NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 198

STATE LAWS AND REGULATIONS ON TRUCK SIZE AND WEIGHT

R. J. HANSEN ASSOCIATES, INC.
ROCKVILLE, MARYLAND

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. FEBRUARY 1979

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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FOREWORD

By Staff
Transportation
Research Board

This report is recommended to transportation officials responsible for planning and implementation of highway programs, and federal and state legislators responsible for policy decisions on proposed legislation having an impact on legal vehicle weights and dimensions. The report contains information on the consequences of nonuniformity in state laws and regulations restricting truck size and weight. Recommendations are made for increasing the size and weight limits in some states to allow significant benefits to be derived from a greater degree of interstate uniformity.

The U.S. Congress and state legislatures have the continuing responsibility for considering legislation limiting motor vehicle weights and dimensions. There is evidence that the diverse requirements of current state laws, regulations, and interstate agreements controlling the interstate and interregional movements of trucks add unnecessarily to the cost of trucking operations and state administration. A need has existed for comparative analyses of the effects of the existing diversity of truck size and weight regulations, and for establishment of alternatives to eliminate or minimize those effects by increasing the degree of uniformity of the laws, regulations, and agreements. Alternative systems are needed to facilitate interstate and interregional truck operation, with due consideration given to economy, safety, and administrative efficiency.

The objectives of this project were to (1) describe the effects of current state size and weight laws, regulations, and interstate agreements on trucks and the highway systems they use; (2) investigate the potential benefits and disadvantages of increased uniformity in truck size and weight limits among the states; and (3) evaluate the available alternatives for eliminating or minimizing the differences in these limits.

The approach taken by R. J. Hansen Associates, Inc., in conducting the research was to compile and update data on truck configurations, truck transport economics, and state regulations on truck sizes and weights. A comprehensive survey of the trucking industry and state highway agencies was carried out, supplemented by visits by the researchers. A national commodity flow model was developed to examine the relative efficiency and costs of truck movements under existing conditions and conditions of improved uniformity.

It is concluded from the research results that significant benefits will accrue from adoption of an optimal level of uniformity in the regulation of interstate truck traffic. These findings are particularly timely in view of the current emphasis on energy efficiency by highway users and the need for highway agencies to control maintenance costs.

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The research reported herein was conducted under NCHRP Project 20-16 by R. J. Hansen Associates, Inc., under the general direction of Ralph D. Johnson, co-principal investigator, who was assisted by John C. Laughland of Snider, Blanchard and Laughland, co-principal investigator, and by Peter D. Johnson of RJH. Dr. Everett C. Carter, Professor of Civil Engineering, University of Maryland, was a consulting member of the project team for all phases. Although not involved extensively, Dr. Charles A. Taff, Professor of Transportation, University of Maryland, provided invaluable consultation in early project stages. Further involvement by Dr. Taff, as originally planned, became unnecessary because of the extent to which answers to project questions could be readily obtained from his book, *Commercial Motor Transportation* (Cornell Maritime Press, 5th Ed., 1975), which was relied on extensively. Dr. Mathew W. Witczak, Professor of Civil Engineering, University of Maryland, provided assistance in the development of pavement performance curves. Shou Min Tsao, graduate student, University of Maryland, was an invaluable member of the project team for more than a year and is primarily responsible for development and operation of the complex electronic computer programs that led to creation of the national interstate truck commodity flow network.

Numerous individuals from government agencies and private companies were consulted throughout the project. These included personnel of highway, motor vehicle, and enforcement agencies, as well as trucking associations and individual trucking firms in California, Colorado, Iowa, Louisiana, Maryland, Massachusetts, Nebraska, North Carolina, Oklahoma, Pennsylvania, Wisconsin, and Wyoming. The Federal Highway Administration contributed time and special data runs through its Offices of Program and Policy Planning and Highway Planning.

The Bureau of the Census was consulted frequently, especially Dayton Jorgenson, Transportation Branch, Economic Surveys Division. T. Q. Hutchinson and Pat Balef, Economic Research Service, Department of Agriculture, also provided invaluable help. In addition, numerous other Federal Government agencies were contacted for information on commodity movements not covered in the 1972 Census of Transportation.

National trucking associations provided advice, consultation, and mailing lists, especially the American Trucking Associations, Western Highway Institute, Private Truck Council, Private Carriers Conference (ATA), and the National Independent Truckers Unity Committee. Publishers of national and regional trucking industry journals also provided assistance, especially Chilton Publishing Company, publishers of *Owner-Operator Magazine,* who furnished a mailing list for independent truckers and some advice on the compilation of questionnaires.

NCHRP project panel members provided valuable insights, assistance, and comments. So many others were contacted and contributed in some measure to the conduct of this research that individual acknowledgments would occupy several pages. It is hoped that those who have made the most significant contributions have been duly noted. Grateful acknowledgment is extended for the help and contributions received from all sources.

STATE LAWS AND REGULATIONS ON TRUCK SIZE AND WEIGHT

SUMMARY

Nonuniformity in state laws relating to motor vehicle sizes and weights is costing the American public from $1.6 to $2.8 billion annually. Although these additional costs most directly affect the trucking industry, transportation costs are ultimately reflected in the marketplace and in the cost of living.

Transportation rates by truck can be substantially lower than rates by other modes because the costs of facilities on which the trucks operate are shared by a broad population of motor vehicle users, including automobile operators. There is no inequity, provided the trucks pay their fair share of these costs. Moreover, automobile owners, through their sharing of the highways with commercial vehicles, are helping to reduce their living costs. Commercial use of the highways is of benefit to everyone.

However, the lack of optional uniformity not only is costing the American public excessive amounts for transportation, but it also results in the unnecessary use of between 400 million and 875 million gallons of motor vehicle fuel, largely diesel. There are environmental effects—nonuniformity produces a larger number of truck trips than otherwise would be necessary to transport the same quantity of commodities, resulting in an additional increment of noise and air pollution that otherwise would be avoided.

This research has conclusively shown that these are major effects of the present situation of nonuniformity. The ranges in values of economic and other savings represent minimum to maximum amounts, depending on the advantage that segments of industry would take of more uniform provisions. The minimum amounts are consistent with the advantage that already has been taken in some corridors where a substantial degree of uniformity prevails. This advantage has been limited by the fact that some trips in these corridors are destined to corridors beyond—where the same laws and regulations do not prevail. Maximum values are based on competitive industry taking full advantage of the opportunity to reduce transportation costs.

The Costs of Optimal Uniformity

What will it cost the public to have optimal uniformity and realize the indicated savings? This research has shown that the costs would be moderate—extremely small in terms of economic and energy savings that can be realized.

Provisions for optimal uniformity will not increase highway costs substantially either for the roadways or for the structures. From all presently available information, they will not reduce highway safety; and they should produce no additional enforcement requirements.

Because of increased transportation efficiency through optimally uniform provisions, there will be moderate increases in the number of axle loadings used as a basis for highway design, expressed as 18,000-lb (8.16-t) equivalents. As a result of these increases, highway expenditures to achieve uniformity have been estimated at $2.0 billion on a one-time basis—this to produce annual savings in transportation cost of probably over 2.0 billion.

This cost comparison must be presented with reservation. The annual savings have been developed for only the first year; they will increase to larger annual amounts year-after-year as truck traffic follows its normal increase pattern. On

the other hand, the highway costs are based on overlaying existing pavements to maintain present service lives. When these lives are expended, there will be additional highway expenditure requirements for the additional equivalent axle loads. However, these expenditures will represent only very small increases in normal highway costs because the required increments of new construction will cost much less than the overlays on which the $2.0 billion estimate is based. The $2.0 billion is a highly conservative figure because states will not immediately need to overlay all of their pavements for the moderate increases in equivalent axle loadings. Thus, although not representing a precise comparison of costs and benefits, the $2.0 billion one-time highway costs versus over $2.0 billion annual savings reasonably reflect the comparative merit of the proposals of optimal uniformity.

The Nature of Optimal Uniformity

Optimal uniformity does not mean that all states necessarily will have equivalence among all of their laws and regulations regarding motor vehicle size and weight.

The early stages of this research and the early chapters of this report indicate that few states match in having completely uniform laws and regulations, even as applying to all basic loadings and dimensions. Where there is an apparent match, there is a good chance that the way laws are written or carried out imposes non-uniform requirements. Influenced by the recommendations of the American Association of State Highway Officials (now State Highway and Transportation Officials) and by the actions of the Federal government, there is a degree of uniformity in axle loads permitted among groups of states, in gross weight, and, to a lesser degree, in dimensions.

There is uniformity in the sense that there are several configurations, sizes, and weights of large and heavy commercial vehicles that can meet the requirements of every state; and, if licensed appropriately, these vehicles travel throughout the country without special oversize or overweight permits. Within some groups of states, the weights and dimensions generally accepted are much more liberal than others. For example, axle loadings of 22,400 lb (10.15 t) single and 36,000 lb (16.33 t) tandem are commonly accepted in a tier of eastern states. A small group of western states permits gross weights exceeding the more common value of 80,000 lb (36.28 t), and another larger group permits combination vehicle lengths to exceed the more common value of 65 ft (19.81 m). On the other hand, a tier of eastern states restricts combinations to 55 ft (16.76 m).

Probably, the largest present hindrance to more efficient interstate vehicle movements is caused by the so-called barrier states. These largely are states in a midcountry tier stretching from Lake Michigan to the Gulf of Mexico. They generally restrict axle loadings to 18,000 lb (8.16 t) single and 32,000 lb (14.51 t) tandem, and gross vehicle weights to 73,280 lb (33.23 t). These limits contrast with AASHTO recommendations, adopted by most of the states, for axle loadings of 20,000 and 34,000 lb (9.07 t and 15.42 t) and gross weights of 80,000 lb (36.28 t).

In order to have optimal uniformity allowing for efficient cost-effective transportation of goods interstate, it is not necessary for all states to have equivalence in all of their laws and regulations regarding motor vehicle size and weight.

Laws and regulations governing commercial vehicle size and weight have always been a state prerogative, which is in keeping with the states' basic responsibilities for the construction and maintenance of their highway systems. For optimal uniformity, it is not necessary that this situation be changed, unless individual states are noncooperative in such a way as to detrimentally affect the welfare of the nation's people as a whole.

Some commercial transportation needs are related to natural resources, industries, or agricultural activities that are limited in geographic area or are of special importance to the economy of one state or a few adjacent states. It is appropriate for the states affected to make special provisions for these movements or to regulate and control them on a state-by-state basis.

On the other hand, there are interstate movements where transportation costs, energy use, and other results can have a significant effect on the national welfare. Provision can be made for these movements, if each state voluntarily will adapt its laws to allow them to take place efficiently and effectively.

This research has indicated that states need not change their laws radically to provide for optimal uniformity. However, some of the changes will result in some additional costs, particularly in the barrier states, and some public reaction largely due to misunderstanding.

Basic Recommendations for Optimal Uniformity

Study, during this research, centered on potential changes in the efficiency and costs of commercial transportation that could occur as a result of changes in state laws and regulations to uniformly permit interstate operation of different sizes and weights of vehicles.

To meet the objectives, the research, for the first time, identified the actual flows of commodities taking place in trucks in all interstate corridors throughout the nation. It identified what each truck is presently carrying and how the truck is loaded. For the first time, it developed operating cost nomographs to determine the relative cost efficiency of different vehicle types for different commodity movements.

Using the electronic computer, it was possible to simulate the use of optimally efficient vehicles—based on present vehicle design technology—to allow the more cost-effective transport of the commodities. It is on these simulations, supported by extensive interviews and questionnaire responses from the trucking industry and highway officials, that the conclusions of this research are based.

The study concludes that the most efficient and cost-effective transportation could be provided if all states would adopt uniform provisions as follows:

1. Allow double trailer combinations with 40-ft (12.19-m) trailers, so-called turnpike twins, and triple combinations with 28-ft (8.54-m) trailers to operate on all controlled-access highways throughout the country, with access permitted to terminals within a reasonable distance.

2. Bring the maximum axle load provisions of all states with lesser limits to the AASHTO recommended limits of 20,000 lb (9.07 t) single and 34,000 lb (15.42 t) tandem.

3. Retain the bridge formula as commonly applied, but eliminate unnecessarily restrictive gross weight limits.

With adoption of these recommendations, additional highway costs will largely occur as a result of changes in axle loadings in the barrier states. There is no basis for believing that highway safety will be adversely affected. Braking characteristics of the combinations indicated compare favorably with those of vehicles now permitted in every state, and under wet-pavement conditions these vehicles are safer than single semitrailer combinations in panic stops.

The ranges of benefits as compared to costs, have been indicated, and there will be beneficial environmental effects as previously noted.

Problems in Achieving Optimal Uniformity

There are likely to be adverse reactions to these recommendations from different quarters. Some will relate to legitimate problems that will need to be overcome. Others will relate to common misconceptions in more than one area of concern.

One problem has to do with the increase of costs to adopt the 20,000-lb (9.07-t) and 34,000-lb (15.42-t) axle provisions in the barrier states. (This will be the largest contributor to increased equivalent axle loadings.)

The fact that the $2.0 billion one-time expenditure is a conservative estimate of what it will take to maintain all present pavement service lives on arterial highways as a result of the changes does not altogether describe the problem area. Presently, according to the national inventory used for analyses of resulting pavement costs, large mileages of arterial highways are already in or close to failed condition—serviceability index 2.5 or less. However, although these highways may be failed theoretically, they are still in service because there are insufficient funds to reconstruct them—and they generally require reconstruction, not just an overlay. The problem of putting increased loads on these sections is that they are likely to break up altogether, creating increased demands on present budgets that cannot be met. This problem is a real one and is not limited to barrier states—other states will experience axle-load increases as a result of elimination of the barriers.

Perhaps an answer to this problem can be found in a Federal-aid program for surface reconstruction and restoration where eligibility is limited to states meeting the AASHTO recommended limits.

Another problem relates to the possibility of additional trucking advantages in the competition with railroads for surface transportation. However, the criterion that obviously should be applied in coming to grips with this problem is not public advantage. Actions in support of railroads should not negate reduction in over-all transportation costs unless some other compensating advantage can be realized. In the main, railroad problems need to be solved through actions relating specifically to rail and not to other modes of transportation.

As indicated, adverse reactions to the recommendations may occur as a result of misconceptions. There are misconceptions about the effects of trucks in generally damaging highway surfaces. There are misconceptions about the effects of trucks on bridges. There are also misconceptions about the safety of trucks. Concerns, in these respects, are discussed in Chapter One, and specific information on the relationships involved are provided in Chapter Three.

This research did not deal with differences in laws and regulations on highway speed among the states since there are virtually none. There are differences, however, on the enforcement of speeds and of sizes and weight regulations that have a marked effect on how they are observed.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

BACKGROUND

Research Problem

Each state has developed its vehicle size and weight limits independently of neighboring jurisdictions. Consequently, an extensive diversity in size and weight laws and regulations has developed among the states. For example, gross vehicle weight limits on major highway systems vary from 73,280 lb (33.23 t) to more than 125,000 lb (56.7 t). Truck combination length limits vary from 55 ft (16.76 m) to more than 100 ft (30.48 m).

Project 20-16 was formulated because there was evidence that the diverse requirements of these limits added unnecessarily to the cost of interstate and interregional trucking operations as well to state administration. A need existed for comparative analyses of the effects of these diversities and for the establishment of alternatives to eliminate or minimize those effects by improving the uniformity of the laws, regulations, and interstate agreements. Alternative systems were needed that would be designed to facilitate interstate and interregional truck operation, with due consideration given to economy, safety, and administrative efficiency.

Research Objectives and Scope

The project statement outlined three primary research objectives, as follows:

1. Identify and describe the effects of current state size, weight, and speed laws, regulations, and interstate agreements on trucks and the highway systems they use.
2. Investigate the potential benefits and disadvantages of increased uniformity in truck size, weight, and speed limits among states.
3. List and evaluate the available alternatives for eliminating or minimizing the differences in truck size, weight, and speed limits among states.

Speed was incorporated in the objectives at the time the energy crisis was raising the possibility of a national speed limit. With the adoption of the nationwide 55-mph (88.5-km/h) limit, *de jure* speed law uniformity has become a reality, and was not a major consideration in this study.

Several specific tasks were to be accomplished during the 23-month study. Among these were:

1. Compilation and comparative summarization of size and weight laws and regulations on all highway systems.
2. Analyses of the effects of nonuniformity in size and weight limits on trucking operations in terms of such things as equipment and route selection, equipment utilization, operating costs, and fuel consumption.
3. Identification and description of the influence of different maximum allowable sizes and weights on the structural and geometric requirements of highways, with appropriate consideration of safety and operational characteristics.
4. Identification of special state problems and costs associated with administration of the current system of diverse limits.
5. Development of a national commodity flow network.
6. Evaluation of alternative levels of uniformity and their potential impacts.
7. Development of recommended approaches to uniformity.

Historical Perspective

Trucks were first manufactured in the United States in 1898. Both the highway system and trucking have developed rapidly during the past 80 years. In 1904 there were 204,000 mi (328,236 km) of surfaced roads and streets in this country. There are now over 3 M mi (4,827,000 km) of surfaced roadways, although total roadway mileage has not increased greatly. Over the same period, motor truck registrations have grown from less than 1,500 to more than 24 million (*1*).

Motor trucks operating on the highways now provide service to every community in the country, including more than 39,000 communities that are not served by any other freight transportation mode. In 1974, trucks traveled more than 265 billion veh-mi (426×10^9 veh-km). Trucks currently deliver nearly 60 percent of all intercity shipments of manufactured products, 80 percent of all fruits and vegetables, and 100 percent of all livestock.

Over the past 80 years, each state has enacted laws and regulations to limit the dimensions and weights of trucks. Levels adopted by individual states often varied from those adopted by other states. Lack of uniformity has been a matter of concern for at least 40 years, as evidenced from its presentation, as a topic, at the 1938 AASHO convention.

Trends in Weights

Following World War I, rapid improvements in the nation's highways, coupled with improvements in truck technology, enabled trucks to carry heavier weights, greater distances more rapidly. Demand for heavier size and weight limits arose with varying response from the different states. Regional similarities developed in basic requirements together with significant differences in axle and gross weight limits among regions.

The Federal government first intervened in the matter of sizes and weights with the enactment of the Federal Aid

Highway Act of 1956. This act provided extensive funding for the completion of the national system of Interstate and defense highways over the following 16 years. The act also established maximum vehicle weights permissible on highways of the Interstate System. The weight limits were 18,000 lb (8.16 t) on a single axle, 32,000 lb (14.51 t) on a tandem axle, and 73,280 lb (33.23 t) gross vehicle weight. A "grandfather clause" was included which allowed states with limits already greater than those specified to preserve the higher limits for their portions of the Interstate System. At the time of enactment of the Federal Aid Highway Act of 1956, 25 states qualified to retain higher limits under the grandfather clause.

In 1975, Federal legislation was passed that allowed states to increase maximum weight limits permitted on the Interstate System to 20,000 lb (9.07 t) single axle, 34,000 lb (15.42 t) tandem axle, and up to 80,000 lb (36.28 t) maximum gross weight, dependent on a formula governing number of axles and axle spacing. This legislation followed the imposition of the 55-mph (88.5-km/h) national speed limit in December 1973, which, some truckers argued, reduced trucking productivity by increasing trip time. The intent of the weight increases was to allow trucks to offset productivity losses due to lower speeds. However, 10 states and the District of Columbia have maintained their weight limits at the 1956 levels. One other state increased its weight limits after passage of the 1975 Federal legislation, but recently enacted a rollback of the increase to pre-1975 levels. In contrast, 25 states continue to use grandfather clause exceptions permitting axle and/or gross vehicle weights on the Interstate System that are still larger than the new Federal limits. Also, several of these 25 states recently learned that they can apply grandfather clause exceptions to permit operations. Pertinent clauses allow the issuance of permits for reducible loads as well as irreducible loads.

Weight limits on major state highways other than Interstate have generally followed the same trend. However, several states have failed to enact the same increase of limits for other highways that they enacted for the Interstate System. Also, in some cases, limits for other highways are higher than the Interstate limits established by the Federal Aid Highway Act. These variances in limits are shown in tables later in this chapter.

Trends in Lengths and Permissible Combinations

The trend since World War I has been towards longer tractor-semitrailer combinations and towards tractor-semitrailer combinations towing one or more additional trailers. No Federal legislation has imposed length or combination type limits for vehicles on the Interstate System.

Tractor-semitrailer combinations are the only type of combination vehicle currently permitted in every state. There has not been any significant change in over-all length limits for these vehicles during the past 15 to 20 years. The 20 western states generally have permitted lengths of 60 ft (18.29 m) or more, while the standard length limit in the eastern states has been 55 ft (16.7 m).

On the other hand, the length of the trailer within the tractor-semitrailer combination has been steadily increasing. Thirty years ago most trailers produced were less than 34 ft (10.36 m) in length. Twenty years ago, more than 70 percent of the trailers were between 34 ft (10.36 m) and 38 ft (11.58 m) in length. Ten years ago more than 70 percent of all trailers were 40 ft (12.19 m) or longer, while only 7 percent were 42.5 ft (12.95 m) or longer. Today more than 50 percent of all trailers produced are 42.5 ft (19.95 m) or longer (*2*). The advent of the cab-over-type tractor has had much to do with the ability to increase trailer length over the last 20 years while keeping within over-all length limits. One manufacturer recently introduced the prototype of a vehicle combination, eliminating the tractor and incorporating the driver's compartment and engine into the lower left, front corner of the first of two 26.5-ft (8.08-m) trailers.

There has also been substantial growth over the last 20 years in the legalization and use of multiple-trailer combinations. The most common multiple-trailer combination is a truck-tractor towing two trailers, each less than 30 ft (9.14 m) in length, with an over-all combination length of 65 ft (19.81 m). These combinations are most commonly known as "doubles" or "twins." Twenty years ago only 10 western states permitted doubles. Today, 35 states permit doubles, although five of those states restrict the combination length to 60 ft (18.29 m) or less.

A larger version of the doubles combination is the "turnpike twins"—a combination consisting of a truck-tractor towing two 40-ft (12.19-m) trailers. The over-all combination length is 98 ft (29.87 m). These combinations have been permitted on the Kansas Turnpike for 22 years, and on the toll roads of Indiana, Ohio, New York, and Massachusetts for the past 10 to 15 years.

In recent years there has been growing pressure, especially in western states, to permit "triples," combinations consisting of a truck-tractor towing three trailers. The trailers are each less than 30 ft (9.14 m) in length, and the over-all combination length limit is most commonly 98 ft (29.87 m) to 105.5 ft (32.16 m). Four western states now permit the operation of triples combinations on designated highways. They have been tested in at least 6 other states.

Inefficiencies in Truck Transportation

Diversities in size and weight limits among states give rise to truck transportation inefficiencies. In the interstate transportation of goods, the trucker either will have to use a vehicle which, when loaded, meets the size and weight limitations imposed by the most restrictive of the states traversed, or the trucker will have to reduce the load or change the vehicle before crossing the border of more restrictive states. When there are many states to be traversed and only one or two have limits substantially more restrictive than the others, they impose a substantial burden on the trucking industry that is reflected in increased transportation costs over large segments of the country. For example, a 65-ft (19.8-m) double-trailer combination would be able to travel nonstop from New York or Boston to California except for one 45-mi (72.4-km) stretch of highway in one state where that type of vehicle combination is not permitted. The prohibitive section of highway amounts to less than 1½ percent of the total trip mileage.

In other cases, truckers may opt for circuitous routing to bypass restrictive states or highway systems, resulting in greater mileage and energy consumption than would accrue on the more direct route.

To some extent, the large variety of trucks on the nation's highways is a result of diversity in size and weight laws. A vehicle designed to be most efficient under one set of limits may not be efficient under another set of limits.

Very little research has been done in the past to measure the extent to which transportation inefficiencies exist and the resulting noneconomies because of diversities in size and weight limits. Chapter Two contains further discussion of the inefficiencies, specific cases, and cost impact estimates.

Highway Concerns

If transportation inefficiencies result from diversities in size and weight limits, the question arises as to why the more restrictive states have not changed their limits to match those of other states. One answer is the concern state authorities have over possible consequences to their highway systems. Among their concerns are effects of dimension and weight increases on pavement life, bridges, geometric requirements, highway costs, and public safety. Some of the concerns in each of these problem areas are discussed in the following.

Pavement Life Concerns

The service lives of highway pavements, both asphalt and portland cement concrete, are influenced by axle weights and numbers of axle load repetitions. Modern highways are initially designed to withstand a specific number of load repetitions of a specified magnitude for a selected future period of time—the anticipated service life.

The design procedure involves the projection of expected truck traffic over the future period and the number of axle loadings of various magnitudes that this truck traffic will produce. These axle loadings are then converted, through use of a formula, to equivalent axle loads of a fixed magnitude, usually 18,000 lb (8.16 t). Typically, a 14,000-lb (6.35-t) axle will have an accepted equivalence of 0.34, meaning that the passage of one of these axles has only one-third the effect of an 18,000-lb (8.16-t) axle in pavement design requirements. A 22,000-lb (9.98-t) axle loading, on the other hand, has the equivalence of 2.37 passages of an 18,000-lb (8.16-t) axle.

The projected number of equivalent axle loadings is the design basis for determining the thickness of pavement that will be built and, therefore, its relative cost. As may be seen from the example equivalents, the relative effects of different weights of axles are some multiple of their proportionate values.

The scale of equivalents is different for tandem axles than for single axles. A tandem is generally far less demanding on pavements than the same nominal weight single axle. Thus, a tandem axle of 31,000 lb (14.05 t) has about the design equivalence of a single axle of 18,000 lb (8.16 t).

When a highway is properly designed, it presumably will require only routine surface maintenance throughout its service life provided the expected number of axle load repetitions is not exceeded. In other words, it will not be damaged by the traffic it is designed to support.

This is an important point because there are prevalent misconceptions that trucks damage pavements more than passenger cars. This is only true when (1) the pavements are underdesigned for the amount of truck traffic that is actually using them; (2) trucks, through overloading generally, are imposing heavier axle loads than anticipated; or (3) other factors not properly evaluated in design have affected the ability of pavements to support traffic.

Cost increases associated with the design of brand new pavements are not the only concern of state authorities when permitted axle loadings are increased. Indeed, for moderate increases in load, such as from 18,000 lb (8.16 t) to 20,000 lb (9.07 t) for single axles, the increment in cost of new pavements is quite small. However, the increased axles will largely be placed on existing pavements designed for less loading. Thus, their service lives may be shortened. Compensation can be made by applying overlays that will result in preserving the existing service lives. The costs of such overlays have been applied in this study to determine highway costs associated with any changes in equivalent axle loadings caused by proposed uniformity provisions.

Bridge Concerns

It is important to realize that highway structures are subject to potential damage from vehicle size and weight characteristics in an altogether different way than roadway surfaces. In this case, it is a combination of axle load and axle spacing that must be accommodated both in bridge design and subsequent use of the structure. This combination is specified by a bridge formula that is commonly used to regulate and control the loads that can be safely applied to the structure—it defines the combination of permissible gross vehicle weight, axle loads, and axle spacings.

States are rightly concerned about the magnitude of any structural problems that will result from changes in vehicle size and weight provisions. A large number of bridges on arterial highway systems are presently deficient in one respect or another. A recent report, based on one inventory, indicates that there are 33,500 deficient bridges on the Federal-aid systems (*3*). Responses from state transportation agencies to questionnaires for this research project pointed out 25,000 bridges posted for reduced loads (or eligible for such posting) on state systems alone, with only between 40 and 60 percent (estimated) of the total number of such bridges evaluated. The numbers of posted bridges reported in response to the questionnaires were based on evaluations of safe loadings as a specific percentage of yield stress. Differences in reports from other sources may be due to the use of less rigorous estimating procedures.

At any rate, the problem of existing bridge deficiencies is very large in every state and generally beyond the present fiscal resources of the states to correct.

The problem associated with permitting greater loads than those defined by the bridge formula is not in the cost of new bridges to accommodate these loads. The added costs to new bridges would be small both because the additional loading is incremental and because it is "live" loading, which is less of a bridge cost factor than "dead" loading—the weight of the bridge itself with such provisions as for wind loads.

The problem associated with permitting increased loads is the number of additional bridges, designed for present loadings, that would be made deficient. This problem was considered to be of such potential magnitude that the bridge formula was generally accepted, in this study, as defining a probable limit for uniform vehicle provisions inasmuch as there appeared to be no reasonable expectation of finding the kind of economic justification (transportation benefits) that would warrant exceeding it.

Geometric Requirements

In considering whether to permit vehicle dimension or weight increases, a state must consider the extent to which existing geometrics will accommodate larger vehicles. Highway geometrics involve such factors as lane widths, turning radius of curves, intersection design, climbing lanes, and the like. As vehicle sizes or weights increase, geometrics may be affected. For example, vehicles can only attain a certain width before they protrude into another lane, or they can only reach a certain length before they can no longer negotiate a curve or intersection without encroaching on a shoulder, another lane, or a curb.

Highway Costs

In each of the categories previously discussed, changes in vehicle sizes and weight levels may affect the costs necessary to construct, maintain, or reconstruct highways. One of the main problems faced by state transportation authorities when highway cost increases are threatened, even though they may be entirely justifiable from an economic standpoint, is that the benefits seldom put money directly into the funds from which the highways are built and maintained. Commercial transportation cost savings, for example, ultimately affect consumer prices that do not increase highway funds. In fact, energy savings may have a detrimental effect on the availability of needed funds because less fuel use means less fuel taxes.

Unfortunately, national and state legislatures are not prone to increase fuel taxes and other highway user charges (which represent almost the sole source of revenues for major arterial highways) in proportion to highway costs. In one typical state, the fuel tax, as a percent of fuel cost, decreased by 8 percent during a period when construction and maintenance unit costs increased by 120 percent. There appears to be little legislative consciousness that the investment in highways in constant dollars must keep abreast of the growth in highway service demands (represented by traffic growth) if these demands are to be met adequately.

There is evidence from recent national studies that major highways have been depreciating for the last 7 or 8 years at a faster rate than they are being improved (*32*). It is not surprising, therefore, that transportation officials are prone to react negatively to any action that will further increase highway costs.

Public Safety

States must consider whether vehicle size and weight increases will affect the public safety. Some of the areas in which public safety might be affected have already been discussed in that bridge deficiencies can have safety impacts along with any inabilities of truck combinations to keep entirely within their lanes or otherwise properly negotiate highway configurations. There is the question of braking performance of large and heavy vehicles. Also, longer vehicles will require more time to pass, increasing exposure to oncoming traffic. There are considerations relative to the spray from certain combinations in inclement climatic conditions that may affect vision. Additionally, as passenger-vehicle sizes decrease while truck sizes increase, the question of whether injury and fatality rates and numbers will change must be addressed.

Costs to the Public

The extent to which the public will either benefit or be harmed is an important issue when considering truck sizes and weights. To the extent that better uniformity permits greater sizes or weights in the more restrictive states, transportation cost savings will accrue because the capability to move greater loads will result in less trips to move the same amount of goods. Energy consumption will likewise be reduced.

The initial disposition of such transportation cost savings is not clear. In some cases, shipping costs may be reduced. In other cases, the rate of shipping cost increases may be slowed. Savings that are immediately realized might be used for purchase of more efficient equipment. In the long run, however, because of the competitive situation, there is little doubt that the public would benefit.

With regard to the issue of public harm arising as a result of increasing truck sizes and weights, there are general safety concerns and concerns over effects on other transportation modes. These are controversial concerns and very little definitive data are available. Currently available statistics indicate that heavy trucks have a substantially higher involvement in fatal accidents than passenger cars and light trucks on a per vehicle basis. However, there are no statistics indicating the relative involvement of combination vehicles as compared with other heavy trucks. It is known that the frequency of accident involvement of combinations is far below that of other vehicle types on a per vehicle-mile basis (see Chapter Two, Table 9). But even if combinations had the same fatality involvement per registered vehicle as other heavy truck types, their ratio of travel to that of a passenger car would bring their involvement on a per vehicle-mile basis to about the same level. In fact, the annual American Trucking Trends shows that the fatality rates for tractor-trailers, based on the vehicles primarily responsible, are consistently less than those for passenger cars.

Analyses of fatality occurrences relating to the weight of vehicles have not been conclusive, but they indicate that the effect of the weight of a vehicle may level off at about 60,000 lb (27.2 t).

It is important to note that all of the considerations and relationships described relate to vehicles that are currently on the road in common use. Large and heavy vehicle configurations that are now being tested or are in limited use often have substantially better safety records than existing vehicles. However, the limited-use situation may not properly reflect their behavior under expanded use—particularly, because their drivers, at present, tend to be especially selected and paid at premium rates.

In addition to other considerations, greater efficiency in truck transportation may help to reduce accidents. Theoretically, trucks carrying greater payloads would move a given quantity of freight in less trips, resulting in reduced truck exposure in the traffic stream, which should generate a reduction in the number of accidents.

Intermodal concerns relate to truck-rail competition. The question is whether permitting truck size and weight increases will result in capture of more of the rail market. Although this question is pertinent at this time in that decisions presently need to be made relative to possible government support of railroads, it does not appear to be a question that is particularly relevant to this research project.

With respect to the competitive situation, there appears to be only one sound basis on which to base a decision not to take every opportunity to reduce net transportation costs by highway. Net transportation costs are defined as the transportation costs that properly should be incurred by truckers to move commodities when they are paying their fair share of all highway costs. The only basis would be a demonstration of net advantage to the public of maintaining or expanding the railroads current share of shipments subject to cost competition. Such an advantage might occur through energy savings, if these were of such value to the public as to offset lower transportation costs.

Without such a demonstration, the public net advantage would appear to be served by taking every opportunity to reduce transportation costs on both modes.

If there are specific advantages in making certain shipments by rail where any cost advantage of trucking should be overlooked, actions should be taken selectively to encourage these shipments by rail or prevent them by truck.

It would appear not to be good business to avoid reducing truck costs when no net public advantage can be demonstrated. It obviously is beyond the scope of this project to comparatively evaluate public advantages through shipments by rail and truck. For this reason, intermodal concerns are not considered a major issue in this research.

Safety issues are discussed more specifically in Chapter Two.

Related Research

In recent years, the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) have conducted or sponsored several studies involving truck size and weights and their effects on highways and transportation costs. Some of these studies are ongoing.

The American Association of State Highway Officials pioneered in determining the effects of vehicle weights on highways with the road tests conducted in Illinois, Maryland, and Idaho (WASHO) in the late 1950's and early 1960's. Most highway design mechanics in use today and most of the analyses that have been conducted on the impact of increased vehicle sizes and weights on the highway system are based on the Illinois AASHO Road Test results.

An FHWA study, completed in 1968, concluded that axle weights and gross weights could be increased substantially above current levels with resulting savings in truck transportation costs being 12 times greater than the additional cost to the highway system that would be necessary to accommodate the heavier vehicles (*7*). This study, however, predicated additional highway costs mainly on the basis of differences in construction, reconstruction, and resurfacing schedules that would occur as a result of shortened service lives because of increased equivalent axle loads. Estimated service lives were based on highly theoretical road survivor curves. No adjustments were made for the condition of existing pavements. The equivalent axle load determinations were based on questionable assumptions regarding the advantage that would be taken of increased axle load provisions. For these reasons, the relationship between transportation cost savings and additional highway costs for the axle loadings recommended appears to be substantially overstated. However, the basic findings of the very comprehensive study were undoubtedly valid: that substantial net transportation cost savings can be realized through changes in laws and regulations to permit optimal types of commercial vehicles to use the nation's highways to full advantage (*7*).

In 1972, the study previously described was summarized in an FHWA report that updated the earlier study and discussed some of its implications (*8*). This report was prefaced by a statement that said in part that "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 for appropriate maximum loads."

The Highway Research Board (now Transportation Research Board) published a report in 1973 identifying highway system factors that are influenced or impacted by truck sizes and weights, including the types of benefits and disbenefits that might be expected (*9*). The National Association of Australian State Road Authorities is also conducting comprehensive studies on truck sizes and weights, highlighting the factors that need to be considered (*10*).

A recent Federal government interagency task force report, which forecasted transportation needs and goals over the next 20 years, envisioned truck weight and size increases to levels substantially above those currently permitted (*11*).

Recent work at Oregon State University led to the development of a computer model for analyzing changes in size and weight of trucks (*12, 13*). This research is still in process, but preliminary findings indicate that nonuniformity poses a major problem to truck transportation.

Austin Research Engineers, Inc. is conducting an FHWA study of the effects of vehicle size, weight, and configuration on pavement performance and maintenance requirements (*14*). The output from this study may be able to verify the impacts on pavements identified in this research.

Although possibly not properly designated as research, one of the best sources for truck commodity flow data is the U.S. Bureau of the Census, Census of Transportation, Commodity Transportation Survey. The most recent survey has been modified to obtain consistency of commodity flow and manufactured goods by integration with the Census of Manufacturing (*15*). This will make this data source even more useful. It should be noted that the Bureau of the Census collects the data but does no data manipulation.

There is substantial research being undertaken continuously by the U.S. Department of Agriculture in such divisions as the Agricultural Research Service and the Statistical Reporting Service. Many reports are developed on agricultural production, consumption, and shipments, which were invaluable in the conduct of this study. Of particular note is the annual Agricultural Statistics.

Research undertaken by the Transportation Systems Center in Cambridge, Mass., contributed significantly to this study—particularly in the area of motor vehicle operating costs (*16*), as did research in the same area conducted in Australia (*17*).

In addition, other research sources were identified and used in the many statistical and technical areas embraced by this study, which are referred to elsewhere in this report and listed in the references.

RESEARCH APPROACH

The research was conducted over a period of 20 months and consisted of the following tasks:

1. Compilation and analysis of laws and regulations.
2. Analysis of the trucking industry.
3. State visits and canvass of state highway agencies.
4. Development of a national commodity flow model.
5. Evaluation of alternative levels of uniformity and their potential impacts.
6. Development of recommended approaches to uniformity.

Compilation and Analysis of Laws and Regulations

Nine existing compilations of state laws and regulations relating to truck sizes and weights were identified and compared. Two of the sources obtained their information from the other sources. The remaining sources obtained their information primarily through direct contact with each state. These sources were synthesized into a compilation designed specifically for the needs of this project. Disagreements among the sources on specific size and weight limits were identified and reconciled. Accuracy was confirmed with each state.

Analysis of the Trucking Industry

The analysis of the trucking industry involved the following elements: (1) contacts with national organizations and agencies, (2) review of literature, (3) classification of carriers, and (4) truckers' questionnaire.

National Contacts

Interviews were conducted with representatives of the following organizations:

1. American Automobile Association.
2. American Association of Motor Vehicle Administrators.
3. American Association of State Highway and Transportation Officials.
4. American Trucking Association (Highway Engineering Section, Reciprocity Section, and Department of Interstate Cooperation).
5. Federal Highway Administration (Office of Traffic and Operations, Office of Research, Office of the General Counsel, Office of Highway Safety, and Office of Program and Policy Planning).
6. Highway Users Federation for Safety and Mobility.
7. International Association of Chiefs of Police.
8. Motor Vehicle Manufacturers Association.
9. National Independent Truckers Unity Committee.
10. Private Truck Council.
11. Truck Trailer Manufacturers Association.
12. Western Highway Institute.
13. Staff Members of the Subcommittee on Roads of the House Investigative Committee, House of Representatives, U.S. Congress.

The purpose of the interviews was to identify the concerns and viewpoints of interested organizations and agencies; confirm cooperation and assistance by the trucking associations in all areas, including selection of the carrier sample; and identify additional sources of information of relevance to this research.

Literature Review

A bibliography of related literature was developed using HRIS searches supplied by the Transportation Research Board, surveys of the Department of Transportation library and University of Maryland library, and literature obtained from or suggested by various individuals during the visits with national organizations and agencies. New reports were reviewed as they became available.

The bibliography is contained in Appendix A.

Carrier Classification

The project statement specified that "classifications should be developed based on the type of carriers and operations that are responsive to differences in vehicle size and weight." A list of possible impacts on carriers was developed and supplemented through interviews with national trucking organizations and a literature review. Logical groupings of types of operation characteristics were prepared. These were related to existing classification systems, including those of the ICC.

The carrier classification was used as a basis for stratifying the truckers' questionnaire and identifying key variables for analysis.

Truckers' Questionnaire

A draft truckers' questionnaire was prepared and tested by review with national and state trucking associations and with selected truckers. This field testing resulted in some modification and in the deletion of some questions where it became apparent that answers would not be known (such as operational cost data in a large number of instances). The product was lengthy and detailed, but the trucking associations and truckers agreed that this was necessary because the information requested is not otherwise available.

A second questionnaire was prepared, especially for owner-operator/independent truckers, because the former questionnaire raised many questions not relevant to this group (such as in the areas of breakbulk, terminal operations, etc.) The second questionnaire was reviewed with the chairman of one of the associations of independent truckers and with the market research of a trucker's magazine catering to owner-operators.

A letter of endorsement from one of four truckers associations accompanied each mailing to the common and private carriers. These associations were the American Trucking Associations, Western Highway Institute, Private Truck Council, and Private Carriers Conference. In total, 7604 questionnaires were mailed.

Appendix B contains a copy each of the truckers' questionnaires.

State Visits and Canvass of State Highway Agencies

State Visits

Visits to 12 states were conducted to identify costs and problems associated with nonuniformity and to gain insight into historical explanations of the existence of the diverse range of limits. The states were selected based on: (1) evaluation of the variation in laws and regulations among the states to ensure coverage of limitation levels; (2) geographical features, trucking population characteristics, and degree of use of routes within the state; and (3) consideration of the recommendations of representatives from national organizations and agencies.

