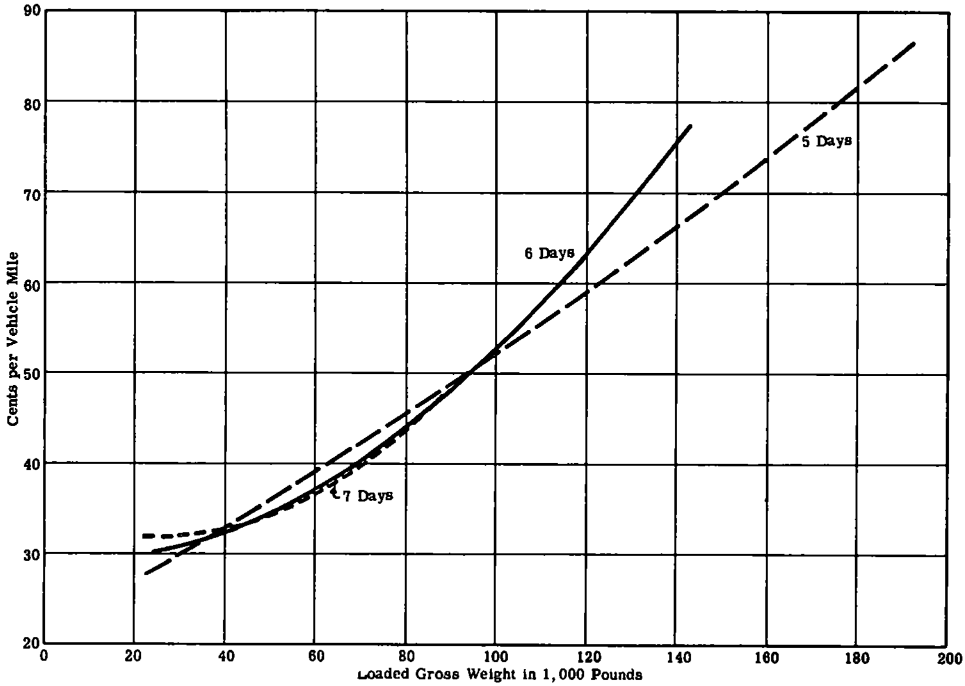

Figure 46. The effects of number of days operated per week on gross operating costs of trailer combinations, by loaded gross weight.

In Figure 47 the small circles indicate the means of the fuel consumption rates for the gasoline engine powered trailer combinations in each 5,000-lb class-interval of loaded gross weight. The small triangles indicate similar data for diesel engine powered trailer combinations. Straight-line curves appear to best show the trends, and those shown were computed by the least-squares method.

At 40,000-lb loaded gross weight the diesel fuel consumption rate from the curve is 0.172 gal per mi, whereas the gasoline fuel consumption rate is 0.224 gal per mi, indicating that the diesel fuel consumption rate is 76.8 percent of the gasoline rate. At 100,000 lb-loaded gross weight, similar data are diesel fuel rate at 0.258 gal per mi, with gasoline rate at 0.324 gal per mi, indicating that the diesel fuel consumption rate is 79.6 percent of the gasoline rate.

EFFECT OF FUEL TAXES ON FUEL COSTS

Fuel taxes were not included in fuel costs in the study, because they are considered as payment for the highways, and not as vehicular costs. In the committee's over-all analysis, the cost of highway facilities are to be developed separately and in a manner in which they can be combined with vehicular costs to develop over-all transportation costs. This stipulation was discussed in the section on "Fuel Costs."

However, because of the interest in the impact of fuel taxes on carriers out-of-pocket expenses, Figure 48 shows the average State and Federal fuel tax costs per vehicle-mile for gasoline engine powered trailer combinations, and for diesel engine powered trailer combinations. These fuel tax costs per vehicle-mile are related on the chart to the loaded gross weights of the trailer combinations.

The average of the State and Federal gasoline taxes, reported by the carriers, was found to be $0.0874 per gal, whereas the similar average for diesel fuel was found to be $0.0897 per gal.

