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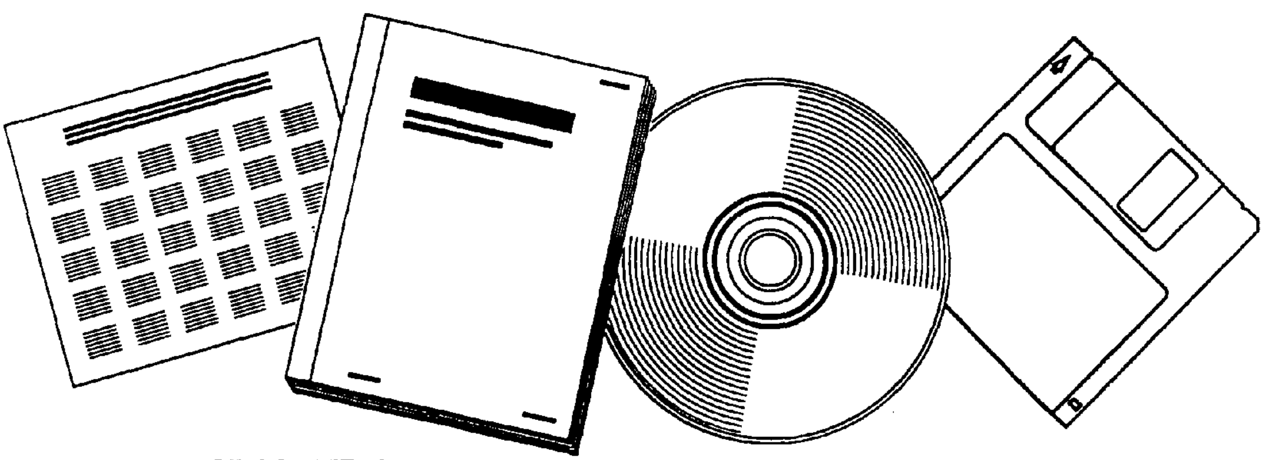
ECONOMICS OF THE MAXIMUM LIMITS OF MOTOR VEHICLE DIMENSIONS AND WEIGHTS, VOLUME 1

FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON, D.C.

SEPT 68



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May 1974

This report should provide useful perspectives to transportation agencies and legislative bodies responsible for recommending changes related to motor vehicle sizes and weights regulations and policies.

This report was originally produced in 1968 but was not released for publication until a thorough review of the findings and methodology was completed. This review, titled "Summary and Assessment of Sizes and Weights Report" (Report No. FHWA-RD-73-67) is a companion volume which is required reading for anyone who seriously considers using the findings reported in the subject report. The assessment extends the analysis, examines assumptions made by Winfrey and others, and points out particular limitations of the "Sizes and Weights" report.

This report demonstrates a substantial economic benefit to be obtained by rebuilding the highway system to higher weight limits and advocates an "immediate" implementation of policies to move in that direction. In addition, vehicles hauling heavier loads would need to be designed with adequate propulsion, braking, steering and suspension systems to operate safely and efficiently with mixed traffic on the upgraded highway system. However, any substantial increase in legal loads without a massive program to update, monitor, and maintain the highway system would create disastrous effects in many States. Many pavements would need to be overlaid and bridges reinforced or posted for limiting maximum loads. These consequences of an immediate increase in legal vehicle size and weight restrictions without an investment to upgrade the capacity of existing pavements and bridges were not analyzed.

Important related questions not addressed in this report:

1. Is it in the national interest to encourage further shift of cargo from other transportation modes to highways, even when more economical?

2. How are the conclusions affected by increased fuel costs and limited petroleum supplies?

Both of these questions have gained considerable importance in the years following the original preparation of the report and should be considered in evaluation of specific size and weight policies or proposed legislation.

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Charles F. Scheffey
Acting Associate Administrator
for Research and Development

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16. Abstract
Determining the desirable maximum limits of dimensions and weights of motor vehicles is approached on the basis of highway cost and the operating cost so far as the factors of economy are concerned. Axle weight, gross vehicle weight, and vehicle length are analyzed on the basis of six highway systems consisting of the rural and urban systems within the Interstate, primary and secondary highway systems. The analysis is based on data on truck weight studies conducted in 46 States; operating cost data obtained from truck fleet operators; and experimental data on pavements and bridges obtained from the comprehensive AASHO road test. Numerous other studies also contributed to the findings of the report. The desirable limits of dimensions and weights for [redacted] use were found to be the following:

1. Vehicle height of 13.5 feet
2. Vehicle width of 102 inches
3. Maximum lengths on all highways of 40 feet for single-unit trucks and trailers, 55 feet for tractors and semitrailers, and 65 feet for any other combination of vehicles.
4. Axle weight limits of 22,000 and 38,000 pounds for single and tandem axles respectively.
5. Gross weight limit of at least 120,000 pounds, or better yet, no gross weight limit at all with control of axle weight and spacing.

17. Key Words
Sizes and Weights; load limits; benefit-cost analysis; economy of truck transport; trucking cost; truck dimensions; truck axle weights; legal limits of vehicle dimension and weights; economic vehicle dimensions and weights; highways and truck limits

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PREFACE

This 1968 research report is the direct result of a project started in September 1963 as an outgrowth of the report completed by the Bureau of Public Roads in 1963, revised and resubmitted to the Department of Commerce in January 1964, and finally published in August 1964 as House Document 354, 88th Congress, 2d Session. The 1963 report on the desirable dimensions and weights of motor vehicles came into being as the fulfillment of Section 108(k) of the Federal-Aid Highway Act of 1956.

For many years prior to the beginning of the study of the limits of dimensions and weights of motor vehicles, as a result of the 1956 Highway Act, the Bureau of Public Roads and the American Association of State Highway Officials were active on the subject. The list of references in Appendix A of Volume 2 gives the more important papers appearing since 1920.

This 1968 report does not specifically review the literature on the subject. Further, the report does not discuss the state of the art, the good and bad aspects of prior work, opinions, and policies. Rather, the research project which resulted in this 1968 report was designed to accomplish the specific results herein reported.

Two quotations from House Document 354 (1964) will help to place this 1968 report in proper perspective. In the Letter of Transmittal the Secretary of Commerce says,

> The findings of the report do not necessarily represent the ultimate maximum limitations that would be desirable, or any improved methods of governing motor vehicle dimensions and weights. Such improved methods are under study as part of the comprehensive highway research program of the Department. A research plan to realize more modern approaches to size and weight administration is suggested in the report.

On page 2, under Summary and Recommendations, the report states,

> The resources of technical research available for this report have been considerable; nevertheless, the field is so complex and the variables so many that each conclusion is subject to important qualifications. Furthermore, the interrelationship between each conclusion requires further exploration to provide overall solutions for a highway system. The conclusions available from present research cannot justify greater standards than those proposed in this report; a more comprehensive program of research and investigation must proceed to enable future standards to be related specifically to technical criteria, and applicable to additional components of the Federal-aid highway systems.

One important factor missing in all prior reports (except the preliminary analysis in House Document 354) is any analyses to show the transportation economy of the limits of vehicle dimensions and weights. Prior studies stressed the design of pavements and structures and traffic safety. Thus, this report is the first to explore thoroughly the economy of the limits of vehicle dimensions and weights, considering both highway cost and motor vehicle transport cost.

About 1945 the Highway Research Board appointed a Committee on Economics of Motor Vehicle Size and Weight. This committee is still in existence, though less active than it was up to about 1962. The long tenure of the committee indicates that there was early and continued interest in the subject and that the objectives have not been achieved. The Highway Research Board committee was the motivating force which produced Highway Research Board Bulletin 9A on time and fuel consumption of trucks on grades and Bulletin 301 on the overall operating cost of line-haul trucks.

This present 1968 report has as its main objectives the development of the economic and technical guides essential to policy and legislative considerations and the procedural techniques for future research application. There is no attempt (at least not a deliberate one) to recommend what public policy should be or to recommend changes in the Federal and State laws. For this reason the AASHO policy on maximum dimensions and weights of motor vehicles as published October 21, 1963, is not discussed.

House Document 354 (1964) and this 1968 report furnish recently assembled facts for the guidance of policy makers on the probable consequences of increasing limits of vehicle dimensions and weights.

ACKNOWLEDGMENTS AND STAFF

This report on the research project to determine the desirable dimensions and weights of motor vehicles is the result of individual work by some 50 or so persons, including some 30 professionals working as a task force. To all these individuals, whether or not they are named here, full appreciation for their contribution is expressed.

The project as a whole was directed by Robley Winfrey, who is also responsible for the design and the writing of the overall report of the project and this condensed report. Certain sections of these reports, however, were extracted from separate staff reports.

Much of this report is supported by separate staff reports and research on the individual studies into which the main project was divided, studies that were assigned to specialized members of the task force. These staff reports and their authors are listed at the end of these acknowledgments.

Special credit is given to the late Hoy Stevens of the Traffic Systems Division, Office of Research and Development, for his overall counsel on many aspects of the research. Professor Robert G. Hennes of the University of Washington, Special Consultant, offered many suggestions and helpful discussions.

A special word of appreciation is also due Professor William G. Adkins of the Texas Transportation Institute, Texas A&M University, and Professor Hennes for their comprehensive review of the manuscript. The report benefited from their helpful suggestions.

Elizabeth Samson is especially mentioned for her painstaking efforts in editing manuscript, arranging for the production of all materials, and for supervising the work of the assembly of the report. Her splendid performance freed the project leader to concentrate on analysis of the results and writing of manuscript. Miss Samson also reviewed the State laws and brought up to date the summary of maximum limits given in Chapter 3.

Malcolm F. Kent made important contributions in connection with adopting the procedure of calculating equivalent 18,000-pound axle weights for the computer program, the analysis of hauling 2,000 tons of payload by different classes of vehicles, and in summarizing the A. T. Kearney report and reducing its results to pavement costs.

Charles Dale contributed to the 2,000-ton study following Mr. Kent's retirement. Duke Niebur computed the truck operating costs to accompany the Kearney-Kent study, as well as refining the early calculations by Mr. Kent and Mr. Dale. Mr. Niebur also did the work on the marginal limits of axle weight, gross vehicle weight, and average daily traffic. He also developed the relationships between empty vehicle weight, horsepower, and practical maximum gross vehicle weight.

James R. Link wrote the computer program for the pavement design, motor vehicle operating costs, and the early phases of the computer program for the financial cost of reconstruction and resurfacing. Ezio C. Cerralli wrote the computer program for calculating the E 18-kip axles for each type of vehicle and completed and perfected the program for the financial studies.

Maude M. Sparagna, William F. Warlick, Lillian Washington, Carol B. French, Barbara A. Price, and Edna Wolf performed hundreds of thousands of general statistical calculations, coding entries, and transfers of data involved in the economy and financial studies.

Typing of the report was done largely by Agnes McHugh, Carol B. French, Marian Higgins, and Linda Cameron, though many other typists, stenographers, and secretaries in the Economics and Requirements Division and elsewhere contributed greatly to this major task.

Special acknowledgment is due the Office of Planning for cooperation and assistance in making available the truck weight study data. Appreciation is expressed specifically to Alexander French, Ted Dickerson, and Alma Clark. The Office of Engineering and Operations and the Office of Administration furnished many construction statistics by highway systems that were important factors in the study.

The project leader gratefully acknowledges the support and teamwork of the professional and support members of his Engineering Economy Group, which shouldered the responsibility for Chapters 4, 7, 8, and 10 through 17. The study leaders are especially thanked for their cooperation and fine production in the accomplishment of the objectives of the study as a whole.

STAFF REPORTS AND AUTHORS OF INDIVIDUAL STUDIES OF THE OVERALL PROJECT

Study No.	Title of Staff Report	Authors
1	A Forecast of Highway Traffic by Vehicle Type, 1962-1990	Edmond L. Kanwit Walter H. Bottiny Alma F. Eckartt Beatrice T. Goley
2	Analysis of the Truck Weight Frequencies and ADT Composition by Road Systems (Results not written up as a separate staff report, but incorporated directly into the overall project report.)	Principal investigators were R. W. L. Doering Phebe D. Howell
3	Urban Street System Use by Heavy Trucks	This study was not undertaken.
4	A Study of the Effect on Truck Transport Practice of Liberalizing Weight and Dimensional Limitations of Vehicles	A. T. Kearney & Company under research contract
5A	Braking Performance of Motor Vehicles as Found Operating on Public Highways	Samuel C. Tignor F. William Petring
5B	Offtracking of Vehicles on Turns	Hoy Stevens
5C	Relationship between Gross Weights and Horsepowers of Commercial Vehicles operating on Public Highways	John M. Wright
5D	Analysis of Accident Experience--Frequency and Cost of Accidents	Charles M. Billingsley
6	Pavement Design	H. D. Cashell Stuart Williams G. W. Ring, III T. J. Pasko
7	Highway Geometric Design	A. A. Carter J. W. Hess

Study No.	Title of Staff Report	Authors
8	Design of Structures	E. G. Wiles R. F. Varney C. F. Galambos
8A	Inventory of Bridges	Charles W. Dale Earle Newman
9	Highway and Structure Construction Costs (Results not written up as a separate staff report, but incorporated directly in the overall project report.)	Principal investigator was John G. Trapnell
10	Line-Haul Trucking Costs in Relation to Vehicle Gross Weights	Hoy Stevens
11	Analysis of the Economy of Motor Vehicle Size and Weight	Robley Winfrey R. W. L. Doering Phebe D. Howell
12	Financing	T. R. Todd James V. Boos
13	Effects of Increased Size and Weight Limitations on Other Modes of Intercity Freight Transport	E. M. Nolan
14	Regulation of Transport Carriers and Tariffs	Josephine Ayre
15	Public Attitudes Toward Increased Size and Weight of Vehicles	This study was not undertaken.

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DEFINITIONS

<u>Vehicle</u> - An assembly of wheels and axles with connecting frame and with or without a body for containing goods or people, which may be towed or moved under its own power over the highway. A passenger car, a bus, a truck, a trailer, a tractor are separate individual vehicles. Also, the word <u>vehicle</u> as used generally includes any combination of two or more separate vehicles such as a tractor and semi-trailer or a truck and full trailer.

<u>Vehicle Combination</u> - Two or more vehicles combined so as to move over the highway as one train of connected vehicles.

<u>Unit</u> - A single vehicle; one of the vehicles within a vehicle combination.

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

<u>Single-unit motor truck</u> - A self-propelled motor truck constructed to carry only its own cargo and not equipped to pull a trailer.

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

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

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

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

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

A semitrailer with two axles grouped under the rear half of the vehicle frequently is known as a tandem-axle semitrailer.

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

Trailer converter dolly - A short chassis assembly consisting of axle and wheel assembly, tires, springs, frame for lower fifth wheel, drawbar, and other parts designed to slip under the front end of a semitrailer to convert it to a full trailer.

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

Double-trailer or tandem-trailer combination - A tractor, semitrailer, and full trailer. This combination frequently is called a "double bottom" because it has two cargo bodies.

Line-haul service - also called over-the-road service--A general term designating truck operations over intercity and rural highways. Such operations may include some minor auxiliary off-highway operations, especially where the payload is picked up from a loading area off the public highway.

Tandem axle - Axle groups having two or more axles spaced more than 40 inches apart and no more than 96 inches apart. More generally, tandem axles are two axles spaced about 48 inches apart.

Cargo, payload, and freight - The material contents, commodities, or goods in the truck body which are being hauled and upon which the freight tariff is paid in common or contract carriage.

Empty weight - The weight of the entire vehicle or vehicle combination with driver on the road without any cargo, or payload, but with any packing material, racks and tools usually hauled for convenience and not for revenue. Vehicles carrying empty drums, pallets, crates, and other cargo containers or leveling devices are classed as with load.

Tare weight - The weight of the entire vehicle or vehicle combination, exclusive of driver, passengers, packing material, cargo containers, cargo handling devices, and all objects not a fixed part of the vehicle.

ADT - The average daily traffic expressed in numbers of vehicles of all classes unless specifically stated differently. The daily average is for the year unless stated otherwise.

Benefit-cost ratio or B. C. ratio - An index of the relative economy of one alternative as compared to another, expressed as the quotient resulting from dividing the equivalent uniform annual benefit in dollars by the equivalent uniform annual cost in dollars required to obtain the benefit.

E 18-kip axles - The number of single axles weighing 18,000 pounds which would be equivalent to another number of axles weighing more or less than 18,000 pounds, as measured by their effect on the pavement structure. A kip is 1,000 pounds.

Motor vehicle operating cost - The total cost of operating the vehicle in road service, including costs of repairs and servicing, tires and tubes, fuel, driver, overhead, depreciation, and interest, but excluding terminal costs of handling cargo, and road-user taxes.

SUMMARY

Key Words: economy of truck transport; trucking cost; truck dimensions; truck axle weights; legal limits of vehicle dimensions and weights; economic vehicle dimensions and weights; highways and truck limits

Determining the desirable maximum limits of dimensions and weights of motor vehicles is approached on the basis of the highway cost and the operating cost of motor trucks, so far as the factors of economy are concerned. Vehicle operations on the highway are concerned with the factors of gross vehicle weight per net horsepower, braking distance, traffic accident frequency and severity, and highway capacity. The placement of the vehicle on the roadway so far as the highway geometrics are concerned is a factor considered. Earthwork, the pavement and shoulder structure, and individual structures are the three items of construction cost affected by any change in vehicle axle weight or gross weight. Other items of the total highway, such as right-of-way, engineering, and traffic facilities, are considered to be unaffected by the maximum legal limits of dimension and weight.

In the economy studies, axle weight, gross vehicle weight, and vehicle length are analyzed on the basis of six highway systems consisting of the rural and urban systems within the Interstate, primary and secondary highway systems. The work

is further divided by the ten census divisions, which approximates a grouping of the States having the same limitations of dimensions and weights, even though these limits vary considerably among all States.

The main basis of the analysis is the 1962 data on the truck weight studies conducted in 46 States. The axle weights, gross weights, frequency distribution by class of vehicle, number of empty vehicles, and the payload carried per vehicle are the main data utilized in these studies.

Considering all the factors involved in determining the desirable limits of maximum vehicle dimensions and weights, the following general conclusions were reached:

1. From the standpoint of economy of transportation, there are no major benefits to be gained by a vehicle height in excess of 13.5 feet, so that any higher limit than 13.5 feet does not need to be seriously investigated at this time.

2. A vehicle width of 102 inches as a maximum is desirable for the reasons that it would improve the loading facilities for certain modular-dimension products, and that it would provide additional desirable space at the rear axle for improvement of the differential and the braking system.

3. Existing highways will accommodate vehicle combination lengths up to 65 feet including two trailers. On

the Interstate system with full access control, combinations 100 feet long are feasible utilizing two 40-foot trailers.

4. There is considerable economy in overall transportation to be gained by axle-weight limits up to at least 26,000 pounds single and 44,000 pounds tandem. The benefit-cost ratio of such increases is significantly large--say, somewhere between 3.0 and 20.0--depending upon the highway system, the census division, and the character of the traffic involved.

5. Increasing the maximum length of vehicles up to 65 feet and permitting the combination of tractor, semitrailer, and full trailer results in a decrease in truck operating cost up to 30 percent, with no measurable increase in highway costs.

6. Gross vehicle weight for combination vehicles is economical up to 25,000 pounds.

7. During the 20-year period from 1965 to 1984, for the 22/38-kip designs, highway construction on the Interstate and Federal-aid primary systems would cost 0.5 to 1.9 percent more than the estimated totals under existing axle-weight limits. The above percentages amount to $95,537,000 and $348,370,000, respectively, for the 20-year period.

8. On all highways, the use of the 22/38-kip axle-weight limits would result in a truck operating cost decrease of $36 billion for the 20-year period, 1965 to 1984.

A FEW FINDINGS IN BRIEF

The desirable limits of dimensions and weights for [redacted] use were found to be the following:

1. A vehicle height of 13.5 feet

2. A vehicle width of 102 inches

3. Maximum lengths on all highways of 40 feet for single-unit trucks and trailers, 55 feet for tractor and semitrailer, and 65 feet for any other combination of vehicles

4. Axle-weight limits of 22/38 kips, single/tandem axles for universal use

5. A gross weight limit of at least 120,000 pounds, or better yet, no gross weight limit at all with control of axle weight and axle spacing.

CHAPTER 1

BACKGROUND AND THE RESEARCH PLAN

The goal of this report is to present the results of research designed to discover and evaluate the factors of transportation economy involved in the legal maximum limits upon the dimensions and weights of motor vehicles. The report attempts to provide the factual basis for improved judgment as to the requirements for legislative and regulatory policy with respect to these limits and also for engineering design.

1. BACKGROUND

The geometrics of highway design have changed over the years to accommodate both larger volumes of vehicles and faster moving vehicles and to increase the safety of travel. As the standards of design have been raised from year to year, vehicles in the commercial group have been getting larger and heavier. From time to time the States have changed their laws controlling the maximum dimensions, maximum axle weights, and total vehicle gross weights allowable on the highways. It is fully as logical to consider the economy of maximum limits on dimensions and weights of vehicles as it is to revise from year to year the standard geometric design and the design criteria that have been adopted by the American Association of State Highway Officials.

For many years highway officials and members of legislative bodies have been aware of the effects that dimensions and weights of vehicles have upon the traffic stream, upon highway cost, and upon transportation in general, as well as upon the economy of the country, which is dependent upon the movement of goods and people. The United States Congress recognized this element in passing the 1956 Federal-Aid Highway Act, when it directed the Secretary of Commerce in Section 108(k)

> . . . to take all action possible to expedite the conduct of a series of tests now planned or being conducted by the Highway Research Board of the National Academy of Sciences, in cooperation with the Bureau of Public Roads, the several States, and other persons and organizations, for the purpose of determining the maximum desirable dimensions and weights for vehicles operated on the Federal-Aid highway systems, including the Interstate System, and after the conclusion of such tests, but not later than March 1, 1959, to make recommendations to the Congress with respect to such maximum desirable dimensions and weights.

A report carrying out the intent of Section 108(k) was submitted to the Department of Commerce by the Bureau of Public Roads in the fall of 1963. It was subsequently revised, updated somewhat, and resubmitted in January 1964. 1/

1/ This report was forwarded to Congress by the Secretary of Commerce on August 18, 1964. It was published as House Document No. 354, 88th Congress, 2d Session. The title is "Maximum Desirable Dimensions and Weights of Vehicles Operated on the Federal-Aid Systems."

2. GENERAL OBJECTIVES AND CONTENT OF THIS REPORT

The present report is intended to carry forward the earlier (1964) work, and it therefore covers the more recent developments. The factors considered were those determining the economy of transportation and capable of being quantified and priced. They include highway construction and maintenance costs, motor vehicle operating cost, and certain economic and service aspects of the highway transport industry, such as cargo handling and fleet operations. If existing legal dimensional and weight limits on motor vehicles are increased, it will be solely because of the demand of the trucking industry, made in the conviction that transport will be more economical at the higher limits. If overall economy of total highway transportation costs -- including both highway and vehicle costs -- can be achieved by any proposed change to higher limits, the legislative bodies concerned must then consider such a change with respect to such factors as structures, geometrics, effects upon passenger car travel, effects upon other modes of transportation, and public policy. On the other hand, if there is no economy in transportation at higher limits, these other factors need not be examined.

The economy of transportation is, therefore, the most important subject to be examined in determining the desirable legal limits on the dimensions and weight of motor vehicles. For this reason, in this study considerable effort has been devoted to making certain of the merits of the two basic elements -- highway and vehicle costs -- as determining factors in establishing what maximum limits are desirable from the point of view of the economy of transportation.

The objective was to make the sum of the two cost factors, or the total transportation cost, a minimum consistent with a desirable level of service, of safety, and of provision for serving the needs of the Nation socially as well as economically. The highway cost problem further divides itself into two aspects: (1) the cost of providing newly constructed highways to take care of increased vehicle dimensions and weights as compared with (2) the effects of increased vehicle dimensions and weights upon existing highways that are in acceptable condition for the operation of vehicles complying with current laws regarding dimensions and weights.

No attempt was made to evaluate the effects of increased vehicle dimensions and weights upon such socio-economic factors as land values, trade volumes, air pollution, and aesthetic values. Neither is full treatment given to the part played by different modes of transportation, the effects on the general economic growth of the country, or the development and use of resources. But the necessary limits upon the extent of this study are not intended to suggest that such social and general economic factors are not relevant and important to the policy issues involved. It is to be presumed that, based upon their judgment as to the relationships that such factors bear to the desirable levels of maximum legal limits on the dimensions and weights of motor vehicles, the policy makers will give them their proper weight in the policy decisions.

The changes in the technology of highway design, changes in the manufacture of motor vehicles and their use, changes in the character of industry, and the rapid increase in population and its centralization in urban areas have each contributed to changes in transport practice. Growth in population and in the Nation's total freight to be moved by all modes of transportation are the two main developments bringing about the well established trends: increasing numbers and weights of vehicles on the highway and payloads carried per vehicle.

The analysis of the economy of vehicle dimensions and weights in this report is based upon hauling a constant number of tons of payload on a given highway. This constant number of tons was used because the relative economy at various levels of dimension and weight limits could not be determined unless the usage factor was the same for all the conditions compared.

The resulting indication of a reduced number of trucks in the ADT at higher maximum limits in no way implies that, if the legal limits were raised, the number of trucks operating on the highway would in fact decline. To produce such a result, a fantastic reduction in the number of trucks would be required to overcome the effects of increases in population and in total freight to be carried.

In most intercity commodity haul, greater economy of motor vehicle movement is obtained from increased dimensions and weights of vehicles in that the cost per payload ton-mile is reduced as the gross vehicle weight increases up to some limit such as 200,000 to 225,000 1/ per vehicle combination. It can be safely assumed that any lowering of the cost of freight transport by highway will accelerate the increase in highway use. Cost reductions will cause the highways to attract a greater share of the total freight movement and to generate new movements.

Nevertheless, increased payload per vehicle permits any given total payload necessary to serve the population of the country to be transported in fewer vehicles, slowing down the rate of increase that would otherwise occur and thus providing an advantage to the traffic stream as a whole. Moreover, even though the truck traffic is greatly increased at some disadvantage to total traffic movement, the economy arising from higher maximum dimensions and weights of vehicles may be so great that society in general and the National economy might be better off for it. However, as mentioned earlier, it is not the purpose of this report to discuss the social and economic policies involved.

Provision for legal use on the public highways of vehicles having greater dimensions and axle-weight limits than

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1/ On a "loaded gross weight basis" (Highway Research Board Bulletin 301), these limits would be 160,000 to 180,000 pounds.

were permitted under 1962 laws would result in some inconvenience to or interference with the movement of smaller vehicles, particularly passenger cars. But such interference by larger and heavier commercial vehicles will be partially or completely offset by the fact that fewer of these vehicles would be required to transport the same total tons of cargo. Thus, to haul the given tonnage of payload, the trade-off would be larger and heavier vehicles for a reduced number of vehicles in the traffic stream.

However, the Nation's highways are designed to serve both the passenger car and the truck, and the extent to which one class of vehicle operates at the expense of another is one of the policy questions outside the limits of this research. This is not to say that the consequences of changes in the traffic distribution upon passenger cars and other small vehicles is not a factor to be taken into account when legislative bodies consider authorizing higher limits of vehicle dimension and weight.

No consideration is given in this report to the military and defense use of highways. The needs of the military with respect to the limiting dimensions and weights of vehicles is a separate problem from that of the requirements to satisfy day-by-day civilian needs. Primarily they constitute a policy matter, not an economic or practical transport matter, and should be a separate consideration in the weighing of any proposals to change the legislation controlling the limits of dimensions and weights of vehicles.

Bus dimensions and weights are considered only partially. Full consideration is desirable, but because so much of the information necessary to an adequate analysis of their desirable limits is not available, most of the analyses have omitted them. On an axle-weight basis, the bus would be comparable to the heaviest 2D truck, but their number on the highway is so small that it would have little effect on the analysis for the economy of axle weight. Only a few intercity buses have tandem axles at the rear.

Limits of dimensions and weights that are less than those prevailing in 1963 in the majority of States are given very little attention. It was reasoned that nothing would be gained by investigating the desirability of limits less than the prevailing ones, because any changes to reduce limits to the lowest of those now prevailing would not be even a remote possibility and no economy or improvement in transportation would result from establishing limits at that level. This conclusion is supported by the trend over the last 40 years, during which the legal limits have, with minor exceptions, moved steadily upward. The increase over time directly reflects public opinion and policy and the recognition of the increased economy and social benefits to be gained from the higher limits.

CHAPTER 2

PARTIAL SUMMARY OF THE JANUARY 1964 REPORT "MAXIMUM DESIRABLE DIMENSIONS AND WEIGHTS OF VEHICLES OPERATED ON THE FEDERAL-AID SYSTEMS"1/

The 1964 report includes much detailed information and discussion of the many factors involved in determining the desirable maximum limits of weights and dimensions of motor vehicles. The reader is referred to the original publication (House Document No. 354), because to summarize its 172 pages would require more space than in warranted in this condensed report. The summary and principal conclusions, however, are given here. The summary and recommendations of the January 1964 report are reproduced below directly from House Document No. 354.

1/ Published as House Document No. 354, 88th Congress 2d Session, August 19, 1964.

8. SUMMARY AND RECOMMENDATIONS

The summary and recommendations of the January 1964 report on the desirable dimensions and weights of motor vehicles are reproduced below directly from House Document No. 354.

MAXIMUM DESIRABLE DIMENSIONS AND WEIGHTS OF VEHICLES OPERATED ON THE FEDERAL-AID SYSTEMS

SUMMARY AND RECOMMENDATIONS

From the technical point of view the effects of the weight and dimensions of a vehicle differ. Weight primarily affects the serviceability and life of the pavement and structures through the stresses it places upon them. Overstressing decreases the serviceability and hastens the reconstruction or replacement of highway facilities. Greater axle weight requires greater pavement thickness and stronger bridges. Gross weight can be a critical factor for bridges carrying vehicle combinations having short wheelbases. On the other hand, increased lengths make possible greater gross weights. Vehicle size affects the operations of highway traffic including the general behavior of vehicles in the traffic stream. Greater width requires wider pavement and bridges and greater length and height of vehicles require increased dimensions of highway geometric patterns and clearances. In the absence of minimum performance requirements, weight can also affect highway capacity; that is, a slowly moving vehicle affects adversely the speed of others and hence the capacity of the roadway. But basically axle weight affects the serviceability of a highway and vehicle size affects its capacity.

In setting dimensions and weight standards a mediation of various values in conflict is necessary. Any standard proposed must provide for maximum safety of operations. Beyond this overriding need, balances must be achieved within major areas of consideration. There must be a balance between the benefits inherent in increasing standards, and the costs of providing for them; between larger vehicle dimensions and the welfare of other users of the highway. The use of public funds by Federal, State, county, and urban governments to provide highway facilities and administration implies that many sectors of the public interest beside commercial transportation are involved in determinations of vehicle standards. There must be a clear showing that increases in vehicle sizes and weights are in the public interest. Highway vehicle standards must also be weighed in the balance with other modes of transportation to permit highway transport to make its optimum contribution in meeting the needs of the Nation's commerce. Such tests will provide for the most effective use of our transportation resources.

Examination of the benefit-cost equations where available for the various alternates can assist in determining some of these balancing points in the evaluation of standards; quantified benefits can be offset against comparable costs. Not least among the considerations is the ability or willingness of beneficiaries to pay the increased costs they occasion.

Structures comprising our present highways were designed for and are maintained at a level of serviceability to accommodate specific vehicle dimensions and axle weights for a preselected period of time. Most structures built over the past decade for the primary highway systems are intended to accommodate greater vehicle standards and provide better serviceability than those built in the decade following World War II. The initially selected period of service life of highway structures is also the basis for the programing of funds which the public makes available whether obtained from bond issues, user charges, dedicated tax revenues, or other sources. Increases in vehicle standards which occasion greater capacity or strengthening of highway structures, or accelerated deterioration of their serviceability, cannot be justified unless corresponding increases are provided in the revenues required to meet the costs of highway widening, resurfacing, reconstruction, and maintenance which they entail.

Balance is also desirable in the application of vehicle standards both as to their scope and timing. Through annual model changes automotive vehicles can be transformed from one to another dimension and weight standard very quickly. The upgrading of an entire highway system cannot be so easily provided. Prior to their construction, highway structures must be designed to meet capacity and strength requirement anticipated over their lifetime. Any abrupt change in vehicle standards could possibly bring about wasteful obsolescence of technically and economically sound structures and weaken the public's continuing high investment in highway systems. Further, while in the interests of uniformity it is desirable to have only one vehicle standard for all highway systems, it is not possible at this time as a practical economic, technical, or legislative matter. On the other hand, neither is it feasible to establish Federal vehicle standards for certain highways unless as a minimum they comprise a very considerable mileage of connected routes forming an interstate system.

The resources of technical research available for this report have been considerable; nevertheless, the field is so complex and the variables so many that each conclusion is subject to important qualifications. Furthermore the interrelationship between each conclusion requires further exploration to provide overall solutions for a highway system. The conclusions available from present research cannot justify greater standards than those proposed in this report; a more comprehensive program of research and investigation must proceed to enable future standards to be related specifically to technical criteria, and applicable to additional components of the Federal-aid highway systems.

Recommendations for the standards of vehicles utilizing the Federal-aid highway systems follow. They provide for progressive implementation of increased vehicle standards over the next 3 years. They are, therefore, predicated on the continued financial support by all participating governments of presently approved program levels for the construction, reconstruction, maintenance, and operation of these systems:

1. With regard to the Federal-aid primary and secondary systems and their respective urban extensions, there is need for additional

important information regarding the serviceability and capacity of critical structures comprising each component of these systems, and the makeup of the actual dimensions and weights of vehicles using each. It is not feasible to recommend any Federal standards for vehicles using these primary and secondary systems until the required information is obtained and analyzed.

2. Section127 of title 23, United States Code, specifies the maximum axle weights, gross weight, and width of vehicles which the States shall permit to use the Interstate System. The following recommendations apply to the basic weights and widths specified in existing law:

a. That the existing maximum overall vehicle width of 96 inches shall be retained through June 30, 1967.

b. That the existing maximum single-axle weight of 18,000 pounds and tandem-axle weight of 32,000 pounds shall be retained through June 30, 1967.

c. That the existing maximum gross weight of 73,280 pounds shall be amended by providing that for a period, beginning 6 months following the enactment of such an amendment to and through June 30, 1967, the maximum overall gross weight of a vehicle shall be that given in bridge table A on the following page for the respective number of axles of the vehicle and the distance between the extreme axles of the group measured longitudinally to the nearest foot. The following general formula is the basis for preparing bridge table A:

$$W=500\ (LN/N-1+12N+32)$$

where W=maximum weight in pounds carried on any group of two or more axles.

L=distance in feet between the extremes of any group of two or more consecutive axles.

N=number of axles in the group under consideration.

TABLE 1(a).—*Permissible gross loads for vehicles in regular operation*

Based on weight formula $W=500\ (LN/N-1+12N+32)$, modified [1]

[Bridge table A]

Distance in feet between the extremes of any group of 2 or more consecutive axles	Maximum load in pounds carried on any group of 2 or more consecutive axles [2]							
	2 axles	3 axles	4 axles	5 axles	6 axles	7 axles	8 axles	9 axles
4	32,000							
5	32,000							
6	32,000							
7	32,000							
8	32,000	40,000						
9		41,000						
10		41,500						
11		42,000						
12		43,000	48,000					
13		44,000	49,000					
14		44,500	49,500					
15		45,000	50,000					
16		46,000	50,500	56,000				
17		47,000	51,500	56,500				
18		47,500	52,000	57,000				
19		48,000	52,500	58,000				
20		49,000	53,500	58,500	64,000			
21		50,000	54,000	59,000	64,500			
22		50,500	54,500	60,000	65,000			
23		51,000	55,500	60,500	66,000			
24		52,000	56,000	61,000	66,500	72,000		
25		53,000	56,500	61,500	67,000	72,500		
26		53,500	57,500	62,000	67,500	73,000		
27		54,000	58,000	63,000	68,000	74,000		
28			58,500	63,500	69,000	74,500	80,000	
29			59,500	64,000	69,500	75,000	80,500	
30			60,000	65,000	70,000	75,500	81,000	
31			60,500	65,500	70,500	76,000	81,500	
32			61,500	66,000	71,000	76,500	82,500	88,000
33			62,000	66,500	72,000	77,000	83,000	88,500
34			62,500	67,000	72,500	78,000	83,500	89,000
35			63,500	68,000	73,000	78,500	84,000	89,500
36			64,000	68,500	73,500	79,000	84,500	90,000
37			64,500	69,000	74,000	79,500	85,000	91,000
38			65,500	70,000	75,000	80,000	85,500	91,500
39			66,000	70,500	75,500	81,000	86,500	92,000
40			66,500	71,000	76,000	81,500	87,000	92,500
41			67,500	71,500	76,500	82,000	87,500	93,000
42			68,000	72,000	77,000	82,500	88,000	93,500
43			68,500	73,000	78,000	83,000	88,500	94,000
44			69,500	73,500	78,500	83,500	89,000	95,000
45			70,000	74,000	79,000	84,000	89,500	95,500
46			70,500	75,000	79,500	85,000	90,500	96,000
47			71,500	75,500	80,000	85,500	91,000	96,500
48			72,000	76,000	81,000	86,000	91,500	97,000
49				76,500	81,500	86,500	92,000	97,500
50				77,000	82,000	87,000	92,500	98,000
51				78,000	82,500	88,000	93,000	98,500
52				78,500	83,000	88,500	93,500	99,000
53				79,000	84,000	89,000	94,500	100,000
54				80,000	84,500	89,500	95,000	100,500
55				80,500	85,000	90,000	95,500	101,000
56				81,000	85,500	90,500	96,000	101,500
57				81,500	86,000	91,000	96,500	102,000
58				82,000	87,000	92,000	97,000	102,500
59				83,000	87,500	92,500	97,500	103,000
60				83,500	88,000	93,000	98,500	104,000

[1] The permissible loads are computed to the nearest 500 pounds. The modification consists of limiting the maximum load on any single axle to 18,000 pounds.

[2] The following loaded vehicles must not operate over H15-44 bridges: 3-S2 (5 axle) wheelbase less than 36 feet; 2-S1-2 (5 axle) with wheelbase less than 42 feet; 3-3 (6 axle) with wheelbase less than 44 feet; and 7-, 8-, and 9-axle vehicles regardless of wheelbase.

3. It is recommended that section 127 of title 23, United States Code, be further amended to provide that there be added to the present provisions the following seven additional limitations on the dimensions of vehicles using the Interstate System, to be effective 6 months after the enactment of such amendment:

a. Maximum length of single-unit truck, 40 feet.

b. Maximum length of single-unit bus, 40 feet.

c. Maximum length of semitrailer, 40 feet.

d. Maximum length of trailer, 40 feet.

e. Maximum overall length of truck-tractor and semitrailer, 55 feet.

f. Maximum overall length of all other combinations, 65 feet.

g. Maximum overall height—13 feet, 6 inches.

4. That in the interests of safety and the efficient utilization of highways by all types of vehicles, performance standards be added to the dimension and weight standards prescribed in section 127 of title 23, United States Code, for vehicles operating on the Interstate System. Further that these Federal performance standards shall be those prescribed by the Secretary of Commerce and published in the Federal Register, and shall take effect on such date as the Secretary of Commerce shall determine, but in no case less than 1 year or more than 3 years after section 127 has been amended to provide therefor. These performance standards provided for by the amendment of section 127 shall be:

a. A minimum performance standard specifying a ratio of gross weight of the vehicle to the net horsepower of its engine available for movement of the vehicle.

b. A minimum performance standard for vehicle braking systems.

c. A standard for the linkage between combinations of vehicles.

5. That section 127 of title 23, United States Code, be further amended to provide that effective July 1, 1967, and thereafter, the following standards shall be those of vehicles which the States permit to use the Interstate System:

a. The maximum overall vehicle width shall be 102 inches.

b. The maximum single-axle weight shall be 20,000 pounds and maximum tandem-axle weight shall be 34,000 pounds.

c. The maximum gross weight shall be that given in table B on the following page for the respective number of axles of the vehicle and the distance between the extreme axles of the group measured longitudinally to the nearest foot. The following general formula is the basis for preparing bridge table B:

$$W=500\ (LN/N-1+12N+36)$$

where

W=maximum weight in pounds carried on any group of two or more axles.

L=distance in feet between the extremes of any group of two or more consecutive axles.

N=number of axles in the group under consideration.

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TABLE 1(b).—*Permissible gross loads for vehicles in regular operation*

Based on weight formula $W=500\ (LN/N-1+12N+36)$, modified [1]

[Bridge table B]

Distance in feet between the extremes of any group of 2 or more consecutive axles	Maximum load in pounds carried on any group of 2 or more consecutive axles [2]							
	2 axles	3 axles	4 axles	5 axles	6 axles	7 axles	8 axles	9 axles
4	34,000							
5	34,000							
6	34,000							
7	34,000							
8	34,000	42,000						
9	39,000	42,500						
10	40,000	43,500						
11		44,000						
12		45,000	50,000					
13		45,500	50,500					
14		46,500	51,500					
15		47,000	52,000					
16		48,000	52,500	58,000				
17		48,500	53,500	58,500				
18		49,500	54,000	59,000				
19		50,000	54,500	60,000				
20		51,000	55,500	60,500	66,000			
21		51,500	56,000	61,000	66,500			
22		52,500	56,500	61,500	67,000			
23		53,000	57,500	62,500	68,000			
24		54,000	58,000	63,000	68,500	74,000		
25		54,500	58,500	64,500	69,000	74,500		
26		55,500	59,500	65,000	69,500	75,000		
27		56,000	60,000	65,000	70,000	75,500		
28		57,000	60,500	65,500	71,000	76,500	82,000	
29		57,500	61,500	66,000	71,500	77,000	82,500	
30		58,500	62,000	66,500	72,000	77,500	83,000	
31		59,000	62,500	67,500	72,500	78,000	83,500	
32		60,000	63,500	68,000	73,000	78,500	84,500	90,000
33			64,000	68,500	74,000	79,000	85,000	90,500
34			64,500	69,000	74,500	80,000	85,500	91,000
35			65,500	70,000	75,000	80,500	86,000	91,500
36			66,600	70,500	75,500	81,000	86,500	92,000
37			66,500	71,000	76,000	81,500	87,000	93,000
38			67,500	72,000	77,000	82,000	87,500	93,500
39			68,000	72,500	77,500	82,500	88,500	94,000
40			68,500	73,000	78,000	83,500	89,000	94,500
41			69,500	73,500	78,500	84,000	89,500	95,000
42			70,000	74,000	79,000	84,500	90,000	95,500
43			70,500	75,000	80,000	85,000	90,500	96,000
44			71,500	75,500	80,500	85,500	91,000	96,500
45			72,000	76,000	81,000	86,000	91,500	97,500
46			72,500	76,500	81,500	87,000	92,500	98,000
47			73,500	77,500	82,000	87,500	93,000	98,500
48			74,000	78,000	83,000	88,000	93,500	99,000
49			74,500	78,500	83,500	88,500	94,000	99,500
50			75,500	79,000	84,000	89,000	94,500	100,000
51			76,000	80,000	84,500	89,500	95,000	100,500
52			76,500	80,500	85,000	90,500	95,500	101,000
53			77,500	81,000	86,000	91,000	96,500	102,000
54			78,000	81,500	86,500	91,500	97,000	102,500
55			78,500	82,500	87,500	92,000	97,500	103,000
56			79,500	83,000	87,500	92,500	98,000	103,500
57			80,000	83,500	88,000	93,000	98,500	104,000
58				84,000	89,000	94,000	99,000	104,500
59				85,000	89,500	94,500	99,500	105,000
60				85,500	90,000	95,000	100,500	105,500

[1] The permissible loads are computed to the nearest 500 pounds. The modification consists in limiting the maximum load on any single axle to 20,000 pounds.

[2] The following loaded vehicles must not operate over H15-44 bridges: 3-S2 (5 axles) with wheelbase less than 38 feet; 2-S1-2 (5 axle) with wheelbase less than 45 feet; 3-3 (6 axle) with wheelbase less than 45 feet; and 7-, 8-, and 9-axle vehicles regardless of wheelbase.

6. That the Secretary of Commerce shall, in consultation with the Governors of the States, develop a feasible program for the establishment of maximum vehicle standards which are inclusive of all enforcement, weighing scale or other tolerances.

CHAPTER 3

REVIEW OF 1963-67 LEGAL LIMITS ON VEHICLE DIMENSIONS AND WEIGHTS AND FACTORS TO RECEIVE RESEARCH ATTENTION

A review of State and Federal legal limits on the dimensions and weights of motor vehicles is essential to an understanding of the research program underlying this report and the discussion of its results. The objective of the review presented here is to demonstrate the following facts:

(1) There is a wide range from State to State in specific legal limits on vehicle dimensions and weights.

(2) The existing legal limits are sometimes without obvious support in logic based on their effects on either highway or transport operation.

(3) The varying specific limits cannot all be best, that is, in the best interests of the Nation and the individual States.

(4) Interstate transport now must operate under a variety of laws and regulations, resulting in more costly haulage than would be the case under more nearly uniform laws.

(5) A review of existing limits indicates specific areas where research should be focused and the scope of that research.

1. STATE LEGISLATION, 1964 THROUGH 1967

For this report, a complete analysis of the State legal limits on dimensions and weights of motor vehicles was made as of December 31, 1963. This study was brought up to date in a summary fashion by a table published by the Bureau of Public Roads as of December 31, 1964. The 1964 information was updated from secondary sources insofar as it was possible, and the changes through December 1967 are given in table 3-2.

The period from the beginning of 1964 through 1967 was marked by the continuing spread among the States of existing legal maximum limits of dimensions and weights of vehicles. Little change took place in width limits, which were already almost uniform at 96 inches throughout the Nation. Height limits moved closer to uniformity at 13.5 feet, with five States raising their limits to that point in 1965, two in 1966, and one in 1967. Among all the dimensional and weight factors, length limits were the subjects of the greatest legislative activity. The present trend is in the direction of increasing combination length and number of axles. In contrast to the situation existing in 1963, all the western States and much of the Midwest now permit the operation of the 65-foot, three-unit combination. In addition, two contiguous eastern States have recently passed laws permitting these combinations to operate, although such operation will be limited by the isolation of these States in an area generally forbidding it. Very little change took place in weight limits.

