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Highway-User Taxation

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Highway-User Taxation

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Objectives and Concepts of Highway-User Taxation

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● ALONG with the growth of motor-vehicle transportation in this country, a highly specialized but not fully articulated theory of highway finance has been developing over the last three decades. Many of the concepts that have evolved in this effort to deal scientifically with problems of highway financing have found their way into public policy but others, corollary in nature, have not. As a matter of fact, there is no full agreement, even among highway specialists, on certain fundamental objectives and concepts of highway-user taxation. And where there is agreement on principle, there often is no economic or engineering calculus to translate it into practical application.

What is more disconcerting than the fact that all aspects of user-tax theory have not been publicly adopted is the fact that the basic premises of user taxation are questioned and even rejected by many. It may seem somewhat futile for highway specialists to worry themselves over theoretical refinements and mathematical formulas under these circumstances. For it is not alone among the uninformed that the logic of user taxation is neglected. The requisites which highway specialists seek to ascribe to user taxation are denied in highly respectable quarters, especially among students of public finance.

For example, it may seem self-evident to the highway specialist that costs should be apportioned among the several beneficiaries of highways and that special taxes on highway users should be used exclusively on highways that benefit them most, but public finance students are more than a little reluctant to embrace even such simple propositions without reservation. Many will agree with Groves, "The highway dollar has (or should have) to compete with dollars needed for other governmental purposes" (1), or with thoughts of similar nature which are often regarded as heresy in highway circles.

Perhaps we can discover why this is so. For it is the purpose here, in dealing with objectives and concepts of highway-user taxation, to reexamine and perhaps restate some of the fundamental premises of the current theory of highway finance. It is also intended to consider the relationship between highway finance and public finance in general. For while highway specialists are critical of those whom they think fail to grasp the basic principles of user taxation, they are themselves vulnerable in dismissing general taxation as no concern of theirs.

Actually, a firm foundation for user taxation can be established in economic and political theory which is consonant with current thought on general taxation.

NATURE OF USER TAXES

Before we go further into theory, it may be useful to distinguish between a user tax and a general tax. A user tax has been defined economically as one paid incident to the ownership and operation of a motor vehicle which has no significant counterpart among taxes that apply to other transportation agencies or to the general public. Stated another way, user taxes have been defined as those which motor-vehicle operators are required to pay for highways, over and above their obligations for support of the general government.

Now, these statements permit us to identify major user taxes, but in some cases the distinction between a general tax and a user tax is not easy to make. Outstanding examples are found in the federal excises on motor fuels and motor-vehicle products, about which there is debate over their proper classification.

We need not here become exercised over the finer distinctions between user and general taxes, for our main interest lies in establishing the more basic fundamentals. We can generally agree, I think, that the family of state taxes consisting of gasoline and diesel excises, annual license taxes on motor vehicles, and the diverse group of special imposts on motor carriers, which are reported annually by the Bureau of Public Roads, are, for the most part, highway-user taxes, both in an economic sense and in legal contemplation. In 1952 these particular taxes produced about $3 billion, nearly all of which were used by state or local governments for highway purposes. In addition about $2 billion was made available for highways through federal aid and local taxes.

BACKGROUND OF USER TAXATION

History reveals that no carefully worked out theory anteceded the adoption of user taxation as we know it today. The theoretical foundation, such as it is, was built after the framework was erected.

It is often thought that user taxation was developed primarily in response to the demands for better roads associated with development of the motor vehicle. However, a good-road movement of considerable impetus was making forward strides for some time before the motor vehicle was anything more than a novelty. Moreover, a number of states, of which California was one, had adopted state highway systems and provided funds for their "completion" a number of years before any thought was given to the significance of motor vehicles or to their taxation. But certainly, the added burden of accommodating a growing volume of motor-vehicle traffic stimulated the demand for good roads and greatly increased expenditure requirements. And it was soon discovered that the vehicle and the fuel used to propel it provided convenient and apparently equitable objects of taxation in the face of growing needs for highway funds.

Regarding the early history of highway-user taxes, it may be observed that forces not directly related to the transportation problem were at work, which played an important role then and continue to play a part in the development of motor-vehicle taxation. Then, as now, there was considerable dissatisfaction with the general tax structure, particularly with the property tax, from which was derived the major support of highways. This tax was said to have two faults: it was wrong in theory and it didn't work in practice. A third might be added: it was thought to be too high. The situation was of such nature that a leading authority commented, "Practically, the general property tax as actually administered is beyond all doubt one of the worst taxes known in the civilized world"(2).

Under the circumstances it is not surprising that the states were searching for alternative revenue sources in order to relieve the burden on property. What could be more logical than to shift part of the tax burden to the motor-vehicle user in the form of imposts which could produce substantial revenues with convenience and certainty, especially since a ready-made rationalization in terms of highway benefit was at hand. What is somewhat ironical against this background is that even today current user-tax theory, as popularly interpreted, generally calls for substantial contributions from property in support of the highway function.

A somewhat-different view of development of user taxation is suggested by Peterson. He believes the development of motor traffic removed highways from their local role because "the close connection between community benefit and local advantage dissolved"(3). The result, he suggests, was acceptance of "the idea that highway service, unlike other basic government activities, might be developed by ordinary investment standards and financed by specific beneficiaries, rather than the general public." He points out an interesting analogy to the turnpike era of the 18th and early 19th centuries when somewhat similar standards of financing prevailed until, as he notes, "railroad development pushed the highway back into its former local role"(4).

Following Peterson's thesis, historians may conclude the mid-20th century toll-road movement we are now witnessing is a response to similar forces. Phenomenal growth of traffic, new and costly conceptions of highway design, failure to adjust user taxation to investment requirements, and possible misuse of user-tax funds from the motorists' standpoint may, in concert, have given rise to the modern version of an old method of getting capital for highways and the means of repaying it.

Transportation requirements, of course, stimulated the adoption of user taxation, but it is unlikely that more than a few people foresaw such emerging problems as competition among transportation agencies when user taxes were born. On the other hand, the tax situation provided a favorable atmosphere for the development of user taxation and appears to be the motivating force of the continuing trend towards greater reliance on user taxation for support of the highway function.

It may be immaterial whether the primary force for adoption of user taxes resulted from a new conception of the highway function in relation to overall transportation policy on the one hand, or on the other from the desire to better the tax system by introducing alternatives thought to be superior to existing tax bases. The significant fact, as has been suggested, is that even now transportation specialists and tax students view user taxes with different perspective, and not infrequently find their basic conceptions in apparent conflict. Surely, reconciliation of basic views on general public finance and on highway finance is a prerequisite of enlightened public policy.

In any event, we must agree with Peterson that, "There was not, and has not been, any general and explicit adoption of the view of highways which would exclude them from that category of public functions in which we put the defense of the realm and the preservation of order." And yet, the whole theoretical foundation of user taxation is grounded upon a conception of the highway function as fundamentally different from other functions of government. And the fact is that state governments are raising more than $3 billion a year in taxes ostensibly based upon principles which differ from those underlying the general tax structure. What, then, do they seek to achieve through user taxation?

OBJECTIVES OF USER TAXATION

On first impression the sole purpose of user taxation seems to be to raise money with convenience and certainty in order to finance highway programs. Stated in terms that have more meaning and broader implications, the purpose of user taxation is to recover for government some part or all of the costs of supplying highway service through direct charges on those using the service. But these statements do not suggest why user charges instead of some alternative should be used. Some answer must be found in the purported objectives of user taxation.

One of the first questions that may be asked is why the highway function should be treated differently than most other functions of government. One economist joined the issue bluntly in these words: "It seems incredible the extent to which highway people have buffaloed the general public and the legislature into believing that highways are a distinct problem in government finance and taxation" (5).

Tax Equity

As a partial answer it may be suggested that (1) highway services are not distributed uniformly throughout society and (2) society does not deem it desirable to underwrite the uneven distribution of services through normal tax channels. The kind of sociopolitical judgment which has decreed community support of education, for example, without consideration of differential individual or group benefits is not now accepted for the highway function. In the absence of such a judgment, since highways still must be provided by government, a question arises as to the most-equitable system of raising revenue for highways. Is the imposition of direct charges for highway service more equitable than alternative methods of financing? As Owen says "The question raised is whether . . . it is desirable to include transportation facilities in the same category with general governmental services, such as education and defense, or whether transportation should rather be looked upon as similar to the supplying of food and clothing, of which it is a part, and therefore financed by the user" (6). If the latter decision is made, it appears that a convincing basis for user taxation is established solely on grounds of public policy in terms of the equity of fiscal alternatives.

Tax Neutrality

But there is another and, perhaps, more-compelling ground for distinguishing the highway function from other governmental functions. Government is furnishing one element of a full-scale transportation service competitive in major respects with other transportation media which are privately managed and financed. Ordinary economic prudence dictates that each transportation agency bear full economic costs if traffic is to be allocated among them in relation to the economy and fitness of each. The assessment of user charges against highway carriers is a direct means of charging against them, and hence against their customers, the costs of supplying highway service. Thus, user charges may be designed to remove all or the major subsidy elements involved in government provision of highways, thereby promoting the economic allocation of resources. This might be called the transportation argument or neutrality standard of user taxation.

Investment Criteria

Although equity among taxpayers and neutrality among transportation agencies are the more obvious objectives of user taxation, its rational use may serve other purposes. Government is faced constantly with difficult expenditure questions, both with respect (1) to the level of all governmental services and (2) to the allocation of funds among its various services. In most areas, the decisions must be socio-political rather than economic in nature, for there is no direct connection between those called upon to pay the bill and those enjoying the services. Highway-user taxation tends to establish a direct connection between the costs of supply and effective demand. This connection serves to provide criteria for establishing appropriate highway expenditure levels in two ways.

First, it is possible to estimate, at least in a general way, the value of a given highway program to those who will pay for it. Thus, we can calculate tangible economic savings to highway users in terms of reductions in vehicle-operating costs, in accidents, and in time which might accrue to users from a highway program. The computed relationship between user-tax requirements and highway benefits in terms of savings or other values indicates whether a program is economically justified. Owen has summed it up this way:

"Since economy in transportation relates to the sum of both highway and vehicle-operating costs, we can afford to increase our highway program as long as additional expenditure for this purpose reduces the outlays required for gasoline, tires, accident insurance, and other vehicle-operating items. Further additions to the highway program would be warranted to the extent that improvement in service, not readily measured in monetary terms, were judged to be worth the expenditure" (7).

Although this calculus can be made irrespective of user taxation, direct charging for highway services makes the relationship more obvious.

The second way in which user taxation aids in reaching expenditure decisions is related to the first but stems from the reaction of the users themselves, rather than from economic calculations. The latter, when dealing with a comprehensive program rather than with individual projects is still in a formative stage.

But as Dearing and Owen have observed: "Willingness to pay for improvements provides a rough indication of the desirability of undertaking them" (9). Taxation that bears directly upon those who demand services furnishes a test of their willingness to pay. It might be added that the imposition of direct user charges provides a built-in restraint to highway demands that would be absent if only general taxation were used for highway support. Highway-user groups by following their self interest will play an active part in highway management and improvement programs and thereby aid in the development of enlightened public policy.

The third objective of user taxation, then, is to provide some basis for correlating the effective demand for highway service with the economic costs of supplying the service. And by this means, user taxation tends to promote the economic allocation of resources as between highways and alternative uses.

Budgeting Criteria

As a related proposition, but one which is more political than economic in nature, it may be observed that user taxation facilitates the sound budgeting of highway funds, first, by providing a continuing source of revenue upon which the general treasury has no outright claim and, second, by providing a logical basis for the allocation of funds among alternative highway projects.

Any comprehensive program of highway development involves long-range planning and stage development which are greatly facilitated, to say the least, by having available dedicated revenues rather than having to depend upon the possible capriciousness of annual or biennial legislative budgeting. Moreover, the budgeting decisions of the highway agency may be guided by the principle that expenditures of funds collected in compensation for highway service should be made to provide maximum service and economy for those who pay the bill, rather than by broader but less-definitive principles of public expenditure.

Summary

Owen (10) has summed up the major objectives of user financing in few words as follows: "First is the objective of obtaining the necessary funds and of doing so on a sound basis. Second, since the productive resources absorbed are extensive, the method of finance should encourage their careful and economical employment. Again, since public facilities will assist private transport undertakings, but assist them unequally, it is desirable to finance in such a way as to offset any unfair competitive advantages which might lead to an uneconomic division of traffic among agencies. . . ."

The several objectives of user taxation appear to be salutary. No one would doubt that user taxation is a highly desirable tool for the economy to the extent that it encourages optimum allocation of economic resources as it purports to do (1) among transportation agencies when the neutrality standard is honored and (2) among all economic activities to the extent that economic investment standards are made applicable. And if user taxation also appears to promote tax equity when considered in the light of alternatives, the case could seem to be incontrovertible. What, then, are the obstacles to full public adoption of user-tax theory and its ramifications?

LIMITED PUBLIC ACCEPTANCE OF CONCEPTS

Peterson suggests "the main economic issues concerning highways seem to have their root in a vacillating allegiance to the procedures of typically governmental activities on the one hand and, on the other, to the principles and standards which operate in the private economy (11). In describing the latter, he points out that two features dominate: "(1) Goods are supplied, activities are expanded and contracted, on the basis of market demand and production cost. The demand sums up the interest of individuals in various products, the cost reflects the value of all resources, human and material, used in providing them. On this basis private decisions are reached regarding investment and production. There is thus no overall collective judgment of what the public requires, of what a socially desirable assignment of productive resources would be. (2) Goods are paid for by the individuals who get them and have the use of them. This payment is based presumably on their cost—that is, on the value of the productive resources that go into them" (12).

Now the objectives of user taxation, over and above that of equity in terms of alternatives, seek to apply to the highway function insofar as possible these standards which control in the private economy.

But as Peterson has observed: "Effective changes in policy do not come through formulating new theories and imposing them. Insofar as highways have been subjected in recent decades to the principles which operate mainly in the private economy (as distinguished from those applying to typically governmental activities), the change has come through the pressure of new problems. . . . Changes so induced go no further than the impelling circumstances require; so that there has been no clear break with the older way of viewing roads or of providing them (13).

And if there are impelling circumstances in the area of transportation economics that decree unusual treatment of the highway function, there are also impelling circumstances in the area of general public finance which retard, if they do not forestall, the full acceptance of a commercial concept of highway financing which would be essential to the simultaneous fulfillment of the several objectives of user taxation we have suggested.

However, it is not fair to charge apparent neglect of a user-tax discipline solely to extraneous circumstances. Sweep away the public lethargy, the barriers of law and tradition, the combat of self-interests, the compromise of the political forum, and there remain basic issues which have not been resolved. The techniques of user charging are themselves exceedingly crude. We have not yet formulated a model system which would be workable as a practical matter and would still bear a close resemblance to the ideal suggested by the objectives.

PRACTICAL APPLICATION OF USER-TAX CONCEPTS

Consider the ideal user charge system. Sufficient funds would be raised to supply the highway services required to meet the effective demand of users. Charges would be so assessed against users that an appropriate share of the economic costs of supplying the service would be recovered from each. On the one hand, users would not be expected to pay for services that would be enjoyed by future users. On the other, individual users would not be expected to pay for facilities they did not use. It is not being facetious to say that an ideal system of user charging based upon a commercial concept would require (1) the use of credit financing and (2) the establishment of toll gates on every road.

But the state is faced with inalterable facts. No one would accept ubiquitous toll gates. Law or tradition may preclude credit financing. User charges as we know them are uniform throughout the taxing jurisdiction. Highway costs in terms of costs per mile, and more significantly in terms of costs per service unit, such as the vehicle-mile, vary tremendously on different segments of the plant. The state is operating a dynamic highway plant. Let us consider concessions to reality which have to be made to accommodate these facts.

The Neutrality Standard

Neutrality is honored when users meet economic costs. Such costs include amortization of the existing highway plant, operation and maintenance expenses, real or imputed interest, and property-tax equivalents. But they include no funds for plant expansion.

Prudent management dictates that the state anticipate future traffic demands and design highway facilities accordingly. When investment requirements exceed funds made available by assessing costs, in theory credit financing would be necessitated. When they are less, presumably an excess of user-tax funds would be collected which might be allocated to the general treasury.

Now, no state embraces the full logic of this approach, despite popular preoccupation with the subsidy issue which underlies much of the discussion of user taxation. In a time of needed highway expansion, constitutional or institutional obstacles frequently stand in the way of credit financing. If the time should come when highway costs exceed the legitimate demand for highway expenditures, the assessment of interest charges and tax equivalents may, it is feared in some quarters, lead to uneconomical investment in highways, because constitutional or traditional barriers will preclude the allotment of the excess funds or "profits" to other government functions.

Though formal public-aid studies, such as the Federal Coordinators' report and the Board of Investigation study, deal with highway costs, finance studies made in many states in postwar years deal with expenditures.

Practical considerations are largely responsible for this approach. One is the obvious difficulty of estimating annual highway costs with any reasonable precision. Moreover, highway problems are dynamic. There appears to be a continuing need for highway improvement, and no end is in sight. Few engineers now have the temerity to predict "completion" of the highway plant, though there is still talk of catching up with the "back-log." When we add to all of the imponderables of financing on a cost basis the radical departure from established policy involved, it is not surprising that the expenditure basis is used.

It does not seem unreasonable under the circumstances to include with charges to users amounts for expansion of the plant. An analogy is found in the accumulation of capital out of earnings by private industry. Moreover, as long as savings to users resulting from highway improvement exceed the charges, the investment is clearly advantageous from their viewpoint, even though they pay more than costs.

Even so, to charge current users either more or less than annual costs involves a departure from a neutrality standard of user taxation. Over time the seriousness of the departure is mitigated because costs and expenditures tend to balance, but it is never completely rectified, for there is no reasonable identity of users over time in such a highly volatile field as motor transportation.

In an event, in a period of great highway expansion, such as we are now witnessing, it would appear that users will be called upon to bear more than highway costs as long as states continue to rely heavily on pay-as-you-go financing. Under these conditions consideration of imputed interest or property-tax equivalents is academic.

Investment Criteria

Current practices of user taxation also limit its usefulness as an investment guide. Again we are confronted with the costs-versus-expenditures issue. Investment in a highway facility may be justified if estimated annual savings to users exceed estimated annual costs. But the particular facility cannot possibly be financed on a pay-as-you-go basis with its own user-charge earnings. What pay-as-you-go financing requires, then, is that earnings on other segments of the highway plant yield sufficient surplus to permit improvement of the facility in question. After it is in operation it may yield a surplus to permit expansion of other facilities.

The unfortunate fact from the standpoint of theory is that the costs of different highway facilities vary tremendously, even when reduced to some unit of use such as the vehicle-mile. On the other hand, user taxes for administrative reasons are imposed upon a uniform basis throughout the taxing jurisdiction. The result is that many roads and streets would not earn enough in user revenues to defray their costs, even if the level of charges were high enough to meet costs of the entire plant. This fact has been given considerable attention with respect to roads and streets carrying little traffic and has been advanced as one argument in support of supplemental financing of highways from nonuser revenue sources. However, it is becoming increasingly clear that high-traffic-volume roads of expensive design and right-of-way requirements may also fail to meet costs out of user earnings and must depend upon surplus earnings of the plant if they are to be financed by traditional methods.

In this connection we might consider again the current toll-road movement. Not only does modern toll financing through the use of revenue bonds permit a closer correlation of charges to costs, but it permits a differentiation of the charges for the high-cost facilities which is not possible under a uniform user-tax structure. It seems quite clear that when current toll charges, upwards of a cent a vehicle mile, are necessary to sustain a toll road, the facility could never be financed on a "free" basis without a substantial "subsidy" from roads that have excess earnings, even if credit financing were used. When toll financing is used, of course, the facility which might have been a drain on the rest of the systems yields a "profit" if user taxes continue to be collected without allocation to the toll facility.

A great deal of thinking about investment criteria has not been adapted to the realities of the user-tax structure. In general, highway specialists deal with estimated cost-savings and cost-earnings relationships for an individual highway project but have found no way to relate the values produced by the entire plant to the costs (or tax requirements) of the entire plant. For the present, at least, user-tax analysis provides no more than a rough guide to the economic justification of any proposed future highway program. Its principal merit, as we have suggested, is that it incites the active interest and participation of users themselves in the highway function.

Apportionment of the Highway Burden

Exponents of user-tax principles are ordinarily unwilling to accept the view that the highway systems should be considered as an integrated plant for purposes of financing solely with user taxation. Part of the reluctance to embrace fully a commercial concept of highway management stems from the observation made regarding the variability of costs and the uniformity of taxes. "It is for this reason," Owen says, "that property owners, for example, have been charged a sum over and above their user-tax contributions to defray the higher-than-average unit costs of the local facilities in which they have an exclusive or special interest" (14).

But many highway specialists expound reasons other than problems of collecting and spending user taxes in making a case for nonuser-tax support of highways. They would not grant, as Owen does, "that the benefits derived from highway development are not to any significant degree something apart from the user of highways by motor vehicles. . . ." (15). They continue to cling tenaciously to a benefit doctrine of taxation, often carrying it to extreme lengths. For example, in a recent publication it is said: "Roads and streets serve all the people, directly and indirectly. The costs of these facilities should be fairly allocated to the various beneficiaries" (16).

In expanding upon the benefit thesis, it is observed (17): "Our 3,300,000 miles of roads and streets serve all the people generally whether or not they own motor vehicles. Highway facilities are needed for national defense; fire and police protection; sanitation and health; delivery of the mails; school buses and transit lines; conduits for gas and electricity; telephone lines; and pedestrians. Roads and streets add appreciably to the value of property, both in urban and rural areas.

Perhaps the more-critical students of highway affairs would not go as far in benefit apportionment as the above statement implies; but if the benefit principle is admitted at all it is difficult to fix any limits or for that matter any basis of measurement. Moreover, it appears that the case for a division of highway costs between users and others is grounded on some preconceived notion of tax equity. But since highway specialists rarely consider the equity of tax alternatives, their arguments are often discredited by those who must deal with the tax universe.

No one would seriously contest the wide-spread beneficial effects of highway improvement or deny that highways create social economic values which may be distributed unevenly throughout society. But these facts do not in themselves justify general tax support of the highway function.

In the first place, any precise tracing of the benefits to ultimate beneficiaries is virtually impossible, a fact which has long been recognized in other areas of government finance. Even the highway benefits ordinarily associated with motor-vehicle use are, it would appear, shifted to other members of society. Strangely, the economic implications of shifting are recognized with respect to highway taxes but are virtually ignored with respect to benefits. For example, lower transportation costs resulting from highway improvement eventually benefit consumers. In another paper, I have suggested that the enhancement or stabilization of property values which we attribute to highway improvement is largely a result of shifting of benefits enjoyed by users to owners of property (18).