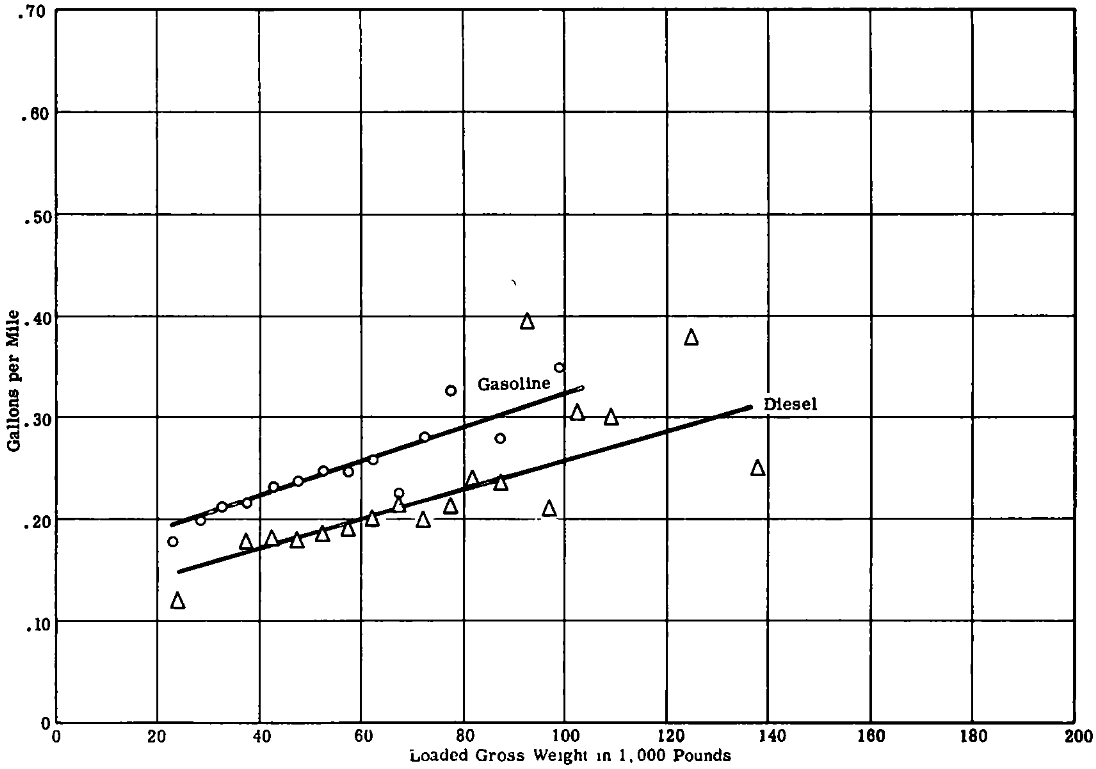

Figure 47. Gasoline and diesel fuel consumption rates for trailer combinations, by loaded gross weight.

RATIOS OF TRAILERS TO POWER UNITS OF 611 MOTOR CARRIERS INTERVIEWED

As was discussed in the section on "Number of Vehicles in Line-Haul Fleet," the number of trailers in use in the United States has not been determined accurately. However, an estimate of the number of trailers in use was developed, and was believed reasonable by the committee members representing the motor carriers and the trailer manufacturers, but that number of trailers must be regarded only as a considered estimate because of the lack of precise data.

Additional data on this topic were obtained during the study. From each of the 611 carriers that supplied data for the study, there was obtained the ratio of the number of trailers to the number of power units used in line-haul service. These data are given in trailer/power-unit ratio blocks in Table 42. These trailer/power-unit ratios differ greatly from the assumptions that were used in developing the estimated number of trailers in Table 9. It must be borne in mind, however, that the 611 carriers interviewed were successful carriers, which had extensive cost records, and which were selected because they had good cost records. The trailer ratio data were incidental to the cost records. For these reasons the trailer/power-unit ratios undoubtedly are biased towards the practices of the larger carriers and are unlikely to be representative of small carriers and the trucking industry as a whole. It is not believed that the trailer/power-unit ratios of the 23,384 power units of the study can be expanded to the 602,475 power units reported in Table 9.

Table 42 is included only to show the trailer/power-unit ratios of the carriers reported in the study. Incidentally, these differences in trailer/power-unit ratios, and the different ratios reported in the ICC statistics (2), point up the need for better data regarding the number of trailers used in line-haul service, and the number used in city delivery service.