The states visited were Massachusetts, Pennsylvania, Maryland, North Carolina, Iowa, Nebraska, Oklahoma, Louisiana, Wyoming, Colorado, California, and Wisconsin. In each state, interviews were conducted with state officials, trucking association officials, and an average of 5 truckers with varying size and type of operations. State officials interviewed included representatives of the legal, planning, maintenance, bridge, traffic, highway safety, permits, and dimension and weight enforcement offices of highway departments, the police enforcement agency, and some state legislators. A standard visitation format was used.

Highway Agency Questionnaire

Questionnaires were sent to the state highway agencies in all of the 48 contiguous states. The questionnaire sought the following kinds of information: (1) basic documents such as laws, maps, in-house studies of truck weights, truck-related trend data, and pavement and bridge design procedure; (2) legal truck size and weight limits for various highway systems including exceptions and pending legislative changes; (3) bridge condition data; (4) pavement design data; (5) accident experience; (6) potential impacts of three uniformity level options; (7) interstate cooperation; and (8) enforcement.

The questionnaire is shown in Appendix C. The results are discussed in Chapter Two.

Development of a National Commodity Flow Model

One of the major undertakings of this project, basic to the definitive accomplishment of the objectives, was the creation—for the first time—of a computerized, national interstate truck commodity flow network. This identifies the vast majority of commodity flows within the interstate corridors in which they occur and the trucks presently carrying them by type, size, weight, and load status.

Numerous data sources were used in the creation of this model with heavy reliance on three: (1) 1972 Census of Transportation (Commodity Transportation Survey, Truck Use Inventory); (2) U.S. Department of Agriculture Statistics; and (3) Truck weight studies conducted cooperatively by the individual state transportation agencies and the Federal Highway Administration.

Other data sources are mentioned in Appendix D and in the bibliography in Appendix A. They provided data on specific kinds of movements, such as exports and imports and movements of natural resources. Several of these movements had to be constructed from source and destination information. Numerous discussions were held with representatives of government and other agencies, who developed the statistical information, to assure their proper interpretation.

Once the existing commodity flows by truck were simulated on the computer in the different corridors, a base was provided for transferring the flows into more efficient truck types, sizes, or weights that would be permitted under alternative uniformity provisions. This led to the definitive conclusions, relative to the impacts of nonuniformity and the nature of optimal uniformity, that are presented in this report.

The commodity flow model is described in greater detail in Appendix D, and illustrations are provided to show the corridor link and node network (Fig. D-1) and basic computer programs used in constructing the model (Figs. D-2, D-3, and D-4). Briefly, the model can be described as composed of the following components:

1. *Commodity Flow Network*—The tonnage of 14 major commodity classes was determined for each direction on each of 154 links of a national network with 54 nodes.
2. *Truck Type Distribution*—The distribution of 10 truck classifications was determined for each direction on each of the 154 links based on truck weight study data from 297 state operated loadometer stations. Three years of loadometer data were used.
3. *Commodity Flow Disaggregation*—The tonnage and ton miles of each commodity were disaggregated to each truck classification within each link based on average payload and loading characteristics of the truck classifications.

Evaluation of Alternative Levels of Uniformity and Their Potential Impacts

This phase of the research involved the development of vehicle operating and highway impact cost factors, the formulation of alternative levels of uniformity, and, finally, the evaluation of these alternatives in light of the cost factors and the commodity flows.

Vehicle Operating Costs

Vehicle operating costs were defined to include fuel costs, motor vehicle maintenance costs, depreciation and finance costs, and labor costs. Previous studies were used to develop values for these costs. In particular, studies by the DOT Transportation Systems Center, the National Association of Australian State Road Authorities, Whiteside et al. (*NCHRP Report 141*), and the Oregon State University were found most useful.

Cost data in each of the four categories were developed for several vehicle types ranging from the relatively small 2-S1 (two-axle tractor, single-axle semitrailer) to the 3-S2-4 (three-axle tractor, two-axle semitrailer, four-axle trailer). Costs were then aggregated and portrayed in two nomographs from which the line haul cost per mile may be obtained, given the vehicle configuration and either the gross combination (vehicle) weight or, assuming a loaded vehicle, the density of the commodity being hauled.

Highway Cost Factors

Determination of highway costs involved the development of pavement surface conditions regionally, broken down by highway mileage, and development of regional overlay and reconstruction costs for intermediate and high-type pavements. Performnace curves were developed for rigid and flexible pavements, relating equivalent axle load repetitions, pavement thickness requirements, and pavement surface ratings. These various factors were used to determine highway costs necessary to offset regional increases in equivalent axle load repetitions.

Levels of Uniformity

Alternative levels of uniformity were developed after examination of current national and regional limits, and with consideration to the recommendations of both trucking officials and highway officials. Vehicle safety characteristics, economy, and extent of current usage were also primary concerns.

Evaluation of Nonuniformity Impacts

A multilevel analysis was conducted of the benefits and disbenefits that could arise at different levels of uniformity. One method employed was the redistribution of commodities among vehicle types within one region to match the current distribution in a second region that had a differing set of size and weight limits. Another method was to transfer commodities currently being transported in fully loaded vehicles to vehicles capable of carrying greater loads, or to permit vehicles currently loaded to legal weight limits to carry additional weight to match higher weight limits. In each case, changes in number of trips were computed. These were translated into changes in trip mileage, transportation cost, energy consumption, equivalent axle load repetitions, and accident occurrences.

The highway cost factors were applied to the changes in axle load repetitions to determine regional costs for additional overlay or reconstruction of the current highway plant that would be necessary to offset the computed increase in equivalent axle load repetitions.

Development of Recommended Approaches to Uniformity

Early in the study, certain practical maximum limits for truck sizes and weights were identified. These outer limits were based on (1) existing vehicle capabilities and (2) the maximum limits allowed by any individual state or major toll road.

During the analyses, numerous variations or scenarios within these limits were evaluated. These led to the determination of probable ranges of benefits and costs associated with different uniformity options which provided the basis for the conclusions and recommendations of this study.

Some recommendations were formulated for implementating uniformity—taking into consideration the legislative process, the limits of authority of various governmental bodies, and advocacies on both sides of truck size and weight issues.

CHAPTER TWO

FINDINGS

The diversity in truck size and weight limits that exists across the country creates transportation inefficiencies that result in higher costs and unnecessary energy consumption. Yet, it is difficult to define exactly what the optimal level of uniformity should be. It is not necessarily at the most liberal level of sizes and weight provision by any state, because economic benefits associated with these most liberal levels may not justify the highway and public costs that are involved. If net economic benefit is the criterion, it does not necessarily require that every state have exactly the same laws and regulations governing vehicle size and weight because individual states and sometimes groups of states have special enterprises that may deserve special transportation provisions important to their economies. It is presumed that economic and other benefits in these states would outweigh highway and public costs to provide them. However, these same provisions, at similar cost, may produce minimal benefits in other states, the bulk of the movements not being interstate in nature or confined to a few states. Thus, to maximize benefits versus costs in these cases, states would have different laws and regulations.

Optimal uniformity logically occurs when there is general provision for all interstate movements traversing all states where it can be demonstrated that the aggregate public benefit, converted to economic terms, exceeds all public and highway costs, also converted to economic terms.

It is obvious that there is not adequate common provision for all of these movements. The laws and regulations in some states and groups of states form barriers to more efficient, cost effective, and energy conservative interstate truck movements that are generally permitted in most other states. In some cases, more efficient movements of a higher order are permitted in only a few states and sometimes on limited systems, which, if generally permitted under properly controlled circumstances, would earn added benefits far outweighing added costs.

These findings are discussed in this chapter. Current size and weight laws are presented and their diversity is examined. How the trucking industry is affected by the laws is discussed, as is the effect of truck sizes and weights on the highway system. Estimates of transportation cost savings, other benefits, and additional highway costs that would accrue at several alternative levels of greater uniformity are also presented.

PRESENT LAWS AND REGULATIONS

Summary of Laws

Size and weight limits vary substantially among the states. Each state separately assigns vehicle height and width limits. Length limits may or may not be specified for single unit trucks, semitrailers, full trailers, and combination vehicles. Types of combination vehicles permitted vary significantly from tractor semitrailers only in some states to triple-trailer combinations in others. Weight limits may or may not be assigned to tires, wheels, steering axles, other single axles, tandem axles, and triaxles. Maximum weights are determined in some states by a formula or table, whereas other states specify maximum weights by vehicle type or number of axles and axle spacing. Weight formulas and axle spacing requirements vary among the states.

Table 1 is a summary of size, weight, and speed laws and regulations by state. The range of variation of size and weight limits among states is given in Table 2.

Characteristics of Laws and Regulations

Establishment of Limits

Limits may be established by a law or a regulation. A large majority of states specify each limit in their law. In some cases, the state legislature empowers state highway authorities to establish limits and/or designate highway systems or routes on which limits may be used. In those cases noted where state highway authorities have established limits, the limits are usually made at least equal to those of contiguous states.

Intra-State Differences

Limits sometimes will vary among highway systems within a state. Exceptions to limits may be provided for carriers of specific types of commodities or for selected industries. Toll-road limits may differ substantially from limits on other state highways. Some states also designate certain routes on which they will permit heavier or larger vehicles.

Table 1 includes limits for each type of highway system where they differ within a state. There are 25 states that vary their limits on differing highway systems or that designate routes for larger vehicles to use.

Tolerances

Eighteen states have statutory tolerances on axle weights. Nine of those states also have tolerances on gross weights. The tolerances normally range from 5 percent to 10 percent over specified weight limits.

It became readily apparent during the study that truckers consider axle-weight limits to be the specified limit plus the tolerance. In fact, some of the size and weight limit publications heavily used by truckers list weight limits including, but not identifying, tolerances. For example, a 20,000-lb (9-t) axle limit plus 10 percent tolerance would be listed in the publication simply as a 22,000-lb (10-t) axle limit.

Permit Operations

All states provide for permits that can be obtained for nonreducible oversize and overweight movements. In 11 states, permits are also available that are of annual or long-term duration, allow multiple trips, and are not limited in commodity application. These are generally provided at little or no cost and serve to effectively increase state limits. Similar permits are available for use on toll roads in eight other states. Examples of permit use within these 19 states include permits for the use of triple trailer combination vehicles that are available in 4 western states, permits for use of turnpike doubles on toll roads in 5 states, and permits allowing heavier weights in all 19 of the states even though the loads carried are easily reducible. Limit increases available under regular multiple trip permits are specified in Table 1.

Grandfather Clause

The Federal Aid Highway Act of 1956 placed a limit on weights for vehicles operating on Federal-aid Interstate highways of 18,000 lb (8.16 t) on single axles, 32,000 lb (14.5 t) on tandem axles, and 73,280-lb (33.23-t) gross vehicle weight. Vehicle width was limited to 96 in. (2.44 m). Many states permitted greater weights, and two permitted greater widths at the time; under a grandfather

TABLE 1

LEGAL MAXIMUM SIZE, WEIGHT, AND SPEED LIMITS

	SIZE									WEIGHT																			SPEED
	WIDTH[1]	HEIGHT	LENGTH FOR SINGLE UNITS AND PERMISSIBLE COMBINATIONS (ft.)							TIRE, WHEEL AND AXLE LIMITS (KIPS)							GROSS WEIGHT LIMITS (KIPS)					SPECIFIED MAXIMUM LIMITS (KIPS)							
										WHEEL	STEERING	SINGLE AXLE		TANDEM AXLE			TYPE	APPLIES TO		MAX	MAX. GVW	TRUCK		OTHER COMBINATION VEHICLE					
	(in.)	(ft.)	TRUCK[2]	TRAILER SEMI/FULL	TRACTOR and SEMI-TRAILER	TRUCK and TRAILER	TRACTOR SEMI-TRAILER and TRAILER (Doubles)	TRUCK and TWO TRAILERS	TRACTOR SEMI-TRAILER and TWO TRAILERS (Triples)	and/or •Lbs per In. of Tire Width	AXLE[3]	limit	plus tolerance	minimum spacing (in)	limit	plus tolerance	of LIMIT[4]	any group of axles	extreme wheel base only	GVW	plus tolerance	two axles	three axles	three axles	four axles	five axles	six axles	seven or more axles	
ALABAMA	96	13.5	40	NS	55	NP	NP	NP	NP	NS	NS	20	22/20	40	40/36	44/39.6	tB		X	84/80	92.4/80	40	60	60	75	80	80+ 10%/80	80+ 10%/80	50/55
ALASKA	96+	13.5	40	45/40	65	70	70	70	NP	•500	NS	20		40	34		tB			114		40	60	60	80	92	96	101+	50
ARIZONA	96	13.5 14DP	40	NS/40	65	65	65	NP	NP (105P on I-15 only)	NS	NS	20		40	34		tB	X<18'	X>18'	80 105.5P on I-15 only									55
ARKANSAS	96	13.5	40	NS	60	65	65	65	65	9	12	18		40	32		AL SM			73.28									
CALIFORNIA	100w/l 96/96	13.5 14 w/l	40	40e	60e	60e	65	65	65	10.5	12.5e	20		42	34		tB	X	X>18	80		40	60	60	80	80	80		55
COLORADO	96+	13 13.5D	35	NS	65	65	65	65	65	9	NS	18/20		40	36		of/fB SM	/X	X/	85/80		/30	/46	/60	/80	/80	/80	/80	55
CONNECTICUT	102	13.5	55	NS	55	NP	NP	NP	NP	•600	NS	22.4	22.848 (+2%)	NS	36	36.72 (+2%)	SL			73		32 36De	53.8 58.4De	53.8 58.4De	67.4 73De	73			55
DELAWARE	96	13.5	40	NS	60	60	65	NP	NP	NS	NS	20		48	40/36		SM/tB	/X		80		40/40	65/60	60/60	70/70	80/80	80		55
DIST. of COLUMBIA	96	12.5	40	NS	55	55	NP	NP	NP	NS	NSe	21	22	40	37	38	ot		X	72.28	73.28								55
FLORIDA	96	13.5	40e	NS/40e	55	55	NP 110 TP	NP	NP	•550	NS	20	22 (+10%)	40	40	44 (+10%)	ot tB	X>73.5K	X<73.5K	80 133.8TP					76	80	80		55
GEORGIA	96+	13.5	55	NS	55	55	55	55	55	9 10.17w/t	NS	18	20.34e (13%)	40	36	40.68	tB	X		80		40.68	60	60	76.5	80	80		55
HAWAII	108	13.5	40	NS	55	65	65	NP	NP	12	NS	24		42	34		tB	X		80.8									55
IDAHO	102/96	14	40D	NS	65De 75e	75	65 98DP	75 98DP	75 98DP	10 •800e	NS	20		48	34e/34		fB tB	X		80 105.5P									55
ILLINOIS	96+	13.5	42	45/42	55 65e	60	60 65D	NP	NP	NS	NS	18e		40	32		SM ot		X	73.28		36	50	50	64	73.28			55
INDIANA	102T 96	13.5 14T	36	NS	55 51.2w/t	55	65 98TP	NP	NP	9 •800	NS	18 22.4T	19e	40	32 36T	33e	SL AL			73.28 124.4TP		36	50	54					55
IOWA	96	13.5	40	NS/35	55	55	60	NP	NP	NS	NS	18	18.54	40	32	32.96	ot	X		72.634	72.38								55
KANSAS	96+	13.5 14T	42.5	NS/42.5	50	65	65 105TP	65 1.5TP	65	9 100	NS	20		40	34		ot	X		130TP 85.5/80									55

TABLE 1—(Continued)

	SIZE									WEIGHT																			SPEED
	WIDTH[1] (in.)	HEIGHT (ft.)	LENGTH FOR SINGLE UNITS AND PERMISSIBLE COMBINATIONS (ft.)							TIRE, WHEEL AND AXLE LIMITS (KIPS)							GROSS WEIGHT LIMITS (KIPS)					SPECIFIED MAXIMUM LIMITS (KIPS)							
			TRUCK[2]	TRAILER SEMI / FULL	TRACTOR and SEMI-TRAILER	TRUCK and TRAILER	TRACTOR SEMI-TRAILER and TRAILER (Doubles)	TRUCK and TWO TRAILERS	TRACTOR SEMI-TRAILER and TWO TRAILERS (triples)	WHEEL and/or •Lbs per In of Tire Width	STEERING AXLE[3]	SINGLE AXLE limit	SINGLE AXLE plus tolerance	TANDEM AXLE minimum spacing	TANDEM AXLE limit	TANDEM AXLE plus tolerance	TYPE of LIMIT[4]	APPLIES TO any group of axles	APPLIES TO extreme wheel base only	MAX GVW	MAX. GVW plus tolerance	TRUCK two axles	TRUCK three axles	OTHER COMBINATION VEHICLE three axles	four axles	five axles	six axles	seven or more axles	
KENTUCKY	96D	11.5 13.5D	35D	NS	55D	NP	65DP / 65	NP	NP	•600	NS	20	21 / 20	42	34	35.7 / 34	AL			82D / 80									55
LOUISIANA	96	13.5	35	NS	65	65	65D	65D	NP	•450	NS	18		40	32		AL			73.28									55
MAINE	102 / 96+	13.5 14w/l	45	45	56.5	56.5	NP	NP	NP	•600		22		48	38 / 34		SM fB			80		34 / f	54 / f	54 / f	69 / f 69e	80 / f			
MARYLAND	96+	13.5	40	NS	55	55	65D	55	55	NS	NS	22.4	23.4	48	40	41	of SM		X	73.28	74.28		55	55	65	73.28			
MASSA-CHUSETTS	96+ 102T	13.5 14TP	35	NS / 33	55	55e	NP 108TP	NP	NP	•800	NS	22.4	23.52P	NS	36	37.8P	fB SM		X	80 99P 127.4TP		46	80	80					
MICHIGAN	96	13.5	40	NS	55	59	59 65D	NP	NP	700	NS	18 20D 34DP		42	26 34D		fB AL			139D / 80									
MINNESOTA	96	13.5	40	45	60	60 65DP	65DP	NP	NP	9	NS		20	40	34		tB	X		80									
MISSISSIPPI	96	13.5	35	NS	55	55	55	NP	NP	formula tire size	NS	18D		40 48D	28.65 32D		of	X		73.28 D / 73.28									
MISSOURI	96+	13.5	40	NS	55	65D / 65	65D / 65	65	65	NS	NS	18		40	32		of		X	73.28 D / 73.28									
MONTANA	102 / 96	13.5	40	NS	60 65P	65P 85DP	65P 85DP	NP	NP	NS	NS	18 20DP		40	32 34DP		fB of	X<18' +	X>18'	76.8 105.5 DP		40DP /	60DP /	60DP /	80DP /	85.5 DP /	90DP /	105.5 DP /	
NEBRASKA	96	14.5	40	NS / 40	60	65	65	65e	NP	10 / 9	NS	20 / 18	20 / 18.9 20P	40	34 / 32	34 / 33.6 34P	of	X		95 / 95P 73.28		40 /	60 /	60 /	85 /	85.5 /	90 /	95 /	
NEVADA	96+	14	40	NS	70 75	75	75	75	10 P	NS	12.5	20		40	34		fB tB			129P 109 / 80									
NEW HAMPSHIRE	96	13.5	35	NS	55	55	NP	NP	NP	•600	NS	22.4		NS	36		tB SM	X		80		33.4	55e / 47 e	52.8	66.4	73.28			
NEW JERSEY	96	13.5	35	NS / 35	55	55	55	55	NP	•800	NS	22.4	23. 2	40	34	35.7 / 34	AL tire limits	X		80									
NEW MEXICO	96+ 102D	13.5	40	NS	65	65	65	NP	NP	11 •600	NS	21.6		40	34.32		of	X<18'	X>18'	86.4									
NEW YORK	96	13.5	35	NS / 35	55	55	55D 108TP	NP	NP	11.2 •800	NS	22.4		46	36		tB			7 8, 127.4TP									
NORTH CAROLINA	96	13.5	4	NS	55	55	NP	NP	NP	9 •600	NS	19	20	48	36	38	SM of	X		76	79.8	30 31. w/t	47.5 49.9w/t	47.5 49.9w/t	64 67.2w/t	76 79.8w/t			

TABLE 1—(Continued)

	SIZE									WEIGHT																			SPEED
	WIDTH[1]	HEIGHT	LENGTH FOR SINGLE UNITS AND PERMISSIBLE COMBINATIONS (ft.)							TIRE, WHEEL AND AXLE LIMITS (KIPS)							GROSS WEIGHT LIMITS (KIPS)					SPECIFIED MAXIMUM LIMITS (KIPS)							
												SINGLE AXLE		TANDEM AXLE				APPLIES TO				TRUCK		OTHER COMBINATION VEHICLE					
	(in.)	(ft.)	TRUCK[2]	TRAILER SEMI/FULL	TRACTOR and SEMI-TRAILER	TRUCK and TRAILER	TRACTOR SEMI-TRAILER and TRAILER (Doubles)	TRUCK and TWO TRAILERS	TRACTOR SEMI-TRAILER and TWO TRAILERS (Triples)	WHEEL and/or *Lbs per In of Tire Width	STEERING AXLE[3]	limit	plus tolerance	minimum spacing	limit	plus tolerance	TYPE of LIMIT[4]	any group of axles	extreme wheel base only	MAX GVW	MAX. GVW plus tolerance	two axles	three axles	three axles	four axles	five axles	six axles	seven or more axles	
NO. DAKOTA	1820/96	13.5	40	NS	65D	60D	65D	NP	NP	550 9/10		20D		40	34D		tB-D SM/of			105.5D/64 64/80									
OHIO	96	13.5	40	45	60	65	65 108TP	65	65	.650		20		48	34 32T		of ot		X	80 127.4TP									
OKLAHOMA	102/96	13.5	40	NS	65	65	65	65	NP	NS	NS	20		40	34		tB	X		90/80			64	64	80	85/80	90/80		
OREGON	96+	13.5	40	NS/35	60D	65D 75D	65D 75D	NP	105PD	10 .550	NS	20		40	34		tB	X<18'	X>18'	80 105.5									
PENNSYLVANIA	96+ 120T	13.5	40	NS	55 70T	55 70T	NP	NP	NP	.800	NS	22.4	23.07	NS	36	37.08	SM ot	X		73.28 100T 125TP		44.8T	58.4T	50	60 62				
RHODE ISLAND	102	13.5	40	NS/40	55	55	NP	NP	NP	NS	NS	22.4		40	36		SM			73.28/80P		36	44	53.8	67.4	73.28			
SOUTH CAROLINA	96	13.5	40	NS	55	55	NP	NP	NP	10	NS	20	22/20	40	36/32	39.6/35.2	SM tB	X		80		35	46	50	65/76	73.28/80			
SOUTH DAKOTA	96	13.5	35	NS	70	70	70 80D	NP	NP	.600	NS	20		40	34		tB	X		95/80									
TENNESSEE	96	13.5	40	NS	55	55	NP	NP	NP	NS	12	18		NS	32		AL			73.28									
TEXAS	96	13.5	45	NS	65	65	65	65	65	10 .650	NS	20		40	34		tB	X		80									
UTAH	96	14	45	45	65P	65P	65P	65P	105P	10	NS	19.8 20P		40	34 36P/34		tB	X		125PD 84P/80									
VERMONT	96	13.5	60	NS	60	60	NP	NP	NP	11 .600	NS	22.4	23.52/22.4	48	36		ot		X	80									
VIRGINIA	96+	13.5	40	NS	55 56w/t	55 56w/t	NP	NP	NP	.650	NS	20	21/20	40	34	35.7/34	SM ot	X		76	79.8	36	50	54	68	70			
WASHINGTON	96+ 102DP	14	35	45 47PD	65 70	65 73P	65	NP	NP	.550	NS	20		42	34		tB	X		80 105.5P									
WEST VIRGINIA	96	12.5 13.5D 13T	40	NS	50 55D 55TP	50 55D	NP	NP	NP	NS	NS	20		40	34		tB	X		65 80D									
WISCONSIN	96	13.5	35	45	55	55	NP	NP	NP	10 11	13	20		42	34		tB	X		80									
WYOMING	102D/96	14	60	85	85	85	85	85	NP	NS	NS	20		40	34		tB	X		101/80									

TABLE 1—(Continued)

In General

(1) When two different limits are shown which are separated by a diagonal line, the limits above the line are applicable to non-Interstate System highways and below the line apply to the Interstate System.

(2) P = A permit is required. This designation is used only when the permits are of an annual, multiple trip nature.

(3) D = Designated highways only. The state specifies which highways can be operated on under the given limits.

(4) N.S. = Not specified. The law does not specify any limits.

(5) N.P. = Not permitted by law.

(6) w/l = With load. This specifies a size limit including the load if the law permits the load to extend beyond the vehicle length limit.

(7) w/t = The limit including any statutory tolerance.

Specific Footnotes to Table

(1) Width: The plus sign following some width limits indicates that the state allows such things as mirrors, other safety devices, and pneumatic tires to protrude an additional six inches.

(2) Truck length: Limits listed are for 3 axle vehicles. State limits for 2 axle vehicles may be less.

(3) Steering axle weight limits: Limits are specified only when there is a specific limit other than the single axle limit for steering axles.

(4) Type of Gross Weight Limit:

(a) fB = Bridge Formula B ($w = 500(\frac{LN}{N-1} + 12N + 36)$)
(b) tB = A table of axle weights derived from Bridge Formula B
(c) of = A formula other than Bridge Formula B
(d) ot = A table other than Bridge Table B
(e) SM = Specified Maximum Limits
(f) AL = Axle Limits

Conversion factors
1 inch = 2.54 centimeters; 1 foot = 0.3048 meters; 1 lb = 453.6 grams; 1 kip = .4535 tonnes.

TABLE 2

RANGE OF MAXIMUM SIZE AND WEIGHT LAWS

	RANGE OF VARIATION IN WEIGHT LAWS		
	Single Axle Weight (lbs.)	Tandem Axle Weight (lbs.)	Gross Vehicle Weight (lbs.)
Minimum	18,000	32,000 (1)	73,000
Maximum	22,400 (23,520) (2)	40,000 (44,000) (2)	139,000

	RANGE OF VARIATION IN DIMENSION LAWS								
	Weight (inches)	Height (ft.)	Length of (in feet):						Number of Units Permitted to be Towed
			Truck	Semi Trailer	Full Trailer	Tractor Semitrailer	Other Combination		
Minimum	96	12.5	35	40	33	55	55		1
Maximum	102 (3)	14	60	NS (45) (4)	NS (45) (4)	85	108		NS

(1) Michigan permits 32,000 lbs. on designated highways; 26,000 on all other highways.

(2) Number in parenthesis represents maximum permitted including tolerance.

(3) 108" in Hawaii; 120" on Indiana and Pennsylvania Turnpikes.

(4) N.S. means the limit is not specified by law. The number in parenthesis is the largest specified limit.

Conversion Factors
1 inch = 2.54 centimeters
1 foot = 0.3048 meters
1 kip = 0.4535 tonnes

clause in the Federal Aid Highway Act, these states were allowed to continue to permit those greater limits on their Interstate highways. Although Federal law in 1975 allowed increases in weight limitations to 20,000 lb (9.07 t) on single axles, 34,000 lb (15.4 t) on tandem axles, and 80,000-lb (36.28-t) gross weight, 25 states and the District of Columbia presently permit greater weights and/or widths on their Interstate highways under the grandfather clause. Table 3 lists current grandfather clause size and weight applications.

Grandfather Clause Applied to Permit Operations

In recent years, some states have made permits available for the regular operation of vehicles on their Interstate highways at weights in excess of Federal levels. These permits can be provided only in those states which, prior to the Federal Aid Highway Act of 1956, did not specify in their law that permit-overweight operations were allowed only in the case of irreducible or not-readily-dismembered loads. All of the states listed in the gross weight column of Table 3, except New Mexico, provide such permits.

Regional Characteristics

Many similarities in size and weight limits can be found by region. For example, a comparison of single axle weight limits on a regional basis (see Fig. 1) reveals that the northeastern states from Maryland north, except Delaware, permit weights of 22,400 lb (10.15 t) on single axles, while a number of states bordering the Mississippi River limit single-axle weight to 18,000 lb (8.16 t). The remaining states in the southeast and west permit 20,000 lb (9.07 t), although some of the states allowing 20,000-lb (9.07-t) single-axle weights require annual permits and, for some others, the 20,000-lb (9.07-t) limit includes statutory tolerances.

Examination of tandem axle weight limits, shown in Figure 2, reflects similar regional patterns. It can be seen from Figure 3 that maximum gross weights permitted in the west and southeast are generally greater than gross weights permitted in the northeastern and Mississippi Valley states.

There are also regional characteristics in lengths (Fig. 4) and types of combination vehicles permitted (Fig. 5).

TABLE 3

GRANDFATHER CLAUSE APPLICATIONS ON INTERSTATE SYSTEM

	Single axle weight limits (lbs)	Tandem axle weight limit (lbs)	Gross vehicle weight limit (lbs)	Width (1) (inches)
Federal Limit	20,000	34,000	80,000	96
weight or width permitted on Interstate highways				
1. Alabama		36,000 (2)		
2. Colorado		36,000		
3. Connecticut	22,400 (2)	36,000 (2)		102
4. Delaware		36,000		
5. District of Columbia	21,000 (2)	37,000 (2)		
6. Florida	22,000 (3)	40,000 (2)		
7. Georgia	20,340 (3)	36,000 (2)		
8. Idaho			105,500 (4)	
9. Maine	22,000			
10. Maryland	22,400 (2)	40,000 (2)		
11. Massachusetts	22,400 (5)	36,000 (5)	99,000 (4)	
12. Montana			105,500 (4)	
13. Nebraska			95,000 (4)	
14. New Hampshire	22,400	36,000		
15. New Jersey	22,400			
16. New Mexico	21,600	34,320	86,400	
17. New York	22,400	36,000		
18. North Carolina		36,000 (2)		
19. Oregon			105,500 (4)	
20. Pennsylvania	22,400 (2)	36,000 (2)		
21. Rhode Island	22,400	36,000		102
22. Utah			105,500 (4)	
23. Vermont	22,400	36,000		
24. Washington			105,500 (4)	
25. Wyoming		36,000		

(1) Width limit exceptions are noted only for those states allowing the body of the vehicle to extent beyond 96". Several additional states allow widths beyond 96" for such things as extremes of pneumatic tires, mirrors and other safety devices, and/or loads.

(2) Does not include statuatory tolerance.
(3) Includes tolerance.
(4) With permit.
(5) Higher weights available under permit.

Conversion Factors
1 inch = 2.54 centimeters
1 kip = 0.4535 tonnes

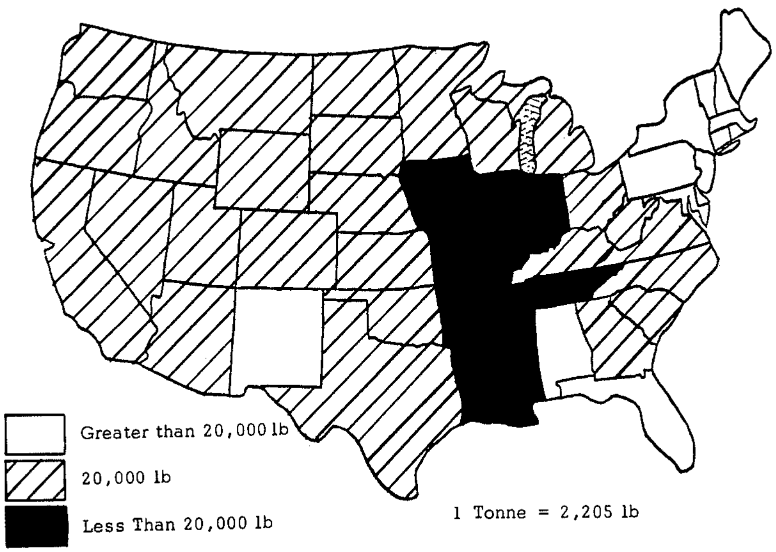


Figure 1. Single axle weight limits. Weight limits depicted include tolerances and annual permits; if limits on the Interstate System differ from limits on other state highways, the Interstate limits are shown.

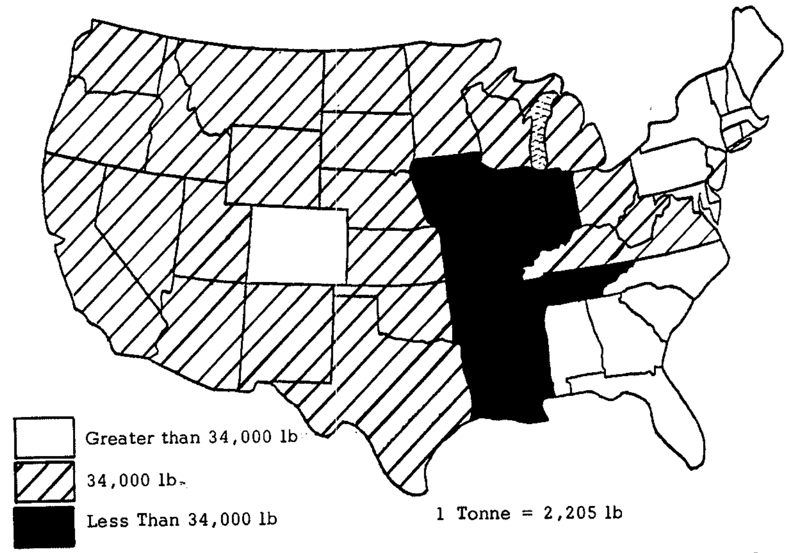


Figure 2. Tandem axle weight limits. Weight limits depicted include tolerances and annual permits; if limits on the Interstate System differ from limits on other state highways, the Interstate limits are shown.

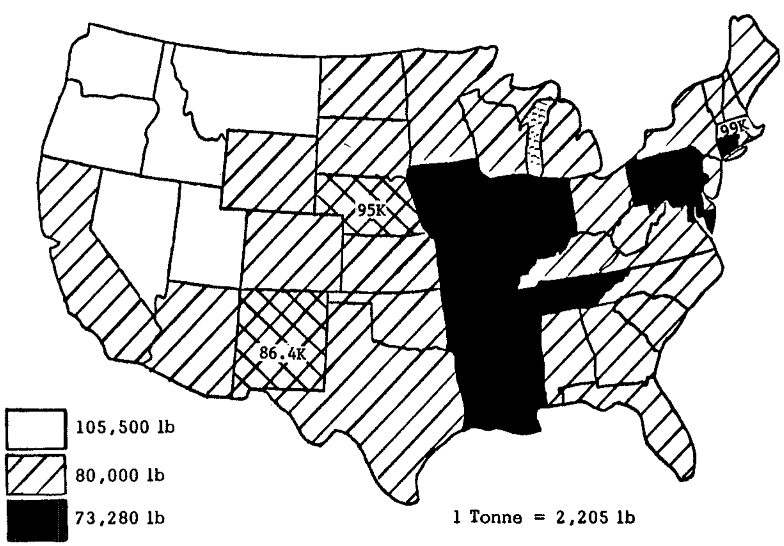


Figure 3. Gross vehicle weight limits. Limits depicted include tolerances and annual, multiple trip permits; if weight limits differ for Interstate System and state primary highways, the Interstate limits are shown.

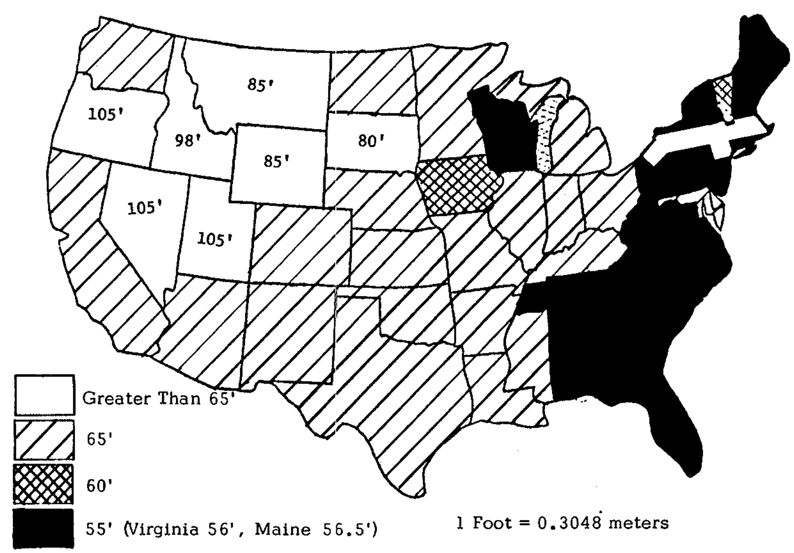


Figure 4. Vehicle length limits. Limits depicted include tolerances and annual, multiple trip permits; if limits differ for Interstate System and state primary highways, the Interstate System limits are shown.

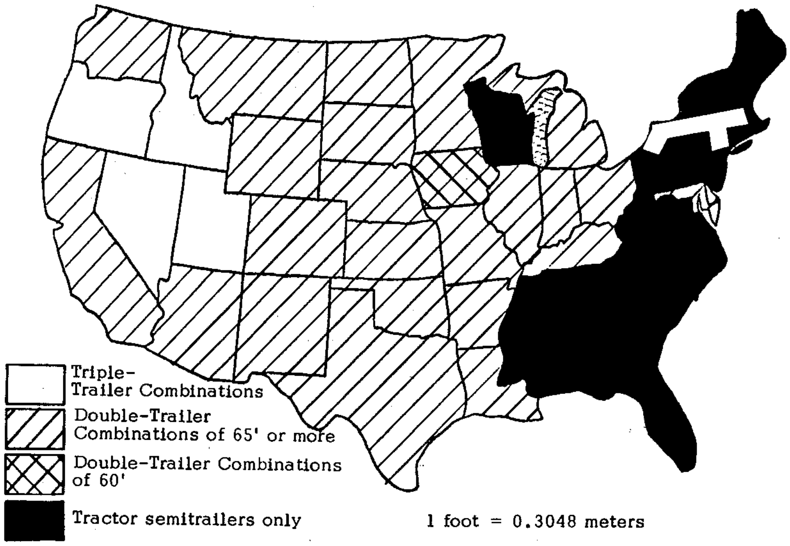


Figure 5. Legality of multiple trailer combinations. This figure depicts the practical use of multiple trailer combinations when combining length laws with laws governing the number of units permissible with a combination. For example, the laws of Arkansas, Colorado, Kansas, Missouri, Ohio, and Texas do not prohibit triples; however, the length limits in those states do not make the use of triples practical. Likewise, doubles combinations would be legal in Georgia, Mississippi, New Jersey, and New York, but the 55′ length limits make the combination impractical.

Most eastern seaboard and southeastern states do not permit lengths in excess of 55 ft (16.76 m), with the exceptions of some toll roads; the remaining states allow lengths generally of 65 ft (19.8 m). A block of states in the west allows combination vehicle lengths of 105 ft (32 m) or more. Eastern seaboard and southeastern states are also consistent in prohibiting combination vehicles of more than two units or in restricting lengths to the extent that use of combination vehicles of greater than two units would not be economically viable.

Cooperative Agreements

It does not appear that there are any cooperative agreements among states on uniformity in size and weight laws, with the possible exception of the Multistate Highway Transportation Agreement (MHTA), which has been adopted by two western states, and which is designed specifically to facilitate interstate commercial transportation by adopting minimum weight and dimension standards. A few states cited efforts made with neighboring states that were abandoned because of inability to reach agreement on specifics. A copy of the MHTA is included in Appendix F.

Legal Applications Contributing to Diversity

Statutory Omissions or Ambiguities

Recently, the trucking industry has taken full advantage of loopholes that exist in the size and weight laws of several states, and this serves to further diversify limits among the states. For example, not long ago the weight laws in one western state controlled gross vehicle weight by a formula governing the spacing between the first and last axles, but did not specify percentage distribution of weights on those axles or interior axle sets. The law, designed to protect bridges, permitted gross vehicle weight to increase as the distance between the first and last axle increased. The dump truck operators rapidly availed themselves of this loophole opportunity by towing an empty boat trailer, thereby increasing the extreme axle spacing and allowing them to carry more weight than otherwise permissible or intended.

In other states, where weight laws do not distribute load carrying responsibilities among axles or between the two axles of a tandem axle set, trucks have been designed with an axle that can be raised and lowered. Lowering the axle to the point where it just touches the ground and the wheel turns gives the incorrect appearance that it is in tandem with and sharing equal load-bearing responsibilities with the other axle, thereby allowing the two axles together to carry weights permitted on tandem axle sets.

In these cases, the trucker obtains the advantage of being able to carry heavier payloads, but at the same time a greater impact is placed on the highway plant than would otherwise result with laws requiring proper distribution of the load among the axles of a vehicle.

Legal Interpretations

Interpretations of the law can differ among states and this contributes to diversity. For example, most states restrict the type of combination vehicle that can operate within their boundaries by restricting the number of units that can be included in the combination. States commonly restricting doubles usually limit permissible combinations to two units, which normally are considered to be the tractor and semitrailer. In one state, however, a tractor-semitrailer combination has been legally interpreted to be one unit, which has allowed the addition of another trailer for the operation of a doubles combination within the two unit confines of the law.

Short-Term Laws

In a number of states, laws or regulations have been passed that were intended to be short-term but have never been rescinded. These may apply to such things as the movement of energy resources, where weight limits are "temporarily" increased during energy shortages, and to the movement of highway building materials during the construction of highways.

Laws and regulations originally intended to be temporary generally involve permitting greater axle or gross weights. Failure to rescind the laws has apparently resulted in serious reductions in pavement life in several states.