But the real weakness of the benefit argument stems from the fact that all public and private expenditures affect the economy. Indirect benefits of material value will flow through the economy to others than those who directly consume the products or services for which the expenditures are made. A feature of the private economy is that the consumers are expected to defray the full costs of the product or service irrespective of indirect benefits to others and independent of the creation of general social and economic values.

What is more essential to the population than water? Would any property have value without access to water? Does this mean that water should be supplied with general tax support? Railroads and steel mills are essential to the national defense but this fact is not ordinarily used to justify general tax support of the facilities. The same is true of the telephone system and its value to police and fire protection.

When public policy decrees that principles applicable in the private sector of the economy should generally control, a case for subsidization with general tax support is found only when products or services deemed desirable by society either now or in the future will not be forthcoming without such assistance. Thus, subsidization of the railroads, highways, or airways may be deemed advisable until the industries reach maturity. Or again if the national defense requires facilities such as highways which would not otherwise be available if financed solely by users, general tax support would be warranted.

To grant that there may be reasons to supply highway facilities over and beyond the facilities which would be supplied to meet the effective demand of users is quite a different thing from justifying general tax support of highways on the basis of benefit apportionment. For the latter would mean that, if a highway would serve military or school requirements as well as user requirements with no additional outlay, some portion of the cost should be borne by the general taxpayer, a principle which would be summarily rejected if proposed for other sectors of the economy.

Basic criteria of user taxation become illusory if benefit apportionment is undertaken. With respect to neutrality, if some portion of all highway costs is borne by general taxpayers because of defense benefits, then some portion of railroad costs should also be borne by the general taxpayer. With respect to investment, if some portion of the highway cost is warranted on the ground of inestimable general benefits, then we are left without any guide to the economic justification of a specific program.

Conclusion

The fact that user taxation cannot be precisely molded to a theoretical ideal does not vitiate its usefulness as a fiscal and economic tool. Certainly user taxation is the way to greater neutrality and more-rational investment decisions, even if expenditures instead of costs must govern changes. If perfect tax equity is not done does any alternative yield superior results?

Perhaps the greatest weakness of user taxation is that it cannot be adapted to the variability of highway costs in terms of service units. In my view, greater progress will be made in mitigating this weakness if highway specialists will forget old bromides about highway benefits and abandon a futile quest for their measurement. In the final analysis, apportionment of the highway burden must rest upon informed judgment. This judgment can be favorably influenced by stressing cost-earnings relationships.

The essential public decision to be made is the point at which the disparity between costs and earnings on particular facilities is so great that it is unreasonable to draw earnings from the rest of the highway system to make up the entire difference. If such facilities are still demanded to serve particular interests or what is deemed to be the general welfare, a legitimate claim to general tax revenues or a case for special assessment or toll financing might then be established.

It may be concluded that the accomplished fact of highway-user taxation not only has productivity, convenience, and certainty on its side, but also has a solid foundation in economic theory, particularly to the extent that it promotes neutrality and encourages optimum resource allocation. But we have yet to consider the relationship of user taxation to the general tax system. For without denying anything we have said about user-tax theory, the general tax student may remain skeptical of efforts to impose a portion of the highway cost upon the general treasury. He may not be at all convinced that spreading any portion of highway costs by general taxation will be more equitable than spreading the entire amount by taxes on users. In fact, he may go further and suggest that part of the costs of general government might be spread by user taxes or, more accurately, taxes similar in nature to user taxes as equitably as by the general taxes now in effect. To understand this attitude it is necessary to give some consideration to the general tax problem.

GENERAL TAXATION

First, it is important to know that few if any theorists now embrace any single criterion of tax equity. The "overworked shibboleths" of benefit and ability-to-pay as tests of equity in taxation were being discarded by many authorities, even under the comparatively light burdens of the prewar years. With today's huge budget requirements, complicated intergovernmental fiscal relationships, and growing appreciation of the inevitable fact that tax policy is an instrument of economic control which should be intelligently used, probably only the unsophisticated would advocate any single standard of taxation. However, because of the popular notion that user taxation is based on a benefit theory, while ability-to-pay is the accepted standard for general taxation, it may be useful to explore each concept a little further.

The Benefit Principle

The idea of benefit taxation is an apparent anomaly when governmental activities are viewed in a limited way, for it directly conflicts with the essence of the tax obligation. All government expenditures are presumed to serve the public benefit. But government services are usually nondiscrete. The benefits may be incapable of measurement or of rational assignment to individuals or to identifiable groups. Benefits may be shifted and diffused throughout society. Moreover, government functions are often undertaken to achieve a wide distribution of services that, it is believed, will advance the public good. Thus, government provides public education, external and internal security, protection of health and morals, unemployment and other kinds of relief, all of which run directly counter to a benefit theory of taxation.

On the other hand, the cavalier dismissal of benefit taxation by many theorists seems to have been somewhat ill-advised, or at least premature, in view of the broad complex of government operations today. Government undertakes many activities where the objective is not broad and impartial distribution of services but is to provide service which cannot be provided privately or cannot be provided as effectively privately. In such circumstances, it may be appropriate to assess the cost directly against those who enjoy the services. It is not quite realistic to dismiss charges so assessed as fees, public prices, or insurance premiums and thus, by careful use of semantics, maintain the thesis that taxation according to benefit is contrary to public policy.

Many will agree with Groves that the benefit principle "is not nearly as antiquated and obsolete as many recent critics would have us believe" (19). With respect to certain activities of government, it is possible to associate benefits in a rough way with individuals or identifiable groups of individuals. Still, in most areas of government service, benefits cannot be measured or apportioned in any scientific manner, and most students have given up the attempt. Certainly the benefit principle standing alone does not furnish an adequate standard of tax equity.

The Ability-to-Pay Principle

The second principle of burden distribution advanced most often is ability to pay. As a single standard, it too has theoretical weaknesses. As a general rule it conflicts directly with the benefit principle. Economists generally hold the view that ability to pay must be regarded as a personal concept. Over the years ability to pay has been enlisted to support taxation that is progressive in terms of net income. Economists have endeavored to support it with one or another of several sacrifice theories derived from an assumption of diminishing marginal utility of income, but without conclusive results. It appears that the ability-to-pay theory is based upon an over-simplified view of the modern economy and the impact thereon of public finance.

Thus, while ability to pay strikes a responsive chord of justice in the public mind and has come to be deeply imbedded in political and social conceptions of tax equity, economists do not find it satisfactory as a controlling principle of burden distribution.

The Socio-economic Principle

With the partial rejection of both the benefit and the ability-to-pay principles and an apparent conflict between them, tax students have sought a realistic substitute. Buehler (20) sums up the issue: "With the evolution of ideas of justice in the distribution of tax burdens, the costs and benefits of government services have been found inadequate as principles of tax distribution, and the popular principle of ability to pay has arisen. This theory has proved to be inconclusive, however, and it is being suggested increasingly that the justice of taxes depends on their effects upon the whole community."

Fagan (21) has suggested that the problem be approached this way: "A strong case can be made for defining equitable taxation as taxation which will increase to the maximum the objective criteria of welfare, i.e., the basic economic, political, and social conditions under which there would be the optimum opportunity for the fullest development of the intellectual, moral, and physical capacities of every member of the state."

Although such an approach to the tax problem is sometimes regarded as the abandonment of principle to expediency, it certainly opens the way for realistic consideration of the economic, political and social consequences of alternative tax policies. As Groves (22) observes: "The proponents of the social-expediency theory take the pragmatic view that those revenue sources and that revenue system are best which work best. In order to determine what sources such a theory would support, the specific taxes must be examined and their operation observed."

The implications of such an approach are manifest. The taxation of business as such, which finds no support in the ability-to-pay principle and very little in the benefit concepts, may be found to be not only necessary to raise revenue, but also desirable as compared to alternatives. In the evaluation of alternatives, weight is given to such obvious factors as administrative cost, certainty, and compliance problems. The approach gives opportunity to consider the tax system as a whole, intergovernmental fiscal relationships, the political and economic facts which require diversification of tax sources. Recognition is given to the advisability of reconciling ability-to-pay considerations with the sequential effects of progressive taxes on incentive, investment, savings, consumption, and the like. The nonfiscal effects of taxes are accorded proper treatment. The way is open to harmonize tax and expenditure policies.

HIGHWAY-USER TAXATION VERSUS GENERAL TAXATION

On first impression, there appears to be nothing at all inconsistent between this approach to the general tax problem and the theory of highway-user taxation. As a matter of fact, user taxation meets the general approval of tax authorities, because it bears a closer relationship to the benefit principle than can usually be established in other areas of public finance. It gives diversification to the tax system and produces revenue with certainty and convenience.

What, then, are the possible grounds for conflict between general tax policy and highway-user tax theory? The basic issue appears to be whether taxes imposed upon highway users as such may legitimately be used to meet nonhighway expenditures.

The Diversion Controversy

Highway groups vigorously oppose diversion of user-tax funds to nonhighway purposes as "the enemy of good roads." Along with this policy they also decry "dispersion," by which they mean the expenditure of highway-user taxes on roads which they do not believe to be the responsibility of highway users.

On the other hand, specialists on government expenditure policy ordinarily object to earmarking of public funds and vigorously oppose efforts to tie specific revenues to particular expenditures as contrary to public policy. Their case rests on the proposition that the state should be free to expend its resources to maximize returns. In making up the general governmental budget, the problem is resolved theoretically by comparison of the return from the marginal expenditure for Function A with the return from the marginal expenditure for Function B. The objective being to maximize returns, it is accomplished when marginal returns are equal. Stated another way, the maximum advantages of total public expenditures are obtained only when financial support is so distributed among different functions that the last dollar spent on each returns service of equal value.

Granting that such an approach to budgeting is sound with respect to general functions of government, is it sound with respect to the highway function? It could only be so if we rejected the concept of user taxation based upon the general objectives we have described. For the state has no legitimate claim to revenues derived from highway-users under this concept, except for highway purposes.

Possibly circumstances may arise in which optimum expenditures for highways should not be made even when justified from the users' viewpoint because of general fiscal considerations. Dearing (23) describes such a situation and provides a good answer in the following:

"This might occur when it is found necessary to utilize a relatively larger portion of the state's taxable resources for other governmental objectives. This does not mean that the amounts which could be exacted from motor-vehicle owners as a charge for the mobility values of a technically optimum general-purpose road system may be used appropriately to supply budgeting deficiencies incurred on account of the necessary expansion of such other governmental activities as education and public welfare. It merely means that through the reduction of special levies for highway purposes, the taxable capacity of motor-vehicle owners as general taxpayers will be relatively increased."

In my view, Dearing's argument effectively disposes of the general expenditure case against diversion, but the issue of general tax policy cannot be summarily dismissed.

Clear thinking on the issues posed by the apparent conflict of views between highway users and general tax students is needed. In the first place, there is no agreement as to what constitutes diversion. It is generally conceded that highway users should not be excused from general tax responsibilities by virtue of highway-user-tax payments. Thus, the use of general retail-sales taxes collected on automobiles for nonhighway purposes is not usually questioned. But what of concessions made to users in the general tax system presumably because of user tax imposts?

Nearly all of the states which have general retail-sales taxes exempt motor fuel from the tax base. Many of the states in which tangible personal property is taxed specifically exempt motor vehicles. In drawing up any economic balance sheet of user-tax contributions and highway expenditures, it may be contended with strong force that estimated-sales-tax and personal-property-tax components should be deducted to determine net-user-tax contributions. But highway users who decry diversion are not inclined to recognize such adjustments.

Even when a particular tax is fairly well defined in legal and economic contemplation, as is the case with the California "in lieu" tax, user groups sometimes claim it is a user tax and publicize its diversion. Certainly it must appear to general tax students that highway groups sometimes want to have their cake and eat it too. Diversion is a sin but exemption from general taxes is tacitly approved.

Other grounds for controversy arise. For example, many tax students will argue that there is no diversion unless user taxes exceed total expenditures on highways, roads, and streets. The narrower interpretation embraced by highway users is that there is diversion if the proceeds of recognized user taxes are used for nonhighway purposes, regardless of whether other tax funds are used on highways.

But this narrow view is not especially enlightening. One state may use all of its user-tax collections for highway purposes and have virtually no general tax support for highways, either at the state or local levels of government. Another may use user taxes for, say, school purposes and yet derive considerable support for roads from local taxes. The latter is said to be practicing diversion, and yet highway users may be paying a larger part of the highway burden in the state with no diversion.

The key to the controversy lies not in the use or misuse of particular tax dollars but in the relationship between total user taxes and total highway expenditures. User groups would, I imagine, support this view but defend an antidiversion policy on practical political grounds. They may be able to stop diversion, though they may not be able to control the amount of nonuser revenues used for highway purposes. They argue that diversion is a "breach of faith" with highway users and, at the same time, emphasize the critical inadequacy of the highway plant, particularly the facilities of major importance to users.

Special Imposts on Users For General Purposes

In my view, the basic economic issue does not involve the narrow question of diversion. The true ground for differences of opinion lies in the propriety of special highway users which are justified on grounds having no connection with the highway function.

For example, Buehler (24) contends: "The automobile is no-more sacred than other property, and taxes against it in excess of the benefits which it enjoys from the highways may be as just and reasonable as taxes on other objects for the general upkeep of government which are levied against taxpayers, without regard to the particular benefits they may enjoy from government services." Groves (25) states the argument more bluntly: "Probably there are better ways of raising general revenue than the gasoline tax, but there are also worse, for example, the retail-sales tax, which includes in its base, as a rule, most of the necessities of life."

Unfortunately, when views along these lines are taken, it is easy to overlook or ignore the fact that the taxes in question may have been imposed in the first instance, overtly or tacitly, as compensation for highway use, in which case there would be no justifiable basis for diversion of the proceeds to nonhighway uses (except possibly for imputed-interest and property-tax components if user charges were actually fixed on a cost basis).

On the other hand, if it is forthrightly argued that, regardless of the highway function and over and above recognized user tax obligations, special imposts on gasoline, on motor-vehicle products or in other ways bearing on highway users may be suitable as general revenues, a new set of issues arises. In this event, the case for or against such taxes must rest squarely on criteria appropriate to evaluation of general taxes without reference to highways. Such taxes cannot be ruled out of consideration, simply because users are already paying highway charges.

On the positive side, it may be argued that taxes of this sort are productive, convenient, and certain. They give diversity to the general tax structure. Considered in the light of available alternatives, they may be believed to be superior to general retail-sales taxes, as Groves suggests, if the ability-to-pay principle is accepted as a guiding criterion. Or again, they may be regarded as superior to heavier impositions on property, in the light of known abuses and weaknesses of property taxation in general.

In this connection, a fact rarely mentioned is that the general property tax itself is a crude instrument for distributing any part of the burden of highway support, even if it is agreed that property owners have some responsibility for highway support by virtue of benefits gained. If property taxation fails to distribute the burden of highway support in some reasonable relationship to benefits to property, it may be felt that it is at least no-less equitable to distribute the burden by special excises on highway users.

Again there are involved the problems of tax administration and inter-governmental fiscal relationships, in the light of which it may be felt that motor-vehicle imposts collected by the state and shared with local governments are one method of improving the financial structure.

Finally, there may be circumstances in which it may be deemed advisable to use taxes of this sort as rationing devices to cut down use of motor vehicles as during war or to reduce the "spill-over" costs of highway congestion when highway facilities are badely inadequate (26).

Against these considerations, negative considerations must be weighed. It should be repeated that highway service or highway benefit is not to be used as a crutch to support the taxes, hence, they must stand on their own merits.

First, regarding the taxes as impositions on consumption, it should be recognized that we are not dealing with luxury products. Nor does there appear to be any rational basis for sumptuary taxation. To the extent that ability to pay is a controlling principle, the taxes are regressive in nature, perhaps less regressive than sales taxes but surely far more regressive than certain alternatives, such as the personal-income tax.

Looked upon as selective excise taxes, the burden of proof of suitability lies with those who support them. Certain adverse presumptions must be overcome. In the first place, such taxes will tend to violate the neutrality standard as it applies to competing transportation agencies, for they single out highway carriers for special burdens and, hence, distort the economic allocation of traffic. Thus, while user taxation may be designed to promote neutrality, additional imposts may violate this basic objective by making the tax structure unneutral in the opposite direction. Then, too, as is common with all selective excises, they tend to distort the optimum allocation of economic resources which would be established by the ordinary forces of supply and demand for various goods and services.

As a matter of fact, it appears that little consideration has been given to the suitability of special imposts on motor-vehicle fuel or products, unconfused by thoughts regarding their desirability as means of defraying all or some part of the highway burden. This is especially evident now with so much confusion existing over future highway policy of the federal government. As Behling recently suggested, the issues deserve much "hard thinking." Either the present federal excises on motor fuels and products should stand or fall on their merits as general taxes, or the need for federal highway-user taxation should be ascertained and the suitability of the existing excises as user charges should be determined.

At any rate, the desirability of special imposts on motor-vehicle users for general purposes should be determined quite apart from all thinking on the highway function. With this issue thus isolated and, in effect, assigned to the general economist and tax student, the highway and transportation specialist is left free to develop a logical basis of user taxation to accomplish the basic objectives we have considered.

SUMMARY

User taxation is a convenient and workable method of financing a vital economic function which government must undertake. Fundamentally, the ground for user taxation is the public decision that highway finance should be governed by principles that apply in the private sector of the economy. User charges as prices bearing a relationship to the costs incurred by government in supplying highway services are believed to be an acceptable means of financing the service which public policy dictates should not be financed through the general tax structure. Within the limits of practicability, forces of supply and demand are permitted to operate. User charges encourage the economic allocation of resources as between highways and other public and private undertakings. They tend to promote the economic allocation of traffic among competing transportation agencies by eliminating major elements of subsidy. The fact that user charges do not serve all possible objectives perfectly is a matter of small consequence. Other measures may be needed to implement public transportation policy. But when we consider that user taxation was conceived of expediency, born of necessity, and nurtured of politics, it is surprising that the offspring is as healthy and works as well as it does to serve sound economic objectives.

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Estimate of User Taxes Paid by Vehicles in Different Type and Weight Groups

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In this article an estimate is made of the amounts of state highway-user taxes paid by vehicles of different types and general size groups. Of the total of $3,088 million of state motor-vehicle-tax payments made in 1952, fuel-tax payments accounted for $1,968 million or 64 percent; registration-fee payments, $910 million or 29 percent; motor-carrier-tax contributions, $64 million or 2 percent; and drivers licenses, miscellaneous fees, etc., $146 million or 5 percent.

Comparisons established in this study show that passenger cars represented 83 percent of all motor vehicles registered, accounted for 81 percent of the traffic on our highways, and contributed 65 percent of total state road-user-tax payments. If panel, pickup, and other light trucks are combined with passenger cars, the percentages become 93, 89, and 74, respectively. Medium and heavy trucks and combinations accounted for 6 percent of the registrations, 10 percent of the traffic, and contributed 24 percent of the road-user payments. Tractor-semi-trailer and truck-trailer combinations included in the preceding group accounted for 1 percent of the registrations, 3 percent of the travel, and 12 percent of user-tax payments. Buses accounted for less than 1 percent of the registrations and travel, and 2 percent of the user-tax payments.

On the basis of user-tax payments per mile of travel, passenger cars and light trucks paid 0.5 cent per mile, buses paid 1.6 cents, and medium and heavy trucks and combinations paid 1.5 cents. The rate for truck combinations alone is slightly more than 2 cents per mile of travel, tractor-semitrailer combinations paying 2.1 cents and truck-trailer combinations 2.7.

● LAST year, there was presented before the Highway Research Board a comparison of the taxes imposed in different states on a selected group of vehicles. The sole purpose of that study was to compare the tax rates of the states, and no effort was made to compute the total or average tax payments of any group.

An entirely different, though related, matter is the total highway-user-tax payments on the different major groups of vehicles. Information on this subject is of considerable importance to highway authorities, legislatures, and vehicle operators in determining the equitability of the total tax burden on various groups of vehicles and in weighing the tax burden on the group against the costs of providing the service and the benefits derived from the service.

It cannot be overemphasized that the work presented here constitutes a series of estimates, and it is fully recognized that some may disagree with these methods or findings. Furthermore, it is possible, even probable, that given better basic data, or more time for intensive study of individual phases of the estimates, it might be found necessary to modify or to revise them. But it is believed that the findings are sufficiently within the areas of reasonableness and general validity to be useful.

Although the principal value of this study lies in the findings, an outline of the data on which the study is based, together with a brief review of some of the problems encountered and the assumptions that were made, should be useful to those who may have occasion to evaluate or apply the findings.

In 1952 the states collected a net total of $1,967,831,000 in motor-fuel taxes and related fees. The total registration fees and associated revenues amounted to $1,069,439,000, but for practical purposes, the $12,859,000 of fines and penalties received have been eliminated, leaving a remainder of $1,056,580,000. This was done on the theory that fines and penalties are not actually road-user revenues, even though they are miscellaneous receipts of the highway departments in some states. State motor-carrier taxes collected during the year amounted to $64,036,000. The total of the state road-user taxes considered in this study is, therefore, $3,088,477,000.

Precise information is available on the amounts of state registration fees that were paid by automobiles, the amounts that were paid by trucks, and the amounts paid by busses. Various related fees, such as drivers' and chauffeurs' licenses, title fees, etc., can be allocated to various classes of vehicles without fear of substantial error. Motor-carrier taxes can also be allocated with some degree of confidence. Their payment is accounted for, primarily, by busses and heavier trucks.

At first glance it might seem that the allocation of gasoline-tax payments to the various groups of vehicles should be fairly easy; but this is not the case. To assign gasoline-tax payments to the various groups of vehicles requires the determination of the amounts of travel of each group of vehicles; and this is particularly important among the groups of trucks, since different rates of fuel consumption are assigned to each group. The formulation of an acceptable fuel-consumption curve is, in itself, no small task, and relatively minor changes in the rates of fuel consumption assigned would make substantial changes in the computed tax payments. The yield from fuel taxes accounts for approximately two thirds of all road-user-tax payments. According to the results of this study, motor-fuel taxes constitute 68.1 percent of the total state road-user taxes on automobiles, 63.7 percent of the taxes on busses, and 56.1 percent of the taxes on trucks.

Wherever reference is made in this study to state motor-fuel-tax receipts, motor-fuel usage, highway use of special fuels, and state motor-vehicle receipts, the data are taken from the Bureau of Public Roads' publication "Highway Statistics 1952". Such information is given therein in tables G-1, G-21, G-25, and MV-2, respectively.