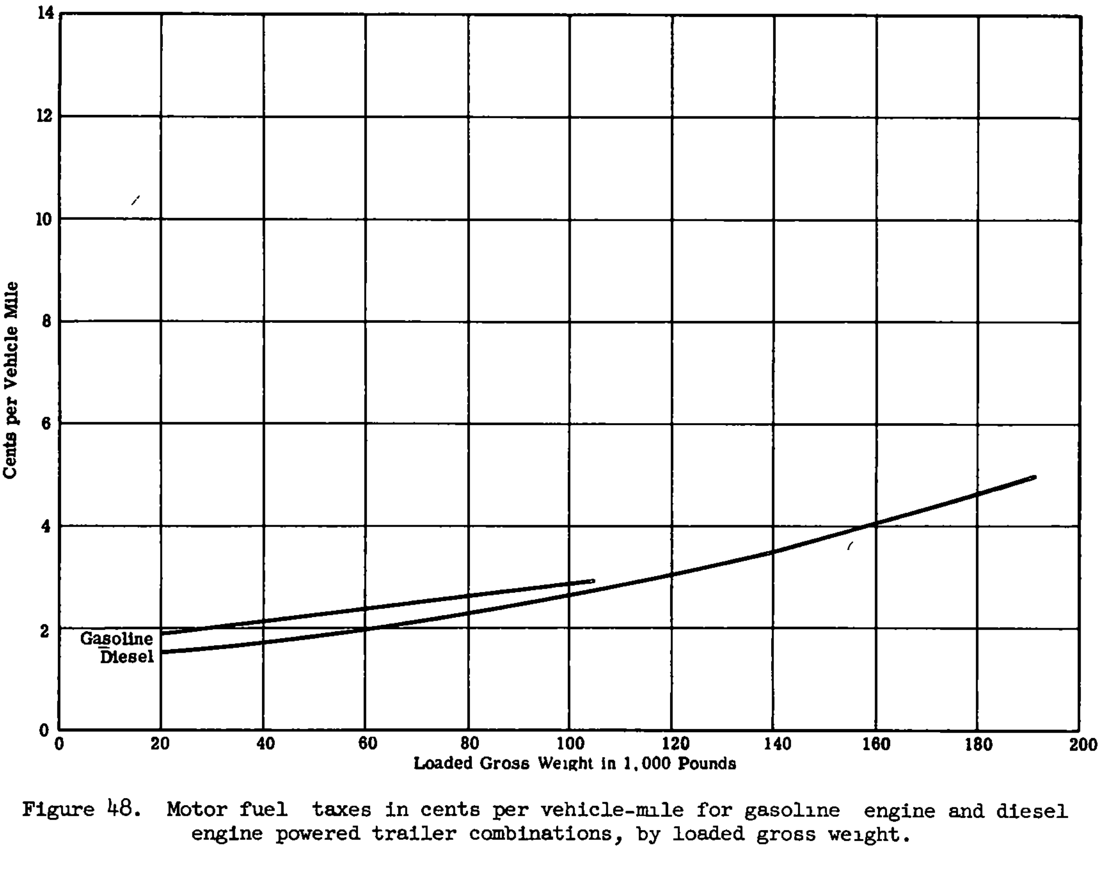

Figure 48. Motor fuel taxes in cents per vehicle-mile for gasoline engine and diesel engine powered trailer combinations, by loaded gross weight.

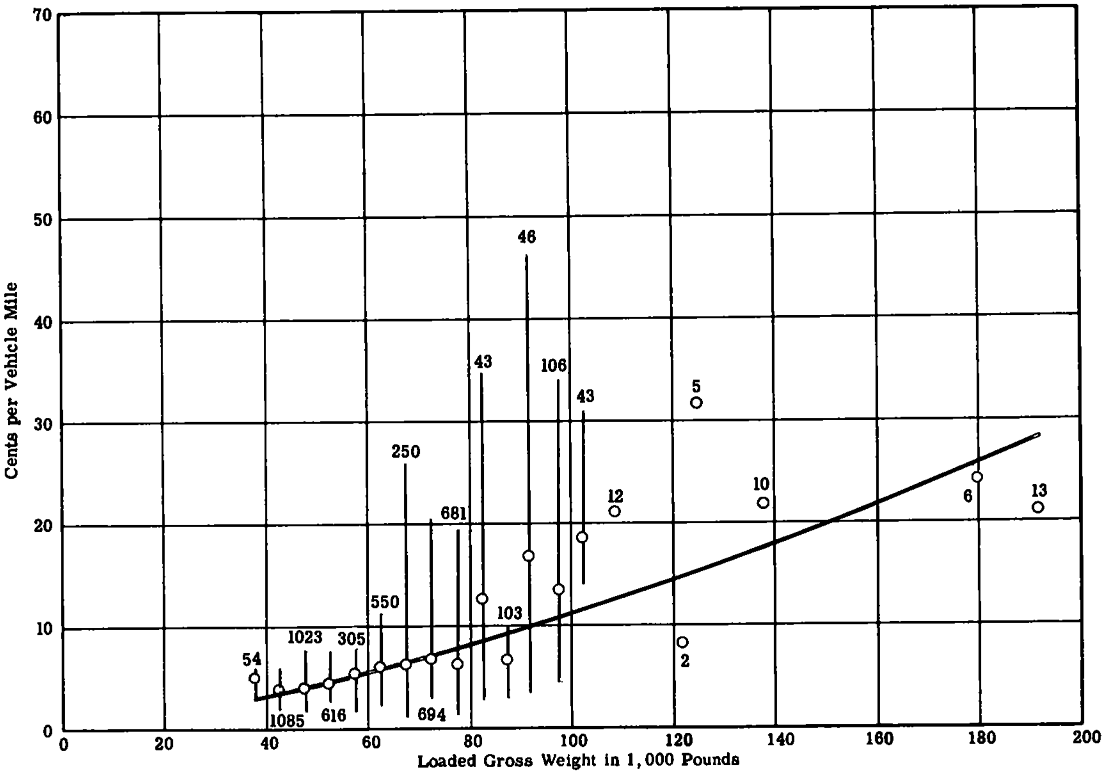

Figure 49. Ranges of variations in cost data showing numbers and means of values, together with computed trend line.

The data in Table 42, however, do give some relative information as to the extra trailers owned and used by private and exempt-for-hire carriers, about which there previously had been practically no data.