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete, and some interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Alabama	Length, feet	1965	55	60	Tractor-semitrailers	Added 5-foot permissible load extension.
	Length, feet	1965	55	75	House-trailer combinations	
Alaska	Height, feet	1965	12.5	13.5	---	
	Length, feet	1965	35	40	Single-unit trucks	
	Length, feet	1965	60	65	Other combinations	
	Maximum gross weight, pounds	1966	76,800	100,000	3-S2-3	Across-the-board increases in gross weight limits.
Arkansas	Axle weight	1965	-	Permit	Certain heavy haulers	Specially designed and with 18,000 pounds on steering axle.
	Length, feet	1967	55	65	Other combinations	Effective 2-21-67.
California	Width, inches	1965		100	Plywood haulers	
	Height, feet	1965	13.5	14	Auto transporters	Single-trip or annual permit required.
	Length, feet	1965		40	4-axle transit-mix trucks	
	Height, feet	1967	13.5	14	All commercial vehicles	Temporary provision to be effective from 11-8-67 to 1-1-70.
Colorado	Length, feet	1965	60	65	2-unit combinations	On designated highways.
Connecticut	Length, feet	1965	50	55	Single-unit trucks	
	Length, feet	1965	NR	40	Semitrailers	
	Length, feet	1965	50	55	Tractor-semitrailers	
	Maximum gross weight, pounds	1965		73,000 or (73,280)	Combinations	Made absolute maximum including tolerance.
	Height, feet	1967	12.5	13.5		Effective 5-27-67.
	Length, feet	1967	NS	80	Pole vehicles	

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete, and some interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Delaware	Length, feet	1967	60	65	Other combinations	Effective 8-2-67.
	Length, feet	1967	60	70	Pole and piling trailers	Effective 8-2-67.
	Length, feet	1967	60	65	Auto transporters	Effective 8-2-67.
	Maximum gross weight, pounds	1967	46,000	65,000	3-axle vehicles	Effective 6-2-67.
Georgia	Length, feet	1964	35	55	Single-unit trucks	
	Length, feet	1964	40	55	Bus	
	Length, feet	1964	50	55	Tractor-semitrailer	
	Number of towed units	1964	1	NR	---	
	Maximum gross weight, pounds	1964	63,280	73,280	---	
Hawaii	Axle weight	1967	-	-	Vehicles with 3 or more consecutive axles	New table of axle weights, effective 7-1-67.
Idaho	Length, feet	1967	65	98	3- or 4-unit combinations	Effective 5-30-67, may be operated on highways designated by the Board of Highway Directors
Illinois	Length, feet	1965	60	65	TST (stinger-steered only)	On designated highways. Annual permit required.
	Length, feet	1967	-	-	65-foot tractor-semitrailer	Effective 7-6-67, may operate on all 4-lane highways without a permit. Highway department may authorize operation on certain 2-lane roads.
Indiana	Length, feet	1965	55	65	3-unit combinations	
	Number of towed units	1965	1	2	---	
	Width, inches	1967	96	114	Mobile-home, sectionalized-building combinations	Effective 3-7-67, may be operated under permit.
	Length, feet	1967	60	75	Same as above.	Same as above.

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete, and some of the interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Iowa	Length	1965	-	-	Vehicles over 50 feet long	Provision repealed prohibiting vehicles over 50 feet long from operating on highways with paved surfaces less than 22 feet.
Kansas	Length, feet	1965	35	42.5	Single units	Including trailers and semitrailers.
	Length, feet	1965	50	55	Tractor-semitrailers	
	Length, feet	1965	50	65	Other combinations	
	Number of towed units	1965	1	2		
	Width, feet	1967	8	10	Fertilizer dispensing machines	
	Length	1967	-	-	65-foot combinations	Operation has been extended by State Highway Commission to all highways on the State systems.
	Number of towed units	1967	-	-	Saddle-mount, tow-bar, or full-mount combinations	More than 2 towed vehicles prohibited.
Kentucky	Length, feet	1964	50	55	Tractor-semitrailers	Maximum combination length permitted. Full trailers prohibited.
	Axle-weight, pounds	1964		32,000	2 or more axles	Limit when axles are spaced within 120 inches.
	Height, feet	1966	-	13.5	All highways	Formerly applied only to designated highways.
	Length, feet	1966		55	Mobile-home combination	Effective 1-1-67.
Louisiana	Length, feet	1966	55	60	Tractor-semitrailers	Effective 7-27-66
	Length, feet	1966	60	65	Other combinations	
Maine	Axle weight, pounds	1965	32,000	36,000	Tandem axles	On highways other than the Interstate system.
	Gross weight, pounds	1965	40,000	46,000	Certain 3-axle trucks	Brakes on wheels of all axles; distance between extreme axles less than 16 feet; on highways other than Interstate.

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete, and some of the interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Maine	Gross weight	1965	-		Additions to 4-axle table	
	Weight tolerance	1965		10%	Farm products and refrigerated cargo	
	Gross weight tolerance	1967	-	10%	Mineral transport vehicles	Effective 9-17-67, if maximum gross weight does not exceed 110% of the registered weight or of the MGW permitted by the table of axle-weight limits.
Maryland	Height, feet	1965	12.5	13.5	---	
	Gross weight	1964	-	-	Tied to number of axles	
	Length	1966	-	-	Auto transporters	May exceed 55-foot limit by overhang of transported vehicles.
	Length, feet	1967	-	65	Tractor-semitrailer-trailer	Permitted, effective 6-1-67.
	Gross weight tolerance	1967		5%	Vehicles transporting bulk milk.	MGW cannot exceed 73,280 pounds with tolerance.
	Gross weight, pounds	1967		40,000	2-axle, single-unit dump trucks	The radius of operation of these single-unit
	Gross weight, pounds	1967		65,000	3-axle, single-unit dump trucks	vehicles is limited. Effective 6-1-67.
Massachusetts	Length, feet	1966	50	55	Tractor-semitrailers	Effective 9-2-66.
	Length, feet	1967	-	40	Buses	Without special permit, effective 9-21-67.
Michigan	Length, feet	1964	55	60	Auto transporters	
	Axle weight, pounds	1965		32,000	Tractor-semitrailers	2 tandem axle assemblies with single-axle weights of 16,000 pounds permitted on designated highways.
	Length, feet	1966	55	65	Other combinations	No more than 11 axles. Effective 6-14-66.

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete, and some of the interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Minnesota	Length, feet	1967	NR	40	Single semitrailers	Effective 4-22-67. Five-percent tolerance for vehicles transporting livestock, boats, or motor vehicles.
	Length, feet	1967	50	55	Tractor-semitrailers	Effective 4-22-67.
Missouri	Height, feet	1965	12.5	13.5	---	
	Length, feet	1965	35	40	Single-unit trucks	
	Length, feet	1965	50	55	Tractor-semitrailers	
	Length, feet	1965	50	65	Other combinations	
	Length, feet	1965		60	Auto transporters	
	Length, feet	1967			65-foot double-cargo combinations	From operation on designated highways to operation on all Interstate and State primary routes plus an additional 5 miles to and from such routes.
	Axle weight, pounds	1967		36,000	2-axle, tandem special vehicles	Vehicles transporting construction equipment and farm machinery. Chief engineer required to issue permits for such operation, effective 10-13-67.
	Axle weight, pounds	1967		48,000	3-axle, tandem special vehicles	
Montana	Axle weight, pounds	1967		20,000	Single axles	Effective 1-1-68 on highways other than Interstate system.
	Axle weight, pounds	1967		34,000	Tandem axles	
	Maximum gross weight, pounds	1967		105,000	All vehicles	
Nebraska	Length, feet	1965	60	65	Other combinations	
Nevada	Length, feet	1967	NR	40	Single units	Effective 7-1-67
	Length, feet	1967	NR	70	Vehicle combinations	
	Length, feet	1967	NR	105	Vehicle combinations	By rule and regulation of State highway department.

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete, and some of the interpretations are doubtful.

State	Item of dimension and weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
New Hampshire	Length, feet	1965	-	40	Buses on all highways	Formerly on designated highways only.
	Length, feet	1965	-	55	Combinations	Limit scheduled to expire in 1968 made permanent.
New Jersey	Length, feet	1964	53	55	Tractor-semitrailer	May not exceed 50 feet including load when semitrailer exceeds 40 feet.
	Number of towed units	1965	1	2	---	
	Length	1967	-	-	Single units	35-foot limit to include load.
New York	Length, feet	1964	50	55	Tractor-semitrailers	
	Length, feet	1964	50	55	Other combinations	
	Height, feet	1966	13	13.5	---	
	Number of towed units	1966	-	-	Combinations	Vehicles hauling disabled tractor-semitrailers exempted from 3-unit prohibition.
	Length, feet	1966	55	60	Auto transporters	
North Dakota	Length, feet	1965	60	65	Other combinations	On designated highways.
Ohio	Axle weight, pounds	1965	31,500	32,000	Tandem axles	
	Length, feet	1967	40	NR	Semitrailer	Effective 8-11-67.
	Length, feet	1967	35	40	Single-unit trucks	
	Length, feet	1967	60	65	Other combinations	
	Number of axles	1967	-	2	Intercity buses	Now permitted to operate.
Oklahoma	Length, feet	1965	35	40	Single-unit trucks	
	Length, feet	1965	50	55	Tractor-semitrailers	
	Length, feet	1965	50	65	Other combinations	
	Length, feet	1965		65	House-trailer combinations	
	Number of towed units	1965	1	2		

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1968

Note: This information is not guaranteed to be complete, and some of the interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Oklahoma	Width	1967	-	-	Trailers	Law authorizing permits for manufacturers to move trailers between 10 and 12 feet wide repealed.
Oregon	Height, feet	1967	13.5	14	Auto transporters	By permit. Effective 8-2-67
	Wheel weight limit, pounds	1967	9,000	10,000		Effective 9-12-67
	Axle weight, pounds	1967	18,000	20,000	Single axles	On highways other than the Interstate system.
			32,000	34,000	Tandem axles	
Pennsylvania	Height, feet	1965	12.5	13.5	---	Effective 2-5-66
	Length, feet	1965	50	55	Tractor-semitrailers	Measurement of semitrailer length excludes devices attached to front.
	Length, feet	1965	50	55	Other combinations	
Rhode Island	Length, feet	1965	50	55	Tractor-semitrailers	
	Length, feet	1965	50	55	Other combinations	Double saddlemount combinations permitted.
	Height, feet	1965	12.5	13.5	---	
South Carolina	Maximum gross weight, pounds	1967	32,000	35,000	2-axle, single-unit vehicles	Effective 7-12-67.
	Axle weight	1967	-	-		Table of axle spacings.
South Dakota	Length, feet	1967	35	40	Highway post-office buses	Effective 7-1-67.
Tennessee	Length, feet	1967	35	40	Single-unit trucks	Effective 7-3-67.
	Length, feet	1967	50	55	Vehicle combinations	
	Length, feet	1967	55	60	Auto transporters	Extra 5 feet allowed for bumper overhang.

Table 3-2. -- Summary of State legislation changing the limits of motor vehicle dimensions and weights, January 1964 through December 1967

Note: This information is not guaranteed to be complete and some of the interpretations are doubtful.

State	Item of dimension or weight	Change in legal requirement				
		Year	From-	To-	Applied to-	Explanation
Texas	Length, feet	1965	35	40	Single units	
	Length, feet	1965	50	55	Tractor-semitrailers	
	Length, feet	1965	50	65	Other combinations	
	Number of towed units	1965	1	NR	---	
	Number of towed units	1967		3	Saddlemount combinations	
Vermont	Axle weight, pounds	1964	NS	22,400	Single axle	23,500 with tolerance.
	Axle weight, pounds	1964	NS	36,000	Tandem axle	
	Maximum gross weight, pounds	1964	66,400	73,280	Other combinations	
	Gross weight	1964	-	-	All trucks and combinations	Table of axle spacings added.
Virginia	Length, feet	1966	50	55	Combinations	Effective 2-28-66.
	Number of units	1966	1	2	---	Permit from State Highway Commission required. Effective 6-27-66.
Washington	Height, feet	1965	13.5	14	Auto transporters	
	Length, feet	1967	60	70	Tractor and stinger-steered semitrailer	With load. Without load, 65 feet. Effective 5-11-67.
West Virginia	Height, feet	1965	12.5	13.5		On designated highways.
	Length, feet	1965	35	40	3-axle trucks	
	Length, feet	1965	50	55	All combinations	
Wyoming	Length, feet	1967	40	50	Single-unit vehicles	Effective 5-19-67.
	Length, feet	1967	65	70	Certain combinations	Combinations hauling automobiles; concrete, laminated, or steel beams; and one-piece pipe. Also forest products or baled hay, under special permit for from one month to one year.

2. FEDERAL LIMITS AS OF DECEMBER 31, 1967

Some State legislative activity in the area of vehicle dimension and weight limits has been generated by the Federal limits with respect to the Interstate highway system. Under Subsection 108(j) of the Federal-Aid Highway Act of 1956 (Title I of Public Law 627, 84th Congress, now codified as "Title 23: Highways, United States Code"), Federal aid for the Interstate highway system is limited to those States which prohibit use of that system by vehicles having widths greater than 96 inches, single axle weights above 18,000 pounds, tandem axle weights above 32,000 pounds, and gross vehicle weights above 73,280 pounds, except as higher State legal maximum limits were in effect on July 1, 1956.

These Federal limits apply only to the Interstate highway system and to the three factors of vehicle width, axle weight, and gross vehicle weight. By this Federal act, tying certain requirements for vehicle dimensions and weights to the allocation of Federal-aid highway funds for the Interstate highway system, Federal law has in effect frozen these three factors at the limits existing on July 1, 1965. For with the exception of gross vehicle weight, the State maximum limits were already equal to or above those specified in the 1956 act. In subsequent years, and especially in 1963, many States raised their gross vehicle weight limits to meet the Federal maximum of 73,280 pounds.

3. SUMMARY OF STATE MAXIMUM LIMITS AND INDICATED SCOPE OF RESEARCH ON EACH FACTOR OF DIMENSION AND WEIGHT

This section gives the main features of the State laws related to the maximum dimensions and weights of motor vehicles. Any consideration of the economy of such dimensions and weights should include some statement of the existing legal limits. On the following pages, therefore, the State maximum limits are summarized factor by factor as of December 31, 1967. It is recognized that no two investigators are likely to arrive at precisely the same results, because the many regulations, variations, interpretations, exceptions, and special features of the laws produce difficulties in developing an exact and fully descriptive summary of them. However, the general trends are clear and indisputable. Besides indicating the status of State legal limits, the summary suggests possible lines of research and offers some basis for arriving at reasonable maximum limits of vehicle dimensions and weights.

A. Width of Vehicles

The predominate upper base limit on overall width of vehicles today is 96 inches, the exceptions all being greater than the base limit. The States of Connecticut, Maine, and Rhode Island follow the AASHO recommendation of 102 inches, and Hawaii has a legal maximum of 108 inches. Thus, of the 52 States,[1/] 48 have a legal maximum vehicle width of 96 inches;

1/ Throughout this report, the word "State" includes the District of Columbia and Puerto Rico.

3, of 102 inches; and 1, of 108 inches. Several States provide for urban transit bus widths of 102 and 104 inches. See the summary on the following page.

There is, then, no need to be concerned with widths less than 96 inches, but the desirability of 102-, 104-, or 108-inch widths should be examined. The factors that determine the desirable maximum limits are the following: (1) the transport factors of commodity loading and freight terminal facilities, (2) safety of traffic with respect to traffic lane width, (3) clearance on horizontal curves, and (4) lane width on horizontal curves. It is in terms of these transport and highway factors, therefore, that width of vehicle is examined in Chapter 4.

B. Height of Vehicles

As shown in the summary of vehicle height limits on page 3-15, 13.5 feet is the legal limit in 45 States, with 3 States below that limit, 2 above, and 2 not specified. One State--California--with a base limit of 13.5 feet, in 1967 raised that limit on a temporary basis to 14 feet, effective until January 1, 1970.

With such a preponderance of States in agreement on a maximum vehicle height of 13.5 feet, a limit less than this is assumed to be undesirable. However, whether greater height is needed and feasible will be considered. Depending upon the conclusion reached based on a 13.5-foot limit, the desirable limit could be 14 feet or more.

VEHICLE WIDTH LIMITS

Summary of State Basic Limits (December 31, 1967)

Limit, inches	Number of States
96	48
102	3
108	1
Total	52

Special Provisions

(In the tabulation below, the basic width limit is shown in parenthesis.)

Colorado (96) Idaho (96) Indiana (96) Montana (96)	Buses, 102" on highways of surfaced width of at least 20', or otherwise as administratively authorized.
Maryland (96)	Vehicles loaded with hogsheads of tobacco may be 103".
New Jersey (96) North Dakota (96)	Vehicles in excess of 96' by special permit in advance.
New Mexico (96)	On designated highways, 102"; body 96", additional 6" for tires only.

VEHICLE HEIGHT LIMITS

Summary of State Basic Limits
(December 31, 1967)

Limit ft. - in.	Number of States
12-6	2
13-0	1
13-6	44
14-0	3
NS	1
NR	1
Total	52

Special Provisions

(In the tabulation below, the basic height limit is shown in parenthesis.)

California (14-0)	Limit in effect until January 1, 1970.
Maine (13-6)	Including load, 14-0.
Oregon (13-6)	On class AA or designated highways; for log and lumber trucks, 12-6 on all highways. Auto transporters, 14-0, by permit.
Washington (13-6)	For auto transporters, 14-0.
West Virginia (13-6)	On designated highways; on other highways, 12-6.

The factors affecting vehicle height examined in Chapter 4 are as follows: (1) overhead structures on the highways, (2) the most advantageous height for cargo stowage, and (3) the vehicle height requirement for freight handling at terminal facilities. The effect of additional height on the tendency of the vehicle to overturn is a minor consideration.

C. Length of Vehicle

Two general groups of vehicles need to be considered separately with respect to length limitation: (1) the single unit and (2) the combination. The next several pages summarize the length limits for five classes of vehicles: (1) the bus, (2) the single-unit truck, (3) the semitrailer or trailer, (4) the tractor-semitrailer, and (5) the combination with two or more cargo bodies.

For single vehicles, including the bus, the maximum legal length varies from 35 to 55 feet. For buses, tractors, and semitrailers, 40 feet is the most frequent limit. For single-unit trucks, the 35-foot limit has only a slight edge, as the movement in the direction of the 40-foot limit progresses. In 37 States no limit is placed on the trailer alone.

The tractor-semitrailer is limited to 50 feet in 2 States, 55 feet in 34 States, 60 feet in 10 States, and 65 feet in 5 States. Other combinations are limited to lengths

LENGTH LIMITS - BUS

Summary of State Basic Limits
(December 31, 1967)

Limit, feet	Number of States
35	3
40	38
42	2
42.5	1
45	2
50	1
55	4
NR	1
Total	52

Special provisions

(In the tabulation below, the basic length limit is shown in parenthesis.)

Iowa (40) Louisiana (40) North Carolina (40) North Dakota (40) Ohio (40) South Carolina (40) West Virginia (40)	Less than 3 axles, 35'.
California (40)	Articulated bus, 60'.
Idaho (40)	On designated highways only.
Kentucky (35)	On designated highways; on other highways, 30'.
New Jersey (35)	Or as prescribed by P.U.C.
New York (35)	40' for trackless trolleys and buses of 7 or more passengers by P.S.C. certificate.

LENGTH LIMITS - SINGLE-UNIT TRUCK

Summary of State Basic Limits
(December 31, 1967)

Limit, feet	Number of States
35	22
36	1
40	[a] 20
42	1
42.5	1
45	1
50	1
55	5
Total	52

[a] Includes Idaho. See below.

Special Provisions

(In the tabulation below, the basic length limit is shown in parenthesis.)

Florida (35) North Dakota (35) South Carolina (35) West Virginia (35)	Three-axle vehicle may be 40'.
Idaho (40)	On designated highways; on other highways, 35'.
Kentucky (35)	On designated highways; on other highways, 26.5'.

LENGTH LIMITS - SEMITRAILER OR TRAILER

Summary of State Basic Limits 1/
(December 31, 1967)

Limit, feet	Number of States
35	1
40	11
42	1
42.5	1
45	1
NR	31
NS	6
Total	52

1/ Tabulation is based on the semitrailer limit in cases where the limits on semitrailers and trailers are different. For trailer limits in those cases, see the special provisions given below.

Special provisions

(In the tabulation below, the basic length limit is shown in parenthesis.)

State	Provision
Iowa (NR) New Jersey (NR) New York (NR)	Full trailer, 35'
Florida (NS)	Two-axle trailer, 35' three-axle trailer, 40'
Connecticut (40) Kentucky (NR)	Trailers allowed to operate by permit only.
Minnesota (40)	Vehicles designed for hauling livestock, 45'
Nebraska (NR) Ohio (NR) Tennessee (NR)	Full trailer, 40'
Oregon (40)	On designated highways, otherwise, 35'

LENGTH LIMITS - TRACTOR-SEMITRAILER

Summary of State Basic Limits
(December 31, 1967)

Limit, feet	Number of States
50	2
55	34
60	10
65	5
70	1
Total	52

Special Provisions
(In the tabulation below, the basic length limit is shown in parenthesis.)

Alabama (55)	With load extension, 60'
Indiana (55)	House-trailer and auto-transport combinations
Idaho (60)	Auto transports, 65'
Illinois (55)	Tractor and stinger-steered semitrailer, auto transports, 65'
Iowa (55)	Auto and boat transports on highways with 22' surface width, 60'; otherwise, 50'
Kentucky (55)	On class AA highways; on other highways, 45'
Nevada (70)	Lengths up to 105' may be authorized by the State highway department.
Oklahoma (55)	Auto transports and oil field equipment by special permit only, 60'
Oregon (60) South Dakota (65)	On designated highways
Washington (65)	Tractor and stinger-steered semitrailer with load, 70'
West Virginia (55)	On designated highways; otherwise, 50'
Wyoming (65)	Motor vehicles hauling logs, utility poles, automobiles, concrete or steel beams, and one-piece pipe, 70'

LENGTH LIMITS - COMBINATIONS OTHER THAN TRACTOR-SEMITRAILER

Summary of State Basic Limits 1/
(December 31, 1967)

Limit, feet	Number of States
50	2
55	17
60	1
65	24
70	1
75	1
98	1
105	2
NP	3
Total	52

1/ These are maximum limits, including those available for continuous operation for a specified period under permit or for operation on designated highways.

Special Provisions
(In the tabulation below, the basic length limit is shown in parenthesis.)

Colorado (65) Kansas (65) Michigan (65)	On designated highways
Idaho (98)	Three-unit combinations on designated highways; otherwise, 65'
Illinois (65)	Three-unit combinations on four-lane highways or such other highways as are designated by the highway department; 2-unit combinations other than tractor-semitrailer, 60'
Indiana (65)	Three-unit combinations; otherwise 55'
Iowa (55)	Three-unit combination may use 60' on highways with 22' or wider surface; otherwise, 50'
Kentucky (55)	On class AA highways; on other highways, 45'

LENGTH LIMITS -
COMBINATIONS OTHER THAN TRACTOR-SEMITRAILER
Sheet 2 of 2

Louisiana (65)	Two-unit combinations only
Maryland (65) **Pennsylvanua** (55)	Vehicles hauling poles, pilings, structural units, rowing sheet, etc., 70'
Michigan (70)	Permit required; good for nine months
North Dakota (65)	Three-unit combinations on designated highways; otherwise, 60'
Oregon (65)	On designated highways by permit unless a resolution is adopted by the highway authority allowing operation of 65-foot combinations on a regular basis without permit. Statutory limit of 60 feet on Oregon routes 86 and 242.
South Carolina (55)	House trailers, 60'
South Dakota (65)	On designated highways; a permit is required for a 3-unit combination.
Utah (75)	Limit is based on legal provision that additional length granted by permit cannot exceed the specified maximum (60 feet) by more than 25 percent.

of 50 feet in 2 States, 55 feet in 17 States, 60 feet in 1 State, 65 feet or more in 29 States, and are not permitted to operate in 3 States. See the tabulation on the next page. These limits cover a wide range, indicating a difference of opinion as to what maximum length is desirable as well as a lag in providing for changing conditions. However, there is a noticeable clustering about the 55- and 65-foot limits in the case of the truck with full trailer and the tractor-semitrailer with full trailer.

The existing limits of up to 55 feet on the length of single-unit vehicles suggest that consideration should be given to the economy of 40- to 55-foot maximum limits. For combinations, the range of lengths from 50 to 100 feet should be considered. The 100-foot length is worthy of attention because combination vehicles of this length are now operating on five toll turnpikes.

The factors related to the desirable length of vehicles considered in this study include the following: (1) overtaking and passing vehicles in traffic, (2) sight distance of other vehicles and stability in traffic, (3) offtracking on curves, (4) lane width, (5) pavement and structure design with respect to numbers of axles and axle spacing, (6) stowage of cargo, (7) flexibility of short or long vehicles, (8) number of vehicles per combination, (9) feasibility of combining vehicles, and (10) vehicle operating cost.

D. Number of Towed Vehicles

The makeup of the vehicle combination is an important factor to be related to the factor of length. Since all States permit a tractor towing a semitrailer, the differences lie in the question of what additional units are permitted to be towed by a full truck or by a tractor-semitrailer. As shown on the next page, 49 States permit a full trailer to be towed by a single-unit truck (i.e., a combination of two cargo bodies, one of which is a towed unit). A full trailer towed by a tractor-semitrailer (i.e., a combination of two cargo bodies in a three-vehicle combination with two towed units) is permitted to operate in 32 States, although in some States the operation may be limited in certain respects.

The tabulation of State length limits for combinations other than the tractor-semitrailer points up the substantial movement toward the 65-foot limit for two-cargo combinations. Table 3-3 shows this development more specifically. Two States--New Hampshire and New Jersey--permit three-unit combinations, but are omitted from this table because of their length restriction to 55 feet. The 65-foot, three-unit combination is universally permitted in the West, and is spreading eastward. Delaware and Maryland enacted laws permitting it during 1967.

In addition to the total length of vehicle or combination, the following factors are important with respect to the number of vehicles per combination: (1) safety in the

NUMBER OF TOWED UNITS
(December 31, 1967)

Legal restriction	Number of States with restrictions on number of towed vehicles by vehicle class		
	One semitrailer	One full trailer a/	Tractor-semi-trailer and full trailer b/
Not permitted	--	c/ 3	c/ 20
Permitted	42	d/ 39	22
Number not restricted	10	10	10

a. Colorado and New Jersey permit towing of two full trailers.
b. Idaho permits three towed units, one of which must be a semitrailer drawn by a tractor.
c. By order of the Commissioner of Highways and under annual permit, Kentucky permits the truck with full trailer and the tractor-semitrailer-trailer to operate on the Interstate system, the toll road system, and 10 miles over connecting roads.
d. Connecticut requires a special permit.

Table 3-3.--Comparative length limits for two-cargo combinations in States permitting the operation of three-unit combinations more than 55 feet long

States permitting three-unit combinations longer than 55 feet as of December 31, 1967	Type of two-cargo combination	
	Tractor-semitrailer-full trailer	Truck-full trailer
	(feet)	(feet)
East of the west borderline of Minnesota-Louisiana:		
Delaware	65	65
Illinois	1/ 65	60
Indiana	65	55
Iowa	60	55
Maryland	65	55
Michigan	2/ 65	55
Missouri	3/ 65	3/ 65
Ohio	65	65
West of Minnesota-Louisiana:		
Arizona	65	65
Arkansas	65	65
California	65	65
Colorado	2/ 65	2/ 65
Idaho	2/ 98	65
Kansas	2/ 65	2/ 65
Montana	4/ 70	4/ 70
Nebraska	65	65
Nevada	5/105	5/105
New Mexico	65	65
North Dakota	2/ 65	60
Oklahoma	65	65
Oregon	6/105	6/105
South Dakota	2/ 65	7/ 60
Texas	65	65
Utah	8/ 75	8/ 75
Washington	65	65
Wyoming	65	65

Alaska, Hawaii, and Puerto Rico exluded.

1/ Without permit on all four-lane highways and by annual permit on certain two-lane roads.

2/ On designated highways.

3/ On Interstate and State primary highways and five miles to and from such highways.

4/ For vehicle including load under permit good for nine months; otherwise 60 feet.

Table 3-3.--Comparative length limits for two-cargo combinations in States permitting the operation of three-unit combinations more than 55 feet long

5/ By rule and regulation of the State highway department; otherwise, 70 feet.

6/ Under permit for continuous operation of particular combinations on designated highways; certain highways are designated for maximum vehicle lengths of 75 or 65 feet without permit.

7/ Not permitted except under annual permit

8/ Based on the legal provision that additional length granted by permit for up to 90 days cannot exceed the specified maximum (60 feet) by more than 25 percent.

traffic stream, (2) offtracking on curves, (3) mechanical risk at connections and braking, (4) adaptability in transport service, and (5) handling at freight terminals.

4. LEGAL MAXIMUM WEIGHT LIMITS

On this and succeeding pages, the State limits on axle weight, single and tandem, and on maximum gross vehicle weight are discussed. The various State legal limits with respect to weight are summarized in three tabulations that appear in this section.

A. Enforcement Tolerance

The basic statutory axle-weight limit is sometimes increased, in effect, by provision for an enforcement tolerance. Such a tolerance is provided for in the law of 15 States. The extent of the additional weight permitted by the enforcement tolerance varies from State to State, but it is most often expressed as a percentage (say, 2 to 10 percent) of the basic statutory limit.

Analyses of the truck weight data indicate that the transport agencies regularly utilize the enforcement tolerance, since axles so loaded can operate legally. Therefore, the legal limits considered in this report include the tolerance.

B. Single-axle Weight Limits

In 22 States a maximum weight of 18,000 pounds is permitted on single axles, including any enforcement tolerance.

AXLE-WEIGHT LIMITS - SINGLE AXLES

Summary of State Basic Limits (December 31, 1967)

Limit, pounds 1/	Number of States
18,000	22
18,001 to 18,999	5
19,000 to 19,999	5
20,000 to 20,999	5
21,000 to 21,999	1
22,000 to 22,999	9
23,000 to 23,520	3
24,000	1
NS	1
Total	52

1/ Includes enforcement tolerance.

Special Provisions

(In the tabulation below, the basic axle-weight limit is shown in parenthesis.)

Idaho (18,000)	For hauling timber products, ores, aggregates, and agricultural products, 18,900 lbs.
Illinois (18,000)	On designated highways; on other highways, 16,000 lbs.
Indiana (19,000)	On designated highways, 22,400 lbs.
Kentucky (18,900)	On class AAA and AA highways
Maine (22,000)	Various exceptions up to 10 percent above basic limit for hauling forest and mineral products and construction materials
Wisconsin (19,500)	On 2-axle trucks transporting milk from farm to market or hauling peeled or unpeeled forest products, 21,000 lbs.

Of these States, however, 2 (Idaho and Illinois) allow higher limits for hauling specified products or for travel on specified highways. Therefore, only 20 States have an absolute limit of 18,000 pounds on the weight of a single axle.

The range of legal weight limits for single axles is from 18,000 pounds to 24,000 pounds, with 9 States in the interval from 22,000 to 22,999 pounds and 5 States above that level (including Puerto Rico without a specified limit). Thus 14 States allow weights of 22,000 pounds or more for a single axle.

C. Tandem-axle Weight Limits

The weight limit of 32,000 pounds for tandem axles prevails in 21 States. Of these States, 1 (Idaho) has a higher limit of 37,800 pounds for hauling designated products, so that only 20 States can be said to have an absolute limit of 32,000 pounds on tandem axles.

The range of legal weight limits on tandem axles is a rather wide one, from 32,000 to 44,000 pounds. The tandem-axle weights in 10 States fall in the interval from 36,000 to 36,999 pounds, and 9 States (including Rhode Island and Puerto Rico with no specified limit) have limits greater than 36,999 pounds. It should be noted that the States do not follow a

AXLE-WEIGHT LIMITS - TANDEM AXLES

Summary of State Basic Limits
(December 31, 1967)

Limit pounds 1/	Number of States
32,000	21
32,001 to 32,999	2
33,000 to 33,999	7
34,000 to 34,999	3
35,000 to 35,999	0
36,000 to 36,999	10
37,000 to 37,999	1
38,000	2
39,600	1
40,000 to 40,680	2
44,000	1
NS	2
Total	52

1/ Includes enforcement tolerance.

Special Provisions

(In the tabulation below, the basic axle-weight limit is shown in parenthesis.)

Idaho (32,000)	For hauling timber products, ores, aggregates, and agricultural products, 37,800 lbs.
Indiana (33,000)	On designated highways, 36,000 lbs.
Vermont (36,000)	On a 3-axle tandem, 42,700 lbs.

consistent ratio of tandem- to single-axle weight limit. Some of the ratios are as follows: 33,600/23,520 = 1.43; 36,000/22,400 = 1.61; 32,000/18,000 = 1.78; and 40,680/20,340 = 2.00.

D. Maximum Gross Vehicle Weight Limits

Only four States now have gross vehicle weight limits of less than 73,000 pounds, and 15 States have limits of 76,000 pounds or more. There is fair agreement between the gross weight limits and the sum of the legal limits on the axles.

During 1963, about 17 States raised their gross vehicle weight limits for the 5-axle tractor-semitrailer to 73,280 pounds, the limit provided for under Federal-aid legislation as applied to the Interstate highway system. This 73,280-pound limit is approximately equal to 32,000 pounds for the two tandem-axle pairs and 9,000 pounds on the front or steering axle, or 32,000 + 32,000 = 73,000 pounds.

The gross vehicle weight, as such, is not a factor affecting pavement design. In the AASHO Interim Design Formula, the design factor is based upon the axle weight and the number of axle applications. Consequently, so far as the gross weight is concerned, its limit could equal the sum of the maximum limits of the axles.

In considering bridges, however, the gross vehicle weight in relation to the spacing of the axles is important.

MAXIMUM GROSS VEHICLE WEIGHT LIMITS

Summary of State Limits
(December 31, 1967)

Limit, pounds 1/	Number of States 2/
70,000 to 72,999	4
73,000 to 73,999	32
76,000 to 76,999	7
78,000 to 80,000	3
86,400 to 88,000	2
100,000 to 105,000	2
No limit	1
Total	51

1/ Maximum legal limit or the practical legal limit for the 5-axle semitrailer or other combination, including double trailer combinations, whichever is greater.

2/ Puerto Rico is excluded.

Close spacing of axles carrying the legal axle weights produces greater stress on bridge structure than the same axles carrying the same weights but spaced farther apart.

Gross weight is, therefore, a factor to investigate, and the desirable gross weight maximum limit for the most commonly used vehicles should be the sum of the legal axle weights adjusted for the lighter weight of the steering axle.

For the closely coupled vehicle or the vehicle with an uncommonly large number of axles for its length, the gross vehicle weight needs to be considered in relation to axle spacing.

5. CONCLUSIONS

Summary of the maximum limits of vehicle dimensions and weights for individual States suggests the following conclusions:

(1) Interstate commerce by highway has much to gain in improved operations and economy from greater uniformity in legal limits on the dimensions and weights of motor vehicles.

(2) There is no easily found support for variations in these limits among States.

(3) Study of highway transport is needed to arrive at the limits on dimensions and weights that are desirable from the point of view of the public interest as a whole.

CHAPTER 4

DESIRABLE MAXIMUM LIMITS ON MOTOR VEHICLE DIMENSIONS

The dimensions of motor vehicles, which may be considered separately from axle weight, control the volume of freight that may be carried on a specific vehicle. From the standpoint of the transport industry, vehicle width, height, and length affect loading practices and terminal facilities. From the standpoint of the pavement, they affect pavement and shoulder width, overhead clearance of structures, safety and traffic, and the movements of passenger cars. The desirable limits of vehicle dimensions will be examined in this chapter on the basis of these effects.

This chapter gives scant attention to the desirability of dimensional limits less than those that now predominate in the 50 States. The general trend in limits over time has been upward, thereby enhancing transport economy. Industry does not want lower limits. For these reasons, no advantage could be seen in investigating limits lower than the most frequently used of the limits now prevailing.

1. WIDTH OF VEHICLE

The prevailing maximum vehicle width specified in the laws of the States is 96 inches. (See page 3-14.) The desirability of additional width will be discussed first from the point of view of the transport industry, involving factors primarily concerned with the vehicle itself, and then from the point of view of traffic factors, involving the relationship between vehicles in operation and the highway over which they travel.

A. Transport Factors

The effects of additional width of vehicle upon transport operations may be considered in two groups: (1) effects having to do with requirements for cargo stowage and handling and other transport operations and (2) effects on the chassis design of the vehicle.

From the standpoint of transport operations, the carriers of freight see no need for as much as a foot of additional width, or a total width of 108 inches, because it would prove impractical for freight handling (not considering safety of operation on the highway, of course). For example, such a width would require a certain amount of alteration to dock and terminal facilities. Thus, there is little apparent demand at this time for truck widths greater than 102 or 104 inches.

A vehicle width of 102 inches would offer carriers a fair degree of advantage over the 96-inch width. Experience indicates that the operation of vehicles this wide is advantageous and feasible as well. Freight carriers have seen operations in 3 States where 102 inches is the legal limit and in other States that permit operation of buses having 102- to 104-inch widths.

Vehicles of this width could be loaded or unloaded without much disadvantage in handling or necessary remodeling of dock and terminal facilities. While the additional 6 inches above 96 offer no particular advantage for transporting bulky or heavy commodities, for light-weight commodities such as household furniture, the extra width has certain advantages. But primarily, the 102-inch width would permit such cargo as plywood in 8-foot lengths to be carried crosswise of the vehicle. It might also work out better for goods of other dimensions or any modular article that could be fitted into a width of 8 feet. However, in order to allow for side wall thickness of the vehicle and for clearance for handling cargo, an outside vehicle width of 104 inches would be preferable to 102 inches.

From the standpoint of chassis design, the 102-inch width would allow for excess width across the rear tires, since vehicles now being manufactured are often more than 96 inches at that point. On designated highways, New Mexico allows the additional width of 6 inches to take care of the over-dimension across the tires. Other States take care of it by liberal enforcement of their width requirements.

Additional space for the differential and braking equipment in the design of the vehicle at the rear axle would be a significant advantage of the 102-inch maximum width. As vehicles have become heavier and are operated at higher speeds, additional braking capacity has become desirable. Gradually most of the available space within the 96-inch overall clearance has been utilized on the driving axle. Therefore, a change to 102-inch width would permit a better chassis design from the standpoint of power transmission and braking apparatus. This advantage is in addition to the greater space in which to fit tires without exceeding the legal limits on vehicle width.

Another advantage of the greater width of vehicle would be to make the vehicle more stable against overturning forces. The wider base without any rise in center of gravity would produce a safer vehicle.

B. Effect of Vehicle Width on Traffic

Vehicle placement studies and observation of the traffic on the 10-foot lanes of 13th Street, N.W., Washington, D.C. [1], indicate that traffic for which 12-foot lanes would be desirable does operate successfully, although less efficiently, on 10- and 11-foot lanes. Therefore, it is reasonable to predict that, at a vehicle width of 102 inches, traffic would not encounter any major restrictions on 12-foot lanes on multilane highways. For example, it may be noted from the Highway Capacity Manual that 11-foot lanes on multilane highways produce a capacity reduction of only 3 percent from the 12-foot lane level, other conditions being satisfactory.

1/ "The Effect of Busses on the Traffic Flow on Urban Arterials," Bureau of Public Roads, in progress.

On most existing urban street systems, particularly those already being operated beyond their design capabilities, wider vehicles may interfere somewhat with the freedom of movement of traffic. On the other hand, vehicles of 102-inch width would not comprise a significant percentage of the traffic stream in such areas, assuming that the transition from 96 to 102 inches would be a gradual one during which the arterials and other main highways accommodating the bulk of the traffic would be improved into multilane facilities with 12-foot lane widths. The operation of the 102-inch vehicle on ramps and in short turning movements is not particularly critical.

C. Conclusion on Vehicle Width

The foregoing analysis indicates that there is no great demand for vehicle width above 102 or 104 inches and that vehicles 102 inches wide can be accommodated satisfactorily on the highways. Therefore, so far as the remainder of this report is concerned, the 102-inch width will be regarded as the desirable maximum limit.

The economy of increasing vehicle width to 102 inches is discussed on pages 13-27 to 13-30. But to the extent that width can be increased in view of the restrictive effects of highway geometrics, highway safety, and suitable freight terminal facilities, overall economy of such width is not as important a consideration as are the factors of stowage of modular cargo and space for power transmission and braking equipment.

2. HEIGHT OF VEHICLE

The factors relating to the desirable height of vehicle will be examined individually. Of importance among these factors are, first, the clearances on the public highways at overhead bridges, tunnels, other structures, and utility lines; secondly, the clearances in private and public terminal areas, dock facilities, warehouses, and terminals in general; and thirdly, the general transport requirements for loading and unloading freight from the standpoint of withstanding stacking to high levels.

A. Highway Overhead Clearance

The overhead structures on public highways which would not clear vehicles of 13.5 feet in maximum height are becoming fewer each year, as the older highways are rebuilt to newer standards of design. As indicated by the present limit (December 1967) of 13.5 feet in 44 States, there is certainly no basic restriction against the use on the highway systems of vehicles 13.5 feet high, although higher vehicles may encounter difficulties on a few highways because of overhead obstructions. Therefore, since the 13.5-foot limit is almost universally the existing limit, examination of any need for height above 13.5 feet, arising from the requirements of the transport industry, is in order.

B. Transport Requirements

Most transport carriers and trailer manufacturers see no particular need at present for a legal height of vehicle above 13.5 feet. The automobile carrier industry, however, wants a higher limit. The experience of the industry so far has been that, because of obstructions on some highways at overhead crossings, some locations on urban streets, and existing shipping docks and terminals, any height above 13.5 feet may offer some difficulty. But this difficulty offers less restriction to transport than do factors in the transport industry itself that have nothing to do with highway vertical clearances.

To consider the problem first with respect to the covered-van type of trailer, industry has some difficulty in stacking and unloading freight to the full inside height of these vehicles. The considerations here are the difficulty of stacking packaged or cartoned cargo at greater heights because of the labor involved and the difficulty of maneuvering the right type of mechanical lifter to utilize any more height. Another problem is the fact that certain kinds of cargo cannot be stacked high, because it will be crushed under its own weight.

At present the practical height from the pavement to the cargo floor of large closed-van trailers is approximately 4.5 feet. For an overall vehicle height of 13.5 feet, there is, therefore, an inside floor-to-ceiling height of 9.0 feet less the thickness of the roof structure. Commodities loaded in van trailers are predominately merchandise freight or packaged commodities. This means that this freight is handled and stacked by manpower. While packaged goods are increasingly assembled as a unit on pallets and handled by forklift trucks, much LTL (less-than-truckload) freight is handled and stowed by manpower.

Inside a van trailer or other cargo body, a man cannot safely stack cartons or packaged goods more than 7.5 feet high. With forklift-pallet shipments, it may be possible to stack palletized loads to a height of 8 feet. To accomplish this, however, the forklift truck requires for manipulation about a foot of headroom above the load height. For these types of loadings, an 8.5-foot floor-to-roof height is necessary, but the maximum useful storage height is about 7.5 feet, leaving about 2.0 feet between the cargo and the outside roof level when the overall vehicle height is 13.5 feet. This 7.5-foot height, rather than the floor-to-ceiling height, should be used in calculating the storage capacity of a closed-van trailer.

There are one or more types of van trailers and some cargos that can be loaded to nearly 9 feet high. Certain bulk vegetables, such as cabbages, can be stored nearly to the van ceiling, if the permitted legal axle weight will allow it. On the other hand, watermelons have a definite load height limit because of their frangibility. Livestock carriers can load hogs, sheep, and calves to 9 feet high in stock rack vans by using an intermediate deck, upon which a second or top layer of animals may be loaded.

The haulers of household goods and furniture generally can use greater height of cargo body. Household goods have a loading density of about 8 pounds per cubic foot, and therefore, axle weight seldom controls the total load. Because household goods may be stacked to ceiling height in a van body, some additional height above the 13.5 feet would offer an advantage. The highway movement of such goods and other light commodities is so small a percentage of total highway movement that higher legal limits for this purpose alone are hardly justifiable.

It must be realized that a fair amount of the cargo hauled over highways is not necessarily hauled in a covered-van type of body. The 13.5-foot height of cargo is also desirable for other types of freight vehicles. Many kinds of machinery and special equipment are carried in open-top trailers or on platform trailers. In such instances, the height of 13.5 feet is sometimes used to advantage. One specific case is the transport of automobiles by carrier. Some States allow a 14.0-foot height for hauling of automobiles.

C. Traffic Considerations Related to Vehicle Height

The overturning tendency of a vehicle would be increased if the vehicle height were increased without a proportional increase in the vehicle width. On the basis that a vehicle of 102 inches width could be authorized by law, a slight increase in vehicle height could also be authorized without changing the relative safety of the vehicle from the standpoint of overturning. On the other hand, inasmuch as there seems to be no present demand for an increase in vehicle height above 13.5 feet, the center of gravity and overturning tendency are not an important factor at this time. The adoption of a maximum width of 102 or 104 inches and retention of the 13.5-foot limit on height would reduce the tendency to overturn.

Within practical limits, the height of the vehicle has little effect upon traffic safety or the operation of other vehicles. Unlike vehicle width, height does not restrict sight distance, except for an occasional view of an overhead traffic signal. At tops of grades, additional height of the vehicle or of the driver's eyes above the pavement is an advantage in affording longer sight distance.

D. Summary and Conclusions on Vehicle Height

In viewing the traffic stream as a whole, the commercial vehicles on the highway that could use to advantage any excess height above 13.5 feet would be primarily those classes of vehicles hauling extra-tall mechanical equipment, automobiles, or special apparatus in open vans.