DETERMINATION OF VEHICLE CLASSIFICATIONS

Gross-Weight Distribution

Although registrations and fee payments are segregated in state records by major types of vehicles, the further task of distributing numbers and fees among various

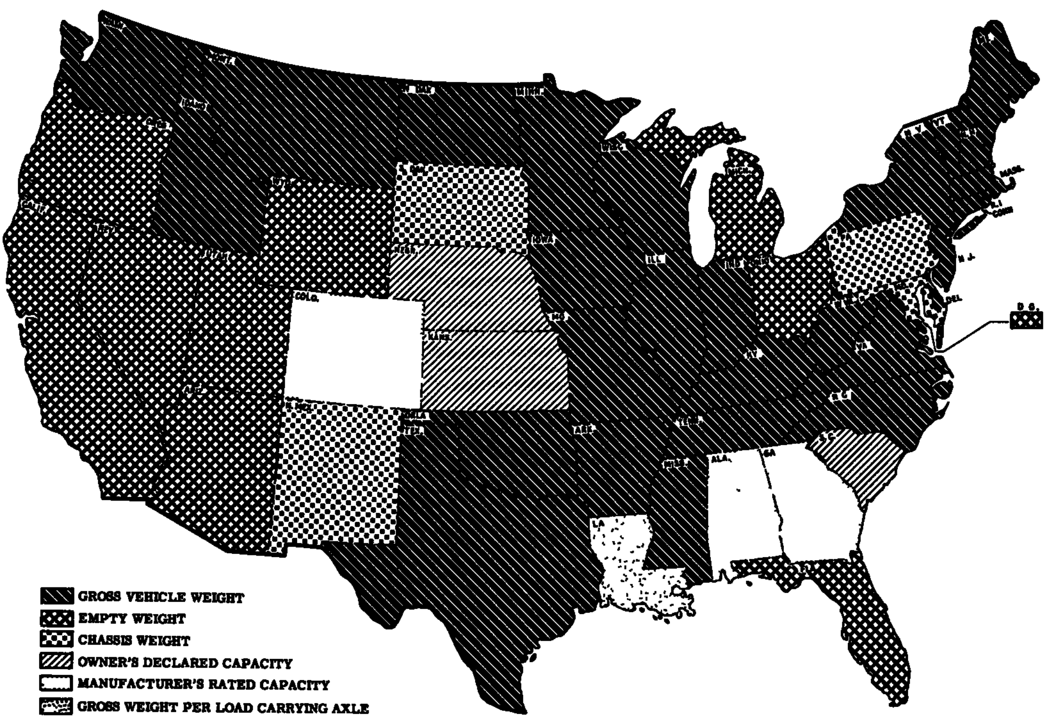

Figure 1. Basis of truck registration fees.

TABLE 1

ESTIMATED DISTRIBUTION OF TRUCKS AND COMBINATIONS BY VISUAL CLASSIFICATION AND REGISTERED GROSS WEIGHTS 1952

(In thousands of vehicles)

Registered Gross Weight	Single-unit Trucks: Two axles, Four tires: Panels and Pickups: Number of Vehicles	Percentage of Total Vehicles	Two axles, Four tires: Other: Number of Vehicles	Percentage of Total Vehicles	Two axles, Six tires: Number of Vehicles	Percentage of Total Vehicles	Three axles: Number of Vehicles	Percentage of Total Vehicles	Vehicle Combinations: Tractor-semitrailer: Number of Vehicles	Percentage of Total Vehicles	Truck-trailer: Number of Vehicles	Percentage of Total Vehicles	Total: Number of Vehicles	Percentage of Total Vehicles
8,000 lb and under	4,497	51 000	706	8 000	476	5 400	-	-	-	-	-	-	5,679	64.400
8,001 to 10,000 lb	132	1 500	88	1 000	424	4 800	-	-	-	-	-	-	644	7 300
10,001 to 12,000 lb.	-	-	88	1 000	441	5 000	-	-	-	-	-	-	529	6 000
12,001 to 16,000 lb.	-	-	-	-	656	7 440	17	0 200	29	0 330	2	0 030	704	8 000
16,001 to 20,000 lb.	-	-	-	-	385	4 360	26	0 300	29	0 330	1	0 010	441	5 000
20,001 to 24,000 lb.	-	-	-	-	142	1 615	18	0 200	73	0 825	5	0 060	238	2 700
24,001 to 30,000 lb.	-	-	-	-	60	0 685	26	0 300	37	0 415	9	0 100	132	1 500
30,001 to 40,000 lb.	-	-	-	-	62	0 700	65	0 735	82	0 925	4	0 040	213	2 400
Over 40,000 lb	-	-	-	-	-	-	23	0 265	192	2 175	23	0 260	238	2 700
Total	4,629	52 500	882	10 000	2,646	30 000	175	2 000	442	5 000	44	0 500	8,818	100 000

groups of trucks is a complex matter. The difference among the various state bases of registration had to be reconciled, and to do this, factors were developed for converting the available data that the states had supplied to a gross-weight basis. Thirty-one states had supplied, for 1952, data on weight or capacity groupings according to their own registration bases. In a few states this was the unrealistic manufacturers' rated capacity. In some, it was on variations of net or empty weight, but for the majority, it was gross vehicle weight. Some use a combination of factors. Although more than half of the states now register trucks and combinations on the basis of gross weight, it can be seen in Figure 1 that quite a few, including some of the larger ones, register on different bases. Conversion factors were estimated, and for each state for which data were available on some basis other than gross vehicle weight, the conversion factors were applied to obtain an approximation of the state's registration according to the groups in which they would have fallen if all states required registration on a basis of gross vehicle weight.

While there is no need at this point to outline those conversion factors in detail, here are some examples: Single-unit trucks of 4,500 lb. or less empty weight in states registering on empty weight were considered to be in the gross-vehicle-weight class of 1.8 times their empty weight. Single-unit trucks in the group 4,501 to 8,000 lb. empty weight were considered to belong with vehicles of exactly twice their weight when registered on a gross-weight basis, and vehicles with an empty weight of more than 8,000 lb. were converted to gross-weight values of 2.5 times their empty weight. In states where tractor trucks are registered on an empty weight basis they were considered to represent combinations of five times the empty weight of the tractor alone; and tractors registered on a gross-weight basis were converted to gross combination weights of 1.8 times the gross registered weight of the tractor alone.

All in all, there were 18 states for which data were available on a gross-vehicle-weight basis, and it was possible to convert the data from an additional 12 states registering on other bases. However, in order to obtain balance, and because of questionable factors in the original material, data for 15 states were selected as representative. These 15 states registered more than 44.2 percent of all trucks in the United States in 1952. The percentages thus obtained from this sample were applied to national totals of trucks registered. This distribution is shown in Table 1 and Figure 2.

In 1952, the year on which this study is based, there were 8,818,000 trucks registered, excluding publicly owned vehicles. Of these, after converting to a gross-vehicle-weight basis, as described above, there were 5,679,000 in the 8,000-lb.-and-under group, or 64.4 percent. An additional 26.3 percent, or 2,318,000 were in the groups from 8,001 to 20,000 lb. Only 370,000, or 4.2 percent, of the trucks were in the 20,001-to-30,000-lb. range; and another 212,000, or 2.4 percent, were between 30,001 and 40,000 lb. The trucks and combinations of over 40,000 lb. accounted for 2.7 percent of the total, or 238,000 vehicles and combinations. Thus, only 9.3 percent of all trucks were more than 20,000 lb. in gross weight.

Visual Classification of Vehicles

The previous discussion concerns the distribution of vehicles on registration bases, and some of the difficulties encountered in computing a uniform distribution on the basis of vehicle or combination gross weights. An entirely different problem arises in adapting the computed gross-vehicle-weight basis to the actual vehicles operating on the highway as they are observed from counting or weighing stations. Determination of the taxes paid by various vehicles requires considerable knowledge of the mileages they travel; and these must be computed primarily from observation. Registration fees do not vary with the amount of travel. Motor-carrier taxes do vary to a considerable degree with the amount of travel, and fuel taxes paid vary in direct proportion as travel varies.

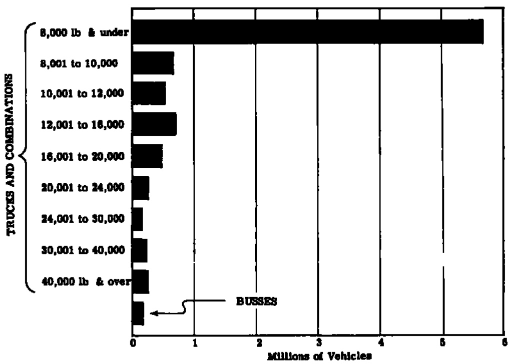

Figure 2. Commercial vehicles by gross-weight-registration classes.

The visual classification of vehicles shown in Table 1 and Figure 3 is that ordinarily used in recording and publishing traffic-volume information. This was the principal reason dictating its adoption for this study, although another factor prompting its use was that this classification is more meaningful than is a classification based solely upon gross weight.

Although the visual classification is so commonly used in presenting traffic data, vehicles in use or registered cannot readily be classified on this basis. In spite of the fact that tractor trucks or panels and pick-ups are registered separately in a few states, there is none in which the visual classification has been adopted in a general way as a basis for vehicle registration. Manufacturers' and trade-association statistics are no more helpful; manufacturers' gross-vehicle-weight rating has understandably become the basis upon which these groups publish most of their statistics on production and sales.

As a consequence, it became necessary in preparing the visual distribution of vehicles shown in Table 1 and Figure 3 to resort to other sources of information. One of these was the findings of the motor-vehicle-use studies conducted in five states as presented in the project reports made on those studies. Another was the distribution of vehicles for seven urban areas reported in the home-interview samples taken in origin-and-destination studies. A third was a report prepared on an analysis of the 1952 truck registrations in North Carolina made by the Division of Statistics and Planning of the North Carolina State Highway and Public Works Commission (1). Although none of these sources provided all of the information desired, it was possible by piecing this information together with that which was available from registration records in a few states to develop the distribution shown in Table 1 and Figure 3.

Some of these sources also provided gross-vehicle-weight distributions of individual visual classifications. With the help of these it was possible to calculate a cross-classification of vehicles by both visual and gross-weight classifications. This tabulation, Table 1, provided a means of allocating registration and related fees and taxes according to both classifications. A comparison of the percentage distribution by both classifications is shown in Figure 4.

DETERMINATION OF REGISTRATION-FEE AND CARRIER-TAX PAYMENTS

Registration Fees and Related Imposts

Total revenue from state registration fees and associated imposts amounted to \$1,069,439,000, or \$1,056,580,000 if the \$12,859,000 of fines and penalties are excluded. Of this net amount \$910,211,000 were registration fees and the remainder of \$146,369,000 was accounted for by title fees and taxes, transfer and reregistration fees, operators' and chauffeurs' licenses, and other miscellaneous allied revenue. Operators' and chauffeurs' licenses alone accounted for \$57,088,000.

Registration Fees. In order to allocate registration fees between the various prin-

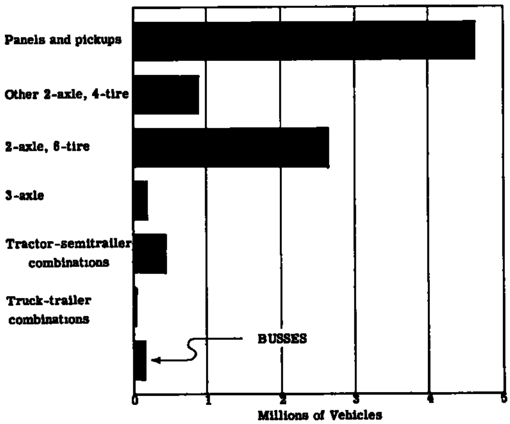

Figure 3. Commercial vehicles by visual classification.

cipal groups of vehicles, average registration fees were computed from the basic data on which the study, "State Road-User and Property Taxes on Selected Motor Vehicles, 1953," was based (2). Although this present study deals in national totals, it is well to remember that there are great differences among the states in their taxation of motor vehicles. A good visual measurement of these differences appears in Figures 5 and 6.

Property taxes on motor vehicles are not within the scope of this study, but it is of interest to note that there is considerable variation in their imposition and magnitude as shown in Figures 5 and 6.

The average registration fee for automobiles, derived by simple division, is $11.81. The computed truck-registration fees derived by multiplying the numbers of vehicles in each group by the estimated average fees, yielded a total of $368,605,000, or not quite 0.9 percent more than the known total of $365,404,000. The average fees were therefore reduced the 0.9 percent to arrive at the $365,404,000 total.

The amount of truck and tractor registration fees, for 1952, as shown in Table MV-2, is $320,251,000. To this amount was added the $59,270,000 of fees paid on various types of trailers and semitrailers, from which was deducted $14,116,000 estimated to have been paid on house trailers, light car trailers, etc. The resulting amount, $365,404,000, makes allowance for the fact that semitrailers and trailers are registered separately in many states

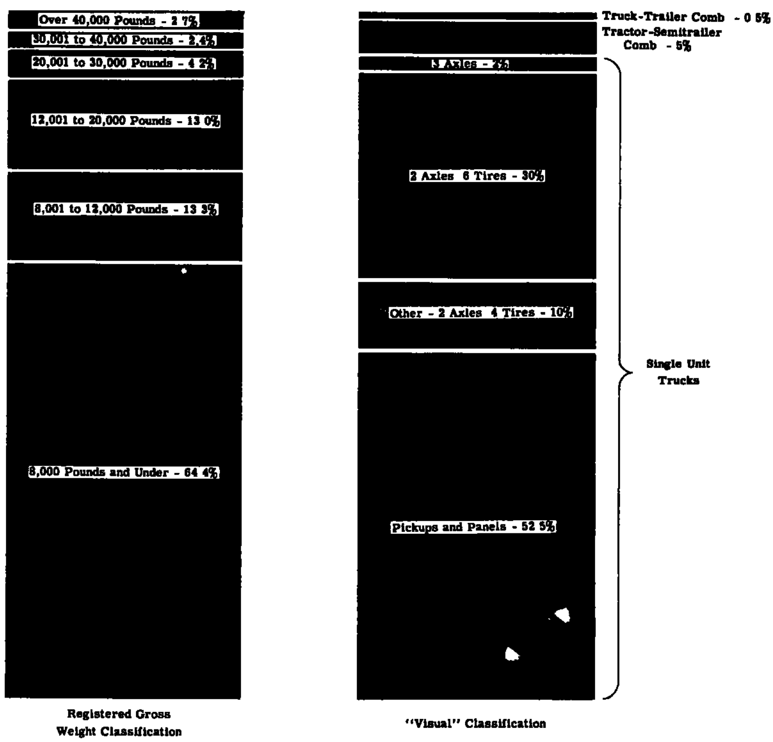

Figure 4. Comparison of trucks and combinations by registered gross weight and visual classifications.

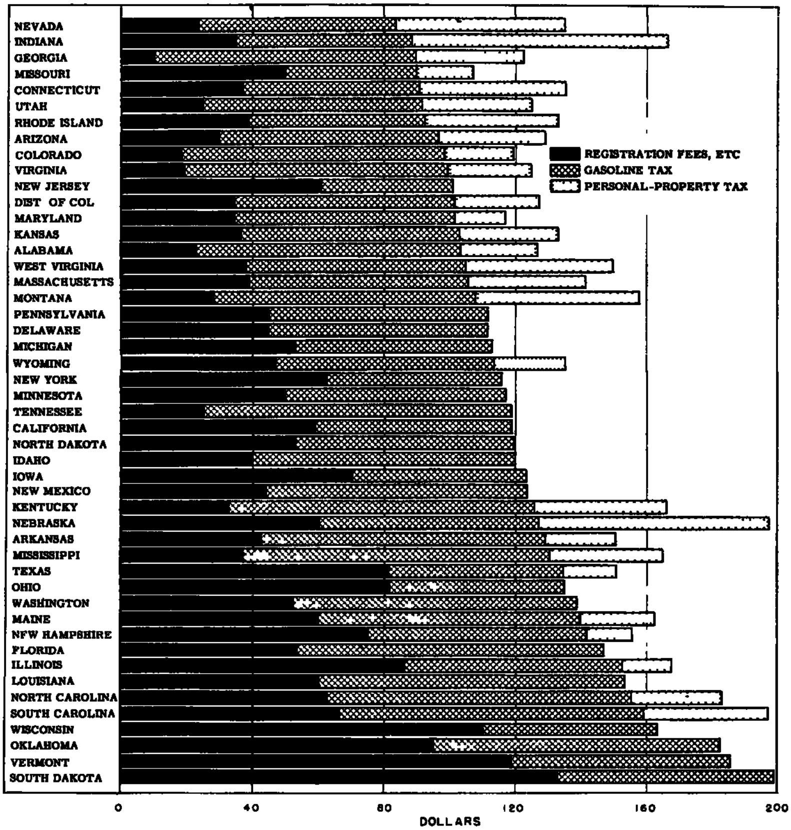

Figure 5. Road-user and personal-property taxes on a "1½-ton" (12,500-lb. G.V.W.) stake truck in private use, ranked according to road-user taxes.

and that there are considerably greater numbers of semitrailers than tractors.

There were 5,679,000 trucks in the weight group of 8,000 lb. or less. When converted to the visual classification, 4,497,000 fell into the panel-and-pickup group with four tires, 706,000 were other single-unit trucks with four tires, and 476,000 were two-axle, six-tire, single-unit trucks. The total registration fees of these groups amounted to $103,417,000. It seems probable that the panels and pickups pay slightly smaller fees than the other vehicles in this group.

In this respect, it is interesting to note that a great many states impose lower registration fees on farm trucks than on vehicles not qualifying for that classification. These reductions are very substantial, as can be seen in Figure 7. The vast majority of farm trucks are in the pickup and other light groups. To make allowance for this difference in fees, it was assumed that the average registration fee of the 706,000 four-tire single-unit trucks other than panels and pickups had a value of X and that the registration fee of the panels and pickups had an average value of X minus 5 percent and that the two-axle, six-tire vehicles in the group had a registration fee with the value of X plus 5 percent. The same technique was applied to the fees of the vehicles in the 8,001-to-10,000-lb. group. For the 529,000 trucks in the 10,001-to-12,000-lb. group, it was assumed that the 88,000 four-tire trucks had an average registration fee of 5 percent less than the 441,000 six-tire, single-unit trucks in the group. A similar method was followed in distributing the registration fees of each of the weight classes to the visual classifications. In each instance, however a heavier weighting factor was given to the registration fees for combinations when they fell in the same gross-weight group as single-unit trucks.

Operators' and Chauffeurs' Licenses and Miscellaneous Imposts. The allocation of operators' and chauffeurs' licenses had to be arbitrary. Some states do not require chauffeurs' licenses and others do not require ordinary operators' licenses of those who hold chauffeurs' licenses. The total chauffeurs' license fees attributed to truck operators was $9,229,000. It was assumed that one chauffeur's license at an average fee of $1.80 should be attributed to each vehicle in the gross-weight classes of 20,000 to 40,000 lb. and 1.5 chauffeurs' licenses should be attributed to each vehicle over 40,000 lb. The remainder of the chauffeurs' licenses and the fees derived therefrom were attributed to trucks in the various groups under 20,000 lb. Chauffeur-license payments attributed to bus operators were computed as approximately two per vehicle or 290,000, and at $1.80 each these amounted to $522,000. Motorcycle operators' licenses were estimated at $0.25 per registered motorcycle, and amounted to $102,000. The remainder of operators' and chauffeurs' license payments, $47,235,000, was allocated to passenger-car operators.

After allocating operators' and chauffeurs' license revenues to various groups of vehicles there remained $89,281,000 of miscellaneous fees to be assigned. This was done insofar as possible by examination of the individual state reports and allocating the fees to individual groups where possible. As a result of this examination of state reports, $17,571,000 was assigned to trucks. This amounted to $1.99 each. In this distribution, however, consideration was given to size and value of the vehicles, since these factors affected the receipts. Title fees, transfer fees, and issuance fees were distributed to trucks on a numerical basis. Nonresident tag fees and a small amount of other miscellaneous fees were distributed between trucks on the basis of a five-state sample drawn from the individual reports of the states in the Bureau of Public Roads files. The truck share of special titling taxes, amounting to

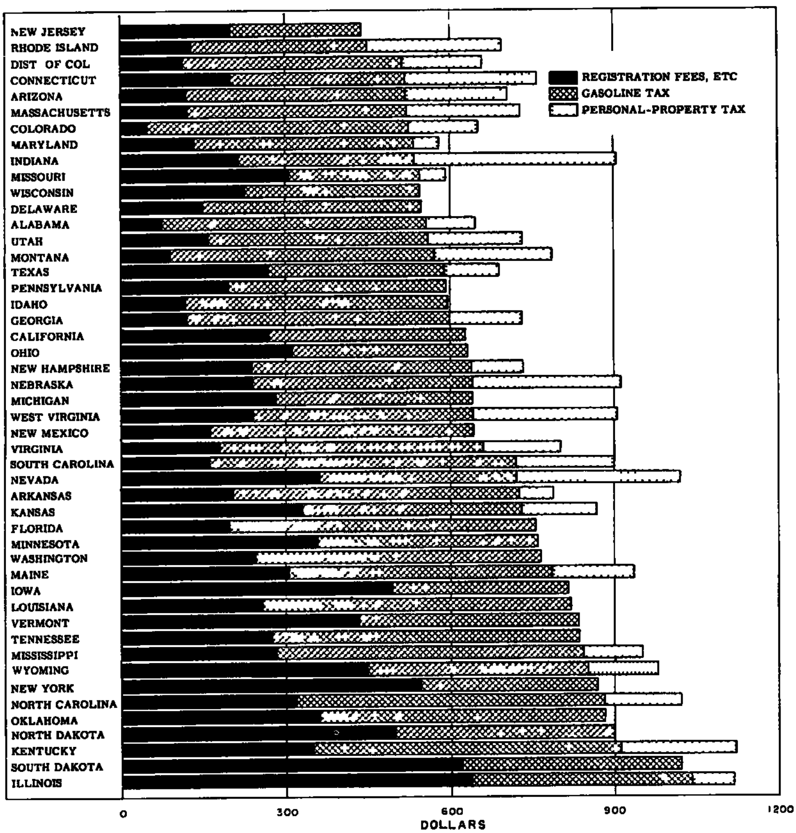

Figure 6. Road-user and personal-property taxes on a 40,000-lb. three-axle tractor-semitrailer combination in private use in each state, ranked according to road-user taxes.