The number of spare trailers in Table 42 was calculated by using the mid-point values of the ratio intervals and is not a precise inventory of the trailers, but is representative of the trailer ratios of the carriers reported.

RANGE OF VARIATIONS IN COST DATA

Much of the data presented in the figures show the means of the values in each 5,000-lb class-interval and the number of vehicles included in each class-interval. Although these means and numbers of vehicles are used in computing the trend curves, they do not reveal the whole extent of the variations in data that are encountered in a study of a complex industry, such as the trucking industry, which consists of many individual companies with different managements operating under a wide variety of circumstances.

To illustrate the ranges of values which must be processed by statistical means to produce representative trends, Figure 49 shows the ranges of the vehicle-mile costs for the "Repair, Servicing and Lubricant Costs" of all the diesel engine powered trailer combinations. This figure has the same data that were used in the Repair, Servicing and Lubricant Costs chart in Figure 23. The ends of the vertical line, through each small circle locating the mean of each 5,000-lb class-interval, indicate the extremes of costs which were obtained from carriers.

Similar wide ranges of data were encountered for the gasoline engine poowered trailer combinations, and for both types of vehicles in the data for tire and tube costs, and in the data for fuel costs. The cost elements of driver costs, indirect and overhead costs, and depreciation and interest costs do not have as wide a range of values because of their method of computation which was described earlier in appropriate sections of the text.

Figure 49 and this discussion are included in this report merely to indicate the extent of the problem of developing detailed unit costs of different elements of expense in as diverse and discrete a business as the operation of motor trucks. The vagaries of the data may help explain the inconsistencies that appear in certain subdivisions of trucking operations where the number of cases was rather sparse. Additional data would have been very useful to develop data in certain small segments of trucking operations, but it was not possible to search out such specific information within the limits of the study.

Taken as a whole, the number of vehicles generally cover the typical trucking operations and the over-all mass of data is believed to be valid and representative of vehicular costs of trucking operations in the United States during 1956.

COST DATA REGARDING DISCRETE HIGHWAY VEHICLES

In the course of the field interviews of the study, cost data were obtained regarding a number of trailer combinations and straight trucks whose operations did not comply with the criteria set up for the line-haul trucking cost study. These data, although not extensive, nevertheless are information about specific trucking operations that are not included in the report. Rather than discard completely these discrete data, because they indicate the cost characteristics of cértain types of trucking operations, the costs and descriptive information about the operations are presented in Table 43 and 44.

Table 43 gives vehicular and operational characteristics together with vehicle-mile and payload ton-mile costs of gasoline engine powered straight trucks operating on public roads.

Table 44 gives similar data for diesel engine powered trailer combinations and large straight trucks operating on private roads.

No conclusions are drawn from these data, and the information is presented only to preserve the findings for such informational use as may develop later.

Glossary of Definitions and Trade Terms

The trucking industry, like most industries, has a vocabulary of technical terms pertaining to various divisions of the industry, to operating practices, and to equipment types. In addition, it has a vernacular which varies from one part of the country to another. In general, the definitions given here follow recognized authorities (26). However, there are listed certain definitions which do not have clear authoritative backgrounds but are generally acceptable in the industry and are used in this report.

Truck or motor truck — A single self-propelled commercial motor vehicle carrying its load on its own wheels and primarily designed for the transportation of property or commodities. (When used as a general term, "truck" may refer to any type of commercial motor freight vehicle.)

Single-unit motor truck — One constructed to carry only its cargo, and not equipped to pull a trailer.

Power unit or power vehicle — A general term referring to any vehicle equipped with an engine for propulsion and arranged to pull a trailer.

Tractor or truck tractor — A self-propelled motor vehicle designed primarily for pulling semitrailers and constructed so as to carry part of the weight and load of a semitrailer. (A tractor is basically a motor truck with a short wheelbase and no cargo body.)

Tractive truck — A motor truck constructed to carry a cargo body and to pull a trailer. (Trailer pulled may be either a semitrailer or a full trailer depending on whether the tractive truck is equipped with a semitrailer fifth wheel, or with a full trailer pintle hook.)

Dromedary power unit — A cross between a tractive truck (which carries a cargo body) and a tractor (which pulls a semitrailer). In this study it is classed as a tractive truck.

Trailer or truck trailer — A commercial motor vehicle designed to carry a cargo and to be pulled by a tractive truck or a tractor. (When used as a general term it may mean either a semitrailer, a full trailer or a pole trailer, and may be equipped with any one of the various types of cargo bodies.) (Trailers built as mobile living quarters are known as trailer coaches and mobile homes, but frequently are called house trailers.)

Semitrailer — A truck trailer equipped with one or more axles and constructed so that a substantial part of its weight and load is carried by the tractor or tractive truck which pulls the semitrailer. A semitrailer may have one or more load-carrying axles located under the rear half of the vehicle. A semitrailer with two axles grouped under the rear half of the vehicle frequently is known as a tandem-axle semitrailer.