Enforcement

The extent to which a state enforces its size and weight limits contributes informally to size and weight diversities among states. This applies especially to weight enforcement, because lengths and permissible combinations are readily apparent and, therefore, more easily enforceable.

States develop reputations relative to level of enforcement. In those states that have low enforcement levels, there tends to be a high percentage of overweight trucks, especially if contiguous states have less restrictive limits. In one such state, weighing data revealed that 30 percent of the trucks traveling on an across-state stretch of Federal-aid Interstate highway were overweight. In effect, states that do not enforce their limits have more liberal limits than their laws and regulations reflect.

Political Aspects of Nonuniformity

Legislation Not Objective

Various pieces of legislation concerning vehicle sizes and weights are presented to the legislature each year in virtually every state. In some cases, such as where doubles are not permitted, legislation has been reintroduced annually for a number of years. Major industry associations—representing the needs of the larger interstate carrier—do attempt to coordinate legislation on a national basis. Localized industry, however, tends to press for size and weight benefits most suited to its particular needs, often without consideration of uniformity with contiguous states. Increases in limits resulting from localized industry pressure generally contribute to nonuniformity.

Twelve states were visited during this study; and, in a majority of cases, authorities in these states had no hard data on how various proposed changes in truck size and weight legislation would influence the highways, the driving public, or the trucking industry. In one state, analyses had been made of potential impacts with conclusions by highway officials that substantial net benefits would accrue to the state and country permitting 5 ft (1.5 m) longer doubles combinations. However, the Governor vetoed legislation that would have allowed the increase in double length.

Organized Opposition to Trucks

Organized opposition to size and weight increases stems from several differently motivated sources. In some cases, the basis for opposition is misunderstanding caused by lack of information or inaccurate information. In some cases, the basis is protection of self-interest. In other cases, the basis is honest concern that appears to be justifiable. But in still other cases, the basis appears to be entirely political.

An example of misinformation or lack of information may be evident in the highway safety area where it is believed that the relative safety of trucks, as they affect other traffic, is proportional to their size and weight. Another common example is the belief that heavy trucks do more damage to highways and bridges than passenger cars, regardless of structural design.

Railroad supporters, including the Association of American Railroads, are against any increases in truck sizes and weights, simply because it is liable to give trucking another competitive edge.

Environmentalist groups oppose more lenient provisions for trucks, because they perceive large and heavy trucks as contributing disproportionately to noise and air pollution. They are inclined to overlook counter considerations, such as reduction in number of trips, which, in aggregate, could reduce the two types of pollution that are their concern.

Environmental and energy groups also oppose improved provisions for trucks because, rightly or wrongly, they have the impression that trucks use more energy in transporting goods than railroads.

Political interests sometimes join the opposition simply to be aligned with what they perceive as the predominant public viewpoint.

Highway and public officials often join the organized opposition because, although trucks do not damage highways properly designed to carry them, they are capable of shortening the service lives of underdesigned highways. Trucks that are loaded heavier than provided for in the design process can, and do, shorten the service lives and sometimes impose noticeable damage on highways and bridges. Even when axle-load increases may only be small. the highway fraternity is prone to resist, regardless of benefits, because of the present financial situation when any shortening of service lives poses additional construction and maintenance problems for which there is no apparent solution.

Thus, there can be a substantial organized body of opposition to any truck size and weight increases even when the net benefits far exceed the net costs.

Truck and Rail Competition

The issue of competition between truck and rail is important to the cause of uniformity in highway sizes and weight legislation because it is cited as a key issue that needs to be carefully considered in advocating measures for better uniformity. The subject was brought up by transportation department personnel many times during the research. Undoubtedly, the issue does deserve serious consideration in connection with any prospective changes in highway laws and regulations on motor vehicle sizes and weights. However, there is substantial danger that the competitive issue will not be viewed in its true perspective as it relates to uniformity and that contrary actions will result that are not to the best advantage of the populace.

The major problem is the difficulty of supporting railroads when trucking takes over an ever-increasing share of the commodity shipment market due to transportation cost advantages. The railroads already are largely out of the low-density, high-value general freight; refrigerated produce; and personal transportation pictures. Many of the railroads in the United States have recently encountered serious financial difficulties with abandonment of many services and other well-known results. The fact is, transportation of many commodities by truck offers distinct advantages to the shipper over transportation by rail for these and many other reasons.

The most significant advantage, in many cases, is the cost advantage. Trucking costs are substantially less than other surface transportation costs because of one underlying factor—sharing of the costs of the roadbeds over which trucks operate. Railroads must pay not only for rolling stock and terminals but also for control systems and the entire roadbed, whereas trucking concerns share costs with many other highway users in both roadbed and operating categories.

This sharing, an outcome of the tax situation where different highway user components are charged a proportion of the costs of highways, is viewed incorrectly by some as a subsidy to truckers. The word "subsidy" is applicable only where truckers are not paying their fair share of the costs. When this occurs, it is an indication that the highway tax structure needs correction.

Although trucking costs may be further reduced as a result of some uniformity measures, the competition problem needs to be viewed with a clear perspective to ensure that what is done operates to the net advantage of the populace and not exclusively to advance the cause of another mode for which a better course of action probably can be formulated. In other words, there should be ways, selectively, of taking advantage of reduced transportation costs by highway, while still providing for railroad transportation where it offers significant advantage. Since transportation costs are a component of what everyone pays for goods in the marketplace, there obviously are significant cost-of-living advantages to reducing these costs to the lowest possible level, consistent with other public costs and benefits.

Additional costs on the highways are of concern. Consideration must be given to whether the advantages in reduced transportation costs would be consumed in additional highway costs, either through structural or geometric requirements, or maintenance, or operational costs. Highway safety, energy efficiencies in transportation, and environment quality issues must all be addressed.

Further reduction of income to the railroads is definitely of concern. It still is generally accepted that the railroads—which built this nation in the first place—are a necessary component of an adequate transportation system. There would be a substantial increase in highway costs and nuisances if some commodities currently transported by rail were, instead, transported by truck on general use facilities. Nuisances would occur in greatly increased highway congestion and even danger—many more hazardous materials would be on the roads. The national defense would suffer.

These are a few indications that railroads continue to meet fundamental needs. There are other more complex issues. It is sufficient to say that there are advantages to the public of maintaining strong railroads for some types of shipments.

However, it is not to the public advantage to try to maintain economically viable railroad operations by artificially keeping net transportation costs on the highways at a higher level than they might otherwise be. It is possible, as shown in this research project, to substantially reduce transportation costs by road for many commodities that already are transported largely by truck and where rail is not even closely competitive.

A problem occurs because the actions permitting these cost reductions can result, also, in further competitive advantage of truck-over-rail in areas where the two modes are strongly competitive. It would be wrong to suggest that this might not be a likely result. However, the answer—to provide the best net advantage to the public—would appear to reside in selective study and action. The study would determine the advantages to the public of different types of transport of different commodities by different modes. The selective action would encourage or assure the transportation result desired without punitive effects on transportation costs in general. Subsidies to railroads for the movements of some commodities might be in order. Consideration might even be given to limiting the distance of truck movements for some commodities. But it would not appear to be to the public advantage to prevent improvements in highway transport that can result in a lower cost of living without offsetting disadvantage.

These are important issues because misunderstanding of the facts, on the part of the public, is probably the biggest bar to greater uniformity in truck size and weight regulation.

Public Antitruck Sentiments

One of the most serious problems in obtaining public acceptance of more uniform laws and regulations with a potential for significant transportation cost and energy savings is the general public attitude toward trucks on the highway. Unfortunately, this attitude is not based on factual knowledge of such things as, for example: (1) the actual safety record of trucks; (2) the damage trucks do to highways; (3) the availability of products on the market and reduction in the cost of living that results from trucks on the highways; or (4) the tax contribution of trucks as it relates to their fair share of highway costs.

Instead, a largely emotional climate has been developed due, partially, to the representations of specific interest groups; partially to natural irksome and intimidating characteristics of large trucks; and, partially, to the behavior of some truck drivers.

With respect to the last, almost every automobile operator has experienced a discomfiting situation involving a large motor truck. An example is the all-too-common situation where such a vehicle plays side-by-side leap frog in hilly terrain, often tail-gating on downgrades.

This and other irksome elements, such as lane-blocking, are not inclined to endear the motor-truck population to the passenger-car population. And the idea of still larger trucks, especially when passenger cars are generally becoming smaller, is not popular with a large segment of the public. Contributing to this sentiment are news media coverage of truck-auto accidents highlighted with spectacular photographs providing, to an impressionable public, an incorrect perspective on the relative safety of trucks.

The average passenger-car operator does not consider that there are significant differences between categories of truck operations and types of truck drivers that are reflected in the way trucks are operated—courteously, safely, legally, or otherwise. Acts of discourtesy without due regard for safety or consideration of other road users are probably limited to a small segment of the motor-truck population.

Newspaper editorials concerning size and weight issues certainly influence the public. In some areas, newspapers have been noted to be consistently antitruck and often convey images of trucks crushing pavements and falling through bridges.

Factual education of the public with respect to truck operations—their economic role, their safety record, the damage they do, or do not do to highways—is sorely needed. Politicians ultimately will decide on how trucks will be encouraged or allowed to operate on the highways, and politicians are influenced by public attitudes.

Inconsistent Demands of Trucking

Truck legislation favorable to the trucking industry most often is initiated by the state trucking association. These associations are made up of a mix of interests, such as intercity common carriers, motor vehicle manufacturers, truckers connected with localized industries, and sand and gravel haulers. The more active trucking interests largely influence the size and weight limits being requested. For example, if a majority of the membership in one state is involved in local sand and gravel hauling, the state association probably will push for weight increases and will resist laws requiring the covering of loads, and the like. Another state association with a different mix will push for other laws. These variations in membership undoubtedly have contributed to an inconsistency from state-to-state in what laws the "trucking industry" has promoted and backed. This contributes to nonuniformity.

Never-Ending Requests for Increases

An opinion expressed often in highway departments visited was that demands for truck size and weight increases were never-ending. If laws should be liberalized one year, legislation would be proposed for even more liberal laws the next. These demands for ever-increasing limits conflict with the basis of highway design, the selection of a specific loading, and the shortages of funds available for reconstruction and maintenance. Accordingly, the highway officials who see this continuity of demand are inclined to oppose any increase.

Job Reduction

Officials in several states have indicated that opposition to changes in truck-limit laws occasionally comes from labor unions. The unions believe that more efficient truck operations will result in reduced manpower requirements and thus reduce the number of jobs under the jurisdiction of the union. The truck industry and the drivers' union have resolved this problem in most cases by establishing higher wage scales for drivers of larger trucks.

Impact on Tax Systems

One important factor relevant to the costs of transportation is taxation on trucks. Trucking, as a mode of freight transportation, already enjoys a cost advantage over the rail mode because the costs of the basic facilities used by trucks are shared with a large number of other users. Of course, the general populace is the beneficiary because the lower transportation costs are passed on to consumers. The system is more or less in balance, provided trucks pay their fair share of highway costs. If they pay less, a subsidization of this mode of shipment is involved and transportation costs to the consumer (also a highway user) are more than those reflected in freight rates.

An accepted method of determining a fair share of highway costs for a truck of a given size and weight has been the incremental analysis that determines and assigns the costs of increments of the highway structure required by heavier vehicles.

Highway officials in many states will not support weight increases if the legislation does not include increases in truck taxes to offset effects on the highway system of the additional weight limits. On the other hand, many truckers appear not to be aware of the implication that they logically should pay more taxes per vehicle or per vehicle mile for heavier axle weights.

Purely as an indication of what kind of tax increases may be involved for typical vehicles imposing heavier axle weights, the tax responsibility results of three incremental solutions—two in western states and one in an eastern state—were plotted against axle loadings on semilogarithmic paper, as shown in Figures 6 and 7. The results are reasonably straight lines (agreeing with an observed general tendency of incremental results). Interestingly, the responsibility trends for the different states, as related to axle loads, are also reasonably parallel, although different highway cost bases obviously are signified. Because of the consistency of the trends, it seems reasonable to extrapolate the average of the curves to indicate probable cost responsibilities of heavier axle loads that are not now permitted. If this extrapolation holds, a vehicle now paying $355 per year when imposing a 20,000-lb (9.1-t) axle load should pay $480 if it imposes a 26,000-lb (11.8-t) axle, an increase in taxes of 35 percent. Similar plots were made for tandem

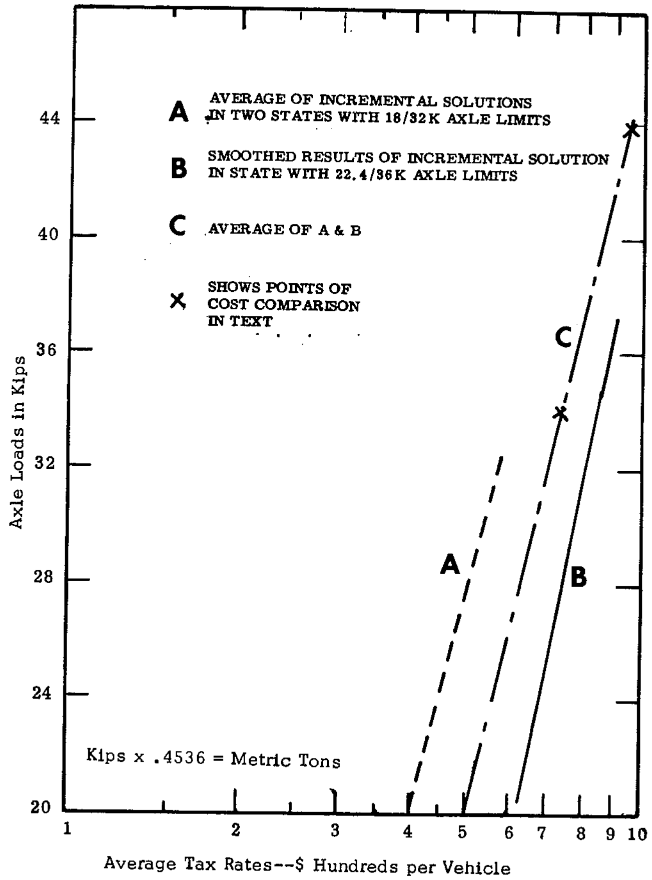


Figure 6. Tax responsibility per vehicle—3-axle SU vehicle.

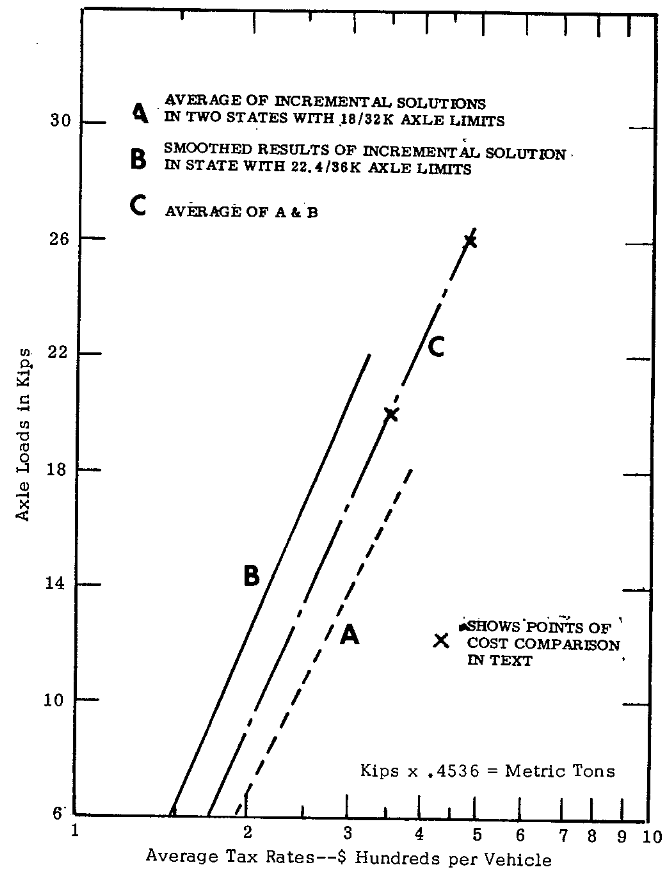


Figure 7. Tax responsibility per vehicle—2-axle vehicle.

axles in three states. In this case, the increase in taxes for a single unit vehicle going from a 34,000-lb (15.4-t) tandem to a 44,000-lb (20-t) tandem would be on the order of 32 percent.

THE TRUCKING INDUSTRY

Characteristics of the Industry

The trucking industry is not a single entity, but is composed of many diverse and sometimes conflicting elements and interests. These are discussed in this section.

General Nature of the Industry

Trucking can be separated into two major classes: for-hire carriers and private carriers. For-hire carriers transport commodities for remuneration. Private carriers transport their own products.

For-hire carriers are subdivided into common, contract, and exempt carriers. Common carriers serve the general public. Contract carriers obligate themselves to carry the goods of specific individuals or organizations. Both common carriers and contract carriers transporting commodities across state lines must have Interstate Commerce Commission (ICC) authorization. The ICC limits the regions in which they can operate and may also restrict them to operation on specified highways. They are limited, also, to carrying only specified commodities.

Exempt carriers transport commodities not specifically regulated by the ICC and do not need ICC authorization to operate. Primary commodities in the exempt category are unprocessed agricultural products and livestock.

Those truckers referred to as "independents" or "owner-operators" are normally persons who own their own tractor, may also own the trailer, and do their own driving. Some may own more than one tractor and rent to other individuals. They either haul exempt commodities or they lease both the truck and their services as driver to an ICC-certified common or contract carrier.

Private carriers are governed by the particular aspects of the private business that operates them. For example, a retail store trucking operation will probably be of a radial nature operating out of a central warehouse facility to keep its regional stores supplied. The ICC does not allow private carriers to haul the property of others, including the property of sister companies.

There are estimated to be roughly 12,000 common carriers, 3,000 contract carriers, 40,000 exempt carriers, and 105,000 private carriers operating in the United States. In addition, there are estimated to be approximately 125,000 independent owner-operators (*18*, pp. 111-120). Although these categories overlap to some degree, the figures given represent primary classifications. Fleet sizes vary from a single truck to fleets consisting of several thousand truck-tractors and as many as 10,000 trailers. There were 23 to 24 million commercial trucks registered in the United States in 1975, of which approximately 1,065,000 were truck-tractors used in combination vehicles.

Truck operations can be divided into line-haul operations and pickup and delivery operations. Pickup and delivery operations normally concentrate shipments at a central point from a given radial area or disperse the shipments into the radial area from a central point. Line-haul operations move goods intercity.

Payload carried may be less than truckload (LTL) or truckload (TL) lots. Common carriers, especially of general freight or household goods, generally handle LTL shipments and may specifically locate a portion of their terminals for break-bulk (consolidation or distribution of LTL lots) purposes.

Vehicle selections for a specific trucking operation are based both on the commodity carried and on the nature of the operation. The influence of commodity largely centers on the density of the product as packaged and/or carried. The higher the density, the smaller the storage area required in the vehicle before the load achieves the maximum weight permitted by law. Conversely, the lighter the commodity, the larger the cargo area needed. The nature of the operation also defines vehicle limits, to some extent, depending on size of operation, type of road system normally traveled on, extent to which operation is line haul or pickup, and delivery.

The value of a commodity can influence the range of operations. For example, low-value commodities, such as gravel, cannot competitively be marketed at locations beyond a very limited distance because transportation costs are such a high percentage of total cost.

Most commodities transported interstate by truck have unit costs by weight in excess of \$0.05/lb (\$0.11/kg). Truck transportation costs for these commodities usually do not account for much more than 5 percent of the total cost of the item and may be less than 1 percent. On the other hand, high-density, low-cost commodities may have unit costs in the neighborhood of \$0.002/lb (\$0.0044/kg), and costs to transport these commodities long distances by truck can easily account for more than half the market cost.

Classification of Carriers

In trying to gain an understanding of the way nonconformity affects interstate truck operations, several ways of classifying truck operations were initially evaluated. Ultimately, however, the decision was made to use a relatively simple classification scheme that appeared to provide a sound basis for analyzing the comparative impacts of alternative uniformity provisions.

This classification is based on the relationships found to exist between commodity type, commodity density, and truck size and weight requirements. The nonuniformity problems of a carrier depend largely on what he hauls and whether or not it is heavy or light. Very dense commodities do not tend to use all available cargo space within the confines of current size and weight limits and, therefore, might be benefited by additional gross-weight or axle-weight provisions—provided vehicles are otherwise capable of carrying the additional loads without greatly increased costs or other undesirable effects. On the other hand, carriers of light commodities are more concerned about cargo space, inasmuch as they "cube out" before they fully utilize gross-weight and axle-load provisions. They, therefore, are candidates for longer, wider, and possibly higher trucks with the same reservations on increased costs and other possible negative impacts. Commodity type is important because it relates to packaging, which can have a significant effect on the type of vehicle required for maximum transport efficiency.

The simplified classification scheme consists of 10 vehicle types and 14 commodity classes, the latter reflecting relative densities, packaging, and industry requirements. The 10 truck types are given in Table 4.

Single trucks were not included except in truck-trailer combinations, because they generally are not used in interstate/intercity line-haul operations.

The commodity types are given in Table 5.

Operating Characteristics and Costs

During the study, the following operating characteristics stood out as important because of economic and other impacts both on carriers and segments of the general public:

1. Size, weight, and payload capacity.
2. Ratio of payload to gross combination weight.
3. Fuel economy.
4. Vehicle operating costs.
5. Power requirements.
6. Turning radii or maneuverability.

TABLE 4

CLASSIFICATION OF TRUCK TYPES

Truck Type Code	Truck Type
0	Three-axle tractor, two-axle semi-trailer (3S-2) weighing 56,000 lbs. (25.4t) or less.
1	Tractor semi-trailer with total of 4 or less axles weighing 56,000 lbs. (25.4t) or less.
2	Tractor semi-trailer weighing between 56,100 (25.4t) and 69,000 lbs. (31.3t).
3	Tractor semi-trailer weighing between 69,100 (31.3t) and 74,000 lbs. (33.6t).
4	Tractor semi-trailer weighing between 74,100 (33.6t) and 85,000 lbs. (38.5t).
5	Tractor semi-trailer weighing more than 85,000 lbs. (38.5t).
6	Twin-trailer combinations (tractor, semi-trailer, trailer) with either a two-axle tractor or a single-axle semi-trailer; and a maximum of 7 axles (essentially a conventional twin trailer combination)
7	Twin-trailer combinations with a minimum of 7 axles and with two axle semi-trailers; and in most cases, a three-axle tractor.
8	Truck and trailer combination.
9	Tractor, semi-trailer and two trailers (triple trailer combination).

TABLE 5

COMMODITY TYPES

Commodity Code	Commodity Type
01	Agricultural, Marine and Dense Food Products (Unrefrigerated)
02	Agricultural, Marine and Food Products (Refrigerated)
03	Forest Products
04	Bulk Extractive Resources (Ore, Coal, Gravel, etc.)
05	Fuels, Oils, and Chemicals
06	Building Materials
07	Textiles and Textile Products
08	Pulp, Paper, Printed Material
09	Furniture and Household Goods
10	Transportation Equipment (Auto, Boats, etc.)
11	Light Manufactured Products
12	Medium Density Manufactured Products
13	Heavy Manufactured Products
14	General Freight

7. Stability—relative to breaking and swaying.
8. Accident experience.
9. Negative impacts on other road users.
10. Irritants to other road users, particularly passenger vehicle drivers.

Each of these characteristics is discussed as follows.

Size, Weight, and Payload Capacity

Large commercial vehicle combinations will probably have an empty or tare weight in excess of 25,000 lb (11.3 t). A truck tractor will normally weigh more than 15,000 lb (6.3 t) and an empty 40-ft (12.2-m) trailer will weigh more than 10,000 lb (4.5 t).

Payload capacity is a function of vehicle capacity, commodity density, and allowable legal weights.

Vehicle capacity is defined as the amount of available cargo space. The approximate available cargo space in various commonly used vehicle types and configurations expressed in cubic feet is as follows:

- 40-ft (12.2-m) long trailer—2,500 cu ft (70.8 cu m)
- 45-ft (13.7-m) long trailer—2,900 cu ft (82.1 cu m)
- 27-ft (8.2-m) long trailer—1,700 cu ft (48.1 cu m)
- twin 27-ft (8.2-m) trailers—3,400 cu ft (96.3 cu m)
- twin 40-ft (12.2-m) trailers—5,000 cu ft (141.6 cu m)
- twin 45-ft (13.7-m) trailers—5,800 cu ft (164.3 cu m)
- triple 27-ft (8.2-m) trailers—5,100 cu ft (144.4 cu m)
- 26-ft (7.9-m) truck with 35-ft (10.7-m) trailer —3,400 cu ft (96.3 cu m)

Ratio of Payload to Gross Combination Weight

A high ratio of payload to gross combination weight is desirable. The higher the ratio, the more efficient the fuel consumption and manpower use. Payload to gross combination weight (GCW) ratios are presented in operating cost nomographs later in this chapter.

Cargo space is extremely important to the carrier of low-density (light) commodities. Because of the lightness of the commodity, the carrier need not be concerned with weight limits.

On the other hand, carriers of high-density commodities are not constrained by space limitations. Legal gross-weight limits are reached long before all available cargo space is occupied. Payload capability in this case is a function of the legal weight limits. These include gross-weight limits and axle-load limits. The gross-weight limits are commonly governed by what is called the bridge formula discussed elsewhere in this report. The bridge formula, based on design relationships between safe structural capacity and the magnitude and spacing of loads, is basically of the form:

$$\text{Allowable Gross Vehicle Weight (GVW)} = 500\left(\frac{LN}{N-1} + 12N + 36\right) \qquad (1)$$

where L = center to center distance between any group of axles in feet, and N = number of axles in the group.

This relationship relates to pounds. An approximate kilogram/meter conversion would be:

$$GVW = 30.48\left(2.29\frac{LN}{N-1} + 89.29N + 267.87\right) \qquad (2)$$

The gross-weight limits apply either to the entire vehicle or combination with all its axles or to any group of axles. There are variations of the formula in some states. It is applied differently in different states. Often, in the law, it is reduced to a table of permissible loads as related to axle spacings.

Also, in addition to bridge-formula-based controls on gross weight, all states establish a maximum value that cannot be exceeded except under special permit. As indicated previously, this varies among states.

The commodity density at which a vehicle "cubes out" varies with the vehicle type and cargo storage capacity. For example, a twin 27-ft (8.2-m) trailer combination (2S1-2) cubes out at the relatively low density of 12 lb/cu ft (192 kg/cu m), whereas a tractor, semitrailer combination with a 45-ft (13.7-m) trailer cubes out at the much higher density of 17 lb/cu ft (272.3 kg/cu m). The lower the vehicle storage capacity for a given GVW or GCW, the lower the cube-out density. Thus, movers of very low density commodities want a vehicle with as high a ratio as possible of volume capacity to permissible axle load. Within the general size limitations, they often do not require maximum permitted axle loads. The most common vehicle for this type of commodity is the 2S1 combination—2-axle tractor, single axle semitrailer. Movers may find general advantage in the moderately more spacious 5-axle doubles combinations with 27- to 30-ft (8.2- to 9.1-m) trailers; the twice as spacious turnpike twins with 5 axles; or similar capacity triples combinations.

On the other hand, movers of high density commodities want a vehicle with a high ratio of axle load to volume capacity. However, as indicated in other sections of this report, the need or desire to exceed axle loadings currently permitted in the majority of states, for the purposes of interstate commerce, was not found to be high for several reasons. These include: (1) the small proportion of commodities in very high density categories being moved interstate, (2) operating cost considerations, and (3) motor vehicle structural considerations. Accordingly, the most common interstate carrier of high-density commodities is the 3S2—3-axle tractor, 2-axle semitrailer. Movers using these vehicles may find advantage in the 3S2—4- or 9-axle doubles combinations.

For any commodity at any density, the desire of truckers generally is to maintain the highest possible payload to GVW ratio.

Fuel Economy

Fundamental statements that can be made about fuel economy are that big trucks burn more fuel per mile than small trucks, and that big trucks burn less fuel per ton-mile than small trucks. There are exceptions and limitations to both of these statements, but they generally hold true within the range of vehicles used in interstate trucking.

Fuel consumption per ton-mile is the logical measure of fuel economy. The Post-1980 Goals study conducted by a U.S. Government interagency group reviewed the current state of fuel economy knowledge and developed a curve relating fuel consumed per payload ton-mile versus gross combination weight (GCW) based on two equations for specific fuel consumption (SFC). Figure 8 shows the curve.

The ratios of net reduction in SFC for various ranges of GCW (1 lb = 0.4536 kg) are:

GCW (lb) From	To	% Reduction in SFC
40,000	50,000	33.0
50,000	60,000	25.0
60,000	70,000	17.3
70,000	80,000	13.9
80,000	90,000	11.4
90,000	100,000	8.6
100,000	110,000	7.1
110,000	120,000	5.1

Vehicle Operating Costs

Line-haul trucking costs for different combination types and different gross combination weights (GCW) were derived from Refs. (*13, 16-18, 20-24*).

Information on the nature and general amounts of costs as related to different cost components was derived from seven of the sources referenced, with heavy reliance on the work done by the DOT Transportation Systems Center (TSC) at Cambridge. One area where the order of accepted costs differs from those determined by the Cambridge researchers has to do with cost related to local pickup and delivery. The TSC group found that pickup and delivery costs for doubles combinations with 27-ft (8.2-m) trailers, based on terminal-to-terminal movement in truckload lots, were considerably higher than costs for a single-trailer combination. The rationale was that two return trips were generally necessary between the shipper and the terminal to pick up or deliver the trailers versus one return trip for a single semitrailer combination. However, the premise of such additional pickup and delivery costs was at variance with statements of doubles' combination users. The reason may be related to the nature of TL and LTL shipments, since the Cambridge theoretical determinations were based on LTL. The users, on the other hand, cited advantages of dropping smaller trailers at the primary loading point to obtain full loads. Because of this variance, based on actual experience of large users, additional pickup and delivery expense has not been added to doubles operational costs.

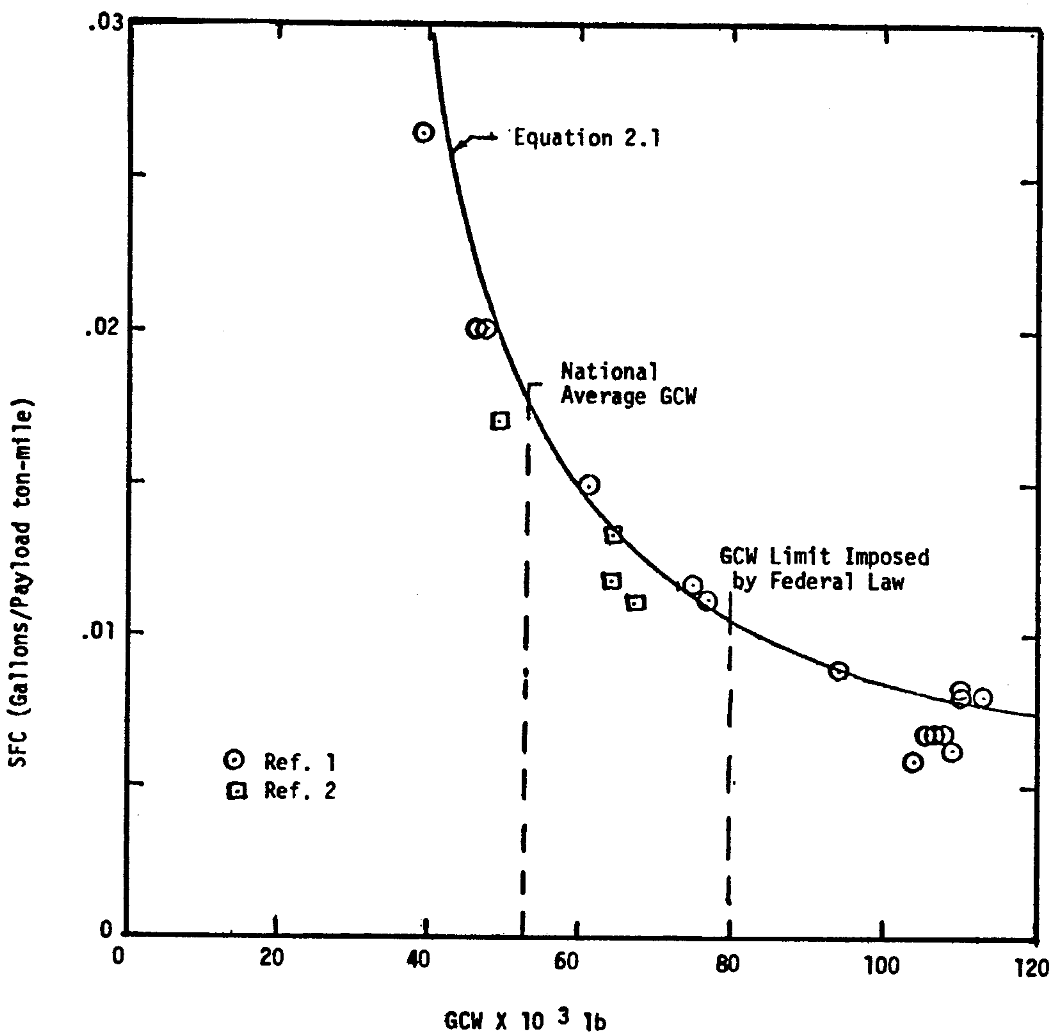
TSC also was in disagreement with other sources in the amount of direct labor cost. However, in this case, there was agreement with TSC that wage rate alone, as given in other reports, is not truly representative of labor costs. Accordingly, fringe benefits and overhead at approximately 90 percent of base wage rates were added to bring labor costs in line with those of the TSC.

Because the TSC research and the other sources dealt with a limited number of combination types, it was necessary to use additional sources to obtain more relative values for different types and GCW designations. For this relativity, the heaviest reliance was placed on the Australian study (*17*) and *NCHRP Report 141* (*9*) which updated studies in the early sixties by Hoy Stevens. Recourse also was made to other reports on relative costs of different vehicle types, including doubles and triples. The Australian and *NCHRP Report 141* results were given about equal weight in relating costs for combinations of different weights and types.

A recent Oregon study draft report (*13*) was not available until after the cost relationships had been developed. However, it has been noted that the costs developed in that study were derived from *NCHRP Report 141* and the Australian study, updated to 1975. A comparison was made of costs per payload ton-mile versus gross weight derived in this study and those derived in the Oregon study. This comparison is shown in Figure 9. Because the NCHRP 20-16 curve already is above the Oregon curve, no attempt was made to reduce the latter to a 1974 base.

The development of line-haul costs for different combination types at different gross weight levels was performed so that determinations could be made of cost advantages that would result from changing vehicle types. Since these advantages are strongly related to the densities of shipments, two nomographs (Figs. 10 and 11) have been developed to relate costs per payload ton-mile at different densities to the loaded capacities of different vehicle types, given in terms of their GCW.

The left-hand side of the nomograph is based on determinations of typical tare weights and capacities for different vehicle types and, therefore, their gross weights loaded at different densities. Maximum loadings of the vehicle types and configurations portrayed are limited by the bridge formula that was accepted as an absolute control because of the present deficient bridge situation discussed elsewhere. In keeping with general limitations on this project (study



[1] Fax and Kaye, "Truck Noise IIID, The Economics of Quieting the Freightliner Cab-Over-Engine Diesel Truck," DOT-TSC-75-22, October 1974, p. 8

[2] Hutton, T.D., "Freightliner Comparative Fuel Economy Test," Freightliner R&D Memo. No. 75-03, April 1975.

1 lb = .4536 Kg

S.F.C. x 2.593 = liters/payload tonnes-km

Figure 8. Fuel consumption per payload ton-mile vs. gross combination weight. Source: U.S. Government Inter-Agency Study of Post-1980 Goals for Commercial Motor Vehicles, 1976.

of uniformity), maximum current single axle loadings are also accepted as a limit.

These nomographs were developed exclusively for this project and represent the best information available for determining relative vehicle costs. In deriving the values on which they are based, the various sources used were employed in a highly complex manner because none were sufficient to provide more than partial data often based on different years and including different contributing factors. The process used was generally one of finding a commonality of elements in two studies that allowed the relationships developed in one to be applied to findings of the other. Thus, the TSC costs, amended by information from other sources as indicated previously, were extended to other vehicle types and weights from the Australian study. Values for combinations such as triples were added from other sources. Since all vehicle weight groups were not covered, values associated with some were extrapolated to others on the basis of proportionate weight relationships in the *NCHRP Report 141*. Where source data were from different years, statistical trend data were used for appropriate projections. This is indicative, but certainly

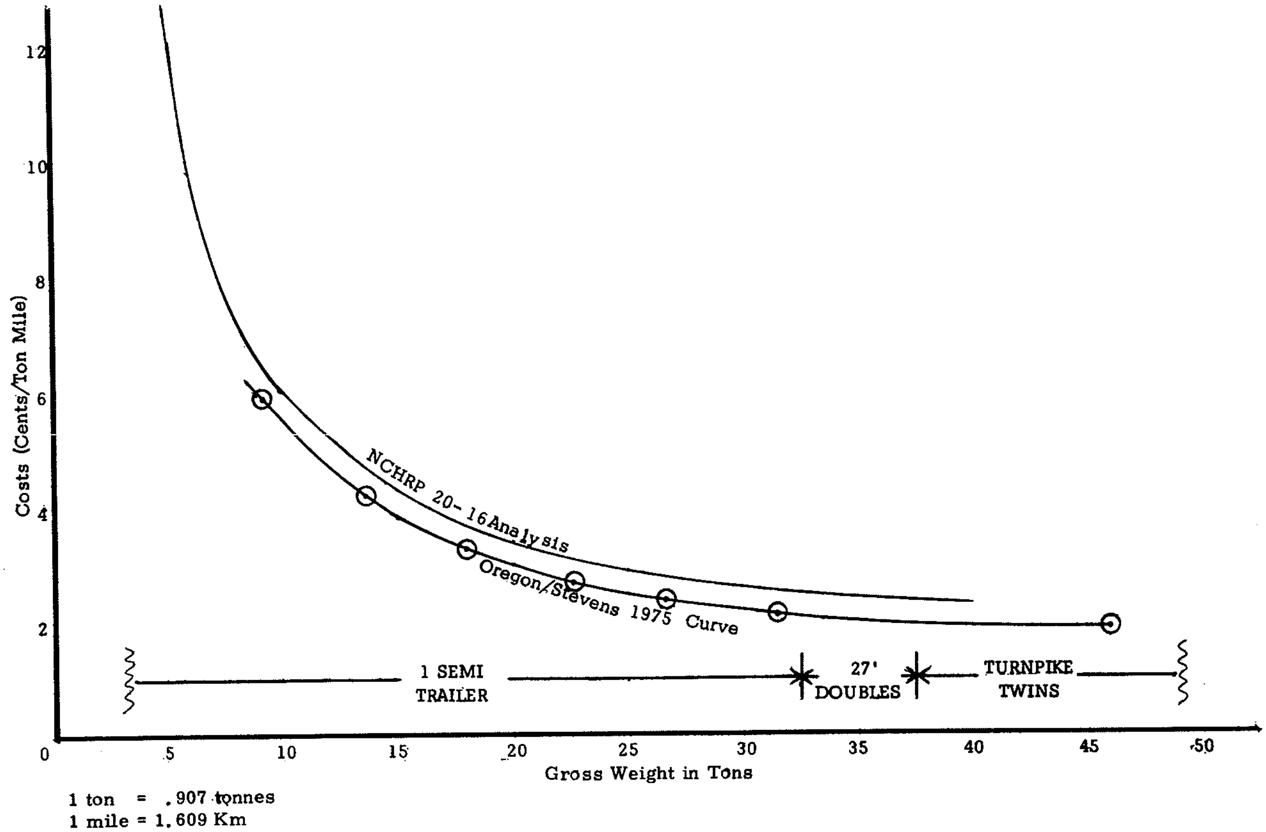


Figure 9. Costs per payload ton-mile for fully loaded vehicles (1974).

not inclusive, of the methodology employed in an area where information comparable to the nomographs given in this report was totally lacking. Finally, cost determinations were made using these nomographs to compare with cost estimates made in various reports pertaining to the operating costs of a specific vehicle type and weight classification. The results have generally proven the nomographs to be reflective of actual 1974 costs.