The second use of the greater height of vehicle would be in the hauling of household goods and furniture and other low-density commodities that could be stacked high. The bulk of the haulage on the highway, however, is of types of goods having such densities that the legal axle-weight limits are reached before the interior height of the cargo body. Thus, height of vehicle above 13.5 feet would afford an advantage to a comparatively small percentage of the total traffic on the public highways.

Bridges and tunnels with less than 13.5 foot height clearance are growing fewer year by year. A legal height of 13.5 feet overall, from pavement to outside top of the vehicle or to the top of the cargo, is all that is at present justified on the basis of transport needs. There is no need at this time for exploring the economics of transportation at vehicle heights either lower or higher than 13.5 feet.

3. LENGTH OF VEHICLE

The overall length of a vehicle combination and the axle weight are the two most critical factors in the total problem of arriving at the desirable dimensions and weights of motor vehicles. The length and weight need to be considered together to some extent, because as the length of the vehicle is increased, the number of axles can also be increased so that additional gross loads can be hauled without increasing the maximum legal limit of axle weight. Furthermore, the length of the vehicle is the means by which more cubage capacity is added to cargo space (passenger space for buses) -- more than is practical to add by increasing the width or height of the vehicle.

A. Factors of Vehicle Length to Consider

The length of vehicle needs to be considered from two points of view: (1) the length of the individual vehicle (full truck, tractor, or trailer) and (2) the overall combination length. The critical factors of vehicle length that affect desirable operations in the traffic stream as well as the entire process of cargo handling are primarily as follows:

(1) The length of the vehicle with respect to loading and unloading at dock and warehouse facilities.

(2) The length of the vehicle with respect to horizontal turns and curves.

(3) The effect of the length of vehicle upon the traffic stream, with particular reference to overtaking and being overtaken and passed by other vehicles.

The length of a single vehicle or combination and the combination make-up are influenced by the commodities to be hauled and the quality of the service to be rendered. For instance, commodities such as liquids or granular bulk items, capable of being rapidly loaded and unloaded, can be hauled to advantage in trucks or tractive-truck-and-trailer combinations, because the truck may be turned around with minimum dock time. Dry freight and bulky equipment, slow in being loaded and unloaded, are best hauled in tractor-trailer combinations, so that the tractor (power vehicle) need not be tied up during the loading or unloading time.

B. Length of Buses

As a generalization, it can be said that only four States have a 35-foot limit for buses and 38 States have a 40-foot limit. There is a trend to longer buses, and 11 States now have limits of 42 feet or more. There is reason to explore the 45-foot limit as a desirable maximum.

The trend in manufacturing is toward intercity buses seating more passengers and also buses with restrooms and other conveniences and comforts. This means longer buses. Further, the trend is toward the tandem rear axle, even for school buses. These trends indicate that a maximum length of 45 feet would serve some useful purpose, particularly in allowing more passenger seats in the three-axle bus, which cannot be loaded to tandem-axle capacity in a length of 40 feet.

About 27 States now allow a greater maximum length (usually 5 feet) for buses than they do for single-unit trucks. As discussed in a later section, 40 feet is a practical maximum limit for the length of single-unit trucks. Therefore, the maximum length of bus would be 45 feet, if based on the "5 feet additional" criterion. Because of the favorable weight-power ratio of the bus and its low count in the traffic stream, a maximum bus length of 45 feet should not interfere unduly with other traffic.

C. Requirements of Length and Attitude of Transport Industry

The following discussion is condensed from the report of the A. T. Kearney Company to the Bureau of Public Roads:

> In general, ...the highway transportation industry would be better served if over-all equipment lengths were to be increased to permit the use of double trailer combinations. For the most part, carriers reported...in the conduct of this and other studies in the industry, that 40-foot trailers represent the largest single unit that can be efficiently operated (except in certain areas) for the following reasons:
>
> 1. Longer trailers are too difficult to maneuver.
>
> 2. Terminal docking space and shipper facilities are inadequate for longer trailers.
>
> 3. Loading and unloading elapsed time is too long and man-hours are lost with the added walking associated with longer equipment.
>
> 4. Streets and alleys of many older urban areas present too many obstacles for trailers in excess of 40 feet in length.
>
> Although trailers of 45-foot length are now used in certain areas of the country, as, for example, Florida [and Utah], and might eventually be used by some carriers throughout the country if legally permitted, they are generally felt to be impractical for wide-scale usage by the trucking industry for the reasons cited above.
>
> Carriers felt that single 40-foot trailers, although still presenting a few maneuvering problems in congested urban areas, have proven to be feasible, operations-wise. Since single 40-foot trailers can presently be operated, two 40-foot trailers in combination, which would mean a 100-foot overall length limit, were felt to be practical since they could be moved in double trailer combinations on controlled access multi-lane highways to a particular...[interchange, then]as [two] single

trailer combinations to final destinations [off the controlled access highways].

Most operators and all Western carriers felt that overall length limits for all highways should be 65 feet. This length would permit double trailer combinations (two 27-foot trailers) to spread from the Western States, where they are now legal, throughout the remainder of the country. These individuals were convinced that the direction of the highway transportation industry must be toward double trailer combinations if it is to survive in face of competitive modes of transportation. They further felt that present [legal] regulations favor development [and use] of ...single 40-foot trailers, which for reasons of customer service, maneuverability and loading efficiency are less desirable than 27-foot double trailer combimations. These contacts also pointed to the obvious advantages of breaking 27-foot double trailer combinations at...central... [places] and [then] using single 27-foot semitrailers with lesser powered city tractors in metropolitan areas as compared to doing the same with 40-foot trailers.

It was suggested [by some carriers] that limited access multi-lane highways should allow the operation of triple units of 27-foot trailers, [a combination length of 95 to 100 feet]. Several Western carriers have made tests of such a unit and found it to track well and present no apparent problems. Actual operations of triple 27-foot trailers have been successful in Nevada.

We found interest among carriers in the Wolfwagon concept. The wolfwagon is a train of two or more straight trucks, [complete single units], each with its individual power unit and controls, which are coupled together and operated by one driver in the forward unit. Individual units may be dropped off en route, or at destination, and since each unit is a separate power unit, an additional power tractor is not required.

D. Length of Trailers as Manufactured

Since 1948 the length of trailer having the greatest frequency of manufacture has moved upward from the 20-to-30-foot bracket in 1948 at 27.5 percent of the total production to the 38-to-40-foot bracket in 1962 at 82.4 percent of total production. See table 4-1.

This trend to 40-foot length is striking. It proves, in general, that under existing legal limits the transport demand may be for trailers longer than 40 feet. However, since no State that permits the larger commercial trailers to operate legally restricts trailer lengths to less than 35 feet and since 37 States do not have a maximum length limit on the trailer itself and another 14 States restrict the length to from 40 to 42.5 feet, the transport industry could legally use trailers longer than 40 or even 45 feet, if it cared to do so. Thus, the manufacture of trailers confirms the conclusion of the Kearney report (Staff Report No. 4) as to vehicle length that 40 feet is an acceptable length for trailers.

Trailers having 26- to 28-foot lengths show a higher percentage of total production in 1964 than those of any other length below 38 feet. But compared to all trailers produced, this percentage (4.4) is low, primarily because in a single-trailer combination the 27-foot length is not as economical as the 40-foot length, and only nine States (all western as of 1964) permit double trailers and the total combination length of

Table 4-1.-- Trends in trailer lengths

Length in Feet	1948	1953	1956	1958	1960	1962	1964
Under 22	1.4%	1.9%	3.8%	-	1.6%	.7%	0.1%
22-24	5.3%	1.6%	1.6%	2.5%	.5%	.2%	0.2%
24-26	6.5%	1.8%	1.0%	.5%	1.0%	.9%	2.9%
26-28	18.8%	1.1%	.6%	1.0%	6.4%	1.3%	4.4%
28-30	27.5%	3.2%	.9%	2.0%	2.5%	.6%	1.7%
30-32	23.9%	10.4%	2.0%	3.0%	2.0%	.6%	1.2%
32-34	16.6%	58.7%	14.8%	5.5%	2.8%	.9%	0.7%
34-36	-	18.9%	68.6%	64.0%	16.6%	7.4%	3.3%
36-38	-	2.4%	6.7%	8.5%	6.5%	2.4%	1.2%
38-40	-	-	-	10.0%	60.0%	81.8%	82.4%
40-42'6"	-	-	-	3.0%	.1%	3.2%	1.1%
Over 42'6"	-	-	-	-	-	-	0.8%

Source: Truck Trailer Manufacturers Association

65 feet required for two 27-foot trailers. The manufacture of trailers 26 or 27 feet in length will increase, because about 15 States have legalized the 65-foot double trailer combination since 1963.

The legal limit on gross vehicle weight of 73,280 or 76,000 pounds is the major deterrent to more rapid development of the use of truck-and-full-trailer and two-trailer combinations in the West where the 65-foot length is legal. The 3-S2 trailer combination with 18/32-kip axle limits can be loaded to the gross vehicle weight limit of 73,280 pounds. Adding a full trailer to make the two-trailer combination 3-S2-2 or 3-S2-4 would give a maximum capacity of 109,000 or 137,000 pounds, respectively, weights far above the legal limits. Consequently, the trucking industry has not developed extensive use of the 27-foot trailers in a 65-foot combination. Because of the gross weight limit, the 3-S2 combination is more practical. The 27-foot trailer would very likely rise rapidly in production and the 40-foot trailer decline, if the gross weight limit should be raised to about 100,000 pounds.

Vehicle length limits permitting the use of trailers 30 feet long have advantages. From the point of view of transport, one factor determining the advantageous trailer length is compatibility with respect to maximum length of the individual units comprising the combination. Thus, the 40-foot trailer can be combined with only a tractor, under a 65- or

70-foot maximum length limit for the combination. It cannot be used as a trailer to a tractive truck, except to an uneconomically short one. The 40-foot trailer is usable in tandem when the maximum combination length is 95 to 100 feet.

From the standpoint of the trucking industry, the 40-foot and 27-foot trailers are not compatible in combinations using either tractor or tractive-truck power. If all the States adopted a maximum combination length of 65 feet and a tractive-truck length of 40 feet, the 27-foot trailer could be used for heavy-density cargos either singly as a full trailer behind a 35-foot tractive truck (also with a 27-foot body) or paired as a semitrailer and full trailer in a combination powered by tractor.

There is some justification for the 70-foot maximum combination limit that would permit two 30-foot trailers to be used with a cab-over-engine tractor or one such trailer to be used with a 37-foot tractive truck. The 70-foot combination length is considered to be acceptable for use on all highways, although not as acceptable as the 65-foot maximum.

E. Summary of Length Requirements of the Transport Industry

From the foregoing discussion it is readily apparent that, if all of the States were to permit the double-cargo combination with a maximum length of 65 feet, it would enable the carriers to use a flexible type of vehicle on all highways. The main length restrictions for all States would be brought into agreement.

Little need is indicated for a single cargo unit longer than 40 feet. On the other hand, two 40-foot cargo units have been used successfully in a total combination length of around 100 feet on the five toll turnpikes where this type of vehicle is permitted. For general use on all highways, the transport industry would favor using 27-foot trailers in combinations of 65-foot length with two cargo bodies. Thus, two-cargo combinations offer greater flexibility and more cargo space than the 40-foot single trailer. The total length of 65 feet has proved to be practical in those States now permitting double cargo units.

F. Vehicle Turning Movement and Offtracking

Before considering length in relation to the offtracking of vehicles, it might be well to look into the way overall vehicle combination length is computed. With the cab-over-engine design, as little as 4 feet is required from the front bumper to the back of the operator's cab. About 3 feet is required from the back of the tractor cab to the nose of the semitrailer. Then, with a semitrailer length of 27 feet, such a tractor-semitrailer combination would have a total length of 34 feet.

If a second cargo body--a full trailer--were added, it would require about 3 feet of space between the rear of the forward semitrailer and the nose of the following full trailer. Again, using a full trailer length of 27 feet, the added distance for the second cargo body would be 30 feet. Therefore, a 65-foot overall combination length would accommodate two 27-foot trailers in a 3-vehicle combination of tractor, semi-trailer, and full trailer. But to provide for a sleeper-cab-over-engine design, a trailer length of 26 feet would be the practical maximum length within an overall combination length of 65 feet.

When pulled by a cab-behind-engine tractor, the 40-foot trailer body would produce an overall length of approximately 51 feet. This length is made up as follows: 8 feet from the front bumper to the back of the cab, 3 feet to the nose of the semitrailer, and 40 feet for the semitrailer. Using a double-trailer combination made up of a semitrailer and full trailer, each 40 feet long, and a cab-behind-engine tractor, the overall train length would be about 94 feet. With a cab-over-engine tractor, the 40-foot double-trailer combination would be 90 feet long. For some of the older-model tractors and towing connections, the combination length with two 40-foot trailers is about 105 feet.

(1) Turning track widths summarized

Table 4-2 summarizes turning track widths for various classes and lengths of single-unit trucks and trailer combinations at city street intersections (90-degree turn on 50-foot turning radius). It is significant that some of the longer vehicles requiring excessive turning track widths on city street intersections can successfully negotiate the cloverleaf ramp loops. However, on cloverleaf ramp loops, the 100- to 105-foot double-trailer combinations require either a longer radius of curvature or pavement wider than 16 feet.

Table 4-2 is based on a vehicle width of 96 inches. If wider vehicles are considered, the respective values for turning track width will increase by the additional amount above 96 inches. For instance, the turning track width for a vehicle 102 inches wide over the tires will be ½ foot wider than the respective value indicated in table 4-2. Furthermore, the indicated value of 14½ feet for the 2-S1 and 3-S2 combinations having an overall length of 60 feet would become 15 feet.

(2) Comparison of four different trailer combinations

Semitrailers of 40-foot length are satisfactory for total trailer combination lengths of 50 and 55 feet. The 50-foot overall lengths can be attained with cab-over engine tractors; and the 55-foot overall lengths, with cab-behind-engine tractors.

Table 4-2.-- Turning track widths for various classes and lengths of vehicle combinations on city street intersections and interchange ramp loops

Vehicle Class	Number of axles	Overall length in feet	Overall wheelbase in feet	Turning track width in feet: City street intersection (90° turn on 50-ft. radius of curvature)	Turning track width in feet: Interchange ramp loop (270° turn on 165-ft. radius of curvature)
2D or 3A	2 or 3	35	22	13.2	9.1
		40	25	13.7	9.5
		40	35	18.2	10.8
		45	40	18.6	11.3
2-S1	3	50	45	20.1	12.1
		55	50	22.5	13.0
		60	55	25.5	14.5
2-S2		40	29	16.5	9.7
		45	33	17.2	10.3
2-S2	4	50	37	17.9	10.5
		55	42	19.1	11.0
		60	47	21.0	11.4
		40	35	18.2	10.7
		45	40	18.6	11.2
3-S2	5	50	45	20.1	12.1
		55	50	22.5	13.0
		60	55	25.5	14.5
		55	50	16.2	10.4
		60	55	16.5	10.5
2-S1-2	5	65	60	17.4	10.9
		70	65	18.5	11.5
		75	70	19.9	12.2
		90	85	24.4	14.8
		95	90	26.2	15.8
3-S2-4	9	100	95	28.0	17.0
		105	100	30.1	18.3
		110	105	32.8	19.7

See Reference 67, STEVENS, Tignor, and Lojacono. Offtracking Calculations for Trailer Combinations. Public Roads, Vol. 34, No. 4, October 1966.

As may be seen in table 4-3, a double-trailer combination made up of two 27.5-foot trailers in an overall length of 65 feet has a narrower turning track width than the 55-foot single-trailer combination. In fact, two 30-foot trailers in a double-trailer combination 70 feet in overall length have a narrower turning track width than the single 40-foot semitrailer combination. Thus it appears that for manipulation on primary roads and on some commercial streets, the use of two 30-foot trailers in a combination 70 feet long is as practical as a single-trailer combination 55 feet long.

In table 4-4, comparisons are made of the same series of trailer combinations for 270-degree turns on 100-foot, 165-foot, and 225-foot turning radii such as may be found at the ramps of cloverleaf intersections of multilane, divided highways with a limited number of ingress and egress points and with acceleration and deceleration lanes. The offtracking of the trailer combinations and their resulting turning track widths are a little greater than for 90-degree turns. It is obvious that 65- and 70-foot double-trailer combinations can travel such ramps as easily as the 55-foot combination with a single 40-foot semitrailer. In addition, on ramps permitting 165-foot and 275-foot turning radii of the 100-foot, double 40-foot-trailer combination, the turning track width is not excessive. However, the turning track width of this 100-foot combination on the 100-foot turning radius is so much as to bar

Table 4-3.-- Comparison of turning track widths on 90-degree turns required by various practical trailer combinations

Class of trailer combination	Lengths of trailers (feet)	Overall length of combination (feet)	Turning track width in feet on 90-degree turns		
			50' Turn Rad.	100' Turn Rad.	165' Turn Rad.
2-S1, 3-S2	40.0	55	22.5	16.5	12.9
2-S1-2	27.5	65	17.4	13.0	11.0
2-S1-2	30.0	70	18.5	14.0	11.5
3-S2-4	40.0	100	28.0	21.5	16.2

Table 4-4.-- Comparison of turning track widths on 270-degree turns required by various practical trailer combinations

Class of trailer combination	Lengths of trailers (feet)	Overall length of combination (feet)	Turning track width in feet on 270-degree turns		
			100' Turn Rad.	165' Turn Rad.	275' Turn Rad.
2-S1, 3-S2	40.0	55	17.0	13.2	12.0
2-S1-2	27.5	65	13.4	11.2	10.5
2-S1-2	30.0	70	14.3	11.8	10.8
3-S2-4	40.0	100	24.4	17.2	14.0

the use of this turning radius at multilane, separated interchanges on freeways.

(3) Discussion and conclusions on vehicle length as related to offtracking

Overall length and the effective wheelbase of semitrailers and full trailers is the most important factor in the offtracking and turning track width of trailer combinations. Tractors are generally made short, whether cab-over-engine (COE) or cab-behind-engine (CBE). However, it can be expected that the industry trend will continue to be towards COE tractors in order to obtain the maximum possible cargo-space lengths in the trailer bodies.

Total length of 40 feet with a maximum wheelbase of 33 to 35 feet is about the maximum that should be permitted for single semitrailers or full trailers in either double- or single-trailer combinations. For single-unit trucks, similar lengths also appear desirable. The 40-foot overall length appears to be an optimum maximum for single-unit trucks, since they must maneuver through city streets of various widths.

When trucks are used as the tractive power vehicles of truck-full-trailer combinations, the optimum overall truck length may be less than 40 feet, to permit a proper balancing of load capacity with the full trailer in a combination that is within the overall legal length limit. Because of the various possibilities for arranging single and tandem axles on truck-full-trailer combinations, it is difficult to prescribe an optimum length for the tractive truck, except to say that it should have a total length less than 40 feet. The cargo bodies on the tractive truck and the full trailer should be about the same length.

G. Effect of Length of Vehicle on the Traffic Stream

Increasing the maximum legal length of commercial vehicles may affect other traffic and the design of highways in the following ways:

(1) Longer combination vehicles may have greater tendency to offtrack laterally at their rear ends, thus taking up slightly more pavement width. Offtracking always exists on curves, but may also be found on tangents.

(2) The longer the vehicle, the more restricted is the view ahead that is available to the drivers of following or approaching vehicles.

(3) The longer the vehicle to be passed, the greater the distance required to overtake and pass it, thus requiring longer passing sight distances.

(4) On four-lane, divided highways, long combination vehicles overtaking and passing each other on plus grades (usually at speeds much slower than the desired speed of passenger cars) will block both lanes for a longer time than is required for shorter combinations.

The transverse movement of the rear wheel tracks of a moving vehicle, especially when decelerating from high speed, offers some reason for concern to the drivers of trailing vehicles or vehicles attempting to pass on 2-lane, bidirectional highways. Besides having psychological effects upon the following or approaching drivers, such movement would decrease the effective horizontal free distance between passing vehicles. For vehicles well maintained and properly operated, this factor has been of no importance in the States permitting combinations 65 feet long. Neither has it been an objectionable condition in the operation on toll turnpikes of 100-foot double trailers.

On high-crowned pavements, there is a tendency for the right rear wheel of a vehicle to offtrack to the right. This offtracking may require steering the left front wheel near the center line or left lane line in order to keep the vehicle within its own lane. Because the condition of high crown is not widespread on the highways where the vehicle 65 feet or longer is apt to travel, this factor need not be given further consideration. The transverse movement of the rear end of a long vehicle or its offtracking on high-crowned pavement is not sufficiently great to cause concern for traffic safety or the movement of other vehicles.

On 2-lane bidirectional highways, the length of a vehicle restricts the view around it of drivers of following or approaching vehicles. The reported experience in States now having 65-foot legal length limits for combination vehicles indicates that, at least up to the 65-foot maximum, the length factor is not important in restricting the view available to drivers of other vehicles.

The five toll highway authorities that permit double-trailer combinations of about 100 feet in length report successful operation of these vehicles on their 4-lane, divided highways. The item of view around long vehicles, therefore, should not be a factor restricting vehicle length up to 100 feet on divided highways.

The longer the vehicle to be passed on the highway, the greater is the passing distance required. The greater the required passing distance, the longer the sight distance that is needed, especially where the vehicles to be accommodated have greater length than is being allowed for in the design vehicles used to determine the factor of sight distance. Passing sight distance is required only on 2-lane, 2-way roadways. Only stopping sight distance need be provided on 4-lane, divided highways.

In addition to requiring longer sight distance, longer combinations perhaps inflict some additional expense upon passenger cars in passing maneuvers. In the first place, they might prevent passenger cars from passing for longer periods of time than would shorter trucks. When the cars did pass, in order to complete the passing maneuver, they would have to maintain a higher speed for a longer time and distance or accelerate for a longer time.

Passing sight distance might require some upward revision, perhaps in the neighborhood of 10 to 20 percent, if substantially longer vehicle combinations (say, longer than 60 to 70 feet) are allowed on 2-lane, 2-way highways. For example, consider a vehicle combination 40 feet longer than is presently allowed, traveling 50 miles per hour. If such a vehicle were passed by a car averaging 20 miles per hour faster, the passing car would require 140 feet of extra distance in the left lane in order to pass successfully.

Also to be considered, though not readily evaluated without research, is the psychological effect of long combinations traveling in the higher speed ranges of, say, 40 to 60 miles per hour. Because of fear or inability to judge the distance required, drivers of trailing vehicles might possibly refuse to accept passing opportunities with adequate sight distance. Certainly the decision to pass involves more margin for error with long combinations than with shorter ones.

On 4-lane, divided highways, even on plus grades as low as 1 percent, heavy trucks and combinations often overtake and pass slower moving vehicles. When the overtaking vehicle has power for a gain of only 5 miles per hour over the speed of the vehicles being passed, such a passing movement holds up all those vehicles behind whose drivers wish to travel faster than the speed of the passing truck or combination. In this situation, additional delay both to the passing vehicle and to the blocked vehicle will result, should longer vehicles be permitted. The consequence is the same in effect as that produced by the passing maneuver on 2-lane highways, but is not often thought of, because the slow vehicles stay in the right lane--that is until they move out to pass a slower vehicle.

H. Summary and Conclusions on Vehicle Length

The desirable lengths of vehicles as indicated by the discussion presented in this chapter are summarized as follows:

The single-unit truck and the trailer unit of 40-foot maximum length are satisfactory both from the point of view of industry requirements and highway use.

Although the 40-foot trailer is at present standard for industry, this length has been dictated more by the existing maximum limits of length and of gross vehicle weight as established by State law than by its merits in the light of transport requirements. Industry prefers two 27-foot trailers in combination to the single 40-foot trailer.

Combinations with two cargo bodies are in demand by the transport industry because of their economy in line-haul operation, their flexibility in terminal operations, and their convenience and economy in the urban distribution of cargo.

The 65-foot maximum combination length has proved successful in the Western States, and the 100-foot combination has been successful in operation on toll highways.

Highway systems as they now exist can accommodate the 65-foot combination length with proper regard to highway design and geometry and to traffic safety. Some slight cost to passenger cars and light trucks may result.

Without considering the number of axles per vehicle or per combination or the axle spacing in feet, the foregoing discussion of the requirements of the transport industry, the offtracking of vehicles on curves, and the factors of highway safety indicate that the following maximum lengths of vehicles are desirable:

(1) For use on all highways and streets:

a. Bus with a maximum length of 45 feet.

b. Single-unit truck with maximum length of 40 feet.

c. Single semitrailer or full trailer of 40 feet maximum length.

d. Tractor-semitrailer combination (single cargo body) with maximum overall length of 55 feet, including a semitrailer of 40-foot maximum length.

e. Tractor-semitrailer-and-full-trailer combinations (double cargo trailers) with a maximum overall length of 65 feet, including two trailers of 27-foot maximum length each.

f. Truck-and-full-trailer combinations (two cargo bodies) with a maximum overall length of 65 feet.

g. Two Wolfwagons in combination, not to exceed 60 feet in overall length.

(2) For use on multilane, divided highways with controlled access (Interstate system):

a. Tractor-semitrailer-and-full-trailer combinations (double-cargo trailers) with maximum length of 100 feet, including two trailers of a maximum length of 40 feet each.

b. Tractor-semitrailer and two full trailers (triple cargo units) with a maximum length of 100 feet.

c. Three Wolfwagons in combination (three cargo units) with maximum overall length of 90 feet.

CHAPTER 5

EFFECTS OF GROSS VEHICLE WEIGHT ON MOTOR VEHICLE PERFORMANCE IN TRAFFIC

From the point of view of highway safety, the performance of motor vehicles on the highway and the consequences of that performance to all other vehicles in traffic are involved in the consideration of desirable maximum vehicle dimensions and weights. Performance may be satisfactorily measured in terms of accelerating and speed ability (ratio of gross weight to net horsepower) and braking ability (deceleration and stopping distance).

Accelerating ability is a safety factor in traffic, particularly as it enables a vehicle to accelerate rapidly from low speed and to maintain near traffic speed on plus grades. The weight-horsepower ratio is an index of the ability to accelerate and to maintain traffic speed. Braking ability, usually measured by the distance required to stop from an initial speed, is also a safety factor in traffic. Accident experience is a third factor to be examined in the light of the way traffic safety is influenced by vehicle dimensions and weights.

1. FIELD SURVEYS OF VEHICLE WEIGHT, HORSEPOWER, AND BRAKING PERFORMANCE

Since about 1941, the Bureau of Public Roads and the State highway departments have conducted periodic surveys of the weight, horsepower, and braking performance of motor vehicles. In 1963 some additional surveys were conducted especially for this project on the desirable dimensions and weights of motor vehicles. Some review of these surveys made in 1949, 1950, 1955, and 1963 and the methods used is presented next.

The 1955 study included the brake testing of 862 commercial vehicles in California, Maryland, and Michigan. Horsepower information was obtained at the same time.

The field testing and survey in 1963 was conducted at or near the same roadside locations in California, Maryland, and Michigan that were used in 1949 and 1955. The brakes on 952 vehicles were tested, and the gross weight and horsepower data were obtained on 1,026 commercial vehicles.

The pertinent horsepower is the net horsepower: the gross brake horsepower of the engine less the horsepower required to operate the normal accessories, such as fan, air compressor, generator, and muffler. The net horsepower is that horsepower which is available at the clutch, or its equivalent. As a general average, the net horsepower is about 90 percent of the gross brake horsepower.

2. VEHICLE GROSS WEIGHT AND NET HORSEPOWER

The results of the analysis of gross weight and net horsepower for 1963 are presented in some detail and compared with the results for 1949, 1950, and 1955, to show the trend of the weight-power ratio over time.

A. Results of Survey of Weight-Power Ratio

A summary of the horsepower, weight, and weight-power ratio for each vehicle type is shown in table 5-3 for the 1963 brake tests. There is a definite increase in the gross weight, net horsepower, and weight-power ratio as the number of axles per vehicle increases, up to five axles. For five or more axles, the measures tended to remain fairly constant. The presentations in table 5-3 show that hill-climbing ability and accelerating ability as measured by the weight-horsepower ratio vary widely between and within vehicle classes.

The smaller weight-power ratios for each vehicle class were generally for empty vehicles with large engines. For example, an empty 3-S2 vehicle weighing 29,100 pounds had a net engine horsepower of 310 and a weight-power ratio of 94, the smallest for this vehicle class. The net horsepower of 310 was the largest observed for any vehicle in the sample obtained in the 1963 study.

A separate analysis was made of the 1963 data considering only loaded vehicles. For this analysis, all empty

Table 5-3 .--Range and average of the gross weight, net horsepower, and weight-power ratio for all commercial vehicles weighed in the 1963 test.

Vehicle class	Gross weight, pounds		Net horsepower		Weight-power ratio	
	Range	Average	Range	Average	Range	Average
ALL VEHICLES						
2S - single tired	2,545- 11,120	4,795	50-165	109	24-128	44
2D - dual tired	5,700- 31,410	13,230	80-198	136	42-267	97
3	11,000- 47,410	22,785	95-222	157	71-282	145
2-S1	13,000- 45,400	24,630	118-230	165	84-304	149
2-S2	15,900- 64,805	39,030	110-238	172	89-427	227
3-S2	22,010- 94,650	50,625	128-310	184	94-701	275
3-2	22,400- 78,200	48,070	128-250	184	93-511	261
2-S1-2	24,500- 82,770	59,595	130-235	186	111-590	321
Other	16,000-132,570	54,995	153-288	188	88-625	292
LOADED VEHICLES ONLY						
2 - single tired	3,270- 11,120	5,275	63-165	108	29-128	49
2 - dual tired	6,020- 31,410	15,425	80-198	136	45-267	113
3	11,000- 47,410	27,460	95-222	157	82-282	175
2-S1	14,500- 45,400	28,700	118-230	167	99-304	172
2-S2	19,270- 64,805	44,625	110-235	172	120-427	259
3-S2	27,240- 94,650	60,775	134-255	185	151-701	329
3-2	49,600- 78,200	73,150	150-209	182	329-511	403
2-S1-2	36,600- 82,770	73,685	134-235	185	203-590	398
Other	16,000-132,570	67,285	133-234	187	88-625	359

trucks were excluded from the sample. A vehicle was considered loaded if it carried any cargo or payload, regardless of the amount.

As would be expected, the net horsepower for all vehicles (table 5-3) was nearly the same as for loaded vehicles only. The larger weight-power ratios were for heavily loaded vehicles with small engines. For example, one 3-S2 vehicle had a gross weight of 94,650 pounds and a net engine horsepower of 135, giving a weight-power ratio of 701, the largest ratio for any vehicle in the 1963 study. This particular vehicle was operating under a special permit, because of tandem axle weights in excess of the legal limit for the State in which it was operating.

The cumulative frequency distributions of the weight-power ratios for the various vehicle classes for 1955 and 1963 are shown in figures 5-2 and 5-3, respectively. These curves include all vehicles and again illustrate the wide range in performance among and within the vehicle classes.

A summary of the 15, 50, and 85 percentile values of the cumulative frequency distributions of weight-power ratio for 1955 and 1963 is shown in table 5-4. Considerable reduction has occurred between 1955 and 1963 in the ratios for all vehicle classes. The percentage decreases shown in the table are particularly significant.

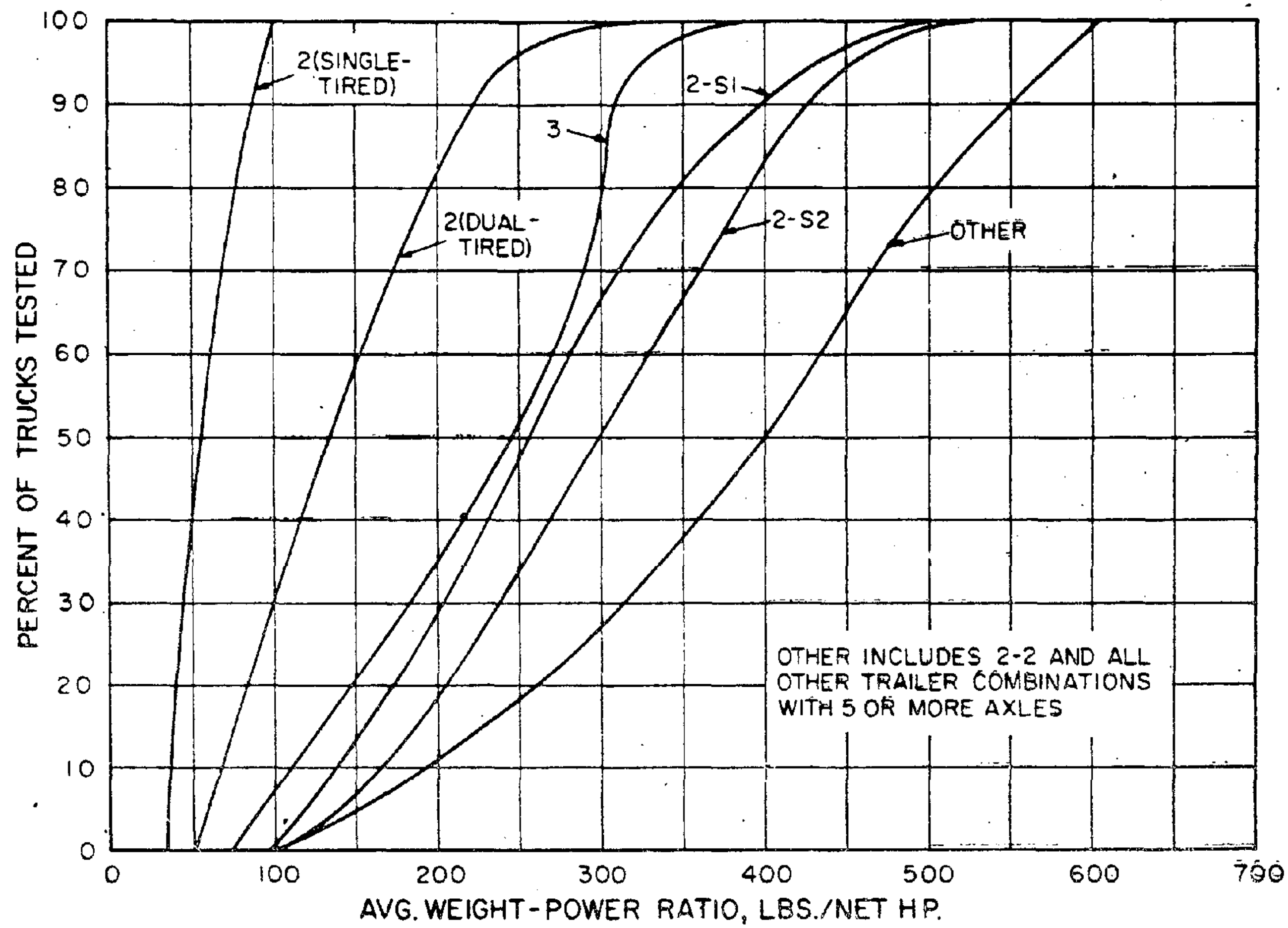

Figure 5-2.—Cumulative frequency distributions of weight-power ratios for all commercial vehicles, 1955 brake test.

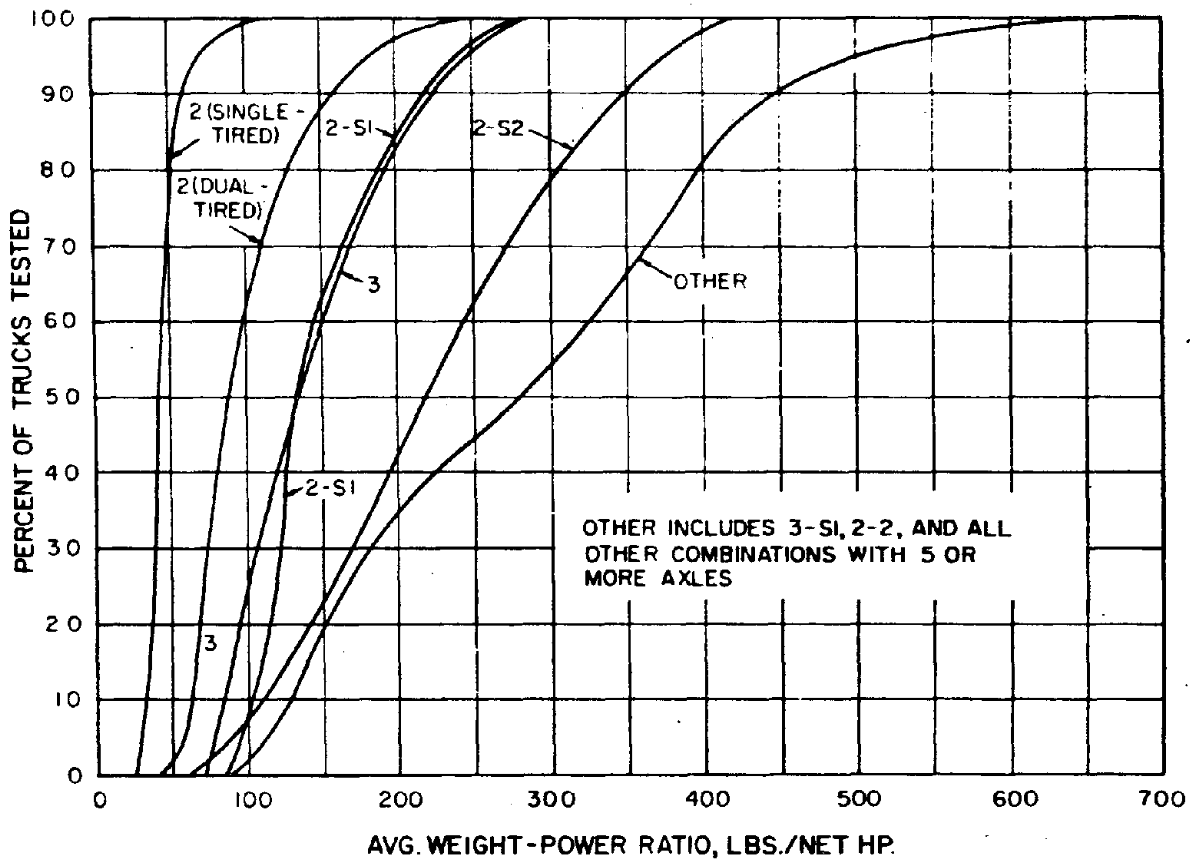

Figure 5-3. *—Cumulative frequency distributions of weight-power ratios for all commercial vehicles, 1963 brake test.*

Table 5-4.--Comparison of percentile values from cumulative frequency distributions of weight-power ratios for all commercial vehicles weighed in 1955 and 1963

Vehicle class	Weight-power ratio in pounds per horsepower								
	15 percentile			50 percentile			85 percentile		
	1955	1963	Percentage decrease	1955	1963	Percentage decrease	1955	1963	Percentage decrease
2S- single tired	41	32	22	58	42	28	85	56	34
2D- dual tired	73	64	12	135	87	36	208	142	32
3A	132	88	33	245	135	45	306	208	32
2-S1	161	108	33	256	133	48	376	204	46
2-S2	186	126	21	300	218	27	406	327	19
Other	232	138	41	400	278	30	531	428	19
3-S2	-	157	-	-	272	-	-	377	-
2-S1-2	-	141	-	-	360	-	-	431	-

Figure 5-4 presents the cumulative frequency distributions of weight-power ratios for vehicle classes 3-S2 and 2-S1-2. These curves have been separated out of the "other" curve for 1963 data shown in figure 5-3. The irregularity in the curve for the 2-S1-2 vehicles is caused primarily by the fact that nearly all of the vehicles were either empty or heavily loaded. Only five of a total of 51 vehicles in this class had gross weights within the range of 35,000 to 70,000 pounds.

Cumulative frequency distributions of the weight-power ratio in 1963 for loaded vehicles only are shown in figure 5-5, by vehicle class. The curve designated as "other" includes all vehicle combinations with 5 or more axles. The 3-S2 and 2-S1-2 vehicles are included in this "other" curve, but have also been shown separately because they are the largest groups making up the "other" curve.

Table 5-5 presents a summary of the 15, 50, and 85 percentile values of the cumulative frequency distributions of the weight-power ratios for the loaded vehicles in 1963.

Figure 5-6 illustrates the trend in weight-power ratios from 1949 to 1963. The curves are based on average data for all commercial vehicles weighed in the brake studies of 1949, 1955, and 1963. The average ratios for all vehicles in the 1950 truck weight survey sample are also plotted in figure 5-6, as indicated by the triangular symbols. It is apparent that

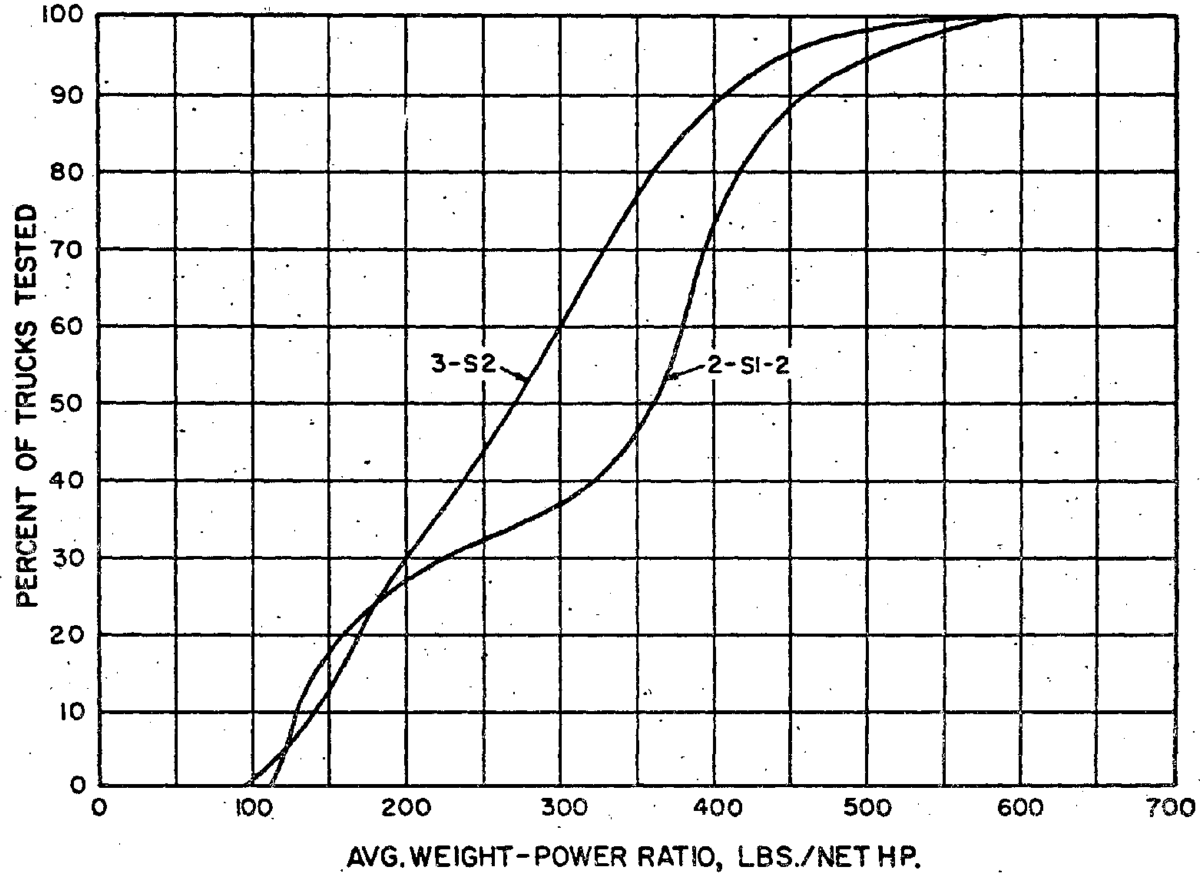

Figure 5-4.—Cumulative frequency distributions of weight-power ratios for all 3-S2 and 2-S1-2 trailer combinations, 1963 brake test.

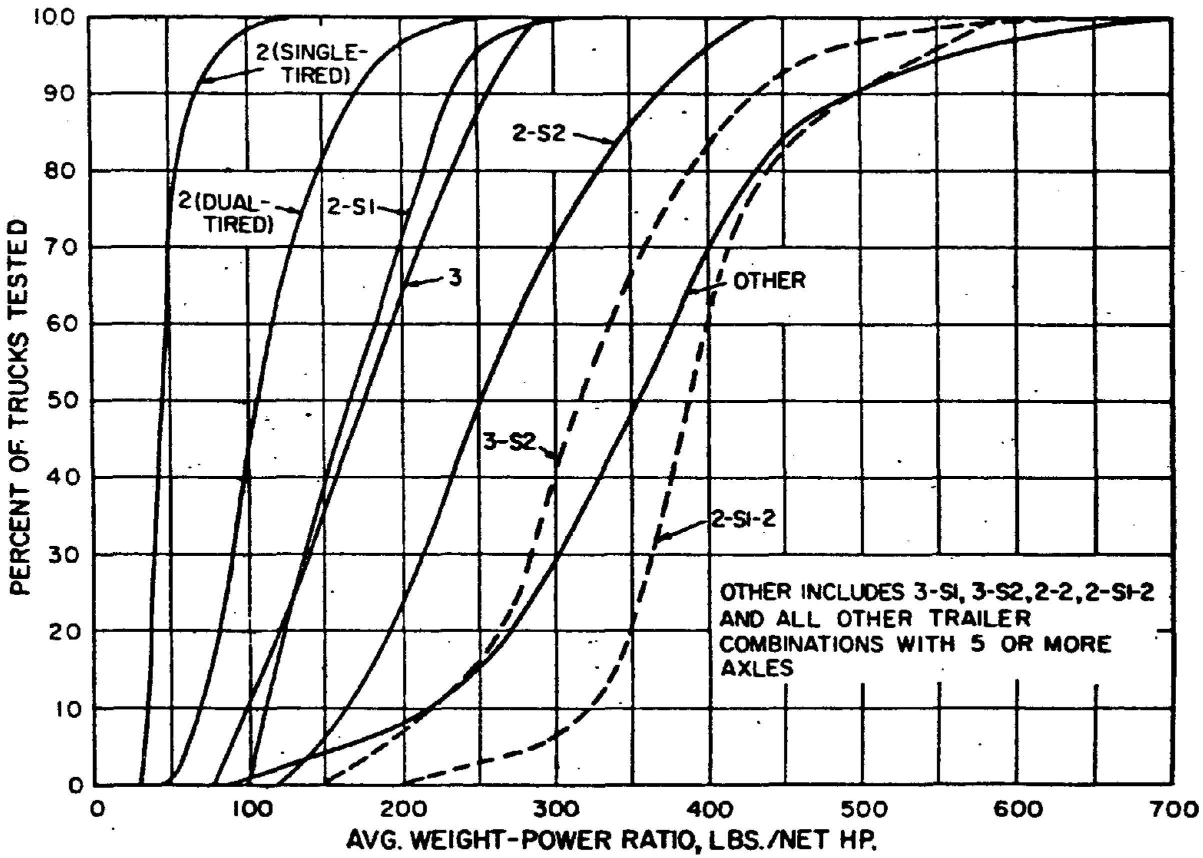

Figure 5-5. —Cumulative frequency distributions of weight-power ratios for loaded commercial vehicles, 1963 brake test.