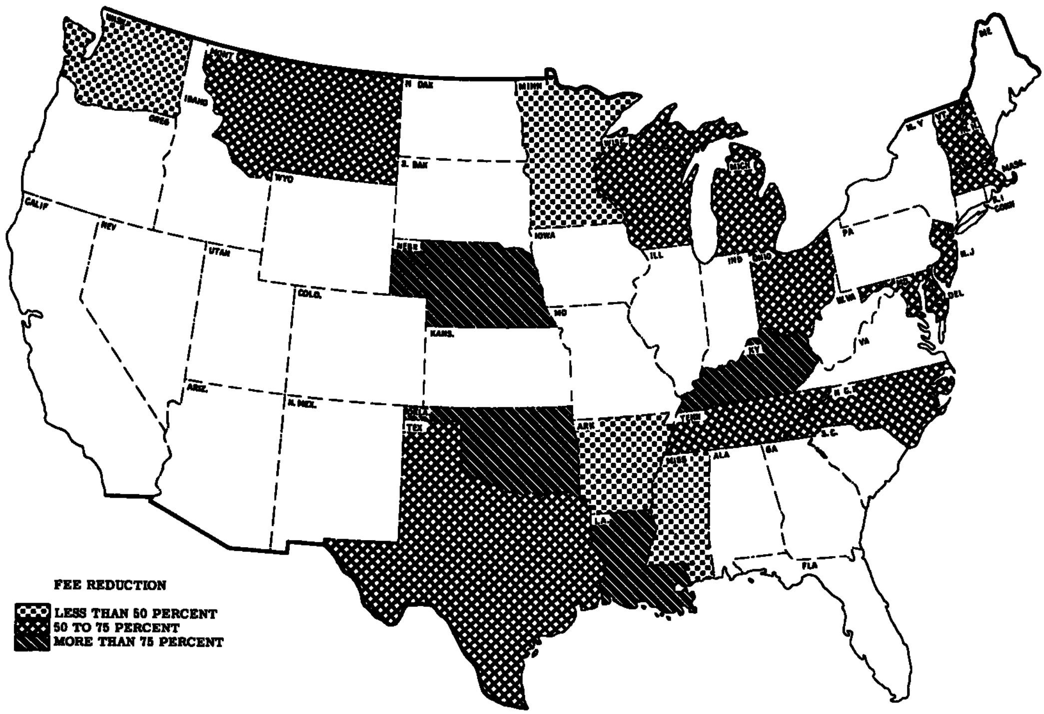

Figure 7. Reduced registration fees for farm trucks (1½-ton stake).

$32,489,000, was distributed on the basis of gross vehicle weights, since these are ad-valorem taxes and it seemed that there should be a high degree of correlation between value and weight. Undoubtedly this is susceptible of refinement, but it is probable that no great violence is done by this approach.

It was assumed that the miscellaneous revenues to be assigned to busses averaged the same as those assigned to trucks, i.e., $1.99 each, or a total of $289,000. Miscellaneous revenues of $1 each were attributed to the 407,000 registered motorcycles. The remaining miscellaneous fees, $71,014,000, were attributed to automobiles, and amounted to $1.63 per automobile when the amount is divided by the number of registered vehicles.

Carrier Taxes

The prior discussion has outlined the major phases of assigning registration and associated fees. The assignment of the $64,036,000 in motor-carrier tax revenues was made by study of the individual reports of the states. This indicated that $7,268,000 might be assigned to busses and the remaining $56,768,000 assigned to trucks. Undoubtedly there are some instances of certain carrier taxes or public-service permit fees and related revenues that may be attributed to taxicabs, but insufficient evidence was found of such payments to make any allocation. In any case, it is improbable that a substantial amount would be involved.

For the purpose of this study it was also assumed that carrier taxes can be assigned entirely to busses and to trucks of more than 12,000 lb. in gross-vehicle-weight rating. Since the individual state records did not distinguish between the classes of vehicles upon which carrier taxes were levied, an arbitrary procedure was adopted in assigning them to the various groups. By taking the average amount of motor-carrier tax that would be paid by a vehicle of over 40,000 lb. as the quantity X, it was assumed, in computing carrier taxes, that vehicles in the group from 30,001 lb. to 40,000 lb. could be assigned a value of 0.75 X; that trucks and combinations in the group from 24,001 lb. through 30,000 lb. could be assigned a value of 0.5 X; vehicles in the group from 20,001 lb. through 24,000 lb. were assigned a value of 0.25 X; vehicles in the group from 16,001 lb. through 20,000 lb. were assigned 0.1 X; and vehicles of 12,001 to 16,000 lb. had a value of 0.05 X. The value of X was found to be $94.32. It might be said that this is reducing guessing to a system, and there would be more than a grain of truth to it. Yet, in the absence of detailed basic data any assignment of motor-carrier taxes to various groups of vehicles must necessarily be on an arbitrary basis, and regardless of the complexity of any formula adopted, it would be reasonably certain to contain many of the properties of the estimate made here.

ASSIGNMENT OF TRAVEL AND FUEL-TAX PAYMENTS

Although much is known about the character and extent of motor-vehicle use, there is a present lack of complete information about the distribution of highway travel in rural and urban areas, especially that pertaining to the subdivision of this travel among the classes of vehicles for which it was desired to make estimates in this study. Nevertheless, such an estimate of travel during 1952, classified according to these vehicle types, had to be made if the fuel use and fuel-tax payments of the individual types of vehicles were to be calculated.

Assignment of Motor-Vehicle Travel

Estimates of passenger-car, bus, and truck travel in the continental United States were issued by the Bureau of Public Roads for each of the years from 1936 through 1948 (3). The principal factors controlling the calculations made for 1936 were the traffic volumes, characteristics and relationships as determined from rural traffic counts, and from the studies of motor-vehicle allocation and road use conducted between 1935 and 1939, covering both rural and urban travel.

These projects were included in the program of basic highway-planning studies undertaken jointly by the state highway departments and the Bureau of Public Roads. Estimates for the succeeding years were based upon the calculations made for 1936, such modifications being made as were necessary to reflect known trends in motor-vehicle registrations, fuel consumption, and vehicle use. The principal factors controlling the calculations for the individual years were: (1) annual estimates of rural-road traffic made by Public Roads from traffic counts obtained by the highway-planning surveys; (2) annual reports of the highway use of motor fuel made by state authorities to Public Roads; and (3) reports of motor-vehicle registrations, also made by state authorities to Public Roads. Publication of these estimates was discontinued after 1948 because it was felt that some of the basic relationships existing in 1936, and upon which the entire structure of the estimates was predicated, might have changed considerably. Since that time only estimates of rural travel have been published.

The same basic procedures employed in preparing the estimates for 1936 through 1948 were used in developing the estimate of the total passenger-car, bus, and truck travel for 1952 as presented in Table 2. For purposes of this study, however, it was necessary to subdivide the estimate of total truck travel into the various visual classifications shown in the table. In rural areas, classification counts have been made regularly by the state highway departments as a part of the highway-planning-survey operations, and the percentage distribution shown by these counts was used in subdividing the total rural vehicle mileage of trucks. In urban areas, comprehensive classification-count data are not available. Two other sources of information are available from the planning-survey operations conducted by the states, however, and these were used in subdividing the total urban vehicle mileage of trucks. Estimates of travel by the various visual classifications of trucks were developed for the large cities from information collected in origin-and-destination traffic studies of the home-interview type, and for the smaller cities from information obtained in motor-vehicle-use studies.

In the home-interview origin-and-destination studies, it is standard practice to collect data concerning the type of truck, the licensed gross weight, and the daily mileage traveled in the urban area, as well as the origin and destination of each trip. Information is also available in these studies concerning the number, type, origin, and destination of all trucks entering and leaving urban areas. Twelve cities (Camden, Dallas, Duluth, Houston, Madison, Minneapolis, Philadelphia, Racine, St. Paul, Seattle, Superior, and Washington, D. C.) were selected from those in

TABLE 2

ESTIMATED TRAVEL DURING 1952 IN THE UNITED STATES CLASSIFIED BY PLACE OF TRAVEL AND BY VEHICLE TYPE

(Travel in millions of vehicle miles)

Type and class of vehicle	Amount of travel in –			Percentage of travel in –		
	Rural areas[1]	Urban places[1]	All places	Rural areas[1]	Urban places[1]	All places
Passenger cars (including taxicabs)	213,464	197,404	410,868	77.01	83.98	80 21
Busses:						
Commercial	1,444	1,750	3,194	0.52	0 74	0 62
Other	1,026	114	1,140	0 37	0.05	0.22
Subtotal	2,470	1,864	4,334	0.89	0.79	0.84
Trucks and combinations:						
Single-unit trucks –						
Two-axle Four tire trucks–						
Panels and pickups	22,075	13,324	35,399	7 97	5.67	6 91
Others	2,083	5,834	7,917	0.75	2.48	1 55
Subtotal	24,158	19,158	43,316	8 72	8 15	8.46
Two-axle Six-tire trucks	20,453	13,600	34,053	7 38	5 79	6.65
Three-axle trucks	1,557	388	1,945	0.56	0.16	0 38
Subtotal	46,168	33,146	79,314	16 66	14.10	15 49
Vehicle combinations –						
Tractor-semitrailer	14,013	2,465	16,478	5 06	1.05	3 22
Combinations involving full trailers	1,061	187	1,248	0 38	08	0.24
Subtotal	15,074	2,652	17,726	5.44	1 13	3 46
Total trucks and combinations	61,242	35,798	97,040	22 10	15 23	18 95
Total all vehicles	277,176	235,066	512,242	100.00	100 00	100 00

[1] "Urban areas" includes all incorporated places and other urban places, the remainder is included in "rural areas"

which home-interview studies have been made and special tabulations of the urban travel by type of truck were made for these cities. Some of these tabulations were made by the state highway departments and some by the Bureau of Public Roads. Percentages and factors developed from these data were used in estimating the urban vehicle mileage of trucks by visual types in the larger cities for the country as a whole.

The motor-vehicle-use studies are also home-interview studies designed to obtain on a statewide basis much the same types of information as are obtained for a single city or urban area in the home-interview origin-and-destination studies. Because of their statewide, rather than local emphasis, the sampling rates employed within cities in the motor-vehicle-use studies are much lower than those used in the origin-and-destination studies; therefore, the stability and reliability of the motor-vehicle-use samples are lower when only a single city or size group of cities is considered. However, the data available from these studies could be used to good advantage in estimating the travel of various classes of trucks and combinations in the smaller-sized cities and villages as a whole. Data obtained in seven states, the only ones in which motor-vehicle-use studies have been completed up to the present, were used in making these estimates. In addition to the travel data applied, information obtained through these studies relative to the distributions of dwelling units, population, and motor vehicles was also used in refining the calculations.

Other sources of information used included estimates of travel by commercial and other busses reported by the industry in the 1953 statistical issue of "Bus Transportation" (4), and estimates of automobile use reported by the Automobile Manufacturers Association in "Automobile Facts and Figures" (5).

Total motor-vehicle travel on all roads and streets during 1952 was calculated to be 512 billion vehicle-miles, of which 411 billion (about 80 percent) was estimated to have been performed by passenger cars, 79 billion (nearly 16 percent) by single-unit trucks, 18 billion (somewhat more than 3 percent) by tractor-semitrailer and truck-trailer combinations, and 4 billion (nearly 1 percent) by busses.

This tabulation includes the travel of publicly owned non-military vehicles. It was desired to limit the calculation of fuel consumption and fuel-tax payments to the classifications of private and commercial vehicles shown in Table 1 and Figure 3.

Consequently, the travel of publicly owned vehicles had to be eliminated from the estimated travel of all vehicles shown in Table 2.

Estimates of the travel and fuel consumption of federal civilian vehicles were determined from statistics compiled by the United States Bureau of the Budget, while estimates of the travel and fuel consumption of motor vehicles owned by state, county, and local government agencies were developed from reports made by most of the state highway departments to the Bureau of Public Roads.

The travel of publicly owned vehicles was determined to be 6 billion vehicle-miles, of which the amounts contributed by the individual vehicle types were as shown in the second column of Table 3. The total travel of private and commercial motor vehicles, after deduction of public-vehicle travel, was 506 billion vehicle-miles, of which 409 billion was performed by passenger cars, 76 billion by single-unit trucks, 17 billion by combinations of freight-carrying vehicles, and nearly 4 billion by busses. The percentage distribution of this travel by vehicle groups was practically the same as for the total travel of all public, private, and commercial vehicles. This distribution is shown in Figure 8.

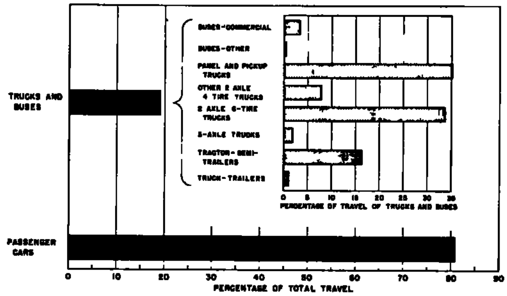

Figure 8. Percentage distribution of travel by private and commercial motor vehicles in the continental United States during 1952.

Operating Characteristics of Various Types of Vehicles

In order to estimate the fuel consumption and fuel-tax payments for the individual classes of vehicles used in this study, it was necessary to determine certain of their operating characteristics, such as average gross weights, percentages of vehicles using fuel other than gasoline, and rates of fuel consumption.

Average Operating Gross Weights. The calculated average operating gross weights used in this study for each type of vehicle are shown in Table 4 and Figure 9. Different methods were employed in arriving

TABLE 3

ESTIMATED TRAVEL DURING 1952 IN THE UNITED STATES CLASSIFIED BY OWNERSHIP AND BY VEHICLE TYPE

(Travel in millions of vehicle miles)

Type and class of vehicle	Amount of travel by —			Percentage of travel by —		
	All vehicles	Government owned vehicles	Private and commercial vehicles	All vehicles	Government owned vehicles	Private and commercial vehicles
Passenger cars (including taxicabs)	410,868	1,597	409,271	80.21	25.42	80.89
Busses						
Commercial	3,194	-	3,194	0 62	-	0.63
Other	1,140	770	370	0.22	12.26	0.07
Subtotal	4,334	770	3,564	0.84	12.26	0 70
Trucks and combinations:						
Single-unit trucks —						
Two-axle Four-tire trucks —						
Panels and pickups	35,399	1,428	33,971	6.91	22 73	6.71
Others	7,917	319	7,598	1 55	5.08	1 50
Subtotal	43,316	1,747	41,569	8.46	27.81	8.21
Two-axle Six-tire trucks	34,053	1,374	32,679	6.65	21.87	6 46
Three-axle trucks	1,945	79	1,866	0.38	1 26	0.37
Subtotal	79,314	3,200	76,114	15 49	50.94	15.04
Vehicle combinations —						
Tractor-semitrailer	16,478	664	15,814	3.22	10.57	3.13
Combinations involving full trailers	1,248	51	1,197	0.24	0.81	0.24
Subtotal	17,726	715	17,011	3.46	11.38	3.37
Total trucks and combinations	97,040	3,915	93,125	18 95	62.32	18 41
Total all vehicles	512,242	6,282	505,960	100.00	100.00	100.00

at the weights adopted for the various classes of vehicles.

The average operating gross weight of passenger cars was determined by a complex method of calculation in which these vehicles were divided by makes roughly into four groups, according to the weight of the most-popular four-door sedan of each make. An average operating road weight was calculated for each make by adding to the shipping weight of the four-door sedan an allowance to cover nonstandard equipment, such as radios and heaters, fuel, water, two passengers, and baggage. The allowances varied from 600 lb. in the case of the vehicles in the lightest group to 900 lb. in the case of the heaviest vehicles. It was assumed that vehicles of all weight groups would have the same average travel. The average operating gross weight for all passenger cars was calculated to be 3,965 lb.

The weights shown for the various classes of trucks and combinations are averages obtained from loadometer studies conducted in 1952 by the state highway-planning organizations. A total of 134,564 vehicles was weighed as found in the traffic stream on main rural roads. Some were empty, some overloaded, and some only

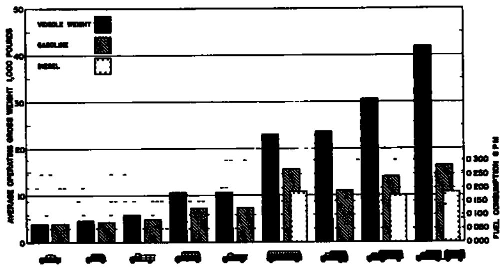

Figure 9. Operating characteristics of various types of motor vehicles.

TABLE 4

OPERATING CHARACTERISTICS OF VARIOUS TYPES OF MOTOR VEHICLES

Type and class of vehicle	Average operating gross weight	Distribution of travel according to type of fuel used			Rates of fuel consumption, by type of fuel used		
		Gasoline	Diesel	Other	Gasoline	Diesel	Other
	(pounds)	(percent)	(percent)	(percent)	(g p.m.)	(g p m.)	(g p m.)
Passenger cars:	3,965	100 0	(a)	(a)	0.06704	-	-
Busses:							
Commercial	23,000	39 1	55.9	5.0	0.26870	0.18590	0.26690
Other	11,600	100.0	(a)	(a)	0.12540	-	-
Trucks and combinations							
Single-unit trucks —							
Two-axles, Four tires —							
Panels and pickups	4,639	100.0	(a)	(a)	0.07350	-	-
Others	5,834	100 0	(a)	(a)	0.08420	-	-
Two axles, Six tires	11,684	100.0	(a)	(a)	0.12590	-	-
Three axles	23,611	100.0	(a)	(a)	0.18980	-	-
Combinations —							
Tractor-semitrailer	35,602	86.5	12 6	0.9	0.24120	0 17230	0.26800
Truck-trailer	46,885	86.5	12.6	0 9	0.28320	0.20230	0.31470

[a] Percentage negligible.

The operating characteristics of commercial busses differed so greatly from those of other types of busses, that these were treated separately from the other types, such as privately owned busses operated by schools or institutions. The operating gross weight of 23,000 lb. assigned to commercial busses was determined by adding to the curb weight of a typical 42-passenger bus, such as used in either city or suburban service, the weight of a load of 21 passengers. The operating gross weight of 11,600 lb. assigned to "other" busses represents the combination of the curb weight of a typical medium-sized school bus and the weight of an average load of 20 children.

partially loaded. The weights reported reflect these conditions. Since no data were available on weights of vehicles operating in cities, the rural road weights had to be applied to all traffic.

Use of Fuels Other Than Gasoline. Although the use of fuels other than gasoline in the propulsion of motor vehicles is increasing rapidly, the amount of such so-called special fuels used is still a relatively small percentage of the total fuel consumed on the highways. In 1952 the total of all motor fuel so used in the United States was 40 billion gallons (Public Roads Table G-21), while the total amount of special fuels used for highway purposes was only 805 million gallons (Public Roads

Table G-25). This relatively small segment of motor-fuel consumption assumes greater importance, however, when it is considered that nearly all of this fuel is consumed by the larger commercial vehicles.

Information reported by the commercial bus industry indicates that large portions of its operations are now carried on with busses propelled by diesel fuel, liquefied petroleum gas, and other nongasoline fuels. The specific percentage relationships used in this analysis are based upon reports from 24 intercity, intracity, and suburban operators reported by "Bus Transportation" magazine (6). These data, which appear to be supported by other reliable information, indicate that more than 50 percent of the fuel now used in common-carrier busses is diesel fuel, while the use of liquefied petroleum gas has become an important factor in some instances. On the other hand, although there is undoubtedly some use of these fuels in busses engaged in other types of operations, available information seems to indicate that up to the present such use is insignificant.

Nongasoline fuels are also used to some extent in single-unit trucks, but inasmuch as the achievement of significant savings from the use of these fuels requires large-scale operations, such use is thought to be negligible and all of the consumption of these fuels in freight-carrying vehicles was assigned to combinations rather than single vehicles.

Estimates of Fuel-Consumption Rates. The rate at which a certain motor vehicle or combination of vehicles will consume fuel in its operations over the highways is affected at any given time by a number of factors, among which the following are of major importance: type and grade of fuel used, characteristics of the engine, gear ratios, frequency of stops, condition of the vehicle, gradients encountered, types and conditions of roads traveled, weather, operating gross weight of vehicle (or combination) and contents, and driving techniques employed.

When the universe of all motor vehicles in service, operating throughout the year under widely varying conditions, is being considered, and if only a broad and general analysis is undertaken, as was the case in this instance, the effects of such factors as frequency of stops, topography, weather, condition of the vehicle, and driving techniques employed tend to become compensating and have little effect upon the determination of average rates of fuel consumption. Consequently, in the analysis undertaken for this study no attempt was made to take any factor other than gross vehicle weight into account, except in a very limited way as noted subsequently.

Figure 10 shows the compromise curve indicating the relationship between gross weight and gasoline consumption plotted from the equation developed for this paper and the other fuel-consumption data that were considered in developing it. This equation is intended to indicate approximate gasoline-consumption rates for gross vehicle weights up to at least 72,000 lb. operating under average conditions.

This gasoline-consumption equation was not statistically developed in the ordinary sense. Rather, it is a composite of values for numerous gross-weight groups obtained from each of several previous determinations by other investigators. Since it was beyond the scope of this study to assemble original data on the fuel-consumption rates of motor vehicles, it was necessary to draw on the work of others. Although many sources of data were investigated, none was found which appeared to meet present needs in all respects.

Some, like the determinations of the Federal Coordinator of Transportation (7), were developed from information that is now so old that it does not reflect conditions now known to prevail especially in the higher gross-weight brackets. Others, like the fuel-consumption rates developed from the Ford data reported upon by Robley Winfrey (see p. 36 of this bulletin) are based upon limited coverage of engines, vehicle types, or loadings, and so tend to give values, for certain weight ranges, that deviate rather widely from the consensus of findings.