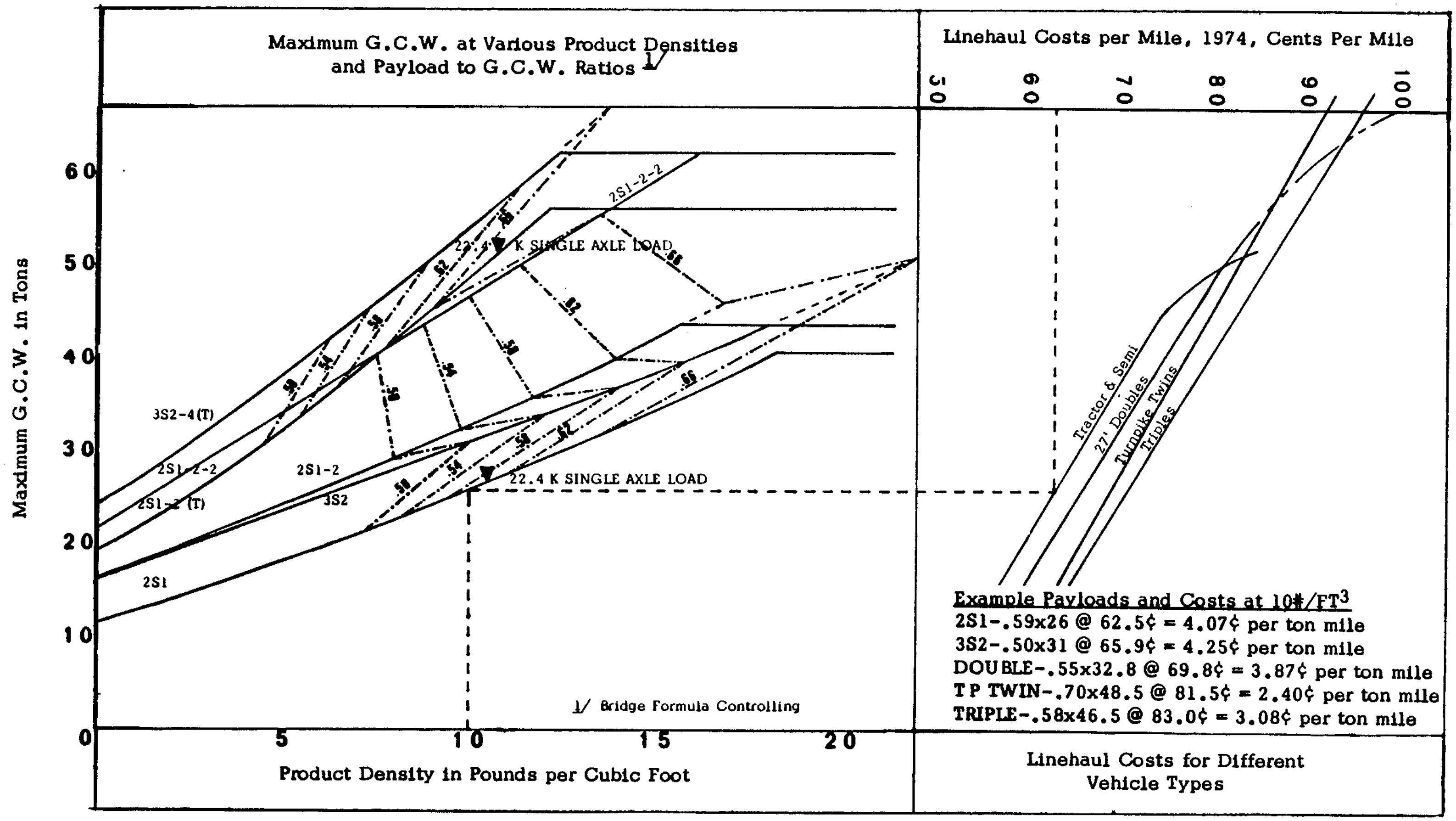
The nomographs were used in conjunction with the commodity flow network. The nomographs were entered at specific densities to determine: (1) the typical cost per payload ton-mile for the present vehicle fully loaded; and, (2) the typical cost per payload ton-mile for greater gross weights and different vehicle types at the same densities. Note that higher gross weights do not necessarily mean more actual or equivalent axle loadings. They may mean reduced loadings. The proportion of payload to gross weight is determined from where the tare/gross ratio lines, dash-dot with a 2-digit ratio, intersect the maximum GCW/vehicle type curves. The example in Figure 10 shows how comparable costs per payload ton-mile are determined for a commodity with a density of 10 lb/cu ft (160.2 kg/cu m) being transported in a tractor-semitrailer. As a further example, note that triple combinations at a cost of $0.0308/ton-mi ($0.0449/tonne-km) offer a 20 percent transport cost advantage over doubles at $0.0387/ton-mi ($0.0565/tonne-km) when the shipment density is 10 lb/cu ft (160.2 kg/cu m). This generally agrees with the results of test studies of triples (*22*).

As weight of cargo increases, tare weight of the vehicle tends to increase. It may be necessary to go to tandem axles from single axles, for example. Bigger tires, heftier springs, stronger trailer frames, and more powerful motors all lead to greater tare weight, greater initial capital expenditure, and greater operational and maintenance costs. These trade-off factors must be considered when transferring to a larger and heavier vehicle. The cost relationships depicted in Figures 12 through 16 reflect these factors.

Power Requirements

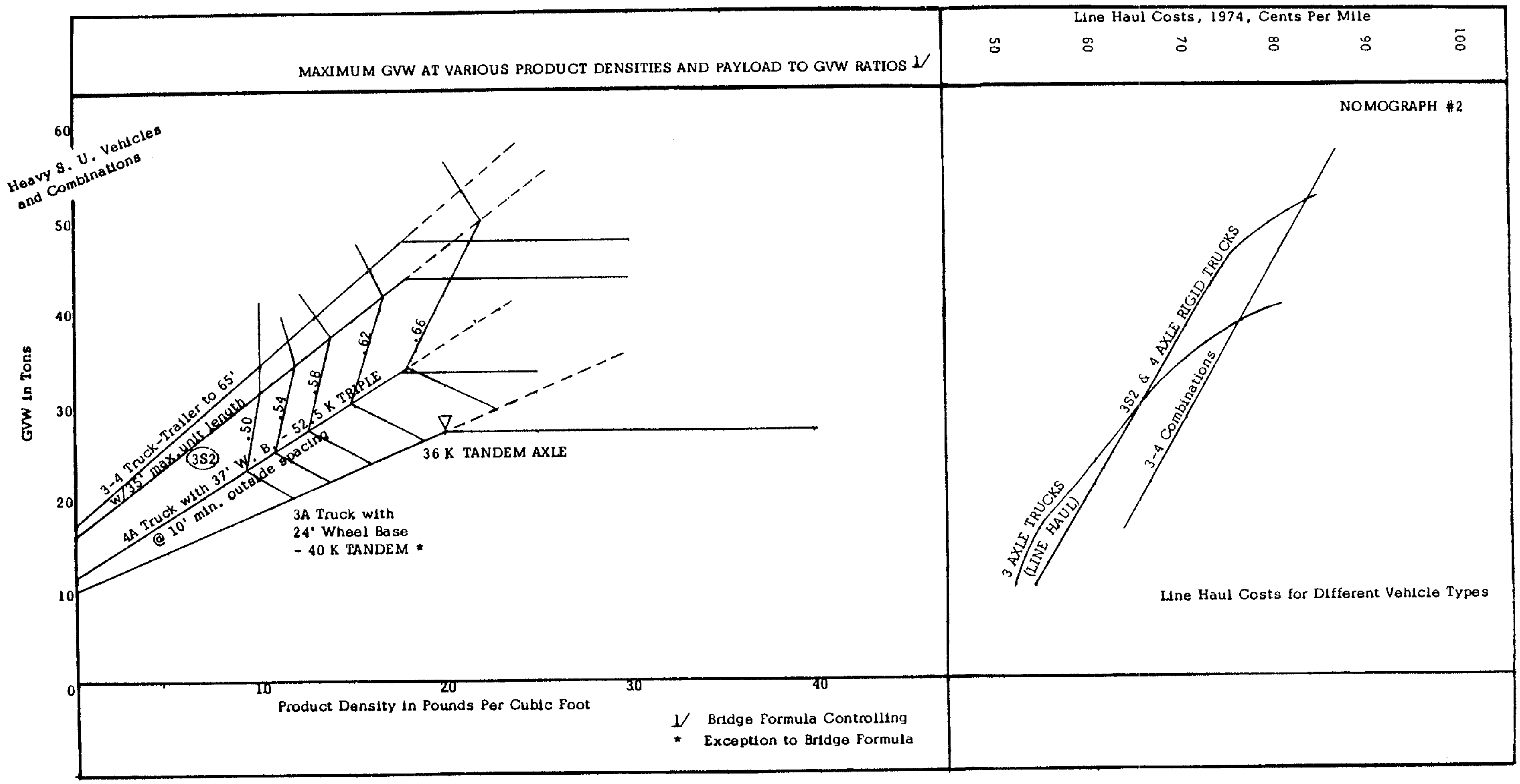
Only two states currently have minimum power requirements for trucks. AASHTO recommends that GVW should not exceed a ratio of 400 lb per engine net HP to the clutch. This power level is considered sufficient to ensure a minimum speed of 25 mph on grades up to 3 percent. This translates to gross HP values of 224, 241, and 260 for gross vehicle weights of 73,280 lb (33.2 t), 79,000 (35.8 t) and 85,500 (38.8 t), respectively, on a 3 percent grade.

Instead of such specific requirements on motor vehicles, several truck industry spokesmen indicated preference for a performance standard. A performance standard would simply require that a truck be able to maintain a specified minimum speed on a specified grade. Truckers would then have more flexibility to selectively power their equipment in accordance with gradient conditions.



1 ton = 0.907 Tonnes
lbs/cu ft x 16.02 = Kg/cu m

Figure 10. Operating cost nomograph. Nomograph to determine relative costs per ton-mile for using different vehicle types and cross combination weights for products of different densities.



1 ton = 0.907 Tonnes

lbs/cu ft x 16.02 = Kg/cu m

Figure 11. Operating cost nomograph. Nomograph to determine relative costs per ton-mile for using different vehicle types and gross combination weights for products of different densities.

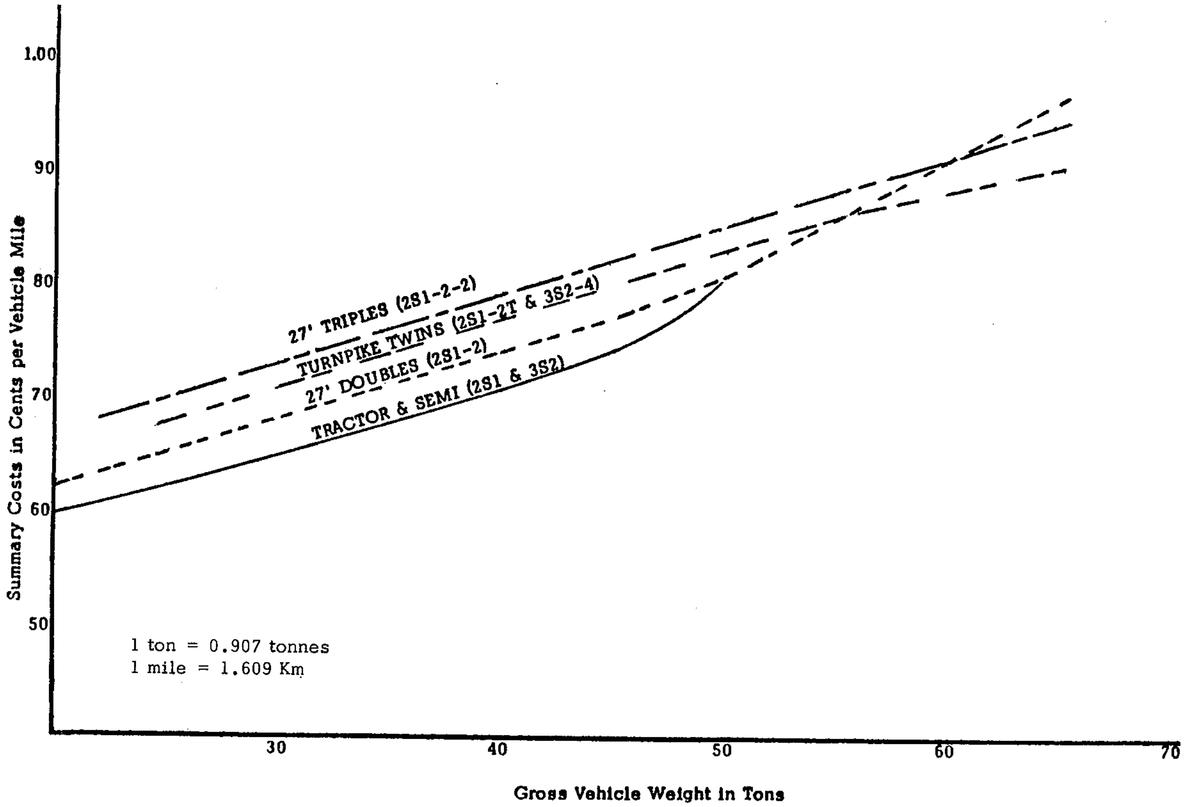


Figure 12. Summary linehaul costs per mile for different vehicles (1974).

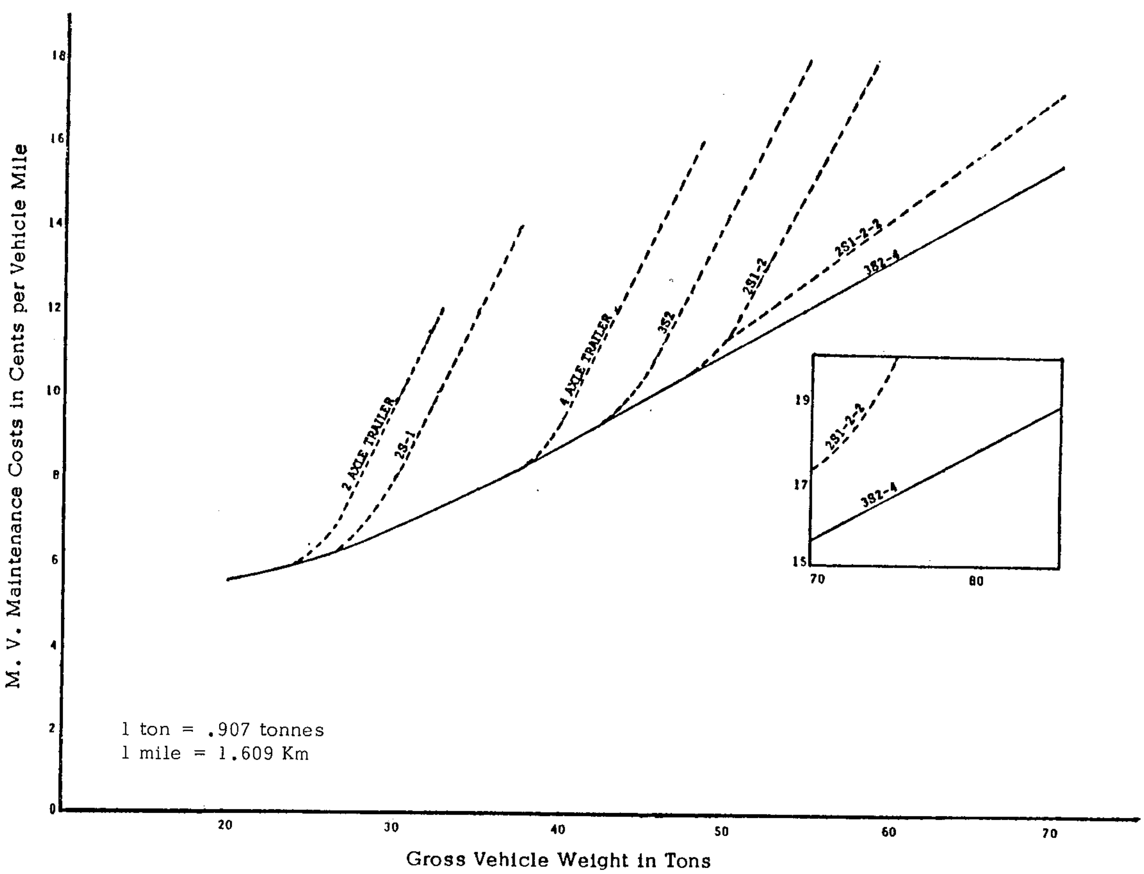


Figure 13. Maintenance costs per mile for different vehicles (1974).

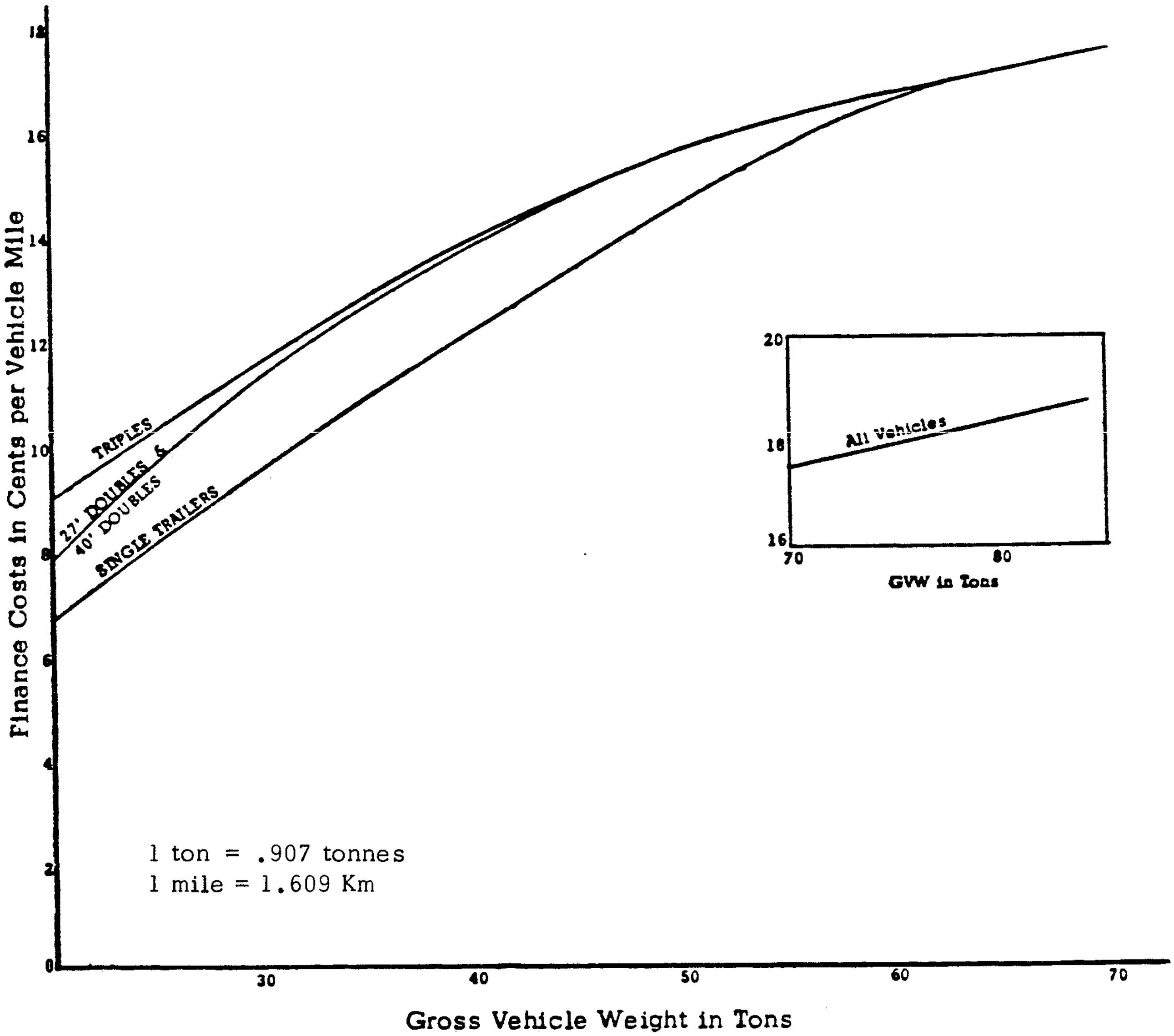


Figure 14. Depreciation and finance costs per mile for different vehicles (1974).

An analysis of trucks manufactured in 1970 by White Motor Company indicated that the average gross HP was 258.1. By 1972 the average had increased to 297 HP. After deleting trucks not normally used in over-the-road tractor operations, White estimated that the average gross HP of line-haul tractors was 270 in 1970 and 320 in 1972.

An increase in GVW from 73,280 lb (33.2 t) to 85,000 lb (38.8 t) results in a speed decrease of approximately 2 to 4 mi/hr (3.2 to 8.4 km/hr) within a grade range of 0 to 7 percent, for vehicles in the 240 to 350 HP range.

Turning Radii and Offtracking

Offtracking is defined as the difference between the path of the inside rear wheel of the vehicle and the path of the inside front wheel as the vehicle negotiates a curve (*22*). Offtracking is a function of the turning radii, the wheel base of the unit, and the number and location of articulation or pivot points of the combination. It can be expressed mathematically as follows (*9*, p. 74):

$$MOT = R_1\sqrt{R_1^2 - \Sigma(L)^2} \qquad (3)$$

where:

MOT = maximum off-tracking;
R_1 = turning radius of outside front wheel;
L_1 = wheelbase of tractor;
L_2 = wheelbase of first trailer or semitrailer;
L_3 = distance between rear axle and articulation point (pintle hook);
L_4 = distance between articulation point and front axle of next trailer; and
L_5 = wheelbase of trailer.

This relationship does not account for front or rear overhangs between wheels and bumpers or projections outside the wheel tread.

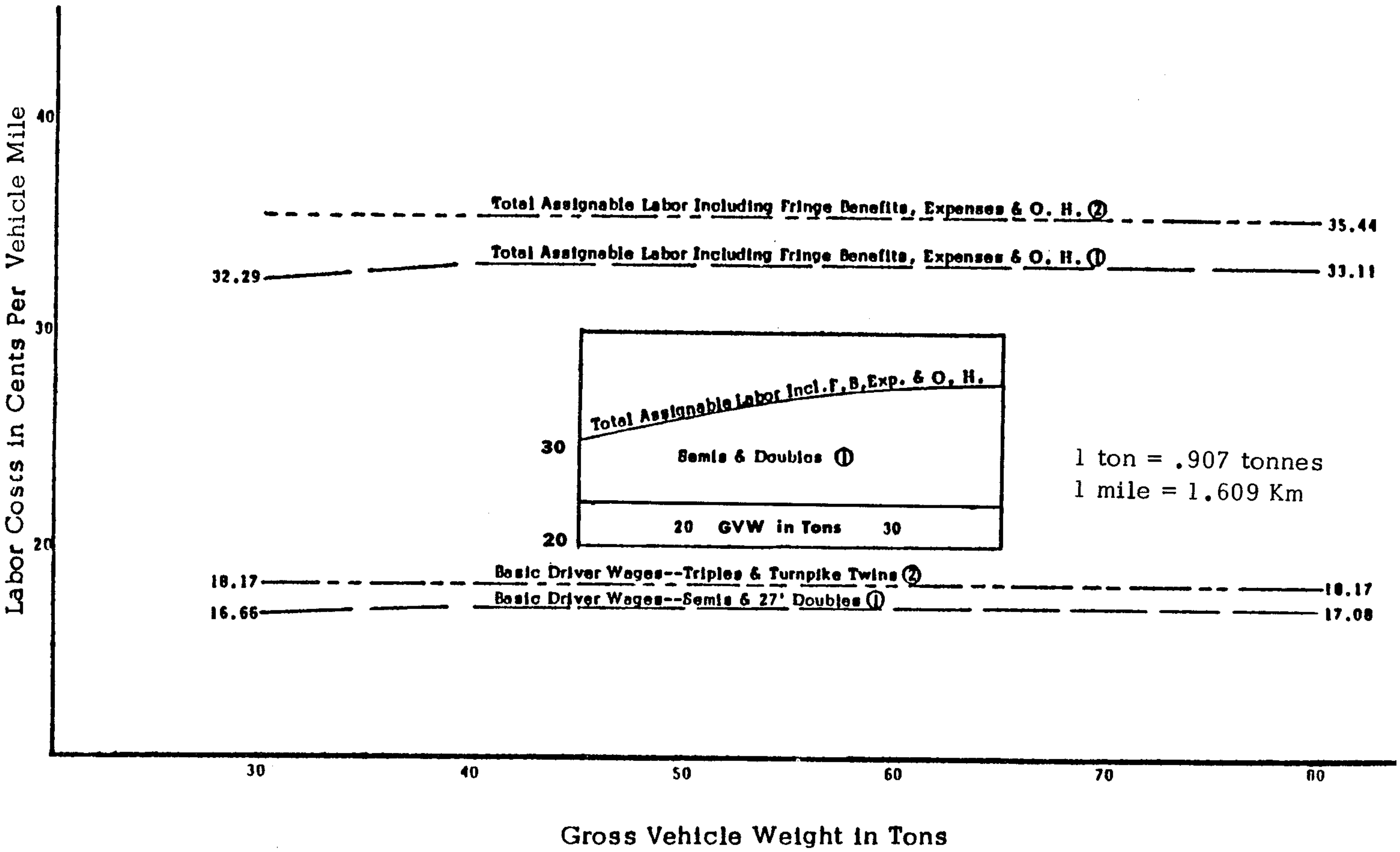


Figure 15. Linehaul labor costs per mile for different vehicles (1974).

The equation was tested by the Utah Department of Transportation in early May 1974 at the yard of IML Freight, Inc. The test results compared well with the calculated values except where the turning radius was less than the sum of the squares of the wheelbases. This situation occurs for the single trailer with the 26-ft (7.9-m) curve radius and the triples with the 31.5-ft (9.6-m) radius. The tests showed that a 91.6-ft (27.9-m) wheelbase triple-trailer combination could be operated on ramps and streets that will presently accommodate a 51-ft (15.5-m) wheelbase single-trailer combination.

Comparisons of offtracking for various vehicle types from the Utah Study (*22*) are given in Table 6. A further comparison is provided by applying the equation to turnpike doubles at 105-ft (32-m) over-all length on a 90-ft (27.4-m) radius curve. In this case, the offtracking is 14 ft (4.3 m). The relevance of the 90-ft (27.4-m) radius is that it is typical of tight curvatures in some ramp designs.

Western Highway Institute (WHI) has worked out a table of offtracking values for a curve radius of 165 ft (50.3 m). These values are given in Table 7 (*25*).

Figures 17 through 19 are diagrams of turning paths for three basic design vehicles, WB-40, WB-50, and WB-60 (*21*).

Truck Safety Characteristics

In California (*26*) tests employing panic stops from 55 mph (88 km/hr), triples with gross weights of 90,800 lb (41.2 t) stopped 23 ft (7.0 m) shorter than doubles at 76,000 lb (31.8 t) on dry pavement—152 ft (46.3 m) versus 173 ft (52.7 m). The doubles were not tested on wet pavement but the triples, on wet pavement, stopped in the same distance as doubles on dry pavement. In alignment during the stops, the farthest the doubles deviated from a straight track was 2 ft (0.6 m); the farthest for the triples was 6 in. (15 cm).

Concerns about large trucks often focus on safety characteristics including stopping ability, jackknifing tendencies, sway or other lack of stability, and spray in inclement weather.

Controlled tests have been conducted in several states comparing some of the safety characteristics of twin 27-ft (8.2-m) trailers, triple trailers, and more conventional 3-S2 combinations. These tests have consistently shown that twin and triple combinations have favorable stopping characteristics as compared with the 3-S2. In Utah (*22*), triples at 107,000 lb (48.5 t) took 20 to 25 ft (6 to 8 m) further to stop under dry-pavement conditions at 40 mph (64 km/hr) than doubles at 77,000 lb (34.9 t). Under wet-pavement conditions, the stopping distances were about the same. Under dry conditions, the doubles stopped 5 to 8 ft (1.5 to 2.5 m) shorter than single-semitrailer combinations at 70,000 lb (31.7 t). There were no panic-stop tests of the single semis from 40 mph (64 km/hr) under wet-pavement conditions because of fear of jackknifing.

The rear unit of a triples combination does tend to sway. However, the amount of sway is a function of load distribution and equipment matching. Tests have indicated that swaying can almost be eliminated by adhering to proper loading and equipment matching principles.

Tests conducted in Oregon compared backspray of single-trailer, twin-trailer, and triple-trailer combinations (*27*) and concluded that doubles and triples produced an equal amount of spray, which was 20 percent less than the spray produced by the single.

Truck Accidents

Highway safety, as influenced by large trucks, was carefully considered to the degree available data would permit. Unfortunately, few states maintain accident records in such a way as to differentiate truck accidents by size, weight, or configuration of the vehicle except, perhaps, to distinguish combinations from single unit vehicles. Only about a half-dozen states, in questionnaire responses, indicated the ability to distinguish between multiple-trailer and single-trailer combinations in rural accident occurrences.

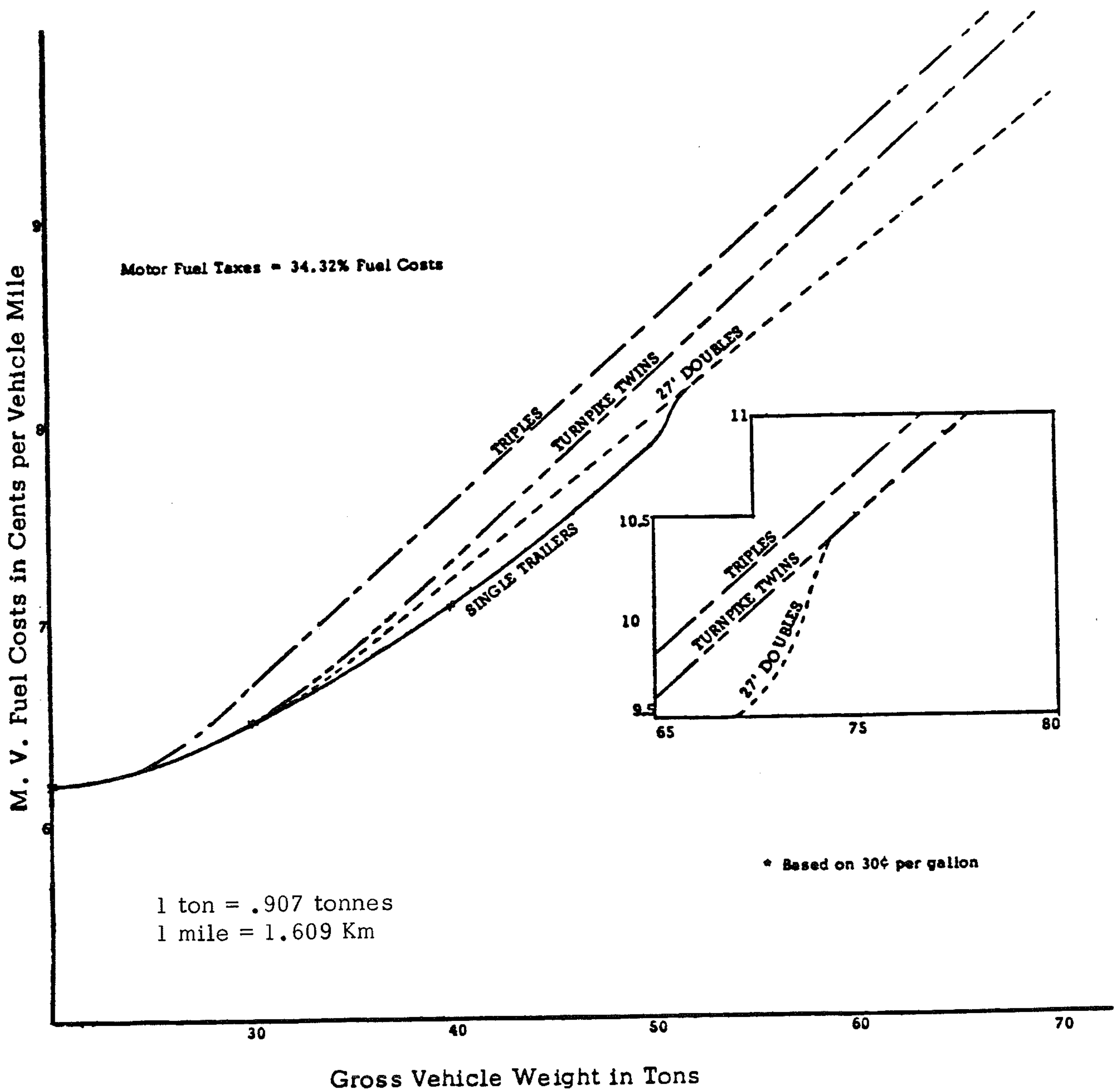


Figure 16. Fuel cost per mile for different vehicles (1974).

TABLE 6

OFFTRACKING—UTAH DOT TESTS

TYPE	PROFILE	SYMBOL	OVERALL LENGTH FT.	LENGTH EACH TRAILER FT.	CURVE RADIUS FT.	MAXIMUM OFFTRACKING FT. MEAS.	MAXIMUM OFFTRACKING FT. CALC. W.H.I.
FIVE-AXLE TRACTOR-SEMITRAILER		3-S2	51	40	90.0	7.6	8.5
					26.0	30.6	
SEVEN-AXLE TRIPLETS		2-S1-2-2	91.6	26	90.0	8.8	7.8
					31.5	22.7	
FIVE-AXLE DOUBLES		2-S1-2	65	26	90.0	6.0	5.3
THREE-AXLE TRACTOR-SEMITRAILER		2-S1	35	26	90.0	3.3	2.7

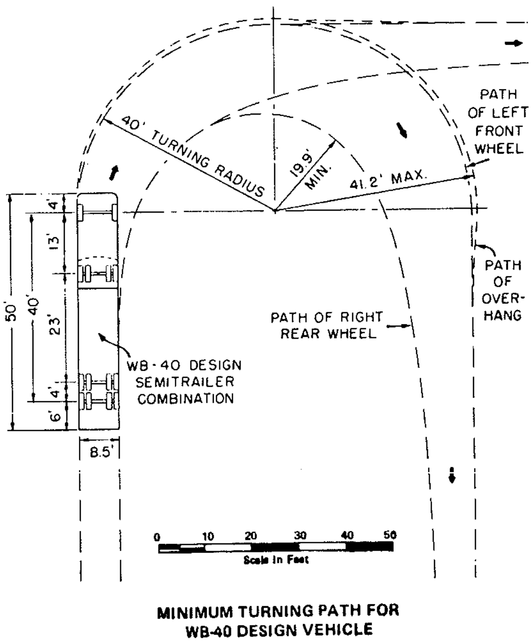
Source: Utah DOT (22)   1 foot = 0.3048 meters

TABLE 7

MAXIMUM OFFTRACKING OF VARIOUS TRUCK COMBINATIONS

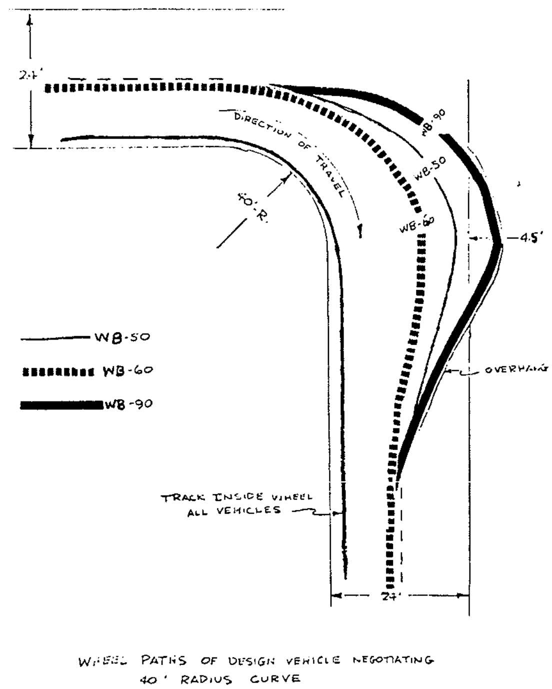
TYPE	PROFILES	SYMBOL	OVERALL LENGTH FT.	LENGTH EACH TRAILER FT.	AB	BP_1	P_1C	CP_2	P_2D	DE	EP_3	P_3F	FG	MAXIMUM OFFTRACKING 165' CURVE RADIUS FT.
Single Unit Truck		3	40		33									3.4
3-Axle Tractor-Semitrailer		2-S1	40	27	10	25								2.3
4-Axle Tractor-Semitrailer		2-S2	50	40	11	33								4.0
5-Axle Tractor-Semitrailer		3-S2	50	40	11	33								4.0
5-Axle Tractor-Semitrailer		3-S2	55	40	16	33								4.2
5-Axle Tractor-Semitrailer		3-S2	60	45	16	38								5.4
5-Axle Tractor-Semitrailer		3-S2 Stinger	65	40	17	7	29							3.4
5-Axle Truck and Trailer		3-2	60	27	19	4	13	20						2.4
5-Axle Truck and Trailer		3-2	65	30	21	4	13	23						3.5
5-Axle Doubles		2-S1-2	65	27	10	20		3	6	21				3.0
7-Axle Triplets		2-S1-2-2	95	27	10	20		3	6	21	3	6	21	4.5
9-Axle Doubles		3-S2-4	100	40	16	30		3	6	34				8.1

Source: WHI (25)   1 foot = 0.3048 meters



ft = .3048m

Figure 17. Minimum turning path—WB-40. Source: Ref. (21, p. 75).



1 ft = .3048m

Figure 19. Wheel paths of design vehicle—40' radius curve. Source: Ref. (21, p. 78).

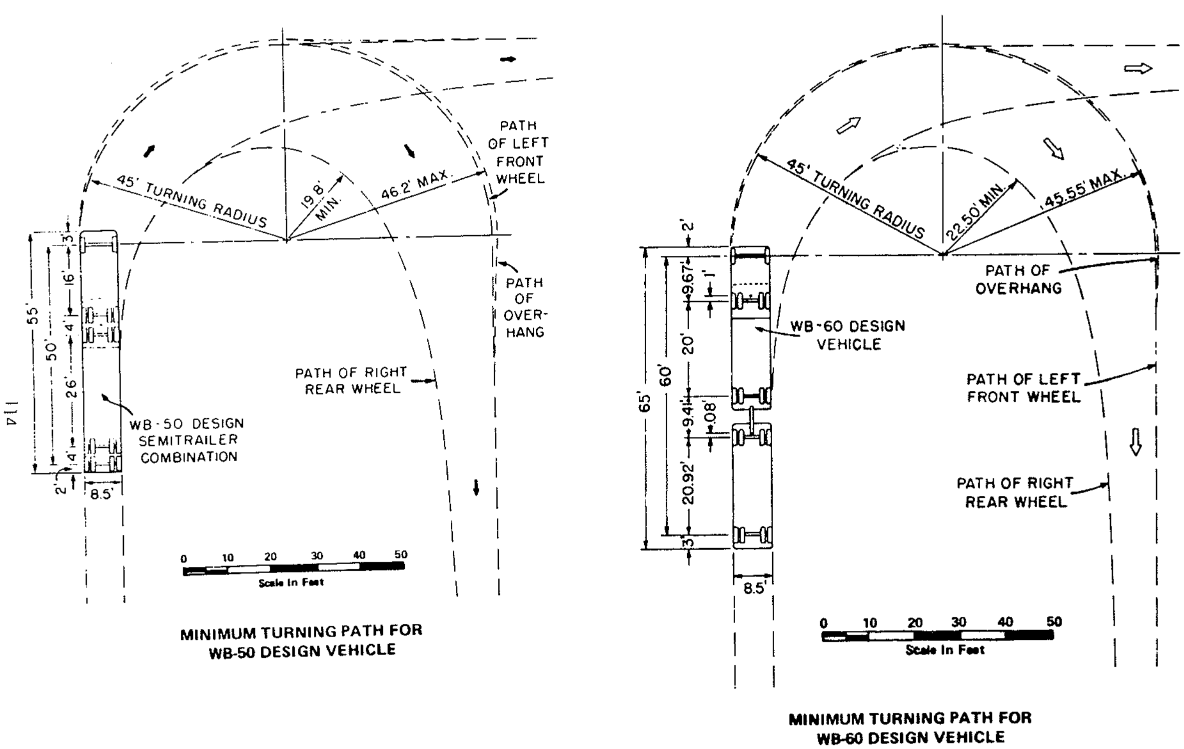


Figure 18. Minimum turning path—WB-50, WB-60. Source: Ref. (21, pp. 76, 77).

Available data on accidents by vehicle configuration reflect favorable or, at least, equal accident rates for doubles compared to the tractor semitrailer. The data from several large carriers, which use both vehicle types, show favorable records for doubles. The experience of five such carriers is presented in Table 8.

In a legal brief filed on behalf of two carriers suing for doubles to be permitted in one state, affidavits from a representative of the Bureau of Motor Carrier Safety and from highway officials and police officials from several states stated that doubles have an equal or better accident record than tractor semitrailers (*28*). Records of accidents from several of the Turnpike Authorities permitting the operation of turnpike doubles (40 ft (12.2 m) trailers) show that these vehicle combinations have superior accident rates.

Triples have been operated under study conditions in Arizona, California, Idaho, Montana, Nevada, New York (Thruway), Oregon, Utah, Washington, and Wyoming. In some of these states, the study simply has involved the operation of triples over a period of time with, perhaps, some control of movements in inclement weather operations. In all cases, the safety records have been excellent.

All published research and available data show that doubles with 27-ft (8.2-m) trailers have safety records comparable to those of semis. Turnpike twins have comparably excellent safety records over operational periods of 10 to 20 years.

It should be noted that one factor, which probably contributes to the good safety records of multiple trailer combination vehicles, is the training and experience of the drivers. Generally, only the best drivers are assigned to these vehicles and a pay differential is often involved. It should also be noted that the accident records of the carriers, while they may be thorough and accurate, probably do not involve the operation of different vehicle types over the same highways. The carriers will operate doubles as much as possible where it is to their benefit and tractor semitrailers or other vehicle combinations where they are not permitted to employ doubles, so that differing environmental or traffic factors may be involved in the accident rates for the differing vehicle types.

Trucks have lower accident rates than cars, as reflected in Table 9. At the same time, fatality rates are higher for truck-involved accidents than for nontruck-involved accidents. No data are available, however, which can be used to determine how fatality rates vary as a function of truck weight or size. For example, a National Highway Transportation Safety Administration (NHTSA) paper published in January 1976 (*29*) concluded, on the basis of the Bureau of Motor Carrier Safety (BMCS) data, that the fatality rate for nontruck occupants increased as the weight of the truck increased. This was countered by a Federal Highway Administration paper published in September 1976 (*30*), which concluded that the relative safety of light and heavy trucks cannot be determined on the basis of the very same BMCS data. Other recent reports likewise reflect contradictory findings.