Full trailer — A truck trailer constructed so that practically all of its weight and load rests on its own wheels. It may have two or more load-carrying axles.

Trailer converter dolly — A short trailer chassis assembly consisting of axle and wheel assembly, tires, springs, frame for lower fifth wheel, drawbar, and other parts designed to convert a semitrailer to a full trailer.

Pole trailer — A special type of semitrailer designed to be pulled by a truck or tractor and attached by means of a reach or pole, or by being "boomed" or otherwise secured to its tractive truck or tractor, and intended for transporting long or irregularly shaped loads, such as poles, logs, pipes, or structural materials which are capable generally of sustaining themselves as beams between the supporting vehicles.

Trailer combination or combination — A general term used to describe two or more vehicles, one of which is a power vehicle, that are connected together for operation on the road. In general, the name of each combination indicates the types of vehicles that are connected together in the combination.

There are different types of trailer combinations in common use in the United States. Because vehicles with different numbers of axles can be used in making up these combinations, the convenient axle classification code developed by the Bureau of Public Roads is used in this report. In this code, each digit represents the number of axles of one vehicle of a combination. The symbol for a trailer combination consists of two or three digits separated by hyphens. The first digit of a combination represents the power unit. An "S" before the second digit in a combination symbol indicates a semitrailer, the power unit usually being a truck tractor. A digit appearing without an "S" in either the second or third position in a combination symbol represents a full trailer. If a digit without an "S" appears after the digit for the power unit, it indicates that the trailer is a full trailer and that the power vehicle is a tractive truck. A tractor semitrailer and full trailer combination requires three digits, the center one of which is preceded by an "S".

The names, axle classification symbol (Fig. 50), and number of axles for typical trailer combinations are shown, as follows:

Name of Trailer Combination	Axle Classification Symbol	No. of Axles in Combination
Tractor and semitrailer	2-S1	3
	2-S2	4
	3-S2	5
	3-S3	6
Tractive truck full trailer	2-1	3
	2-2	4
	3-2	5
	3-3	6
Tractive truck and semitrailer (Dromedary power unit)	3-S2	5
	4-S2	6
Tractor semitrailer and full trailer (Double trailer)	2-S1-2	5
	2-S2-2	6
	3-S1-2	6
	3-S2-2	7
	3-S2-3	8
	3-S2-4	9
Single-unit trucks	2	2
	3	3

Double trailer combination — A tractor, semitrailer and full trailer. (This combination frequently is called a "double bottom" combination. Also, in some areas a tractive truck full trailer combination is called a "double bottom" because it has two cargo bodies.)

Cargo body types — Trucks and trailers are equipped with many types of cargo bodies to accommodate different commodities. At times, the descriptive names of these cargo bodies are used as prefixes to the type of truck or trailer. From the highway viewpoint, however, it is the basic construction of the vehicles, mainly the number and spacing of axles, which is important, whereas the body type is of less importance. The basic vehicle constructions include single-unit truck, tractive truck, tractor, full trailer, semitrailer, pole trailer, and the several trailer combinations, as defined previously. Cargo body types are generally understood from their common names which usually are descriptive, such as:

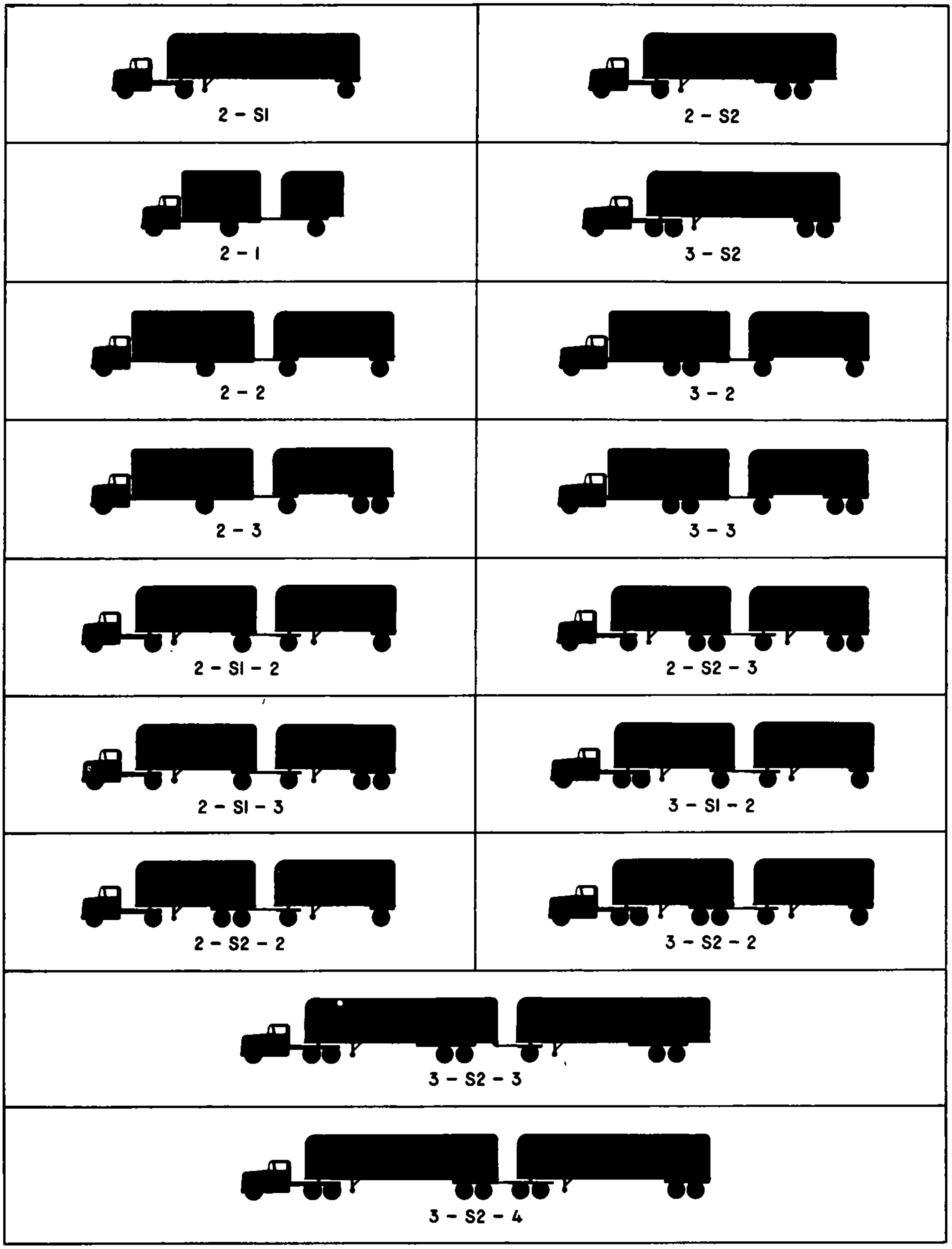

Figure 50. Commercial vehicle types as designated by code based on axle arrangement.

- closed van
- open-top van (tarpaulin covered)
- refrigerator van
- insulated van
- ventilated van
- furniture van
- rack van (livestock)
- stake body
- low side bulk body (for grain, etc.)
- flat bed
- platform body
- lumber body
- log body
- tank
- hopper
- dump
- mixer
- automobile carrier
- armored body
- utility service
- other special purpose bodies

Carriage — The act of conveying or transporting goods and property.

Motor freight service — A general term referring to the various kinds of trucking transportation services.

Trucking industry — The business of transporting freight or commodities by motor truck. It is a general term referring to all classes of carriers and all types and kinds of freight transportation over streets, roads and highways.

Intrastate freight service — Freight transportation within the boundaries of a State. It may mean either line-haul service, peddle service, or city pickup and delivery service.

Interstate freight service — Trucking service between terminals, docks, plants, and loading areas located in different States.

Off-highway service — Operation over the natural surface of land, usually after it has been only cleared and graded, and frequently with vehicles built for this purpose.

Line-haul service (also called over-the-road service) — A general term designating truck operations over intercity and rural highways. Such operations, for the purposes of this study, may include some minor auxiliary off-highway operations with highway vehicles, especially where the payload is picked up from a loading area off a highway. Examples of this occur in strip mine service, logging operations and agricultural movements.

Carrier or motor carrier — A general term meaning a person, a company, or a department of an industrial or mercantile company or business that operates commercial motor vehicles for the transportation of property. From the national viewpoint, there are several broad classes of carriers, each of which has subdivisions. For this study, the following list of simplified definitions of the several classes and subdivisions of motor carriers is adequate to describe the field of the study.

1. For-hire carriers (certificated):
   (a) Common carriers (serving many shippers while operating under certificates of authority from the Interstate Commerce Commission and/or State public utility commissions).
   (b) Contract carriers (serving specific shippers in lieu of private carriage and operating under certificates from the Interstate Commerce Commission and/or State public utility commissions).
   (c) The Interstate Commerce Commission classifies the ICC certificated carriers into three groups according to their annual revenues. Different reports are required of the different classes, with the Class I making the most comprehensive reports. The three ICC classes are: Class I, annual gross revenues of $1,000,000 or more; Class II, annual revenues between $200,000 and $1,000,000; Class III, annual revenues less than $200,000. These classifications became effective January 1, 1957.
2. Exempt-for-hire carriers — Serve several shippers but haul only exempt commodities, primarily agricultural products, which by law may be transported by for-hire carriers that need not obtain operating certificates from the ICC for the interstate hauling of such exempt commodities. (State regulations vary in regard to this type of carrier.)