After plotting all of this information, as shown in Figure 10, it became evident that a new curve, or set of curves, should be developed. Some students of the problem contend that a single fuel-consumption curve cannot be developed to fit all types of vehicles from passenger cars through the heaviest combinations. When the gasoline-consumption equation adopted for use in this study was developed, it had not been predetermined that a single curve could be applied to all gross weights. However, when average fuel-consumption rates for

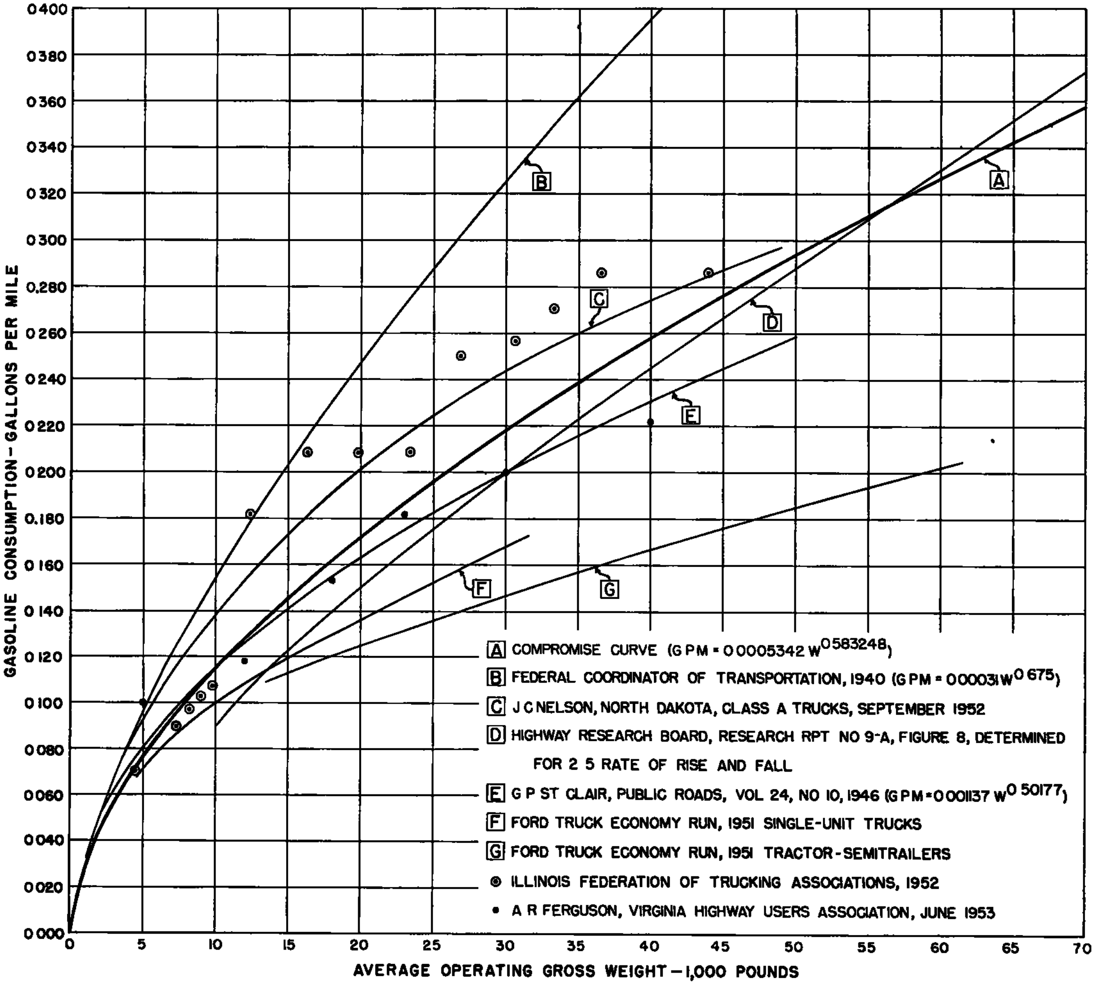

Figure 10. Estimated variation of fuel consumption of gasoline-powered vehicles with average operating gross weight.

each of numerous values of operating gross weights, ranging from 3,000 to 50,000 lb. had been calculated and plotted to logarithmic scales, it was found that they closely fitted a straight line having the following equation:

Let GPM = gallons per mile
W = average operating gross weight of vehicle

Then $GPM = 0.000534 W^{0.583}$

Consequently, it was decided that, for purposes of the present analysis, this fuel-consumption equation could be applied throughout the entire range of gross weights for which gasoline consumption would need to be calculated.

As stated previously, this equation applies only to gasoline-powered vehicles. It is known that different rates of fuel consumption will apply to diesel-powered vehicles, but there are not sufficient data at hand to permit the calculation of an equation for them. After consultation with representatives of the trucking industry, it was decided to assume that, for operating gross weights above 20,000 lb., diesel vehicles will consume on the average, about 30 percent less fuel than will gasoline-powered vehicles of equal weight. No special allowance was made for vehicles using other fuels, such as liquefied petroleum gas, partly because of their negligible importance in the nationwide picture and partly because available data seemed to indicate that such vehicles generally have fuel-consumption rates closely approximating those of similar gasoline-powered vehicles.

All of the gasoline-consumption rates shown in Table 4 and Figure 9 were developed by applying the derived equation to the average operating gross weights shown, except in the case of commercial busses. Available operating data indicate that relationships between the gasoline-consumption rates and average operating weights of intercity busses are almost in line with the corresponding relationships calculated by use of the equation, but that in the case of intracity and suburban busses the rates are much higher, probably because of the combined effects of frequent stops, urban congestion, and other factors peculiar to such operations. The composite gasoline-consumption rate shown was developed from operating statistics of the 24 companies previously cited.

Fuel Consumption and Fuel-Tax Payments

Table 5 presents the calculated fuel consumption and fuel-tax payments of each of the various classes of vehicles indicated in the visual classification adopted for this study. Figure 11 shows the percentage distribution of indicated total fuel consumption.

Fuel consumption. The fuel-consumption data shown were calculated by multiplying the total mileages indicated in Table 5 by the corresponding rates shown in Table 4 and Figure 9. Separate calculations of gasoline, diesel, and other fuel used were made on the basis of the percentages of total use there indicated.

The total calculated consumption of 39,807 million gallons of fuel of all kinds is 91 million gallons, or 0.225 percent, below the 39,898 million gallons of fuel used by private and commercial vehicles for highway purposes in 1952 reported in Public Roads Table G-21. However, the analysis made for this paper did not take into account fuel consumed by motorcycles, motorscooters, and other similar vehicles, nor did it give consideration to the use of fuel on which highway-user taxes were paid and no refunds claimed for such nonhighway purposes as the operation of

TABLE 5

FUEL CONSUMPTION AND TAX PAYMENTS IN 1952 CLASSIFIED BY VARIOUS TYPES OF PRIVATE AND COMMERCIAL MOTOR VEHICLES

Vehicle type	Total miles traveled	Gasoline powered vehicles		Diesel powered vehicles		Vehicles powered by other fuels		Fuel consumed		Total tax paid
		Mileage	Fuel consumed	Mileage	Fuel consumed	Mileage	Fuel consumed	Total gallons	Percent	
	Millions	Millions	Million gallons	Millions	Million gallons	Millions	Million gallons	Millions		Million dollars
Passenger cars	409,271	409,271	27,438	-	-	-	-	27,438	68.771	1,353.3
Busses										
Commercial	3,194	1,249	336	1,785	332	160	43	711	1 782	35.0
Other	370	370	46	-	-	-	-	46	0 115	2.3
Subtotal	3,564	1,619	382	1,785	332	160	43	757	1 897	37 3
Trucks and combinations										
Single-unit trucks —										
Two-axles, Four-tires										
Panels and pickups	33,971	33,971	2,497	-	-	-	-	2,497	6.259	123.2
Other	7,598	7,598	640	-	-	-	-	640	1.604	31.5
Subtotal	41,569	41,569	3,137	-	-	-	-	3,137	7.863	154.7
Two-axles, Six-tires	32,679	32,679	4,114	-	-	-	-	4,114	10 311	202 9
Two-axles	1,866	1,866	354	-	-	-	-	354	0.887	17 5
Subtotal	76,114	76,114	7,605	-	-	-	-	7,605	19 061	375 1
Combinations —										
Tractor-semitrailer	15,814	13,679	3,299	1,993	343	142	38	3,680	9.223	181 5
Truck-trailer	1,197	1,035	293	151	31	11	3	327	0 820	16.1
Subtotal	17,011	14,714	3,592	2,144	374	153	41	4,007	10.043	197.6
Total trucks and combinations	93,125	90,828	11,197	2,144	374	153	41	11,612	29,104	572.7
Total all vehicles	505,960	501,718	39,017	3,929	706	313	84	39,807	99.772	1,963.3
Difference (consumption by motorcycles, etc.)								91	0.228	4.5
Total fuel consumed and tax payments								39,898	100.000	1,967.8

gasoline-powered lawnmowers, garden tractors, or small boats.

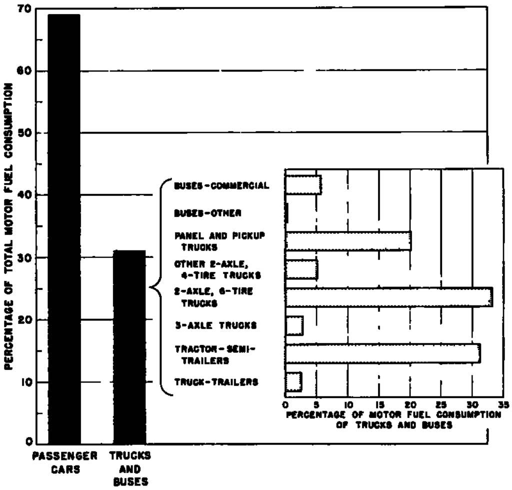

Figure 11. Percentage distribution of motor-fuel consumption by private and commercial motor vehicles in the continental United States during 1952.

There were about 408,000 private and commercial motorcycles, motorscooters, and similar vehicles registered in 1952. If it can be assumed that these vehicles consumed an average of 200 gallons of fuel each during the year, their total consumption would have been nearly 82 million gallons, a not-unlikely figure. Other investigators have averaged the annual consumption of motorcycles at 250 gallons, or even more. (The Federal Coordinator of Transportation used a fuel-consumption rate of 0.027041 gallons per mile and an average annual mileage of 15,000 in estimating motorcycle fuel consumption in 1932; see "Public Aids to Transportation," Vol. IV, p. 143.)

Fuel-Tax Payments. Public Roads Table G-1 indicates that $1.97 billion was collected during 1952 from state taxes upon motor fuel used for highway purposes. This total excludes taxes refunded upon nonhighway use of motor fuel and allowance made in a few states to taxpayers for costs of tax collection. It includes the incomes from certain miscellaneous receipts, such as distributors' and retailers' license fees, inspection fees, etc.

The total motor-fuel consumption covered by these tax payments is not exactly the same as the total of highway motor-fuel consumption by private and commercial vehicles of almost 40 billion gallons shown in Table G-21. The reason is that Table G-1 shows tax collections during 1952, regardless of when the fuel was used, while G-21 is designed to present actual fuel consumption during the year. Although there may not be much time lag between the payment of the fuel tax and the actual use of motor fuel in most instances, the procedures used in the various states for handling tax refunds for nonhighway use may result in a considerable imbalance between net collections and highway use during any calendar year. Thus, tax-refund claims for nonhighway use in the fall of one year may not be paid and be deducted from collections until after the first of the following year.

For this reason it was decided not to attempt to calculate tax payments directly from the gallonage distribution shown in Table 5. Instead, a percentage distribution was calculated from these data and applied to the total collections of $1.97 billion shown in Table G-1, on the assumption that the percentages of use reflected by the collections would be essentially the same as those reflecting actual use during 1952. The results of this calculation are shown in the last column of Table 5 and in Figure 11.

FINDINGS OF THE STUDY

In this paper, the attempt has been made to develop the amounts of state road-user taxes paid by vehicles of different types and general size groups. Because the problem is a complex one and the estimates are necessarily approximate, much time has been devoted to describing the procedures and techniques used. It is time now to ask and to answer the question, "What does it all amount to?"

The answer is found in the summary figures given in Tables 6 and 7 and in Figures 12 and 13, which portray the results graphically. The summary data compare the numbers of vehicles in each visual classification, the user taxes paid, vehicle-miles travelled, average payments per vehicle, and average payments per mile of travel.

Table 6 brings together the classified estimates of tax payments that were described individually in previous sections of this paper. It will be observed that fuel-tax payments accounted for $1.968 billion (or 63.7 percent) of the total of $3.088 billion of state motor-vehicle-tax

TABLE 6

ESTIMATE OF STATE ROAD-USER-TAX PAYMENTS BY MAJOR GROUPS OF VEHICLES 1952

(In thousands of dollars)

Vehicle group	Registration fees	Motor carrier taxes	Oper. & Chauff. licenses	Misc. fees	Motor fuel taxes	Total	
						Amount	Percent
Automobiles	515,750	-	47,235	71,014	1,353,280	1,987,279	64.34
Busses	13,171	7,268	522	289	37,337	58,587	1.90
Motorcycles	1,769	-	102	407	4,488	6,766	.22
Camp & other light trailers	14,117	-	-	-	-	14,117	.46
Trucks and combinations:							
Single unit							
Two axles, Four tires:							
Panels and pickups	83,804	-	4,436	5,966	123,156	217,362	7.04
Other	18,729	-	836	1,186	31,567	52,318	1.69
Two axles, Six tires	129,887	2,613	2,647	5,417	202,909	343,473	11.12
Three axles	27,309	225	297	1,083	17,461	46,375	1.50
Subtotal	259,729	2,838	8,216	13,652	375,093	659,528	21.35
Vehicle combinations:							
Tractor-semitrailer	94,307	49,529	917	3,533	181,504	329,790	10.68
Truck-trailer	11,368	4,401	96	386	16,129	32,380	1 05
Subtotal	105,675	53,930	1,013	3,919	197,633	362,170	11 73
Total trucks and combinations	365,404	56,768	9,229	17,571	572,726	1,021,698	33.08
Total vehicles	910,211	64,036	57,088	89,281	1,967,831	3,088,447	100 00

payments made during 1952. Registration-fee payments totaling $910 million brought in 29.5 percent; motor-carrier tax contributions of $64 million provided 2.1 percent; operators' and chauffeurs' license incomes provided $57 million (1.8 percent; and miscellaneous fees totaled $89 million (2.9 percent).

The most-natural comparison of total payments is that between passenger cars and other types of vehicle. Of the $3.088 billion in state road-user taxes paid by all vehicles in 1952, $1.987 billion was paid by passenger cars; $1.022 billion was contributed by trucks and combinations; $59 million by busses. The remainder is accounted for by nearly $7 million assigned to motorcycles and $14 million assigned to camp, farm, and other light trailers.

Table 7 and Figure 12 indicate that automobiles constituted 83.0 percent of motor-vehicle registrations in 1952 and accounted for 64.8 percent of the user taxes. Busses, relatively negligible in the gross totals, were approximately 0.3 percent of the numbers registered and contributed 1.9 percent of the user-tax revenues. Trucks and combinations accounted for 16.8 percent of the vehicles and 33.3 percent of the revenues.

A different grouping of vehicles brings out the relation of numbers and payments more clearly. If the values for panels and pickups and other four-tired trucks are added to those for automobiles, we have what may be called the light-vehicle group. With this grouping it is found that automobiles and light trucks formed 93.4 percent of the registered vehicles in 1952 and contributed 73.6 percent of the road-user-tax payments. Medium and heavy trucks and combinations accounted for 6.3 percent of the vehicles and 24.5 percent of the user-tax payments. This finding is two-edged, in a sense. By the act of putting light trucks with passenger cars, the total of the truck contribution is diminished, but the weighting of payments in relation to numbers is increased from less than two to one to nearly four to one.

Some of the figures for individual types in the visual classification are revealing. Two-axle, six-tired trucks amounted to 5.0 percent of the vehicles, and the tax contribution was 11.2 percent of the total. Three-axle trucks, constituting 0.3 percent of the vehicles, contributed 1.5 percent of the revenues. Tractor-semitrailer combinations, which added only 0.84 percent to the vehicle total, paid 10.8 percent of the user-tax revenues. Truck-trailer combinations constituted 0.08 percent of the vehicles and contributed 1.1 percent of the tax payments. Combinations, as a group thus amounted to less than 1 percent of the vehicles and contributed nearly 12 percent of the revenues.

In average payments per vehicle during 1952, it is found that the value for automobiles was approximately $45.50; that for busses was $404; and that for trucks and combinations was slightly less than $116. Within the truck and combination group, there is found an average payment of $47 by panels and pickups and $59 by other two-axle, four-tire trucks; the general average for two-axle, four-tire trucks was $49. Two-axle, six-tire trucks paid, on the average, $130, and three-axle trucks about $265. The average payment for combinations as a group was $745, $746 being the average for tractor semitrailers and $736 that for truck trailers. Too much should not be made of the comparison between the two types of combinations, because of the wide difference in both numbers and geographical distribution.

In the regrouping of vehicles, automobiles and light trucks are found to have made an average payment per vehicle of $46; the average for medium and heavy trucks and combinations was $227.

Comparisons on a vehicle-mile basis are also given in Table 7 and illustrated in Figure 13. Here it is found that automobiles, which constituted 83.0 percent of the registrations in 1952, accounted for 80.9 percent of the traffic volume. This may be compared with their contribution of 64.8 percent to the total road-user revenues. If again automobiles and light trucks are combined, it is found that this group contributed 89.1 percent of the vehicle-miles and 73.6 percent of the revenues. Medium and heavy trucks and combinations accounted for 10.2 percent of the traffic volume and 24.5 percent of the revenues. Combinations taken alone provide an interesting comparison. They constituted 0.92 percent of the vehicles, travelled 3.4 percent of the vehicle-miles and provided 11.8 percent of the revenues.

The final comparison shown in Table 7 and Figure 13 is that made on the basis of average road-user-tax payments per mile of travel. The average payment by automobiles was 0.49 cents per vehicle-mile, or almost exactly ½ cent. Busses paid 1.64 cents per mile of travel and trucks and combinations, as a group, paid 1.10

TABLE 7

ESTIMATE OF STATE HIGHWAY-USER TAXES PAID IN 1952 BY VEHICLES IN DIFFERENT TYPE AND WEIGHT GROUPS

Vehicle group	Motor vehicles registered[a]		Vehicle-miles travelled		State highway user taxes paid		Average rates of user-tax payments	
	Number	Percentage distribution	Amount	Percentage distribution	Amount[b]	Percentage distribution	Per vehicle	Per vehicle-mile
	Thousands		Millions		$1,000			Cents
Passenger cars	43,654	82.96	409,271	80.89	1,987,279	64 78	$45.52	0.49
Busses	145	28	3,564	70	58,587	1 91	404 05	1.64
Trucks and combinations·								
Single units:								
Two-axle, Four-tire								
Panel and pickup	4,629	8.80	33,971	6 72	217,362	7 08	46.96	.64
Other	882	1.68	7,598	1 50	52,318	1 71	59.32	69
Two-axle, Six-tire	2,646	5.03	32,679	6.46	343,473	11.20	129.81	1 05
Three-axle	175	0 33	1,866	.37	46,375	1 51	265 00	2 49
Subtotal	8,332	15 84	76,114	15 05	659,528	21.50	79.16	.87
Vehicle combinations								
Tractor-semitrailer	442	.84	15,814	3 12	329,790	10.75	746 13	2.09
Truck-trailer	44	08	1,197	24	32,380	1.06	735.91	2.71
Subtotal	486	.92	17,011	3.36	362,170	11 81	745.21	2.13
All trucks and combinations	8,818	16.76	93,125	18 41	1,021,698	33.31	115 87	1 10
All motor vehicles	52,617	100.00	505,960	100.00	3,067,564	100.00	58.30	.61
Regrouping of vehicle types[c]								
Automobiles and light trucks	49,165	93.44	450,840	89.11	2,256,959	73.57	45 91	50
Medium and heavy trucks and combinations	3,307	6.28	51,556	10 19	752,018	24 52	227 40	1.46

[a] Private and commercial motor vehicles only Publicly owned vehicles, motorcycles, and light trailers omitted.
[b] Public Roads table DF, 1952, gives $3,101,306,000 as the amount of State imposts on highway users collected in 1952 Omitted from the amounts given in this column are $12,859,000 in fines and penalties, $14,117,000 assigned to light trailers, and $6,766,000 assigned to motorcycles
[c] Panels and pickups and other Two-axle Four-tire trucks grouped with passenger cars

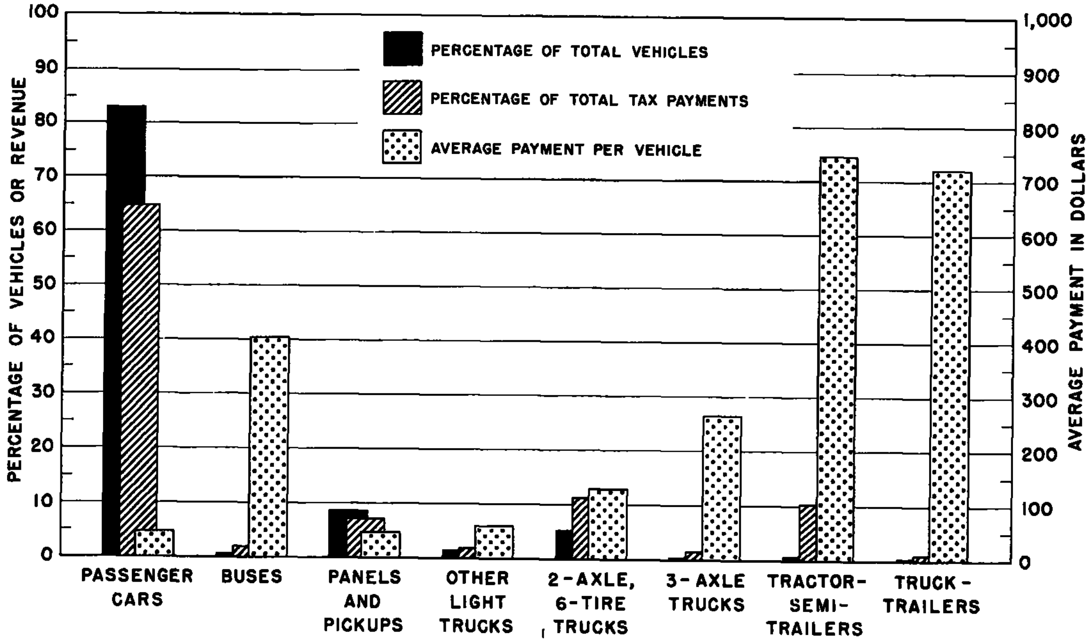

Figure 12. Comparison of registrations and tax payments by vehicle groups.

cents. The average for all vehicles was 0.61 cents per mile of travel. When automobiles and light trucks are combined, the average payment per mile comes out exactly at ½ cent. Medium and heavy trucks and combinations, taken as a group, contributed 1.46 cents per vehicle-mile.

Among the general group of trucks and combinations, it is found that two-axle, four-tire trucks paid between 0.6 and 0.7 cents per mile of travel. Two-axle, six-tire trucks paid 1.05 cents per vehicle-mile, and three-axle trucks 2.49 cents, the average for single-unit trucks being 0.87 cents. The rate per vehicle-mile for combinations as a group was 2.13, tractor-

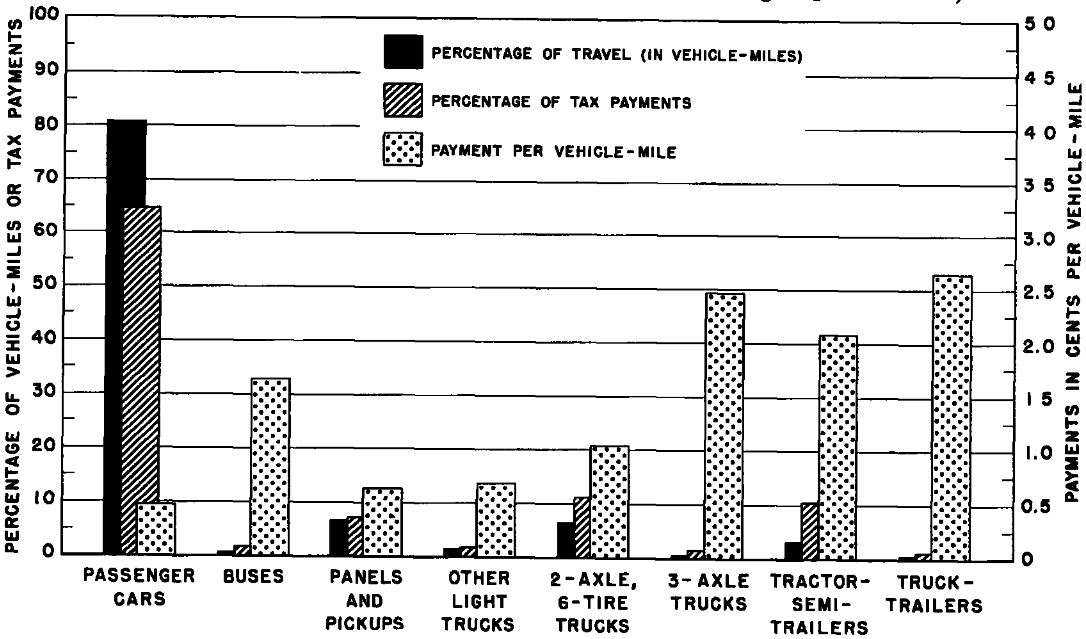

Figure 13. Comparison of travel, tax payments, and payments per vehicle mile.

semitrailer combinations paying 2.09 cents per mile and truck-trailer combinations 2.71 cents.