Table 5-5. -- Percentile values from cumulative frequency distributions of weight-power ratios for loaded vehicles in 1963.

Vehicle class	Weight-power ratio in pounds per horsepower		
	15 percentile	50 percentile	85 percentile
2S - single tired	37	45	60
2D - dual tired	75	106	157
3A	110	125	243
2-S1	117	116	223
2-S2	180	252	346
Other	251	354	452
3-S2	247	315	408
2-S1-2	338	388	454

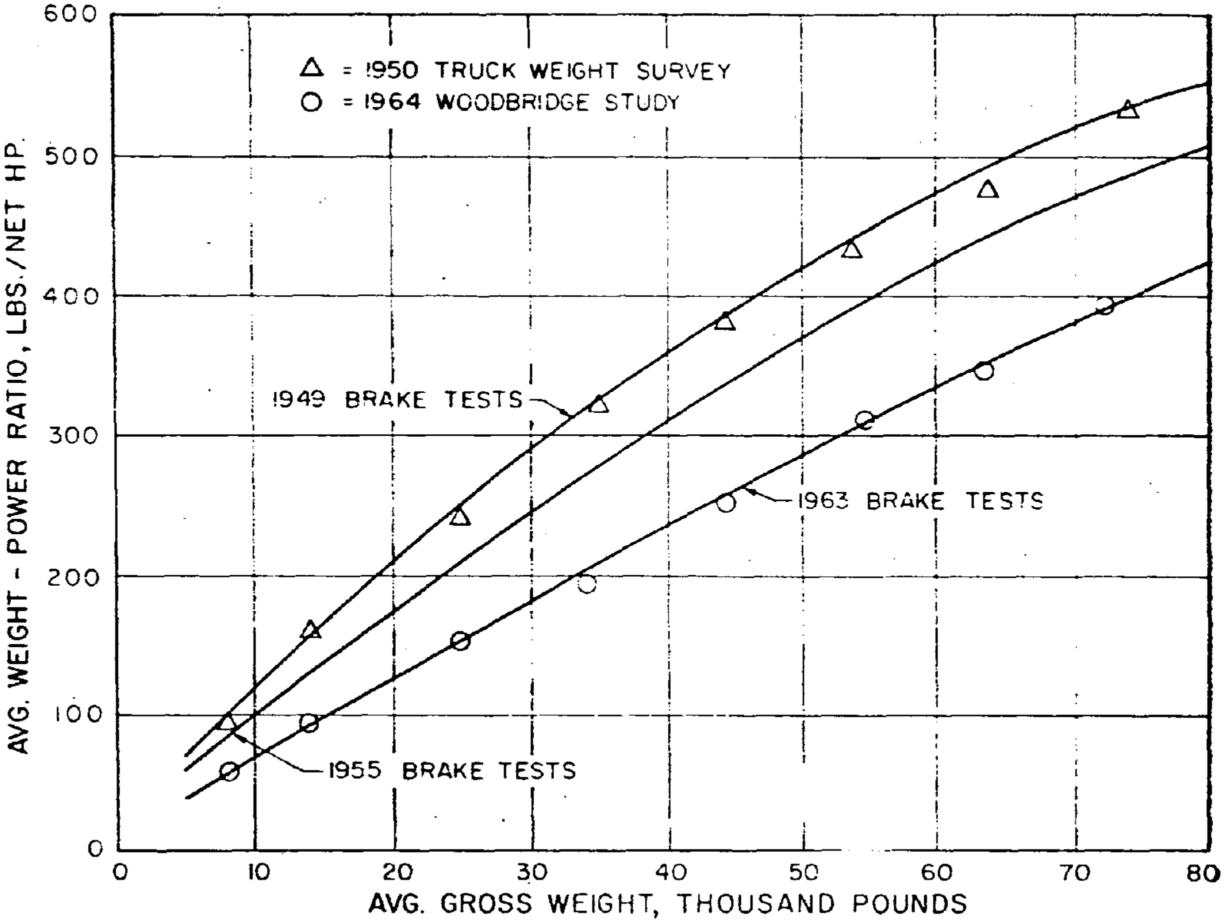

Figure 5-6.—Trend in weight-power ratios from 1949 to 1963 based on average data for all types of commercial vehicles.

the average ratios for the 1950 truck weight survey closely follow the curve for the 1949 brake test data.

The reduction in the weight-horsepower ratios from 1949 to 1955 amounted to about 15 percent for gross weights less than 40,000 pounds. Above that weight, the change decreased to about 8 percent at 80,000 pounds. From 1955 to 1963, the reduction amounted to about 25 percent for gross weights up to 40,000 pounds. The change gradually decreased to about 16 percent at 80,000 pounds gross weight.

The 1963 data were also analyzed using only the loaded trucks. The curve obtained closely approximated the curve which included all trucks. At weights less than 40,000 pounds, the difference in the two curves amounted to 2 percent or less. Above that weight, the two curves were identical. Therefore, the curve for the 1963 data in figure 5-6 is representative of the loaded vehicle classification as well as of all vehicles.

Table 5-6 shows the trend in the average weight-power ratios by vehicle class from 1949 to 1963. In general, there is agreement between the percentage changes 1949 to 1955 and 1950 to 1955. All vehicle types showed a reduction in the ratios from 1955 to 1963, with the larger percentage reductions observed for the 2-axle dual-tired trucks, 3-axle trucks, and the 2-S1 tractor-semitrailer. The overall reduction between

Table 5-6. -- Comparison of average weight-power ratios for all vehicles, by vehicle class, for 1949, 1950, 1955, and 1963

Vehicle class	Number of vehicles				Average weight-power ratios				Percentage reduction of weight-power ratios		
	1949	1950	1955	1963	1949	1950	1955	1963	1949-55	1950-55	1955-63
2S - single tires	19	239	99	130	81	75	57	44	30	24	23
2D - dual tires	275	3,642	272	312	142	135	142	97	0	-5	32
3A	38	263	67	42	227	244	231	145	-2	5	37
2-S1	228	3,900	117	108	291	294	264	149	9	10	44
2-S2	87	1,991	145	217	369	357	301	227	18	16	25
3-S2	46	483	57	112	422	411	348	275	18	15	21
2-3, 3-2, and 2-S1-2	51	136	71	78	394	384	418	300	-6	-9	28
Other	38	72	34	27	428	421	374	292	13	11	22
Total vehicles	782	10,726	862	1,026							
Weighted averages					260	253	228	165	12	10	28

1949 and 1955 was about 12 percent. The corresponding reduction from 1955 to 1963 was approximately 28 percent.

The percentage of all vehicles weighed in 1955 and 1963 that could not meet various weight-power levels are compared in table 5-7. The percentages for vehicle classes 3-S2 and 2-S1-2 are not shown for 1955 because of inadequate sample sizes. In 1955, 50 percent of the vehicles with five or more axles and 14 percent of the total sample had weight-power ratios greater than 400 pounds per horsepower. In 1963, only 20 percent of the vehicles with five or more axles and 5 percent of the total sample had weight-power ratios greater than 400.

Table 5-8 shows the percentage of the loaded vehicles sampled in 1963 that could not meet various performance levels. In 1963, 30 percent of the loaded vehicles with five or more axles and 8 percent of the total sample of loaded vehicles had weight-power ratios greater than 400.

B. Significance of Weight-Horsepower Ratios with Respect to Desirable Maximum Weight of Vehicles

Table 5-9 gives the net horsepower required to give a ratio of gross vehicle weight to net horsepower of 400 for several classes of vehicles at five levels of maximum axle weight. The ratio of 400 pounds per net horsepower is sufficient to maintain the vehicle speed at a minimum of 20 miles per hour up a 3-percent grade and is generally considered to

Table 5-7. -- Percentage of all vehicles weighed in the 1955 and 1963 tests that could not meet indicated performance levels

Vehicle class	Percentage of vehicles with weight-power ratios greater than											
	250:1		300:1		350:1		400:1		450:1		500:1	
	1955	1963	1955	1963	1955	1963	1955	1963	1955	1963	1955	1963
2S - single tired	---	---	---	---	---	---	---	---	---	---	---	---
2D - dual tired	3	---	1	---	---	---	---	---	---	---	---	---
3A	48	10	21	---	2	---	---	---	---	---	---	---
2-S1	53	2	34	1	20	---	10	---	2	---	---	---
2-S2	66	37	50	21	34	10	17	3	5	---	1	---
All other combinations	82	55	73	46	62	34	50	20	35	10	22	7
3-S2		57		38		23		12		5		2
2-S1-2		67		65		55		28		12		6
Total vehicles	38	20	29	14	20	9	14	5	8	2	4	1

Table 5-8. -- Percentage of loaded vehicles weighed in 1963 that could not meet indicated performance levels

Vehicle class	Percentage of loaded vehicles with weight-power ratios greater than					
	250:1	300:1	350:1	400:1	450:1	500:1
2S - single tired	---	---	---	---	---	---
2D - dual tired	---	---	---	---	---	---
3A	12	---	---	---	---	---
2-S1	4	1	---	---	---	---
2-S2	51	29	14	4	---	---
Others	85	71	52	30	15	9
3-S2	84	59	34	17	7	3
2-S1-2	97	94	80	40	18	9
Total vehicles	33	23	15	8	3	2

Table 5-9. -- Net horsepower required for a weight-power ratio of 400 pounds per horsepower for different classes of vehicles and a range of maximum axle-weight limits.

Vehicle class	Maximum axle-weight level single/tandem, kips									
	18/32		20/35		22/38		24/41		26/44	
	Gross weight, kips	Horsepower	Gross weight, kips	Horsepower	Gross weight, kips	Horsepower	Gross weight, kips	Horsepower	Gross weight, kips	Horsepower
2D	25.4	64	28.2	71	31.0	78	33.8	85	36.6	92
3A	41.6	104	45.7	114	48.8	122	52.4	131	56.0	140
2-S1	43.7	109	48.1	120	52.3	131	56.4	141	60.5	151
2-S2	58.5	146	63.8	150	69.0	172	74.3	186	79.6	199
3-S2	73.7	184	80.0	200	86.3	216	92.6	232	98.9	247
2-2	62.6	156	68.8	172	75.0	188	81.2	203	87.4	218
2-3	76.6	192	83.8	210	91.0	228	98.2	246	105.4	264
3-2	77.9	195	85.3	213	92.6	232	100.0	250	107.4	268
2-S1-2	80.7	202	88.9	222	97.1	243	105.3	263	113.5	284
2-S2-2	95.3	238	104.7	262	114.1	285	123.5	309	132.9	332
2-S2-3	109.3	273	119.7	299	130.1	325	140.5	351	150.9	377
3-S2-4	138.0	345	150.3	376	162.6	406	174.9	437	187.2	468

be the maximum acceptable for all highways. Because of the higher general speed of traffic now as compared to the speed when the 20 mph and 3-percent grade criteria were developed, a lower ratio is to be preferred, at least for all vehicles of 5 axles and less.

The foregoing tables and figures show a trend since 1949 to lower weight-power ratios such that in 1963 the vehicles of 73,000 pounds gross weight had an average of 400 pounds gross weight per net horsepower.

Because the power is now available, industry could rapidly shift to the 400-pound (or lower) ratio. At any gross weight limit above about 80,000 pounds, the trucking industry would most likely use only new equipment especially designed for the higher gross weights. The weight-horsepower ratio would not then be held high because of the hauling of high gross weights with old, low-power tractors. The five toll authorities have been successful in enforcing their power requirements for the 100-foot long double trailers at gross weights of about 125,000 pounds. The gross weights in table 5-12 are now authorized on the indicated toll turnpikes.

3. BRAKING PERFORMANCE OF COMMERCIAL VEHICLES

The commercial vehicles tested for braking performance were grouped according to vehicle class (visual axle arrangement), capacity group (manufacturers gross weight rating), and

Table 5-12. -- Turnpike or toll highway exceptions to normal limits on vehicle length and gross weight

Turnpike	Width	Maximum combination length, feet	Maximum gross combination weight, pounds	Number of units in combination
Indiana Toll Road	96	98	127,400	3
Kansas Turnpike	96	105	130,000	3
Massachusetts Turnpike	102	98	127,400	3
New York Thruway	96	108	127,400	3
Ohio Turnpike	96	98	127,400	3
Pennsylvania Turnpike	96	70	1/ 73,280	2

1/ Combinations exceeding 73,280 pounds required to have special hauling permit from Turnpike Commission.

brake system type. The braking performance of like or similar vehicles was then compared for the respective groupings.

A. Braking Performance by Vehicle Class

The differences in braking performance as attributed to different classes of vehicles are apparent in figure 5-7, which shows frequency distribution curves for the combined distance required for brake system application and for braking deceleration and the distribution of maximum deceleration attained for various classes of vehicles. The curves indicate the braking performance as a percentage of vehicles by vehicle class that stopped within a given distance or reached a deceleration of a given or greater value when simulating an emergency stop from 20 mph. It should be noted that the decelerations measured were not sustained throughout the stops, but were the maximum decelerations indicated during the stop.

In figure 5-8 the improvement from 1941 to 1963 in braking distance performance for various classes of vehicles is shown at the 15-, 50-, and 85-percentile levels. In general, the braking performance improved during the years, both through a reduction in the distance required to stop and through a decrease in the variability of brake system application and braking distance as found for all similar classes of vehicles.

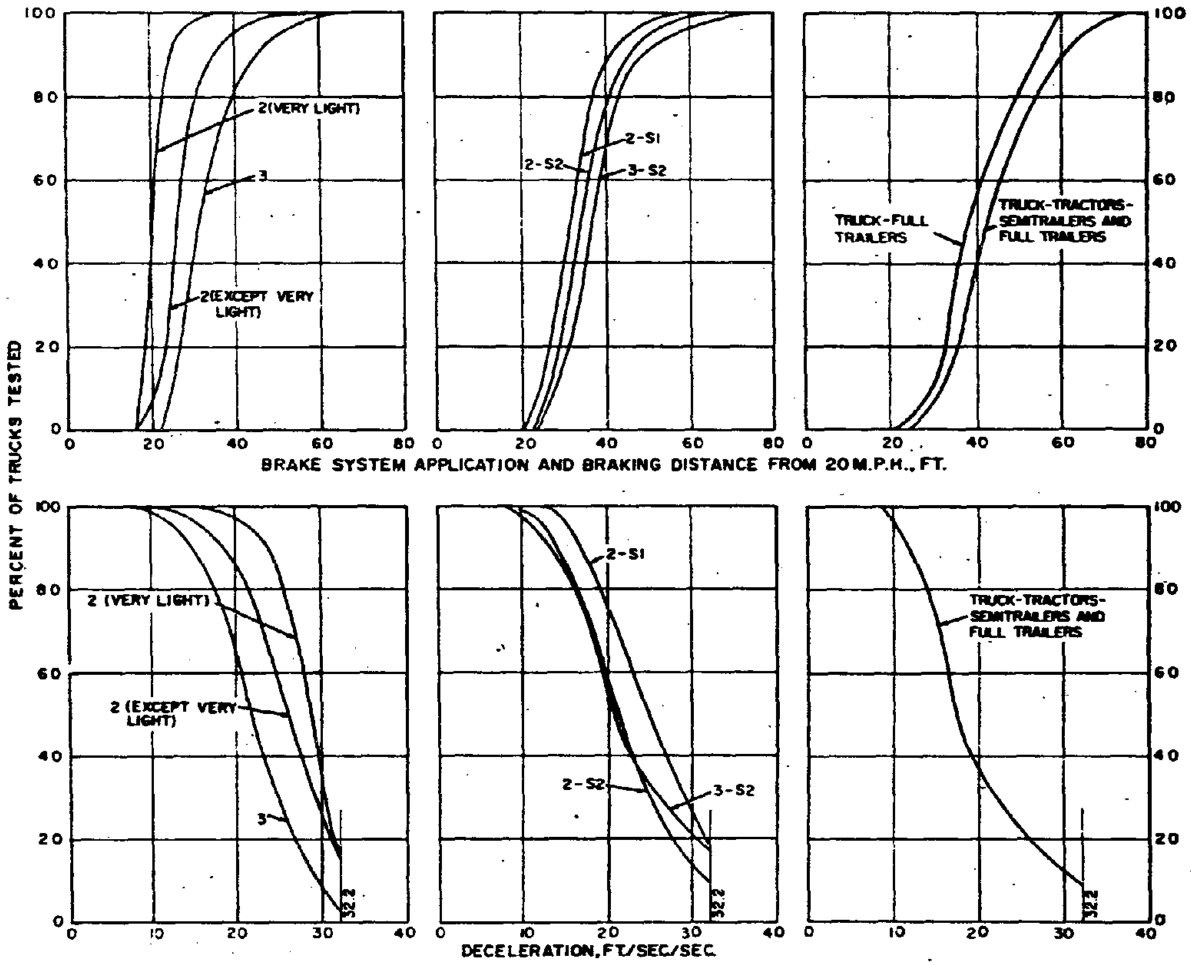

Figure 5-7. —Cumulative frequency distributions of minimum brake system application and braking distances and decelerations.

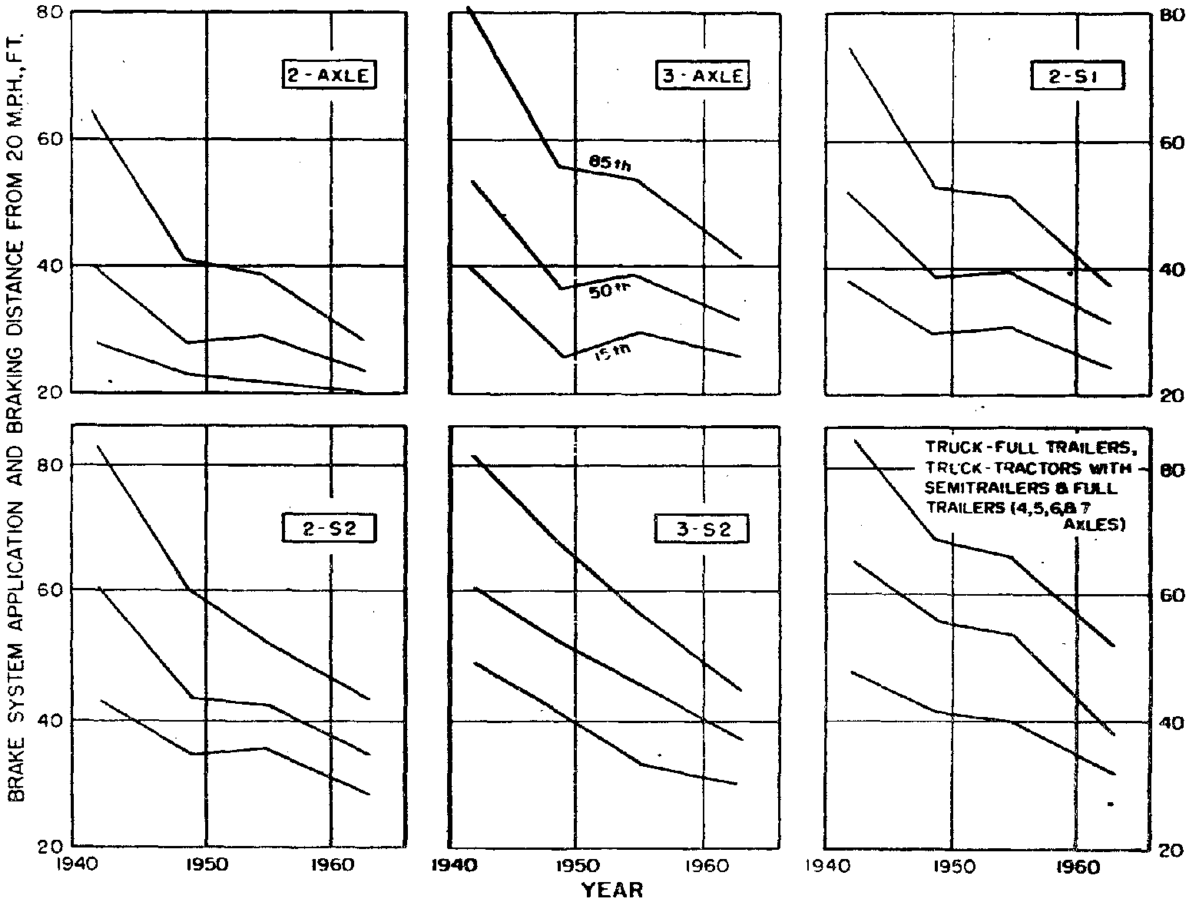

Figure 5-8. ***—Percentile levels of brake system application and braking distances for vehicles by year.***

B. Capacity Groups and Weight Groups

Any changes reflected in the braking performance should be compared with the weight of the vehicles sampled to determine whether or not such changes might be attributed to weight rather than to the braking system or to the vehicle sample. In table 5-13, the average weight and the average brake system application and braking distance are given by class of vehicle for the vehicles tested in both 1955 and 1963. For some vehicle classes the average gross weight varied little from that found in the 1955 study; other vehicle classes varied considerably. Part of the variation in average gross weight can be explained strictly on the basis of the chance of selecting vehicles to be tested that differed appreciably in weight. But part of the variation can also be attributed to the fact the commercial vehicles tested in 1963 were not the same makes, models, or body designs as those tested in 1955.

C. Braking Performance Compared to the Uniform Vehicle Code

The National Committee on Uniform Traffic Laws and Ordinances specified in its "Uniform Vehicle Code" the minimum deceleration and the maximum brake system application and braking distance values, both factors based on simulating of emergency stops from 20 mph. As shown in table 5-14, a large percentage of vehicles met the Code's requirements. The vehicle classes which compared less favorably with the Code requirements

Table 5-13. -- Average vehicle weight and brake system application and braking distance (BSABD) for vehicles tested in 1955 and 1963

Vehicle class	1963			1955		
	Number of vehicles	Average gross weight, pounds	Average BSABD from 20 mph, feet	Number of vehicles	Average gross weight, pounds	Average BSABD from 20 mph, feet
Single-unit trucks:						
2-axle, very light	118	4,740	22	107	5,200	24
2-axle, other very light	297	13,100	28	293	14,200	31
3-axle	43	16,600	34	73	28,400	39
Truck-tractors with semitrailers:						
2-S1	103	24,500	33	129	32,100	40
2-S2	199	39,000	36	153	40,400	42
2-S3	2	32,600	42	none	-	-
3-S2	100	50,300	38	66	53,700	46
Trucks with full trailers:						
2-2	2	42,800	42	16	45,900	51
3-2	26	49,000	41	46	63,900	54
Truck-tractors with semitrailers and full trailers:						
2-S1-2	49	59,800	47	44	59,700	56
2-S2-2	5	75,400	50	7	62,200	54
2-S2-3	4	88,800	40	2	52,000	41
3-S1-2	1	52,200	31	1	78,600	43
3-S2-2	2	37,000	37	none	-	-
3-S3-5	2	132,500	58	none	-	-

Table 5-14. -- 1963 Brake test results compared to the Uniform Vehicle Code

Vehicle class	Deceleration			BSARD 1/		
	UVC requirement, feet/sec./sec.	Vehicles within requirement, percent		UVC requirement, feet	Vehicles within requirement, percent	
		1963	1955		1963	1955
2-very light	14	100	100	30	97	84
2-other	14	98	94	40	95	84
3	14	91	85	40	75	53
2-S1	14	97	83	50	97	81
2-S2	14	91	82	50	94	80
3-S2	14	89	76	50	92	64
Truck-full trailer	14	80	51	50	86	38
Tractor-semitrailer-full trailer	14	79	69	50	71	41

1/ Brake system application and braking distance.

were the truck-full-trailer and the tractor-semitrailer-full trailer combinations. However, there is evidence that when the brakes on these large vehicle combinations are adjusted properly, they can meet the Code requirements. For example, two 3-S3-2 vehicle combinations were tested, each weighing approximately 133,000 pounds. The two tractors were the same make, model, and year, and the brake system utilized in each was an air-mechanical type. One combination required 69 feet in which to stop from 20 mph, whereas the other stopped in 48 feet, or 2 feet under the Uniform Vehicle Code requirement.

D. Braking Performance in Relation to Axle Weight

Not all vehicle classes could be considered in the axle-weight analysis, because either the number of vehicles of a given class was too small or the weights carried on the principal load-carrying axles varied excessively. Only the classes 2, 2-S1, and 2-S2 vehicles could be analyzed with respect to axle weight. The results of the analysis of classes 2 and 2-S1 vehicles were compared with the results of similar vehicles from previous studies.

Figure 5-10 illustrates the performance of classes 2 and 2-S1 vehicles for the brake studies conducted in 1949, 1955, and 1963. In general, improvements have been found in the braking performance for these vehicles each year the studies have been performed. In preparing figure 5-10, only the

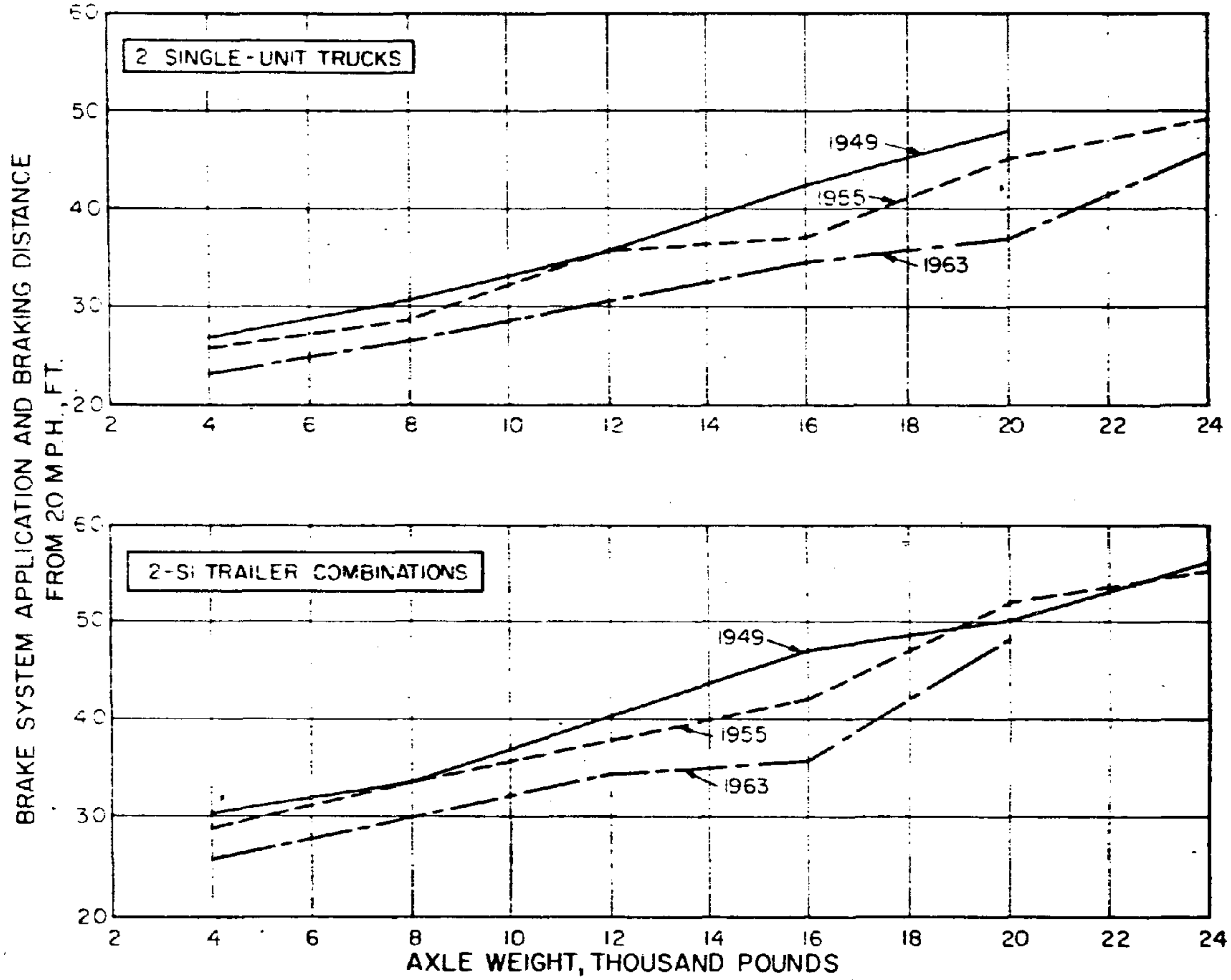

Figure 5-10. —***Brake system application and braking distances by vehicle axle weights, by test years.***

principal load-carrying axles and not the steering axles were considered. For the class 2 single-unit vehicle, the rear axles were grouped into increments of 4,000 pounds, and the braking performance was then computed for these groups. The performance was plotted at the mid-point of the weight group. The same analysis was conducted for the 2-S1 vehicles. However, only those combinations were considered in which the weights of the tractor drive axle and the trailer axle fell within the same 4,000-pound grouping.

Figure 5-11 illustrates the braking performance for the 2-S2 and 3-S2 combinations. In preparing the curve for the 2-S2 combination, only the weight on the tandem axles was considered. The tandem axles were grouped into increments of 4,000 pounds, and the performance was then computed for each group. The performance was plotted in figure 5-11 at the mid-point of the weight group.

E. Braking Performance without Brakes on the Steering Axle

In their motor vehicle regulations, the Interstate Commerce Commission and various States permit certain vehicles to operate without brakes on the steering axle. In the 1963 brake test, a number of combination vehicles were tested that did not have front wheel brakes (See table 5-15.) With the exception of the 3-S2 vehicle, a rather large difference in

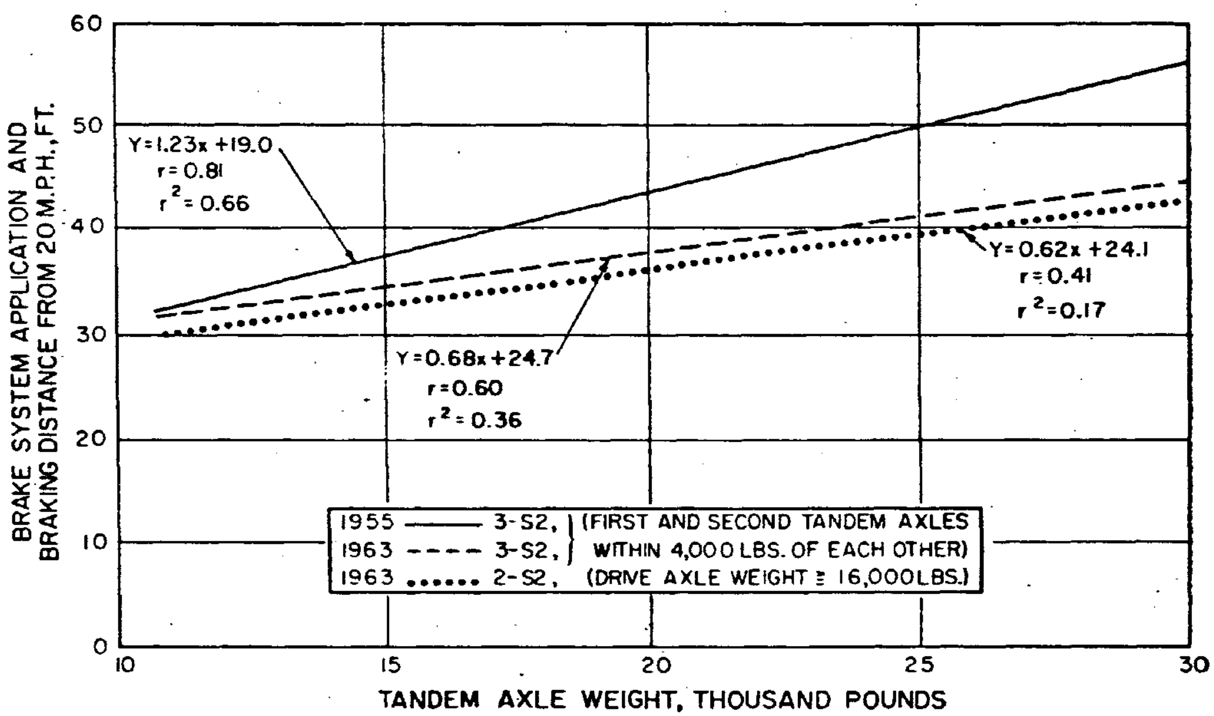

Figure 5-11.—Brake system application and braking distances by tandem axle weights for 2-S2 and 3-S2 vehicles.

gross weight existed between the combinations which had and those which did not have brakes on the steering axle. Consequently, the poorer performance for the combinations without front wheel brakes cannot be entirely attributed to the fact that one axle was not braked, but would be influenced in addition by the weight differential.

In 1958 the National Safety Council's Committee on Winter Driving Hazards conducted tests on dry pavement for empty combination vehicles both with and without braked steering axles. Table 5-16 shows its findings in terms of the brake system application and braking distance found when emergency stops were made from 20 mph for both braking conditions.

4. SUMMARY AND SIGNIFICANCE OF THE BRAKING FACTORS

The foregoing test of braking distance may be summarized as follows:

1. Since 1955 the brake system application and braking distance has been reduced by 2 to 3 feet for the very light 2-axle vehicles and by 10 or more feet for some heavier two-trailer combinations.

2. All vehicle types showed higher values for deceleration in 1963 than for 1955. For light 2-axle trucks, the values were 5 percent higher and for the heavier 2-trailer combinations, 15 percent higher.

Table 5-16 .--Braking performance with and without brakes on the steering axle

Vehicle class	Gross weight, pounds	BSABD[1] in feet from 20 mph	
		All axles braked	Steering axle not braked
3-S2	24,830	24	30
3-2	22,300	21	25
2-S1-2	22,090	26	31

1/ Brake system application and braking distance.

3. The variability in brake system application and braking distance has continued to decrease over time for all classes of vehicles.

4. In 1963 a greater percentage of vehicles were capable of meeting the Uniform Vehicle Code recommended by the National Committee on Uniform Traffic Laws and Ordinances than in 1955, both with respect to brake system application and braking distance and with respect to deceleration.

5. Brake system application and braking distance has in general decreased since 1955, regardless of the vehicle class, weight group, or capacity group.

6. An axle-weight analysis revealed that the brake system application and braking distance for similar axle weights decreased by approximately 3 feet from 1963 to 1955 for both 2-axle, single-unit vehicles and for 2-S1 combinations.

7. The 1963 test results indicate that the brake system application and braking distance at 20 mph is greater by 4 to 6 feet when the steering axle is not braked as opposed to when it is braked.

CHAPTER 6

HIGHWAY SAFETY

Highway traffic accidents are the composite result of a countless number of factors. To isolate the influence of the factors of vehicle dimension and weight on accident experience and then to predict the accident experience with increased vehicle dimensions and weights is a most difficult task. There follows, however, an attempt to accomplish this task with the meager facts that can be assembled.

1. ANALYSIS OF ACCIDENT EXPERIENCE--FREQUENCY AND COST OF ACCIDENTS

In assessing the highway safety aspects of the various highway systems and motor vehicles of different dimensions and weights, data have been developed from accident cost studies conducted in Illinois, Massachusetts, New Mexico, and Utah.[1] These studies, based on Statewide accident experience, were designed to measure costs directly attributable to traffic

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1/ Cooperative studies of the Bureau of Public Roads and State highway departments as follows: Passenger car studies--Massachusetts, 1953; New Mexico and Utah, 1955; and Illinois, 1958. Truck studies--Massachusetts, 1955; New Mexico, 1956; Utah, 1957; and Illinois, 1958.

accidents. More specifically, the costs determined included those incurred by vehicle owners, drivers, and passengers of automobiles and trucks and by pedestrians who may have been involved. The area of investigation included all costs occasioned through property damage, personal injuries, work-time loss, loss of use of vehicle, services of attorneys and attendant fees, and other cost items of an intangible nature for which accident victims were compensated through tort action.

A. Accident Frequencies and Cost Related to Highway Systems

Table 6-1 illustrates that accident-involvement and cost rates were considerably higher for passenger cars than for single-unit trucks and vehicle combinations. Among trucks, the combination class had the most favorable accident-involvement rates, although accident cost rates were somewhat higher than for single-unit trucks. In this and subsequent comparisons, it should be kept in mind that more than half of the single-unit trucks involved in accidents were panels and pickups.

A rural-urban comparison of accident involvement and cost rates shows a relationship of approximately four accidents involving passenger cars in urban areas to one accident in rural areas. Accident costs per vehicle-mile in urban areas were more than double those in rural areas. The involvement ratio for trucks was about five urban accidents to one rural accident,

Table 6-1.-- Accident-involvement and direct-cost rates for passenger cars, single-unit trucks, and vehicle combinations, classified by rural and urban accident location and highway system[1].

Vehicle class and highway system	Rural		Urban		Statewide	
	Accident involvements per 10 million vehicle-miles	Cost of accidents per 10 million vehicle-miles	Accident involvements per 10 million vehicle-miles	Cost of accidents per 10 million vehicle-miles	Accident involvements per 10 million vehicle-miles	Cost of accidents per 10 million vehicle-miles
Passenger cars:						
Federal-aid primary. . .	123	$45,565	404	$ 90,868	245	$ 65,243
Federal-aid secondary. .	149	39,090	517	120,328	222	55,289
Non-Federal-aid.	205	54,487	674	116,478	578	103,709
All highway systems. .	148	46,534	584	108,517	403	82,830
Single-unit trucks:						
Federal-aid primary. . .	73	31,114	283	27,618	137	30,040
Federal-aid secondary. .	67	17,915	225	48,265	87	21,782
Non-Federal-aid.	116	23,597	481	40,332	348	34,218
All highway systems. .	83	26,598	407	36,521	222	30,825
Vehicle combinations:						
Federal-aid primary. . .	42	25,748	212	65,965	83	35,569
Federal-aid secondary. .	40	49,124	146	23,796	57	44,881
Non-Federal-aid.	94	44,197	518	45,267	410	44,993
All highway systems. .	45	31,240	333	56,497	140	39,540
All trucks:						
Federal-aid primary. . .	63	29,814	265	37,042	122	31,662
Federal-aid secondary. .	65	24,411	237	45,930	87	27,235
Non-Federal-aid.	118	24,956	489	41,096	357	35,358
All highway systems. .	76	27,631	399	39,802	208	32,587

1/Data were obtained from cooperative motor vehicle accident cost studies of the Bureau of Public Roads and State highway departments as follows: Passenger car studies--Massachusetts, 1953; New Mexico, 1955; Utah, 1955; and Illinois, 1958. Truck studies--Massachusetts, 1955; New Mexico, 1956; Utah, 1957; and Illinois, 1958.

and the cost rates were approximately 45 percent higher in urban areas than in rural areas.

B. Accident Occurrences of Loaded and Empty Trucks

Table 6-2 provides a comparison of accident-involvement rates for loaded and empty trucks of four vehicle classes. On a Statewide basis, accident-involvement rates for each class of truck, when operated loaded, were greater than twice the rates of those involved in accidents when empty.

For either loaded or empty trucks, the frequencies of accidents in urban areas were three or more times those in rural areas, and with the exception of 3-axle, single-unit trucks, the cost rates in urban areas exceeded those in rural areas. On rural highways, loaded trucks had substantially higher involvement rates than empty trucks. In urban areas, the difference was somewhat less for some classes of vehicles, but loaded trucks had a consistently higher involvement rate than empty trucks. Vehicles capable of carrying the heaviest gross loads, i. e., combinations having four or more axles had the lowest accident-involvement rates of all truck classes. No doubt, regulation of carriers, better trained drivers, and a higher level of management contribute to the lower accident rate for the heavier vehicles.

Table 6-2.--Accident-involvement and direct-cost rates for loaded and empty trucks, by vehicle class and rural and urban location 1/

Vehicle class	Rural		Urban		Statewide	
	Accident involvements per 10 million vehicle-miles	Cost of accidents per 10 million vehicle-miles	Accident involvements per 10 million vehicle-miles	Cost of accidents per 10 million vehicle-miles	Accident involvements per 10 million vehicle-miles	Cost of accidents per 10 million vehicle-miles
Single-unit trucks:						
2-axle trucks--						
Loaded	113	$32,955	498	$40,162	311	$36,718
Empty	63	21,731	286	32,830	135	25,524
Subtotal	82	26,095	408	37,027	227	30,745
3-axle trucks--						
Loaded	183	66,786	510	33,527	312	52,111
Empty	44	18,692	291	7,066	156	13,621
Subtotal	115	43,169	403	20,672	248	33,306
All single-unit trucks:						
Loaded	116	34,246	498	39,978	314	37,221
Empty	62	21,659	287	31,928	140	25,192
Total	83	26,598	407	36,521	222	30,825
Truck combinations:						
3-axle tractor-semitrailer--						
Loaded	76	42,431	576	77,106	309	58,312
Empty	20	16,892	244	33,497	103	23,422
Subtotal	57	34,009	485	65,146	210	47,610
Other vehicle combinations--						
Loaded	46	35,933	294	56,692	114	41,639
Empty	31	18,667	116	39,647	51	24,883
Subtotal	41	30,312	232	50,738	92	36,067
All vehicle combinations:						
Loaded	54	37,555	414	65,393	173	46,769
Empty	28	18,218	160	37,535	71	24,470
Total	45	31,240	333	56,497	140	39,540

1/Data were obtained from cooperative motor vehicle accident cost studies of the Bureau of Public Roads and State Highway departments as follows: Massachusetts, 1955; New Mexico, 1956; Utah, 1957; and Illinois, 1958.

C. Accident Frequencies and Costs Related to Gross Vehicle Weights

Trucks of the heaviest registered gross weights had the lowest accident frequencies and the highest accident cost rates, as shown in table 6-3. This trend simply follows that shown in table 6-2, in which vehicles are classified on the basis of visual types. Truck combinations with four or more axles would fall in the weight category above 41,000 pounds. Table 6-3 adds the element of accident severity. For each severity class, with increased registered weight, there is an upward trend in the accident costs per 10 million vehicle-miles of travel.

With increased registered weight, truck involvements in which one or more persons were fatally injured show an upward trend per 10 million vehicle-miles of travel. Nonfatal-injury involvements have rather consistent rates for all weight groups, and except for the weight group from 24,001 to 41,000 pounds, the trend in "property-damage-only" involvement rates is downward with increased registered weight. An investigation of the relatively high rate of property-damage-only involvements for the 24,001-41,000-pound weight group indicated that vehicles used in construction and city delivery service were largely responsible.

D. Accident Frequencies and Costs Related to Type of Accident

Accident frequencies and costs per 10 million vehicle-miles of travel, by type of accident, are shown separately for

Table 6-3.--Number of trucks involved in traffic accidents, direct costs of truck accidents, and involvement and cost rates, classified by severity of accident and registered gross weight of trucks 1/

Registered gross weight of trucks (pounds)	Number of trucks involved in accidents	Direct Cost of Truck Accidents	Accident involvements per 10 million vehicle-miles	Accident cost per 10 million vehicle-miles
FATAL-INJURY ACCIDENTS				
12,000 and under..	174	$940,961	0.41	$2,218
12,001-24,000.....	68	405,190	.36	2,149
24,001-41,000.....	37	130,349	.77	2,721
41,001-72,000.....	62	330,920	.79	4,211
Total...........	341	1,807,420	.46	2,445
NONFATAL-INJURY ACCIDENTS				
12,000 and under..	9,518	$6,608,277	22	$15,576
12,001-24,000.....	2,492	1,285,468	13	6,819
24,001-41,000.....	968	625,881	20	13,065
41,001-72,000.....	1,608	1,365,119	21	17,371
Total..........	14,586	9,884,745	20	13,371
PROPERTY-DAMAGE-ONLY ACCIDENTS				
12,000 and under..	86,861	$6,094,971	205	14,366
12,001-24,000.....	37,615	3,098,978	200	16,439
24,001-41,000.....	13,177	962,803	275	20,098
41,001-72,000.....	11,348	3,106,015	144	39,524
Total............	149,001	13,262,767	202	17,940
ALL ACCIDENTS				
12,000 and under..	96,553	$13,644,209	228	$32,159
12,001-24,000.....	40,175	4,789,636	213	25,407
24,001-41,000.....	14,182	1,719,033	296	35,884
41,001-72,000.....	13,018	4,802,054	166	61,106
Total...........	163,928	24,954,932	222	33,756

1/. Data were obtained from cooperative motor-vehicle-accident cost studies of the Bureau of Public Roads and State highway departments as follows: Massachusetts, 1955; Utah, 1957; and Illinois, 1958 (New Mexico data were excluded because trucks are not registered on the basis of gross vehicle weight).

single-unit trucks and vehicle combinations in table 6-4. Accidents involving single-unit trucks or vehicle combinations and one or more other vehicles were the most frequent type of encounter. For single-unit trucks, angle and turning-movement collisions ranked highest in frequency as well as in cost on a vehicle-mile basis, followed by the group designated head-on, rear-end, and sideswipe collisions. Among accidents involving vehicle combinations, head-on, rear-end, and sideswipe collisions as a group ranked highest, with angle and turning-movement collisions a close second.