Some research is currently underway that should supply the needed data. An FHWA study scheduled to be completed by the end of 1978 has been studying truck accidents and exposures at 80 sites in 6 states. BMCS data are expected to improve substantially. NHTSA accident reporting systems are being instituted and improved. Until these efforts produce additional data, there is no sound basis for specifically associating accidents with truck weight or size.

TABLE 8

SELECTED ACCIDENT EXPERIENCE—TWINS vs. SEMIS

Carrier	Truck Type	Vehicle* Miles	Total Accidents	Accidents Per 1,000,000 Vehicle Miles*
A	Semi's	14,386,842	25	1.75
	Twins	3,580,760	1	0.27
B	Semi's	207,978,650	800	3.85
	Twins	373,611,300	1022	2.74
C	Semi's	225,048,870	519	2.31
	Twins	183,604,640	210	1.14
D	Semi's	179,624,590	849	4.73
	Twins	86,361,381	227	2.63
E	Semi's	64,844,952	242	3.73
	Twins	189,095,668	503	2.66
All Five Carriers	Semi's	691,883,880	2435	3.52
	Twins	836,253,740	1963	2.35

*For metric conversions, multiply vehicle miles by 1.609 to obtain vehicle kilometers and divide accident rates by the same factor for accidents per vehicle kilometer.

Commodity Characteristics

Certain basic characteristics of commodities dictate how commodities are carried and the extent to which nonuniformity in truck size and weight laws influence their transport.

Density

Density emerged as the most important commodity characteristic. Specific details concerning the density of major commodities were developed from the truckers questionnaire responses and were verified by the commodity flow network output.

The density of specific commodities, as determined from the truckers questionnaire responses, are given in Table 10. The commodity classifications used in the table are Interstate Commerce Commission classifications.

On the basis of the truckers' questionnaire, histograms were plotted of vehicle mileage distributions by density ranges for general freight, refrigerated solid products, agricultural products, building materials, and other commodities. These are shown in Figure 20.

Density distributions for the commodity flow network commodity classifications also were developed based on

TABLE 9

ACCIDENT RATES—TRUCK vs. PASSENGER VEHICLES

	Rates per Million Vehicle Miles Truck	Passenger Vehicle	Ratio Truck Ratio/ P.V. Rate
Intercity Carriers (Common, Private, and Contract vs. Passenger Fleets)	3.56	8.35	0.426
All Trucks vs. All Passenger Vehicles	9.86	8.35	1.181
FHWA "Review of Safety and Economic Aspects of Increased Vehicle Size and Weight			
Large Vehicle Combinations vs. All Passenger Vehicles	4.5	14.8	0.304
R. Winfrey "Economics of the Maximum Limits of Motor Vehicle Dimensions and Weights			
12,000 lb Trucks	22.8	40.3	0.566
12,001 - 24,000	21.3		0.529
24,001 - 41,000	29.6		0.734
41,001 - 72,000	16.6		0.412
Motor Vehicle Traffic Accidents in Utah (1974) Heavy Trucks vs. Passenger Cars	1.97	8.09	0.244

1 mile = 1,609 Km
1 kip = 0.4535 tonnes

the ton mileage for the first six truck types, all of which are tractor-semitrailer combinations grouped according to progressively increasing GCW ranges. As shown in Figure 21, distributions for low-density commodities tend to peak on the left side with the lighter GCW vehicles, whereas the high-density commodities tend to peak on the right. The distributions generally conform to inferences from truckers' questionnaire responses. The only inconsistency occurs in the distributions for light and medium density manufactured goods. The light goods distribution resembles what would have been expected for the medium goods distribution and vice versa.

It may be that many of the lightest "light manufactured goods" were categorized as general freight because of a study criteria that assigned payloads less than 6,000 lb (3.0 t) to this category. It was not always possible to assure that all of the many types of manufactured goods were properly assigned to the commodity groupings. However, the inconsistency does not have an impact on study findings.

The distribution for furniture and household goods dramatically demonstrates that carriers tend to choose the right vehicle for the load being carried. Furniture is very light and the truck type used to carry over 70 percent of the ton-miles is a light (4 axles or less) tractor, semitrailer combination.

Regional Variations

The output from the commodity flow network was analyzed regionally to identify regional variations. The regions shown in Figure 22 conform to ASSHTO regions with the exception of one state.

The first analysis was a comparison of the percentage of regional truck mileage attributable to each of the 14 commodities. The results are given in Table 11. Some contrasts reflecting regional differences in economic activity are as follows:

1. Almost 30 percent of all interstate truck mileage in the western region was attributable to agricultural commodities, whereas only 17 percent of all interstate truck mileage in the eastern region fell into this category. Percentage distributions for the other two regions, midwestern and southeastern, were 24 percent and 23 percent, respectively.

2. In contrast to agricultural movements, interstate movements of heavy manufactured commodities accounted for 17.4 and 15.2 percent of all interstate truck mileage in the midwestern and eastern regions, respectively, but only 7.4 and 8.7 percent in the western and southeastern regions.

3. Textiles accounted for 6.3 percent of all interstate

TABLE 10

DENSITY OF SPECIFIC COMMODITIES

Commodity	Mean Average #/Cu.ft.	No. of Samples	Range #/Cu. ft.	Mode #/Cu. ft.
General Freight	19.17	63	1 to 80	14.0
Household Goods	7.8	11	1 to 15	7.0
Heavy Machinery	53.95	10	10 to 100	40.0
Liquid Petroleum Products				
Refrigerated Liquid Products	24.5	4	1 to 45	26.0
Refrigerated Solid Products	27.9	21	1 to 100	
Dump Trucking	62.0	9	40 to 90	56.0
Agricultural Commodities	33.8	29	7.5 to 91.76	30.0
Motor Vehicles	7.9	3	7.5 to 8.3	8.0
Building Materials	64.4	23	2.5 to 160	50.0
Forest Products	49.5	9	13 to 100	50.0
Mine Ore	40	1	-	-
Retail Store Delivery Service	16.0	11	6.25 to 30.0	13.0
Explosives or Dangerous Articles	50.0	7	13.0 to 100.0	50.0
Other:				
0 - 9.9 lb/cf.				
. Fiberglass	6.0	1	-	-
. Potato Chips	1.87	1	-	-
. Health Care Products	8.0	1	-	-
. Honeycumb cellular	4.0	1	-	-
. Cooling Structure Boxes	8.35	1	-	-
. Corrugated box	6.0	1	-	-
. Plastic Pipe	7.0	1	-	-
. Glass Products	8.5	2	6 to 11	-
. Baked Goods	9.0	1	-	-
10.0 to 14.9 lbs/cf.				
. Cans	11.7	3	7 to 21	7
. Shoes	10.0	1	-	-
. Pianos	10.0	1	-	-
. Textiles	13.9	6	10 to 16	15
. Toys	12.0	2	9 - 15	-
. Fiberglass Tanks	12.0	1	-	-
. Liquid Gyrogenics	12.0	1	-	-
15.0 to 19.9				
. Paper	17.5	2	10 to 25	-
. Refinery Vessel	17	1	-	-
. Household goods	17.5	1	10 to 25	-
20.0 to 29.9				
. Groceries	25	1	-	-
. Glass Tubing	20	1	-	-
. Fiberboard	22	1	-	-
. Fiberglass Dock	22	1	-	-
. Hydrate	27	1	-	-

TABLE 10—(Continued)

Commodity	Mean Average #/Cu.ft.	No. of Samples	Range #/Cu. ft.	Mode #/Cu. ft.
30.0 to 39.9				
. Plastic Pellets	30	1	-	-
. Carbonated Beverages	34	1	-	-
. Piece goods	30	1	-	-
. Absorbant Clay	32	1	-	-
. Tanners Oil	37.5	1	-	-
. Plastics	35.0	1	-	-
. Machine Parts	31.0	1	-	-
. Vegetable Protein	31.8	1	-	-
40.0 to 49.9				
. LP Gas	49.5	2	40 to 59	-
. Foodstuffs	40.0	1	- -	-
. Livestock Feed	47.0	1	- -	-
50.0 to 59.9				
. Tallow and Bone Meal	52.5	1	50 to 55	-
. Coal Aggregates	50.0	1	-	-
. Lube Oil	55.0	1	-	-
. Gear Boxes	50.0	1	-	-
. Electrical Equipment	54.0	1	- -	-
. Liquid chemicals	58.0	1	-	-
. Vegetable Oil	56.0	1	-	-
. Lime	55.0	1	50 to 60	-
. Chemicals	58.0	4	20 to 112	-
60.0 to 69.9				
. Salt	60.0	1	-	-
. Plastic Synthetic Liquid	66.0	1	-	-
. Pebble	60.0	1	-	-
70.0 to 79.9				
80.0 to 89.9				
. Brick	84.0	1	-	-
. Syrup	85.0	1	-	-
90.0 and over				
. Steel	294.0	5	150 to 500	-
. Non-ferrous scrap	272.0	1	-	-

lbs./cu. ft. x 16.02 = Kg/cu. m.

truck mileage in the southeast, but the other regions had much lower percentages.

4. Forest products accounted for 4.2 and 3.4 percent of mileage in the west and southeast, respectively, but only 1.3 and 0.7 percent in the midwest and east. However, percentages for pulp and paper are highest in the east and southeast.

5. Percentages for building material were very similar in the west, midwest, and southeast (2.1 to 2.2 percent) but moved up to 4.9 percent in the east.

The second factor investigated was average payload by commodity. On a national basis, the average payload ranged from 20.9 tons (18.95 t) for bulk extractive resources to 7.20 tons (6.53 t) for household goods and furniture. Average payloads by region and commodity are given in Table 12. On a regional basis, the averages were highest in the west and lowest in the east with a downward tendency from west to east. The regional variations are consistent with differences in legal limits.

Use of Twin Trailers

Another analysis relevant to the impacts of nonuniformity compared use of the twin-trailer combination. Regional comparisons reflect differences in permitted use of this combination. Analysis of its use in regions uniformly permitting it, especially in the western region, may reflect its potential utilization throughout the United States under conditions of uniformity permitting its universal use.

The percentage of the ton-miles of each commodity being transported in twin tractors, either twin 27 ft (8.2 m) or 40 ft (12.2 m), is given in Table 13. The following contrasts were noted in the analysis:

1. Sixteen percent of all interstate ton-miles in the western region are carried in twin trailers. Percentages for the midwest, southeast, and east are 4.1, 0.6, and 0.7 percent, respectively. Nationally, 5.2 percent of interstate ton-miles are carried in twin-trailer combinations.

2. The use of the twin combination to transport heavy commodities—such as bulk extractive resources, heavy manufactured goods, and refrigerated agricultural products—tends to be low, even in the western region where twin 27-ft (8.2-m) trailers are allowed almost universally.

3. Carriers of general freight use twin trailers far more than other carriers. Forty-eight percent of all general freight ton-miles in the western region are carried in twin trailers. Percentages in the midwest, southeast, and east are 16.1, 2.4, and 2.8 percent, respectively. On some links in the west, the percentages ran as high as 80 percent.

The use of twins currently reflected in the western region is indicative of that which could be expected nationally if western legal limits were adopted nationally. However, national use would probably be higher still, since the present western use is influenced to some extent by the more restrictive limits to the east. A coast-to-coast trip from California to North Carolina could not be made in twins because they are not legal in all states along the route. In contrast, one-third of all truck combinations counted at a loadometer station between Los Angeles and San Francisco were twins.

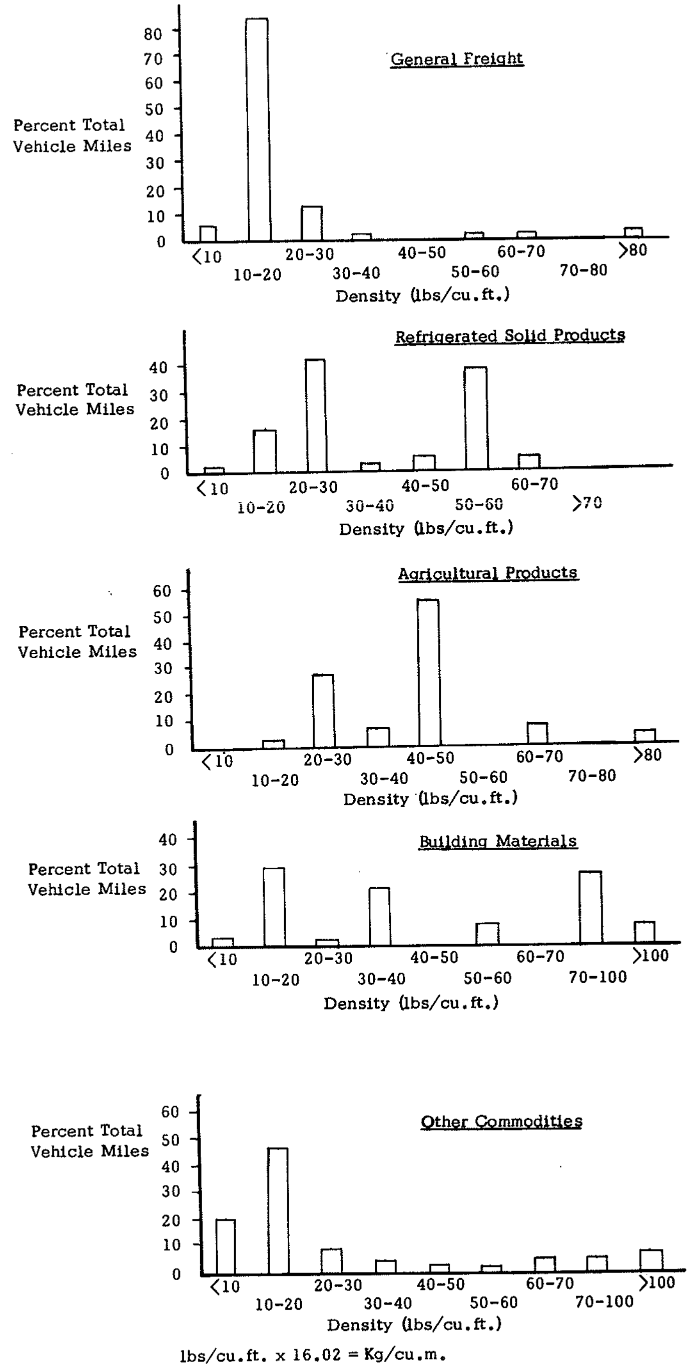


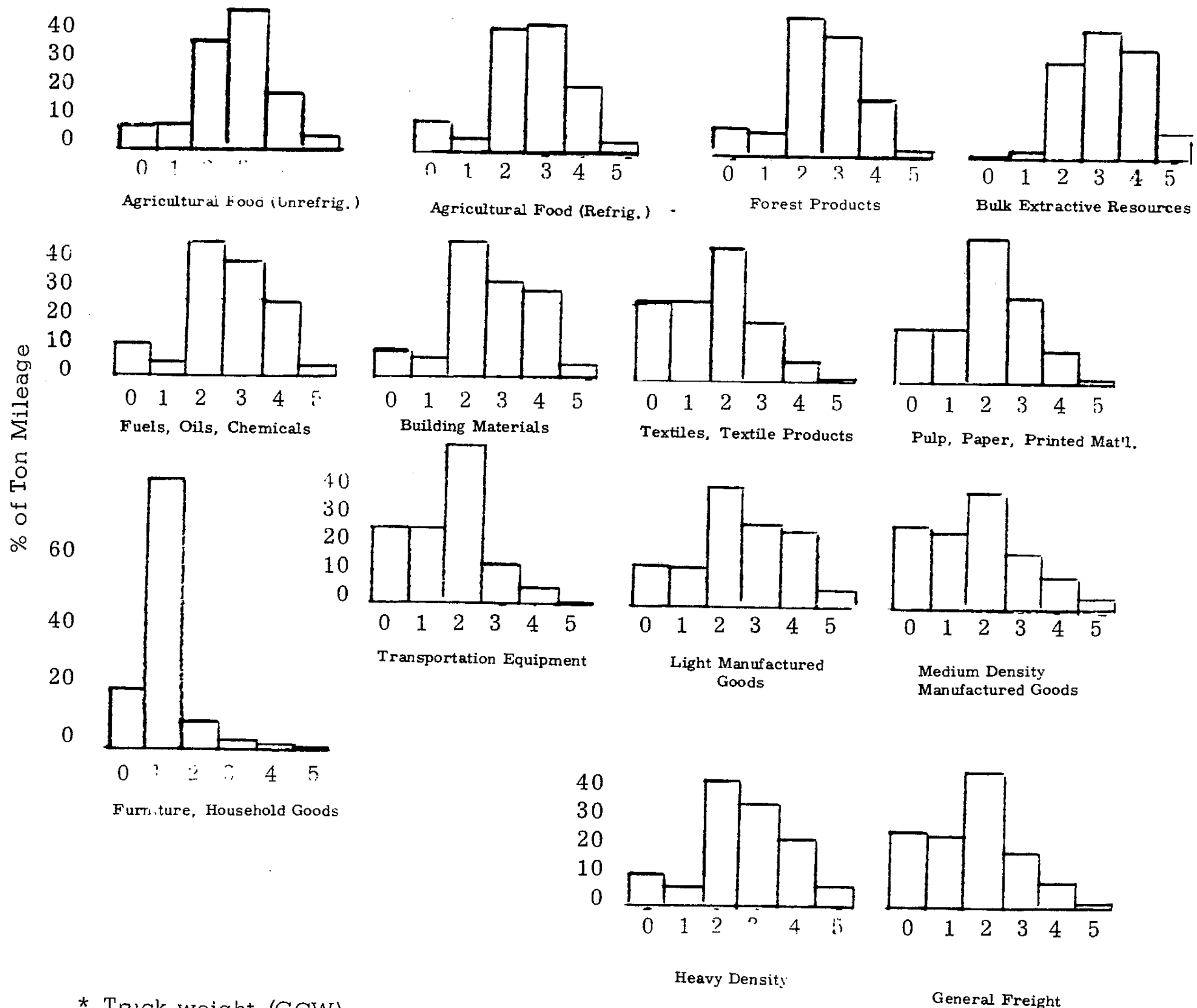
Figure 20. Vehicle mileage distribution vs. density.

TRUCKING EFFECTS OF NONUNIFORMITY

Nonuniformity in state laws governing truck sizes and weights results in inefficient vehicle use and circuitous routing. Discussions with truckers and representatives of trucking associations, and responses to the truckers' questionnaire, clearly identified the specific situations discussed in the following sections.

Route Diversions

Many of the carriers who were interviewed or who responded to the questionnaire cited examples of diversions



* Truck weight (GCW) groups are arranged from low (1) to high (5). See Table 4.

*Figure 21. Ton mileage distributed by truck type.**

around states that are more restrictive than others along the route. The most commonly cited example is the Iowa-Wisconsin restriction not permitting use of 65-ft (19.8-m) twin-trailer combinations. More general freight in the western states is carried in 65-ft (19.8-m) twin-trailer combinations than in any other type of vehicle. Rather than break bulk to traverse Wisconsin or Iowa, carriers choose to go around Iowa using U.S. Route 36 in Missouri. The average increase in trip length from Seattle to Chicago is approximately 280 mi (450 km) or 10 percent of the trip length.

A comprehensive study by the Iowa Department of Transportation (*31*) concluded that allowing 65-ft (19.8-m) twin-trailer combinations in that state, with no increase in weight above current levels, would result in national annual reductions of 6.5 M veh-mi, (10.5×10^6 v-km), 96 accidents, and 0.6 fatalities. (The state currently allows 60-ft (18.3-m) doubles.) Net 20-year benefits to Iowa would be approximately $190 million and to the nation as a whole, approximately $285 million. Fuel consumption over 20 years would be reduced by 150 M gal.

Other major bypass situations for twin-trailer combinations are as follows:

1. Midwest to/from New York City—Pennsylvania's restriction on twin trailers results in carriers circumventing Pennsylvania via the New York State Thruway.
2. Boston to/from New York City—Connecticut does not allow twin trailers. Consequently, carriers utilizing twins use the Massachusetts Turnpike and the New York State Thruway. This bypass increases the trip length by 60 percent; however, the toll roads allow turnpike twins (two 40-ft (12.2-m) trailers), thereby making the bypass economical.

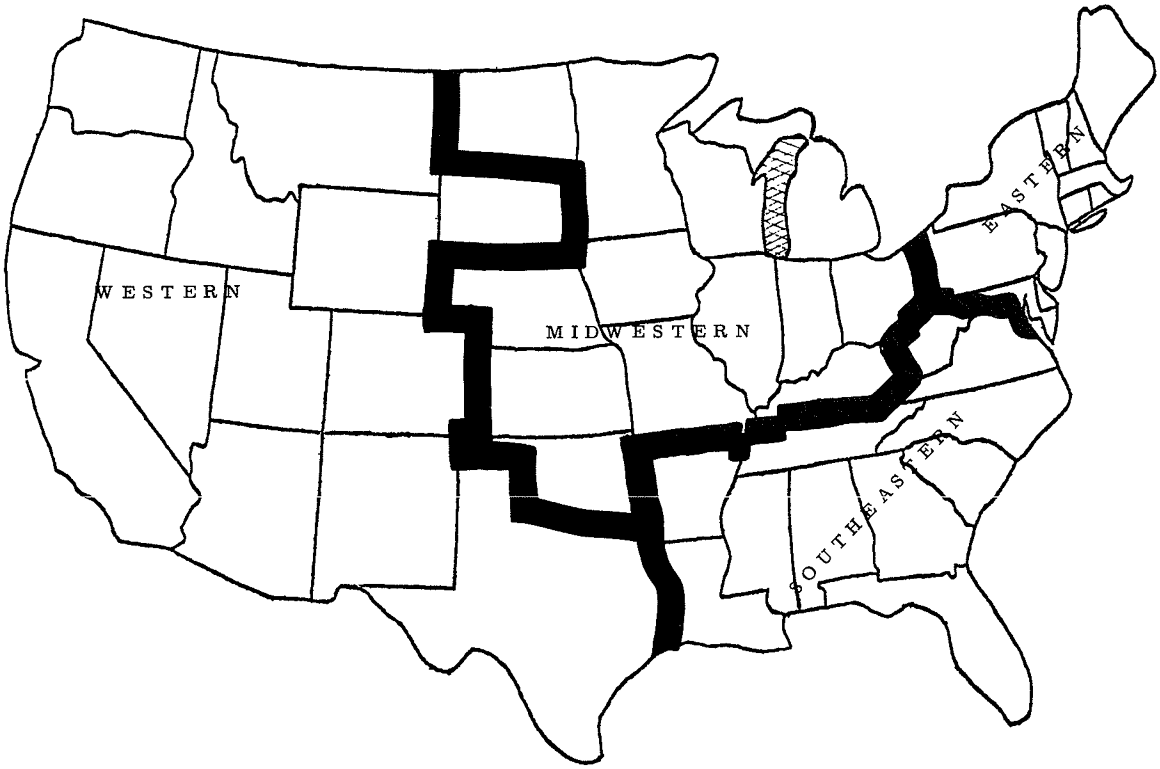


Figure 22. Regional divisions in commodity flow network.

Turnpike twins, two 40-ft (12.2-m) trailers, are allowed on the toll roads of Kansas, Illinois, Indiana, Ohio, New York, and Massachusetts. Many coast-to-coast carriers will route their shipments via the toll roads, although this routing may be less direct, in order to take advantage of the ability to use the doubles combinations.

Separation of Combinations

There are several situations where bypassing is not possible, but the distance to the destination, or through the restrictive state, is relatively small. In these cases, many carriers use the twin-trailer combination up to the border of the restrictive state and then break the combination into two separate units to continue into or through the state.

The best known of these situations occurs on I-90 across the "Pennsylvania Stovepipe," the 45-mi (72-km) northwestern section of Pennsylvania separating Ohio and New York. Both 65-ft (19.8-m) and 98-ft (29.9-m) twin-trailer combinations are allowed on the Ohio and New York sections of I-90. They are not allowed in Pennsylvania, but for this 45-mi stretch of highway, 65-ft (19.8-m) twin-trailer comoinations would be able to operate from the west coast to New York or Boston. Many carriers, therefore, run their twin units to the Pennsylvania border, drop the rear trailer, and continue across the 45-mi (72-km) section with the first trailer only. They must then drop the first trailer on the other side and return to retrieve the second.

A representative of one large carrier who was interviewed stated that the carrier pays $500,000/yr to another trucking service solely to ferry second trailers across the stovepipe. Another carrier schedules twin-trailer combinations going in opposite directions to arrive at each border of the stovepipe simultaneously. Each combination drops its second trailer and takes the first across, where it picks up the second trailer from the other combination and returns. Each of the trailers is then at the opposite border, while the tractors are at the border where they originally arrived. The tractors hook up the new trailers and return in the opposite direction from which they came.

Another type of combination separation occurs in order to haul individual 27-ft (8.2-m) trailer units to or from a destination or origin within a state not allowing the 65-ft (19.8-m) twin combination. According to truckers' questionnaire responses, acceptable haul distance for these individual units normally does not exceed 10 percent of the total trip length.

Equipment Utilization

Current nonuniformity in size and weight laws can make equipment purchasing, selections, and utilization decisions quite difficult for a carrier. For example, the following are the types of questions that must be considered:

1. When a carrier maintains a large fleet of twin 27-ft (8.2-m) trailers, what kind of vehicle does he operate in the states that do now allow doubles? Forty-ft (12.2-m) and 45-ft (13.7-m) trailers are inefficient in states allowing the doubles with twin 27-ft (8.2-m) trailers. It is also inefficient to use a combination with only one 27-ft (8.2-m) trailer.

TABLE 11

TRUCK MILEAGE DISTRIBUTION BY COMMODITY AND REGION

COMMODITY	PERCENT OF INTERSTATE TRUCK MILES IN REGION			
	Western	Midwestern	Southeastern	Eastern
Agricultural (non-refrigerated)	19.95	17.83	15.82	12.93
Agricultural (refrigerated)	9.87	5.95	7.01	3.94
Forest Products	4.17	1.26	3.35	0.74
Bulk Extractive Resources	0.17	0.72	0.95	0.95
Fuel, Oils, Chemicals	12.04	7.09	10.06	10.67
Building Materials	2.10	2.22	2.10	4.91
Textiles, Textile Products	1.83	1.28	6.28	1.71
Pulp, Paper, Printed Material	4.07	4.98	5.68	6.23
Furniture/Household Goods	0.63	0.74	0.85	0.57
Transportation Equipment	1.26	1.94	1.35	1.30
Light Manufactured Products	4.53	5.08	6.44	8.32
Medium Density Manufactured Products	5.25	6.34	4.63	5.37
Heavy Manufactured Products	7.38	17.41	8.65	15.15
General Freight	26.76	27.15	26.83	27.19
TOTAL	100.00	100.00	100.00	100.00

2. When buying a tractor does a carrier select a short wheel-based tractor that will allow room for a 45-ft (13.7-m) trailer within the 55-ft (16.8-m) over-all length limit of some states? Or does the carrier buy a more comfortable, longer wheel-based tractor and sacrifice the capability to operate with 45-ft (13.7-m) trailers in 55-ft (16.8-m) limit states? Many independents pick the second option and restrict their marketing. This also limits the availability of owner-operators who can flexibly handle company trailers when under contract to a common carrier.

3. When operating in Iowa, which only allows a 60-ft (18.3-m) over-all length for twin-trailer combinations, should a carrier use 24-ft (7.3-m) trailers that are inefficient in other states? Or should he operate a fleet of 55-ft (16.8-m) long tractor-semitrailer combinations that carry less cargo?

4. In California, when loading lumber destined for Illinois, should the carrier load up to 73,280 lb (33.23 t), which is the limit in Iowa and Missouri? Or should he load to 80,000 lb (36.28 t), which is allowed in the states west of Iowa/Missouri, and offload part at the Iowa or Missouri border? The carrier without terminals at which to offload will probably load up to 72,280 lb (33.23 t) only.

5. Where tollways allow turnpike twins, should a transcontinental carrier use twin 27-ft (8.2-m) trailers for compatibility with its western operations? Or should he use the turnpike twins for more efficiency in eastern operations? Or should he split the difference?

6. Should an auto-carrier buy an articulated rig that carries 8 full-size cars but cannot be operated in many eastern states? Or should he use a 7-car rig, achieve full flexibility, but lose efficiency because of the limits in western states?

In answering these questions, different carriers make different decisions. However, the fact that such decisions must be made demonstrates that efficiency in equipment use is diminished relative to the possibilities under national uniformity.

Vehicles, such as the twin 27-ft (8.2-m) trailers and the turnpike twins, are efficient vehicles to operate for many types of haul. Given the legal authority to do so, carriers tend to shift a substantial proportion of their cargoes to these combinations. This is demonstrated in some western corridors where almost 90 percent of all general freight is moved in doubles.

In most states that limit the over-all length of a vehicle combination to 55 ft (16.8 m), a 45 ft (13.7 m) long semitrailer is permitted. This usually results in the use of short wheel-based tractors if low-density, high-cube commodities are being transported. However, numerous respondents to the truckers' questionnaire indicated that short wheel-based cab-over-engine tractors are less comfortable to drive than are the long-nosed conventional cab-behind-engine tractors. They also are considered to be less safe because of additional weight on the steering axle making steering harder and increasing the risk of blowouts as well as providing less of a buffer.

HIGHWAY PROBLEMS IN PROVIDING UNIFORMITY

Importance of Highways

The economic importance of good rural highways is well recognized throughout the world. Even in developing countries where there is a well-developed railroad system, there is current emphasis on the development of a rural highway network to provide adequately for the desirable development of natural resources, agriculture, industry, and commerce. The United States, as the economic leader of the world and with its outstanding national transportation system, is the pattern being followed by these nations.

Why are highways considered so important as related to other surface modes of transportation? What can they do for economic development that other modes cannot?

In the developing countries, including those with well-developed rail systems, the primary use of rural arterial highways is not, as evidenced from the traffic on them, the transportation of persons, but it is the transportation of commodities. In many cases, a larger number of people, proportionately, are probably transported by rail. This may also continue to be true in some European countries.

The reasons highways are so important for the movement of commodities in a developed economy, as well as in a developing economy, are their natural advantages over the rail mode. Primary among these is the capability to transport goods from the production point directly to the place

TABLE 12

AVERAGE PAYLOAD BY COMMODITY AND REGION

COMMODITY	AVERAGE PAYLOAD IN TONS				
	Nat'l.	Western	Midwestern	Southeastern	Eastern
1	16.57	18.28	16.69	15.84	15.37
2	17.21	18.42	17.48	16.12	16.09
3	15.75	18.12	14.12	15.70	14.85
4	20.89	21.44	20.76	20.58	21.65
5	16.99	17.74	17.92	17.55	16.13
6	16.90	18.36	17.05	17.37	16.85
7	11.25	10.29	11.69	11.95	10.58
8	12.54	14.89	12.18	13.55	10.48
9	7.20	8.33	6.77	7.43	8.30
10	12.10	10.53	12.93	11.55	10.70
11	14.66	14.46	14.72	15.52	14.11
12	11.09	12.44	10.76	11.65	11.58
13	16.85	16.40	17.32	15.99	16.91
14	11.85	13.29	12.15	12.34	11.44

1 ton = .907 tonnes

TABLE 13

PERCENT OF TON-MILES TRANSPORTED BY TWIN TRAILER

COMMODITY	PERCENT OF TON-MILES OF COMMODITY WITHIN REGION TRANSPORTED BY TWIN-TRAILER COMBINATIONS				
	National	Western	Midwestern	Southeastern	Eastern
1	3.62	12.56	1.43	0.05	0.02
2	0.59	1.48	0.17	0.06	0.43
3.	3.05	6.67	0.06	0.00	0
4	1.04	17.37	1.58	0.00	0
5	0.75	1.94	0.49	0.00	0.03
6	5.17	30.25	0.07	0.02	0
7	0.86	4.88	0.79	0.24	0
8	3.24	16.88	0.33	0.04	0
9	0.77	3.48	0.84	0.00	0
10	0.74	2.22	1.01	0.00	0
11	1.32	3.66	1.67	0.38	0.04
12	0.99	4.08	0.13	0.00	0.01
13	0.62	1.53	0.69	0.00	0
14	17.11	48.05	16.10	2.37	2.81
All Commodity	5.22	16.28	4.06	0.61	0.67

Ton-miles x 1.46 = Tonne-kilometers

where they are processed, consumed, or exported. Also, there is a relative ease and quickness of construction in different geographic situations as well as lower costs. The operating equipment that utilizes highway is much less expensive per unit and can be afforded by relatively small entrepreneurs. Users of the highway mode are not limited with respect to the routes over which they can operate. Highways preceded the development of the motor car and motor truck as essential routes of transportation.

Highways and their importance to the economy are particularly significant at the present time because the United States is in grave danger of failing to employ its highway system for the maximum advantage to its people. The problem is occurring partially because of general misunderstandings concerning the competitive situation between railroads and trucking, as discussed previously.

The General Direction of Uniformity

In order to understand the possible highway impacts of better uniformity in motor vehicle sizes and weight legislation and regulation, it is necessary to have a clear conception of what uniformity means in terms of existing legal requirements and the changes that need to be brought about.

During the research, questions were raised by some as to whether better uniformity can somehow be obtained without the need of individual states to change their present size and weight laws and regulations. However, reflection will show the impracticality of any arrangements that would not require such changes. Reciprocity would require legal provision, even if it were on the basis of compacts among states, and it is highly unlikely that any state would permit out-of-state vehicles to operate at different size and weight levels than in-state vehicles. The only way for uniformity to be practically achieved is for some states to change their current laws and regulations, in fact to become more lenient.

The fact that the direction of greater uniformity is one of more leniency in restrictive states, rather than the reverse, was questioned during this project. However, it soon became evident that significant reductions of transportation costs can be obtained, as a result of more lenient provisions in a number of states, without commensurate increases in highway costs or other identifiable disbenefits.

Some states possibly do allow vehicle configurations and loadings that appear hard to justify from the standpoint of net public benefit. However, the provisions are largely directed toward in-state movements. They often result from representations by specific industries, agricultural enterprises, or natural resource producers considered important to a state's economy.

The difficulty of getting state legislatures to change this kind of provision leads to an important conviction relative to uniformity, which is that optimal uniformity does not necessarily require every state to have the same laws and regulations regarding motor vehicle sizes and weight. Instead, most of the advantages associated with uniformity can be obtained if all states, within their laws and regulations, will provide for the free interstate movement of those vehicle configurations and sizes and weights shown to produce significant transportation cost savings without commensurate disbenefits. If a state wishes to provide for another movement, important to it and confined within its borders, it simply is outside the sphere of uniformity concern.

While these considerations may not appear to relate to the effect of uniformity on the highway system, they, in fact, set the stage for the determinations that are required to analyze the highway impacts of uniformity. These impacts, to the degree they may occur, are associated with the effects of heavier gross loads and axle loads as well as larger vehicles and possibly different vehicle configurations on the highways.

In order to properly evaluate these effects, it is necessary to consider some of the highway design and operation principles that are involved. The cause of uniformity has probably been ill-served because of many public misunderstandings related to these principles.

Potential Highway Impacts

The highway effects of motor vehicle sizes and weights occur in several categories that can be summarized as follows: (1) structural effects—these include effects related to maintenance; and (2) operational effects, including impacts on highway safety. The principles considered during this research under each of these categories are discussed in the following sections. Structural effects are discussed separately for pavements and bridges, because sizes, weights, and vehicle configurations operate differently on the structural components of highway pavements and highway bridges.

Sizes, Weights, and Pavement Costs

With respect to highway pavements, three national tests that were conducted at different times and places provided considerable insight into the effects of trucks of different sizes and weights on design requirements and service lives. These were Road Test One in Maryland; the WASHO Road Test in Idaho; and the AASHO Road Test in Illinois.

The last of these, the AASHO Road Test, conducted in Illinois between 1958 and 1961, demonstrated that axle load repetitions dictate the type, quality, and thickness of highway surface components. With respect to structural requirements, the number of repetitions of any given axle load can be related to a determinable number of repetitions of another axle load. The proportional relationship of these repetitions provides an axle load equivalence.

Highway design in most states, today, is based on the number of 18,000-lb (8.16-t) axle load equivalents anticipated over a future 15- or 20-year period. When these equivalents are produced by 16,000-lb (7.26-t) axles, a larger number of repetitions is required for the same effect. When they are produced by 20,000-lb (90.7-t) axles, a smaller number of repetitions is required.

The relationship between repetitions is not arithmetically proportional to the axle loading. Instead, a 10,000-lb (4.5-t) axle needs to be repeated many more than 1.8 times the number of repetitions of an 18,000-lb (8.16-t) axle to have the same effect—in fact, more than 12 times. Similarly, a 22,000-lb (9.98-t) axle needs to be repeated less than half the number of times to have equivalent effect.

Table 14 presents the AASHO axle load equivalents of different axle loadings.

Note that tandem axle loads operate as if they were single axles and produce less equivalents than twice the single axle loads represented in the pair. This is because of the way deflections occur and stresses on pavements are distributed.

As long as pavements are properly designed for the future axle load (repetitions that will occur on them (18,000-lb (8.16-t) or 18-kip equivalents)), they should have a predictable service life. The projected axle load repetitions are used in the determination of the pavement thickness necessary to last the desired length of time.

If the axle load repetitions are increased during the course of the pavement life, its life will be shortened by a generally measurable amount unless remedial action is taken. Remedial action would be to increase thickness by adding an appropriate amount of surface overlay (placed before the pavement has deteriorated to an undesirable extent), which would restore the originally expected service life. However, instead of such remedial action, which should be taken at an early stage, the pavement often is permitted to deteriorate to a degree where extraordinary maintenance is required. But such maintenance, which is likely to be costly, can only prolong the operation of an already deteriorated pavement that does not meet service requirements.

It is important to note that pavements designed properly for a specific order of axle loading theoretically do not require more or less maintenance because of the magnitude of that loading. In other words, a pavement designed for 22,000-lb (9.98-t) axle loads and subjected to the number of such loads anticipated requires no more maintenance than one designed for 18,000-lb (8.16-t) loads and subjected to the number of these loadings expected. It is only when the design equivalent axle loadings are exceeded that more maintenance may be required and, as indicated, this occurs at a stage where the additional maintenance does not provide a solution.

Accordingly, for any additional equivalent axle loads likely to occur as a result of the uniformity provisions recommended in this report, the additional highway costs have been calculated on the basis of the amounts of overlay required to fully restore the present surface lives of the pavements unless pavements are already deteriorated. If they are deteriorated, new construction costs were figured for their restoration but only as the basis for determining an increment chargeable to the axle-load increases. The total costs of refurbishing presently deteriorated pavements obviously are not chargeable to proposed increases. In the case of overlays, however, the full costs have been reckoned as a proper charge against the increased loadings that will produce more uniformity.

TABLE 14

EQUIVALENT 18-KIP SINGLE-AXLE LOAD FACTORS—AASHO

Single Axles		Tandem Axles	
Load, kips	Factor	Load, kips	Factor
2	0.0002	4	0.0004
3	0.0008	6	0.0014
4	0.002	8	0.004
5	0.005	10	0.01
6	0.01	12	0.02
7	0.02	14	0.04
8	0.03	16	0.06
10	0.08	18	0.10
12	0.18	20	0.15
14	0.34	22	0.23
16	0.60	24	0.33
18	1.00	26	0.46
20	1.57	28	0.64
22	2.37	30	0.85
24	3.45	32	1.12
26	4.88	34	1.45
28	6.73	36	1.85
30	9.09	38	2.33
32	12.05	40	2.90
34	15.72	42	3.57
36	20.23	44	4.35
38	25.70	46	5.26
40	32.29	48	6.31

2 kip = 0.907t

Source: U.S. Senate, 93rd, 2nd session, Committee on Public Works, hearings on Transportation and New Energy Policies (Truck Sizes and Weights), February 20, 21, and March 26, 1974, Washington, D.C., U.S. Government Printing Office, 1974. p. 72.

Sizes, Weights, and Bridge Costs

Loads from motor vehicles operate differently on bridges than on pavements. In this case, total loaded vehicular weight, axle loading, and spacing between axles operate together and separately to influence structural requirements.

Certain structural members of the bridge must support the entire load of vehicles anticipated to be on the structure at one time. In most cases, this is more dependent on a traffic situation than on a single vehicle's characteristics. Other members, however, are designed to support a specific amount of distributed load. This is dependent to some degree on the gross weight of a vehicle and the length of the bridge deck over which the weight is distributed. Some structural members, perhaps identical members, are also designed to support loading at a point such as may be applied by a single axle. If any of these loading characteristics are exceeded, the bridge presumably will fail. Repetitions of loading also have an effect on the ability of bridges to support loads through fatigue of materials.

Initially, all bridge structures are designed for a specific loading condition anticipated to represent the maximum to which the bridge will be submitted during its service life. However, factors of safety are also incorporated to prevent the first load that exceeds the design condition from causing failure. This results in a question as to what degree the design loading can be exceeded, because of the incorporated safety factor, before a bridge will fall.

The question is complicated because there has not been consistency of practice over time (in particular) with respect to safety factors. A bridge may have a factor of safety of 3, or 2, or 1.5. Some bridges already are supporting loads considerably above their nominal design loadings.

In order to try to determine the actual support capabilities of their bridges, most state highway agencies are now in the process of evaluating them individually on the basis of how they were constructed and their present condition. The methods of evaluation are scientific and involve a determination of load capability as related to the design stresses that actually will cause bridge failure. These evaluations are used both to determine bridge replacement needs and to post limits on bridges indicating loadings that should not be exceeded from a safety standpoint.