In the interpretation of these figures it should be borne in mind that they are nation-wide totals and averages derived by processing in various ways the data reported by 48 states and the District of Columbia, each of which has its own schedule of user taxes, with the rates of payment differing widely from state to state. The vehicles of each type and size group may contribute relatively more in one state and relatively less in another. The findings of this study summarize the situation as a whole, giving approximate values of the aggregate and average payments by each vehicle group, and thereby affording comparisons of the extent to which each group shares in the total burden of state road-user taxation.

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Gasoline Consumption, Weight, and Mileage of Commercial Vehicles

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From a study conducted by the Ford Motor Company in 1950 through cooperation of the owners of 5,591 Ford trucks of 1948-, 1949-, and 1950-year models, a summary of monthly mileage, gross vehicle weight, and gasoline consumption is presented for eight models of single-unit trucks and three models of tractor-semitrailer combinations.

These summaries show a wide variation in each of these three characteristics of use. The range of mileage for the middle 80 percent of the lightest-capacity truck was from 600 to 2,300 miles a month, with 100 percent of these models being driven between 100 and 11,000 miles a month. The range in mileage for the middle 80 percent of the tractor-semitrailer combinations was 1,300 to 7,000 miles a month.

The middle 80 percent of the lightest trucks ranged in gross weight from 3,625 to 4,700 lb. Other single-unit trucks with four tires ranged from 4,625 to 8,150 lb. for the middle 80 percent. The middle 80 percent of the single-unit trucks with dual rear tires ranged from 10,000 to 22,600 lb. The tractor-semi-trailer combinations ranged from 28,500 to 53,000 lb. in weight for the middle 80 percent. The median weight was close to 40,000 lb.

The gasoline consumption of the lightest models ranged from 11.1 to 17.2 miles per gallon for the middle 80 percent with the other single-unit, four-tired vehicles having a range of 8.6 to 15.0 miles per gallon. Similarly, the single-unit, six-tired trucks ranged from 6.2 to 10.8 miles per gallon. The tractor-semitrailer combinations had a range of 4.6 to 8.7 miles per gallon for the middle 80 percent.

These wide ranges in monthly mileage, gross vehicle weight, and gasoline consumption indicate that the performance of any particular vehicle or fleet of vehicles should not be used as representing the average for all vehicles of that class until thorough investigation has shown the particular data to be representative.

The correlation of mileage and gasoline consumption with weight lacks exactness because of not having a sufficient number of vehicles in each 1,000-lb. gross-weight class to fix the location of the gasoline consumption curve throughout its range. The analyses show an increase in rate of gasoline consumption with increasing weight. There is also an increase in monthly mileage with increase in weight. The miles per gallon of gasoline consumed is somewhat higher for weights above 8,000 lb. than given in past published reports for all vehicles. Information available is not sufficient to determine which reports are the more appropriate to use in highway financial and taxation analyses.

A desirable approach to the determination of the average annual mileage and fuel consumption of vehicles registered in a given state would be to statistically select the sample of vehicles, then have accurate records on these vehicles kept for one year.

●ANNUAL mileage, gross weight, and fuel consumption of motor vehicles are three important sets of information needed in highway planning, financial-need studies, studies of highway-user contributions, and in setting rates of highway-user taxes. Despite the importance of these three items to highway and motor vehicle administration, there is a scarcity of reliable data with which to work or on which to base practical applications in planning legislation.

Because of the scarcity of reliable information on annual mileages and road weights of vehicles as related to fuel consumption, investigators and analysts, of necessity, have used what information was available. Because of the wide variation, vehicle to vehicle, in annual mileage, vehicle gross weight, and fuel consumption, the applicability to general studies of just any data available can justifiably be questioned.

The objective of this paper is not to present data for general application in studies which require annual mileage, gross vehicle weight, and fuel consumption, but the objective is to present information to show that extreme care should be exercised in selecting such values for any study involving highway planning, financial needs, taxation, and engineering economy analyses.

The range of annual mileage, the range of gross vehicle weight, and the range of fuel consumption per mile for the vehicles in any specific class are so great that any given report of the performance of a specific vehicle or a fleet of vehicles should be questioned and thoroughly checked before accepting the report for use in any general highway investigation or analysis.

Another point of caution that should be observed is related to the ownership of vehicles. Perhaps less than 2 percent of passenger-car owners keep complete and accurate cost of their operation; the percentage for commercial vehicles may be somewhat larger. But even when accurate costs are available, there is still the need for verification of the cost data to ascertain what cost items are included and how the unit costs were determined. The author has examined reports of passenger-car operation as kept by many individual owners. Rarely did he find two owners that kept their records on the same basis of accounting classification. Likewise, commercial firms have submitted to him reports of their motor-truck operation, but because of the basic differences in accounting systems, it was seldom possible to combine these reports to reach a composite figure of operating cost.

When it is realized that so few vehicle owners keep records of their operating costs, mileages, and weights and that those owners who do keep such records use their own scheme of accounting and record keeping, it should be evident that any offhand report by an owner of what his fuel consumption is, what his annual mileage is, or what his general operating cost is, is information that should be received with but little note. That individual reports of mileage, gross vehicle weight, and fuel consumption bear no known relation to statewide or nationwide average performance should be evident from an examination of the data reported herein for Ford trucks.

THE FORD MOTOR COMPANY STUDY

The data reported in this paper were made available to the author by the Ford Motor Company. It was gathered by the Company in 1950 through the cooperation of 5,591 owners of Ford trucks distributed throughout the 48 states. The detailed data for each of the 5,591 trucks were published by the Ford Motor Company in 1951 under the title, "Final Results—50-Million Mile Ford Truck Economy Run."

The Ford study was conducted for 6 months, July through December 1950. The records for trucks operating less than 4 months were excluded from the final tabulations. The trucks were 1948-, 1949-, and 1950-year models, thus comparatively new when considered in relation to the complete registration in any state for a given year.

The published report by Ford gives the truck body type, place of ownership, and owner's vocation for each truck. Geographical distribution is countrywide; all normal uses of the truck and truck combinations are represented. Twenty-four single-unit, three-axle trucks were removed from this analysis because of the small number.

Table 1 presents the main descriptive information for each of the basic eight models of the Ford truck line. Bodies include a typical selection of the types commonly encountered in general use.

The data on miles driven, load carried, and fuel consumption as published by Ford forms the basis of this analysis. The original publication did not assemble the information in a manner to bring out the wide range of variation, or the relationship of gasoline consumption and monthly mileage to gross vehicle weight.

Any application of the data herein presented should be made with appropriate consideration of the source and quality of the data as originally published.

ADJUSTMENTS IN THE DATA

The original survey did not report the weight of the vehicles empty, or what is sometimes referred to as curb weight.

TABLE 1

NUMBER AND DESCRIPTION OF FORD TRUCK MODELS INCLUDED IN THE FIELD STUDY

Model[a]	Number Vehicles in Study	Recommended Tire Size and Ply Rating		Maximum Brake Horsepower		Manufacturers' Gross Vehicle Weight Rating	
		Min.	Max.	Min.	Max.	Min.	Max
						lb.	lb.
F-1	1,756	6.00-16-6	6 50-16-6	95	100	4,000	4,700
F-2	303	6 50-16-6	7.50-16-6	95	100	4,900	5,700
F-3	514	7.00-17-6	7.50-17-8	95	100	5,600	6,800
F-4	171	7 20-18-8	7.00-20-8	95	100	7,500	10,000
F-5	618	6 50-20-6	7.50-20-8	95	100	10,000	14,000
F-6	1,325	7.50-20-8	8.25-20-10	95	110	14,000	16,000
F-7	120	8.25-20-10	9.00-20-10	-	145	17,000	19,000
F-8	92	9 00-20-10	10.00-20-12	-	145	20,000	22,000
F-5s[b]	21	-	7.50-20-8	95	100	-	24,000
F-6s	216	-	8.25-20-10	95	110	-	28,000
F-7s	144	-	9.00-20-10	-	145	-	35,000
F-8s	292	-	10.00-20-12	-	145	-	39,000
Total	5,572	-	-	-	-	-	-

[a] The trucks were 1948, 1949, and 1950 models. The 24 three-axle, single-unit trucks reported are not included in any of the tables herein presented. The letter "s" denotes a tractor-semitrailer combination.

[b] These 21 Model F-5s tractor-semitrailers are consolidated with the Model F-6s in all summaries and analyses

Note The F-5 to F-8 models are with dual rear wheels. The heavier gross vehicle weight rating in the F-4, also is for dual rear wheels.

These weights were supplied by reference to the Ford Truck Handbook for F-1 to F-6 models and body types supplied by the company, mainly panel, pickup, express, stake, and platform. For Models F-7 and F-8 and for other body types, the chassis weight was taken from the Ford Handbook to which was added an appropriate weight for the body as selected from information furnished by body manufacturers. The empty weight of the semitrailers was supplied by selection from the equipment supplied by other manufacturers. To the empty vehicle weight was added the "average monthly load carried" to obtain the average gross vehicle weight.

A few trial listings of the cards disclosed two dozen or so punchings that appeared completely out of reasonable range. In such case the card was discarded, or repunched to a reasonable figure if a basis for ascertaining the reasonable value was discovered.

There is no reason not to accept the data as being reliable and honestly supplied. As is true with any study dealing with a large cross-section of individuals, the information so supplied will include certain errors of judgment, omissions, duplications, and arithmetical mistakes. Perhaps a few fillings of the fuel tank were not recorded and the loads carried may have been estimated, but the mileage reported should be accurate because of the control of the odometer. It is acknowledged that this study lacks the controls which the true researcher would provide, but such a research person has not yet found the means to conduct a fully controlled study of the use and overall performance of motor trucks. Until he does conduct such a study, applications of mileage, fuel consumption, and the related gross weight to highway planning, financial, and taxation analyses must be based upon less-reliable, but nevertheless useful, reports.

ANALYSIS OF THE MILEAGE DATA

The range of miles driven per month for each model is given in Table 2. The lighter-capacity models were driven as little as 100 to 199 miles a month and the heavier capacity models as little as 400 to 499 miles a month. The heavier vehicles, particularly the tractor-semitrailer combinations, have a concentration in the range of 3,000 to 7,000 miles a month. This concentration decreases as the vehicle capacity becomes less until for the Model F-1, the most-frequent monthly mileage is 900 to 999 miles. The upper limit of mileage is about 10,000 miles a month for most of the models.

The mileage frequencies of Table 2 were summed for Model F-1; Models F-2, F-3, F-4; Models F-5, F-6, F-7, F-8; and for the tractor-semitrailer combinations and converted to percentage of the total in each class. The F-1 model is kept separate because of the large number of vehicles in proportion to other models and because of its type of use. The cumulative percentage curves plotted in Figure 1 show that the spread of monthly mileage becomes greater as the load capacity of vehicle increases. The spread for the lower 10 percent is relatively small, and the spread for the upper 10 percent is relatively great. For the F-1 vehicles the percentage group from 10 to 90 percent ranges from 600 to 2,250 miles with 100 percent of the vehicles falling below 11,000 miles a month.

The group of other single-unit, four-tired trucks have a spread for the middle 80 percent of from 500 to 2,350 miles a month, and the distribution curve is approximately the same as for the F-1 group. The middle 80 percent of the single-unit, six-tired trucks (F-5 to F-8 models) spread from 700 to 3,600 miles a month. The tractor-semitrailer combinations range from 1,400 to 7,000 miles a month considering only the middle 80 percent. Thus, these heavier capacity vehicles exhibit a much greater spread in monthly mileage above and below the average mileage than do the lighter-capacity models.

ANALYSIS OF GROSS VEHICLE WEIGHT

In Table 3 the frequency distribution of average gross vehicle weight (empty ve-

TABLE 2

DISTRIBUTION OF VEHICLES BY MILES PER MONTH FOR EACH VEHICLE MODEL

Miles Per Month Class Interval	Number of Vehicles by Models											
	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-6s	F-7s	F-8s	All
0- 99	-	-	-	-	-	1	-	-	-	-	-	1
100- 199	1	-	2	1	2	1	-	-	-	-	-	7
200- 299	12	4	8	3	11	8	-	-	-	-	-	46
300- 399	27	13	12	9	14	9	-	-	-	-	-	84
400- 499	53	22	33	5	20	15	-	-	2	-	1	151
500- 599	90	12	27	5	44	25	4	-	1	1	1	210
600- 699	105	20	33	14	30	24	3	2	5	2	0	238
700- 799	110	20	30	6	26	36	3	3	2	4	3	243
800- 899	120	29	32	7	42	48	3	2	2	2	2	289
900- 999	157	21	37	4	42	43	3	1	6	2	3	319
1,000- 1,099	113	22	41	10	28	54	4	2	3	0	1	278
1,100- 1,199	123	16	40	16	26	50	5	3	5	1	2	287
1,200- 1,299	117	20	22	6	29	64	5	5	4	0	2	274
1,300- 1,399	101	15	30	8	22	50	3	4	7	2	2	244
1,400- 1,499	87	13	28	8	28	67	8	1	7	1	2	250
1,500- 1,599	75	12	16	9	23	56	5	3	6	2	3	210
1,600- 1,699	62	8	15	5	28	46	2	4	5	3	2	180
1,700- 1,799	55	13	14	4	24	41	1	2	9	1	4	168
1,800- 1,899	40	8	10	2	11	50	3	2	5	1	3	135
1,900- 1,999	36	5	12	5	17	47	0	1	10	2	4	139
2,000- 2,099	41	3	7	5	30	35	5	4	8	0	4	142
2,100- 2,199	36	1	9	2	14	26	6	1	5	3	3	106
2,200- 2,299	21	3	8	6	7	42	2	3	10	1	3	106
2,300- 2,399	28	1	6	1	4	31	2	1	3	3	5	85
2,400- 2,499	21	2	3	1	8	31	4	3	5	1	7	86
2,500- 2,599	16	1	3	1	9	45	6	7	5	5	2	100
2,600- 2,699	19	1	4	4	10	25	5	5	8	2	6	89
2,700- 2,799	15	2	5	1	9	31	1	4	10	7	3	88
2,800- 2,899	17	1	2	1	7	26	3	1	5	2	5	70
2,900- 2,999	6	2	4	1	3	27	2	2	4	0	3	54
3,000- 3,499	20	4	9	9	21	105	6	9	17	13	15	228
3,500- 3,999	13	1	5	3	17	68	9	3	21	17	26	183
4,000- 4,499	4	2	2	4	5	42	5	2	15	11	18	110
4,500- 4,999	4	2	2	2	2	22	4	7	9	14	26	94
5,000- 5,499	4	0	1	1	2	19	2	0	7	9	28	73
5,500- 5,999	2	1	1	0	2	6	3	2	6	6	27	56
6,000- 6,999	2	1	1	2	0	4	1	3	12	13	32	71
7,000- 7,999	1	1	-	-	0	2	1	-	4	9	21	39
8,000- 8,999	1	1	-	-	0	2	0	-	3	2	12	21
9,000- 9,999	0	-	-	-	1	1	1	-	0	1	4	8
10,0000-10,999	1	-	-	-	-	-	-	-	1	0	3	5
11,000 & over	-	-	-	-	-	-	-	-	-	1	4	5
Totals	1,756	303	514	171	618	1,325	120	92	237	144	292	5,572

TABLE 3

DISTRIBUTION OF VEHICLES BY GROSS VEHICLE ROAD WEIGHT FOR EACH VEHICLE MODEL

Gross Vehicle Weight Class Interval in Pounds	Number of Vehicles by Models											
	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-6s	F-7s	F-8s	Total
3,200- 3,299	10	-	-	-	-	-	-	-	-	-	-	10
3,300- 3,399	9	-	-	-	-	-	-	-	-	-	-	9
3,400- 3,499	39	-	-	-	-	-	-	-	-	-	-	39
3,500- 3,599	80	-	-	-	-	-	-	-	-	-	-	80
3,600- 3,699	119	-	-	-	-	-	-	-	-	-	-	119
3,700- 3,799	193	-	-	-	-	-	-	-	-	-	-	193
3,800- 3,899	160	-	-	-	-	-	-	-	-	-	-	160
3,900- 3,999	177	-	-	-	-	-	-	-	-	-	-	177
4,000- 4,099	156	4	1	-	-	-	-	-	-	-	-	161
4,100- 4,199	124	5	0	-	-	-	-	-	-	-	-	129
4,200- 4,299	185	1	0	-	-	-	-	-	-	-	-	186
4,300- 4,399	96	14	6	-	-	-	-	-	-	-	-	116
4,400- 4,499	112	10	4	-	-	-	-	-	-	-	-	126
4,500- 4,599	41	16	6	-	-	-	-	-	-	-	-	63
4,600- 4,699	60	17	10	-	-	-	-	-	-	-	-	87
4,700- 4,799	44	15	15	-	-	-	-	-	-	-	-	74
4,800- 4,899	25	22	11	-	-	-	-	-	-	-	-	58
4,900- 4,999	34	17	21	-	-	-	-	-	-	-	-	72
5,000- 5,099	19	18	28	-	-	-	-	-	-	-	-	65
5,100- 5,199	15	16	17	-	-	-	-	-	-	-	-	48
5,200- 5,299	12	15	25	-	-	-	-	-	-	-	-	52
5,300- 5,399	9	26	23	-	-	-	-	-	-	-	-	58
5,400- 5,499	4	14	26	-	-	-	-	-	-	-	-	44
5,500- 5,599	9	13	37	-	-	-	-	-	-	-	-	59
5,600- 5,699	10	11	11	4	-	-	-	-	-	-	-	36
5,700- 5,799	6	10	22	2	-	-	-	-	-	-	-	40
5,800- 5,899	5	15	22	0	-	-	-	-	-	-	-	42
5,900- 5,999	1	4	18	4	-	-	-	-	-	-	-	27
6,000- 6,499	2	15	97	14	2	1	-	-	-	-	-	131
6,500- 6,999	-	13	45	16	5	1	-	-	-	-	-	80
7,000- 7,499	-	6	34	27	7	1	-	-	-	-	-	75
7,500- 7,999	-	5	22	30	24	3	-	-	-	-	-	84
8,000- 8,499	-	1	11	21	22	10	-	-	-	-	-	65
8,500- 8,999	-	-	1	18	34	2	-	-	-	-	-	55
9,000- 9,499	-	-	1	10	32	5	-	-	-	-	-	48
9,500- 9,999	-	-	-	9	61	13	-	-	-	-	-	83
10,000- 10,499	-	-	-	5	40	20	-	-	-	-	-	65
10,500- 10,999	-	-	-	5	41	28	-	-	-	-	-	74
11,000- 11,499	-	-	-	1	48	16	-	-	-	-	-	65
11,500- 11,999	-	-	-	2	49	31	-	-	-	-	-	82
12,000- 12,499	-	-	-	2	35	46	1	-	-	-	-	84
12,500- 12,999	-	-	-	1	48	50	0	-	-	-	-	99
13,000- 13,499	-	-	-	-	31	44	1	-	-	-	-	76
13,500- 13,999	-	-	-	-	36	42	0	-	1	-	-	79
14,000- 14,499	-	-	-	-	11	52	1	-	0	-	-	64
14,500- 14,999	-	-	-	-	24	65	0	1	1	-	-	91
15,000- 15,499	-	-	-	-	13	58	4	0	0	-	-	75
15,500- 15,999	-	-	-	-	15	75	2	0	0	-	-	92
16,000- 16,499	-	-	-	-	9	63	0	2	0	-	-	74
16,500- 16,999	-	-	-	-	10	62	5	0	2	-	-	79
17,000- 17,499	-	-	-	-	5	61	2	0	-	-	-	68
17,500- 17,999	-	-	-	-	4	58	3	2	-	-	-	67
18,000- 18,499	-	-	-	-	3	64	3	1	1	-	-	72
18,500- 18,999	-	-	-	-	4	60	4	1	0	-	-	69
19,000- 19,499	-	-	-	-	3	46	4	1	0	-	-	54
19,500- 19,999	-	-	-	-	1	64	7	2	1	-	-	75
20,000- 20,999	-	-	-	-	1	87	9	4	3	1	-	105
21,000- 21,999	-	-	-	-	-	86	9	1	1	0	-	97
22,000- 22,999	-	-	-	-	-	54	9	6	2	0	-	70
23,000- 23,999	-	-	-	-	-	46	9	5	6	0	1	67
24,000- 24,999	-	-	-	-	-	10	14	7	5	2	0	38
25,000- 25,999	-	-	-	-	-	1	12	7	9	1	0	30
26,000- 26,999	-	-	-	-	-	-	9	10	5	7	0	31
27,000- 27,999	-	-	-	-	-	-	6	13	10	0	2	31
28,000- 28,999	-	-	-	-	-	-	3	10	15	1	2	31
29,000- 29,999	-	-	-	-	-	-	2	3	7	1	3	16
30,000- 30,999	-	-	-	-	-	-	1	7	17	0	1	26
31,000- 31,999	-	-	-	-	-	-	-	7	16	1	2	26
32,000- 32,999	-	-	-	-	-	-	-	1	10	5	4	20
33,000- 33,999	-	-	-	-	-	-	-	2	11	6	4	23
34,000- 34,999	-	-	-	-	-	-	-	-	17	2	3	22
35,000- 35,999	-	-	-	-	-	-	-	-	20	7	2	29
36,000- 36,999	-	-	-	-	-	-	-	-	17	4	6	27
37,000- 37,999	-	-	-	-	-	-	-	-	8	13	8	29
38,000- 38,999	-	-	-	-	-	-	-	-	10	9	20	39
39,000- 39,999	-	-	-	-	-	-	-	-	7	7	13	27
40,000- 40,999	-	-	-	-	-	-	-	-	11	10	18	39
41,000- 41,999	-	-	-	-	-	-	-	-	3	6	16	25
42,000- 42,999	-	-	-	-	-	-	-	-	3	7	13	23
43,000- 43,999	-	-	-	-	-	-	-	-	3	11	13	27
44,000- 44,999	-	-	-	-	-	-	-	-	4	5	16	25
45,000- 45,999	-	-	-	-	-	-	-	-	2	5	21	28
46,000- 46,999	-	-	-	-	-	-	-	-	2	6	10	18
47,000- 47,999	-	-	-	-	-	-	-	-	2	2	10	14
48,000- 48,999	-	-	-	-	-	-	-	-	1	5	12	18
49,000- 49,999	-	-	-	-	-	-	-	-	1	2	12	15
50,000- 50,999	-	-	-	-	-	-	-	-	1	3	7	11
51,000- 51,999	-	-	-	-	-	-	-	-	1	0	7	8
52,000- 52,999	-	-	-	-	-	-	-	-	0	1	11	12
53,000- 53,999	-	-	-	-	-	-	-	-	0	3	6	9
54,000- 54,999	-	-	-	-	-	-	-	-	1	2	7	10
55,000- 55,999	-	-	-	-	-	-	-	-	-	2	4	6
56,000- 56,999	-	-	-	-	-	-	-	-	-	2	9	11
57,000- 57,999	-	-	-	-	-	-	-	-	-	3	10	13
58,000- 58,999	-	-	-	-	-	-	-	-	-	0	3	3
59,000- 59,999	-	-	-	-	-	-	-	-	-	0	2	2
60,000- 60,999	-	-	-	-	-	-	-	-	-	1	2	3
61,000- 61,999	-	-	-	-	-	-	-	-	-	0	2	2
62,000- 62,999	-	-	-	-	-	-	-	-	-	0	1	1
63,000- 63,999	-	-	-	-	-	-	-	-	-	0	0	0
64,000- 64,999	-	-	-	-	-	-	-	-	-	-	2	2
65,000- 65,999	-	-	-	-	-	-	-	-	-	-	3	3
66,000- 66,999	-	-	-	-	-	-	-	-	-	-	1	1
67,000- 67,999	-	-	-	-	-	-	-	-	-	-	2	2
68,000- 69,000	-	-	-	-	-	-	-	-	-	-	1	1
77,000- 78,000	-	-	-	-	-	-	-	-	-	1	-	1
Totals	1,756	303	514	171	618	1,325	120	92	237	144	292	5,572