Perhaps the most significant finding from the comparison of accident types is the high accident cost rates for combinations involved in noncollision accidents. Although the frequencies of noncollision accidents were rather low, such occurrences tended to be costly. Extensive damage to equipment and cargo undoubtedly accounted for this finding.

E. Intersectional and Nonintersectional Accident Locations

Accident-involvement and cost rates are compared in figure 6-3 on the basis of intersectional and nonintersectional accident locations. As would be expected, in rural areas the nonintersectional accident involvements and costs per 10 million vehicle-miles of travel exceeded the rates for intersectional accidents for both single-unit trucks and vehicle combinations. On the other hand, a comparison for urban areas shows that

Table 6-4.--Accident-involvement and direct-cost rates for single-unit trucks and vehicle combinations, classified by type of accident and by highway system [1]

Type of accident	Federal-aid primary system				Other highway systems				All highway systems			
	Rural		Urban		Rural		Urban		Rural		Urban	
	Single-unit trucks	Vehicle combinations	Single-unit trucks	Vehicle combinations	Single-unit trucks	Vehicle combinations	Single-unit trucks	Vehicle combinations	Single-unit trucks	Vehicle combinations	Single-unit trucks	combinations
NUMBER OF TRUCKS INVOLVED IN ACCIDENTS PER 10 MILLION VEHICLE-MILES												
Collision with other motor vehicles:												
Head-on	0.9	0.3	0.5	0.3	1.6	0.7	2.2	-	1.2	0.3	1.6	0.2
Rear-end	7.3	7.2	77.9	70.7	9.5	4.7	77.6	70.0	8.3	6.9	77.7	70.4
Angle and turning movements	25.2	8.1	119.3	49.8	24.6	23.8	150.9	201.2	24.9	10.2	140.7	114.7
Sideswipe	9.1	5.5	28.2	48.0	6.7	4.8	48.6	46.9	8.0	5.4	42.0	47.5
Other 2/	2.4	4.9	38 1	9.5	6.7	0.9	145.9	106.1	4.4	4.3	111.1	50.9
Single vehicle collisions:												
Pedestrians	0.1	0.1	1.3	0.8	0.3	0.1	7.0	1.8	0.2	0.1	5.2	1.2
Moveable or moving objects	11.4	4.8	6.6	5.3	17.6	7.8	15.7	30.2	14.3	5.2	12.7	15.9
Fixed objects	6.2	1.1	5.1	13.5	8.1	1.1	10.9	33.8	7.1	1.1	9.0	22.3
Non-collision involvements	9.7	9.9	5.8	14.4	21.3	22.7	8.2	3.7	15.0	11.7	7.4	9.8
All accident involvements	72.5	41.8	282.8	212.2	96.4	66.6	466.9	493.7	83.5	45.2	407.5	332.9
DIRECT COST OF ACCIDENT INVOLVEMENTS PER 10 MILLION VEHICLE-MILES												
Collision with other motor vehicles:												
Head-on	$ 1,242	$ 1.286	$ 252	$ 5.597	$ 1.311	$ 779	$ 1,205	-	$ 1.274	$ 1,218	$ 897	$ 3.197
Rear-end	1,881	2,801	7552	5,840	1,134	3237	5,395	$11,895	1.537	2,860	6091	8,436
Angle and turning movements	10,468	4,111	13004	26,119	4,987	8500	16,342	10,784	7,947	4,702	15265	19,544
Sideswipe	6,262	1,708	1380	2,168	867	4918	1,863	3,102	3.780	2,140	1707	2,569
Other 2/	412	418	1214	969	410	188	5,601	2,885	411	387	4186	1,791
Single vehicle collisions:												
Pedestrians	55	138	1305	1,119	253	1403	4,889	2,388	146	309	3733	1,663
Moveable or moving objects	1,224	1,297	677	4,129	3,777	3359	2.385	3,876	2.398	1,575	1834	4.021
Fixed objects	1,485	2.017	1262	6,986	2,553	518	1,923	6,659	1,976	1,816	1710	6,846
Non-collision involvements	8,085	11.970	973	13,037	6,004	23753	1.159	2,293	7.127	16.233	1099	8.431
All accident involvements	31.114	25.748	27618	65.965	21.296	46657	40.761	43.882	26.598	31.240	36521	56.497

1/ Data were obtained from cooperative motor vehicle accident-cost studies of the Bureau of Public Roads and State highway departments as follows: Massachusetts, 1955; New Mexico, 1956; Utah, 1957; and Illinois, 1958.

2/ Includes parking maneuvers, backing in traffic lane, and colliding with parked vehicles.

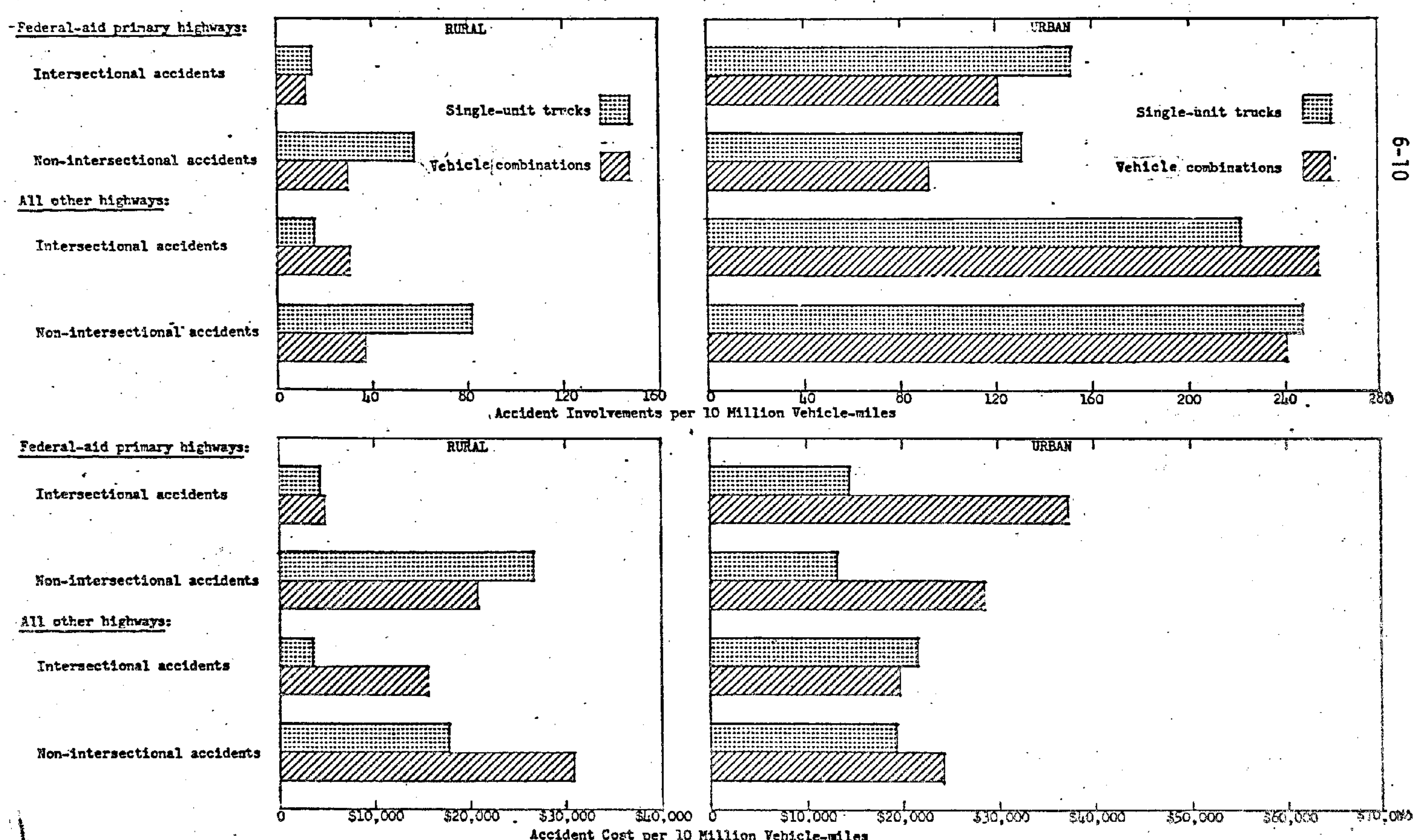

Figure 6-3.—Truck involvement and direct-cost rates for intersectional and non-intersectional accidents occurring on the Federal-aid primary system and on all other highway systems.

involvement and cost rates did not vary greatly between intersectional and nonintersectional locations.

F. Summary and Significance of Findings

Findings of the four-State analysis of traffic accident frequencies and cost point to the following general observations:

(1) Roads and streets of the highest classification, the Federal-aid primary system, had the lowest accident frequencies per vehicle-mile of travel compared with all other road systems. When accidents did occur on the Federal-aid primary system they tended to be more severe and costly.

(2) Among classes of vehicles, passenger cars experienced the highest accident-involvement rates, and were followed in order by single-unit trucks and vehicle combinations. A further comparison of accident cost per vehicle-mile indicated the following highest-to-lowest sequence for the three classes of vehicles: (a) passenger cars, (b) vehicle combinations, and (c) single-unit trucks. Limiting the comparison to the two major classes of commercial vehicles, vehicle combinations had the most favorable accident-involvement rate, but accident cost per vehicle-mile was higher.

(3) A rural-urban comparison of accident occurrence per vehicle-mile for passenger cars indicated a ratio of one accident in rural areas to four in urban areas; for single-unit trucks, a ratio of one to five; and for vehicle combinations, one to seven.

Accident-cost rates in urban areas exceeded those in rural areas by the following percentages: passenger cars, 133 percent; single-unit trucks, 37 percent; and vehicle combinations, 81 percent.

(4) Regardless of axle configuration, commercial vehicles had substantially higher accident-involvement and cost rates when traveling with loads than when traveling empty.

(5) Commercial vehicles of the heaviest registered gross weights had the most favorable accident-involvement rates, but accident cost increased with gross weight. The general observation follows that drivers of the heaviest vehicles were more successful in avoiding accidents, but when they were involved, the accidents tended to be more severe. Both vehicle and cargo value are factors contributing to severity.

(6) The most common types of accidents for both single-unit trucks and vehicle combinations were encountered with one or more other motor vehicles. Angle and turning-movement collisions ranked highest in frequency. Second in order of frequency were rear-end collisions. Of all types of accidents involving vehicle combinations in rural areas, noncollision accidents ranked highest on a cost per vehicle-mile basis. In urban areas, angle and turning movement collisions ranked highest. For single-unit trucks, the cost rates for angle and turning-movement collisions ranked highest in both rural and urban locations.

(7) Frequencies of intersectional accidents in urban areas involving either single-unit trucks or vehicle combinations were approximately equal to nonintersectional accidents. Accident-cost rates associated with intersectional accidents, however, tended to be higher than for nonintersectional accidents.

2. ANALYSIS OF THE PROBABLE RELATIONSHIP OF INCREASES IN VEHICLE DIMENSIONS AND WEIGHTS TO ACCIDENT EXPERIENCE

The preceding analysis of the frequency and cost of highway traffic accidents offers practically no help in determining what effects on highway safety would result from increasing the limits of dimensions and weights of motor vehicles. The hundreds of subfactors contained in the four principal factors--the driver, vehicle, highway, and environment--almost preclude a reliable conclusion of the true role of any changes in legal maximum vehicle dimensions and weights in promoting highway safety. However, the following sections discuss the probable consequences, and until accident analyses can be afforded a better factual basis, judgment must rest upon logical reasoning from meager facts.

Because of the complex interaction of the many factors involved in highway safety, it is most difficult to trace the relationship between the accident experience of the heavy single-unit trucks and combination vehicles and their dimensions and weights. Over the years, by decreasing the weight-horsepower ratio to give higher speeds on grades and by improving other features of both vehicle design and vehicle operations, the safety record of the heavy trucks has been continuously improved.

A. Vehicle Dimensions and Highway Safety

The height of the vehicle has little effect upon the safety performance of single-unit trucks and combination vehicles in the traffic stream. Height, however, does tend to mask the view of traffic signals from other vehicles. It is true that vehicle height has some effect upon the center of gravity, and therefore might contribute to overturning accidents. Generally speaking, freight vehicles are loaded with such heavy material that the vehicle height in itself is seldom a factor in raising the center of gravity to a point high enough to induce overturning of the vehicle.

An increase in overall width from 96 to 102 inches will somewhat reduce the overturning tendency. In addition to this, the additional width of vehicle will permit the development of a better braking system and adequate room for the proper width of tires without exceeding the maximum limit.

As compared to 96 inches, a width of 102 inches probably will result in some accidents that otherwise would not happen. Accidents are caused by split-second timing of events and fractional inches of relative spacing of vehicles and fixed objects. The larger any vehicle is the more it restricts the view from other vehicles. Reasoning from these premises could lead to the conclusion that 102 inches of vehicle width as compared to a maximum width of 96 inches will increase rather than decrease the number of vehicle accidents. However, these factors as causes of an increase in accidents resulting from increasing vehicle width to 102 inches may be offset by the improved braking system and rear axle design along with reduced overturning tendency.

The important factor with respect to vehicle length is its effect on the behavior of the vehicle in traffic. The behavior in traffic refers primarily to keeping the vehicle in the direct line of travel, that is, free from swerving or departures from the normal wheel track. It is true, however, that offtracking of the vehicle in turning movements requires attention from the viewpoint of safety.

In addition to the offtracking as measured in terms of the width of pavement or lane required to enable the wheeltracks to remain within the pavement width or lane width, the effects on other traffic of offtracking of the rear axle of a truck must be considered. On four-lane divided highways with flatter curves, there is little encroachment upon the adjacent lane because of offtracking on curves.

B. Two- and Three-Unit Combinations

In the accident records there is little experience indicating the relative degree of safety of a single-unit truck, a two-unit tractor combination (tractor and semitrailer), two-unit tractive truck (full truck and full trailer), and a three-unit combination (tractor, semitrailer, and full trailer).

The combination vehicle of two or three units may have some tendency, under certain conditions, to swerve when it is heavily braked. This swerving is preventable by the use of proper towing connections that have been developed. All vehicles have a tendency to track slowly to the left or to the right as they progress down the highway on a tangent section. This tendency is because of short undulation in the pavement profile, the effects of wind, and the effects of steering-wheel pressure. The longer the vehicle the more tendency there is for its lateral displacement to be widened from the true forward tangent path. These lateral movements are not unsafe for traffic in a lane that is 12 feet wide.

C. Weight of the Vehicle

The gross weight of the vehicle is a factor primarily affecting braking or stopping distance and the minimum speed on plus grades. The heavy vehicles now have adequate brake systems to take care of all maximum loads within a stopping distance that is in agreement with the Uniform Vehicle Code. In addition, brakes have been developed to give adequate stopping distances for vehicles with a total gross vehicle weight of roughly 125 kips, or that weight now found on toll turnpikes where 100-foot vehicles are permitted.

The weight-horsepower ratio of around 400 pounds per net horsepower is adequate to permit a vehicle to ascend a 3-percent grade at a minimum speed of 20 miles an hour. The horsepowers available and those immediately projected by industry indicate that with increased weight of vehicles up to 125 kips total gross weight, adequate horsepower is available to enable the vehicle to maintain a minimum speed of 20 miles an hour on a 3-percent plus grade.

D. General Considerations - Vehicle and Driver

The high cab of the truck gives the operator a better vision forward, as well as to the left, right, and backward on the left. This additional sight distance compensates somewhat for the shorter stopping distance of smaller vehicles. The driver of the high-cab vehicles can see objects at crowns of hills and around curves to better advantage than can the passenger car driver.

The usually high weight of trucks per square inch of contact between the pavement and tire gives a high utilization of potential frictional force, which in many cases is much superior to that of passenger cars. These heavy vehicles skid less and lose traction less than do passenger cars.

E. Effect of Highway Design on the Safety of Line-haul Freight Vehicles

From the viewpoint of traffic safety, the geometrics of highway design--so far as present standards and practices are concerned--do not contribute more to highway accidents on the part of line-haul vehicles than they do to accidents involving other vehicles. The lane widths seem to be adequate, sight distances are relatively adequate, and for the speeds used, the curves and corners are usually adequate from the standpoint of accident prevention. Strictly from the point of view of the traffic-accident factor, line-haul vehicles can operate on current highways with about the same relative degree of safety as can other vehicles.

F. Effects of Line-haul Vehicles Upon the General Traffic

The width of line-haul vehicles has some effect upon the passing of trucks by faster moving vehicles on two-lane highways. It is perhaps true that some passenger car drivers might be hesitant to overtake and pass a truck 102 inches wide, when they might more readily pass a truck 96 inches in width. However, for all ordinary usage the 12-foot lane affords the necessary safety for overtaking and passing 102-inch wide vehicles. On the 4-lane divided highways, the factor of width up to 102 inches would give rise to no particular problems of highway safety. Where lanes are less than 12-feet wide, the clearance may be less than is desirable, but here generally the ADT will be light and the truck percentage low.

The length of vehicles is also an element that would affect the overtaking and passing maneuver of slower moving vehicles. The longer vehicle to be passed would make necessary a slightly longer passing time and distance and also would restrict somewhat the general view of passenger car drivers, particularly on curves, thereby restricting their tendency to pass.

One of the advantages of greater length, however, is to reduce the total number of combinations on the highway. Under a 65-foot maximum length, it would require fewer vehicles to haul the same total gross tons of payload than under a maximum length limit of only 55 feet. It probably is safer to pass one combination 65 feet long than to pass two shorter vehicles each separately operated.

G. Accident Experience with Double-Trailer Combinations on Toll Turnpikes

The experience of some of the toll turnpikes, with respect to the operation of double-cargo combination units consisting of a tractor and two 40-foot trailers, is some indication of how safe such operations can be. One of these operators has reported the following facts of its operation:

(1) In four years of operation, 95 thousand loads of freight in twin-cargo bodies have been moved, averaging 10 million trailer-miles per year.

(2) The drivers have operated 43 million trailer-miles with an accident frequency of over 1,500,000 trailer-miles per mishap of any kind. This compares with a total system accident frequency of 270,000 miles per accident.

(3) Only 10 of the 29 accidents occurring in this period were classified as preventable. Total insurance claims paid in the four years amounted to less than $28,000 or $7,000 a year.

(4) The drivers operating out of the Manchester headquarters averaged 5,540,000 trailer-miles before becoming involved in an accident of any kind. The Albany drivers operated 2,450,000 consecutive miles and the Boston drivers 3,768,000 trailer-miles without an accident.

H. Test Operations in Idaho with
Double and Triple-Cargo Units

In the fall of 1964, the State of Idaho Department of Highways issued its research report No. 35 under the title "Highway Operations with Truck Trailer Double and Triple Units." The following highlights of the publication are reproduced here because of their pertinency to this report on the desirable dimensions and weights of motor vehicles.

The operations were with tractors pulling double 40-foot trailers and triple 27-foot trailers. The length range was from 94 feet to 96 feet in total. The freight carriers were engaged in regular operations. The only difference was that certain observations and recordings were made for these particular test operations. The gross loads ranged up to 134,900 pounds on a 5-axle tractor-semitrailer with a 4-axle full trailer.

The test units were passed by lighter traffic without any particular difficulty. Seventy percent of the traffic passed the unit in less than 16 seconds, and 95 percent of the light vehicles passed in less than 20 seconds. The heavier units (that is, other trucks and house trailers) took from 12 to 40 seconds to pass the test vehicle, with nearly all of them requiring more than 25 seconds.

The tracking of the trailers was relatively smooth, except for the triple trailers that were hooked together with a pintle-hook hitch. With this hitch the third trailer had a tendency to weave back and forth, causing some swaying of the cab. Braking of the unit stopped this sway. The combinations using the airlock hitch held the units firm under all conditions. The double-cargo combinations gave no indication of swaying at all.

The traffic flow on the 4-lane sections of the Interstate system appeared to be unaffected for the traffic volumes encountered. Modern 2-lane sections having adequate sight distances and climbing lanes on the longer hills caused only slight delays and rarely caused anyone to follow more than 2 or 3 minutes before a passing opportunity occurred.

All 2-lane sections having limited sight distance and no climbing lanes on longer hills did create delays, and often several vehicles would be delayed until sight distance permitted passing. The worst areas for delay to traffic occurred on plus grades when the test vehicles were moving comparatively slowly. This was particularly true in sections where the climbing speed for the test vehicle was 8 to 15 miles an hour.

3. SUMMARY AND EVALUATION OF THE FACTOR OF HIGHWAY SAFETY

Whether or not an increase in the maximum legal limit of axle weights would change the accident experience of motor trucks is not disclosed by the available analysis of accident experience. The same conclusion is reached with respect to gross vehicle weight and for the same reasons. Although table 6-3 shows a higher involvement rate per 10 million vehicle miles (296) for the registered gross weight class of 24,001 to 41,000 pounds as compared to the rate (213) for the 12,001- to 24,000-pound class, the conclusion is not valid that this increase in accident rate from 213 to 296 is a direct result of the increase in registered gross weight. These two vehicle weight classes are each composed of different types of vehicles in different types of usage on many highway systems.

The reasonableness of the foregoing conclusion is proved by the fact that the highest registered gross weight class, 41,001 to 72,000 pounds, has an involvement rate of 166 accidents per 10 million vehicle miles. Moreover, the conclusion would not be valid that gross weights above the 41,001- to 72,000-pound class would result in an accident-involvement rate of less than 166 per 10 million vehicle miles.

It follows then that there is little evidence now available to support any conclusion with respect to what effect an increase in maximum legal limit of axle weight or gross vehicle weight would have on accident rates in traffic. It is likely, however, that any increase in gross weight of trucks would result in a higher cost per accident, principally because of higher investments in the vehicles and in the cargo carried. But such an increase probably would not be an increase per ton-mile of payload transported.

Table 6-4, although showing a decreased accident-involvement rate for vehicle combinations as compared to single-unit trucks, cannot be interpreted as predicting a lesser accident rate for two- and three-cargo units as compared to either single-unit trucks or one-cargo-unit tractor-semitrailers. Here again, there are so many variables involved that any conclusion may reasonably be questioned. The single-unit truck class involves so many 2-axle trucks not affected by any increase in vehicle dimension or weight limits that the comparison of single-unit trucks with vehicle combinations is not usable in a study of the desirable dimensions and weight of vehicles.

As the newer year models of trucks enter the traffic population and the earlier models are retired, the performance --acceleration and deceleration--of vehicles in the traffic stream will be improved, even though no further gains are made in design.

Although no conclusion can be stated with certainty regarding the influence of increased legal maximum limits on accident involvement rates, the limited evidence does not indicate that the resulting accident rates would be above those now prevailing, particularly on a payload ton-mile basis.

CHAPTER 7

ANALYSIS OF THE 1962 TRUCK WEIGHT STUDY

Any study of the desirable vehicle dimensions and weights is greatly enhanced by reliable information on the dimensions and weights of the vehicles using the highways, especially information with respect to their axle weights. Fortunately, this information is available. The 1962 truck weight data are discussed in this chapter for two reasons: (1) in order to develop a better knowledge of the classification and weights of vehicles on the highway and of the comparative weight practices with respect to current legal maximums and (2) in order to present the basic data used in the analysis of the economy of dimensions and weights of motor vehicles.

1. PLAN OF THE TRUCK WEIGHT STUDIES

Each year, as part of their annual collection of information for the Federal-aid highway planning projects, the several States weigh vehicles at permanent and temporary weighing stations. The main information collected is the vehicle classification of each vehicle and axle or tandem pair of axles, whether the vehicle is with cargo or empty of cargo.

Reliable weights (axle and gross) are obtained from the weight data for each class of vehicle except passenger cars and buses, which are not weighed. The traffic volume and classification are obtained from the vehicle count. These two sets of data combined to produce a good vehicle weight study for each weighing station.

2. AXLE-WEIGHT DISTRIBUTION

The AASHO pavement design formulas are based on the application to the pavement of equivalent 18,000-pound single-axle loads. The standard tables presenting the results of the truck weight studies report the axle-weight frequencies by axle-weight groups separately for single and tandem axles by vehicle class. Therefore, an examination of the axle-weight distribution as reported for the 1962 truck weight studies will make possible some progress toward developing the axle-weight distributions and pavement designs required to determine the economy of maximum axle-weight limits reported in Chapter 10.

Figures 7-1 and 7-2 are curves illustrative of the distribution of single and tandem axle weights for different classes of vehicles for California and Maryland. Curves of this type were plotted for each of the 46 States for which truck weight data were available.

The single-axle curves include the front or steering axle, commonly weighing about one-half the weight of single axles carrying full loads. The figures show a few of the load-

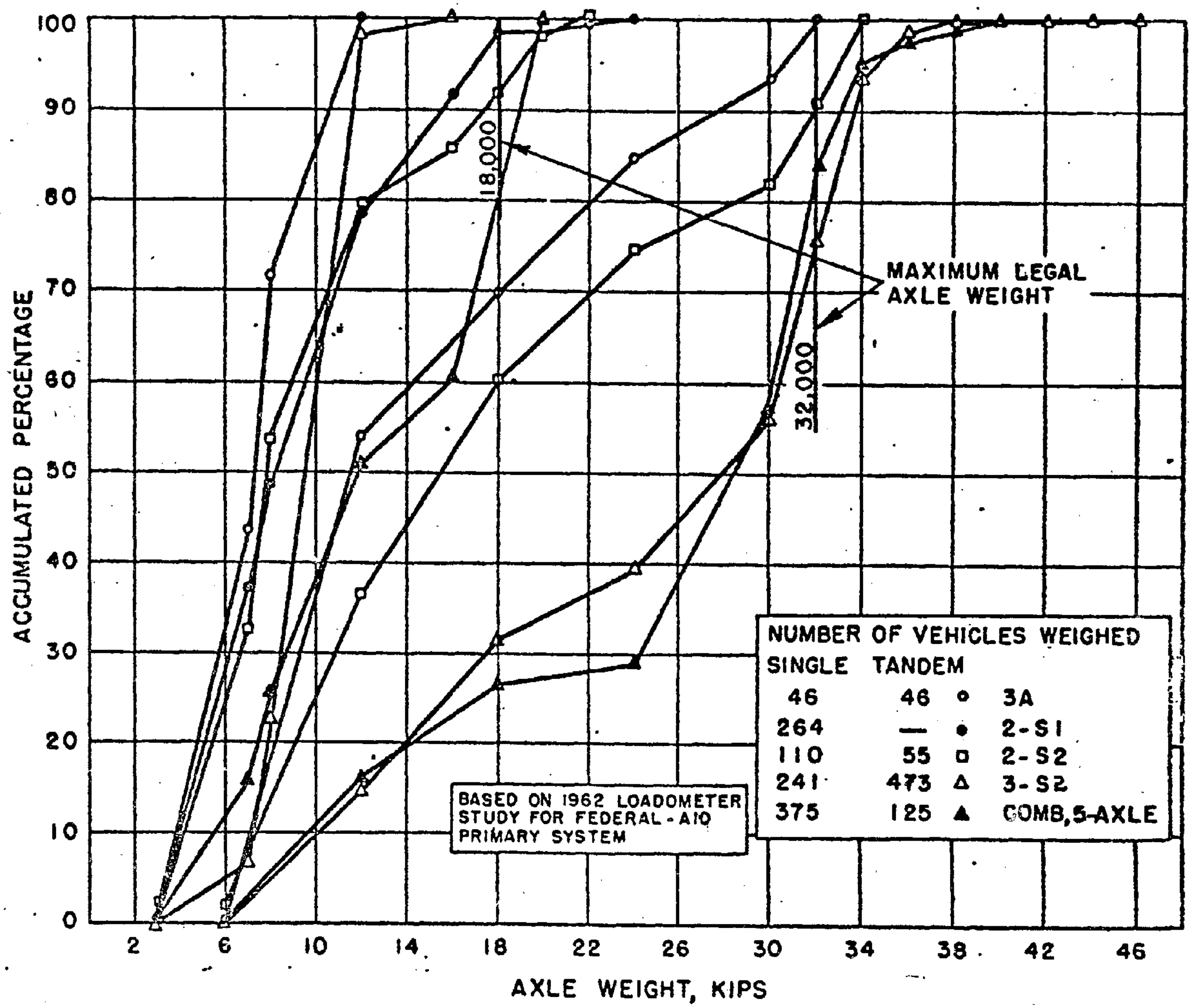

FIGURE 7-1.- DISTRIBUTION OF AXLE WEIGHT BY VEHICLE CLASS IN CALIFORNIA

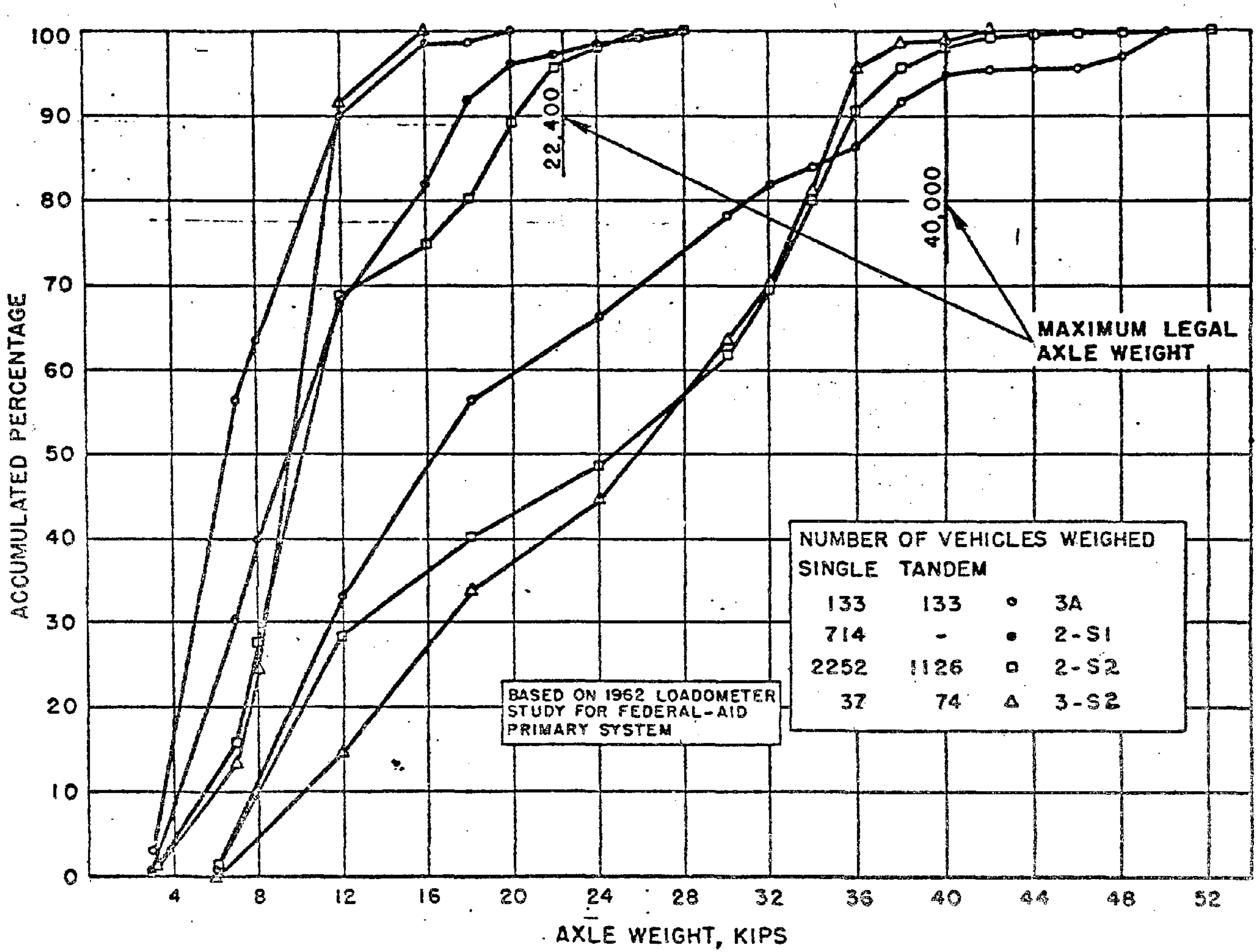

FIGURE 7-2.-DISTRIBUTION OF AXLE WEIGHT BY VEHICLE CLASS

carrying axles over the legal weight limit, particularly in California. As subsequent discussion will show, overloading was common in most States and for most vehicle classes.

A significant point shown by the full set of curves similar to figures 7-1 and 7-2 is that axle weights, single and tandem, are widely distributed from a small fraction of the legal limit to 110 percent or more of the legal maximum. The percentage of axles weighing from about 2,000 pounds less than the legal maximum limit to above the legal limit varies from 10 to 20 percent. Stated differently, 80 to 90 percent of the axles are operated at less than the legal weight limit. Since about 33 percent of all line-haul vehicles on the highway are empty of payload and 50 percent are carrying only partial loads on an axle-weight basis, it follows that only about 17 percent of the vehicles are operating at full legal maximum axle weight.

Table 7-11A summarizes the information dealing with single and tandem axles that was obtained from the 1962 truck weight survey. This information is presented for the primary rural highway system and all census divisions by class of vehicle and axle-weight group based upon State legal limits.

Overloaded axles are found for the full range of legal axle weights. The amount and quality of enforcement of axle-weight limits, State by State, is one factor in the percentage of overloading. Another factor in certain States is that vehicles carrying certain products are legally permitted to

Table 7-11A.--Summary of axle weighings above legal limits for the primary highway system (System 3), by vehicle class and legal weight group
Data are from the 1962 truck weight studies.

Vehicle class and axle-weight limit group	Number of States	Number of axles weighed	Number of axles according to excess axle weight above legal limits																Overweight axles as percentage of total weighed
			1 to 1,000 lbs.		1,001 to 3,000 lbs.		3,001 to 5,000 lbs.		5,001 to 7,000 lbs.		7,001 to 9,000 lbs.		9,001 to 11,000 lbs		11,001 to 13,000 lbs.		13,001 to 15,000 lbs.		
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Single axle																			
18,000 and less	19	1,924	1.0	.05	2.0	.10	--	--	--	--	--	--	--	--	--	--	--	--	.15
18,001 - 18,999	7	907	-	-	-	-	--	--	--	--	--	--	--	--	--	--	--	--	0
19,000 - 19,999	5	671	-	-	.5	.08	.5	.07	--	--	--	--	--	--	--	--	--	--	.15
20,000 - 20,999	3	306	-	-	-	-	1.0	.33	--	--	--	--	--	--	--	--	--	--	.33
21,000 - 21,999	1	41	.4	.97	-	-	--	--	--	--	--	--	--	--	--	--	--	--	.97
22,000 - 22,999	7	625	-	-	-	-	--	--	--	--	--	--	--	--	--	--	--	--	0
23,000 and above	4	283	-	-	-	-	--	--	--	--	--	--	--	--	--	--	--	--	0
All combined (Single)	46	4,757	1.4	.03	2.5	.05	1.5	.03	--	--	--	--	--	--	--	--	--	--	.11
Tandem axle																			
32,000 and less	22	2,419	107.8	4.46	51.5	2.13	18.5	.76	11.3	.47	8.8	.36	5.0	.21	3.0	.12	1.0	.04	8.55
32,001-33,999	7	855	13.3	1.56	17.6	2.06	7.6	.89	4.1	.48	1.8	.21	1.7	.20	1.0	.12	5.7	.67	6.19
34,000 - 35,999	2	135	-	-	1.0	.74	1.0	.74	1.0	.74	3.0	2.22	2.0	1.48	--	--	--	--	5.92
36,000 - 37,999	9	575	15.2	2.64	24.0	4.17	8.0	1.39	7.3	1.27	5.7	.99	--	--	--	--	2.0	.35	10.81
38,000 - 39,999	2	282	5.0	1.77	-	-	--	--	--	--	--	--	--	--	1.0	.35	--	--	2.12
40,000 and above	3	473	4.5	.95	1.0	.21	.2	.04	2.0	.42	4.0	.85	--	--	--	--	--	--	2.47
Not specified	1	18	-	-	-	-	--	--	--	--	--	--	--	--	--	--	--	--	0
All combined (Tandem)	46	4,757	145.8	3.06	95.1	2.00	35.3	.74	25.7	.54	23.3	.49	8.7	.18	5.0	.11	8.7	.18	7.30
-S1 Single axle																			
18,000 and less	19	10,464	207.0	1.98	53.0	.51	21.0	.20	5.0	.05	--	--	--	--	2.0	.02	--	--	2.76
18,001 - 18,999	7	4,725	66.6	1.41	36.0	.76	7.2	.15	3.0	.06	2.0	.04	.1	0	--	--	--	--	2.42
19,000 - 19,999	5	2,784	16.7	.60	2.2	.08	1.0	.04	--	--	--	--	--	--	--	--	--	--	.72
20,000 - 20,999	3	1,356	11.0	.81	21.0	1.55	8.0	.59	2.3	.17	--	--	--	--	--	--	--	--	3.12
21,000 - 21,999	1	354	2.4	.68	2.0	.57	2.0	.57	1.4	.40	--	--	--	--	--	--	--	--	2.22
22,000 - 22,999	7	3,942	31.5	.80	34.7	.88	21.1	.54	8.2	.21	1.7	.04	.6	.02	--	--	--	--	2.49
23,000 and above	4	1,995	4.7	.24	2.5	.13	--	--	--	--	--	--	--	--	--	--	--	--	.37
All combined (Single)	46	25,620	339.9	1.33	151.4	.59	60.3	.24	19.9	.08	3.7	.01	.7	.00	2.0	.01	--	--	2.26

Table 7-11A.- Summary of axle weighings above legal limits for the primary highway system (System 3), by vehicle class and legal weight group

Data are from the 1962 truck weight studies.

Vehicle class and axle-weight limit group	Number of States	Number of axles weighed	Number of axles according to excess axle weight above legal limits																Overweight axles as percentages of total weighed
			1 to 1,000 lbs.		1,001 to 3,000 lbs.		3,001 to 5,000 lbs.		5,001 to 7,000 lbs.		7,001 to 9,000 lbs.		9,001 to 11,000 lbs.		11,001 to 13,000lbs		13,001 to 15,000 lbs.		
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
2-S2 Single axle																			
18,000 and less	19	18,557	928.0	5.00	180.0	.97	38.0	.20	19.0	.10	12.0	.06	1.0	.01	--	-	--	-	6.34
18,001 - 18,999	7	8,854	210.0	2.37	183.2	2.07	65.5	.74	15.9	.18	18.5	.21	1.4	.02	--	-	--	-	5.59
19,000 - 19,999	5	7,142	143.9	2.01	65.5	.92	16.2	.23	3.8	.05	2.2	.03	-	-	--	-	--	-	3.24
20,000 - 20,999	3	5,014	116.2	2.32	136.9	2.73	40.0	.80	10.8	.22	3.0	.06	-	-	--	-	--	-	6.13
21,000 - 21,999	1	488	12.6	2.58	16.1	3.30	5.5	1.13	1.4	.29	.3	.06	.7	.15	--	-	--	-	7.51
22,000 - 22,999	7	9,166	164.8	1.80	190.8	2.08	65.9	.72	9.7	.11	1.0	.01	.4	.01	--	-	--	-	4.73
23,000 and above	4	5,712	22.6	.40	20.6	.36	4.5	.08	--	--	--	-	-	-	--	-	--	-	.84
All combined (Single)	46	54,933	1,598.1	2.91	793.1	1.44	235.6	.43	60.6	.11	37.0	.07	3.5	.01	--	-	--	-	4.97
2-S2 Tandem axle																			
32,000 and less	22	11,785	696.5	5.91	239.5	2.03	88.0	.75	68.0	.58	35.0	.30	13.0	.11	5.5	.05	5.0	.04	9.77
32,001 - 33,999	7	4,880	88.8	1.82	113.4	2.32	52.9	1.08	37.7	.77	33.9	.69	24.2	.50	31.3	.64	37.4	.77	8.59
34,000 - 35,999	2	270	9.9	3.67	16.1	5.96	7.5	2.78	3.3	1.22	1.7	.63	1.0	.37	.3	.11	--	-	14.74
36,000 - 37,999	9	4,591	32.2	.70	55.4	1.21	29.2	.64	16.3	.36	8.9	.19	4.1	.09	2.5	.05	4.0	.09	3.33
38,000 - 39,999	2	1,899	1.5	.08	3.7	.19	2.0	.11	--	--	--	-	-	-	--	-	--	-	.38
40,000 and above	3	3,695	19.6	.53	24.4	.66	8.4	.23	3.6	.10	1.3	.04	1.8	.05	1.2	.03	--	-	1.64
Not specified	1	116	--	--	--	--	--	--	--	--	--	-	-	-	--	-	--	-	--
All combined (Tandem)	46	27,236	848.5	3.12	452.5	1.66	188.0	.69	128.9	.47	80.8	.30	4.41	.16	40.8	.15	46.4	.17	6.72

Table 7-11A. Summary of axle weighings above legal limits for the primary highway system (System 3), by vehicle class and legal weight group. Data are from the 1962 truck weight studies.

Vehicle class and axle-weight limit group	Number of States	Number of axles weighed	Number of axles according to excess axle weight above legal limits																Overweight axles as percentage of total weighed
					1,001 to 3,000 lbs.		3,001 to 5,000 lbs.		5,001 to 7,000 lbs.		7,001 to 9,000 lbs.		9,001 to 11,000 lbs.		11,001 to 13,000 lbs.		13,001 to 15,000 lbs.		
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
3-S2 Single axle																			
18,000 and less	19	9,139	14.0	.15	8.0	.09	3.0	.03	--	-	--	-	--	--	--	-	--	-	.27
18,001 - 18,999	7	4,757	1.5	.03	--	--	--	-	--	-	--	-	--	--	--	-	--	-	.03
19,000 - 19,999	5	2,066	5.2	.25	2.0	.10	1.0	.05	0.8	.04	--	-	--	--	--	-	--	-	.44
20,000 - 20,999	3	105	--	-	--	--	--	-	--	-	--	-	--	--	--	-	--	-	--
21,000 - 21,999	1	450	--	-	--	--	--	-	--	-	--	-	--	--	--	-	--	-	--
22,000 - 22,999	7	371	--	-	--	--	--	-	--	-	--	-	--	--	--	-	--	-	--
23,000 and above	4	559	--	-	--	--	--	-	--	-	--	-	--	--	--	-	--	-	--
All combined (Single)	46	17,447	20.7	.12	10.0	.06	4.0	.02	0.8	.01	--	-	--	--	--	-	--	-	.21
3-S2 Tandem axle																			
32,000 and less	22	20,073	1,040.0	5.18	314.7	1.57	79.5	.40	43.5	.22	21.2	.11	14.7	.07	6.2	.03	29.7	.15	7.73
32,001 -33,999	7	8,895	235.8	2.65	317.8	3.57	150.2	1.69	67.9	.76	26.2	.29	14.0	.16	8.2	.09	6.6	.07	9.28
34,000 - 35,999	2	2,150	50.6	2.35	104.8	4.87	69.6	3.24	36.5	1.70	15.4	.72	7.4	.34	2.7	.13	.4	.02	13.37
36,000 - 37,999	9	1,616	10.5	.65	2.0	.12	1.0	.06	--	--	--	-	--	-	--	-	--	-	.83
38,000 - 39,999	2	190	.7	.37	1.0	.53	.5	.26	--	--	--	-	--	-	--	-	--	-	1.16
40,000 and above	3	378	.5	.13	.5	.13	--	-	--	--	--	-	--	-	--	-	--	-	.26
Not specified	1	0	--	--	--	--	--	-	--	--	--	-	--	-	--	-	--	-	--
All combined (Tandem)	46	33,302	1,338.1	4.02	740.8	2.22	300.8	.90	147.9	.44	62.8	.19	36.1	.11	17.1	.05	36.7	.11	8.04

carry axle weight above the limits for other vehicles. For example, Idaho permits 500 pounds more weight than the generally prevailing limit on single axles and 5,800 more on tandem axles for vehicles hauling timber and timber products, ores, concentrates, aggregates, and agricultural products including livestock.

Because the 1962 truck weight survey did not report the commodity carried, overloading cannot be traced to the type of commodity. It is known that some carriers overload as a standard practice, reflecting the level of enforcement and the magnitude of the fines imposed.

It is highly significant that overloading is found in almost all States for all types of vehicles and for the full range of single-axle limits up to the maximum limit of 23,520 pounds. Table 7-11A portrays the same general facts for tandem axles as are shown for single axles, except that for tandem axles overloading is more severe. For ease of comparison, the totals for single and tandem axles from table 7-11A are brought together in table 7-11B.

In general, the percentage of overweight axles is found to be about the same level regardless of the legal weight limit. There is even some overweight on the steering axles (3A and 3-S2 vehicles). For the class 2-S1 vehicle, the single-axle average of 2.26 percent includes the steering axle along with two load-carrying axles. Therefore, the effective percentage of overweight is about 3.3 percent. These facts clearly show that the

Table 7-11 B.-- **Summary of vehicle axle weights above legal limits grouped according to excess weight, by vehicle class and axle arrangement, for the primary rural highway system (system 3) and all census divisions**

Data are from the 1962 truck weight study.

Vehicle class and axle arrangement	Number of axles weighed	Number of axles above legal axle-weight limits, by excess weight in pounds																Overweight axles as percentage of total weighed
		1 to 1,000		1,001 to 3,000		3,001 to 5,000		5,001 to 7,000		7,001 to 9,000		9,001 to 11,000		11,001 to 13,000		13,001 and over		
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
3A																		
Single axle	4,757	1.4	.03	2.5	.05	1.5	.03	-	-	-	-	-	-	-	-	-	-	.11
Tandem axle	4,757	145.8	3.06	95.1	2.00	35.3	.74	25.7	.54	23.3	.49	8.7	.18	5.0	.11	8.7	.18	7.30
2-S1																		
Single axle	25,620	339.9	1.33	151.4	.59	60.3	.24	19.9	.08	3.7	.01	.7	0	2.0	.01	-	-	2.26
Tandem axle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-S2																		
Single axle	54,933	1,598.1	2.91	793.1	1.44	235.6	.43	60.6	.11	37.0	.07	3.5	.01	-	-	-	-	4.97
Tandem axle	27,236	848.5	3.12	452.5	1.66	188.0	.69	128.9	.47	80.8	.30	44.1	.16	40.8	.15	46.4	.17	6.72
-S2																		
Single axle	17,447	20.7	.12	10.0	.06	4.0	.02	.8	.01	-	-	-	-	-	-	-	-	.21
Tandem axle	33,302	1,338.1	4.02	740.8	2.22	300.8	.90	147.9	.44	62.8	.19	36.1	.11	17.1	.05	36.7	.11	8.04

transport industry will use higher axle-weight limits if they are authorized.