As a result of such evaluations, research questionnaire responses show that the states presently have posted (or identified for posting) some 29,000 bridges on the state systems and that this is the result of evaluations of only a portion of the total number of bridges. More than a quarter of the agencies reported have evaluated less than 50 percent of their bridges; some as few as 10 percent. This means that more than 30,000 bridges on state highways are not now capable of safely supporting the maximum loadings that the individual states otherwise permit.

To give further scope to the problem, estimates have been made that there are, nationally, 150,000 deficient bridges on all highway systems. Although this figure is intended to include geometric as well as structural deficiencies, the number of state bridges posted suggests that it might be quite low. One state agency, which reported posting 5 percent of its bridges, indicated, when visited, that changes in its legal bridge formula to increase loads would result in a sizeable increase in the number of posted bridges.

Although some of the bridges undoubtedly can be strengthened to handle existing legal loadings at something less than new construction cost, complete replacement will be necessary in many cases. The cost of an improvement program to bring all state bridges to existing load standards obviously will be tremendous. And, judging from the 1975 National Highway Inventory and Performance study, current highway expenditures are not keeping pace with obsolescence of the highway facilities.

Recognizing that strong economic justification would be needed for recommendations that would cause a large number of additional bridges to become deficient in terms of the vehicular loads permitted on highways, careful consideration was given to transportation cost savings that possibly could be realized through increasing bridge loads. In the case of the largest volume of commodities transported by road, it was apparent that the demand and economic justification were not there. In the case of some heavy commodities, it became apparent that there are alternatives to the types of vehicles that might require additional load provisions. These alternative vehicles could transport the commodities without the amount of transportation cost increases that would justify the incurrence of additional bridge deficiencies.

The analysis of alternative vehicle types for heavy movements was limited to interstate movements. However, the inclusion of intrastate movements would not change the picture to the degree that heavy movers desiring larger load limits on bridges would be willing to pay the entire cost of the additional bridge replacements that ultimately would be required. Further, in accordance with the theory of cost allocation as reflected in the well-known incremental analysis, there would be no justification, tax-wise, for charging these additional costs to other segments of the trucking population.

Accordingly, it was concluded that there is insufficient cost justification to exceed the commonly used bridge formula that provides a basis for legal control of vehicular sizes and weights in most states. The most common expression of this formula (as recommended by AASHTO) was cited earlier in this chapter and is used in this research as the outside limit of permissible vehicular loading. Since it reasonably defines vehicular loadings that safely can be permitted on present arterial system bridges, the acceptance of this limit means that no option of uniformity analyzed will result in additional bridge costs.

It should be noted, however, that the formula does not define absolutes with respect to vehicular size and axle load, but relative values. In fact, substantial increases in some common weight limits are recommended as a result of this research, but they do not result in increases of bridge costs or, because of distributions, general increases in pavement costs.

Highway Operational Effects of Sizes and Weights

There actually is little logical reason for some current size and weight controls in terms of demonstrable disbenefits that will occur on the highways if the present limits are exceeded. Gross vehicle weights, for example, are not by themselves significant as related either to highway pavement costs or highway bridge costs. It depends on the number of axles they are distributed over and the spacing between these axles. Further, there is no indication that gross weights have any relationship to decreased highway safety. In fact, on a per vehicle mile basis, some of the largest and heaviest trucks may have the best safety records on the highways.

Gross weights do have operational influences that are related to the size of power plants used to move them, effects that can be commonly experienced on grades where they sometimes all but eliminate the traffic movement capability on two-lane, two-way highways and seriously disrupt the capacity of four-lane facilities. But the culprit, in this case, is power-weight ratio coupled, sometimes, with poor driving practices where one slow vehicle tries to pass another going just a little slower.

Because it is not gross weight, *per se,* that has the ill effects, the questions must be asked: "Why limit gross weights? Why not limit axle loads that can damage highways and specify axle spacings, power-weight ratios or minimal speeds, vehicular unit lengths, and other factors that influence the costs, safety, and operational characteristics of highways?"

Total vehicular length and numbers of trailers in combinations are other characteristics which, up to certain practicable limits, have little demonstrable ill effect on multilane highways. The operating characteristics and safety records of turnpike doubles and triples were discussed earlier in this chapter. They are generally accepted as producing no more ill effects than other large trucks.

One concern often expressed is that the public fears traveling on the same highway with the 100-ft (30.48-m) combinations. However, observations of highway department personnel and police personnel do not seem to support this concern where the combinations have actually been tested or used. The following are several relevant quotations collected by the Western Highway Institute (*4*):

> Mr. M. G. Oldfield, Permit Administrator, Washington Department of Highways: In a copy of a report sent to Mr. W. D. Brady of San Leandro, California, May 23, 1968, concerning operational tests of triples from Seattle to Spokane and Seattle to Portland, Mr. Oldfield commented that, of 23 motorists stopped and asked if they noticed the triples, only two said yes. One was a truck driver, the other, a minister who said the 100-foot long unit seemed 12 feet longer than regular combinations. None indicated any difficulties in passing.

> Mr. A. F. Bastron, Planning and Research Engineer, Wyoming Highway Department: In a memo concerning a triples test in Cheyenne, Mr. Bastron commented that during the test run it did not appear that any problems were encountered in traveling the route or that any other vehicles traveling the route were affected by the test vehicle.

> Mr. F. B. Cordiner, Equipment Supervisor, Wyoming Highway Department: In a report on a double 40 combination operated over both two-lane and four-lane highways, Mr. Cordiner stated that observations were made both from a following car and from riding in the tractor cab. It, at no time, appeared to be an inconvenience or hazard to other vehicular traffic. Deviation from normal single trailer tracking was scarcely noticeable and braking was smooth and true at all stops. Even though the axle of the rear trailer was lightly loaded, there was no tendency for it to sway or swing around.

> On page 93 of the 1964 BPR report on desirable dimensions and weights of vehicles, it is stated that observation of 100-foot long trailer combinations on toll highways, built to interstate standards, has indicated that the normal behavior of other traffic was not significantly affected.

> In a memo dated October 6, 1969, to George H. Andrews, State Highway Engineer, Washington Department of Highways, regarding 284 trips and 31,761 miles of triples operation, M. G. Oldfield, the Permit Supervisor, stated: We have followed and observed the units and can honestly state that we do not believe the average motorist is aware of the longer units.

> A letter from a special committee of the Wyoming Highway Department, which was appointed to study longer combination operations, transmitting its formal report to Supt. R. G. Staff, states that during the time period of Wyoming's testing program, we have not received any comments on these operational tests from the traveling public or the general populace. It is difficult to ascertain the long term effect that vehicles of this length, and possible future heavier loads, would have on other vehicles in the traffic stream. The Wyoming Highway Department Committee charged with the responsibility of this testing program of long combination vehicles is of the opinion that these vehicles could operate satisfactorily in Wyoming on four-lane highways as well as modern two-lane sections having adequate sight distance and climbing lanes on the longer hills.

> A report by the Nevada Highway Department to a legislative interim committee studying longer combinations commented that there were no problems with them on four-lane highways; on good two-lane highways they were no more objectionable than other combinations; no objections had been received from other road users (tests were conducted over a one-year period); and nothing had been produced to show the operation of longer combinations on two-lane roads should not be allowed.

> Asst. Chief Weighmaster V. F. Bush of the Oregon Highway Department, in a report on a triples operation between Klamath Falls and Portland, stated that a close observation was made of vehicles overtaking and passing the test equipment. No one appeared to have any difficulty making the maneuver. In fact, hardly anyone appeared to notice anything unusual about the combination. No more than two cars ever came up behind the test equipment before one or both passed. No difficulty was experienced at any location.

> Tom Edwards, Oregon State Highway Engineer in a paper, "Vehicle Sizes and Weights," delivered to Wesern Interstate Committee on Highways and Transportation on November 19, 1968, stated that you are all aware, of course, of the way the public complains about something they don't like. You are all in Government, you all know this. I have to say to you that we have not, in these 14 months had one single complaint from a citizen concerning the operation of the triples unit.

> N. C. Nader, Montana Highway Patrolman commented 3/2/67, relative to his observation of a 98-foot triples traveling between Great Falls and Billings in heavy traffic and bad road conditions, that the triples did not affect traffic any differently than other trucks.

> There is a FHWA study underway to ascertain the public's attitude towards larger vehicles, which may provide more definite findings.

From discussions with trucking and highway authorities and literature on tests, control of the sway of the rearmost trailer of a triples combination appears to be a problem. The sway, which can be controlled as discussed earlier in the chapter, is often mentioned by other road users and cited by triples drivers as a discomforting feature. Other apparent problems with triples are their inability to back properly and the greater length creating passing hazards on two-lane two-way highways. Because of passing problems primarily, triples should not be operated on two-lane highways, except within a short distance of freeways (to allow terminal access).

Although total vehicle length (within practical limits) may not be important in producing bad effects on highways that can accommodate them, vehicular unit length, such as that of the tractor or trailer in any combination or of a single unit vehicle, is another matter. This can considerably influence the ability of a vehicle to stay within its own lane on a highway curve. Doubles combinations with 27-ft (8.2-m) trailers articulate and track much better than large semis with, for example, 45-ft (13.7-m) trailers that are generally 5 ft (1.5 m) shorter. From all available data, there really is very little sound reason for any state to rule the doubles off their highways while permitting the indicated semi operation.

Because control of size and weight, *per se,* is an indirect and sometimes ineffective way of accomplishing desired results on the highways, it would appear more logical to establish sizes and weights limits in terms of vehicular characteristics that are significant in preventing undesirable highway or operational effects. Further, more consideration should be given to direct controls on some types of vehicular operation in lieu of specifications relating to the vehicles themselves. For example, in lieu of power-weight ratio, minimum speeds on grades could be specified. Specifications might control lane occupancy under certain conditions and possibly passing maneuvers.

UNIFORMITY ALTERNATIVES

Current Uniformity

A certain level of uniformity in size, weight, and speed laws exists today. Any vehicle meeting the following limits and being properly licensed can travel in any of the 48 contiguous states and the District of Columbia:

- Width—96 in. (2.4 m)
- Height—12.5 ft (3.8 m)
- Length
  - Truck —35 ft (10.7 m)
  - Semitrailer —40 ft (12.2 m)
  - Full trailer —33 ft (10.1 m)
  - Tractor semitrailer—55 ft (16.8 m)
- Number of units in the combination—2
- Axle weights
  - Single —18,000 lb (8.16 t)
  - Tandem —32,000 lb (14.5 t)
- Gross Vehicle Weight—73,280 lb (33.23 t)

It is noteworthy that not one state in the country has a set of limits identical to those listed, although a large number of states may be in agreement with most of them. These may differ individually in allowing greater height, greater weights, greater lengths, multiple-trailer vehicles, or a combination of such provisions. Add 1 ft (0.3 m) to the height limit and only three states are as restrictive, although one of those three allows a tolerance of 1,500 lb (0.7 t) on single axles on designated routes.

Potential Uniformity Levels

Greater uniformity could be achieved either by having less restrictive states roll back their limits to the more restrictive levels or by increasing limits in the more restrictive states. As discussed earlier in this chapter, the alternative of rolling back limits to achieve uniformity is unrealistic because industry would offer resistance, because transportation costs would be increased substantially, and because analyses conducted in this and other research indicate that substantial transportation cost savings and energy savings would accrue through more liberal uniform size and weight provisions. The question is to what optimal degree should the limits of the more restrictive states be relaxed to maximize the benefits obtained by the populace as compared with public costs of all kinds.

An initial set of possible uniformity alternatives drafted during Phase I of the project is given in Table 15. Initially, as the table indicates, alternatives evaluated allowed single and tandem axle weights of 22,400 lb (10.16 t) and 36,000 lb (16.33 t), respectively, because these limits were already allowable in a sizeable group of states. However, as the research progressed, there was less and less reason to seriously consider these axle load levels for a viable condition of national uniformity. For one reason, there were no strong representations for universal axle loads of these magnitudes from any part of the trucking industry; for another, to make optimum use of these loads for interstate commerce, it is necessary also to increase gross-weight limits. A 3S2 with 34,000-lb (15.42-t) axles can practically load up to 80,000 lb (36.28 t) without an excessive load on the steering axle. The majority of commodity

TABLE 15

POSSIBLE LEVELS OF UNIFORMITY

	tractor-semitrailer length (trailer 45' max.)			double trailer combination length			triple trailer combination length			max. single axle weight (kips)			max. tandem axle weight (kips)			max. GVW (weight controlled by bridge formula)		
	55'	60'	65'	N.P.*	65'	108'	N.P.*	98'	108'	18	20	22.4	32	34	36	73.28	80	105.5
current level	X			X			X			X			X			X		
alternative 1		X			P		X				X			X			X	
alternative 2		X			P			M			X			X				X
alternative 3		X			P	M			M		X			X				X
alternative 4		X			P		X					X			X		X	
alternative 5		X			P			M				X			X			X
alternative 6		X			P	M			M			X			X			X

* N.P. = Not Permitted   X = all highways   P = primary and Interstate highways   M = multi-lane limited access highways only

1 foot = 0.3048 meters

1 kip = 0.4535 tonnes

hauls that might benefit from 22,400-lb (10.16-t) and 36,000-lb (16.33-t) axles have origins in a rural environment that entail significant travel on highway systems with intermediate or low design characteristics. Increases of gross weights in existing vehicles, without spreading them over additional properly spaced axles, could have serious consequences on nonarterial highway systems. Still another consideration is the present level of highway and bridge deficiency. Increases of axle loadings to these levels, with appropriate gross weight increases, would significantly reduce highway service lives and incur more costs accordingly. There also are options in vehicle types that will distribute the loads over more axles without significantly increasing transportation costs per ton-mile (see operating cost nomographs).

Current concern for the condition of bridges resulted in using the AASHTO bridge formula as the basis for limiting gross combination weight (GCW). The bridge formula or a table derived from the formula is currently used in most states. However, gross weights in most states are also arbitrarily limited regardless of whether permitted lengths and numbers of axles would allow greater weights when the bridge formula is applied. For example, many states permit 80,000-lb (36.28-t) GCW. When applying the bridge formula, a 5-axle 55-ft (16.8-m) combination vehicle could not exceed 80,000 lb (36.28 t). However, a 65-ft (19.8-m) combination vehicle of 5 axles could reach a GCW of 85,500 lb (38.78 t) but for the arbitrary limitation, without having axle loads exceeding 20,000 lb (9.1 t).

Within the range of uniformity alternatives evaluated, no changes were made in vehicle height, width, or tire pressure. Vehicle height currently is uniform and limited by the height of overpasses. Tire pressure is not a commonly specified limit.

Vehicle width has not received much attention. Almost all states allow vehicles with widths up to 96 in. (2.44 m). Many allow extensions of 6 in. (0.15 m) for safety devices, such as mirrors, bulging of pneumatic tires beyond wheel rim, and the like. A few trucking industry representatives have indicated that an additional 6 in. (0.15 m) would allow a trailer with an inside width of 8 ft (2.44 m). This would allow two 4-ft (1.22-m)-wide pallets to be loaded side by side. However, the analysis of benefits from uniformity did not assume increased width because questionnaire response reflected limited enthusiasm for it.

On the basis of discussions with highway officials and toll-road authorities allowing twins or triples to operate, it was determined that long vehicles are compatible with existing geometrics and under the following conditions:

1. Twin 27-ft (8.2-m) (65-ft (19.8-m) over-all length) combinations can function well on all primary highways.
2. Triples and turnpike doubles function well on multi-lane-limited-access highways.

Therefore, these vehicle types have been included for evaluation in several of the alternative scenarios for uniformity.

The final set of uniformity options selected for evaluation is presented in Table 16.

Use of Scenarios

If the uniform level of truck size and weight limit changes, how would this influence the use of various truck types? Some trucks would carry more cargo per trip. The use of some truck types would increase substantially; the use of others would diminish. But the specific answer would depend on: (1) the kinds of changes made, and (2) in-

TABLE 16

UNIFORMITY OPTIONS

Options	Tractor Semi-Trailer Overall Length (45-ft. Trailer Allowed)		Double (Twin) Trailer Combination Overall Length			Triple Trailer Combination Overall Length		Maximum Axle Weights in Kips Single/Tandem		Maximum Gross Vehicle Weight (kips)
	55'	60'	N.P.	65'	108'	N.P.	108'	18/32	20/34	
Current Level	X		X			X		X		73.28
Uniformity Option A		X		P		X			X	Bridge Formula (80)
Uniformity Option B		X		P			M		X	(105.5)
Uniformity Option C		X		P	M		M		X	(105.5)
Uniformity Option D		X		P	M	X			X	(105.5)

N.P. = Not Permitted
X = All Highways
P = Primary and Interstate Highways
M = Multi-Lane Limited Access Highway Only
1 Ft = 0.3048 m
1 kip = 0.4535 t

dividual trucking concern's reaction to these changes. While these reactions can be assumed to be economically logical, there are a number of influencing factors that can vary the response of particular trucking firms. Accordingly, to provide for a reasonable range of possible impacts associated with uniformity options, several different scenarios were defined to evaluate several possible responses.

Two basic evaluations were made for each scenario. First, the distribution of commodities among truck types under a new uniformity level was determined on a logical basis. Second, expected payloads were determined.

Two different assumptions were used variously to decide how much of each commodity might be hauled in each type of vehicle for each scenario. They are as follows:

1. *The Existing Distribution Assumption.* The current national distributions of vehicles hauling each commodity will tend toward the current vehicle distributions in links or regions where legal limits are now at the level called for by the option being tested. With the exception of the turnpike doubles, the western region or certain links in the western region provided the basis for estimating future national truck distributions and payloads.

2. *The Full-Truck Assumption.* Changes in vehicle use will involve only those cargoes that currently are being carried in trucks that are either "cubed out" (all available space is used) or "weighted out" (the legal gross weight limits have been reached although space for more cargo remains). The commodities now being carried in these trucks are candidates for transfer to more efficient trucks that might be permitted under a new uniformity situation.

Following the existing distribution assumption, the computer distributed total tonnages by commodity on each link of the national arterial network into truck types in accordance with the distribution from the western region.

The full-truck assumption is based on the logic that if a carrier fills one truck to capacity he will choose a larger truck, provided a change in the law permits him to do so. The determination of which trucks currently are operating "full" was based on the average density of the commodity carried, the gross vehicle weight, tare weight, and the type of vehicle—all outputs of the computerized commodity flow network. The test to determine full vehicles was made on the computer.

Following the full truck assumption, the computer assigned the selected "full" truck tonnages to trucks specified as more efficient. The basis for these specifications was the operating cost nomographs previously described. Several different assignments were made in order to determine the effects of possible variations in equipment selection under new levels of uniformity. The variations are given in Table 17.

The mixes, although difficult to select objectively, were considered necessary because of unknowns in the equipment selection process. For example, the twin 27-ft (8.2-m) trailer combinations, although theoretically the most economical truck type for low-density freight, are not widely used where permitted except by the haulers of general freight. For various reasons, other haulers of low-density commodities have not chosen the twin 27-ft (8.2-m) combinations. Some of these reasons are probably related to the nature of their operations. For example, household goods must be picked up at residences—usually by backing up the truck and trailer. Also, owner-operators may not have the capability to effectively use two trailers.

TABLE 17

VARIATIONS IN FULL TRUCK ASSIGNMENTS

Weight-Out Options	Cube-Out Options
1. All commodities in full trucks assigned to twin 40-ft trailers	1. All commodities in full trucks assigned to twin 27-ft trailers
2. All commodities in full trucks assigned to 3-4 combinations (3-axle truck and 4-axle trailer)	2. All commodities in full trucks assigned to triple 27-ft trailers
3. All commodities in full trucks assigned to a mix of 3-S2's, twin 40-ft trailers and 3-4's	3. All commodities in full trucks assigned to twin 40-ft trailers
4. 3-S2's up to 74,000 lb assigned to heavier 3-S2's; currently heavy 3-S2's assigned to 3-4's	4. All commodities in full trucks assigned to a mix of twin 27-ft, twin 40-ft and triple 27-ft trailers

1 foot = 0.3048m

The selection of a mix was made with the characteristics of trucking as related to each commodity in mind. The theoretically most economic vehicle was assigned the largest proportion of the cargo, unless some characteristic of hauling the commodity suggested otherwise. For example, carriers of agricultural commodities are independent truckers who want a rig that can be used for many kinds of haul and that is maneuverable in the farm fields. Therefore, 3-S2's are likely to remain dominant in the truck mix used to transport agricultural commodities. Or, in the case of furniture and household goods, the twin 40's were made dominant because, in states allowing twin 27's, the carriers of furniture have not used them.

Table 18 contains the mixes used for the weight-out commodities; the cube-out mixes are contained in Table 19.

As previously indicated, average payloads for each vehicle type had to be determined in order to convert the tonnages into trips. Two approaches were used. The first approach was based on average payloads derived from loadometer data for selected links in the western region that are now operating at the uniformity limits being evaluated. The other approach was to calculate a payload based on the available space in the truck combination and the average density of the commodity. The theoretical payloads tended to be higher than those obtained from the loadometer data.

The results of the weight-out and cube-out scenarios are given in Tables 20 and 21, respectively. These tables basically summarize the option and scenario evaluations described later. In comparing them with the individual option results (Tables 22 through 25, which are laid out in matrix form and where the savings from the weight-out scenarios and cube-out scenarios are combined), Tables 20 and 21 show the individual results that need to be added to obtain total savings, as well as changes in equivalent axle loads and mileage.

Impacts of Uniformity Options

Impacts of the uniformity options were estimated on the basis of the scenarios previously described. These impacts related to (1) operating cost savings, (2) fuel savings, (3) mileage savings, (4) change in 18-kip (8.6-t) equivalent axle loads, and (5) accidents.

Uniformity Option A

Option A may be referred to as the AASHTO level. It adopts the AASHTO recommendations on a national basis. In general, this option would have its greatest impact on the states bordering and east of the Missouri and Mississippi Rivers. The western states currently allow the limits proposed in Option A. However, some increased use of double 27's and the 80,000-lb (36.28-t) gross weight vehicle could be expected in the western states related to trips to or from states that formerly allowed 72,280-lb (33.23-t) GVW's or 65-ft (19.8-m) twin trailers. The estimates presented in this option are conservative in that they do not consider this possibility.

Table 22 contains the range in possible savings from uniformity Option A. The first two levels were derived using the distribution method. The third level was derived using the full-truck method.

Uniformity Option B

Option B is the same as Option A except the 105-ft (32.0-m) long triple-trailer combination would be allowed on all multilane, divided highways with full control of access. It does not provide for turnpike doubles.

This option would have a substantial impact on all regions. National use of triples and the 65-ft (19.8-m) long 3-4's on an extensive basis could result in both a large operating cost and fuel savings and a large decrease in 18-kip (8.6-t) equivalents. All of the 18-kip (8.6-t) equivalent decrease is attributable to the use of 3-4's.

TABLE 20

WEIGHT-OUT SCENARIOS

Vehicle Assignment Assumptions	Operating Cost Savings ($1,000)	Fuel Savings (1,000 Gallons)	Change in 18 Kip Equivalent Axle Loads (thousands)	Change in Mileage (millions of miles)
1. Distribution Method	Not segregated by cube-out and weight-out			
2. Modified Distribution Method	Not segregated by cube-out and weight-out			
3. All to Twin 40s	1,416,210.0	363,981	-12,340	-3,242
4. All to 3-4	934,670.0	354,254	-29,406	-2,212
5. Assigned to Mix (3-S2, Twin 40, and 3-4)	863,702.9	259,680	--7,651	-1,985
6. Assigned to Mix (3-S2 and 3-4)	610,611.2	204,156	+11,372	-1,123.4

1 gallon = 3.785 liters 1 Kip = .454 tonnes
1 mile = 1.609 Km 1 foot = .3048 meters

TABLE 18

WEIGHT-OUT TRUCK MIXES

Commodity Number	Commodity Name	% of Commodity Tonnage 3-S2	3-4	Twin 40 3-S2-4	Total
1	Agriculture Goods	50	40	10	100
2	Agriculture Goods (Reefers)	35	40	25	100
3	Forest Products	35	40	25	100
4	Bulk Extractive Resources	35	65	0	100
5	Fuels, Oils, Chemicals	25	45	30	100
6	Building Material	20	60	20	100
12	Medium Density Manufactured	15	45	40	100
13	High Density Manufactured	10	50	40	100

TABLE 19

CUBE-OUT TRUCK MIXES

Commodity Number	Commodity Name	% of Commodity Tonnage Twin 27' Trailers	Twin 40' Trailers	Triple 27' Trailers	Total
7	Textiles	30%	55%	15%	100%
8	Pulp, Paper, et. al.	20	70	10	100
9	Furniture, Household Goods	5	90	5	100
10	Transportation Equipment	0	0	0	*
11	Light Manfactured Goods	35	45	20	100
14	General Freight	50	25	25	100

* These primarily are auto carriers which would be assigned to Vehicle Type 8, truck-trailer, based on the newer articulated design.

1 foot = 0.3048 meters

Table 23 contains the range in possible savings from uniformity Option B.

Uniformity Option C

Option C is the AASHTO level but with a maximum over-all length of 105 ft (32.0 m). This permits use of either the triple 27-ft (8.2-m) trailers or twin 40-ft trailers.

An operating cost saving of $2.8 billion is obtainable under this option. Table 24 contains Option C.

TABLE 21

CUBE-OUT SCENARIOS

Vehicle Assignment Assumptions	Operating Cost Savings ($1,000)	Fuel Savings (1,000 Gallons)	Change in 18 Kip Equivalent Axle Loads (thousands)	Change in Mileage (millions of miles)
1. Distribution Method using Known Payloads	Not segregated by cube-out and weight-out			
2. Modified Distribution Method	Not segregated by cube-out and weight-out			
3. All to Twin 27's	311,866.4	188,150	+12,815	-790
4. All to Triple 27's	1,375,091.4	510,233	+8,581.7	-1,773
5. All to Twin 40's	1,022,623.2	355,847	-11,035.4	-1,754
6. Assigned to Mix	599,874.8	305,299	+1,585.8	N/A

1 gallon = 3.785 liters 1 Kip = .454 tonnes
1 mile = 1.609 Km 1 foot = .3048 meters

TABLE 23

RANGE OF PROJECTED SAVINGS RELATED TO OPTION B

Cube-Out Scenarios	Weight-Out Scenarios: All Full Trucks Assigned to 3-4's	Weight-Out Scenarios: All Full Trucks Assigned to Mix of 3-S2 and 3-4
All Full Trucks Assigned to Triple 27-ft Trailers	$2,309,761,400 864,487,000 gallons 3,984.6 x 10^6 miles 0.3% increase in EALs 10,559 accidents	$1,985,702,600 714,389,000 gallons 2,896.0 x 10^6 miles 15.5% increase in EALs 7,674 accidents

1 gallon = 3.785 liters
1 mile = 1.609 Km

Uniformity Option D

Option D is the same as Option B except the turnpike double is allowed instead of the triple-trailer combination. Table 25 contains the range of potential impacts from uniformity Option D.

Highway Impacts of Uniformity Options

Since none of the uniformity options for which the various scenarios were evaluated involved increases in axle loads over the 20,000-lb (9.07-t) single, 34,000-lb (15.4-t) tandem levels currently recommended by AASHTO, approved by FHWA, and used in a majority of states, it is not surprising that the maximum equivalent axle load (EAL) increases associated with any scenario did not average more than 15.5 percent nationally.

This upper limit of a range of EAL increases produced by the various scenarios was considered less likely to be experienced than other lower values. Increases within the range of EAL's were influenced by assumptions regarding the distribution of loads into different types of trucks that could and probably would vary considerably among regions. Therefore, it was decided that regionalization of this upper figure would be an unwarranted degree of refinement. Recognizing the limitations of most available highway data, the concern was more with the order of

TABLE 22

RANGE OF PROJECTED SAVINGS RELATED TO OPTION A

Cube-Out Scenarios	Weight-Out Scenarios: AASHTO Level (No triples or turnpike twins)	Weight-Out Scenarios: AASHTO Level (Current levels of triples and turnpike twins)	Weight-Out Scenarios: All Full Trucks to 3-4's	Weight-Out Scenarios: All Full Trucks Assigned to Mix of 3-S2's and 3-4's
AASHTO Level (No triples or turnpike twins)	$1,519,830,000 609,976,666 gallons 2,986.2 x 10^6 miles 3.1% increase in EALs 7,857 accidents			
AASHTO Level (Current levels of triples and turnpike twins)		$1,646,972,200 723,612,270 gallons 4,105.4 x 10^6 miles 4.3% increase in EALs 10,879 accidents		
All Full Trucks to Full Twin 27's			$1,246,536,400 542,404,000 gallons 3,001.7 x 10^6 miles 10.6% decrease in EALs 7,954 accidents	$922,477,600 392,306,000 gallons 1,913.1 x 10^6 miles 15.5% increase in EALs 5,069 accidents

1 gallon = 3.785 liters
1 mile = 1.609 Km

TABLE 24

RANGE OF PROJECTED SAVINGS RELATED TO OPTION C

Cube-Out Scenarios	Weight-Out Scenarios: All Weight-Out Full Trucks Assigned to Twin 40's	All Weight-Out Full Trucks Assigned to 3-4's	All Weight-Out Full Trucks Assigned to Mix of 3-S2's, Twin 40's and 3-4's	All Weight-Out Full Trucks Assigned to Mix of 3-S2's and 3-4's
All Cube-Out Full Trucks Assigned to Triple 27's	$2,791,301,400 874,214,000 gallons 5,014.6 x 10^6 miles 2.4% decrease in EALs 13,288 accidents	$2,309,761,400 864,487,800 gallons 3,984.6 x 10^6 miles 0.3% increase in EALs 10,559 accidents	$2,238,794,300 769,913,000 gallons 3,757.1 x 10^6 miles 0.6% increase in EALs 9,956 accidents	$1,985,702,600 714,389,000 gallons 2,896.0 x 10^6 miles 15.5% increase in EALs 7,674 accidents
All Cube-Out Full Trucks Assigned to Twin 40's	$2,438,833,200 719,828,000 gallons 4,995.7 x 10^6 miles 15.0% decrease in EALs 13,238 accidents	$1,957,293,200 710,101,000 gallons 3,965.7 x 10^6 miles 25.9% decrease in EALs 10,509 accidents	$1,886,326,100 615,527,000 gallons 3,738.2 x 10^6 miles 12% decrease in EALs 9,906 accidents	$1,633,234,400 560,003,000 gallons 2,877.1 x 10^6 miles 0.2% increase in EALs 7,624 accidents
All Cube-Out Full Trucks Assigned to Mix of Twin 27's, Twin 40's and Triple 27's	$1,976,084,000 669,280,000 gallons 6.7% decrease in EALs	$1,494,544,800 659,553,000 gallons 17.8% decrease in EALs	$1,423,577,700 564,979,000 gallons 3.9% decrease in EALs	$1,170,486,000 509,455,000 gallons 8.3% increase in EALs

1 gallon = 3.785 liters
1 mile = 1.609 Km

TABLE 25

RANGE OF PROJECTED SAVINGS RELATED TO OPTION D

Cube-Out Scenarios	Weight-Out Scenarios: All Full Trucks Assigned to Twin 40's	All Full Trucks Assigned to 3-4	All Full Trucks Assigned to Mix of 3-S2, Twin 40's 3-4	All Full Trucks Assigned to Mix of 3-S2 and 3-4
All Full Trucks Assigned to Twin 40's	$2,438,833,200 719,828,000 gallons 4,995.7 x 10^6 miles 15.0% decrease in EALs 13,238 accidents	$1,957,293,200 710,101,000 gallons 3,965.7 x 10^6 miles 25.9% decrease in EALs 10,509 accidents	$1,886,326,100 615,527,000 gallons 3,738.2 x 10^6 miles 12.0% decrease in EALs 9,906 accidents	$1,633,234,400 560,003,000 gallons 2,877.1 x 10^6 miles 0.2% increase in EALs 7,624 accidents

1 gallon = 3.785 liters
1 mile = 1.609 Km

highway cost increases that might result from particular options than with closer cost estimates. In some cases, estimates were made of variations in the ranges of EAL increases, as between regions, but these were not considered meaningful.

A separate estimate was made of the maximum increases that might occur within states still at the 18,000-lb and 32,000-lb (8.16-t and 14.5-t) levels of permissible axle loads and 73,280-lb (33.23-t) gross weight limit. Since all of the options and scenarios involved 20,000-lb and 34,000-lb (9.07-t and 15.42-t) axle loads and at least 80,000-lb (36.28-t) gross weight, these states would be the ones most likely to experience the largest increases in 18-kip (8.16-t) equivalent axle loads. In fact, the maximum EAL increases in these states, under any option, were estimated at 17.5 percent. These estimates were derived from the summation of equivalent axle loads on selected 73,280-lb (33.23-t) links of the commodity flow network and by computing the change in EAL repetitions after transferring commodity flows into vehicle distributions from the western region, which permits maximum weights of 20,000-lb (9.07-t) single axle, 34,000-lb (15.42-t) tandem axle, and 80,000-lb (36.28-t) gross weight. Also, the 73,280-lb (33.23-t) links selected placed emphasis on links between states having good reputations for enforcement. It was assumed that these states would experience greater increases in axle loadings from weight-limit increases than states having lax enforcement and a high percentage of trucks already running overweight. Therefore, the estimated increase of 17.5 percent is considered the upper end of the range.

Since states with the lower limits are distributed among the regions, the 15.5 percent is still a reasonable maximum figure for each region.

As indicated, this figure relates to maximum 20,000-lb (9.07-t) and 34,000-lb (15.42-t) axles except in states that now permit higher loadings. As previously indicated, the decision to limit options to consideration of this axle loading came about because economic justification, in interstate commerce, could not be found for higher loadings. Using the operating cost nomographs developed for this study, it was possible to find a vehicle to haul almost any density of commodity at the lowest possible cost without exceeding these loads. This determination was partially influenced by acceptance of the bridge formula as an upper limit of vehicular weight for particular configurations and axle spacings. It was obvious that a heavy demand for additional axle load provisions (over 20,000 lb/34,000 lb) is not indicated in interstate commodity movements by truck. Intrastate movements may be another matter, but these do not relate to the objectives of this research. It is noteworthy that the region containing most of the states allowing 22.4-/36-kip (10.16-/16.33-t) axle loadings had the lowest indicated equivalent axle loads per trip of any region, for the interstate movements evaluated. The 73,280-lb (33.23-t) gross weight limit in many of these states restricts the axle loading on the type of vehicles generally found in interstate commerce.

EAL Increases By Highway Section

As indicated previously, a 15.5 percent increase in equivalent axle loads from interstate truck commodity movements is a conservative maximum of what any state should experience as a result of the uniformity options considered, with the exception of the states at the 18,000-lb/32,000-lb, 73,280-lb levels, for which the maximum figure is 17.5 percent. Again, it is not considered likely that increases of this order will actually occur. Note that these increases reflect changes to the situation that otherwise would exist with normal traffic growth.

Although it was anticipated initially that evaluations of additional highway costs would be made at different EAL increase levels, the costs associated with the maximums, as subsequently shown, are of such a low order relative to benefits that analyses at this level alone were considered sufficient.

Tables 26, 27, 28, and 29 present the expected magnitude of the EAL increases on principal arterial highways by number of lanes, by surface type, and by the present condition of the highway surfaces as measured by their present serviceability indices (PSI). The miles of highways in the different condition categories are given along with presently expected 20-year, 18,000-lb equivalent axle loads.

These expected EAL's were determined by applying the EAL percentage increases from the commodity flow network to the daily vehicle miles of traffic and truck factors developed in a recent national study of highway condition and performance *(32)*. The Federal Highway Administration provided special summaries from the latter study.

Six states did not contribute to the national study. Accordingly, data from other states in the regions affected were expanded so that total system miles would be

TABLE 26

ESTIMATED MAXIMUM INCREASES IN 18 KIP EAL'S—WESTERN REGION

PSI	HIGH RIGID ≥4 LANE (1) Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	HIGH RIGID 2 LANE (1) Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	67	173	9879	1532	75	70	7141	1107
2.0-2.4	56	122	8336	1292	97	75	5918	917
2.5-3.4	856	2085	9319	1444	95	69	5558	861
>3.4	2466	5173	8026	1245	157	88	4290	665

PSI	HIGH FLEXIBLE ≥4 LANE (1) Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	HIGH FLEXIBLE 2 LANE (1) Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	464	686	3778	585	1583	630	3044	472
2.0-2.4	418	570	3612	560	1470	713	3710	575
2.5-3.4	2683	3731	3613	560	6565	2980	3472	538
>3.4	6880	8248	3613	560	8600	3695	3287	509

PSI	INTERMEDIATE AND LOW ≥4 LANE (1) Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)	INTERMEDIATE AND LOW 2 LANE (1) Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)
<2	44	25	2174	337	1865	589	2417	375
2.0-2.4	-	-	-	-	584	125	1640	254
2.5-3.4	4	3	2870	445	1252	342	2089	324
>3.4	45	28	2381	370	914	286	2394	371

(1) Design Lane

1 mile = 1.609 Km

TABLE 27

ESTIMATED MAXIMUM INCREASES IN 18-KIP EAL'S—MISSISSIPPI VALLEY

	HIGH RIGID							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	149	329	8450	1310	226	137	4639	719
2.0-2.4	57	77	5171	802	211	100	3628	562
2.5-3.4	2400	4671	7448	1154	2277	1208	4064	630
>3.4	6559	10283	6000	930	1881	1101	4478	694

	HIGH FLEXIBLE							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	84	196	8929	1384	1188	457	2946	457
2.0-2.4	44	81	7047	1092	1038	333	2457	381
2.5-3.4	1247	1923	5902	915	6153	2937	3652	566
>3.4	2383	4184	6721	1042	7561	3302	3346	519

	INTERMEDIATE AND LOW							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)
<2	4	4	3827	593	282	75	2036	316
2.0-2.4	7	2	1095	170	308	50	1240	192
2.5-3.4	18	7	1488	231	1819	385	1623	252
>3.4	26	11	1619	251	1139	268	1799	279

(1) Design L.

1 mile = 1.6

TABLE 28

ESTIMATED MAXIMUM INCREASES IN 18-KIP EAL'S—SOUTHEASTERN REGION

	HIGH RIGID							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	40	85	8133	1261	20	7	2679	415
2.0-2.4	26	50	7379	1144	28	14	3827	593
2.5-3.4	466	811	6660	1032	127	100	6024	934
>3.4	[illegible]	7649	7766	1204	280	212	5795	898

	HIGH FLEXIBLE							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	36	32	3403	527	124	78	4815	746
2.0-2.4	284	541	7291	1130	205	126	4708	730
2.5-3.4	1515	2285	5772	895	3554	2221	4784	742
>3.4	5868	9640	6289	975	9330	5759	4723	732

	INTERMEDIATE AND LOW							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)
<2	-				73	22	2304	357
2.0-2.4	-				46	9	1500	233
2.5-3.4	26	15	2208	342	414	162	2993	464
>3.4	40	51	4880	756	820	331	3093	479

(1) Design Lane

1 mile = 1.609 Km

TABLE 29

ESTIMATED MAXIMUM INCREASES IN 18-KIP EAL'S—NORTHEASTERN REGION

	HIGH RIGID								HIGH FLEXIBLE							
	≥4 LANE (1)				2 LANE (1)				≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr EAL (x1000)	Δ EAL (x1000)
<2	33	111	12874	1995	3	5	12758	1977	41	117	10922	1693	19	5	2014	312
2.0-2.4	81	236	11152	1729	48	45	7177	1112	229	339	5666	878	70	60	6561	1017
2.5-3.4	371	876	9037	1401	225	241	8199	1271	337	352	3998	620	588	458	5963	924
>3.4	2487	5113	7961	1234	525	542	7903	1225	1607	2745	6538	1013	1309	950	5556	861

	INTERMEDIATE AND LOW							
	≥4 LANE (1)				2 LANE (1)			
PSI	Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)	Miles	Truck DVMT (x1000)	20 Yr. EAL (x1000)	Δ EAL (x1000)
<2	-				24	6	1914	297
2.0-2.4					94	30	2443	379
2.5-3.4	1	1	3828	593	428	184	3291	510
>3.4	32	38	4545	704	217	132	4657	722

(1) Design Lane

1 mile = 1.609 Km

reflected. Although this may introduce some error in specific detail, it still allows a reasonable assessment of the order of highway costs associated with the maximum equivalent axle load increases.

All increases in EAL represent 15.5 percent of the originally expected EAL figure, the maximum EAL percentage increase derived from the commodity flow network, and the most demanding uniformity options. This percentage has been applied to the EAL repetitions of the entire truck volume, representing intrastate as well as interstate movements, to further assure additional conservativeness in the results.

To convert the DVMT into equivalent axle loadings, factors on EAL per vehicle were derived from the commodity flow network and truck weight studies.

Basis for Highway Cost Analysis

In making the analysis of highway costs associated with increased axle loadings, there has been considerable departure from previous national studies of the economics of different motor vehicle sizes and weights. In these studies, it has generally been presumed that (1) existing pavement lives would be shortened by additional axle loadings, (2) future surface and base reconstruction would be advanced to take care of the shortened service lives, (3) new pavements would be designed for the increased loadings, and (4) the net highway cost results of the new loadings would be the additional annual costs due to the shortened service lives and the increment of new construction cost due to the increased loadings.

These studies have resulted in relatively low estimates of increased annual highway cost requirements as related to significant increases in recommended axle loadings.

In this project, the approach had been to determine, through methods described previously, the increased 20-year equivalent 18,000-lb axle loadings that could occur on the interstate network of principal arterials as a result of a uniformity option. These increases have been applied to highway segments in different pavement condition categories, as subsequently described, to determine the amount of overlay needed on each section to provide essentially for originally designed service lives.