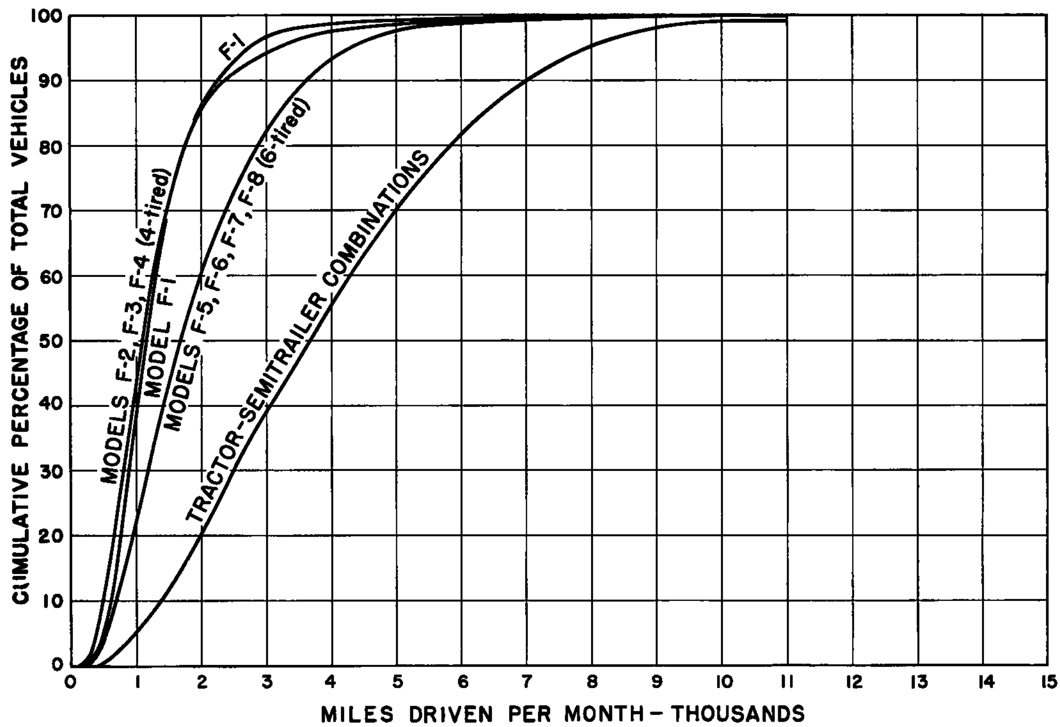

Figure 1. Cumulative percentage distribution of vehicles in order of increasing number of miles driven per month.

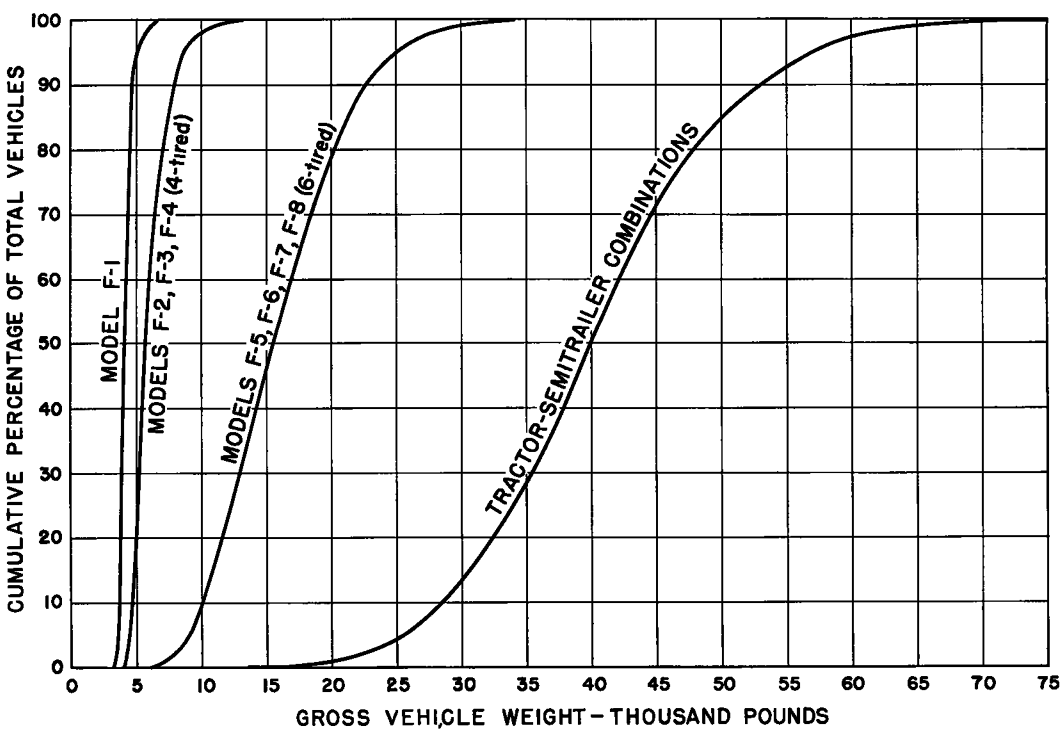

Figure 2. Cumulative percentage distribution of vehicles in order of increasing gross vehicle weight.

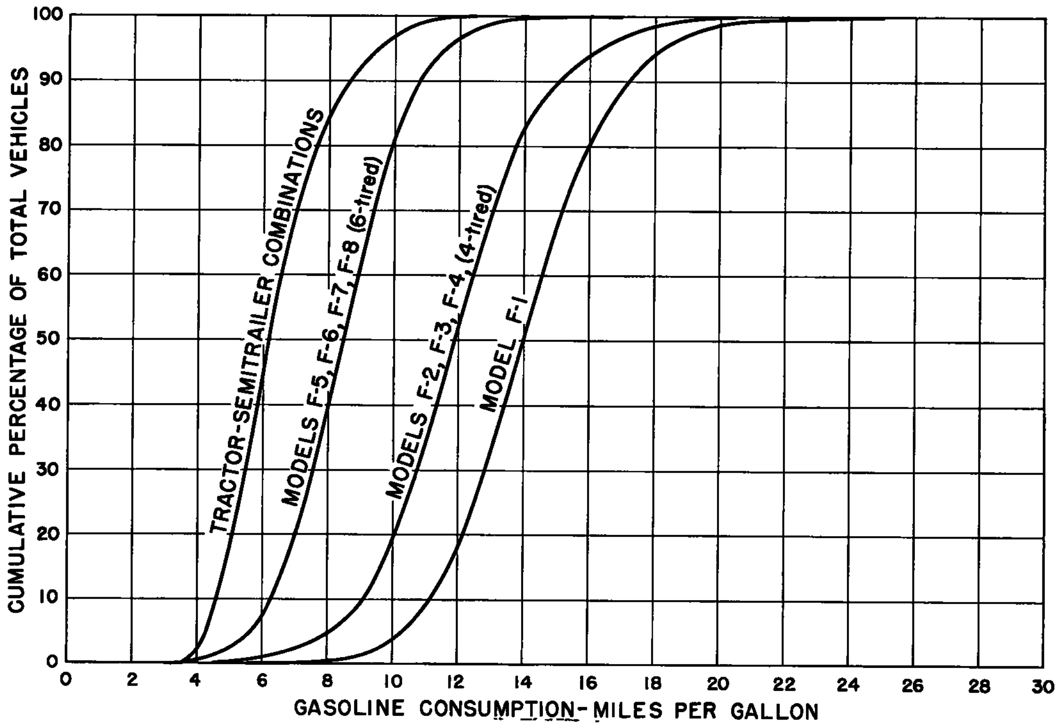

Figure 3. Cumulative percentage distribution of vehicles in order of increasing gasoline consumption in miles per gallon.

hicle weight plus average payload carried) is shown for each truck model. Here again, there is a considerable range in weight for each model, with the heavier models having the greater range. Because the empty weight of the light models has a small range and because the gross load limits of the light models are relatively low, it follows that the range in gross weight is correspondingly low as compared to the heavier models. The single-unit trucks show but a small range of overlap in gross weight with the tractor combinations. Although Table 3 lists one tractor-semitrailer combination Model F-6s in the 13,500-to-13,999-lb. group and two single-unit F-8 models in the 33,000-to-33,999-lb. group, the only significant overlap comes in the range of 23,000 to 32,000 lb.

The cumulative percentage distribution curves of weight are shown in Figure 2. The Model F-1 curve is practically a straight line, nearly vertical, between 5 percent and 90 percent, and covering the range of 3,600 to 4,700 lb. The 10-and 90-percent levels include the range of 3,650 to 4,700 lb.

The curve in Figure 2 for the other single-unit, four-tired models follows

TABLE 4

DISTRIBUTION OF VEHICLES BY MILES PER GALLON OF GASOLINE FOR FOR EACH VEHICLE MODEL

Miles Per Month Class Interval	Number of Vehicles by Models											
	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-6s	F-7s	F-8s	Total
Less than 3 0	-	-	-	-	-	1	-	-	-	-	-	1
3 0 - 3 4	-	-	-	-	-	2	-	1	-	-	-	3
3 5 - 3 9	-	-	-	-	-	2	1	4	-	3	10	20
4 0 - 4 4	-	-	1	-	2	4	2	8	-	4	37	58
4 5 - 4 9	-	-	1	-	3	5	5	11	3	9	50	87
5 0 - 5 4	-	-	0	-	4	16	8	12	6	20	63	129
5 5 - 5 9	1	-	7	-	6	35	17	11	18	38	52	185
6 0 - 6 4	0	-	3	3	13	69	13	17	28	17	30	202
6 5 - 6 9	0	1	5	1	25	92	19	12	27	22	20	224
7 0 - 7 4	3	1	5	1	35	141	17	5	38	11	9	266
7 5 - 7 9	3	1	6	5	41	158	16	7	28	9	6	280
8 0 - 8 4	8	0	9	13	61	186	9	2	24	5	3	320
8 5 - 8 9	12	3	8	12	76	149	6	0	22	4	2	294
9 0 - 9 4	10	6	18	19	88	128	5	1	9	2	1	287
9 5 - 9 9	27	10	27	23	70	118	1	1	14	-	-	291
10 0 - 10 4	36	22	28	23	66	70	1	-	9	-	-	255
10 5 - 10 9	60	16	38	17	32	55	-	-	8	-	-	226
11 0 - 11 4	67	33	46	11	34	36	-	-	0	-	-	227
11 5 - 11 9	93	34	47	15	25	27	-	-	1	-	-	242
12 0 - 12 4	121	26	47	7	10	18	-	-	2	-	-	231
12 5 - 12 9	134	33	47	7	8	5	-	-	-	-	-	234
13 0 - 13 4	156	34	38	8	6	1	-	-	-	-	-	243
13 5 - 13 9	148	20	33	1	6	3	-	-	-	-	-	211
14 0 - 14 4	171	12	25	2	1	1	-	-	-	-	-	212
14 5 - 14 9	122	9	18	0	2	1	-	-	-	-	-	152
15 0 - 15 4	125	9	15	1	1	0	-	-	-	-	-	151
15 5 - 15 9	106	5	12	1	1	2	-	-	-	-	-	127
16 0 - 16 4	86	9	7	0	1	-	-	-	-	-	-	103
16 5 - 16 9	75	4	6	0	1	-	-	-	-	-	-	86
17 0 - 17 4	58	2	6	1	-	-	-	-	-	-	-	67
17 5 - 17 9	28	6	5	-	-	-	-	-	-	-	-	39
18 0 - 18 4	32	2	3	-	-	-	-	-	-	-	-	37
18 5 - 18 9	27	2	3	-	-	-	-	-	-	-	-	32
19 0 - 19 4	14	2	-	-	-	-	-	-	-	-	-	16
19 5 - 19 9	10	0	-	-	-	-	-	-	-	-	-	10
20 0 - 20 4	9	1	-	-	-	-	-	-	-	-	-	10
20 5 - 20 9	4	-	-	-	-	-	-	-	-	-	-	4
21 0 - 21 4	3	-	-	-	-	-	-	-	-	-	-	3
21 5 - 21 9	2	-	-	-	-	-	-	-	-	-	-	2
22 0 - 22 4	1	-	-	-	-	-	-	-	-	-	-	1
22 5 - 22 9	1	-	-	-	-	-	-	-	-	-	-	1
23 0 - 23 4	2	-	-	-	-	-	-	-	-	-	-	2
23 5 - 23 9	0	-	-	-	-	-	-	-	-	-	-	0
24 0 & over	1	-	-	-	-	-	-	-	-	-	-	1
Totals	1,756	303	514	171	618	1,325	120	92	237	144	292	5,572

closely to the F-1 curve. The 80-percent range is from 4,700 to 7,900 lb. For the six-tired, single-unit trucks, the curve in Figure 2 at the 10- and 90-percent levels intercepts the weight range from 10,000 to about 22,700 lb.

The tractor-semitrailer combinations present a weight-distribution curve that approaches the statistical normal frequency distribution. The center of the curve at 50 percent is at about 40,000 lb. The 10- and 90-percent levels intercept the range of 28,500 to 53,000 lb., with the minimum and maximum gross vehicle weights being 13,500 and 78,000 lb.

As discussed in a subsequent section on the relation of gasoline consumption to gross vehicle weight, the weights used in this analysis are perhaps overstated. The original study seems to include as the "average monthly load carried" the total payload hauled instead of the average payload hauled over the full round-trip distance or for the total miles driven daily. Further, the weights estimated for the single-unit bodies and the complete semitrailers are probably too high.

ANALYSIS OF GASOLINE CONSUMPTION

Tables 2 and 3 and Figures 1 and 2 for mileage and weight present variations in vehicle use that vary mainly with the type of use the owner subjects the vehicle to, rather than with fundamental characteristics of the vehicle. In Table 4 and Figure 3 the gasoline-consumption distribution is shown for the same four groups of vehicles. Fuel consumption varies with the characteristics of the engine, gear ratios, type of use, gross weight, care of the vehicle, technique of the driver, topography, weather, and many other factors not within the control of the owner or driver. The distributions of miles per gallon in Table 4 are of consistent pattern with respect to range and with the relative vehicle weights of the models. The F-1 models range in gasoline consumption from 5.5 miles per gallon to over 24.0, with the model consumption being about 14 miles. The F-8s semitrailer combination varied in gasoline consumption from 3.5 to 9.4 miles per gallon.

The range in gasoline consumption is

TABLE 5

RELATION OF GROSS VEHICLE WEIGHT TO MILES PER GALLON AND MILES PER MONTH FOR SINGLE-UNIT TRUCKS, ALL MODELS

Gross Vehicle Weight Class Interval	Number of Vehicles	Average GVW	Average Miles Per Gallon	Average Miles Per Month
lb.		lb.		
3,000- 3,999	787	3,704	14.07	1,278
4,000- 4,999	1,072	4,356	13.53	1,319
5,000- 5,999	471	5,397	12.51	1,324
6,000- 6,999	211	6,370	11.13	1,418
7,000- 7,999	159	7,429	10.49	1,512
8,000- 8,999	120	8,416	9 92	1,502
9,000- 9,999	138	9,494	9.17	1,557
10,000-10,999	139	10,480	8.92	1,533
11,000-11,999	147	11,476	9.02	1,595
12,000-12,999	183	12,482	8.77	1,779
13,000-13,999	154	13,460	8.49	1,739
14,000-14,999	154	14,493	8.37	1,923
15,000-15,999	167	15,451	8.20	1,899
16,000-16,999	151	16,454	8 52	2,140
17,000-17,999	135	17,418	8.44	1,925
18,000-18,999	140	18,432	7.99	2,052
19,000-19,999	128	19,431	8.23	2,091
20,000-20,999	101	20,363	7.86	2,270
21,000-21,999	96	21,414	7.84	2,544
22,000-22,999	68	22,401	7.91	2,432
23,000-23,999	60	23,440	7.64	2,862
24,000-24,999	31	24,248	7.15	2,874
25,000-25,999	20	25,190	6 59	2,745
26,000-26,999	19	26,353	6.39	3,040
27,000-27,999	19	27,463	5.73	2,086
28,000-28,999	13	28,415	6.09	2,749
29,000-29,999	5	29,440	6.08	2,483
30,000-30,999	8	30,175	4.88	2,653
31,000-31,999	7	31,314	5.81	3,118
32,000-32,999	1	32,500	4.95	1,614
33,000-33,999	2	33,100	5.92	3,785
Total & Average	4,899	9,700	9.85	1,614

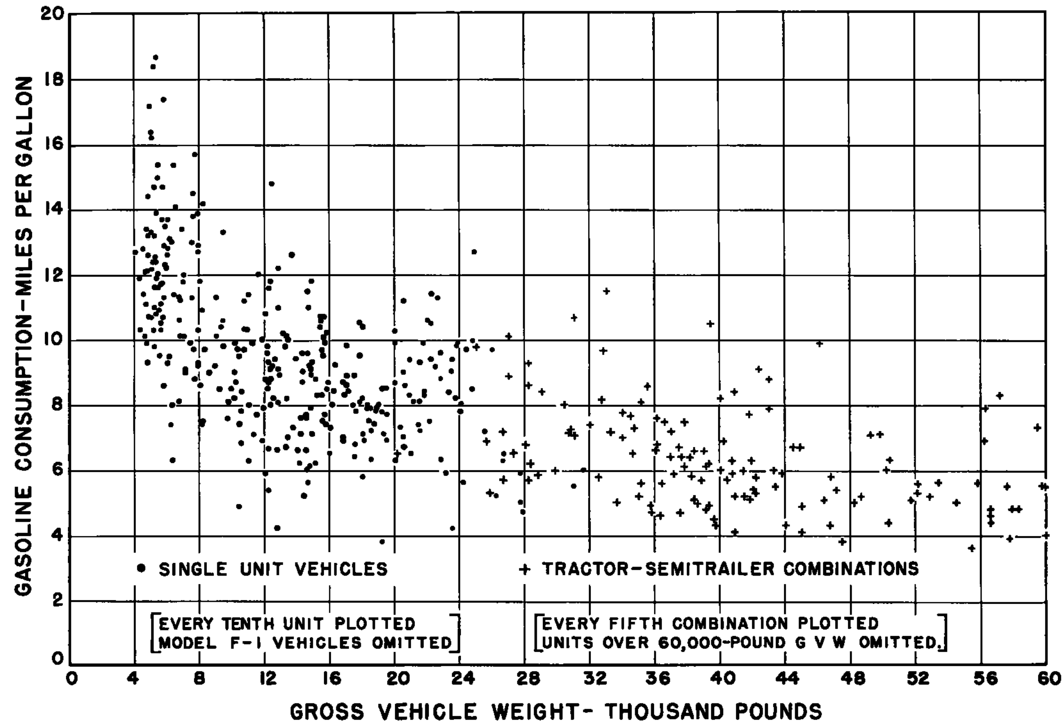

Figure 4. Range of gasoline consumption related to gross vehicle weight.

illustrated in Figure 3. The F-1 model ranges between the 10- and 90-percent levels from 11. 1 to 17. 2 miles per gallon. Other single-unit, four-tired trucks range from 9. 1 to 15. 0 miles per gallon for the same percentage levels. The six-tired, single-unit trucks range from 6. 2 to 10. 8 miles per gallon for the middle 80 percent. The tractor-semitrailer combinations range from 4. 6 to 8. 7 miles per gallon between the 10- and the 90-percent intercepts.

The preceding discussion of mileage, weight, and gasoline consumption illustrates typical ranges in these three items of vehicle use and performance. The ranges are rather widespread. These data are good evidence that for specific models of vehicles the ranges in mileage, road weight, and fuel consumption are such that it is unsafe to use any specific value in highway studies unless reasonable certainty is at hand to prove that such value is applicable to the purposes and conditions of the analysis. When other makes, models, and selections of vehicles are available, frequencies and ranges of values differing from those presented here may be expected. It is to be kept in mind that the trucks reported upon in this study were all of the same make and all of 1948, 1949, and 1950 models.

RELATION OF GASOLINE CONSUMPTION TO GROSS VEHICLE WEIGHT

The tables presented so far indicate that gasoline consumption in gallons per mile and monthly mileage both increase as the loading capacity of the vehicle becomes greater. In many types of taxation, economy, and financial studies, motor-vehicle fuel consumption is related to the gross weight of the vehicle. It is in order, therefore, to see what the relationship is between gasoline consumption and weight for the vehicles reported upon in this Ford study.