3. GROSS VEHICLE-WEIGHT DISTRIBUTION

Figures 7-3 and 7-4 give the percentage curves summing the gross vehicle weights for California and Maryland by vehicle class. These curves, typical of others for the entire 46 States analyzed, are similar in character to those for the axle-weight distribution. The mark at the practical gross limit is for the stated legal limit or practical limit based upon maximum legal axle weight, whichever is lower.

Table 7-12A was compiled using the series of curves represented by figures 7-3 and 7-4 and summarizes the information on overloading as to gross weight for the primary rural highway system and all census divisions. This table, based on data from the 1962 truck weight survey, indicates that the transport industry would use greater gross vehicle weights, if they were made legal.

The relative role of each class of vehicle in hauling payload on the primary rural highway system is given by census divisions in table 7-19. The number of vehicles in each class in the traffic stream is expressed as a percentage of the intercity truck fleet, and the tons of payload carried by each vehicle class is expressed as a percentage of the total tons carried by all vehicles.

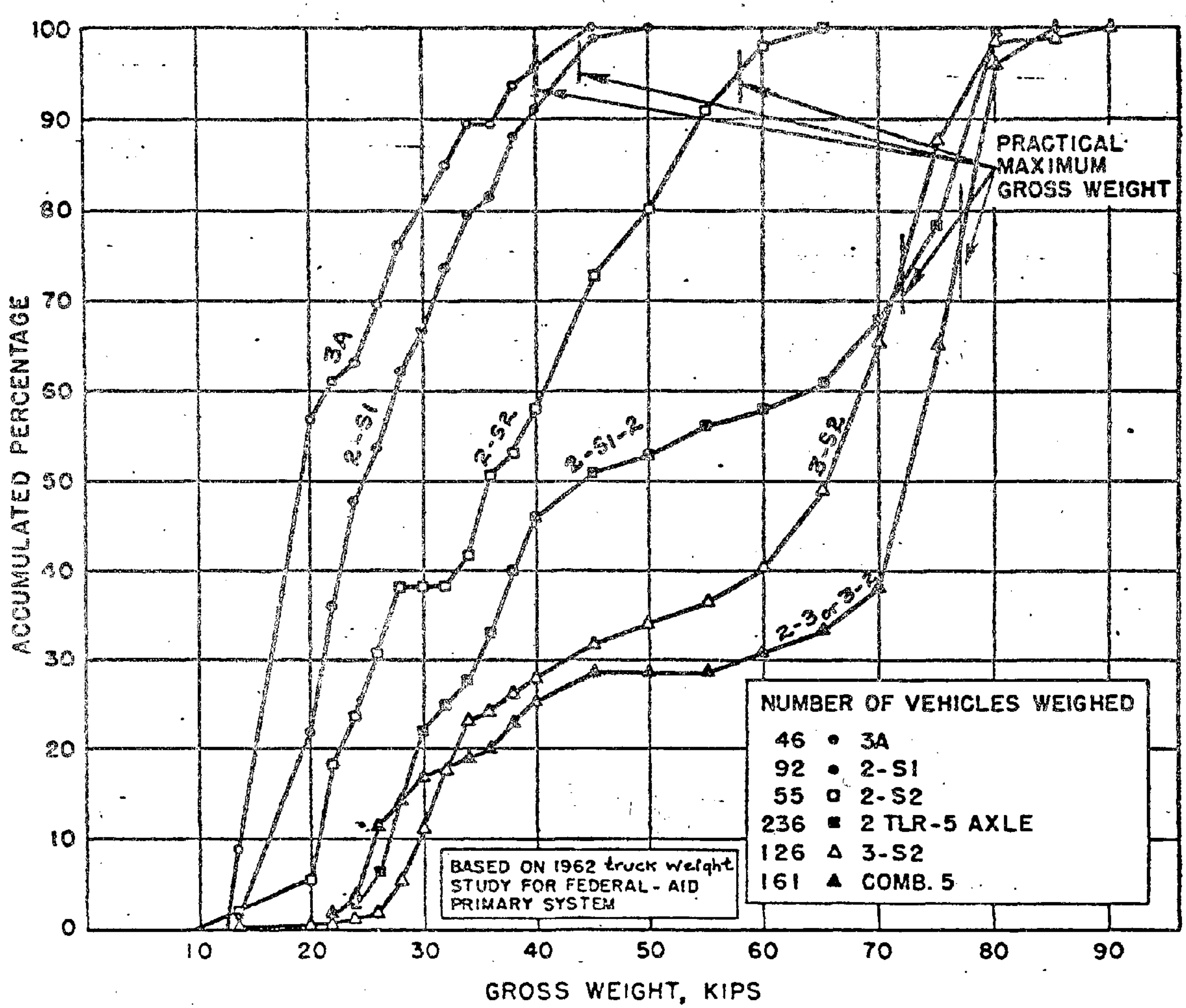

FIGURE 7-3.-DISTRIBUTION OF GROSS WEIGHT BY VEHICLE CLASS IN CALIFORNIA

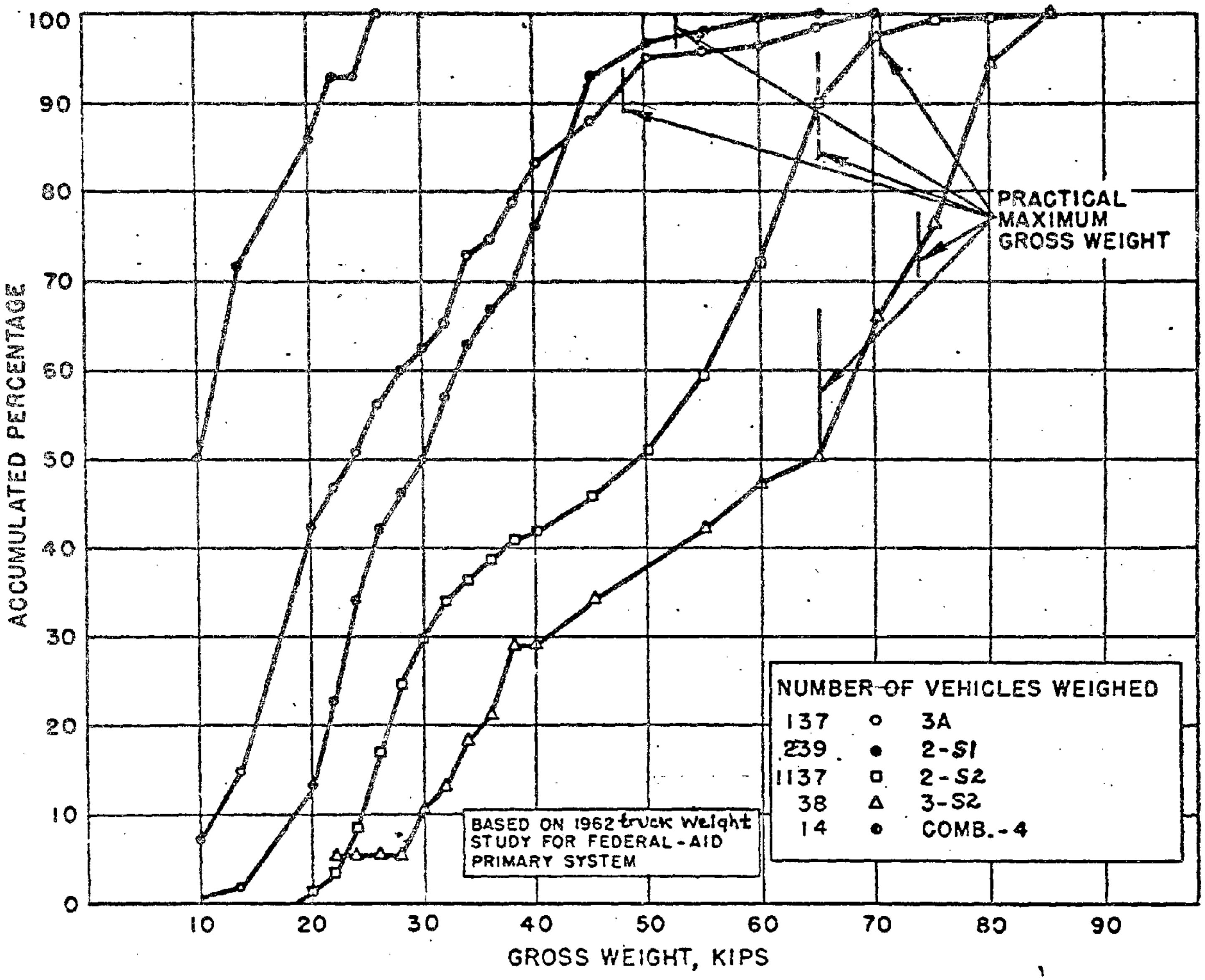

FIGURE 7-4.-DISTRIBUTION OF GROSS WEIGHT BY VEHICLE CLASS IN MARYLAND

Table 7-12A.--Numbers and percentages of vehicle gross weights that are above legal limits, grouped according to excess weight, by vehicle class and legal maximum weight, for the primary rural highway system (system 3) and all census divisions.
Data are from the 1962 truck weight study

Sheet 1 of 3 sheets

Vehicle class and legal maximum gross weight, pounds	Number of vehicles weighed	Number of States	Number of vehicles above gross weight limits, by excess weight in pounds: 1-5,000		5,001-10,000		10,001-15,000		15,001-20,000		20,001-25,000		25,001-30,000		Over 30,000		Overweight vehicles as percentage of total weighed
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
ess than 40,000	317	3	41.9	13.22	16.9	5.33	2.4	.76	0.1	.03	--	--	--	--	--	--	19.34
),001--40,999	2,575	21	238.0	9.24	54.3	2.11	4.0	.16	3.0	.12	2.0	.08	--	--	2.0	.08	11.79
1,000--41,999	678	8	66.9	9.87	22.2	3.27	4.7	.69	3.9	.58	3.5	.52	--	--	1.0	.15	15.08
2,000--42,999	41	1	2.5	6.10	1.0	2.44	2.5	6.10	3.0	7.32	1.0	2.44	--	--	--	--	24.40
3,000--43,999	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4,000--44,999	271	7	16.7	6.16	15.4	5.68	25.6	9.45	5.8	2.14	1.7	.63	.8	.30	1.0	.37	24.73
5,000--49,999	726	5	33.0	4.55	3.4	.47	3.2	.44	2.4	.33	1.3	.18	.5	.07	--	--	6.04
50,000 and over	157	1	13.4	8.53	1.2	.76	--	--	--	--	--	--	--	--	--	--	9.29
al	4,766	46	412.4	8.65	114.4	2.40	42.4	.89	18.2	.38	9.5	.20	1.3	.03	4.0	.08	12.63
51																	
4,000	3,466	20	111.2	3.21	22.2	.64	2.6	.08	.2	.01	--	--	--	--	--	--	3.94
5,000--45,999	1,873	8	36.2	1.93	5.6	.30	2.0	.11	.8	.04	--	--	--	--	--	--	2.38
6,000--46,999	426	2	2.6	.61	.8	.19	--	--	--	--	--	--	--	--	--	--	.80
7,000--47,999	453	2	1.7	.38	--	--	--	--	--	--	--	--	--	--	--	--	.38
3,000-48,999	452	3	10.8	2.39	4.6	1.02	--	--	--	--	--	--	--	--	--	--	3.41
),000--49,999	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
),000--53,000	1,790	10	28.2	1.58	7.6	.42	5.2	.29	2.0	.11	--	--	--	--	--	--	2.40
3,000 and over	85	1	--	--	1.0	1.17	--	--	--	--	--	--	--	--	--	--	1.17
al	8,545	46	190.7	2.23	41.8	.49	9.8	.11	3.0	.04	--	--	--	--	--	--	2.87
52																	
5,000--56,999	3,491	5	438.3	12.56	55.0	1.58	8.9	.25	9.2	.26	4.7	.13	2.8	.08	--	--	14.86
7,000--58,999	5,129	14	437.8	8.54	149.6	2.92	64.9	1.27	51.2	1.00	21.4	.42	1.8	.04	--	--	14.19
),000--59,999	6,323	8	464.7	7.35	130.7	2.07	35.7	.56	8.8	.14	.5	.01	--	--	--	--	10.13
),000--60,999	2,538	6	93.4	3.68	57.3	2.26	17.1	.67	3.9	.15	.8	.03	--	--	--	--	6.79
.,000--61,999	1,461	2	32.5	2.22	23.3	1.59	9.4	.64	3.4	.23	.5	.03	--	--	--	--	4.71
2,000--63,999	3,503	5	253.1	7.21	75.4	2.15	14.5	.41	3.9	.11	.4	.01	--	--	--	--	9.89
4,000--64,999	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5,000 and over	5,002	6	195.5	3.91	87.6	1.75	27.0	.54	3.0	.06	--	--	--	--	--	--	6.26
al	27,452	46	1,915.3	6.98	578.9	2.11	177.5	.65	83.4	.30	28.3	.10	4.6	.02	--	--	10.16

Table 7-12A.--Numbers and percentages of vehicle gross weights that are above legal limits, grouped according to excess weight, by vehicle class and legal maximum weight, for the primary rural highway system (system 3) and all census divisions.
Data are from the 1962 truck weight study.

Sheet 2 of 3 sheets

Vehicle class and legal maximum gross weight pounds	Number of vehicles weighed	No. of States	Number of vehicles above gross weight limits, by excess weight in pounds														Overweight vehicles as percentages of total weighed
			1-5,000		5,001-10,000		10,001-15,000		15,001-20,000		20,001-25,000		25,001-30,000		Over 30,000		
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
52																	
ess than 60,000	21	3	3.6	17.14	2.8	13.33	1.0	4.76	1.0	4.76	.6	2.86	--	--	--	--	42.85
),001--60,999	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
,000--61,999	71	3	9.7	13.66	4.3	6.06	2.2	3.10	--	--	--	--	--	--	--	--	22.82
,000--62,999	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
,000--64,999	2,895	7	185.4	6.40	158.0	5.46	62.5	2.16	11.2	.39	2.4	.08	.2	.01	--	--	14.50
,000--65,999	330	4	33.0	10.00	19.0	5.76	8.0	2.42	2.0	.61	1.0	.30	--	--	--	--	19.09
,000--66,999	778	4	186.4	23.96	89.3	11.48	7.4	.95	.4	.05	.6	.08	.6	.08	.8	.10	36.70
,000--69,999	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
),000--72,999	5,441	11	594.8	10.93	130.6	2.40	32.7	.60	21.1	.39	8.6	.16	1.9	.03	--	--	14.51
,000--73,999	4,893	10	426.4	8.71	181.7	3.71	61.0	1.25	17.5	.36	3.4	.07	.5	.01	--	--	14.11
,000 and over	2,407	4	84.1	3.49	78.2	3.25	18.9	.79	13.7	.57	3.7	.15	--	--	--	--	8.25
al	16,836	46	1,523.4	9.05	663.9	3.94	193.7	1.15	66.9	.40	20.3	.12	3.2	.02	.8	.01	14.69
)																	
,000--62,999	153	17	.8	.52	1.2	.78	--	--	--	--	--	--	--	--	--	--	1.30
,000--63,999	127	3	.6	.47	--	--	--	--	--	--	--	--	--	--	--	--	.47
,000--64,999	134	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
,000--65,999	35	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
,000--66,999	58	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
,800 and over	45	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
al	552	30	1.4	.25	1.2	.22	--	--	--	--	--	--	--	--	--	--	.47
, 2-3																	
,000--64,999	33	3	.4	1.21	12.0	36.36	3.0	9.09	--	--	--	--	--	--	--	--	46.66
,000	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
,000--72,999	135	3	22.5	16.67	19.2	14.22	--	--	--	--	--	--	--	--	--	--	30.89
,000--73,999	62	8	2.6	4.19	--	--	--	--	--	--	--	--	--	--	--	--	4.19
,000--76,999	561	7	122.4	21.82	6.2	1.11	--	--	--	--	--	--	--	--	--	--	22.93
,000--77,999	119	2	11.3	9.50	4.5	3.78	2.0	1.68	--	--	--	--	--	--	--	--	14.96
,520	34	1	2.0	5.88	1.9	5.58	.9	2.65	--	--	--	--	--	--	--	--	14.11
tal	945	25	161.2	17.06	43.8	4.63	5.9	.62	--	--	--	--	--	--	--	--	22.31

Table 7-12A.--Numbers and percentages of vehicle gross weights that are above legal limits, grouped according to excess weight, by vehicle class and legal maximum weight, for the primary rural highway system (system 3) and all census divisions.

Data are from the 1962 truck weight study.

Sheet 3 of 3 sheets

Vehicle class and legal maximum gross weight, pounds	Number of vehicles weighed	Number of States	Number of vehicles above gross weight limits, by excess weight in pounds														Overweight vehicles as percentage of total weighed
			1-5,000		5,001-10,000		10,001-15,000		15,001-20,000		20,001-25,000		25,001-30,000		Over 30,000		
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
3 and more*																	
2,000	2	1	1.2	60.00	--	--	--	--	--	--	--	--	--	--	--	--	*60.00
5,000--76,999	15	5	1.6	10.67	--	--	--	--	--	--	--	--	--	--	--	--	*10.67
3,000	1	1	.4	40.00	--	--	--	--	--	--	--	--	--	--	--	--	*40.00
9,900	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0,000	16	1	5.5	34.37	7.0	43.75	2.0	12.50	--	--	--	--	--	--	--	--	*90.62
and Total	35	9	8.7	24.86	7.0	20.00	2.0	5.71	--	--	--	--	--	--	--	--	*50.57
31-2																	
2,000	42	2	4.6	10.95	4.2	10.00	--	--	--	--	--	--	--	--	--	--	20.95
3,000--73,999	40	3	1.2	3.00	--	--	--	--	--	--	--	--	--	--	--	--	3.00
5,000--76,999	367	5	37.6	10.25	2.0	0.54	--	--	--	--	--	--	--	--	--	--	10.79
9,900--80,000	14	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
and Total 2-T5	463	12	43.4	9.37	6.2	1.34	--	--	--	--	--	--	--	--	--	--	10.71

The "and more" distorts the percentages, which are based on 6 axles.

Table 7-19. -- Total tons of cargo, percentage hauled by each vehicle class, and number of vehicles by class in the total ADT, based on the 1962 truck weight data for the rural primary system (System 3)

Census Division	Average Total ADT	3A			2S1			2S2			3S2			Comb. 5-Axle			2-Tlr. 5-Axle			Total		
		No. Vehicle	Payload Tons	Payload %	No. Vehicle	Payload Tons	Payload %	No. Vehicle	Payload Tons	Payload %	No. Vehicle	Payload Tons	Payload %	No. Vehicle	Payload Tons	Payload %	No. Vehicle	Payload Tons	Payload %	No. Vehicle	Payload Tons	Payload %
1. N.E.	3,562	18 (9.4%)	95.0	7.1	52 (27.2%)	203.1	14.9	117 (61.3%)	998.3	73.4	4 (2.1%)	63.1	4.6	-	-	-	-	-	-	191 (100.0%)	1,360.5	100.0
2. M.A.	4,084	29 (7.8%)	159.5	5.7	64 (17.1%)	244.4	8.7	275 (73.5%)	2,308.4	82.7	6 (1.6%)	79.9	2.9	-	-	-	-	-	-	374 (100.0%)	2,792.2	100.0
3. S.A.N.	4,162	35 (9.5%)	152.6	5.9	52 (14.2%)	203.8	7.8	270 (73.8%)	2,136.8	82.0	9 (2.5%)	112.2	4.3	-	-	-	-	-	-	366 (100.0%)	2,605.4	100.0
4. S.A.S.	2,803	23 (9.6%)	97.1	5.6	30 (12.6%)	118.3	6.8	175 (73.2%)	1,398.0	80.2	11 (4.6%)	130.1	7.4	-	-	-	-	-	-	239 (100.0%)	1,742.5	100.0
5. E.N.C.	3,221	22 (7.4%)	101.5	4.2	46 (15.6%)	192.4	7.9	135 (45.6%)	1,081.4	44.6	85 (28.7%)	936.2	38.6	3 (1.0%)	48.3	2.0	5 (1.7%)	65.0	2.7	296 (100.0%)	2,424.8	100.0
6. W.N.C.	1,563	15 (13.5%	81.3	8.6	13 (11.7%)	55.1	5.8	33 (29.7%)	263.7	27.9	50 (45.1%)	545.5	57.7	-	-	-	-	-	-	111 (100.0%)	945.6	100.0
7. E.S.C.	2,196	14 (6.6%)	66.6	4.3	33 (15.7%)	135.3	8.6	145 (68.7%)	1,158.4	74.1	19 (9.0%)	203.2	13.0	-	-	-	-	-	-	211 (100.0%)	1,563.5	100.0
8. W.S.C.	2,328	13 (5.7%)	58.4	3.1	36 (15.8%)	151.4	7.9	92 (40.3%)	729.0	38.3	87 (38.2%)	965.0	50.7	-	-	-	-	-	-	228 (100.0%)	1,903.8	100.0
9. M.	1,280	5 (8.1%)	17.7	3.0	8 (12.9%)	38.7	6.5	8 (12.9%)	72.3	12.2	32 (51.6%)	346.0	58.2	7 (11.3%)	96.0	16.1	2 (3.2%)	23.8	4.0	62 (100.0%)	594.5	100.0
10. P.	3,286	24 (9.1%)	121.2	4.4	25 (9.4%)	102.4	3.7	16 (6.0%)	123.1	4.5	127 (47.9%)	1,407.7	51.1	42 (15.9%)	603.8	21.9	31 (11.7%)	397.0	14.4	265 (100.0%)	2,755.2	100.0

Note:

The number of vehicles by vehicle class was computed by applying the percentage distribution derived from basic (counted) truck weight data (1962) to the ADT for the corresponding census division.

The payload computed was obtained as follows:

1. The gross weight carried by the single and tandem axles separately was taken directly from the vehicles weighed.
2. The single and tandem gross weights were added to get the total gross vehicle weight.
3. The average empty weight was sub tracted from the total gross weight, to obtain the payload carried.

The average empty weights were for the following single axle maximum weight limit groups of States:

a. New England and Middle Atlantic -- 22,000 pounds
b. South Atlantic North and South Atlantic South -- 20,000 pounds
c. The remaining 6 Census Divisions -- 18,000 pounds

Since, as of 1962, many of the eastern States had gross weight limits of less than 73,000 pounds, the 3-S2 combinations were few in number and low in percentage of total tons carried. In 1962 the 2-S2 was the more popular transport vehicle. In the western States, the reverse was true.

The average gross vehicle weights, empty vehicle weights and payload weights for each census division for the primary rural highway system were compiled in table 7-20. It is significant that, in general, the New England and Middle Atlantic Census Divisions, with 22,400/36,000-pound axle-weight limits, have higher weights than do the East and West North Central census divisions, where the axle-weight limits are 18,000/32,000 pounds. This table also shows that in 1962 the double-cargo combinations were found in the East North Central, Mountain, and Pacific Census Divisions. Because of changes in the State laws from 1962 to 1967, double-cargo combinations are now being used in almost all census divisions.

4. OTHER DATA FROM THE 1962 TRUCK WEIGHT STUDY

The distribution of types of vehicles and vehicle combinations found on the highways of each State is influenced materially by the State law. Table 7-21A prsents census division data from which comparisons by region can be made. This table gives the percentage of trucks by class (3A and upward) counted on the primary rural highway systems of each census division as obtained from the 1962 truck weight study.

Table 7-20. -- Average weight in pounds of trucks as weighed in the 1962 truck weight survey, by axle classification

(Primary rural-highway system)

NOTE: The empty vehicles were included in calculating the average payload per vehicle.

Census Division	Single Unit Trucks			Tractor Semitrailer Combinations									Truck and Trailer Combinations			Two Trailer Combinations		
	3-Axle or More (3-A)			3-Axle (2-S1)			4-Axle (2-S2)			5-Axle or More			Comb. 5-Axle			2-Trailer, 5-Axle		
	Average Gross Weight	Empty Weight	Average Payload	Average Gross Weight	Empty Weight	Average Payload	Average Gross Weight	Empty Weight	Average Payload	Average Gross Weight	Empty Weight	Average Payload	Average Gross Weight	Empty Weight	Average Payload	Average Gross Weight	Empty Weight	Average Payload
1. New England	30,611	19,950	10,661	29,259	21,450	7,809	43,115	26,050	17,065	64,500	32,950	31,550						
2. Middle Atlantic	30,947	19,950	10,997	29,086	21,450	7,636	42,838	26,050	16,788	59,583	32,950	26,633						
3. South Atlantic N.	26,515	17,795	8,720	28,038	20,200	7,838	40,628	24,800	15,828	55,503	30,570	24,933						
4. South Atlantic S.	26,238	17,795	8,443	28,083	20,200	7,883	40,777	24,800	15,977	54,225	30,570	23,655						
5. East North Central	24,862	15,635	9,227	27,315	18,950	8,365	39,570	23,550	16,020	50,217	28,190	22,027	58,167	26,000	32,167	54,500	28,500	26,000
6. West North Central	26,463	15,635	10,833	27,419	18,950	8,469	39,529	23,550	15,979	50,010	28,190	21,820						
7. East South Central	25,142	15,635	9,507	27,150	18,950	8,200	39,527	23,550	15,977	49,579	28,190	21,389						
8. West South Central	24,612	15,635	8,977	27,361	18,950	8,411	39,397	23,550	15,847	50,374	28,190	22,184						
9. Mountain	22,695	15,635	7,060	28,625	18,950	9,675	41,625	23,550	18,075	49,828	28,190	21,638	53,429	26,000	27,429	52,250	28,500	23,750
10. Pacific	25,731	15,635	10,096	27,138	18,950	8,188	38,938	23,550	15,388	50,359	28,190	22,169	54,750	26,000	28,750	54,113	28,500	25,613

Table 7-21A.-- Percentages of trucks with 3 or more axles counted in the 1962 truck weight study, primary rural highway system, by vehicle class and census division

Census Division	Single Unit Trucks	Tractor Semitrailer Combinations			Tractive Truck & Full Trailer Combinations			Tractor, Semitrailer and Full Trailer			Total
	3A	3-Axle (2-S1)	4-Axle (2-S2)	5-Axle or more	4-Axle	5-Axle	6-Axle or more	5-Axle	6-Axle	7-Axle or more	
New England	9.63	27.19	61.17	1.91	0.10	--	--	--	--	--	100.00
Middle Atlantic	7.72	17.02	73.60	0.95	0.64	0.07	--	--	--	--	100.00
South Atlantic (North)	9.58	14.26	73.78	1.70	0.58	0.10	--	--	--	--	100.00
South Atlantic (South)	9.70	12.65	73.03	3.25	1.32	0.05	--	--	--	--	100.00
East North Central	7.47	15.53	45.64	28.71	0.52	0.30	0.15	1.11	0.25	0.32	100.00
West North Central	13.45	11.46	29.74	41.68	2.79	0.85	--	0.03	--	--	100.00
East South Central	6.63	15.83	68.75	8.79	--	--	--	--	--	--	100.00
West South Central	5.73	15.61	40.54	36.89	1.14	0.09	--	--	--	--	100.00
Mountain	8.25	12.53	12.99	51.66	0.68	10.47	0.23	3.02	0.17	--	100.00
Pacific	9.16	9.34	6.25	47.91	1.53	13.85	0.24	11.52	0.20	--	100.00
Total-All Divisions	9.11	14.90	51.14	21.74	1.14	1.13	0.04	0.70	0.05	0.05	100.00

For the 1962 truck weight study, table 7-23A gives the percentage of axles falling within the following percentage groupings of full legal axle weight for each class of vehicle: 0-25, 25-50, 50-75, 75-100, and over 100 percent. The high percentage of axles over legal weight in many States is striking. In a few States, such as Idaho, some of the overweight axles could have been within the legal weight limits because they were hauling commodities legally permitted to exceed the generally applied statutory maximum.

Table 7-24 gives the average empty weights of 13 classes of vehicles and vehicle combinations as developed for five axle-weight limits. These empty weights are based upon the 1962 truck weight data extended to higher axle-weight limits. Note that the average empty weights increase with an increase in legal axle-weight limits. When heavier payloads per vehicle are permitted by law, it is to be expected that the manufacturers of power vehicles and trailers will redesign their vehicles for greater strength, which will produce greater empty weights.

5. TRENDS IN TRUCK WEIGHTS, NUMBER OF AXLES, AND ADT[1/]

Over the years the trucking industry has been gradually changing its many factors of vehicle use, vehicle weight, and number of axles, usually moving them upward. Some picture of

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[1/] Mr. E. M. Nolan supervised the collection of the information given in this section. His source was early reports and microfilm.

Table 7-23A.-- Total number of axles weighed in the 1962 truck weight study distributed according to the relation between their operating weights and the maximum legal axle limits, by vehicle class and CD: System 3

Census Division	Percentage of axles in each percentage group of full legal axle weight limit						Percentage of axles in each percentage group of full legal axle weight limit						Percentage of axles in each percentage group of full legal axle weight limit					
	Axle weight percentage grouping of legal limit						Axle weight percentage grouping of legal limit						Axle weight percentage grouping of legal limit					
	0-25	25-50	50-75	75-100	100+	Total	0-25	25-50	50-75	75-100	100+	Total	0-25	25-50	50-75	75-100	100+	Total
	Class 2D, single axle						Class 3A, single axle						Class 3A, tandem axle					
New England	46.3	41.5	8.5	3.0	0.7	100.0	20.9	58.3	19.1	1.7	0	100.0	3.9	40.0	21.2	15.0	19.9	100.0
Middle Atlantic	47.8	40.0	8.6	3.1	0.5	100.0	21.3	49.4	29.3	0	0	100.0	8.5	31.8	10.9	28.9	19.9	100.0
South Atlantic (North)	32.5	49.0	9.7	6.3	2.5	100.0	27.6	52.1	16.6	3.2	0.5	100.0	16.0	33.6	11.4	24.9	14.1	100.0
South Atlantic (South)	42.3	42.7	10.4	4.3	0.3	100.0	30.8	53.1	15.7	0.4	0	100.0	28.8	27.4	20.7	21.2	1.9	100.0
East North Central	32.9	48.5	12.2	5.8	0.6	100.0	21.2	51.4	24.7	2.5	0.2	100.0	13.3	35.1	17.9	29.9	3.8	100.0
West North Central	32.8	47.7	11.8	6.9	0.8	100.0	22.8	56.8	18.0	2.4	0	100.0	13.4	34.1	17.0	29.4	6.1	100.0
East South Central	33.6	48.2	10.5	5.6	2.1	100.0	27.4	56.6	14.8	1.2	0	100.0	19.5	39.7	14.3	18.5	8.0	100.0
West South Central	31.4	47.7	12.3	6.9	1.7	100.0	24.5	54.6	17.8	2.4	0.7	100.0	13.0	28.6	18.4	29.8	10.2	100.0
Mountain	33.3	46.5	12.5	6.7	1.0	100.0	16.7	51.9	26.9	4.4	0.1	100.0	10.2	36.0	18.5	24.6	10.7	100.0
Pacific	33.7	47.2	12.2	6.3	0.6	100.0	21.6	58.4	19.8	0.2	0	100.0	17.4	39.0	14.7	27.1	1.8	100.0

Table 7-23A.-- Total number of axles weighed in the 1962 truck weight study distributed according to the relation between their operating weights and the maximum legal axle limits, by vehicle class and CD: System 3

ensus Division	Percentage of axles in each percentage group of full legal axle weight limit						Percentage of axles in each percentage group of full legal axle weight limit						Percentage of axles in each percentage group of full legal axle weight limit					
	Axle weight percentage grouping of legal limit						Axle weight percentage grouping of legal limit						Axle weight percentage grouping of legal limit					
	0-25	25-50	50-75	75-100	100+	Total	0-25	25-50	50-75	75-100	100+	Total	0-25	25-50	50-75	75-100	100+	Total
	Class 2-S1, single semi-3 axle						Class 2-S2, single semi-4 axle						Class 2-S2, tandem semi-4 axle					
New England	19.3	47.3	20.9	8.7	3.8	100.0	11.4	52.5	16.6	13.0	6.5	100.0	17.6	35.2	15.3	23.9	8.0	100.0
iddle Atlantic	28.0	45.9	18.0	7.1	1.0	100.0	16.6	52.7	15.7	12.9	2.1	100.0	18.2	30.6	22.3	23.1	5.8	100.0
outh Atlantic (North)	15.5	39.7	24.0	15.8	5.0	100.0	9.3	43.8	21.8	17.4	7.7	100.0	12.9	27.8	14.9	28.3	16.1	100.0
outh Atlantic (South)	17.7	44.2	25.4	11.0	1.7	100.0	15.2	44.6	22.0	14.0	4.2	100.0	16.7	33.2	23.6	24.1	2.4	100.0
East North Central	16.3	43.8	24.7	14.2	1.0	100.0	10.5	40.1	25.8	18.7	4.9	100.0	11.3	32.3	20.7	30.6	5.1	100.0
West North Central	14.4	39.8	24.9	18.5	2.4	100.0	11.9	40.4	23.2	18.8	5.7	100.0	12.0	31.0	18.3	33.3	5.4	100.0
East South Central	17.2	41.6	24.0	12.5	4.7	100.0	10.8	39.6	25.4	16.7	7.5	100.0	17.3	26.2	20.1	25.8	10.6	100.0
West South Central	17.2	41.2	22.2	14.8	4.6	100.0	13.5	40.5	20.1	17.3	8.6	100.0	13.9	29.4	17.3	30.0	9.4	100.0
Mountain	15.3	37.8	24.9	19.6	2.4	100.0	11.0	38.8	28.6	19.0	2.6	100.0	14.6	35.7	29.7	16.9	3.1	100.0
Pacific	16.3	40.2	23.1	18.2	2.2	100.0	13.5	42.1	24.0	17.6	2.8	100.0	12.7	35.3	28.1	20.5	3.4	100.0

Table 7-23A.-- Total number of axles weighed in the 1962 truck weight study distributed according to the relation between their operating weights and the maximum legal axle limits, by vehicle class and CD: System 3

Census Division	Percentage of axles in each percentage group of full legal axle weight limit						Percentage of axles in each percentage group of full legal axle weight limit					
	Axle weight percentage grouping of legal limit						Axle weight percentage grouping of legal limit					
	0-25	25-50	50-75	75-100	100+	Total	0-25	25-50	50-75	75-100	100+	Total
	Single semi-5 axle						Tandem semi-5 axle					
New England	6.2	31.5	11.0	51.3	0	100.0	13.6	37.2	20.4	17.2	11.6	100.0
Middle Atlantic	12.5	74.6	12.9	0	0	100.0	12.7	37.3	31.3	15.1	3.6	100.0
South Atlantic (North)	5.8	57.1	37.1	0	0	100.0	10.0	30.9	22.7	26.8	9.6	100.0
South Atlantic (South)	13.0	53.8	30.8	2.4	0	100.0	14.9	36.3	35.0	12.6	1.2	100.0
East North Central	7.3	46.8	38.6	6.2	1.1	100.0	7.9	25.0	20.9	34.0	12.2	100.0
West North Central	6.5	45.7	46.1	1.7	0	100.0	7.8	23.2	18.5	41.2	9.3	100.0
East South Central	6.8	49.2	42.3	1.7	0	100.0	12.0	27.4	28.9	27.5	4.2	100.0
West South Central	5.7	42.6	46.7	4.9	0.1	100.0	12.0	27.3	22.8	30.3	7.6	100.0
Mountain	1.6	44.9	52.2	1.3	0	100.0	6.9	22.1	23.5	37.5	10.0	100.0
Pacific	2.7	41.1	55.8	0.4	0	100.0	8.9	23.7	10.0	43.4	14.0	100.0

Table 7-24. -- Average empty weights of vehicles and vehicle combinations developed from the 1962 truck weight data and expanded to higher axle-weight limits, by vehicle class and highway system

(All weights in pounds.)

Vehicle Type	Axle weight limits-single/tandem, kips				
	18/32	20/35	22/38	24/41	26/44
System 1. Interstate Rural					
Panel and Pickup	4,315	4,315	4,315	4,315	4,315
2S	5,275	5,275	5,275	5,275	5,275
2D	9,145	9,875	10,600	11,325	12,020
3A	15,940	17,370	18,800	20,230	21,660
2-S1	19,645	20,675	21,700	22,725	23,750
2-S2	23,370	25,060	26,750	28,440	30,130
3-S2	28,040	29,870	31,700	33,530	35,360
2-2 and less	14,000	14,700	15,400	16,100	16,800
3-2 or 2-3	26,000	26,700	27,400	28,100	28,800
3-3 and more	28,800	29,500	30,300	31,000	31,700
2-S1-2 and less	28,500	29,400	30,300	30,800	31,300
2-S2-2	31,800	32,700	33,600	34,500	35,400
3-S2-2 and over	35,400	36,300	37,200	38,100	39,000
System 2. Interstate Urban					
Panel and Pickup	4,290	4,290	4,290	4,290	4,290
2S	5,220	5,220	5,220	5,220	5,220
2D	9,030	9,690	10,350	11,010	11,670
3A	17,015	18,310	19,600	20,890	22,180
2-S1	19,360	20,605	21,850	23,095	24,340
2-S2	23,690	24,545	25,400	26,255	27,110
3-S2	28,940	30,245	31,550	32,855	34,160
2-2 and less	14,000	14,700	15,400	16,100	16,800
3-2 or 2-3	26,000	26,700	27,400	28,100	28,800
3-3 and more	28,800	29,500	30,300	31,000	31,700
2-S1-2 and less	28,500	29,400	30,300	30,800	31,300
2-S2-2	31,800	32,700	33,600	34,500	35,400
3-S2-2 and over	35,400	36,300	37,200	38,100	39,000

Table 7-24. -- Average empty weights of vehicles and vehicle combinations developed from the 1962 truck weight data and expanded to higher axle-weight limits, by vehicle class and highway system

(All weights in pounds.)

Vehicle Type	Axle weight limits-single/tandem, kips				
	18/32	20/35	22/38	24/41	26/44
a/ System 3. Primary Rural					
Panel and Pickup	4,350	4,350	4,350	4,350	4,350
2S	5,360	5,360	5,360	5,360	5,360
2D	9,220	9,510	9,800	10,090	10,390
3A	15,635	17,795	19,950	22,105	24,260
2-S1	18,950	20,200	21,450	22,700	23,950
2-S2	23,550	24,800	26,050	27,300	28,550
3-S2	28,190	30,570	32,950	35,330	37,710
2-2 and less	14,000	14,700	15,400	16,100	16,800
3-2 or 2-3	26,000	26,700	27,400	28,100	28,800
3-3 and more	28,800	29,500	30,300	31,000	31,700
2-S1-2 and less	28,500	29,400	30,300	30,800	31,300
2-S2-2	31,800	32,700	33,600	34,500	35,400
3-S2-2 and over	35,400	36,300	37,200	38,100	39,000
a/ System 4. Primary Urban					
Panel and Pickup	4,300	4,300	4,300	4,300	4,300
2S	5,425	5,425	5,425	5,425	5,425
2D	8,710	9,330	9,950	10,570	11,190
3A	17,360	19,155	20,950	22,745	24,540
2-S1	19,050	19,975	20,900	21,825	22,750
2-S2	24,280	25,340	26,400	27,460	28,520
3-S2	28,970	30,360	31,750	33,140	34,530
2-2 and less	14,000	14,700	15,400	16,100	16,800
3-2 or 2-3	26,000	26,700	27,400	28,100	28,800
3-3 and more	28,800	29,500	30,300	31,000	31,700
2-S1-2 and less	28,500	29,400	30,300	30,800	31,300
2-S2-2	31,800	32,700	33,600	34,500	35,400
3-S2-2 and over	35,400	36,300	37,200	38,100	39,000

a/ Secondary Systems 5 (rural) and 6 (urban) same as for primary systems. Weight data not sufficient to establish separate empty weights.

the past results of truck weight studies is called for to compare with the 1962 data, although historical statistics are neither complete nor wholly reliable.

A. Summary of Some Factors from Truck Weight Studies, 1937 to 1963

The annual truck weight studies were started about 1937 as a phase of the Statewide highway planning studies, and most States have conducted them each year since then. The data are somewhat limited in scope for the years before 1959. For all years, the State-by-State data cannot be regarded as wholly reliable, because the weighings and classifications must be limited in geographical coverage and in survey time at the road site.

The information in tables 7-25, 7-26, and 7-27 and in figures 7-5, 7-6, and 7-7 is based on a summary of the yearly reports from the following 20 States:

California	Kentucky	Missouri	Ohio
Connecticut	Louisiana	Nevada	Oregon
Georgia	Maryland	New Jersey	Pennsylvania
Illinois	Massachusetts	Mew Mexico	Virginia
Iowa	Michigan	North Carolina	Wyoming

B. Significant Trends

Some of the significant facts to be observed are as follows:

1. Tandem axles are increasing.

2. Vehicle combinations with three or more units are increasing.

Table 7-25. -- Summary of data on trucks and combinations for all main rural highways, 1937 -1963

	1937	1942	1946	1949	1952	1955	1957	1959	1960	1961	1962	1963
Number of axleloads (Actual) per 1,000 vehicles (trucks and combinations)												
All vehicles (including 2-axle)												
Single-axle	NA	NA	NA	NA	NA	NA	NA	2,070.2	2,056.4	2,018.2	2,021.9	1,993.1
Tandem-axle	NA	NA	NA	NA	NA	NA	NA	419.4	414.4	450.5	460.7	482.1
Total (tandem as 1 axle)	NA	NA	NA	NA	NA	NA	NA	2,489.6	2,470.8	2,468.7	2,482.6	2,475.2
Total (tandem as 2 axles) 1/	2,220.8	2,348.8	2,410.7	2,447.1	2,572.2	2,769.1	2,857.1	2,870.2	2,879.8	2,908.3	2,938.2	2,961.2
Vehicles with 3 or more axles	NA	NA	NA	3,495.0	3,532.1	3,513.1	3,737.7	3,815.2	3,897.2	3,945.2	3,967.1	4,027.3
Number of axleloads (E-18) per 1,000 vehicles (trucks and combinations)												
Single-axle	NA	NA	NA	NA	NA	NA	NA	318.2	303.8	309.3	308.4	306.3
Tandem-axle	NA	NA	NA	NA	NA	NA	NA	160.6	162.3	195.4	178.6	189.2
Total (tandem as 1 axle)	NA	NA	NA	NA	NA	NA	NA	478.8	466.1	504.7	487.0	495.5
Distribution of vehicles (percent)												
Single-unit trucks	84.31	75.72	73.47	72.6	65.97	60.68	60.26	58.51	58.55	59.23	57.35	58.01
Tractor-semitrailer	14.05	22.15	24.39	26.25	31.90	37.87	38.25	38.76	38.64	38.28	39.73	39.19
Truck-trailer	1.64	2.13	2.14	1.15	2.13	1.45	1.49	1.56	1.52	1.29	1.54	1.46
Two-Trailer	NA	NA	NA	NA	NA	NA	NA	1.17	1.29	1.20	1.38	1.34
Total combinations	15.69	24.28	26.53	27.40	34.03	39.32	39.74	41.49	41.45	40.77	42.65	41.99
All 3-axle or more vehicles	NA	NA	NA	NA	36.00	41.75	42.38	44.68	44.93	44.37	45.78	45.44
Average gross weight of vehicles (lbs.)	12,059	14,278	15,422	15,799	18,703	21,341	22,488	23,422	23,226	24,434	24,610	25,137

1/ Minor differences in totals due to irreconcileable discrepancies in original reports.

NA Not available

Table 7-26. -- Average gross weight by class of trucks and combinations, loaded and empty, on all main rural highways, 1937 - 1963

	1937	1942	1946	1949	1952	1955	1957	1959	1960	1961	1962	1963
Single-unit trucks												
2-axle	8,063	8,695	8,459	7,895	8,049	8,510	8,385	8,424	8,876	9,137	8,957	9,053
3-axle	18,728	20,050	23,614	21,514	26,567	27,296	28,357	29,310	27,062	29,258	27,463	28,647
Total	9,327	9,972	9,781	8,185	8,719	9,405	9,394	9,610	9,804	10,251	10,079	10,223
Tractor-semitrailer combination	25,665	27,158	29,635	32,932	35,480	37,944	39,873	40,683	39,984	41,730	41,737	42,377
Truck-trailer combination	21,311	35,487	40,236	48,571	50,934	47,518	50,611	50,544	50,240	54,618	44,374	39,983
Two-trailer combination	-	-	-	-	-	-	-	-	52,191	56,203	52,765	54,569
All combinations	25,607	27,326	30,021	33,815	35,978	38,296	40,234	40,999	40,463	42,266	42,069	42,620
All 3-axle or more vehicles	23,061	25,476	28,841	33,225	35,424	37,599	39,473	40,211	39,644	41,420	41,078	41,706
All vehicles	12,059	14,278	15,422	15,799	18,703	21,341	22,488	23,422	23,226	24,434	24,610	25,137

- Included in other combinations

Table 7-27. -- Percentage distribution of trucks and combinations by class on all main rural highways, 1937 to 1963.