3. Private carriers (hauling their own goods):
   (a) Manufacturing concerns.
   (b) Mercantile companies and retail stores.
   (c) Fuel supply companies.
   (d) Farmers and agricultural supply businesses.
   (e) Mining and logging companies.
   (f) Construction companies.
   (g) Public utility companies.
4. Other suppliers of vehicles for freight transport service are truck leasing companies that furnish vehicles to the different types of carriers for agreed upon fees. However, as suppliers of vehicles for use only by and under the control of others, truck leasing companies are not carriers.
5. A unique form of truck leasing found quite frequently in the trucking industry is one in which the owner of a tractor leases and drives his tractor to haul an employer's trailer. This type of leasing is known commonly by the term "owner-operator." The owner-operator usually is paid a mileage fee which covers fuel, tires, maintenance and depreciation of the tractor. The wages of the owner-operator may be included in the mileage fee, but frequently the drivers are paid wages separate from the vehicle fees.

Purchased transportation — The hiring of vehicles with drivers. There are three general types of purchased transportation:

1. The use of owner-operators.
2. The use of vehicles and drivers supplied by a subsidiary of the parent carrier, or by a truck rental company.
3. In the case of private carriers, the vehicles and drivers may be furnished by a contract carrier which offers carriage "in lieu" of private carriage.

The Interstate Commerce Commission (frequently referred to as the ICC) — A commission of the Federal Government which has authority to regulate common and contract motor carriers of property that operate across State boundaries and in more than one State, that is, operate in interstate service.

Interstate common and contract carriers — Carriers which operate in more than one State under operating certificates from the Interstate Commerce Commission.

Intrastate common and contract carriers — Carriers whose operations are confined within the boundaries of a State, and who obtain their operating franchises or certificates from the public utility or public service commissions of the respective States.

Classification of accounts or system of accounts — The "Uniform System of Accounts for Class I Common and Contract Carriers — Prescribed by the Interstate Commerce Commission — Issue of 1952," (17). Classification of Trucking Services.

The three primary classes of carriers offer a variety of freight carrying and other services. The several types of trucking services include:

1. Line-haul or over-the-road freight hauling — This service includes predominately terminal-to-terminal movements without pickup or delivery service between terminals. Terminals may be carriers' terminals, shippers' or consignees' terminals, and loading or unloading points in rural areas. However, line-haul vehicles, between road trips, frequently are used to deliver freight or to pick up freight for an impending road trip. Because of the difficulties in accounting, all mileage and expenses (except city drivers' wages) of line-haul vehicles in such minor local services are charged to line-haul service.
2. City local trucking services — These services are provided in cities, towns, and contiguous suburbs, and include:
   (a) Freight service from and to line-haul carrier terminals, warehouses, storage depots, manufacturing plants, etc., and to retail distributors,

sales outlets or to point of use, commonly called city pickup and delivery service.
(b) Retail delivery service from retail sales outlets to purchasers (small shipments or packaged deliveries to homes or other business houses).
(c) Local household goods moving and transfer service.
(d) Local dump trucks used to transport material from and to construction excavations.
(e) Transit-mix concrete trucks.
(f) Local heavy hauling service. (Transport of machinery and other large and heavy objects.)
(g) Fuel delivery trucks. (Coal, gasoline and heating fuels.)
(i) Utility and repair trucks. Vehicles used as mobile shops and supply vehicles by public utilities, and by household and building repair and maintenance men, such as plumbers, painters, carpenters, and electricians.

3. Rural local trucking services — These types of services are provided to areas outside of cities, towns and contiguous suburbs. They include trips wholly within the area outside of cities, towns and contiguous suburbs, as well as trips from a city, town and contiguous suburbs to the surrounding area. These rural services are similar to city delivery and pickup services, and, in addition, include farm trucks. The list of services include:
(a) Peddle service. This service is defined by the Interstate Commerce Commission as follows: "Peddle trips are trips operated out of a local area, consisting of a city or town and contiguous suburban districts for the purpose of delivering freight to consignees and gathering freight from consignors at points outside such area." (A counterpart to city pickup and delivery service.)
(b) Other rural trucking services include the equivalents of those listed under city trucking services.

Shipper — A person or company that originates a shipment, or is the business establishment from which a shipment is received by the carrier. In the case of a private carrier, the carrier may be both the shipper and the consignee, but the term "shipper" is used to designate the initial shipping point or department in a private carrier's operation from which the load was picked up for transportation by the private carrier's motor vehicles.

Consignee — A person, company, or business establishment to which a shipment is to be delivered by the carrier. In the case of a private carrier the term "consignee" is used to designate the receiving point in a private carrier's organization to which a shipment is delivered by the private carrier's motor vehicles.

Freight — A general term referring to all types of commodities or property that is transported. It includes raw products from mines, forests and farms, as well as manufactured goods ready for use by the ultimate consumer. Freight also may be referred to as payload or cargo.

Shipment — A specific amount of freight that is received from one shipper at one point at one time and is transported on a single shipping order, freight bill, or bill of lading. A shipment may contain one or more items or packages, and may include a variety of commodities.

LTL — Defined in different arrangements of words, all of which are intended to mean the same thing. In one source (27) LTL is defined as "less than truckload," whereas another source (2) writes the term out as "less truck load." In either case, LTL refers to the size of a shipment and not to the extent to which the cargo body of a vehicle may be loaded. LTL, when used in reference to a shipment, means a small shipment which pays the LTL freight rate for the subject commodities, instead of the truckload rate. An LTL shipment may contain several packages.