Figure 4 is a scatter-diagram plot of the gasoline consumption in miles per gallon against the gross vehicle weight for every tenth single-unit truck and every fifth tractor-semitrailer combination. Figure 4 indicates that there is a tendency for the miles per gallon to decrease with the increase in gross weight, though the exact path of the decrease is uncertain. The scattering of the points both horizontally and vertically is great. For instance, a fuel consumption of between 9 and 10 miles per gallon is shown for vehicles ranging in weight from 5,000 lb. to 46,000 lb. Similarly, for a range of weight from 14,000 to 15,000 lb. the gasoline consumption ranges from 5.2 to 11.8 miles per gallon. The combination vehicles show only slight evidence of increase in gasoline consumption with increase in weight for weights above 40,000 lb. It is evident from Figure 4 that to arrive at a reliable estimate of fuel consumption for any weight class, great statistical care is needed in the selection of the vehicles to study as well as in the analysis of the data collected.

RELATION OF GROSS VEHICLE WEIGHT TO FUEL CONSUMPTION AND TO MONTHLY MILEAGE

Of the three factors—miles driven, gross vehicle weight, and fuel consumption—weight is the one that perhaps has the widest use in highway design, taxation, and financial studies. Weight is also a factor that can be readily determined by weighing on the road. On the other hand, mileage and fuel consumption need to be taken from information furnished by the owners, a not-too-easily accomplished method. As shown by Figure 5, there is a reasonable correlation of weight with both monthly mileage and gasoline consumption.

Tables 5 and 6 were prepared by sorting the tabulating cards into gross-weight groups by 1,000-lb. intervals. From tabulations prepared for each of the weight groups, the average gross vehicle weight, average miles per gallon, and average mileage per month were calculated. The averages are plotted in Figure 5 for all single-unit vehicles and all tractor-semitrailer combinations.

The upper curve of Figure 5 presents a positive indication that the monthly mileage increases with an increase in weight. Beyond 24,000 lb., the exact trend of this increase is not positively defined. The scatter of plotted points is attributed to lack of a sufficient number of vehicles in each 1,000-lb. grouping. Should at least 50 vehicles have been included in each weight group, perhaps the path of the curve would have been accurately defined. In addition to the lack of a sufficiently large number of trucks to determine a reliable average for each weight group, there is a tendency for the vehicles to fall into particular weight groups and particular monthly mileages. The fact that the 5,572 vehicles in the total

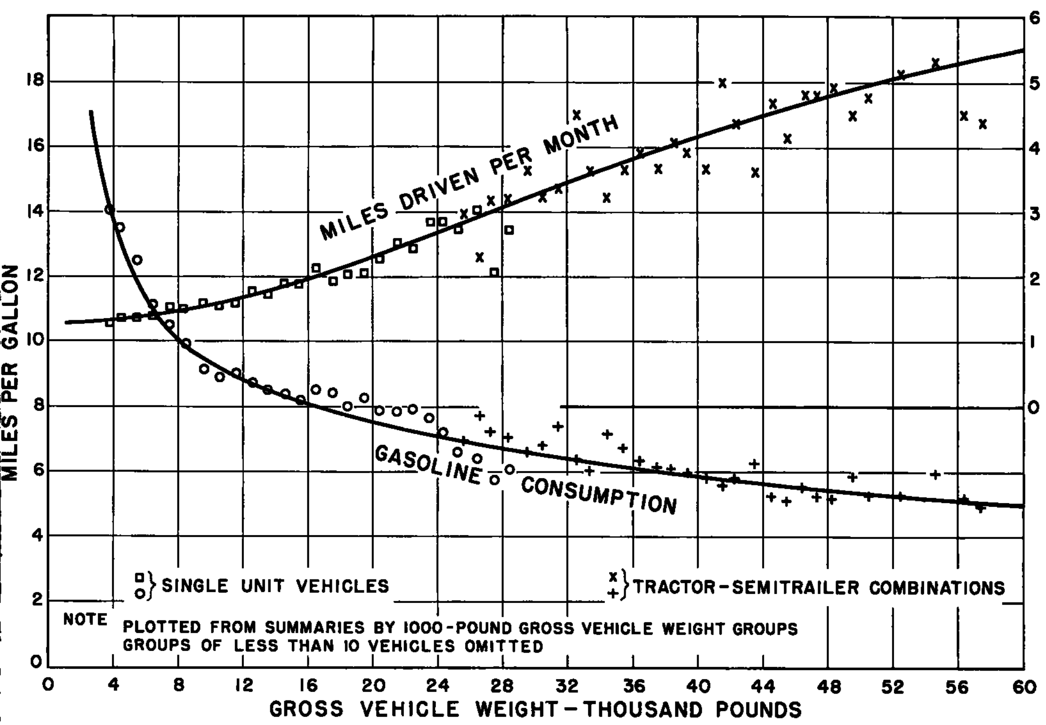

Figure 5. Average gasoline consumption and miles driven per month.

TABLE 6

RELATION OF GROSS VEHICLE WEIGHT TO MILES PER GALLON AND MILES PER MONTH FOR TRACTOR-SEMI"RAILER COMBINATIONS, ALL MODELS

Gross Vehicle Weight Class Interval	Number of Vehicles	Average GVW	Average Miles Per Gallon	Average Miles Per Month
lb.		lb.		
13,000-13,999	1	13,800	5 45	2,496
14,000-14,999	1	14,700	7.07	601
15,000-15,999	0	-	-	-
16,000-16,999	2	16,700	8.87	3,102
17,000-17,999	0	-	-	-
18,000-18,999	1	18,400	9.67	4,260
19,000-19,999	1	19,500	7.04	1,835
20,000-20,999	4	20,175	8.82	2,071
21,000-21,999	1	21,300	7.15	2,274
22,000-22,999	2	22,500	8 05	3,570
23,000-23,999	7	23,500	6.70	2,124
24,000-24,999	7	24,300	7.49	2,202
25,000-25,999	10	25,510	6.85	2,971
26,000-26,999	12	26,483	7 71	2,318
27,000-27,999	12	27,242	7 43	3,177
28,000-28,999	18	28,333	7.06	3,210
29,000-29,999	11	29,454	6 53	3,639
30,000-30,999	18	30,422	6 74	3,233
31,000-31,999	19	31,384	7.36	3,284
32,000-32,999	19	32,468	6 29	4,498
33,000-33,999	21	33,314	6.06	3,615
34,000-34,999	22	34,436	7.16	3,251
35,000-35,999	29	35,410	6 74	3,652
36,000-36,999	27	36,407	6 33	3,926
37,000-37,999	29	37,469	6 11	3,683
38,000-38,999	39	38,413	6 08	4,060
39,000-39,999	27	39,367	5.93	3,936
40,000-40,999	39	40,500	5.77	3,663
41,000-41,999	25	41,492	5.57	5,041
42,000-42,999	23	42,296	5.73	4,382
43,000-43,999	27	43,459	6.26	3,640
44,000-44,999	25	44,476	5.43	4,685
45,000-45,999	28	45,382	5.10	4,192
46,000-46,999	18	46,455	5.60	4,840
47,000-47,999	14	47,307	5.22	4,812
48,000-48,999	18	48,344	5 19	4,936
49,000-49,999	15	49,480	5.91	4,490
50,000-50,999	11	50,445	5.27	4,788
51,000-51,999	8	51,575	5.97	4,640
52,000-52,999	12	52,408	5.25	5,112
53,000-53,999	9	53,378	5 53	4,615
54,000-54,999	10	54,590	5 95	5,321
55,000-55,999	6	55,533	5.20	4,018
56,000-56,999	11	56,382	5 19	4,519
57,000-57,999	13	57,431	4.90	4,368
58,000-58,999	3	58,233	4.67	7,313
59,000-59,999	2	59,650	6.71	3,919
60,000-60,999	3	60,367	4.54	4,581
61,000-61,999	2	61,550	4 67	6,371
62,000-62,999	1	62,700	5 05	3,578
63,000-63,999	0	-	-	-
64,000-64,999	2	64,600	5 06	4,398
65,000-65,999	3	65,333	5.97	4,488
66,000-66,999	1	66,500	4.41	4,197
67,000-67,999	2	67,600	6.43	4,048
68,000-68,999	1	68,100	4.84	5,073
.. ..				
77,000-77,999	1	77,500	4.00	2,522
Total & Average	673	40,272	5.91	3,975

were all of the same manufacture and all 1948, 1949, and 1950 models would cause a certain "bunching" of use characteristics. A wider inclusion of manufacturers' makes and models, would have brought into the data a wider and more-even distribution of weight and mileage. An improved plotting in Figure 5 would probably result should the observations be based on a full year's use rather than for the 4 to 6 months of operation pertaining to these trucks.

Truck mileage increases with the gross vehicle weight because of economic reasons and because of character of usage. The vehicles built for heavy gross weights are likewise proportionally heavier in curb

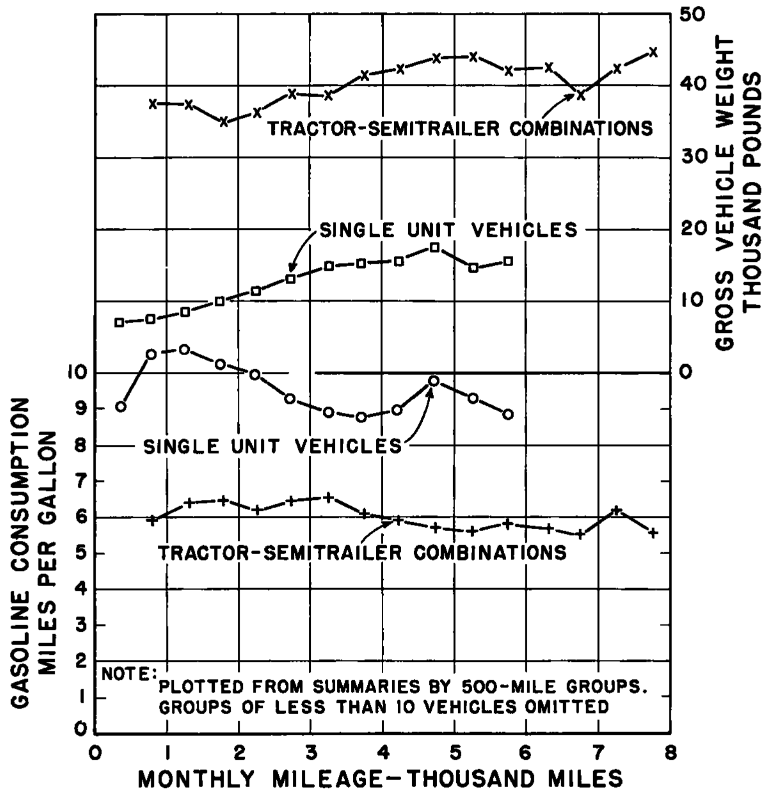

Figure 6. Gasoline consumption and gross vehicle weight related to monthly mileage.

(empty) weight. Their initial investment cost is greater. High annual mileage is therefore desirable in order to keep the unit-mile or ton-mile operating cost low. Generally, the high-load-capacity vehicles are fitted to over-the-road types of use which require large daily mileage. Lighter trucks are adapted to urban types of pickup and delivery services, with slow speeds, many stops, and much idle time. Usually, too, the light types used in commercial services are used only throughout the normal business day. The over-the-road type of vehicle is kept in service with little regard to the hours of the working day or days of the week.

The scattering of the plotting exhibited in Figure 4 is brought fairly well under control in Figure 5, where the gasoline consumption in miles per gallon is plotted from the average consumption for the vehicles by 1,000-lb. groups. For the same reasons as discussed in the preceding section with reference to monthly mileage, the plotted points for gasoline consumption vary from the smooth curve.

For both the single-unit trucks and the combination vehicles, there is uncertainty of the exact location of the miles per gallon curve in the weight range common to the two types of vehicles. Whether or not there is a difference in average fuel consumption in the two types of vehicles for the same weight is not ascertainable from the data in this study. Rolling resistance, air resistance, and type of usage vary and may result in a difference in fuel consumption for the single-unit truck as compared to the combination train at the same gross vehicle weight.

From about 8,000 lb. upward in weight, the corresponding miles per gallon of gasoline indicated in Figure 5, is greater than that shown in other published reports (note paper by Cope, Lynch, and Steele in this bulletin.) For instance, at 20,000 lb. the curve in Figure 5 gives 7.5 miles per gallon as compared to 5.80 in the Cope-Lynch-Steele paper. At 40,000 lb., the miles per gallon are 6.0 and 3.87, respectively. Although there is no positive explanation of this difference in gasoline consumption between that shown in Figure 5 and that in the Cope-Lynch-Steele paper and other reports, some discussion of possible causes of the differences is in order.

The available reports in the literature of fuel consumption of motor vehicles by gross weight of vehicle originated from two basic sources. First, they come from observations made on a particular vehicle, a particular type of operation on which a small fleet of vehicles under one management was used, or they were obtained by averaging other reports. Second, the literature reports fuel consumption on the basis of an estimate made by the particular author on the basis of his experience and his interpretation and evaluation of such reports as were available to him. Thus, when the available published reports of the fuel consumption of motor vehicles are examined in the light of these two basic sources and in the light that fuel consumption varies widely (see Fig. 4) owner to owner, vehicle to vehicle, and use to use, the logical conclusion is that variation in these reports is to be expected. These differences can be reconciled only through a thorough field study of fuel consumption of motor vehicles under conditions which will afford satisfactory statistical control of the study. Perhaps someday a study will be conducted in which the vehicles to be included will be statistically selected, the records systematically and uniformly kept, and the data analyzed by proper statistical methods.

The following statements may explain why the gasoline consumption in miles per gallon indicated in Figure 5 may be higher than that reported by other authors:

1. The field records were maintained only during July to December, thus the amount of winter driving is less than would be included on a full 12-month record.

2. The vehicles were only 0 to 2 years old at the beginning of the observation period. Although there is no material decrease in miles per gallon of motor vehicles with age and usage, new vehicles are used in types of service that require more-constant use and steadier miles with fewer starts and stops than is experienced with older vehicles. This heavier and more steady use of new vehicles as compared to old vehicles probably requires less gasoline per mile.

3. Although the operators of the vehicles could be relied upon to make proper reports of mileage, weight, and gasoline consumption, there is more likelihood that the gasoline gallonage reported is understated rather than overstated. The driver of a vehicle may easily forget to record the purchase of gasoline. Mileage of the vehicle is probably properly stated for the reason that the odometer is a reliable recorder of mileage, which was reported each day during the test period.

4. The gross vehicle weight as computed for this analysis is perhaps overstated. Subsequent analysis of the weights of truck bodies and semitrailers indicates that the weights of the body types estimated for the F-5 to F-8 single-unit models may be 500 lb. to 1,000 lb. too high and that the semitrailers, chassis, and body combined, may be 1,000 lb. to 2,000 lb. too high.

Operators of the vehicles reported daily the payload carried. When no load was carried on a round trip, this zero load was

TABLE 7

WEIGHT, GASOLINE CONSUMPTION, AND MONTHLY MILEAGE OF EACH MODEL

Model	Weight, Pounds					Fuel Consumption, Miles Per Gallon	Average Miles Driven Per Month
	Chassis With Cab	Empty (curb) Weight	Average Monthly Carried Load	Average GVW	Manufacturers' Gross Vehicle Weight Rating		
F-1	2,850	3,264	822	4,086	4,700	13 95	1,337
F-2	3,272	3,772	1,467	5,239	5,700	12.16	1,258
F-3	3,460	4,064	1,784	5,848	6,800	11.69	1,283
F-4	4,020	5,026	2,910	7,936	10,000	10 30	1,605
F-5	4,710	6,211	5,407	11,618	14,000	9 16	1,504
F-6	4,985	6,921	9,821	16,742	16,000	8.28	2,107
F-7	6,465	8,501	13,586	22,087	19,000	6.87	2,478
F-8	6,885	9,994	15,889	25,883	22,000	5 80	2,527
F-5s	4,650	16,133	13,424	29,557	24,000	8.20	2,287
F-6s	4,785	14,927	18,638	33,565	28,000	7 41	3,118
F-7s	6,071	16,669	24,276	40,945	35,000	5 94	3,982
F-8s	6,451	17,464	28,209	45,673	39,000	5 36	4,730

TABLE 8

AVERAGE MILES DRIVEN PER MONTH RELATED TO GROSS VEHICLE WEIGHT AND GASOLINE CONSUMPTION, SINGLE-UNIT VEHICLES

Mileage Per Month Class Interval	Number of Vehicles	Average GVW	Average Miles Per Gallon	Average Miles Per Month
0- 499	286	7,291	9.11	344
500- 999	1,263	7,458	10.54	770
1,000- 1,499	1,294	8,585	10 65	1,241
1,500- 1,999	772	10,029	10.25	1,723
2,000- 2,499	464	11,343	9.98	2,220
2,500- 2,999	334	13,330	9.28	2,717
3,000- 3,499	183	14,810	8.92	3,245
3,500- 3,999	119	15,254	8 78	3,697
4,000- 4,499	66	15,664	8 93	4,221
4,500- 4,999	45	17,527	8.76	4,733
5,000- 5,499	29	14,745	9.29	5,247
5,500- 5,999	17	15,565	8.86	5,741
6,000- 6,499	8	19,612	9.33	6,132
6,500- 6,999	6	13,450	10.75	6,686
7,000- 7,499	2	12,150	12 88	7,327
7,500- 7,999	3	14,667	10.31	7,801
8,000- 8,499	2	9,750	10.32	8,118
8,500- 8,999	2	12,100	10.48	8,811
9,000- 9,499	2	20,000	8.43	9,483
9,500- 9,999	1	12,100	10.03	9,621
10,000-10,499	-	-	-	-
10,500-10,999	1	5,600	13 71	10,712
Total & Average	4,899	9,700	9 85	1,613

averaged in with the reported loads to obtain the average monthly load carried. However, there is reason to believe that the reports do not include the appropriate return mileage at zero load on trips that were made with payload carried in only one direction. Thus a payload of 10,000 lb. hauled a distance of 75 miles with the return trip at zero payload was probably included in the summary as a load of 10,000 lb. at a mileage of 150 rather than as an average payload of 5,000 lb. at a mileage of 150.

To show the effect of such an adjustment, the calculation was made for each of the truck models as a group, but not for the individual 1,000-lb. groupings which were used in the plotting of Figure 5. The revised gross vehicle weight including the payload carried at half its reported poundage resulted in bringing the fuel-consumption curve of Figure 5 for the single-unit vehicles down to the average miles per gallon curve reported by Cope, Lynch, and Steele. The points for the tractor-semitrailer combinations did not come down to the curve, however, by about 2 miles per gallon. Table 7 gives for each model of truck the average monthly load carried as reported and other average weights used in making this trial revision of the gross vehicle weight.

5. Another factor that might contribute to the high miles per gallon of gasoline consumption of these trucks as related to weight is the fact that the vehicles were of materially heavier gross vehicle weights than the manufacturers' rating (see Table 7). Since the heavier trucks did not increase in curb weight proportionally to the increase in payload carried and since 50 percent of the combinations were operated at a gross vehicle weight (as computed from unadjusted reports) in excess of 40,000 lb. as compared to a maximum manufacturers' rating of 39,000 lb., the speed, acceleration, and grade ability of these vehicles were materially reduced.

The purpose of this paper is not to establish the rate of fuel consumption of vehicles, but rather to show that the consumption varies over wide limits as the conditions of use and the source of the information change. The above explanation is important, however, to point out that the gasoline consumption plotted in Figure 5 probably is not appropriate for use in general studies of the performance of trucks.

RELATION OF AVERAGE MONTHLY MILEAGE TO GROSS VEHICLE WEIGHT, AND TO GASOLINE CONSUMPTION

Tables 8 and 9 summarize the weight, miles per gallon of gasoline, and monthly mileage by 500-mile groupings. The averages are plotted in Figure 6. The single-unit vehicles and the combinations produce

TABLE 9

AVERAGE MILES DRIVEN PER MONTH RELATED TO GROSS VEHICLE WEIGHT AND GASOLINE CONSUMPTION, TRACTOR-SEMITRAILER COMBINATIONS

Mileage Per Month Class Interval	Number of Vehicles	Average GVW	Average Miles Per Gallon	Average Miles Per Month
0- 499	3	32,367	6.60	446
500- 999	36	37,522	5 90	783
1,000- 1,499	39	37,400	6.39	1,291
1,500- 1,999	60	35,003	6 49	1,766
2,000- 2,499	61	36,259	6 22	2,249
2,500- 2,999	67	38,837	6.44	2,724
3,000- 3,499	45	38,600	6 54	3,241
3,500- 3,999	64	41,444	6.09	3,743
4,000- 4,499	44	42,441	5 96	4,221
4,500- 4,999	49	43,826	5.70	4,738
5,000- 5,499	44	44,131	5.57	5,247
5,500- 5,999	39	42,264	5.82	5,730
6,000- 6,499	35	42,537	5 64	6,294
6,500- 6,999	22	38,764	5.48	6,748
7,000- 7,499	15	42,427	6.18	7,215
7,500- 7,999	19	44,721	5.56	7,774
8,000- 8,499	7	43,514	4 80	8,164
8,500- 8,999	10	43,300	5.77	8,080
9,000- 9,499	2	42,550	5.95	9,279
9,500- 9,999	3	43,300	5.66	9,790
10,000-10,499	2	43,200	5 95	10,214
10,500-10,999	2	47,400	6.06	10,723
11,000-11,499	-	-	-	-
11,500-11,999	1	54,800	6 85	11,674
12,000-12,499	1	55,400	6 46	12,096
12,500-12,999	1	49,100	7.79	12,686
13,000-13,499	1	36,300	8 35	13,415
13,500-13,999	1	31,200	7.78	13,896
Total & Average	673	40,272	5 91	3,975

a gasoline-consumption rate that is only roughly correlated with monthly mileage. Both of these two types of vehicle classes, however, show an increase in weight with an increase in monthly mileage which agrees with Figure 5. A comparison of Figures 5 and 6 shows that gross vehicle weight is a better index of both gasoline consumption and monthly mileage than is mileage an index of gross vehicle weight and gasoline consumption.

SUMMARY AND CONCLUSIONS

The study conducted by the Ford Motor Company has resulted in a worthwhile contribution to the available information on the mileage, weight, and gasoline consumption of motor trucks. The numerical results of the study furnish certain data that can be appropriately used in highway economy, financial, and taxation studies, though not without proper regard to the source of the information, types of vehicle operation, and probable reliability.

Before the broad field of highway transportation may be blessed with reliable and appropriate information on vehicular mileage, gross vehicle weight, and fuel consumption, a scientifically planned, conducted, and analyzed study of these characteristics of vehicle use and performance is necessary.

Unless adequate information is available about the vehicle, its use, and how the information was assembled, individual reports of the mileage, weight, and fuel consumption of a particular vehicle or a fleet of vehicles should not be taken as being representative of any particular class of vehicles.

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THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government designated by the President of the United States, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY-COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.