Development of Pavement Performance Curves

To realistically and conservatively reflect the actual costs associated with the estimated maximum increases in equivalent axle loads, pavement performance curves were developed for bituminous pavement and portland cement concrete pavement (2 soil support cases). These represent an amalgamation of available research to date in this area. The concept for the bituminous curves was derived largely from a study of truck characteristics and pavement effects by Peterson and Shephard of the Utah Department of Transportation (*33*). This concept was further refined and developed using the results of a study by Stevenson of the National Association of Australian State Road Authorities

(*10*) and design procedures from state highway agencies in Colorado, Illinois, Louisiana, Minnesota, Missouri, Nevada, South Carolina, Tennessee, Texas, Utah, Vermont, and Washington. The rigid pavement performance curves were developed with the assistance of Dr. Mathew Witczak and graduate students from the University of Maryland. The sets of curves are shown in Figures 23 through 25.

In each case, with knowledge of the initial design loading characteristics of a pavement and its present condition, as reflected by its present serviceability index (PSI), these curves permit a determination of the additional surfacing requirements needed to sustain any additional design equivalent axle loads.

Determination of Additional Highway Costs

To use the pavement performance curves in conjunction with the change in EAL values (Δ EAL) given in Table 26 through 29, as related to the mileages of highways in the different PSI groups, it was necessary to assume that the presently expected EAL on the pavements was, in fact, the original design EAL. This provides a basis for using the performance curves and the Δ EAL to determine additional surface needs so that the lives of the pavements will not be shortened by the additional axle loading.

If the additional surface requirements proved to be less than ½ in. (1.27 cm), overlays were not considered to be required. Basically, the requirements could be handled by a heavy maintenance application of chips and seal. However, this is not likely to be done. Although some costs are overlooked on this basis, these additional cost requirements are certainly balanced out by the conservative assumptions that ascribe more costs than actually should be due to the increased axle loadings. As an example of this conservativeness, axle-load increases on pavements with a PSI rating presently as low as 2.0 to 2.5 were charged with additional surface requirements. Actually, many of these pavements are already failed or close to failure according to criteria used in many states. They require new surfaces regardless of increases.

All mileage with a PSI of less than 2.0 was considered to be in a failed condition, requiring immediate reconstruction (e.g. new base and surface). For that reason, only a small increment of the costs of reconstruction of this mileage has been assigned to the increased axle loadings (Δ EAL's). The reconstruction would be designed to handle a 15.5 percent increase in EAL's over a 20-year life, which would result in a small percentage increase in costs. This can be readily seen from the performance curves where, when a highway is newly designed within an applicable range of EAL repetitions, an additional ½ in. (1.3 cm) of asphalt surface will provide for a 35 percent or more increase in axle load applications.

Although the calculations involve approximations as indicated, they nevertheless are sufficiently close for a reasonable order of magnitude estimate of outside cost increases that might occur as a result of the uniformity options considered. Table 30 provides an estimate of these costs on a regional basis.

These costs were regionalized because of regional variations in topography, soil conditions, materials costs, and construction costs and because, originally, greater variations were anticipated in equivalent axle load relationships.

To apply the overlay thickness or reconstruction requirements determined from the appropriate pavement performance curves, cost factors were developed from several sources including reports from the Federal Highway Administration. In addition, costs used in the 1968 Sizes and Weights Report (*7*) were upgraded to 1978 costs by applying the FHWA highway construction cost index. The composite unit costs per mile used are given in Table 30 (Col. 4). Since there are regional variations in highway costs, these costs reflect the relative unit bid prices reported on Federal-aid projects for 1977, by region.

The total cost of $1.95 billion shown in Table 30 is essentially a one-time order of magnitude cost reflecting the maximum total cost required to make the principal arterial systems whole; that is, to see that they have the same service lives as at present, if the most demanding of the uniformity options is adopted.

It is recognized that these costs should be annualized for a rigorous cost benefits analysis and that additional costs

TABLE 30

ESTIMATE OF TOTAL COSTS [1] TO ACCOMMODATE OPTIMUM UNIFORMITY LEVEL

Miles	No. Lanes	Improvement	Cost/Mile	ΔEAL Cost (Thousands)
Western Region				
575	4	SURF. & BASE	$475,200	$ 8,197 2/
3523	2	SURF. & BASE	290,400	30,692 2/
3101	4	1 1/2" SURF.	94,000	291,494
8080	2	1 1/2" SURF.	56,000	452,480
Mississippi Valley Region				
237	4	SURF. & BASE	409,275	2,910 2/
1696	2	SURF. & BASE	250,113	12,726 2/
1291	4	1 1/2" SURF.	90,000	116,190
7191	2	1 1/2" SURF.	54,000	388,314
Southern Region				
76	4	SURF. & BASE	529,650	1,208 2/
217	2	SURF. & BASE	323,675	2,107 2/
1824	4	1 1/2" SURF.	111,000	202,464
4173	2	1 1/2" SURF.	66,000	275,418
North Atlantic Region				
155	4	SURF. & BASE	442,350	2,057 2/
43	2	SURF. & BASE	270,325	349 2/
567	4	1 1/2" SURF.	125,000	70,875
1180	2	1 1/2" SURF.	75,000	88,500
TOTAL ΔEAL COSTS				$1,945,981

1 mile = 1.609 Km

1/ Total costs to prevent additional obsolescence through increased axle loadings over the next 20 years. Expenditure should be made within next few years. Costs limited to surface and base requirements.

2/ Three (3.0) percent surface and base reconstruction costs estimated as chargeable to 15.5% increased EAL (based on NCHRP Report 141). Note that reconstruction requirement is not influenced by increased EAL-surfaces already are in "failed" condition.

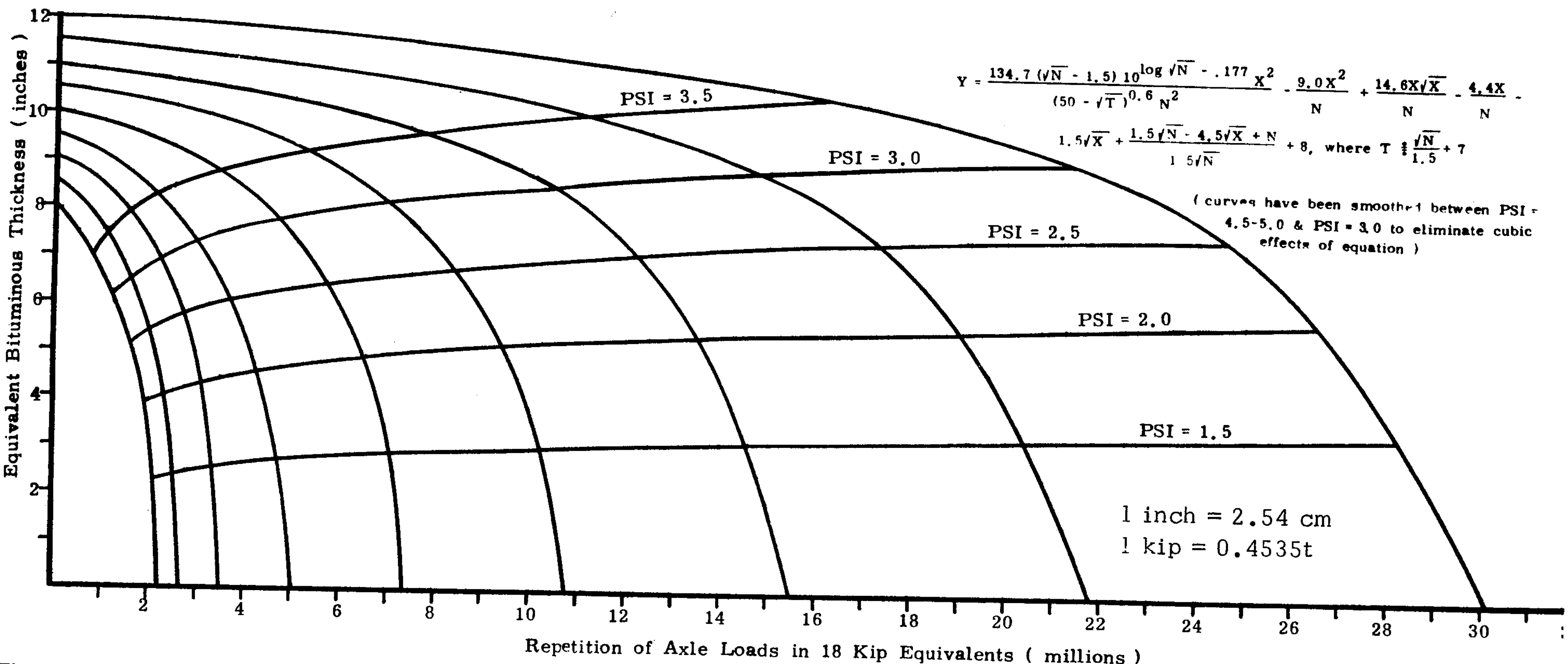


Figure 23. Bituminous pavement performance curves.

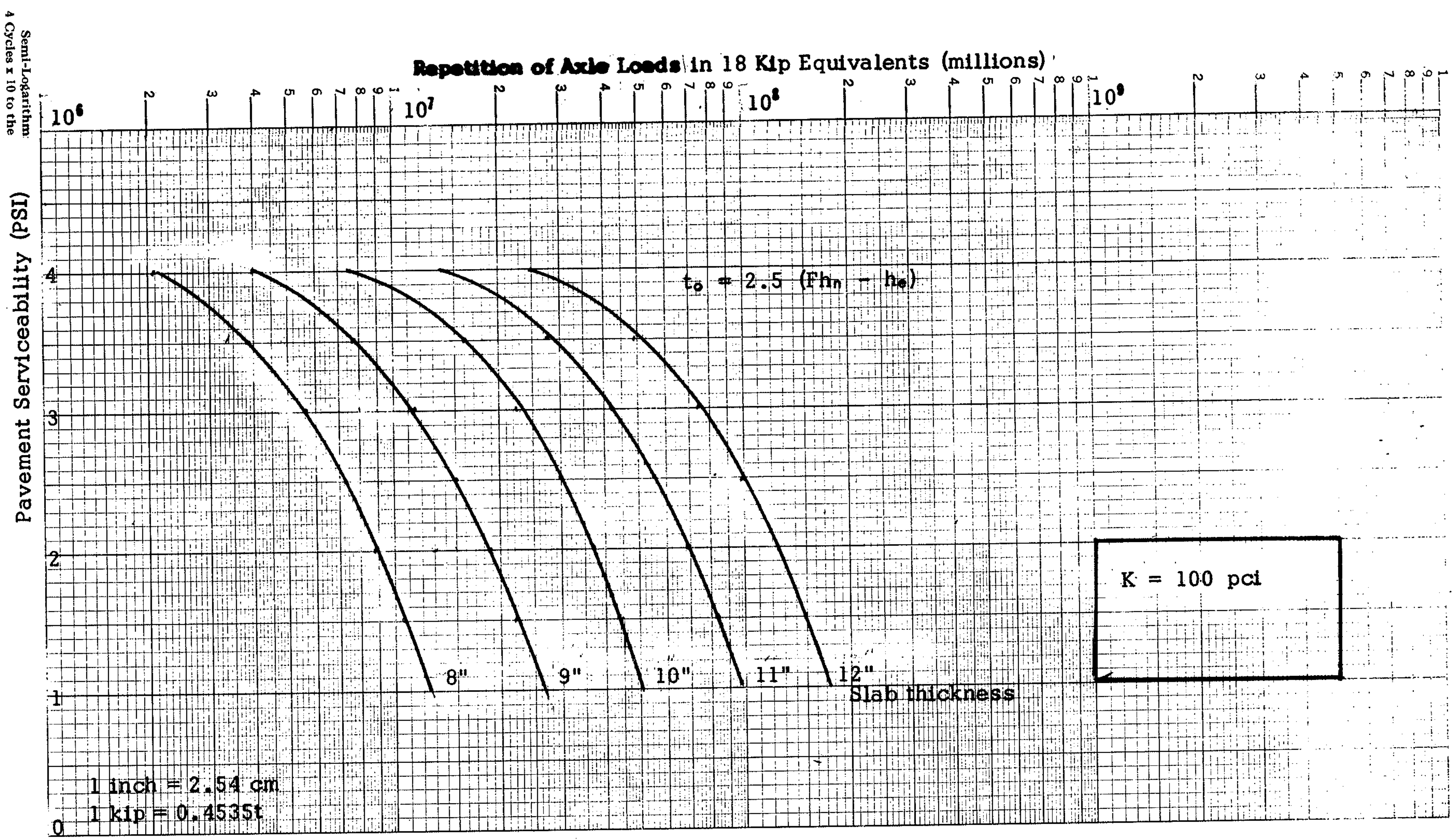


Figure 24. Rigid pavement performance curves, K = 100 pci.

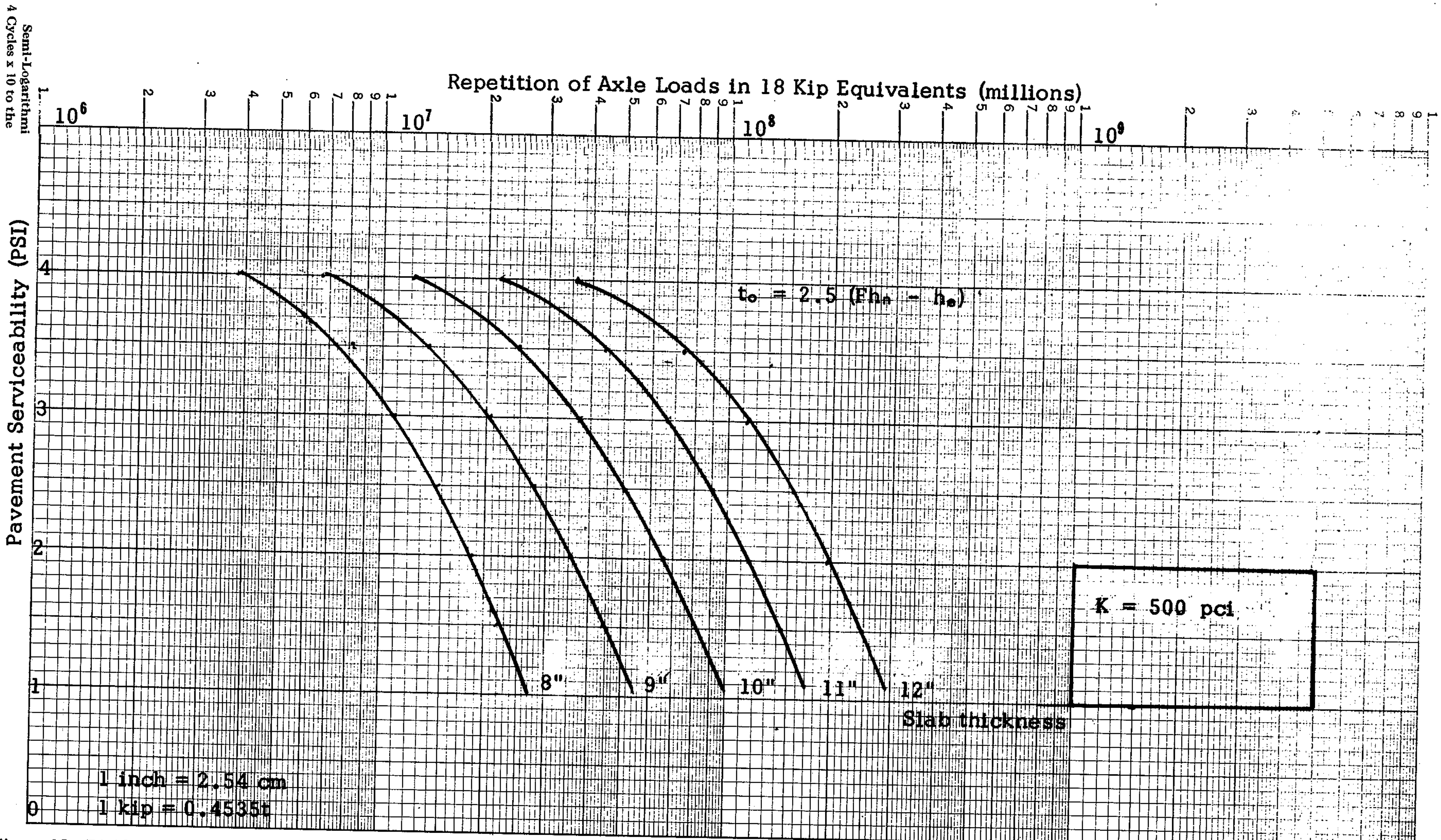


Figure 25. Rigid pavement performance curves, K = 500 pci.

will occur as highway surfaces, after being upgraded for additional applications, eventually wear out. However, when they do wear out (that is, when they are in failed condition), the incremental costs for the increased applications will aggregate only a fraction of the $2 billion estimate. Therefore, additional future costs will be of a decreasing order. For example, if the $2 billion were spread over 10 years at $200 million per year, subsequent comparative costs might be in a range of $10 to 50 million per year.

On the other hand, the $2.5 billion per year potential savings in transportation cost would increase each year as truck traffic increases. Thus, there is no comparison between benefits and costs—the latter (despite difficulties in providing for even these amounts in a tight financial situation) is only a small fraction of the former.

CHAPTER THREE

INTERPRETATION, APPRAISAL, AND APPLICATION

In order to properly interpret the findings of this research project, it will be helpful to refer to the objectives as originally set forth; namely to:

1. Identify and describe the effects of current state size, weight, and speed laws, regulations, and interstate agreements on trucks and the highway systems they use.
2. Investigate the potential benefits and disadvantages of increased uniformity in truck size, weight, and speed limits among states.
3. List and evaluate the available alternatives for eliminating or minimizing the differences in truck size, weight, and speed limits among states.

Although the first objective may appear to be broader, the initial project statement made it clear that it applied only to the effects of the "laws, regulations, and interstate agreements" as they relate to the uniformity question.

MAJOR FINDINGS

In terms of these objectives, the conclusive findings of this research project, discussed in detail in Chapter Two, are as follows:

1. The economic disbenefits to the American people due to the present differences in State laws and regulations governing motor vehicle size and weight are of considerable magnitude. Transportation costs of many goods categories, ultimately reflected in prices paid in the marketplace and in the cost of living, are higher than they need be.
2. Energy disbenefits are significant. Substantially more energy is used in transporting goods than would be necessary under a more uniform and efficient system.
3. The only present nonuniformity in speed regulation is in the enforcement area and, although strong feelings for and against the 55-mph speed were expressed by different trucking interests, nonuniformity in this regard was indicated as troublesome rather than as posing a particular problem.
4. According to analyses conducted during this research, economic benefits of increased uniformity, in terms of transportation cost savings, could be as much as $2.8 billion per year nationally, without commensurate increases in highway costs or other demonstrable disadvantages to the public, if better uniformity were in effect now and if motor vehicle operations were changed immediately.
5. With optimal uniformity, savings in motor vehicle fuel consumption will probably be in the neighborhood of 874,000,000 gal per year (after a few years change-over time).
6. There will be benefits in the administrative area both to truckers and administrative agencies, but these are difficult to measure.
7. It is estimated that one-time highway improvement costs necessary to upgrade the highway system to support optimal uniformity should not exceed $2.0 billion—axle-load increases over 20,000-lb (9.07-t) single axle, 34,000-lb (15.42-t) tandem axle are not envisioned in states not now exceeding these limits.
8. Except in states with present axle-load limits at 18,000/32,000 lb (8.16/14.51 t) and gross weights at 73,280 lb (33.23 t), changes in laws and regulations to produce optimal uniformity can be limited to vehicle configurations and dimensions. Gross-weight controls, except as established by the bridge formula and operating performance requirements, are counterproductive and should be eliminated.
9. Railroads may be adversely affected by optimal uniformity measures. However, commodities or localities served by rail and highway freight modes do not necessarily coincide. Consequently, benefits of better uniformity, in many cases, will be realizable in noncompetitive areas. In competitive areas, it would not seem logical to assist the railways by maintaining unnecessary inefficiencies on the highway.
10. Public attitudes, as reflected in the political and legislative sphere, are a significant bar to achieving the kind

of uniformity that would be most advantageous. Lack of information and misunderstandings are root causes.

CONSTRUCTIVE REGULATION OF SIZES AND WEIGHTS

The whole issue of uniformity is fraught with attitudes and opinions that, in many cases, do not relate to fact. Some of these attitudes and opinions pertain to the role of trucks on highways, which is not clearly understood, and the importance and relevance of this role economically and with respect to other modes of transportation. As a result, there is a danger of confused action taking place that is not in the best interests of the total populace.

This research has demonstrated that the highway systems are not now being operated to produce maximum economic returns from the investment that has been made in them. Types of vehicular movements are being restricted that could result in substantial reduction in transportation costs and substantial energy savings without any disadvantages in significant highway cost increases or demonstrably negative impacts on other segments of the highway population. The qualification "demonstrably," with respect to negative impacts, is necessary because the general public (particularly drivers of automobiles), on the basis of descriptions of testimony at legislative hearings, view large and heavy trucks as less safe than other vehicles and as undesirable accouterments on the highway.

The public attitude is understandable. Some trucks operate in such a way as to be inconsiderate of and to intimidate automobile traffic. Even at best, they cause congestion, especially in urban areas and on two-lane highways.

Nevertheless, the advantages of having them on the highway far outweigh the disadvantages. What is needed is constructive action to control the operation of these vehicles, selectively and positively, in order to maximize transport advantages while minimizing disadvantages to highways and other traffic.

It does not appear that it is in the best public interest to have all commodities move long distances by highways. For example, heavy bulk commodities are moved most economically by railroads; whereas, lighter density goods are moved most economically by truck. In some cases, there may be an apparent slight cost advantage by truck, which would disappear if the trucks making these particular movements were charged directly for the highway costs these particular movements incur. Instead, the costs may currently be spread among a larger contingent of trucks or the entire user population.

This illustrates that effective control of truck sizes and weights to maximum public advantage should be a selective process based on sound knowledge of what is in the best public interest. Besides relative transportation costs, there are other reasons why particular goods are best moved by the rail mode or by the truck mode. Some current rail demonstration projects may indicate the way toward removal of some rail disadvantages in some areas (*34*).

Studies are needed to identify the public impacts of specific kinds of movements by different modes, and to recommend specific actions to encourage or assure the most advantageous movements. This would constitute selective constructive action in the best public interests.

To simply control the sizes and weights of trucks on highways without having a clear picture of the economic results or without factual information concerning the relative highway impacts of different vehicular sizes, weights, and configurations does not constitute selective or constructive action. Yet, this is the position in which most state and national legislative bodies seem to be.

Size and weight laws and regulations differ far too much among states without apparent sound reasons for the differences. These occur principally because of the political processes through which the laws and regulations come into being. Generally, representatives of some segment of trucking or the entire industry propose legislation to relax current requirements. Some opinions or factual data may be obtained from highway and enforcement agencies relative to the proposition. The laws of adjacent states are sometimes reviewed. But whether or not the proposal is enacted into law most often reflects the power of the lobby. Important lobbies include (1) organized truckers for, (2) organized automobile owners against, and (3) railroads often against.

This political process is not likely to change as long as individual states are responsible for sizes and weight regulation. However, they can be influenced so that the result is more likely to be constructive legislative action. The influence can be produced in several ways.

Foremost is objective study and representation by the state's administrative and operative agencies, primarily Departments of Transportation and law enforcement agencies. Such studies and representations should be ongoing, broad in scope, and predictive. They should be designed to present factual data associated with expected proposals. They should be objective and result in guidance for the most generally advantageous operation of the highway system, taking all aspects of benefits and disbenefits into consideration—not just highway damage and the lack of funds. There should be great care to assure that trucks and loads are not blamed, generally, for highway depreciation when they are not singularly responsible. There should be great care to point out what damage trucks are responsible for when they are. Some states allow specific industries extraordinary privileges that show up in more rapid deterioration of road surfaces.

In short, each involved state transportation and enforcement agency knows its legislature is probably going to be faced with a proposal for relaxing size and weight limits in the next session. With this in mind, it should have a report (brochure) available that sums up all pertinent knowledge to date including its most recent objective findings in its sphere of influence.

In the cause of desirable uniformity, representatives of these agencies should meet regularly with their counterparts in other states on committees to formulate conclusions relative to better uniformity, legislative approaches, and possibly specific model laws. These meetings should be conducted at 3 levels—national, regional, and with the adjacent states. The latter meetings should be held in conjunction with uniformity that applies primarily to exchanges between the states that are not regional or national in character. They may apply to a specific industry, such as the logging industry or mining industry, that operates similarly in the adjacent states.

There are other ways in which influence can be brought to bear on state legislatures. For example, a Federal incentive might be provided in the form of Federal-aid funds for resurfacing for which only states conforming to basic uniformity requirements would be eligible. An amount of $1 billion over a 5-year period would account for 50 percent of all resurfacing needs because of adoption of optimal uniformity. It would be an economic and energy measure, since substantial fuel savings should result.

The possibility of Federal preemption has been raised since more uniformity would be in the national interest. However, because size and weight laws involve the probability of highway costs, it would appear that preemption must necessarily be limited to the Interstate System for practical reasons. Preemption, even for movements on this System, has serious drawbacks, however, because there would be a problem of access to terminals. Also, preemption understandingly is not popular with Congress. In the case of highway speeds, it took a national emergency. Certainly incentives, if effective, constitute a far better way to go.

WHAT SHOULD BE REGULATED?

Some vehicular measurements and some weight characteristics do not, by themselves, appear to have adverse effects on the highway or highway traffic. Controlling these may obtusely control the dimensions and weights that do, but also may introduce unnecessary controls over vehicular characteristics that can save transportation cost without adverse effect. This, in fact, is what has happened. Aspects of dimensions and weights are being controlled in most states without any real evidence that these are bad, and some of these controls restrict the most economic use of highways. Discussion of the effects of some size elements will clarify this situation.

Gross Weight

There is no evidence that vehicular gross weight, by itself, has any adverse effect on highways or highway traffic provided some basic requirements are met on the way this weight is transferred to the highway surfaces and bridges; on the power capability of the vehicle to accelerate and to maintain reasonable minimum speeds on grades; and on the braking capability to stop the vehicle within a safe stopping distance. The distribution of weight on bridges is summed up by the bridge formula. The distribution of weight on road surfaces is completely controlled by specifying axle-load limits. The other requirements can be directly specified in different ways. Since gross weight defines payload, there is obvious economic advantage in allowing the maximum that can be carried without ill effect. As noted previously in this report, studies have indicated that the degree of seriousness of truck accidents, in terms of fatalities and injuries, may have a relationship to gross vehicle weight, but the relationship is not dramatic or easily proven and is countered by generally lower accident rates (*29, 30*).

Vehicle Length

Total vehicle length does not appear to pose any real problems on multilane highways, at least under most weather conditions, provided basic requirements can be met with respect to offtracking, braking, stability and swaying, and other aspects of vehicle control. Control in all of these aspects can be specified directly. Control of vehicular unit length perhaps can satisfy the offtracking requirement (see following discussion under "Vehicle Unit Length"). As indicated elsewhere in this report, there have been some differences in findings on whether or not long triples and doubles throw more spray than shorter semis in inclement weather conditions. Of course, it takes longer to get by them, but the question is whether or not view-blocking spray is sustained for the vehicle length. It has been said that it is not, because of a streamlining effect. It does appear that there should be specific controls on the operation of extra long vehicles and recommendations have been made by some (*35*).

Axle Weight

As discussed elsewhere in this report, axle loadings of various magnitudes make different demands on highway surfaces; and these demands are proportional to several times the relative weights, the multiplication factor increasing as axle weight increases. Therefore, because there always are some segments of industry that will take advantage of virtually any weight permitted, highway service lives, maintenance requirements, and resulting annual expenditure requirements may well depend on the axle load limit specified. However, because of developments to date in highways, vehicles and laws, a universal axle load limit at the 20-kip (9.07-t)/34-kip (15.42-t) level, which appears to be strongly justifiable from an economic viewpoint, will meet the present requirements and demands of most of the interstate trucking industry. This finding is based on the fact that vehicle designs appear to be available to haul most commodities long distances at minimum costs without exceeding this axle-load level. It also is based on certain assumptions regarding the industry's desire to move certain amounts of commodities per trip. However, the conclusion is supported by the fact that the current trend is towards reduction in numbers of the heaviest axle loads.

Vehicle Unit Length

The most important reason for controlling vehicular unit length is offtracking, the lateral distance between the tracks made by the rear wheels of a vehicle and the front wheels of a vehicle. With a sufficiently long single unit and rear wheels on a fixed axle, it is quite possible for the rear axle track to encroach in the opposing traffic lane on a two-lane highway. However, offtracking is more strictly dependent on distance between axles, and there are other aspects of unit length that are critical. For example, there can be body overhang so the body encroaches more than the rear axles. Unit length also is important in combination vehicles that offtrack less than single unit vehicles of the same length. Encroaching in other lanes is only one problem associated with offtracking. There is also the problem of negotiating interchanges where the radius of curvature has been adopted with specific vehicle and unit lengths in mind. In addition to offtracking, the stability of combination vehicles can be affected by relative unit length. In short, it appears desirable and necessary that unit length be controlled. In general, the shorter the units, the better a multiple trailer vehicle articulates—that is, the better the road area covered by the rear units conform to that covered by the front unit.

Vehicle Unit Width

Vehicle unit width is important and should be controlled, simply because of the safety aspects of the available lane width occupied. Presuming a truck of the width permitted in most states (96 in. (2.44 m)) occupies the middle of the usual 12-ft (3.66-m) lane, there will be 4 ft (1.22 m) separating it from a similar vehicle in the next lane. There will be considerably more distance if the other vehicle is a passenger car. In the case of the trucks, since vehicles deviate from the lane center to some degree, the 4-ft (1.22-m) clearance does not seem excessive. However, when approaching an object promising to be this close to the side of a vehicle, studies have shown that a vehicle tends to move laterally to provide more clearance. Thus, the 4-ft (1.22-m) distance is usually increased. This is pertinent because the 96-in. (2.44-m) width limitation does hamper truck loading for some kinds of shipments, undoubtedly involving more costs than otherwise would be the case. The shipments in question are standardized at a 4-ft × 8-ft (1.22-m × 2.44-m) dimension, including 4-ft × 8-ft (1.22-m × 2.44-m) building panels and shipping containers. There is no evidence to indicate that an increase in width of 6 in. (0.15 m) would result in an increased number of accidents.

Vehicle Unit Height

Height is another characteristic that has a definite effect both with respect to possible highway damage and traffic safety. The damage can occur to overpass structures designed to accommodate a vehicle of limited height. The safety disbenefits could occur because of decreased stability with respect to sway and rotation. Most states now restrict vehicles to no more than 13 ft–6 in. (4.11 m), and there appears to be no strong reason for increasing this dimension.

Operating Characteristics

There are many different operating characteristics of trucks that have important relationships to highway effects that could be detrimental. Perhaps not quite coming within this definition is the applied load per square inch of tire area imprint, which many pavement designers believe has a bearing on pavement life—the specification is written in several ways. Braking characteristics are obviously very important and should be specified. Power or speed capabilities on grades are important as related to highway capacity—again, the specification can be written in different ways. The degree of sway to be permitted by a trailer or other unit can be specified. This is not intended to be inclusive, but only to point out some characteristics that commonly are and should be controlled. Within the current highway traffic safety infrastructure, there is a Federal function to control vehicular safety aspects with performance standards.

Operations

There possibly has been insufficient regulation of actual vehicle operations in order to assure the most desirable practical relationship between truck traffic and other traffic, taking into consideration the relative needs of both. Certainly, important aspects of vehicular maintenance need to be specified as these relate to highway safety—the BMCS and ICC, of course, have such regulations. Other regulations pertaining to time on duty and driving are equally important. From the standpoint of the states' operations of their highway plants, rules might be considered pertaining to such factors as which lanes trucks can occupy under certain circumstances and which passing maneuvers are permitted. These are not intended to be specified recommendations but to suggest a principle. The idea would not be to penalize trucks but to assure that all conform to the best operating procedures. This is in the direction of positive operation of highways to maximize benefits to the total population. It is more productive to directly control operations that may pose problems for other road occupants than unnecessarily limit aspects of trucking that potentially produce net benefits.

BENEFITS TO THE POPULACE

The question has been raised, during this research, concerning who will really benefit from reduced transportation costs. Put another way, there has been skepticism that a significant part of the savings actually will be passed on to the buyers of merchandise through reduced costs.

In discussions and answers to questionnaires, responses from industry varied on the degree to which current transportation cost rates would be affected. It probably is a fair conclusion that transportation cost rates to shippers would not immediately be reduced but that the rate of increase of these costs would be reduced. There will be a changeover period for industry when new equipment and frameworks for operation are introduced. Also, ratemaking structures are complex and ponderous.

However, there is every reason to believe that the cost reductions ultimately would be passed on to the shipper and the consumer.

Although the trucking industry certainly desires to make as much profit as possible, it is, despite regulatory control of rates, a highly competitive industry. In the first place, only a portion of the industry is economically regulated or subject to established rates fixed, within a service area, by the ICC through the operation of rate bureaus. According to Taff (*18*, p. 187), there are two and one-half times more unregulated carriers than there are regulated carriers operating interstate. These exempt carriers because of the types of commodities they haul; and are generally "perfectly" competitive (according to Taff), although there is some stabilizing influence on rates in many cases.

But even the regulated industry has competition. There is competition from private carriers, which are firms moving their own goods. There is some competition from exempt carriers who have obtained ICC authority for back hauls of certain commodities. There is some competition from other modes. According to Taff (*18*, p. 387), there also is some competition between contract carriers and common carriers within the regulated industry.

Also, even though regulated common carriers do operate generally in a common rate situation, there is some competition between them to reduce rates. Because of potentially cutthroat competition, in this respect, Taff (*18*, p. 385) points out that the ICC has established minimum rates in many cases to protect the industry.

Summarizing the situation, Taff (*18*, p. 385) states: "The large number of motor carriers, the nature of their operations and the ease with which volume shippers can engage in private motor carriage have been factors which have tended to keep motor carrier rates in the lower zone of reasonableness."

Thus, it is reasonable to expect that savings in transportation costs will ultimately be passed on to the public in large measure in the reduced prices of goods. An economic study to determine the actual sensitivity of wholesale or retail prices to interstate transportation costs was outside the scope of this research.

In addition to directly attributable reduction in the cost of living through transportation cost reductions, there undoubtedly are other economic advantages more difficult to quantify. These include:

1. Expansion of market area and the increase of business size and employment that goes with it. For example, it is doubtful that the fruit industry would be as large in California, Texas, or Florida if the produce was not capable of being transmitted so far so quickly at reasonable cost.
2. Development of establishments serving the trucking industry, which increases employment and the industry base for economic centers.
3. Direct effect of truck transportation costs on the cost of living in many cities and towns as evidenced by the fact that more than 39,000 municipalities are entirely dependent on trucks for goods transportation (*5*).

As an example for automobile drivers to consider relative to the importance of trucks on the highway, despite troublesome aspects of truck traffic, it is worth noting that if large trucks did not deliver the fuel on which automobiles depend to service stations and there were only small trucks, fuel prices would skyrocket.

OPTIMAL UNIFORMITY

On the basis of the analysis described in Chapter Two of this report, it is recommended that the 48 contiguous states amend their laws and regulations to permit the following minimum vehicle dimensions and weights:

- Width—102 in. (2.59 m)
- Height—13 ft-6 in. (4.11 m)
- Length—Single truck, 40 ft (12.19 m)
  - Bus, 45 ft (13.72 m)
  - Trailer, 45 ft (13.72 m)
  - Tractor semitrailer combination, 60 ft (18.29 m)
  - Tractor semitrailer full-trailer combination, 65 ft (19.81 m)
  - Full-truck full-trailer combination, 65 ft (19.81 m)
  - Other combinations, 105 ft (32.00 m, on designated routes only—designated routes will be limited to 4 or more lane-divided highways with full access control and on other highways within a given number of miles of a designated interchange (1 mi—1.609 km suggested))
  - Auto carriers, 66 ft (20.12 m)
- Number of towed units—3
- Axle load—Single, 20,000 lb (9.07 t)
  - Tandem, 34,000 lb (15.42 t)
- Operating tire inflation pressure—95 lb per sq in. (6.68 kg/sq cm)
- Gross weight—bridge Formula applied to total wheelbase and/or any group of axles.

These provisions will allow the use of the so-called doubles combinations with 27-ft (8.23-m) trailers universally. They will allow 3-4 truck full-trailer combinations. They also will allow the operation of triple unit combinations and larger doubles combinations (turnpike twins) but only, for the most part, on multilane controlled access facilities. The use of short distances on interchanging facilities will allow access to terminals and marshalling areas.

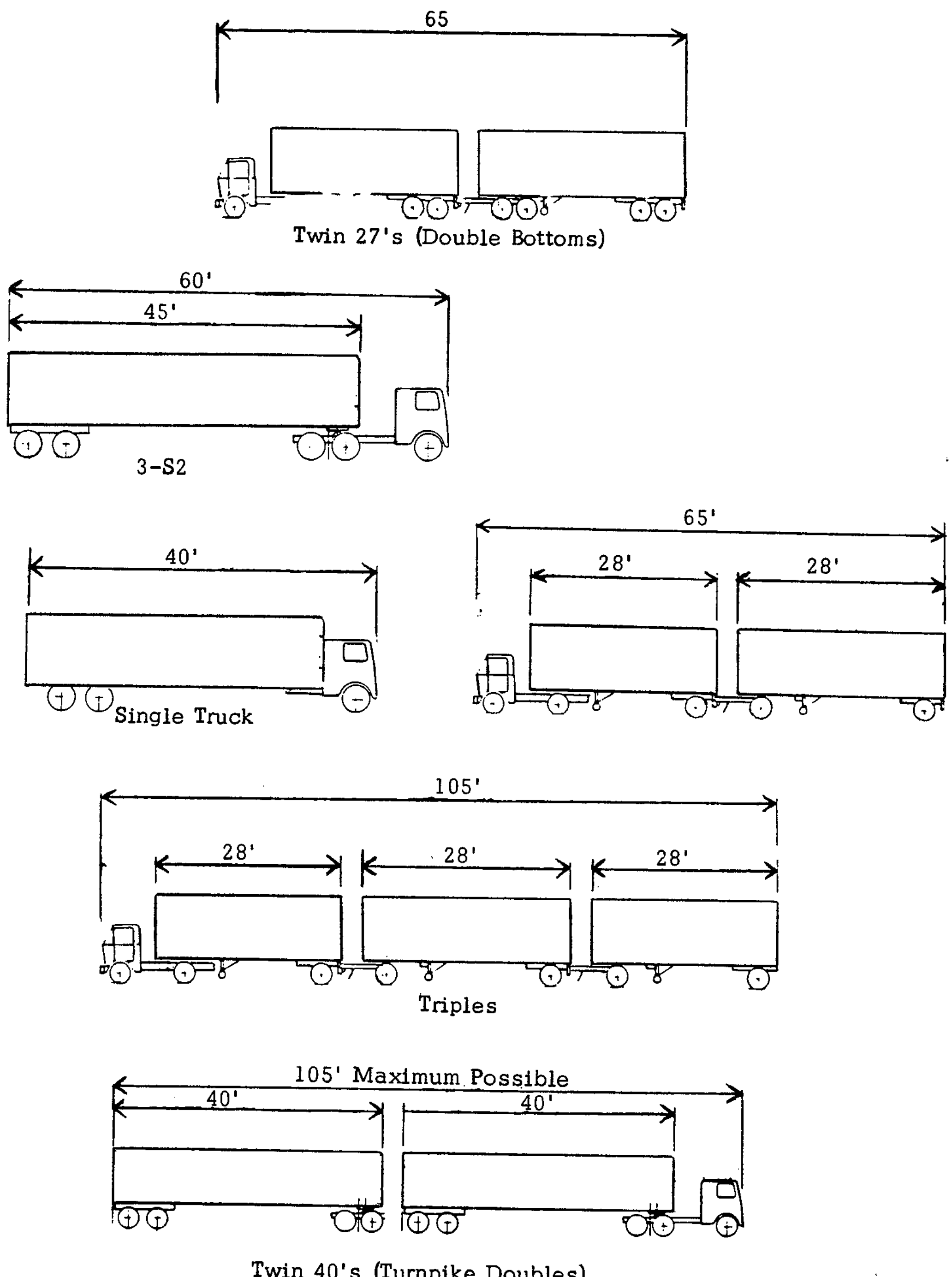
A problem exists in allowing the large doubles to use certain interchanges because of offtracking. Signing may be required to prohibit these vehicles on interchanges where the geometrics are not adequate. Other solutions relative to terminal access for these vehicles may include disassembly yards on or adjacent to the controlled access facility right-of-way financed by charges to industry users, or provision to improve interchanges with industry sharing the cost.

Figure 26 shows a profile of each vehicle type allowed under these uniformity provisions. In reviewing these provisions for uniformity in the light of previous discussion, an apparent contradiction may be noted in the specification of total vehicle lengths. It was previously indicated that total vehicle length *per se*, up to a point, was not a problem.

The length limitations in the foregoing specifications are stipulated to effectively control unit length within certain combination types. With a 45-ft (13.72-m) trailer limit, the 60-ft (18.29-m) over-all length effectively limits tractor length. The 65-ft (19.81-m) length for the generally permitted tractor, semi, full-trailer combination effectively limits the trailers to 27 ft (8.23 m). This may not be the best way of specifying these controls. It was considered outside the scope of this research project to formulate the necessary laws (see recommendations relative to uniformity committees).