Truckload — Has different meanings in the motor freight business.

1. In a general sense, a truckload means a quantity of freight which visibly fills

the cargo space, or which equals the legal allowed payload weight of a vehicle.

2. In a freight rate or freight tariff sense a volume-minimum shipment is frequently called a "truckload" shipment and means a definite minimum weight of a commodity which is specified in the Motor Freight Classification and carrier's tariff schedules, to be handled as a single shipment. A volume-minimum weight of a commodity entitles the shipment to the truckload freight rate which is less than the LTL freight rate.
3. According to a definition prescribed by the Interstate Commerce Commission for use in part of the statistics of the annual reports of ICC certificated motor carriers, the term "truckload" means any shipment which moves on a single bill of lading and weighs 10,000 lb or more, billed weight.

Volume-minimum shipment — A specific weight of a commodity that is specified in the National Motor Freight Classification (27). A volume-minimum shipment is one which entitles the shipment to the volume shipment rate. A shipment may be larger than the listed volume-minimum weight, but such additional weight does not result in a freight rate lower than that specified for the volume-minimum weight.

Empty weight or tare weight — The weight of a vehicle or trailer combination without cargo, but ready for operation on the highway. Empty or tare weight should include full tanks of engine fuel, spare tires, tire chains, tools and cargo stowage equipment regularly carried on vehicle.

Payload or cargo weight — The weight of the freight being transported in a vehicle or trailer combination, including the weight of the packaging material, pallets, skids, removable racks, and other such cargo equipment which is not included in the empty weight of the vehicle or combination.

Loaded gross weight — The predominant loaded operating weight of a vehicle or trailer combination. The loaded gross weight includes the empty (tare) weight of the vehicle(s), plus the payload (cargo) weight when the cargo body is fully loaded; that is, fully loaded in regard to the stowage capacity of the cargo body for light-density commodities, or to the maximum permitted gross vehicle weight when loaded with heavier commodities.

Trip — The one-way travel from a starting point to a terminal point on a route, usually within one driving shift.

Round trip — Either:

1. A one-way trip on a loop which returns the driver and vehicle to the starting point within one driving shift; or
2. An outbound trip specific point followed by return trip to the starting point, with the outbound trip and the inbound trip over the same route, and within one driving shift.

Run — An assigned unit of vehicle operation that is to be performed in accordance with a prescribed schedule of operation over a route. A run may cover the operation of a vehicle for several consecutive trips requiring more than one driver in a long-haul run, or may cover one or more specific trips or round trips that are to be handled by one driver.

Revenue equipment — Trucks, tractors, and trailers that are used to transport freight.

Revenue service — The use of revenue equipment for the transportation of freight.

Service equipment or service vehicles — Equipment or vehicles which are auxiliary to revenue equipment. Service equipment does not carry freight.

Shop or garage — A building or a part of a building which is arranged and used for the repair and maintenance of motor vehicles owned and operated by the carrier, and in which a carrier's employees work. Supplies and repair parts frequently are stored in the same building. Large carriers may have shops at more than one location on their routes.

Service station or servicing area — An area on a carrier's property where the vehicles are serviced; that is, where fuel, engine oil and water are replenished, and where tire inflation, lights, etc., are checked before vehicles start their regular runs.

Dock — A loading platform from which cargo bodies may be loaded with freight and on which freight may be held temporarily before being stowed in or on the cargo body of a vehicle. A dock usually is part of a terminal building or a warehouse.

Terminal — A building and land for handling freight, and usually includes a dock, parking area for cargo vehicles, and offices.

Loading area — An area of ground which is used for loading cargo onto vehicles. The term is usually used in regard to a ground area where there is no dock, but where the cargo may be loaded from stockpiles onto vehicles by means of power lift mechanisms or other devices.

Rural highway — Highways between and outside of cities and towns and their contiguous suburbs, and/or between locations in rural areas. In this study, the term also includes those sections of highways between cities and towns and their contiguous suburbs, along which small business and residential centers have been developed. In this study the rural highways usually had hard, all-weather surfaces.

Expressway — A highway on which, among other features, the access is controlled; that is, the entrances and exits are restricted to specific interchange locations and ramps, and crossings at grade level are not permitted. Expressways may be in either rural or urban areas. Expressways are variously called controlled-access roads, thruways, or turnpikes. Most toll roads are expressways. The new National System of Interstate and Defense Highways is of expressway design.

Bridge formula permissible load — The maximum gross weight allowance of a single vehicle, a trailer combination, or any interior group of axles, when computed by a formula on the order of the following example, which is a simple type of bridge formula:

$$W = C\,(L + 40)$$

in which

W = permitted weight in lb;
C = a constant, minimum recommended value of 700;
L = axle spacing in ft; and
40 = an arbitrary constant value.

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