	1937	1942	1946	1949	1952	1955	1957	1959	1960	1961	1962	1963
Single-unit trucks												
Panel and pickup					33.24	28.25	29.71	29.12	29.30	31.67	30.45	31.40
2-axle, 4-tire					4.00	3.97	3.74	3.94	3.76	3.48	3.84	4.18
Subtotal	NA	NA	NA	NA	37.24	32.22	33.45	33.06	33.06	35.15	34.29	35.58
2-axle, 6-tire					26.76	26.03	24.17	22.26	22.01	20.48	19.93	18.98
3-axle or more					1.97	2.43	2.64	3.19	3.48	3.60	3.13	3.45
Total	84.31	75.72	73.47	72.60	65.97	60.68	60.26	58.51	58.55	59.23	57.35	58.01
Tractor-semitrailer combination												
3-axle					17.59	16.88	12.02	10.21	9.39	7.18	7.09	6.26
4-axle	NA	NA	NA	NA	11.25	18.48	21.66	22.17	21.97	23.06	23.16	22.23
5-axle or more					3.06	2.51	4.57	6.38	7.28	8.04	9.48	10.70
Total	14.05	22.15	24.39	26.25	31.90	37.87	38.25	38.76	38.64	38.28	39.73	39.19
Truck-trailer combination												
4-axle or less					0.38	0.40	0.26	0.17	0.26	0.17	0.35	0.43
5-axle	NA	NA	NA	NA	1.60	0.77	0.87	1.29	1.19	1.06	1.13	0.99
6-axle or more					0.15	0.28	0.36	0.10	0.07	0.06	0.06	0.04
Total	1.64	2.13	2.14	1.15	2.13	1.45	1.49	1.56	1.52	1.29	1.54	1.46
Two-trailer combination												
5-axle or less	-	-	-	-	-	-	-	0.80	1.11	1.02	1.19	1.18
6-axle	-	-	-	-	-	-	-	0.30	0.12	0.11	0.11	0.11
7-axle or more	-	-	-	-	-	-	-	0.07	0.06	0.07	0.08	0.05
Total	-	-	-	-	-	-	-	1.17	1.29	1.20	1.38	1.34
Total combinations	15.69	24.28	26.53	27.40	34.03	39.32	39.74	41.49	41.45	40.77	42.65	41.99
All 3-axle or more vehicles					36.00	41.75	42.38	44.68	44.93	44.37	45.78	45.44
Total Trucks and Combinations	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

NA Not available
\- Included in other combinations

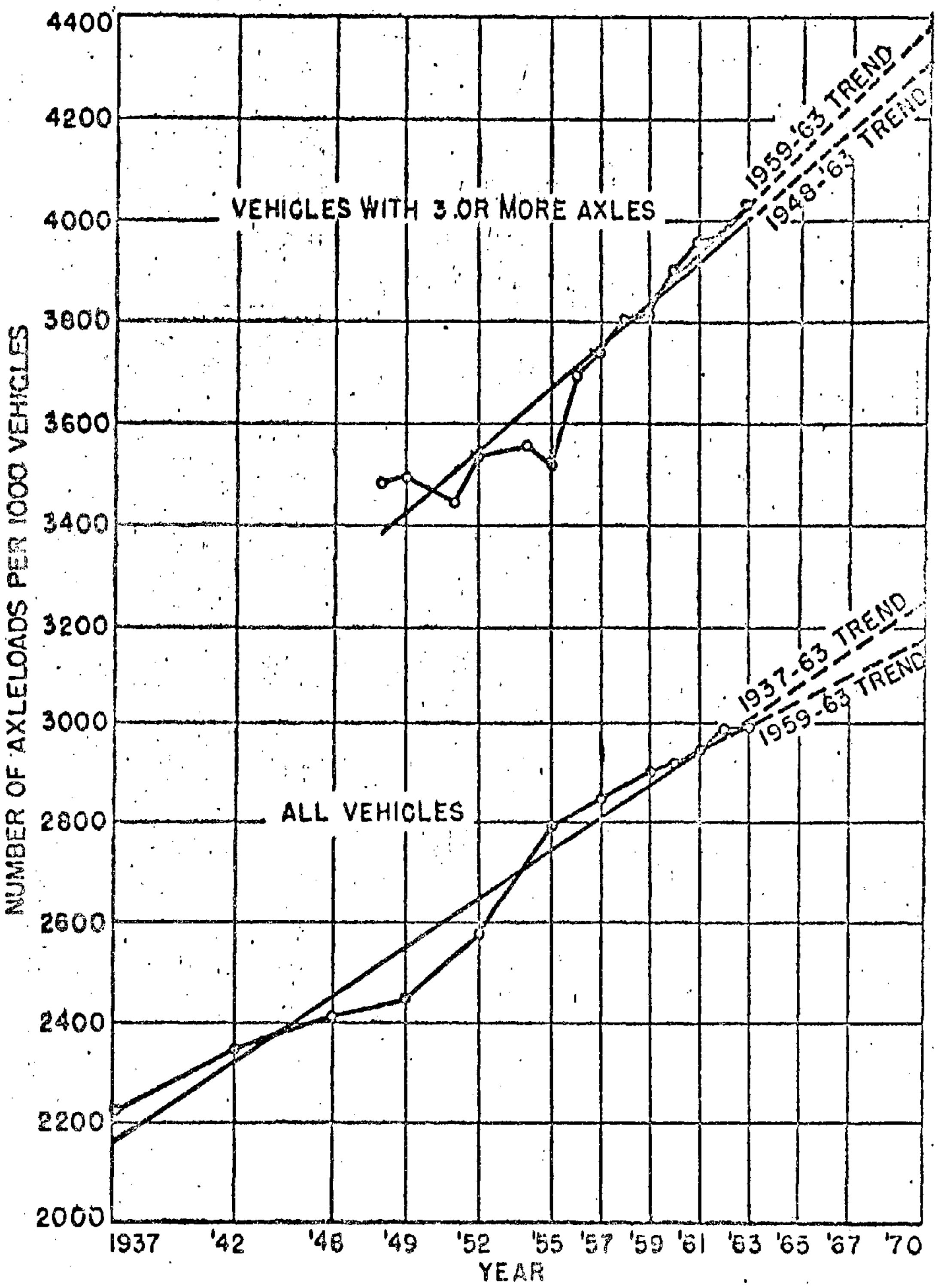

FIGURE 7-5.-TOTAL NUMBER OF AXLES PER 1,000 TRUCKS ON ALL MAIN RURAL HIGHWAYS; AVERAGE OF 20 STATES

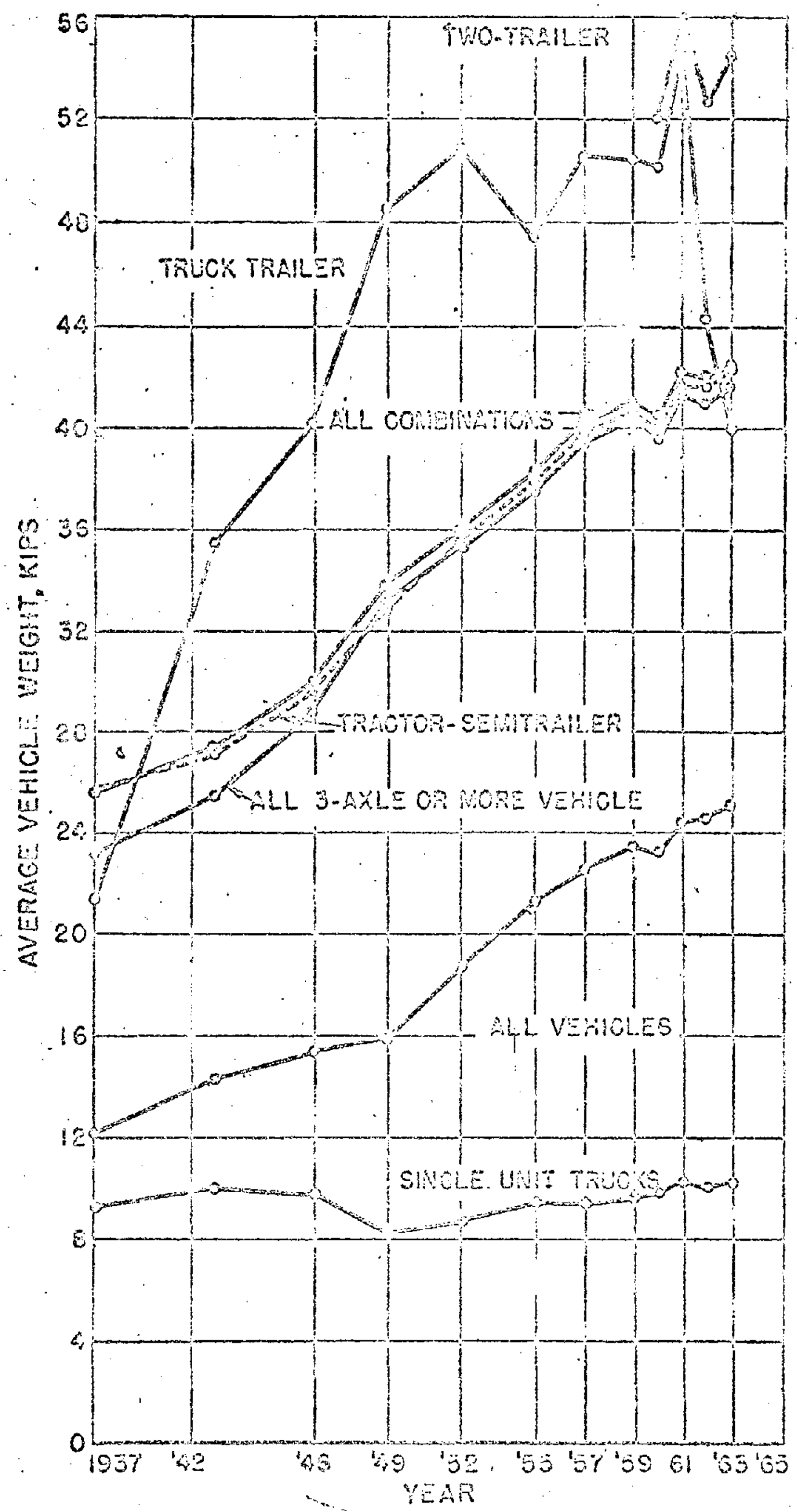

FIGURE 7-6.-AVERAGE GROSS WEIGHT OF 3A AND LARGER TRUCKS ON ALL MAIN RURAL HIGHWAYS; AVERAGE OF 20 STATES

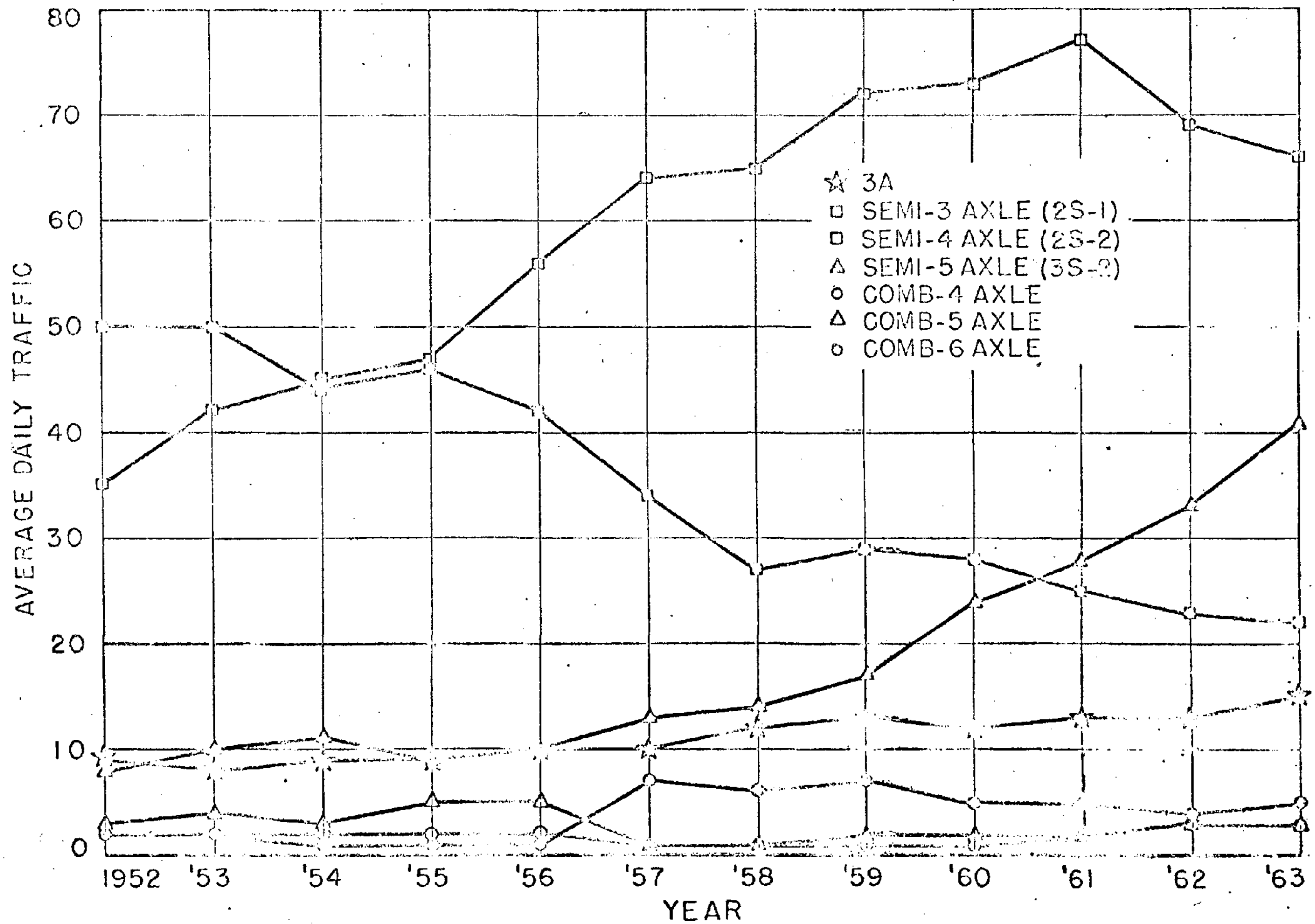

FIGURE 7-7.-AVERAGE DAILY TRAFFIC ON MAIN RURAL ROADS FOR 3A AND LARGER TRUCKS, 1952 TO 1963

3. On the basis of percentage of trucks on the highway, the single-unit truck is decreasing and the tractor-trailer combination is increasing.

4. Single-unit trucks as a percentage of the total number of trucks have decreased since 1937 from 84.31 percent to 58.01 percent in 1963.

5. The tractor-semitrailer combinations have increased in the truck ADT from 14.05 percent in 1937 to 39.19 percent in 1963.

6. From 1952 to 1963, the 2-S1 combination has decreased in average daily volume. The 2-S2 increased until 1961 but is now decreasing, while the 3-S2 began a rapid increase in 1937 which continued through 1963.

7. The average gross weight of trucks increased from 12,059 pounds in 1937 to 25,137 pounds in 1963.

CHAPTER 8

HIGHWAY COSTS

The dimensions and weights of motor vehicles are reflected both in the geometric and in the structural factors entering into the cost of constructing highways. Among the analyses necessary to arrive at the desirable limits of dimensions and weights of vehicles is one dealing with the effects on highway design, construction, maintenance, and operating requirements of the vehicle dimensions and weights considered. This chapter develops the highway construction and maintenance costs on a unit basis that can be applied to finding the highway costs that would be caused by any increase in the legal limits of vehicle dimensions and weights.

1. COST ELEMENTS OF THE HIGHWAY AFFECTED BY CHANGES IN VEHICLE DIMENSIONS AND WEIGHTS

A complete highway may be subdivided into a logical grouping of highway cost elements as follows:

(1) Planning and preliminary engineering
(2) Right-of-way
(3) Clearing of right-of-way (clearing and grubbing)
(4) Earthwork and small drainage facilities
(5) Paving, including subbase, base, wearing surface, and shoulders

(6) Waterway and grade-separation structures
(7) Other structures (retaining walls, riprap, etc.)
(8) Landscape and roadside rest areas
(9) Traffic control devices and signing
(10) Construction engineering

Of these ten items, the following are those that may be affected in an identifiable manner and amount by dimension and weight limitations on motor vehicles:

(1) Right-of-way
(2) Clearing of right-of-way (clearing and grubbing)
(3) Earthwork and small drainage facilities
(4) Paving, including subbase, base, wearing surface, and shoulders
(5) Waterway and grade-separation structures

Preliminary engineering and construction engineering are not considered to be affected by the dimensions and weights of vehicles, because the engineering and planning processes and the man-hours would be the same (at least, the difference could not be reliably measured) for two complete highways, one designed for slightly wider and longer vehicles and heavier axles than the other. The cost of constructing any miscellaneous structures would seem to be unaffected by the dimensions and weights of motor vehicles.

Costs of grade-separation structures, including retaining walls, would be affected by vehicle heights, especially if any major increase in height were considered. However, since this investigation found that the desirability of heights greater than 13.5 feet need not be considered (See p. 4-7.), it follows that there is no need to investigate the cost of grade-separation structures and their associated construction as affected by vehicle height. The costs of traffic control devices and signing are not sufficiently affected by the dimensions and weights of vehicles to warrant their consideration herein.

2. ANALYSIS OF THE RELATIONSHIP OF HIGHWAY CONSTRUCTION COST TO CHANGES IN VEHICLE DIMENSIONS AND WEIGHTS

The following discussion considers individually the factors of highway construction cost, setting forth the degree to which they might be affected by the changes in vehicle dimensions and weights adopted for analysis.

A. Right-of-Way and Clearing

The cost of rights-of-way is composed largely of three items: (1) legal and administrative costs, (2) costs of the land, and (3) costs of damages. Only the cost of the land could be affected by the dimensions of motor vehicles, and then only if the additional width or length of vehicle made necessary wider right-of-way than would otherwise be required. In the analysis discussed here, no such additional width of right-of-way is required.

Trucks in mixed traffic do utilize their share of the vehicular capacity of any roadway and therefore contribute to the need for more lanes when such a need comes about. On the other hand, the issue involved here is whether vehicles of greater dimension or weight would require wider rights-of-way.

Perhaps, in theory, wider vehicles would require wider rights-of-way, but as a practical matter, it is doubtful that any change to greater limits of dimensions and weights of vehicles made today would increase the future costs of rights-of-way.

B. Earthwork and Small Drainage Facilities

Were wider lane and shoulder widths required for wider vehicles, the cost of earthwork would be increased for both width of cut and width of fill. Present cross-section design geometrics will accommodate vehicles of 102-inch width, the maximum that seems to be either desirable or feasible. There is no need, therefore, to consider any increase in the cost of earthwork or of drainage facilities as a result of any increase in the width of vehicles. The length of vehicle does not affect the cost of earthwork.

The maximum height limit could affect the cost of excavation at grade separations by requiring either greater depth of excavation or height of fill. Since this analysis does not propose any increase in the 13.5-foot maximum height of vehicle, only the 5 States with a lower maximum height could be considered to be affected, and the design clearance in these States is probably at least 13.5 feet, since this is the direction in which legal limits are rapidly moving.

The cost of drainage facilities would not be affected by any changes in the height of vehicles.

C. Pavement Structure and Shoulders

The cost of pavement and shoulder structure would be affected by the axle weight of vehicles. As the axle weight increases, an increase is usually expected in the number of applications of E 18-kip axles (axle-weight applications equivalent to 18,000-pound single axles). At places along the length of a highway where the grade elevation of the pavement is controlled by factors not related to the depth of pavement structure or the balancing of cut and fill, the depth of excavation would have to be increased by an amount equal to the additional depth of pavement structure.

In the analyses where an increase in the depth of pavement structure results from an increase in dimensions or weights of vehicles, some increase in the depth of subgrade excavation is assured.

One-half of the distance of the construction is assumed to be cut and the other half fill. Therefore, the extra cost of earthwork attributable to an increase in axle weight is computed by applying the unit cost of excavation per cubic yard to the added depth for one-half the mileage of pavement structure for the full width of pavement plus shoulders.

The small drainage facilities are not considered to be affected by vehicle weight. Culverts conceivably would have to be designed for greater strength for wheel loads transmitted through the fill to the top of the culvert structure. The load distribution effected by the pavement structure and the depths of fill above culverts is such that few culverts would require additional strength above current designs. This factor, then, is considered to be small enough to be neglected.

D. Bridges, Tunnels, and Grade-Separation Structures

The construction cost of bridge structures and tunnels would be increased if an increase in maximum width of vehicles required greater horizontal clearances than are provided by current designs. An increase from 96 to 102 inches can be accommodated in current designs. (See Chapter 4.) Thus, additional bridge cost because of vehicle width is not involved in this analysis. Perhaps, in the long run, as truck and other vehicle traffic and its speed increase, the 102-inch width for vehicles will require greater bridge and tunnel width than is necessary for the 96-inch width. Also, it is possible that these structures for 102-inch vehicle width may impose some additional cost (interference) on the small vehicles.

The vehicle height of 13.5 feet is now the maximum limit in 44 States, 5 additional States having a higher maximum. This means that higher vehicles needing to be accommodated by an increase in vertical clearance of bridges and tunnels would be few and infrequent. Although the vehicle height may be limited to 12.5 feet in a certain State, the vertical clearance for design purposes is usually sufficient to pass a vehicle height of at least 13.5 feet.

Longer vehicles with normal axle spacing would be favorable to bridge design, since the axle loads would be less concentrated. But bridge structures would be affected by increased axle-weight limits. The cost of the increased structural strength required is estimated using the detailed design of bridges to arrive at the weight of steel required.

3. UNIT PRICES OF HIGHWAY COST ELEMENTS

Because the design of highways to accommodate increased dimensions and weights of vehicles would result in the addition of only small quantities of construction materials, the construction costs of such highways had to be estimated using unit prices of material rather than gross costs per mile in order to achieve the required accuracy.

A. Unit Cost of Unclassified Excavation

Table 8-1 lists the summary of cubic yards, unit price, and total cost of unclassified excavation in 1963 on Federal-aid projects on the Interstate and primary highway systems. There is wide variation from State to State in the price per cubic yard. Part of this variation is in the total aggregate cubic yards involved. Other factors, no doubt, are wage rates

Table 8-1.--Unclassified roadway excavation

Cost data based on 1963 bid prices on
Federal-aid projects on
Interstate and primary systems

Sheet 1 of 2

Census Division	Quantity	Price Per Cubic Yard	Total Cost	Weighted Average Price Per Cubic Yard
	Cubic Yards	Dollars	Dollars	Dollars
1. Connecticut	1,704,826	0.86	1,466,150	
Maine	35,410	3.05	108,000	
Massachusetts	1,679,029	0.60	1,007,417	
New Hampshire	293,190	0.51	149,526	
Rhode Island	13,462	4.10	55,194	
Vermont	206,761	1.12	231,572	
Total	3,932,678		3,017,859	0.767
2. New Jersey	2,902,203	1.48	4,295,260	
New York	18,733,140	1.14	21,355,779	
Pennsylvania	48,826,891	0.72	35,155,361	
Total	70,462,234		60,806,400	0.862
3. Delaware	42,000	1.60	67,200	
Maryland	9,875,544	0.68	6,715,369	
Virginia	29,056,638	0.67	19,467,947	
West Virginia	7,850,038	0.66	5,181,025	
Total	46,824,220		31,431,541	0.671
4. Florida	2,445,693	0.57	1,394,045	
Georgia	33,784,871	0.36	12,162,553	
North Carolina	16,604,843	0.37	6,143,791	
South Carolina	10,979,281	0.31	3,403,577	
Total	63,814,688		23,103,966	0.362
5. Illinois	4,276,660	0.92	3,934,527	
Indiana	473,649	0.74	350,500	
Michigan	2,251,317	0.30	675,395	
Ohio	38,207,645	0.58	22,160,434	
Wisconsin	9,379,111	0.38	3,564,062	
Total	54,588,382		30,684,918	0.562

- more -

Table 8-1.--Unclassified roadway excavation

Cost data based on 1963 bid prices on
Federal-aid projects on
Interstate and primary systems

Sheet 2 of 2

Census Division	Quantity	Price Per Cubic Yard	Total Cost	Weighted Average Price Per Cubic Yard
	Cubic Yards	Dollars	Dollars	Dollars
6. Iowa	7,278,310	0.53	3,857,504	
Kansas	3,401,656	0.32	1,088,529	
Minnesota	2,326,219	0.62	1,442,255	
Missouri	841,762	0.80	673,409	
Nebraska	11,751,947	0.25	2,937,986	
North Dakota	-	-	-	
South Dakota	23,730,224	0.36	8,542,880	
Total	49,330,118		18,542,563	0.375
7. Alabama	20,234,009	0.50	10,117,004	
Kentucky	3,817,807	0.89	3,397,848	
Mississippi	26,579,083	0.30	7,973,724	
Tennessee	43,536,088	0.42	18,285,156	
Total	94,166,987		39,773,732	0.422
8. Arkansas	9,163,518	0.52	4,765,029	
Louisiana	223,611	1.10	245,972	
Oklahoma	29,611,140	0.39	11,548,344	
Texas	27,772,653	0.51	14,164,053	
Total	66,770,922		30,723,398	0.460
9. Arizona	6,632,390	0.97	6,433,418	
Colorado	20,268,320	0.57	11,552,942	
Idaho	6,267,220	0.62	3,885,676	
Montana	17,356,756	0.46	7,984,107	
Nevada	1,080,450	0.44	475,398	
New Mexico	4,001,834	0.65	2,601,192	
Utah	14,985,510	0.68	10,190,146	
Wyoming	16,497,166	0.44	7,258,753	
Total	87,089,646		50,381,632	0.578
10. California	37,305,040	0.57	21,263,872	
Oregon	15,560,240	0.75	11,670,180	
Washington	804,030	1.27	1,021,118	
Total	53,669,310		33,955,170	0.632
National Weighted	590,649,185	———	322,421,179	
Price, 1963				0.545
1962	———	———	———	0.610

for labor and local prices. For the analyses of the added highway costs resulting from increased axle weights, the average weighted price per cubic yard for each census division was used, as shown in table 8-1.

B. Unit Prices for the Pavement Structure

The cost of pavement structure is analyzed on the basis of the unit price per cubic yard of the subbase, base, and wearing surface in place. Since the unit cost of each layer in place is affected by the depth (thickness), it is necessary to compile unit bid prices by depth.

For the purpose of this study, the construction bid prices for paving materials were assembled State by State and reduced to a uniform basis. Such factors as the dollar magnitude of the project, quality of material, relative geographical location of source of material and construction site, wage rates for labor, climate, and many other factors caused the bid prices per cubic yard in place to vary widely with depth of paving.

Four paving materials were chosen as representative of those in general use: (1) clay-gravel, (2) stone-macadam, (3) bituminous concrete, and (4) portland cement concrete. The procedure was to group, on a National basis, the many project bid price reports according to the depth of each material and then to compute the weighted bid price for each of the several depths. The final average bid prices were plotted against depth of material. These curves usually required some adjustment or smoothing and extension to produce a satisfactory curve for the required range of depth of paving material.

In each case there was a reduction in bid price per cubic yard as the depth of the structural layer of pavement increased. Such a reduction is to be expected, because such operations as moving in, preparing the subgrade, compacting, setting forms (with some exceptions), and final finishing of pavement surface are independent of depth of paving material. The final bid price per cubic yard in place (table 8-2) reflects this relationship between price and pavement depth.

The bid prices for paving material shown in table 8-2 are National averages. In order to convert these National bid prices to census-division prices, the factors in table 8-3 were applied. The census-division prices were determined by comparing unit prices of structural concrete, plain concrete, and paving materials from 1958 through 1963. These prices were grouped by States into census divisions. The final percentages of the National average bid prices given in table 8-3 for each census division are based upon 1962 and 1963 prices.

C. Unit Price of Structural Steel

The 1962 and 1963 State by State bid prices per pound of structural steel were averaged on a weighted basis to produce by census divisions the prices given in table 8-4.

Table 8-2.--Price of paving materials per cubic yard in place

Price is based upon average of bid prices for 1962 on Federal-Aid construction on a nationwide basis

Depth (thickness)	Clay-gravel	Stone-macadam	Bituminous concrete	Portland cement concrete
Inches	Dollars	Dollars	Dollars	Dollars
1	-	-	22.320	-
2	-	-	17.460	-
3	4.428	7.950	15.552	-
4	3.798	6.794	14.418	-
5	3.412	6.075	13.672	22.176
6	3.150	5.580	13.134	20.544
7	2.956	5.214	12.730	19.344
8	2.808	4.933	12.386	18.427
9	2.688	4.708	12.082	17.696
10	2.588	4.526	11.806	17.100
11	2.502	4.373	11.548	16.602
12	2.427	4.243	11.300	16.191
13	2.361	4.132	-	15.858
14	2.303	4.037	-	15.596
15	2.252	3.956	-	15.400
16	2.207	3.862	-	-
17	2.168	3.794	-	-
18	2.134	3.735	-	-
19	2.105	3.684	-	-
20	2.080	3.640	-	-
21	2.059	3.603	-	-
22	2.042	3.574	-	-
23	2.028	3.549	-	-
24	2.017	3.530	-	-
25	2.009	3.516	-	-

Table 8-3.--Ratio of average census division cost of paving materials to national average

Based upon average of 1962 and 1963 construction bid prices on Federal-aid projects

Census division	Clay-gravel	Stone macadam	Bituminous concrete	Portland cement concrete
	Percent	Percent	Percent	Percent
1. N.E.	66.21	124.92	101.27	113.22
2. M.A.	109.34	179.61	139.34	127.04
3. S.A.N.	154.35	150.17	105.03	105.22
4. S.A.S.	47.53	116.30	95.62	93.51
5. E.N.C.	120.83	88.02	110.16	98.46
6. W.N.C.	98.97	115.96	95.43	102.20
7. E.S.C.	149.87	112.73	99.99	100.28
8. W.S.C.	120.13	87.33	94.73	91.03
9. M.	74.71	53.39	93.81	98.77
10. P.	129.69	82.36	96.66	85.30

Table 8-4.--Average bid price per pound of structural steel, by census divisions

Prices are weighted averages for 1962 and 1963 Federal-aid construction on the Interstate and primary highways

Census division	Bid price per pound	Ratio to national average price
	dollars	percent
1. New England	0.1692	96.95
2. Middle Atlantic	.1837	105.32
3. South Atlantic (North)	.1686	96.69
4. South Atlantic (South)	.1396	80.06
5. East North Central	.1587	91.01
6. West North Central	.2022	115.92
7. East South Central	.1937	111.05
8. West South Central	.1603	91.89
9. Mountain	.2121	121.61
10. Pacific	.2404	137.75
National average	0.1753	100.00

Bid price data for bridge construction on the Interstate and primary systems were used.

4. CONSTRUCTION COST OF STRUCTURES

The cost of highway bridge construction per mile of highway is difficult to estimate. Unlike earthwork and pavement, bridges and other structures are not continuous in length with roadway mileage. Further, bridges vary widely in length, design, material, and in the number and total length per mile of roadway.

A. Inventory and Cost of Bridges per Highway Mile

Determining the extent to which the cost of constructing and maintaining bridges might be affected by increased maximum axle-weight limits divides itself into two particular problems: First, construction of new bridges on new highways must be considered and second, with respect to the existing highway systems, the cost of bridges at the increased axle-weight levels must be estimated on the basis that they would require either extra maintenance and strengthening or earlier replacement than would be true at current maximum axle-weight limits. Thus considered, determining the cost of bridges is complicated.

Bridge costs need to be reduced to the cost per roadway mile in order to be added to the cost of other roadway elements, such as paving and earthwork, that are easily expressed as a cost per mile of highway.

The first approach to the problem was to develop an inventory of the bridges now found on the highway systems.[1] Early efforts were somewhat fruitless, particularly in obtaining the information in the form necessary for reducing it to the number and length of bridges per highway mile.

Acceptable bridge inventory data were finally assembled by use of (1) a 10-percent sample of the defense bridge inventory; (2) a 100-percent sample from this inventory of the number and the total length of bridges and the length of highway on which these bridges existed; (3) the earlier bridge inventories in the 1930-1940 Statewide highway planning surveys; and (4) the final estimates of the cost of the Interstate system. Tables 8-5, 8-6, and 8-7 give the significant facts descriptive of the bridge inventory, including the basic information by which the number of bridges the number of feet of bridge length were obtained and related to miles of highway. They also give the construction cost of bridges on the exisitng system. The cost of the bridges, however, is not the original construction cost. It is based upon the approximate cost of bridge construction for the years 1960 to 1963 taken from Federal-aid projects and records.

1/ The basic data for this inventory were assembled by Charles W. Dale and Earle Newman.

Table 8-5. -- Number, length, and cost of bridges -- Interstate system

ITEM	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P	TOTAL
						RURAL					
1. Number of bridges per highway mile	1.534	1.638	1.759	1.560	1.712	1.256	1.595	1.684	1.161	1.555	1.483
2. Average length per bridge, feet	129	312	142	91	86	99	125	154	74	114	124
3. Feet of bridges per highway mile	198	511	250	142	147	124	199	259	86	177	184
4. Average cost per bridge, dollars	167,373	195,883	156,428	82,214	128,117	87,326	89,468	100,473	71,724	112,631	106,861
5. Cost of bridges per highway mile	256,750	320,856	275,157	128,254	219,336	109,681	142,701	169,197	83,272	175,141	158,475
6. Average cost per foot of length of bridge, dollars	1,297	628	1,101	903	1,492	885	717	653	968	989	861
						URBAN					
Number of bridges per highway mile	5.203	5.284	5.751	4.990	5.422	4.897	5.188	4.471	4.402	5.728	5.151
Average length per bridge, feet	42	75	84	31	30	32	44	52	26	35	48
Feet of bridges per highway mile	219	396	483	155	163	157	228	232	114	200	247
Average cost per bridge, dollars	360,689	418,745	343,359	98,910	271,768	202,308	224,089	143,531	94,894	269,900	250,678
Cost of bridges per highway mile	1,876,665	2,212,649	1,974,658	493,561	1,473,526	990,702	1,162,574	641,727	417,723	1,545,987	1,291,242
Average cost per foot of length of bridge, dollars	8,569	5,587	4,088	3,184	9,040	6,310	5,099	2,766	3,664	7,730	5,228

Source: Office of Engineering, Table 594a, "Cost and Number of all Structures on Rural Roads; table 594b, "Cost and Number of all Structures on Urban Roads," "Number and Cost of Structures Constructed on the Interstate System July 1, 1956 to December 31, 1963" (a series of nine tables); Table SS32-T1, "Status of Development on the Interstate System as of December 31, 1963 - Rural;" and Table SS32-T2, "Status of Development on the Interstate System as of December 31, 1963 - Urban."

Table 8-6.--Number, length, and cost of bridges--Federal-aid primary system

ITEM	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P	TOTAL
						RURAL					
1. Number of bridges per highway mile	0.378	0.253	0.317	0.293	0.230	0.281	0.374	0.417	0.259	0.251	0.295
2. Average length per bridge, feet	130	142	194	238	131	161	194	163	102	198	162
3. Feet of bridges per highway mile	49	36	61	70	30	45	73	68	26	50	48
4. Average cost per bridge, dollars	144,882	173,739	87,670	73,897	110,299	55,958	83,503	50,143	50,857	163,841	80,284
5. Cost of bridges per highway mile	54,765	43,955	27,791	21,651	25,368	15,724	31,230	20,909	13,172	41,024	23,683
6. Average cost per foot of length of bridge, dollars	1,145	1,223	452	310	842	348	430	308	499	827	496
						URBAN					
7. Number of bridges per highway mile	0.614	0.395	0.392	0.298	0.406	0.183	0.400	0.362	0.244	0.620	0.371
8. Average length per bridge, feet	243	246	377	401	229	258	259	274	141	336	275
9. Feet of bridges per highway mile	149	98	148	120	93	48	103	99	34	208	102
10. Average cost per bridge, dollars	296,179	436,544	311,434	363,428	337,288	194,750	107,335	148,814	150,010	419,251	278,500
11. Cost of bridges per highway mile	181,854	172,434	122,082	108,301	136,938	35,639	42,934	53,870	36,602	259,935	103,323
12. Average cost per foot of length of bridge, dollars	1,219	1,775	826	906	1,473	755	414	543	1,064	1,248	1,013

Sources: (a) Bridge records for 1963-1964. "Highway Defense Requirements" - Compiled in compliance with PPM 50-6.1.
(b) Tabulation No. 293 (Program Analysis Division, Office of Administration) entitled Bridges on Federal-Aid Highway Projects completed from January 1, 1960, through December 31, 1963.

Table 8-7.--Number, length, and cost of bridges--Federal-aid secondary system

ITEM	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P	TOTAL
						RURAL					
1. Number of bridges per highway mile	0.250	0.226	0.150	0.268	0.178	0.189	0.380	0.333	0.170	0.147	0.227
2. Average length per bridge, feet	50	68	91	137	75	98	132	116	81	117	101
3. Feet of bridges per highway mile	13	15	14	37	13	19	50	39	14	17	23
4. Average cost per bridge, dollars	79,785	67,953	42,454	17,690	32,941	23,246	30,757	19,196	38,022	50,873	24,804
5. Cost of bridges per highway mile	19,946	15,357	6,368	4,741	5,863	4,393	11,687	6,392	6,464	7,478	5,631
6. Average cost per foot of length of bridge, dollars	1,596	999	467	129	439	237	233	165	469	435	246
						URBAN					
7. Number of bridges per highway mile	0.406	0.353	0.186	0.271	0.314	0.124	0.406	0.290	0.161	0.364	0.286
8. Average length per bridge, feet	93	117	176	229	131	158	177	193	111	200	171
9. Feet of bridges per highway mile	378	413	327	621	411	196	719	560	179	728	489
10. Average cost per bridge, dollars	168,032	171,500	152,127	87,003	100,470	81,072	39,264	32,443	113,040	130,574	86,415
11. Cost of bridges per highway mile	68,221	60,540	28,296	23,578	31,548	10,052	15,941	9,408	18,199	47,529	24,715
12. Average cost per foot of length of bridge, dollars	1,807	1,466	864	380	767	513	222	168	1,018	653	505

Sources: (a) Calculated from State Highway Surveys, 1935-1940 (State System of Highways) and Bridge Records for 1963-1964, "Highway Defense Requirements" Compiled in compliance with PPM 50-5.1.

(b) Tabulation No. 293 (Program Analysis Division, Office of Administration) entitled Bridges on Federal-Aid Highway Projects Completed from January 1, 1960 through December 31, 1963.

Note: Source information was for the combined rural-urban system. The above split is based upon the rural-urban ratio on the primary system.

B. Percentage of Bridges by Span Length

The original inventory of bridges in the 10-percent sample of the defense highway routes gave the number of bridges by span length by 10-foot intervals, beginning at 29 feet and under and ending at 140 feet and over. These data by highway system and census division give much evidence of inconsistencies attributable to the small sample.

In order to produce a more realistic distribution of the length of span, summation curves by percentage were plotted for each census division and highway system. These plotted points were smoothed on the basis of judgment. Final readings from these smooth curves are given in table 8-8.

5. COSTS PER HIGHWAY MILE, TOTAL CONSTRUCTION AND RECONSTRUCTION

Whereas the foregoing unit prices and unit costs of highways were assembled primarily for use in estimating the cost of paving, shoulders, and bridges under designs for five levels of maximum axle-weight limits, overall highway reconstruction and resurfacing costs are necessary for estimates of earthwork costs and for the overall costs of reconstructing existing highways, including such resurfacing as may be required over time under use at each of the five levels of axle-weight limit. By reference to bid prices on Federal-aid construction projects for 1963 and 1964, table

Table 8-8.--Percentage distribution of the span length of bridges by highway system and census division

Page 1 of 5

Span length, feet	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P
1. Interstate Rural										
15-25	7.9	8.0	8.0	11.8	4.4	8.0	4.4	25.5	21.8	3.0
25-35	8.5	10.1	10.1	8.1	11.9	17.8	4.7	30.6	22.6	7.4
35-45	10.8	14.1	14.1	25.3	19.5	16.0	7.3	15.7	18.0	18.2
45-55	12.7	17.8	17.8	31.0	20.2	14.9	11.1	8.7	13.1	17.8
55-65	13.9	16.5	16.5	11.1	15.2	12.5	15.8	5.8	8.6	12.6
65-75	14.2	9.1	9.1	6.3	10.1	10.6	15.1	3.5	5.5	10.2
75-85	10.8	6.2	6.2	3.1	5.8	7.4	12.6	2.4	3.5	8.1
85-95	7.6	4.2	4.2	1.5	2.9	4.9	9.7	1.6	2.4	6.5
95-105	5.0	3.1	3.1	1.0	1.9	2.5	6.8	1.3	1.5	5.0
105-115	2.7	2.8	2.8	.6	1.4	1.8	4.7	1.1	1.0	3.5
115-125	1.7	1.8	1.8	.2	1.2	.6	2.8	.8	.9	2.1
125-135	1.3	1.1	1.1	.0	.9	.6	1.7	1.0	.5	1.1
135-145	1.1	.9	.9	.0	1.0	.9	.9	.3	.3	.1
Over 145	1.8	4.3	4.3	.0	3.6	1.5	2.4	1.4	.3	4.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2. Interstate Urban										
15-25	5.2	5.4	4.1	8.2	-	3.5	5.4	16.4	16.2	3.0
25-35	7.7	4.3	5.0	1.0	4.0	8.7	8.4	14.6	11.3	11.4
35-45	10.1	6.5	2.9	27.2	9.4	2.4	14.2	14.7	19.9	17.9
45-55	12.8	9.6	16.2	24.4	14.0	26.1	16.5	14.2	16.9	19.4
55-65	14.2	13.3	14.5	20.9	17.1	18.7	12.2	12.6	12.4	17.0

Table 8-8.--Percentage distribution of the span length of bridges bridges by highway system and census division

Span length, feet	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P
2. Interstate Urban Cont.										
65-75	19.3	16.4	17.3	7.9	21.0	15.2	10.8	10.9	7.2	14.8
75-85	5.8	17.4	18.5	5.1	14.9	10.0	9.3	6.1	4.6	7.3
85-95	7.2	10.7	10.2	2.9	4.8	6.6	7.5	3.6	2.8	4.2
95-105	4.7	5.5	4.3	1.9	4.4	3.4	5.3	2.4	1.7	1.5
105-115	3.1	2.8	2.7	.3	3.2	1.8	3.4	1.5	1.1	.8
115-125	2.4	1.8	1.8	.2	2.2	.6	2.1	1.1	.8	.3
125-135	1.7	1.1	.6	.0	1.4	.6	1.4	.5	.6	.1
135-145	1.6	.9	1.2	.0	1.2	.9	.8	.2	.5	.2
Over 145	4.2	4.3	.7	.0	2.4	1.5	2.7	1.2	4.0	2.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3. Primary Rural										
15-25	11.8	24.6	16.1	48.8	13.0	19.2	43.7	49.5	46.5	19.4
25-35	20.9	14.4	17.7	19.0	20.1	30.1	16.5	24.6	21.1	13.9
35-45	15.0	12.8	15.8	9.4	18.5	17.4	12.9	10.5	11.3	13.1
45-55	13.4	10.5	12.6	7.4	15.0	10.9	8.3	4.5	6.9	11.6
55-65	10.9	8.2	9.3	4.8	10.9	6.4	5.4	2.9	4.4	9.8
65-75	8.2	5.6	6.7	2.3	7.4	3.7	3.5	2.1	2.9	7.4
75-85	5.5	4.2	4.8	1.5	4.6	2.9	2.3	1.3	2.4	5.2
85-95	3.5	3.3	3.4	.9	2.2	2.7	1.8	1.0	.7	3.5
95-105	2.8	2.8	2.7	.9	1.8	1.8	1.1	.9	.4	2.5
105-115	2.1	2.6	2.3	.7	1.5	1.2	.9	.4	1.2	2.0

Table 8-8.--Percentage distribution of the span length of bridges by highway system and census division

Span length, feet	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P
3. Primary Rural Cont.										
115-125	1.7	2.1	1.9	.7	1.1	.7	.6	.3	.2	1.6
125-135	1.4	2.1	1.7	.6	.9	.4	.5	.0	.2	1.3
135-145	1.0	1.9	1.5	.5	.1	.4	.5	.1	.2	1.0
Over 145	1.8	4.9	3.5	2.5	2.9	2.2	2.0	1.9	1.6	7.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4. Primary Urban										
15-25	26.2	20.1	7.6	26.7	2.6	25.0	43.7	23.4	28.3	15.8
25-35	15.1	12.9	15.2	28.5	8.9	16.2	16.5	17.6	20.5	8.2
35-45	12.4	12.7	14.6	17.1	12.1	13.6	12.9	15.5	16.2	15.9
45-55	9.7	11.6	13.3	8.3	18.8	10.4	8.3	12.5	11.9	12.3
55-65	7.7	10.1	11.5	5.5	20.1	7.0	5.4	9.3	7.6	8.4
65-75	6.1	8.2	8.1	4.2	13.7	5.0	3.5	6.1	5.1	5.8
75-85	5.0	6.2	5.7	2.8	7.8	3.8	2.3	4.4	3.3	4.1
85-95	3.9	4.2	4.4	2.5	4.1	3.0	1.8	3.4	2.1	3.1
95-105	3.3	3.4	3.7	1.5	3.2	2.8	1.1	2.5	1.3	2.6
105-115	2.6	2.5	3.1	.7	2.8	2.2	.9	1.5	.7	2.2
115-125	2.1	1.8	2.8	.8	2.3	2.2	.6	.8	.6	2.0
125-135	1.8	1.1	2.7	.4	1.5	2.0	.5	.4	.1	6.7
135-145	1.5	.9	2.4	.0	.7	2.0	.5	.1	.3	1.7
Over 145	2.6	4.3	4.9	1.0	1.4	4.8	2.0	2.5	2.0	11.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 8-8.--Percentage distribution of the span length of bridges by highway system and census division

Span length, feet	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P
5 and 7. Secondary Rural										
15-25	19.0	22.6	12.1	27.4	7.9	45.1	22.8	64.0	69.0	35.6
25-35	17.2	14.3	15.3	21.2	14.4	19.9	29.5	18.8	3.1	16.1
35-45	13.4	12.7	14.5	17.2	21.9	10.3	13.6	7.7	17.3	13.9
45-55	10.4	10.7	12.7	10.5	18.3	8.1	8.0	2.6	2.9	11.9
55-65	8.3	8.2	15.2	5.2	12.1	3.8	5.1	1.9	1.8	6.9
65-75	6.6	5.5	2.8	3.4	7.1	3.3	3.5	1.3	.9	4.6
75-85	5.3	4.1	5.6	2.3	4.3	2.3	2.9	.8	.8	2.8
85-95	4.3	3.3	4.1	1.8	3.0	1.7	2.1	.7	.7	1.7
95-105	3.4	3.0	3.3	1.6	2.0	1.4	1.9	.6	1.0	1.0
105-115	2.7	2.7	2.9	1.3	1.4	1.0	1.5	.4	.4	.5
115-125	2.2	2.5	2.4	1.3	1.1	1.0	1.4	.2	.4	.4
125-135	1.7	2.3	2.4	1.0	.9	.8	1.3	.1	.5	.2
135-145	1.3	2.3	2.1	1.0	1.1	.8	1.3	.4	.3	.2
Over 145	4.2	6.0	4.6	4.8	4.5	.5	5.1	.5	.9	4.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6 and 8. Secondary Urban										
15-25	27.9	31.4	12.3	15.4	1.9	15.8	27.5	25.8	34.9	3.1
25-35	18.1	18.2	16.4	31.3	12.7	22.8	33.0	16.6	22.9	22.4
35-45	13.8	14.3	15.5	22.1	20.4	23.6	14.9	15.2	15.9	19.5
45-55	9.6	10.1	13.7	14.6	20.5	11.0	8.4	12.2	9.7	15.0
55-65	6.8	6.6	11.3	6.4	15.9	6.4	5.4	10.2	6.0	10.7

Table 8-8.--Percentage distribution of the span length of bridges by highway system and census division

Span length, feet	1. NE	2. MA	3. SAN	4. SAS	5. ENC	6. WNC	7. ESC	8. WSC	9. M	10. P
6 and 8. Secondary Urban Cont.										
65-75	5.2	4.4	7.4	2.9	10.2	4.2	3.4	6.9	3.6	6.8
75-85	4.4	3.1	5.1	2.0	6.9	3.3	2.3	4.4	2.2	4.7
85-95	3.4	2.3	3.7	1.4	3.1	2.4	1.5	3.1	1.3	2.9
95-105	2.8	1.6	2.9	1.1	2.5	1.9	1.0	2.1	1.0	2.0
105-115	2.1	1.4	2.3	.6	2.5	1.6	.7	1.2	.4	1.4
115-125	1.7	1.1	1.9	.7	1.2	1.5	.4	.6	.4	1.0
125-135	1.4	1.1	1.8	.4	.9	1.3	.3	.2	.5	.6
135-145	1.0	1.4	1.7	.3	.5	1.7	.2	.0	.3	.5
Over 145	1.8	3.0	4.0	.8	.8	2.5	1.0	1.5	.9	9.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

8-9 was prepared to show the average construction cost of earthwork and small drainage structures by highway system and census division.

For general estimates of the cost of reconstructing existing highways as determined to be necessary in the future, table 8-10 may be used. Table 8-11 is for use in estimating the cost of resurfacing pavement and shoulders with bituminous concrete as determined to be necessary for restoring the pavement to an acceptable surface smoothness.

6. COST OF MAINTAINING THE HIGHWAY

The annual economic cost of a highway is composed of two primary elements: (1) the annual capital cost as measured from construction cost investment and (2) the annual expense of maintaining the physical highway in a condition suitable for satisfactory service to traffic. The maintenance operations are examined to see which ones may be affected and to what extent they may be affected by changes in the maximum limits of vehicle dimensions and weights.

A. Classification of Maintenance Costs

The cost of labor, materials, and equipment in maintaining the complete highway in a state suitable for traffic operations may be classified under the following six items:

Table 8-9.--Estimated cost of grading and small drainage structures per mile for Federal-aid primary and Interstate projects (Based on 1963 bid prices)

Census division	Total cubic yards	Total cost	Weighted average cost per yard	Secondary 2-lane		Primary 2-lane		Primary 4-lane		Interstate 4-lane	
				Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
1. NE	3,932,678	$ 3,017,859	0.767	$46,160	$66,144	$72,618	$123,845	$137,918	$287,096	$256,698	$664,264
2. MA	70,462,234	60,806,400	0.862	51,877	74,337	81,612	139,184	155,001	322,656	288,492	746,539
3. SAN	46,824,220	31,431,541	0.671	40,382	57,865	63,528	108,344	120,656	251,162	224,568	581,122
4. SAS	63,814,688	23,103,966	0.362	21,786	31,218	34,273	58,451	65,093	135,500	121,153	313,511
5. ENC	54,588,382	30,684,918	0.562	33,822	48,465	53,209	90,744	101,056	210,362	188,089	486,722
6. WNC	49,330,118	18,542,563	0.375	22,568	32,339	35,504	60,550	67,431	140,366	125,504	324,770
7. ESC	94,166,987	39,773,732	0.422	25,397	36,392	39,954	68,139	75,882	157,959	141,234	365,475
8. WSC	66,770,922	30,723,398	0.460	27,684	39,669	43,551	74,274	82,715	172,183	153,951	398,385
9. M	87,089,646	50,381,632	0.578	34,785	49,845	54,723	93,327	103,933	216,351	193,443	500,579
10. P	53,669,310	33,955,170	0.632	38,035	54,502	59,836	102,047	113,643	236,564	211,516	547,346
National	590,649,185	322,421,179	0.545	$32,800	$47,000	$51,600	$88,000	$98,000	$204,000	$182,400	$472,000

Table 8-10. -- Cost of complete new highway, construction or reconstruction, in dollars per mile, by highway system and census division (Based on Federal-aid projects for 1963 and 1964)

Highway system and census division	Engineering	Right-of-way	Earthwork, small drainage	Structures	Pavement costs		Total costs	
					Rigid	Flexible	Rigid	Flexible
1. Interstate rural								
1. NE	86,389	116,987	256,698	272,134	205,673	176,893	937,881	909,101
2. MA	113,944	154,302	288,492	363,916	257,018	249,575	1,177,672	1,170,229
3. SAN	147,827	200,186	224,568	290,639	233,639	254,570	1,096,859	1,117,790
4. SAS	52,315	70,845	121,153	134,860	212,411	128,434	591,584	507,607
5. ENC	76,671	103,827	188,089	225,736	223,272	194,143	817,595	788,466
6. WNC	51,411	69,621	125,504	115,857	218,380	153,142	580,773	515,535
7. ESC	59,407	80,448	141,234	154,266	229,217	204,122	664,572	639,477
8. WSC	64,119	86,830	153,951	175,403	195,950	179,025	676,253	659,328
9. M	49,294	66,754	193,443	86,603	156,427	91,994	552,521	488,088
10. P	68,079	92,192	211,516	186,928	198,987	159,756	757,702	718,471
2. Interstate urban								
1. NE	320,070	997,356	664,264	1,895,066	208,690	180,129	4,085,446	4,056,885
2. MA	590,662	1,840,532	746,539	2,247,594	260,455	254,678	5,685,782	5,680,005
3. SAN	433,368	1,350,396	581,122	2,007,453	230,217	251,906	4,602,556	4,624,245
4. SAS	179,028	557,860	313,511	501,801	214,817	130,234	1,767,017	1,682,434
5. ENC	340,043	1,059,592	486,722	1,481,890	221,510	194,220	3,589,757	3,562,467
6. WNC	187,135	583,123	324,770	1,001,001	220,648	156,144	2,316,677	2,252,173
7. ESC	218,661	681,360	365,475	1,174,574	246,214	225,411	2,686,284	2,665,481
8. WSC	199,334	621,134	398,885	650,445	190,530	174,394	2,060,328	2,044,192
9. M	163,159	508,412	500,579	423,322	169,990	99,956	1,765,462	1,695,428
10. P	355,210	1,106,853	547,346	1,559,994	201,896	160,893	3,771,299	3,730,296

Table 8-10. -- Cost of complete new highway, construction or reconstruction, in dollars per mile, by highway system and census division (Based on Federal-aid projects for 1963 and 1964)

Highway system and census division	Engineering	Right of-way	Earth work, small drainage	Structures	Pavement costs		Total costs	
					Rigid	Flexible	Rigid	Flexible
3. Primary rural								
1. NE	47,000	61,472	137,918	57,948	186,266	160,239	490,604	464,577
2. MA	52,643	68,854	155,001	46,234	226,783	216,478	549,515	539,210
3. SAN	43,852	57,356	120,656	30,777	205,109	215,898	457,750	468,539
4. SAS	35,005	45,784	65,093	23,332	196,185	118,537	365,399	287,751
5. ENC	39,556	51,737	101,056	26,414	194,146	163,054	412,909	381,817
6. WNC	19,407	25,384	35,504	16,485	105,806	75,314	202,586	172,094
7. ESC	22,797	29,817	39,954	32,169	113,232	99,975	237,969	224,712
8. WSC	19,386	25,356	43,551	21,432	92,640	84,615	202,365	194,340
9. M	17,256	22,570	54,723	13,488	72,092	45,801	180,129	153,838
10. P	33,982	44,446	59,836	43,658	172,797	131,530	354,719	313,452
4. Primary urban								
1. NE	86,006	193,324	287,096	190,250	190,530	162,160	947,206	918,836
2. MA	93,936	211,150	322,656	179,210	227,591	217,910	1,034,543	1,024,862
3. SAN	76,025	170,889	251,162	130,440	208,767	223,839	837,283	852,355
4. SAS	57,078	128,301	135,500	111,801	195,941	118,064	628,621	550,744
5. ENC	70,624	158,750	210,362	141,507	196,563	165,764	777,806	747,007
6. WNC	26,782	60,201	60,550	36,549	110,578	79,173	294,660	263,255
7. ESC	29,902	67,215	68,139	44,259	119,811	108,341	329,326	317,856
8. WSC	28,789	64,712	74,274	55,410	93,878	86,462	317,063	309,647
9. M	27,409	61,611	93,327	37,214	82,306	50,388	301,867	269,949
10. P	72,442	162,836	102,047	271,490	189,010	148,722	797,825	757,537

Table 8-10. -- Cost of complete new highway, construction or reconstruction, in dollars per mile, by highway system and census division (Based on Federal-aid projects for 1963 and 1964)

Sheet 3 of 3

Highway system and census division	Engineering	Right of-way	Earth-work, small drainage	Structures	Pavement costs		Total costs	
					Rigid	Flexible	Rigid	Flexible
. Secondary rural								
1. NE	17,475	11,979	46,160	20,338	83,651	73,756	179,603	169,708
2. MA	19,122	13,108	51,887	15,845	96,568	92,593	196,530	192,555
3. SAN	15,556	10,664	40,382	6,745	86,534	88,250	159,881	161,597
4. SAS	13,099	8,980	21,786	5,326	85,442	52,747	134,633	101,938
5. ENC	14,690	10,070	33,822	6,115	86,283	71,316	150,980	136,013
6. WNC	13,870	9,508	22,568	4,626	91,980	64,399	142,552	114,971
7. ESC	15,503	10,627	25,397	12,463	95,347	80,071	159,337	144,061
8. WSC	12,978	8,896	27,684	6,606	77,220	67,102	133,384	123,266
9. M	12,347	8,464	34,785	6,568	64,733	41,937	126,897	104,101
10. P	14,159	9,706	38,035	7,809	75,811	55,996	145,520	125,705
. Secondary urban								
1. NE	4,201	9,820	66,144	78,129	85,982	76,241	244,276	234,535
2. MA	4,510	10,542	74,337	71,782	101,087	98,107	262,258	259,278
3. SAN	3,486	8,148	57,865	36,961	96,244	101,529	202,704	207,989
4. SAS	2,870	6,708	31,218	33,817	92,264	56,066	166,877	130,679
5. ENC	3,240	7,574	48,465	40,589	88,544	73,213	188,412	173,081
6. WNC	2,475	5,785	32,339	13,639	89,682	62,228	143,920	116,466
7. ESC	5,569	13,017	36,392	25,662	99,700	84,550	180,340	165,190
8. WSC	2,496	5,834	39,669	18,090	79,044	68,918	145,133	135,007
9. M	2,603	6,084	49,845	20,879	71,942	42,410	151,353	121,821
10. P	3,803	8,890	54,502	68,593	85,361	66,073	221,149	201,861

Table 8-11. -- Cost of bituminous-concrete resurfacing per highway mile on portland-cement-concrete and bituminous-concrete old surface

Census division	Census-division cost index	Interstate or primary		Primary		Secondary		
		Lanes 48 ft. shoulders 28 ft.		Lanes 24 ft. shoulders 20 ft.		Lanes 24 ft. shoulders 16 ft.		
		76 ft. resurfaced-width		44 ft. resurfaced-width		40 ft. resurfaced-width		
		3-in. depth	1½ in. depth	3 in. depth	1½ in. depth	3 in. depth	2 in. depth	1½ in. depth
	%							
1. NE	101.27	$58,517	$37,420	$33,878	$21,663	$30,798	$23,051	$19,694
2. MA	139.34	80,516	51,487	46,613	29,807	42,376	31,716	27,097
3. SAN	105.03	60,690	38,809	35,135	22,468	31,941	23,907	20,425
4. SAS	95.62	55,253	35,332	31,987	20,455	29,080	21,765	18,595
5. ENC	110.16	63,655	40,705	36,852	23,565	33,502	25,074	21,423
6. WNC	95.43	55,143	35,262	31,924	20,414	29,022	21,721	18,558
7. ESC	99.99	57,778	36,947	33,449	21,390	30,409	22,760	19,445
8. WSC	94.73	54,738	35,003	31,690	20,264	28,809	21,562	18,422
9. M	93.81	54,207	34,663	31,382	20,067	28,529	21,353	18,243
10. P	96.66	55,854	35,716	32,335	20,667	29,396	22,001	18,797
National average	100.00	$57,784	$36,951	$33,453	$21,392	$30,412	$22,762	$19,447

Note: On old PCC pavement, bituminous concrete should be 3 inches in depth, except on low ADT Secondary where 2 inches may be used. All resurfacing of old bituminous concrete could be 1½ inches in depth.

(1) Roadside and drainage
(2) Roadway surface and base
(3) Shoulders
(4) Structures
(5) Traffic services
(6) Snow, ice, and sand control.

Of these six basic operations only three--surface and base, shoulders, and structures--would be significantly affected by vehicle dimensions and weights. Roadside and drainage; traffic services; snow, ice, and sand control would not be affected by vehicular dimension and weight, because these items are more or less unaffected by specific vehicles in the traffic stream. Should an increase in dimensions and weights of vehicles be permitted legally, the total number of vehicles on the highway hauling a given number of total tons of payload or cargo would be reduced. From this viewpoint, to the extent that any one of the six elements of maintenance would be affected by the volume of traffic, some reduction in highway maintenance cost should result. On the other hand, considering axle weight, some probable increase in maintenance cost would occur, should the vehicles be permitted to load to heavier axle weights.

B. Roadway Maintenance Cost Resulting from Increased Vehicle Weight

In the patching of pavement, the roadway shoulders and the main pavement and its base would be subjected to some increased maintenance cost with increased weight of axles.

The general cost of maintaining the surface and base would probably not increase so far as normal operations of cleaning, crack filling, and surface treatments are concerned. However, patching cost because of any failure of the pavement base or subgrade would be increased to the extent that the pavement surface and its base are thicker in order to carry increased axle weights. For this reason, a slight increase in maintenance cost has been charged to maintenance of the shoulders and the pavement surface for each increment of increased vehicle axle-weight limits. No allowance is made for extra maintenance cost due to changes in dimensions of the vehicle.

It is probable that, under legal provisions for increasing the weight of vehicles, the maintenance cost of patching and general pavement repair of existing highway systems would be increased somewhat until such pavements could be reconstructed to the structural design indicated for use of the heavier axle weights. For this reason, when the financing of existing highway systems over the 20-year analysis period is considered, part of any increase in maintenance costs would be chargeable to increase in the legal weight of vehicles. The increase in maintenance cost would result from increased pavement and shoulder wear and tear pending the time when the highway department would resurface the entire section of highway up to the structural requirements indicated by the legally allowable weights of vehicles.

The general assumption is made that design and construction of pavements for increased weights of axles would be on the basis that the resulting maintenance requirements would be relatively no greater for such pavement than they would be for pavement designed for a lower axle-weight limit and used by traffic not exceeding that design limit.

C. Bridge Maintenance Cost Resulting from Increase in Vehicle Weight

New bridges constructed under designs for accommodating the increased dimensions and weights of vehicles would probably cost somewhat more to maintain for two basic reasons: First, when an increase is necessary in vertical clearance, such an increase would require adding some additional height to abutments and piers on overhead structures, thus presenting a greater surface area to be inspected and maintained. Secondly, bridges designed for higher axle weights would have a greater surface of steel or concrete to be maintained because of the increased total pounds of steel or cubic yards of concrete required for the structure as a whole. For these reasons, some increased cost for maintaining bridges has been allowed in the analysis for each increment of increased axle weight considered.

The bridges on the existing highway system would not suffer any increased maintenance cost pending the time that they were reconstructed to design loads permitting the new legal limits, because the extra quantities of steel and concrete would not be included in the bridge, and the traffic itself would not cause the bridge to suffer any more rapid deterioration from weathering and other elements than would be true if the traffic were not operating at the higher weight limits. This assumes, however, that if the bridge becomes structurally weakened to the extent that it is unsafe, it would be strengthened or replaced as the occasion demanded.

D. Overall Average Cost of Highway Maintenance

No reliable authentic information is available in the literature to disclose the cost of maintaining the highways as it may be affected by the dimensions or the weights of the vehicles operating on these highways. Neither is there readily available the maintenance cost of the pavement and base with particular reference to patching, the only element of the roadway maintenance cost which could be related to the weight of the vehicle.

Table 8-12 shows the maintenance cost per roadway mile for the several systems and for the six maintenance cost operations.[1/] These figures are only general guides to the maintenance costs because of the lack of satisfactory reports giving the true costs.

1/ Taken from table 49, page 237, "Supplementary Report of the Highway Cost Allocation Study" (Section 210 Study). July 1964.

Table 8-12,--Incremental study of maintenance costs: Estimated 1964 Costs for the Federal-Aid Systems in the 48 Contiguous States and the District of Columbia

Federal-aid highway systems	System mileage 1961	Maintenance operations: Roadside and drainage	Surface and base	Shoulders	Structures	Traffic services	Snow, Ice and land control	Total
		dollars/mile	dollars/mile	dollars/mile	dollars/mile	dollars/mile	dollars/mile	dollars/mile
Interstate:								
Rural	34,513	644	1,046	352	179	487	525	3,233
Urban	6,400	1,570	1,601	564	527	1,295	1,120	6,677
Total	40,913	789	1,132	386	233	613	619	3,772
Federal-aid primary:								
Rural	143,800	446	823	271	121	291	406	2,358
Urban	16,083	794	1,228	420	386	796	860	4,484
Total	159,883	481	864	286	147	342	452	2,572
Federal-aid secondary:								
Rural	589,679	129	398	79	49	73	122	850
Urban	14,978	324	648	199	118	298	392	1,979
Total	604,657	134	405	82	50	78	129	878
All systems:								
Rural	767,992	212	507	127	68	132	193	1,239
Urban	37,461	739	1,060	356	303	682	717	3,857
Total	805,453	236	533	137	79	158	218	1,361

Source: Table 49, Supplementary Report of the Highway Cost Allocation Study, July 1964.

CHAPTER 9

LINE-HAUL TRUCKING COSTS IN RELATION TO VEHICLE WEIGHTS

Many business concerns operating motor trucks on the public highways keep records of their cost of transportation and, to a certain extent, the cost of operating individual vehicles or classes of vehicles. The motor carriers operating under a certificate of the Interstate Commerce Commission or a State regulatory commission report their cost of transportation operations. Such reports, however, generally do not specify the type of vehicle, the capacity of the freight automotive equipment, the cargo weights per loaded vehicle, or the empty vehicle weights.

Notwithstanding all the records that are available, it is most difficult to find the motor vehicle operating costs necessary for an analysis of the relative cost of transporting goods in vehicles of different dimensions and gross weights. To determine the overall economy of increasing the weight of vehicles, that is, increasing the weight on individual axles as well as the gross weight per vehicle, it is necessary in the current study to tie the cost of operating the vehicles to specific measurable factors.

1. SOURCES OF LINE-HAUL OPERATING COSTS

In 1961 the Highway Research Board of the National Academy of Sciences published Bulletin 301, "Line-Haul Trucking Cost in Relation to Vehicle Gross Weights." This publication is the result of an extensive Nationwide analysis of the cost records of 611 operating companies and 23,384 specific line-haul trailer combinations.

The cost material in Bulletin 301 is priced as of 1956. During 1964, as a part of this size and weight project, the price information upon which the costs in Bulletin 301 were based was updated to a 1964 base. These 1964 revisions provide the basic data for the curves and tables presented in this chapter.

The various elements of operating cost for line-haul combination vehicles were classified as follows:

(1) Repair, servicing, and lubricant cost
(2) Tire and tube cost
(3) Fuel cost
(4) Driver wages and subsistence cost
(5) Indirect and overhead cost
(6) Depreciation and interest cost

2. THE OPERATING COSTS OF LINE-HAUL VEHICLES

The final line-haul operating costs reported on the basis of vehicle gross weight are the results of combining the costs for all types of vehicles without regard to axle classification, body styles, types of engines, engine power, geographical location, or other factors. While it would have been desirable to summarize and present the vehicle operating costs for different types of vehicles, particularly with reference to the number of axles, such a presentation was not made because the cost information was not reliable on such a detailed basis.

Figure 9-1 gives by element the line-haul operating costs of all vehicles as the loaded gross vehicle weight varies, expressed in terms of cents per mile. In figure 9-2 these curves for the individual elements of cost are given on a cumulative basis. The total costs per vehicle-mile are also presented in table 9-2.

A. Meaning of Loaded Gross Weight

The reported line-haul operating costs of trailer combinations are related to the loaded gross weights of these combinations. In Bulletin 301, page 133, loaded gross weight is defined as follows:

> The loaded gross weights used in developing vehicle-mile costs and shown in the abscissas of the cost curves are the sums of the tare weights of the trailer combinations plus the predominately carried payloads.

From this definition it may be understood that the loaded gross weight of each class of trailer combination may vary over some range, depending upon the practices of each carrier and the commodities hauled. The operating cost

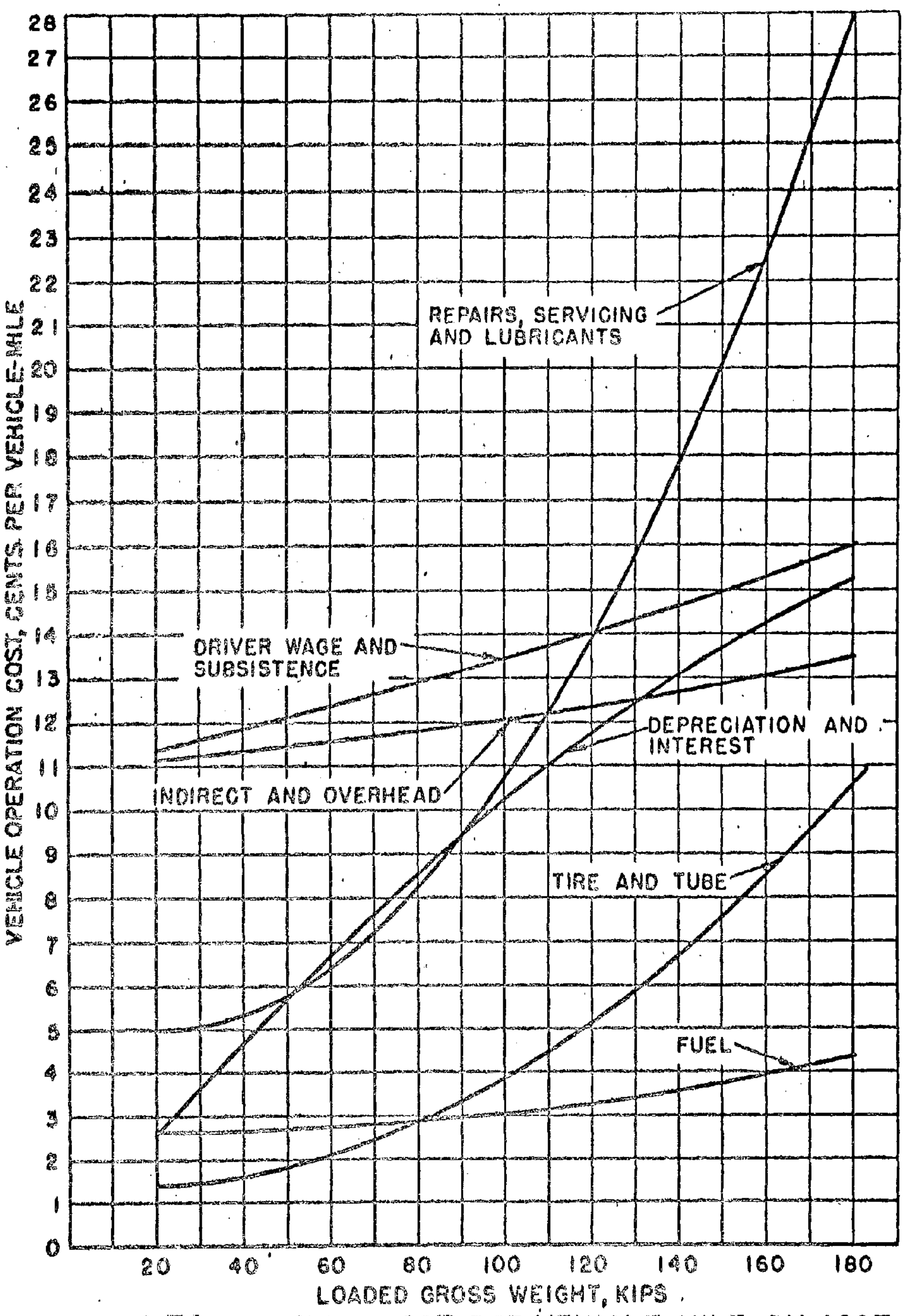

FIG 9-1-OPERATING COST PER VEHICLE-MILE BY COST ELEMENT FOR GASOLINE- AND DIESEL-ENGINE-POWERED TRAILER COMBINATIONS

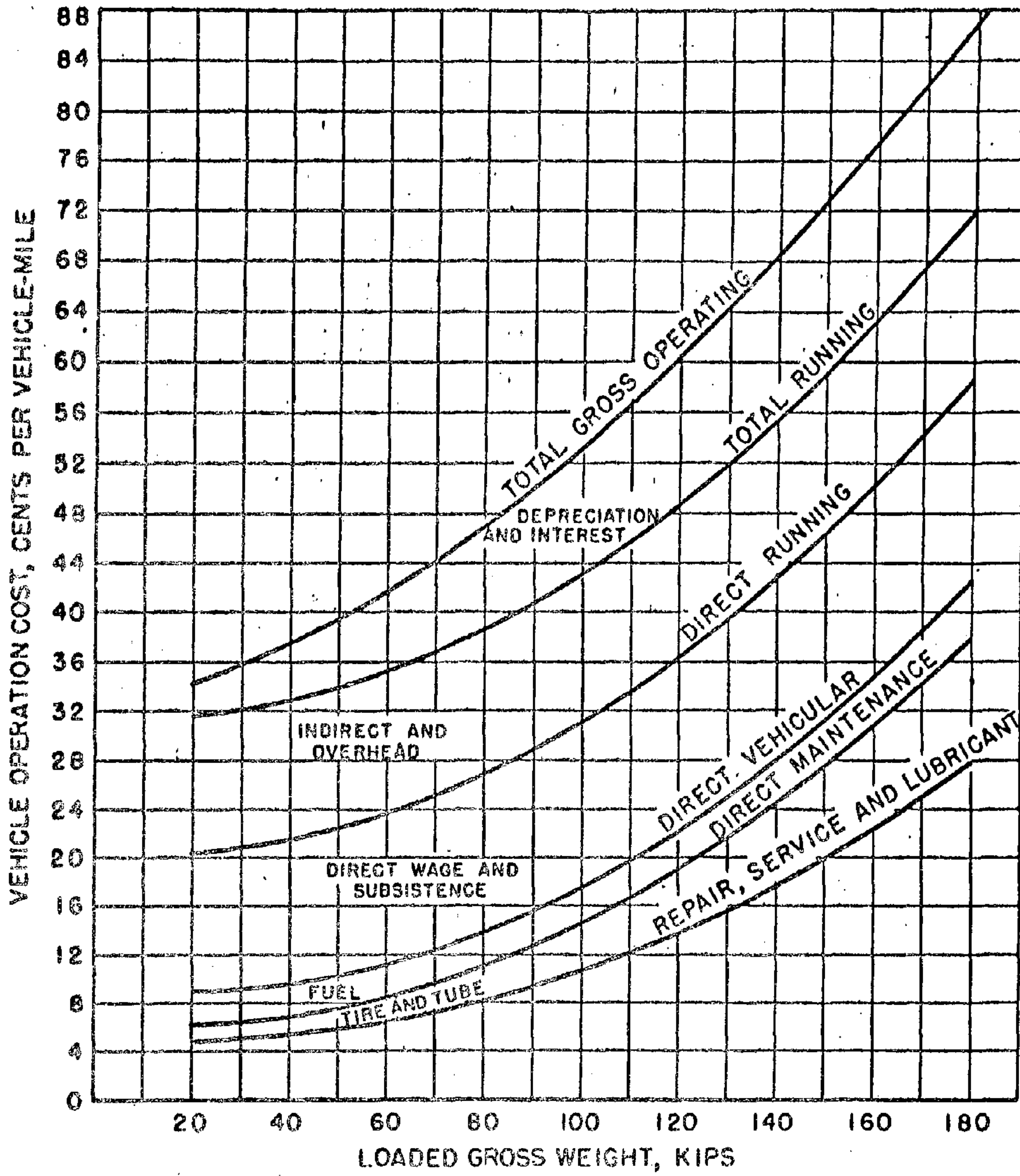

FIGURE 9-2.-OPERATING COST PER VEHICLE-MILE FOR GASOLINE- AND DIESEL-ENGINE-POWERED TRAILER COMBINATIONS BY SUBTOTALS OF THE SIX BASIC COST ELEMENTS

Table 9-2. - Operating cost in cents per vehicle-mile for line-haul vehicles, by loaded gross weight in kips

Kips	Cents per mile	Kips	Cents per mile	Kips	Cents per mile	Kips	Cents per mile
25	34.94	65	43.12	105	55.01	145	70.64
26	35.10	66	43.37	106	55.36	146	71.07
27	35.26	67	43.62	107	55.71	147	71.51
28	35.43	68	43.88	108	56.06	148	71.96
29	35.59	69	44.14	109	56.41	149	72.40
30	35.76	70	44.40	110	56.76	150	72.85
31	35.93	71	44.66	111	57.12	151	73.30
32	36.10	72	44.93	112	57.48	152	73.75
33	36.28	73	45.20	113	57.84	153	74.21
34	36.46	74	45.47	114	58.20	154	74.66
35	36.64	75	45.74	115	58.57	155	75.12
36	36.82	76	46.02	116	58.94	156	75.58
37	37.00	77	46.29	117	59.31	157	76.05
38	37.19	78	46.57	118	59.68	158	76.52
39	37.38	79	46.86	119	60.06	159	76.98
40	37.57	80	47.14	120	60.44	160	77.45
41	37.77	81	47.43	121	60.82	161	77.93
42	37.96	82	47.72	122	61.20	162	78.40
43	38.16	83	48.01	123	61.58	163	78.88
44	38.36	84	48.30	124	61.97	164	79.36
45	38.56	85	48.60	125	62.36	165	79.84
46	38.77	86	48.90	126	62.75	166	80.33
47	38.98	87	49.20	127	63.15	167	80.82
48	39.19	88	49.50	128	63.54	168	81.31
49	39.40	89	49.81	129	63.94	169	81.80
50	39.61	90	50.12	130	64.34	170	82.29
51	39.83	91	50.43	131	64.74	171	82.79
52	40.05	92	50.74	132	65.15	172	83.29
53	40.27	93	51.05	133	65.56	173	83.79
54	40.50	94	51.37	134	65.97	174	84.29
55	40.72	95	51.69	135	66.38	175	84.80
56	40.95	96	52.01	136	66.80	176	85.30
57	41.18	97	52.34	137	67.21	177	85.82
58	41.42	98	52.66	138	67.63	178	86.33
59	41.65	99	52.99	139	68.06	179	86.84
60	41.89	100	53.32	140	68.48	180	87.36
61	42.13	101	53.66	141	68.91		
62	42.37	102	53.99	142	69.34		
63	42.62	103	54.33	143	69.77		
64	42.87	104	54.67	144	70.20		

data were analyzed on the basis of the predominate loaded gross weights for each vehicle class as found in each carrier's records.

The line-haul operating costs are related to loaded gross weight, the one characteristic of operation that can be determined for a vehicle class and held constant for each carrier. Therefore, consideration of the operating costs of trailer combinations that are carrying little or no payload poses a problem. The magnitude of this problem can be appreciated from the information contained in the annual State truck weight studies indicating that approximately 33 percent of all trailer combinations on main rural roads are without payload and 67 percent of them are carrying some degree of payload up to an amount in excess of the maximum legal gross weight or axle weight.

The loaded gross weight as set forth in Bulletin 301 is a good practical unit upon which to base overall operating cost of vehicles and vehicle combinations. It is necessary in this study, however, to know what the loaded gross vehicle weight would be for the several classes of vehicles under the five maximum axle-weight limits studied. To arrive at loaded gross weights that would be in harmony with the way the cost curves of Bulletin 301 were constructed, the original data on which Bulletin 301 was based were analyzed. As a result of this analysis, the loaded gross weight was found to be about

80 percent of the practical maximum gross vehicle weight, defined as the sum of the legal maximum weights on each axle except the steering axle, which is added in at a reasonable practical weight for the particular vehicle class--or the legal gross vehicle weight if it is less than the sum of the axle weights.

B. Operating Cost per Payload Ton-Mile

In determining the economy of highway transport as affected by the maximum limitation on axle weights or by the size of the cargo body, the prime consideration is the long-run cost of transporting the cargo on a payload ton-mile basis. As the foregoing curves show, the cost per vehicle-mile increases with the loaded gross vehicle weight. As these increases take place, the cost in cents per ton-mile of payload decreases to a minimum at about 200 thousand pounds loaded gross vehicle weight. (See figure 9-3.)

(1) Effect of increasing the gross vehicle weight and reducing the number of trips

When considering the use of commercial vehicles on the highways and the tons of cargo in intercity transport, it should be understood that the payload per trip and the vehicle gross weight could be increased by increasing the allowable maximum axle weights or by increasing the number of axles per vehicle combination. With an increased gross vehicle

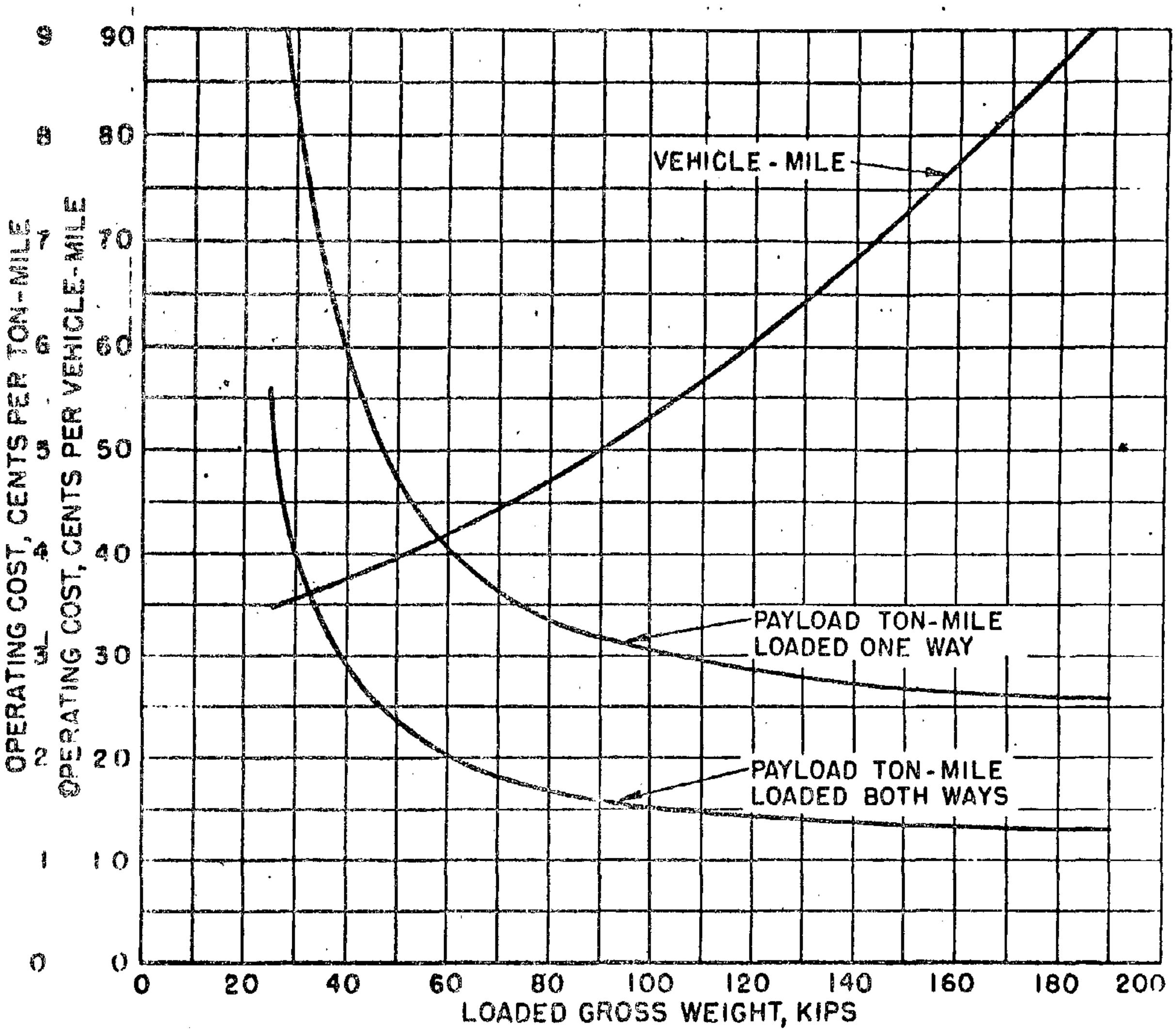

FIGURE 9-3-LINE-HAUL MOTOR VEHICLE OPERATING COST PER VEHICLE-MILE AND PER PAYLOAD TON-MILE AS RELATED TO LOADED GROSS VEHICLE WEIGHT

weight, a given number of tons of cargo could be transported with fewer vehicle trips. As the gross vehicle weight increases up to about 200,000 pounds, the transport cost per vehicle-mile will increase. But the total vehicular cost of transporting the given tonnage of payload will decrease. The number of vehicle trips required to haul the given payload tonnage decreases as the gross load increases. Fewer vehicle trips at an increased cost per vehicle-mile results in a total dollar cost less than the cost of hauling the same total tons of payload in vehicles having lower gross weights at a lower cost per vehicle-mile but requiring more trips.

A tabulation will illustrate this result for a 3-S2 tractor-semitrailer hauling a constant number of payload tons for a distance on one mile.

Number of vehicle trips	Cost in cents per vehicle-mile	Total cost, dollars
115	41.643	47.89
111	42.866	47.58
107	44.149	47.24

Some slight difference in operating cost per mile may exist between trucks having the same loaded gross weight, depending upon whether that weight results from comparatively high axle weights and few axles or the reverse case. The original research could not make this distinction, and the application here assumes no difference in operating cost between trucks of the same gross weight but different axle weights and numbers of axles.

(2) Payload ton-mile cost curves

The general costs of vehicle operation based on loaded gross vehicle weight may also be expressed in terms of payload ton-mile cost. Figure 9-3 gives these costs.

3. APPLICATION OF THE LINE-HAUL TRUCKING COST TO THE ANALYSIS OF ECONOMY OF VEHICLE WEIGHTS

As indicated in the foregoing discussion, the final curves for line-haul trucking costs are based upon loaded gross vehicle weight. This weight is not a specific number of pounds because it represents the normal loading of the various carriers according to their individual practice. When hauling light density cargo, such as furniture or household goods, the average gross weight of the vehicle is far below the total maximum legal gross weight that could be hauled. Furthermore, other trips are made at less than full gross load, either on a cubage basis or on a gross vehicle weight basis. It is possible, however, based upon the maximum legal limitations on axle weights or gross weights, to calculate the practical maximum gross weight of a vehicle.

Table 9-3 gives the vehicle operating cost in cents per mile for 12 classes of vehicles and vehicle combinations

Table 9-3. - Loaded gross vehicle weight and operating cost of selected vehicle classes

Vehicle class	Axle weight limit, kips, single/tandem				
	18/32	20/35	22/38	24/41	26/44
A. 80 percent of maximum practical gross vehicle weight, kips = loaded gross weight					
2D	20.32	22.56	24.80	27.04	29.28
3A	33.28	36.16	39.04	41.92	44.80
2-S1	34.88	38.40	41.84	45.20	48.48
2-S2	46.72	50.96	55.20	59.44	63.68
3-S2	58.96	64.00	69.04	74.08	79.12
2-2	50.08	55.04	60.00	64.96	69.92
2-3	61.28	67.04	72.80	78.56	84.32
3-2	62.24	68.16	74.08	80.00	85.92
2-S1-2	64.56	71.12	77.68	84.24	90.80
2-S2-2	76.24	83.76	91.28	98.80	106.32
2-S2-3	87.44	95.76	104.08	112.40	120.72
3-S2-4	110.40	120.24	130.08	139.92	149.76
B. Operating cost, cents per vehicle-mile for 1965					
2D	32.230	34.565	34.911	35.270	35.640
3A	36.329	36.849	37.388	37.946	38.523
2-S1	36.615	37.349	37.930	38.605	39.289
2-S2	38.919	39.823	40.769	41.757	42.787
3-S2	41.643	42.866	44.149	45.490	46.891
2-2	39.632	40.733	41.891	43.106	44.379
2-3	42.199	43.633	45.144	46.732	48.398
1/ 3-2	42.433	43.921	45.490	47.141	48.874
2/ 2-S1-2	43.006	44.695	46.485	48.374	50.141
2-S2-2	46.083	48.232	50.513	52.926	55.470
2-S2-3	49.332	51.935	54.698	57.623	60.709
2-S2-4	56.905	60.526	64.373	68.446	72.743

1/ The 3-2 is to be used for the 5-axle combination vehicle.

2/ The 2-S1-2 is to be used for the 2-trailer, 5-axle combination vehicle.

and for five levels of axle-weight limits. Notice that the loaded gross weight is expressed as 80 percent of the practical gross vehicle weight.

In the analysis for economy of axle-weight limits, provision was made for an increase of 29 percent in payload per vehicle trip from 1962 to 1990. Although the practical maximum gross vehicle weight would not be changed by this payload increase, the vehicle operating costs would increase for certain items. The three items that would increase are as follows: (1) repairs, servicing, and lubricants; (2) tires, and tubes; and (3) fuel. (See table 9-1.) Consequently, table 9-3 was adjusted to give the results shown in table 9-4. The adjustment was made by increasing the costs for the five levels of axle weight in table 9-3 by the cents-per-mile increase from the base loaded gross weight in table 9-3 to what the base weight would be when the exact number of pounds of payload increase was added.

In other applications, the combination vehicles with only one cargo body are compared with those having two cargo bodies. There would be a higher direct saving than is indicated by the driver and subsistence curves in Bulletin 301. Theoretically, when two cargo units are combined and operated by one driver, the driver costs are only half of what they would be with two separate vehicles and two drivers. Bulletin 301 provides for increasing driver cost on a

Table 9-4. - Loaded gross vehicle weight and operating cost of selected vehicle classes

(For method 1, including 29% increase in payload, 1962 to 1990)

Vehicle class	Percentage of PMGVW	Axle weight limit, kips, single/tandem				
		18/32	20/35	22/38	24/41	26/44
		A. Loaded gross vehicle weight for 1990, kips 1/				
2D	80.0	20.32	22.56	24.80	27.04	29.28
3A	85.0	35.36	38.42	41.48	44.54	47.60
2-S1	83.5	36.41	40.08	43.67	47.18	50.60
2-S2	85.5	49.93	54.46	59.00	63.53	68.06
3-S2	88.0	64.86	70.40	75.94	81.49	87.03
2-2	85.0	53.21	58.48	63.75	69.02	74.29
2-3	89.5	68.56	75.00	81.44	87.89	94.33
3-2	89.5	69.63	76.25	82.88	89.50	96.12
2-S1-2	86.0	69.40	76.45	83.51	90.56	97.61
2-S2-2	86.0	81.96	90.04	98.13	106.21	114.29
2-S2-3	86.0	94.00	102.94	111.89	120.83	129.77
3-S2-4	86.0	118.68	129.26	139.84	150.41	160.99
		B. Operating cost, cents per vehicle mile, for 1990 4/				
2D		34.230	34.565	34.911	35.270	35.640
3A		36.414	36.958	37.524	38.112	38.723
2-S1		36.683	37.356	38.045	38.746	39.458
2-S2		39.166	40.132	41.147	42.212	43.325
3-S2		42.304	43.670	45.110	46.625	48.210
2-2		39.900	41.072	42.311	43.614	44.984
2-3		43.070	44.711	46.450	48.292	50.228
2/ 3-2		43.338	45.043	46.852	48.765	50.782
3/ 2-S1-2		43.611	45.456	47.420	49.497	51.696
2-S2-2		46.977	49.340	51.862	54.534	57.360
2-S2-3		50.554	53.432	56.504	59.759	63.204
3-S2-4		58.914	62.999	67.310	71.877	76.712

1/ Based upon the loaded gross weight in 1990 being the percentage of the practical maximum gross vehicle weight, given in column 2.

2/ The 3-2 is to be used for the combination 5-axle vehicle.

3/ The 2-S1-2 is to be used for the 2-trailer, 5-axle vehicle.

4/ The cents-per-mile cost is increased over the 1962 costs without the 29-percent increase in payload only on the items of repair and servicing, tires and tubes, and fuel; cost for [illegible] continuously increasing loaded gross weight scale, based upon one driver per combination vehicle, but the increased driver costs are far less than doubled for double the loaded gross weight.

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