RATIONALE FOR OPTIMAL UNIFORMITY CONCLUSION

As indicated, there is a very large economic and energy advantage to be gained from the previously described provisions for uniformity. The scenarios, examples of operational patterns related to actual interstate commodity flows, which were evaluated in connection with this unformity option, showed potential transportation cost savings of $2.8 billion, more than one-third the current federal authorization for highways. This estimate was arrived at conservatively. The assumption was that only the loads in large trucks currently running full on the nation's highways would be candidates for transfers to vehicle types permitting significant transportation cost reductions. These were approximately 30 percent of interstate truck movements, based on computer analyses to determine full vehicles, which took into consideration commodity densities and used information from the annual truck weight studies. An alternative assumption, made for comparative purposes, was that distributions of commodities among vehicular types, when size and weight limits were relaxed generally,



1 foot = 0.3048 meters

Figure 26. Optimal uniformity vehicle profiles.

would be the same as now found in corridors within or between states now having the relaxed limits. As indicated previously, the two comparative assumptions did not give greatly different answers.

It is possible that the actual savings, when realized, will be somewhat lower because smaller independent operators may not be able to take advantage of the multiple-unit provisions. However, these operators are probably less in evidence among the existing full vehicles. The savings may be higher because there are cost advantages in use of multiple units even if the vehicles are not running full.

With respect to fuel savings, it is estimated that the uniformity provisions indicated can save 874 million gallons of diesel fuel (basically) per year. The same qualifications relate to these savings. However, the size of the estimated economic advantage and energy savings is such that even a considerable variance makes the indicated provisions extremely worthwhile.

If there were substantially increased highway costs associated with them, the situation would be different. It would also be different if there were significant demonstrable safety or operating disbenefits associated with them, but this has not been found to be the case.

Conversations were held with highway and enforcement people in more than a dozen states throughout the country. Possible problems were explored in questionnaires to administrative agencies.

With respect to highway requirements, only one of 42 state transportation agencies responding to the questionnaire indicated needed geometric changes on the Interstate System other than interchanges, ramps, and climbing lanes for the 105-ft (32.00-m) combinations. In this case, the agency generalized on changes in vertical and horizontal curvature that were related more to the triple combination (major changes) than to the 40-ft doubles (minor changes). This may indicate lack of knowledge of the operating characteristics of the triples that offtrack on a curve of 165-ft (50.29-m) radius better than a tractor semitrailer with a 45-ft (13.72-m) box. Actually, with the degrees of curve used on the Interstate System, the offtracking of either of the longer combinations should not present any problem. The capability of these trucks to climb at reasonable speeds is, of course, dependent on the power-to-weight ratio and, presuming this is as high as for other trucks permitted, there is no reason why the longer combination should be singled out as requiring climbing lanes on the Interstate. As indicated, it would be logical to specify power-to-weight or minimum climbing speed capability under full load.

It is not intended to minimize the ramp problem. Even in the case of diamond interchanges, it has been shown that a double 40-ft trailer combination—according to AASHTO testimony at a Senate hearing on Transportation and the New Energy Policy, February 21, 1974—requires the following:

> . . . a width of approximately 29 feet (8.84m) to negotiate a turn from a ramp of a diamond interchange onto a cross highway. In other words, the vehicle would occupy both lanes of a conventional two-lane highway, as well as the shoulder of the opposite side of the highway, presenting a safety hazard to approaching traffic and making it impossible for them to negotiate the turn at those intersections controlled by traffic signals where the stop line for traffic on the main highway is less than 80 feet (24.38m) from the near side of the intersection.

The solution to nonuniformity proposed by this research is not an easy one, but the potential outcome is believed to be well worth the effort. Since it involves strictly an industry accommodation, it appears reasonable to expect the using industry to pay the cost. There are several possibilities:

1. Forty-foot doubles operations might be allowed by special permit where the permit fee represents a tax levy that will be employed to modify selected intersections signed to permit the large doubles operation.
2. A state might construct disassembly yards with access either on the control access right of way adjacent to it, on a parallel frontage road with slip ramps (in some states) or close to an interchange that will accommodate doubles. Charges to users employing the disassembly yards would cover construction and maintenance costs.
3. Clover leaf and diamond interchanges do not, in all cases, have restrictive geometrics that will not safely accommodate the large doubles.

With respect to safety of the longer combinations, most administrative agencies had no idea of percentage changes of accidents that might occur with their use. Subjectively, it was judged by highway agency personnel that triples would be more dangerous vehicles than others on the highway. This point has not been borne out in studies of the actual operation of these vehicles. In fact, the subjective response from authorities in one state contradicted the general findings of that state's own triples study. In general, the safety findings concerning triples are summed up by the experience of two specific states reported in a California triple-trailer study:

1. Nevada has only one recorded accident involving triples. The accident happened on a two-lane road but could not be attributed to the triples' length.
2. Oregon's Transportation Permits Supervisor said that they have no evidence that triples have been a contributing factor to any accidents directly or indirectly.

The trucking agency in California pointed out that the 8-day triples demonstration study indicated that "so far as being able to stop safely, these triples are probably the best heavy-duty equipment which can be put on the highway."

The large doubles combinations have amassed an enviable safety record on the turnpikes on which they have been operated for many years.

In discussions with law enforcement officials in more than a dozen states across the country, some of which have tested triples, there was no expressed opposition to the use of the longer combination vehicles on expressways. Actual approval of such operations was withheld, in many cases, because officials had not specifically studied the question. However, there was obvious willingness to accept the findings of studies that these are not unsafe vehicles.

One consideration that grows out of this research relates to the decrease in numbers of truck trips that will occur as a result of large doubles and triples. This may result in some actual reduction of accidents.

Returning to the highway cost considerations, the major increases in highway costs that should be associated with the optimal uniformity option are the surface improvement requirements associated with the predicted maximum changes in equivalent axle loadings. Other related highway costs include ramp modifications and disassembly provisions for which the costs should be transferred to the beneficiaries. The magnitude of these costs has been shown to be almost insignificant as related to the cost-savings potential of the option, although $2 billion in increased highway costs is not insignificant in its own right. This figure should be on the high side of the costs actually experienced on a one-time-only basis. There may be some small increases in maintenance costs.

In considering all of these factors, there appears to be very little supportable reason why any state should not adopt the optimal uniformity provisions indicated as expeditiously as possible. It is recognized that all of the problems associated with accommodating the longer combinations on freeways have not been discussed. It is recognized, also, that an action plan needs to be developed in each state, probably with the help of the FHWA, to overcome these problems before legislation is introduced to allow the operations indicated. These problems, however, should not prevent early adoption of the uniformity provisions indicated.

THE BARRIER STATES

In the uniformity question, 13 states maintain the gross-weight limit at 73,280 lb (33.23 t), axle-load limits of 18,000 lb (8.16 t) for single axles or 32,000 lb (14.5 t) for tandems or all three. Six of these states plus 12 other states limit vehicle length so that the 65-ft (19.81-m) doubles combination vehicles cannot operate. They are joined by some states who have higher load limits.

Taken together, these 26 states present a considerable barrier to types of interstate movement that could result in annual national transportation cost savings of $1.6 billion and savings in fuel consumption of 723 million gallons per year (see Table 22, Chapter Two).

These estimates come from evaluation of a uniformity option that would result in the following minimal size and weight provisions in every state:

- Width—96 in. (2.44 m)
- Height—13 ft-6 in. (4.11 m)
- Lengths—Single truck, 40 ft (12.19 m)
  - Bus, 45 ft (13.72 m)
  - Trailer, 45 ft (13.72 m)
  - Truck-semitrailer combination, 60 ft (18.29 m)
  - Other combinations, 65 ft (19.81 m) plus 1-ft (0.30-m) load overhang
- Number of towed units—2
- Axle load—Single, 20,000 lb (9.07 t)
  - Tandem, 34,000 lb (15.42 t)
- Operating tire inflation pressure—95 lb per sq in. (6.68 kg/sq cm)
- Gross Weight—bridge Formula applied to total wheelbase and/or any group of axles.

The indicated cost and fuel savings presume that states (including turnpike authorities) currently providing for triples or turnpike twins will continue to do so. They, admittedly, represent the high figure estimates associated with this option. The scenarios that try to predict the variances in how industry may take advantage of these options by use of different vehicle types give low figure estimates of potential savings at $922 million and 392 million gallons of fuel per year (see also Table 22).

Highway costs associated with achieving uniformity at this level would not be large, generally. EAL increases might be anywhere between 4.3 and 15.5 percent on the average. In the barrier states themselves (that is, those with the lowest gross weight and axle load limits), the increase has been estimated at no more than 17.5 percent. These are essentially the same order of potential increases given, as a maximum, in connection with the optimal option and are the largest associated with any option or scenario evaluated.

Because of shortcomings of available basic data, it has not been practicable to make evaluations of actual highway costs for the barrier states alone. The order of these costs, however, will not be much larger on a per system mile basis than those determined for the different regions on the basis of a 15.5 percent increase in EAL's. In other words, these costs are extremely low as compared with the potential transportation cost savings.

It is an important qualification, however, that these findings are limited to interstate movements on principal arterial highways. It may be that increasing permitted axle loadings from 18/32 kip (8.16/14.51 t) to 20/34 kip (9.07/15.42 t) in the barrier states will result in significantly more rapid deterioration of surfaces on secondary highways from essentially intrastate vehicle operations. Nevertheless, the increases in axle loading also would result in decreases in transportation costs for intrastate movements, and the same relative scale of cost savings to highway costs might well result. In this case, the benefits would be largely derived by in-state industries and residents.

One likely reason some state authorities and legislators have resisted increasing gross weights and axle loads to the more predominant maximum limits is a belief that representations for higher weights are an on-going occurrence that will not abate with the new levels. However, there are indications, reflected in the lack of emphasis on additional axle load requirements by industry officials contacted during this study, that the 20/34-kip (9.07-t/15.42-t) level is, in fact, a plateau that will satisfy major demands for some time. This may be reflected in the fact that there is only a slight upward trend in the frequency of heavy axles (18 kip (8.16 t) or more) per thousand trucks weighed on main rural highways, with the exception of 3-axle vehicles in states with 22.4-/36-kip (10.16-t/16.33-t) axle-load limits (*6*). Three-axle dump trucks apparently will take advantage of everything they can get, but it is pretty difficult to control them on secondary roads in any case.

The only apparent advantage to states that limit length so as to prevent the normal doubles operation with two 27-ft (8.2-m) trailers is the by-passing of the state, which appears to take some through-truck traffic off the state's highways. However, some studies, such as the Iowa doubles study referenced in Chapter Two, have shown that this additional traffic can mean additional economic return to the state. Also, it is a disservice to the whole public in that trip distances and transportation costs are generally increased. In the Iowa situation, for example, east-west doubles are diverted onto U.S. 36 through Missouri, which results in additional accident exposure because vehicle access is not limited and opposing traffic lanes are not separated. Instead, there are Interstate highways—1 east-west and 2 north-south—through Iowa that would be used.

APPLICATION OF FINDINGS

Application of the findings of this research will not be automatic or undemanding with respect to the efforts of agencies and individuals who are genuinely interested in operating the nation's transportation systems to the best advantage of the public.

The transportation agencies are obviously the key to effective action in the uniformity area. But the answer is not compact nor does it involve ways around current laws. Instead, the answer lies in factual data and public education. With the current energy crisis and high cost of living, factual data must be presented to legislative decision-makers so that they have a firm basis for enacting optimally beneficial size and weight controls. Transportation agencies should be able to demonstrate the cost effect of changes in axle loadings and frequencies on their facilities. They should assist the legislatures in prodding industry to demonstrate the reduction in general transportation costs associated with desired accommodations.

It is necessary for each state to have examined the effectiveness of its enforcement program in seeing that its size and weight laws are actually being observed. Judging from trucker's responses and available data, the level of axle loading on a state's facilities is almost as dependent on the nature of enforcement as it is on the state's particular legal levels. Also, particularly in this age of CB radio, weighings at permanent locations obviously are not the sole requirement of good enforcement. In fact, they may become obsolete altogether as an effective method of enforcement. Randomly operated portable scale sites are probably more effective, especially when coupled with significant penalties for overloading.

It is necessary for enforcement agencies to keep accident records in such a way as to determine important characteristics of trucks involved in accidents, as well as the way these characteristics influence the occurrence or severity of accidents.

In other words, there should be, in each state, a base of knowledge for making rational judgments regarding legislation concerning truck sizes and weights. This base of knowledge should be summarized and made available to legislatures before representations are made by vested interests. State agencies can cooperate in having such summary material available, but it should be entirely factual. Opinions should be limited to interpretations of the facts.

In the early stages of this research project, it became apparent that neither highway agencies nor trucking industries (except for very few) had much factual data available relative to the effects of nonuniformity or the advantages or disadvantages of better uniformity. There were opinions, but these, at least in some cases, clearly demonstrated a lack of knowledge of facts. Both the highway department and industry questionnaire responses attest to the lack of factual knowledge.

As a result of the lack of factual data, the state legislatures are being motivated entirely by the political process. This may even be occurring nationally where concern for depreciating highway condition on the major highway systems may motivate ill-considered actions relative to truck sizes and weights. There also is natural concern over the competitive situation with respect to truck and rail but very few facts to indicate the relative merit—economic and otherwise—of particular courses of action that might assure the most productive use of both railroads and highways.

During the research, attention was given to at least one way the two modes might operate together to take advantage of relative merits of both—namely, by trailer on flat car (TOFC) or piggy-back shipments. The situation was found to be complicated by factors that had little to do with the relative merit of these movements. Truck-driver union problems were among the more significant. One large trucking concern indicated that these problems were a major reason for not developing more of this kind of traffic on a particular route. Other problems, often cited, were transit times and schedules. Trucking concerns indicated having to wait inordinate times for transit and delivery as well as inability to depend on schedules.

This research has resulted in the recommendation of only one set of provisions for optimal uniformity. There was an early decision that, for practical reasons—based on different industrial, agricultural, commercial, and natural resource interests—states could not all be expected to make the same provisions for motor vehicle size and weight. Accordingly, the work effort became oriented toward evaluating sets of uniform provisions that states might enact nationally or regionally to optimize public benefits from highways while minimizing highway and other disbenefits associated with trucking.

Through identification of virtually all interstate commodity flows by truck and the development of logical conclusions, based on relative transportation costs for different commodity classes, it has been possible to arrive at and demonstrate the advantage of particular uniformity measures. Of these, one set of provisions stands out to a degree that precludes serious consideration of any others, and it applies nationally. The idea of possible regional uniformity, considered at one stage in the research, was set aside as not having comparative merit.

The one set of provisions that deserves to be enacted by every state, if enacted by all states, will produce substantial economic and energy benefits to the American people without significant disbenefits in terms of increased highway costs or other identifiable harmful effects. There are some associated problems that need to be dealt with and decisions made, with the help of highway and enforcement agencies, before enactment—but these are not of such magnitude as to destroy the merit of earliest possible action.

However, to be realistic, it must be recognized that there will be problems in obtaining favorable action in the different states even with wholehearted support from the states' technical and administrative agencies. Trucking unions are generally opposed to the operation of large doubles and triples, as demonstrated in the testing of triples in Western states, because it reduces the number of trips and resulting use of drivers. Railroad lobbies are still concerned about additional truck competition. State automobile clubs may still fail to recognize the general economic and energy advantage to their members of having large efficient trucks on the highways and learning to live with them.

Part of learning to live with them involves learning how to control the characteristics of their operation that produce undesirable effects, without curtailing the features that can produce public benefit. Users will be dependent on the administrative state transportation and enforcement agencies for positive recommendations on how this can be done effectively. AASHTO and the regional associations readily might take the lead through committee activities.

Government transportation agencies interested both in railroads and highways have an obligation to devote more study to the competition between the two modes with the obligation of learning how to obtain the best total public advantage from both modes. Nonselective action to oppose any reduction in trucking costs almost obviously is not the answer.

The state transportation agencies have built one of the best transportation systems in the world. But there still is much to be learned about how to operate it to maximum public advantage.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

1. Current nonuniformity among state laws and regulations governing truck sizes and weights results in inefficient use of highways for commercial transportation. Major inefficiencies include circuitous routing, inability to use optimum vehicle types, and unnecessary trips.

2. Complete uniformity, where every state has the same laws and regulations for all vehicles, is not likely under the current political process nor necessary to adequately provide for optimum interstate commerce.

3. With optimal uniform provisions for truck sizes and weights, annual operating cost savings could be in the range of $1.2 billion to $2.8 billion annually. The $2.8 billion estimate represents the best economic use of available vehicle types. The $1.2 billion estimate represents the lowest probable employment of these vehicles.

4. If 26 states were to allow twin 27-ft (8.2-m) trailers and total weights up to 80,000 lb (36.28 t), the annual transportation cost savings from these changes alone could be $1.5 billion.

5. Every state will need to revise its laws and regulations to some degree to completely achieve optimal uniformity, because some of the limits incorporated in the optimal uniformity provisions have been patterned after limits currently permitted on some turnpikes.

6. The present bridge formula should be retained by all states as a control on gross and axle loads, at least until there is a substantial change in the national situation with respect to the number of deficient bridges.

7. Optimal uniformity will not require axle loads to be increased to more than 20,000 lb (9.07 t) for single axles or 34,000 lb (15.42 t) for tandem axles, but provisions for these loads should be made on all systems used extensively for interstate trucking.

8. Maximum additional highway costs for the optimal uniformity provisions will not exceed $2.0 billion on a one-time expenditure basis with, perhaps, small additional maintenance costs. (All costs are estimated on a current expenditure basis.)

9. The greatest deterrent to uniformity has been widespread misunderstanding and misinformation, coupled with rigid political positions. The misinformation relates to the nature of the trucking industry, vehicle capabilities, accident experience, and impacts to the highway.

10. In establishing legislation to control commercial operations on the highways, there has been too much emphasis on sizes and weights *per se* and not enough on the particular operating characteristics of vehicles that may cause undesirable impacts on the highway or disbenefits to other traffic.

11. State transportation and highway agencies generally could play more dynamic and effective roles in determining and recommending to their legislatures how to operate the highway systems with respect to controlling truck size and weight and operating characteristics in order to produce maximum economic returns and energy savings and minimal disbenefits.

12. Levels of truck size, weight, and speed enforcement are inconsistent among the states, diminishing the meaning and effect of legal limits.

RECOMMENDATIONS

Recommendations resulting from the findings and conclusions of this research are presented separately for the organizations having responsibility and interest in size and weight regulations.

Highway Agencies, Representative Organizations, and Legislatures

1. *OPTIMAL.* The American Association of State Highway and Transportation Officials (AASHTO) should adopt a policy that all states make provisions for optimal vehicular sizes and weights as set forth in Chapter Three under the heading "Optimal Uniformity." This will permit operation of large double trailer (turnpike twins) and triple combinations on four-or-more-lane controlled access facilities throughout the country.

2. *MINIMAL.* Those states currently having gross weight levels at 73,280 lb (33.23 t) and axle-weight limits less than 18,000 lb (8.16 t) for single axles and 32,000 lb (14.51 t) for tandems, as limiting and thus creating barriers to interstate truck movements, should revise their limits to be consistent with surrounding states. This applies also to states whose length limitations prevent the operation of doubles combinations with two 27-ft (8.2-m) trailers.

3. AASHTO should develop a general policy that control of truck operations on highways should be directed toward obtaining maximum economic return from the investments in the facilities along with maximum highway safety and minimum conflicts with other traffic needs. The policy should make it clear that particular dimensions and weights should be considered as factors (although not the only factors) in establishing such control.

4. National and state transportation agencies should be concerned about truck and rail competition and, accordingly, recommend appropriate selective controls on trucking if this is the best avenue to assure optimum public benefit from both modes. However, recommendation of these controls should be based on the ability to demonstrate their probable effectiveness in achieving a commodity-specific transportation objective, and a positive net benefit to the public associated with that objective. Also, measures other than controls on trucking should be evaluated as alternatives. In addition, there should be thorough study of ways in which both modes can provide for transport needs cooperatively, including ways of eliminating current problems affecting such cooperation.

5. A three-level organizational approach by transportation agencies would provide the capability for greater uniformity and improvement in the entire area of size and weight regulation to assure proper control of elements that are important while eliminating unnecessary controls. The three-level approach, described as follows, would include AASHTO (national), regional associations of state highway and transportation agencies (SHTO), and smaller groups of adjacent states. The following recommendations are made for each organizational level:

a. An appropriate AASHTO committee or subcommittee should be established to pursue the following objectives: (1) carry on a continuing evaluation of representations by industry and others relative to uniform provisions for interstate truck operation; (2) form conclusions relative to uniform provisions taking full account of economic, energy, and other benefits, as well as effects on highways; (3) analyze currently existing state laws as related to such conclusions; (4) develop legislative approaches to improve uniformity; and (5) perhaps develop model laws.

b. The regional associations (of SHTO's) should assign similar objectives to similar committees or subcommittees. In this case, there should be concentration on uniform provisions within a region that might predate or supplement national provisions. It is quite possible that provisions might be desirable for some interstate movements within regions for which favor would not be found nationally.

c. In many cases, there also should be meetings between representatives of adjacent states who share concern for movements not of national or regional concern. These movements will relate, generally, to specific industries or natural resource production, which the states have in common and which require special accommodations on the highways. (Logging movements, mineral movements, and some agricultural movements are examples.) The objective would be to achieve as much uniformity as practicable in provisions for these movements.

This recommended three-level approach should result in steady improvement of uniformity on a selective basis with the adoption of specific provisions at levels where they will be of maximum value.

Trucking Industry

Decisive action by state highway agencies to bring about equitable uniformity should be beneficial to the trucking industry. In response, the trucking industry should assist in the development of legislation to effectively control those aspects of trucks and their operations that have adverse effects on highways and other traffic.

Automobile Clubs

Automobile clubs should give careful consideration to the value of large efficient freight movers on the highways. In response to responsible legislative programs by the trucking industry, the clubs should concentrate on legislation to effectively minimize adverse effects of truck operations on automobiles, in lieu of opposing size and weight changes not shown to be responsible, in themselves, for such adverse effects.

RESEARCH NEEDS

1. *Adequate Up-to-date Commodity Flow Data.* Although the commodity flow model developed for this project has been sufficiently accurate to accomplish the objectives of this project, further refinement would be necessary to answer many questions concerning the economics of commodity flows. The data sources are not as refined as would be desirable.

Basic problems include the following:

a. The U.S. Department of Commerce Census of Transportation (COT) Commodity Transportation

Survey (CTS) was limited to goods shipped from U.S. manufacturers. This meant that shipments by wholesalers, importers, natural resource producers including farmers, and agricultural processors were not covered. This necessitated extraction of data from a number of additional sources. These data were not all of the same quality with respect to degree of refinement, completeness, or accurate statistical representation.

b. Commodity data from most sources do not identify commodity transportation characteristics such as density, dimensions and shapes, perishability, and value.

c. The production area to market area data in the 1972 CTS do not involve a sufficient coverage of production areas in all states to effectively account for commodity flows from all parts of the country. (For this project, the state-to-state flows were used to overcome this problem.)

In order to properly plan and regulate national or state transportation systems, it is necessary to know (1) how commodities flow from point of production or transhipment to destination, (2) the characteristics of these flows that create transportation service demands, and (3) the values and benefits of such flows. It is also necessary to know how the different modes are handling the current flows and demands, and future expected trends.

It would be valuable if COT coverage was extended to all commodities and to second stage shipments as well as to shipments from the original commodity source.

Also, there is need to correlate the information gathered by the Bureau of Census with the information needs and data-gathering efforts of specific user agencies. Such user agencies include the Federal Highway Administration, the Federal Railroad Administration, the International Commerce Commission, and the U.S. Department of Agriculture.

As part of the mutual effort, research is needed to establish guidelines for gathering of data by the Bureau of Census to serve the transportation evaluation, planning, and regulation needs of the data-using agencies and to assure a commodity classification and coding system that will lend itself readily to their data requirements.

2. *Effective Operational Control of Trucking.* Control of sizes and weights *per se* does not necessarily meet objectives such as prevention of undue wear and tear on highways or minimization of highway accidents and undesirable impacts of trucks on highway traffic. In some cases, operational controls to minimize bad vehicle performance or bad driver performance could be more effective. Such controls should be based on known vehicle performance characteristics as well as identified specific situations of unsatisfactory vehicular behavior. There is need for research to develop positive operational control measures, reducing unnecessary restrictions on nonimportant vehicular characteristics, to assure that all vehicles generally perform on the highways in the best interests of the entire public.

3. *Vehicle Performance Characteristics.* There is a need for continuing research into the performance, structural, and other operational characteristics of trucks on the highways as may relate to their safety and their traffic effects. There has been considerable study of the performance characteristics of vehicles of different sizes, configurations, and weights, particularly in the case of the new doubles and triples combinations that have emerged during the last few years. But there has been little study of structural characteristics of vehicles that may be important from a safety standpoint. In Massachusetts, trucks can be registered, on an annual permit basis, at gross vehicle weights up to 99,000 lb if manufacturers will certify the safe structural capacity of a vehicle. The certification is not always obtainable. There also are unresolved questions concerning the safety of tires (including retreads) at different axle loadings, travel distances, and speeds.

4. *Vehicular Safety.* There are still many unanswered questions regarding the safety of large and heavy vehicles. It is known that Class I and Class II carriers have low-accident rates through ICC statistics. It is also known that triple combinations and turnpike twins have excellent accident records. There are conflicting statistics regarding the smaller doubles as related to other combinations. But even knowledge of the accident statistics as related to type (of which there are too few) does not tell the entire story. Instead, in order to make valid statements concerning accident relationship to vehicle characteristics, accident experience must be evaluated in terms of variables such as: (1) driver experience, (2) mileage on different classes of highway, (3) weather and surface conditions, and (4) traffic stream characteristics.

On-going FHWA Project 1-U may answer some of the basic questions concerning accident rates of different truck types. If so, this research need may be met to some considerable extent.

However, there will be a continuing need for more information relating accidents to pertinent vehicle characteristics. This possibly can be gathered in two ways: (1) more pertinent detail in police accident reports and subsequently recorded data; and (2) follow-up investigations of selected truck accidents to get more details.

Judging from recent reports, without specific arrangements to actually gather and record more data on truck accidents, there is little use undertaking studies to try to relate vehicle characteristics and accidents.

5. *Effective Enforcement Procedures.* This research and previous studies have shown clearly that the type and extent of size and weight enforcement, as well as the penalties associated with exceeding these limits, has a considerable effect on observance of size and weight limits. In fact, poor enforcement makes legal limits somewhat meaningless.

There is need to know more about the relative effectiveness of various enforcement programs and procedures. There also is need to evaluate the highway effects of poor enforcement as may be reflected by typically increased equivalent axle loadings.

6. *Truck Versus Rail Competition.* Much study is needed to obtain a clear perspective on truck and rail competition such as to: (1) identify degrees of truck and rail competition for different types of commodity haul in dif-

ferent situations; (2) identify those factors that provide the advantage to one or the other mode; (3) in the closely competitive area, identify the degree of fluctuation in costs that can make the competitive difference; (4) in this same area, make cost/benefit analyses related to the transport of commodities by one mode as compared to the other, taking all benefits to shippers, producers, and the general public into consideration; (5) determine ways of reducing transport costs in the competitive area on both modes in exemplary situation and impacts associated with any such cost reductions; (6) formulate conclusions based on costs and benefits, but not all necessarily economic, on the most beneficial role of each mode with respect to the carriage of different commodities in different situations; (7) develop ways to encourage or assure that these roles are being carried out; and (8) project future costs and benefits. The foregoing is not intended as a representation of research project objectives in an orderly manner but only to indicate some of the evaluations that need to be made for sound transportation policy decisions.

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APPENDIX A

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APPENDIX B

TRUCKERS' QUESTIONNAIRES

Two basic questionnaire packages were prepared for truckers. The first was detailed and intended for large carriers; it contained two parts, one for general information and the other for information concerning a specific trip on which nonuniformity created some difficulty or inefficiency. The second questionnaire was much shorter and was intended for owner-operators and other very small carriers.

Questionnaire recipients for the large carrier questionnaire were selected from a listing supplied by the American Trucking Association of all Class I and Class II regulated carriers, and from membership lists supplied by the Western Highway Institute, Private Truck Council, and Private Carrier Conference.

Questionnaire recipients for the independent owner-operators and very small carriers were selected from a Chilton Publishing Co. mailing list. Chilton publishes the "Owner-Operator" magazine and maintains a listing of all subscribers and all respondents to short form questionnaires often included in the magazine.

Of the total mailing of 7,604 questionnaires, the detailed package accounted for 5,104—all of which were mailed with the endorsement of one of the following trucker organizations: American Trucking Associations (2,863), Western Highway Institute (86), Private Truck Council (1,074), and Private Carriers Conference (1,081).

The short form questionnaires were mailed without an endorsement, in deference to rivalry between independent trucker associations and the impossibility of determining the proper affiliation of the questionnaire recipient.

A total of 636 carriers responded, which represented 41,726 truck tractors, 78,227 trailers, and nearly 2.7 billion annual vehicle miles of travel—approximately 6 percent of all truck miles. The responses were fairly equally distributed among regulated carriers, private carriers, and owner-operators. Although the questionnaire was distributed throughout the country proportionate to trucker population, the responses were largely from the east and midwest where size and weight restrictions tend to be more restrictive than in western states.

In general, the truckers' questionnaire responses provided the following:

1. Verification of suspected commodity/density relationships.
2. Insights into decision criteria used by carriers of various types in response to nonuniform size and weight laws.
3. The nature and magnitude of by-passing to avoid restrictive limits, in a form usable in the Impact Analysis Model.
4. Indications of the kinds of future vehicle selection decisions that would be made, given specified levels of uniformity.

The questionnaire packages are presented in the remainder of this appendix in the following order:

1. *Detailed Package*
   a. American Trucking Associations letter
   b. Western Highway Institute letter
   c. Private Truck Council letter
   d. Private Carrier Conference letter
   e. Questionnaire
      (1) Part I—General Information
      (2) Part II—Specific Trip Information
2. *Short Form Package*
   a. Instructions
   b. Questionnaire

APPENDIX C

STATE QUESTIONNAIRE

The letter and questionnaire sent to highway officials in the 48 contiguous states and the District of Columbia are presented in this appendix.

Questionnaires were returned by 42 state highway agencies. The responses were tabulated and analyzed. Many of the responses reflected considerable thought and effort, thus providing high quality information. A number of highway agencies expressed their special interests and concerns in covering letters returned with their response. Many enclosures were attached to the questionnaires, including agency position papers, studies on various vehicle configurations, dimensions and/or weights, design manuals, copies of size and weight laws and regulations, and truck distribution and weight studies. A number of states amplified their response to specific questions with detailed narrative. One highway agency graphically depicted the effect on bridges of each of the example vehicles in the questionnaire, and another provided a computer printout of the capability of various bridges to stand up to the same example vehicles.

On the other hand, the responses evidenced a general lack of the right kinds of accident data and uncertainty concerning the impact of larger trucks on state highway systems. Responses to questions concerning which vehicle types would create the greatest highway impacts were very mixed.

Appendix B. Continued

AMERICAN TRUCKING ASSOCIATIONS, INC.

1616 P Street, N.W., Washington, D. C. 20036

INDUSTRY RELATIONS DIVISION
J. R. Halladay,
Managing Director

DEPARTMENT OF INTERSTATE COOPERATION
J. L. Reith,
Director
(202) 797-5401

TO: All Class I and II Motor Carriers

SUBJECT: Effect of different state size and weight laws on truck operations.

DATE: March 4, 1977

As a part of a major study sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, R. J. Hansen Associates is attempting to obtain detailed information from motor carriers on the effect of state size and weight laws. As stated in the research proposal, the object of this size and weight study is to develop information "from all types of truck operations with respect to the actual impacts of differences in state laws and regulations on their operations and decision making". Only you can provide the kind of information needed. We ask your support in filling out the attached questionnaire.

We have met on several occasions with the principal investigators from R. J. Hansen Associates and are convinced that they are making a very serious effort to identify the major problems relating to interstate motor carrier movement resulting from differences in state size and weight laws. With your assistance we believe that this study can identify the real economic costs of some of the barriers to interstate transportation caused by differences in sizes and weights. Further, the study should provide a basis of solid facts on which the State and Federal governments can consider whether further action on size and weight matters is necessary or desirable.

We recognize that the attached questionnaire is extremely detailed and that some carriers will not be able to answer all questions. We urge that you complete as many questions as possible in Part I of the questionnaire and that all carriers complete Part II for at least one trip which was affected by vehicle size and weight regulation or would have been operated differently if some dimension or weight limits were changed.

This study can be a very valuable one to everyone involved in highway freight transportation. It will be valuable, however, only if carriers respond to this questionnaire as fully as possible. Your assistance in this cooperative industry-government research project is vital -- and appreciated.

Sincerely yours,

John L. Reith

John L. Reith

/arg

cc: J. R. Halladay
B. C. Whitlock
Managing Directors

A National Federation Having an Affiliated Association in Each State

WESTERN HIGHWAY INSTITUTE
333 Pine Street
San Francisco, California 94104
Phone 415 986-4069

February 28, 1977

TO: Institute members conducting multistate vehicle operations

SUBJECT: Effect of Non-uniform State Size and Weight Laws

The American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, under the National Cooperative Highway Research Program, is sponsoring a major study to obtain detailed information about the effects of state size and weight laws on truck operations. R. J. Hansen Associates, the research contractor, is in the process of collecting information from all types of truck operations with respect to actual impacts of differences in state laws and regulations on their operations and decision making. Only vehicle operators can provide actual information of this kind.

The Institute staff has conferred with representatives of R. J. Hansen and we believe the findings of their study can be very useful to all those who are involved in interstate truck operation. Institute members can help them determine the actual economic costs incurred by those barriers to interstate transportation created by non-uniform size and weight laws. R. J. Hansen will be developing practical proposals for achieving greater uniformity.

The enclosed questionnaire has been designed by R. J. Hansen to provide a means of recording information about your operations and how they are affected by size and weight laws. Admittedly it is a detailed questionnaire, but we earnestly ask that you take the necessary time to complete both parts of the questionnaire, especially those questions that ask how you might operate differently if some dimension or weight limits were changed.

In soliciting your cooperation we want to emphasize that this important study is sponsored by the people who administer the laws. Consequently it provides an excellent opportunity for the industry to provide the facts. Your assistance in this cooperative industry-government research effort is most needed and appreciated.

Sincerely,

Byron L. Geuy
Executive Director

BLG:cp

PRIVATE TRUCK COUNCIL of AMERICA, Inc.

1101 SEVENTEENTH STREET, N.W., WASHINGTON, D.C. 20036

To: PTCA Members

From: John C. White

Subject: Effect of Non-uniform State Size and Weight Laws on Truck Operations

Date: 26 February 1977

The American Association of State Highway and Transportation Officials is sponsoring a major study to obtain detailed information about the effects of State size and weight laws on truck operations. R. J. Hansen Associates is the research contractor and is in the process of collecting information from all types of truck operations with respect to actual impacts of differences in State laws and regulations on their operations and decision making. Only you can provide this kind of information.

We have met with representatives of R. J. Hansen and are convinced that the findings of their study can be extremely useful to all those who have interstate truck operations. We believe you can help them determine the actual economic costs incurred by those barriers to interstate transportation created by non-uniform size and weight laws. R. J. Hansen will be developing practical proposals for achieving greater uniformity.

The enclosed questionnaire has been designed by R. J. Hansen to provide a means for recording information about your operations and how they are affected by size and weight laws. It is a detailed questionnaire. We acknowledge that fact. However, we urge you to take the time to complete both parts of the questionnaire, especially those questions that ask how you might operate differently if some dimension or weight limits were changed.

Again, this is an important study. It is sponsored by the people who administer the State laws. And, consequently, it is a golden opportunity for us to give them the facts. Your assistance in this cooperative industry-government research effort is vital - and appreciated.

JCW/mj
Enclosure

PRIVATE CARRIER CONFERENCE, INC.

1616 P STREET, N.W., WASHINGTON, D. C. 20036 (202) 797-5404

March 23, 1977

To: Members of the Private Carrier Conference, Inc.

Subject: Effect of Non-uniform State Size and Weight Laws and Private Truck Operations

The American Association of State Highway and Transportation Officials is sponsoring a major study to obtain detailed information about the effects of state size and weight laws on truck operations. R. J. Hansen Associates is the research contractor and is in the process of collecting information from all types of truck operations with respect to actual impacts of differences in state laws and regulations on their operations and decision making. Only you can provide this kind of information.

We have met with respresentatives of R. J. Hansen and are convinced that the findings of their study can be extremely useful to all those who have interstate truck operations. We believe you can help them determine the actual economic costs incurred by those barriers to interstate transportation created by non-uniform size and weight laws. R. J. Hansen will be developing practical proposals for achieving greater uniformity.

The enclosed questionnaire has been designed by R. J. Hansen to provide a means for recording information about your operations and how they are affected by size and weight laws. It is a detailed questionnaire. We acknowledge that fact. However, we urge you to take the time to complete both parts of the questionnaire especially those questions that ask how you might operate differently if some dimension or weight limits were changed.

Again, this is an important study. It is sponsored by the people who administer the state laws. And consequently, it is a golden opportunity for us to give them the facts. Your assistance in this cooperative industry-government research effort is vital -- and appreciated.

Sincerely yours,
PRIVATE CARRIER CONFERENCE, INC.

Vincent L O'Donnell

Vincent L. O'Donnell
Managing Director

A QUESTIONNAIRE FOR INTERSTATE TRUCKERS ABOUT THE EFFECTS OF DIFFERENCES IN TRUCK SIZE, WEIGHT & SPEED LAWS

PART I
GENERAL INFORMATION

TYPE OF OPERATION

1. In how many states do you operate trucks or combination vehicles? ________

2. What is your commercial classification? (check appropriate category(s)).

   Common ________ contract ________ private ________ exempt ________ agricultural co-op ________.

3. What is the primary nature of your business (check only one)

   Trucking company ________ truck owner/operator ________ manufacturer ________ wholesaler ________ retailer ________ railroad line ________ government agency ________

4. What is your average length of haul between two or more states? ________ miles

5. How many trips between two or more states do you average per year? ________ trips.

6. What degree of flexibility do you have in selecting your routes when traveling between two or more states? (check one)

   able to select route in all trips ________
   able to select route in 75% or more of trips ________
   able to select route in 50% or more of trips ________
   able to select route in 25% or more of trips ________
   able to select route on less than 25% of trips ________
   restricted to regular route on all trips ________

7. On what percentage of your trips do you follow the same routes? ________% On what percentage do you follow different routes? ________%

8. What percentage of your trips between two or more states are on the National System of Interstate and Defense Highwa and/or other multi-lane, divided highways? ________%

9. What percentage of your trips between two or more states are linehaul? ________% What percentage are pickup and delivery or peddlerun? ________%

10. Beside each of the major commodities listed below that you haul between two or more states, list the approximate annual tonnage that you haul:

    general freight ________ tons
    household goods ________ tons
    heavy machinery ________ tons
    liquid petroleum products ________ ton
    refrigerated liquid products ________ tons
    refrigerated solid products ________ tons
    dump trucking ________ tons
    agricultural commodities ________ tons
    motor vehicles ________ tons
    armored truck service ________ tons
    building materials ________ tons
    films and associated commodities ________ tons
    forest products ________ tons
    mine ore, not including coal ________ tons
    retail store delivery service ________ tons
    explosives or dangerous articles ________ tons
    specific commodities, not subgrouped ________ tons
    other (describe specific commodity) ________________. ________ tons

11. What is the average density, if you know it, of the commodity(ies) which you carry that you listed above?

    general freight ________ lbs. per cubic foot
    household goods ________ lbs. per cubic foot
    heavy machinery ________ lbs. per cubic foot
    liquid petroleum products ________ lbs. per cubic foot
    refrigerated liquid products ________ lbs. per cubic foot
    refrigerated solid products ________ lbs. per cubic foot
    dump trucking ________ lbs. per cubic foot
    agricultural commodities ________ lbs. per cubic foot
    motor vehicles ________ lbs. per cubic foot
    armored truck service ________ lbs. per cubic foot

building materials __________ lbs. per cubic foot
films and associated commodities __________ lbs. per cubic foot
forest products __________ lbs. per cubic foot
mine ore, not including coal __________ lbs. per cubic foot
retail store delivery service __________ lbs. per cubic foot
explosives or dangerous articles __________ lbs. per cubic foot
specific commodities, not subgrouped __________ lbs. per cubic foot
other (describe specify commodity) ____________________________. __________ lbs. per cubic ft.

FLEET CHARACTERISTICS

12. What is the size of the fleet of vehicles you use in the transportation of goods between two or more states, including all vehicles you own, lease and/or have the use of under contract?

- Number of two axle single unit straight trucks

  a. less than 35' in length ______________
  b. from 35' to 40' in length ______________
  c. greater than 40' but less than 45' in length ______________
  d. 45' or greater in length ___________ (specify length of longest truck ______________ ft.)

- Number of three axle single straight unit trucks

  a. less than 35' in length ______________
  b. from 35' to 40' in length ______________
  c. greater than 40' but less than 45' in length ______________
  d. 45' or greater in length ___________ (specify length of longest truck ______________ ft.)

- Number of two axle tractors ______________

- Number of three axle tractors ______________

- Number of one axle semitrailers

  a. less than 25' in length ______________
  b. from 25' to 27' in length ______________
  c. greater than 27' but less than 30' in length ______________
  d. equal to or greater than 30' but less than 40' in length ________
  e. equal to or greater than 40' but less than 45' in length ________
  f. 45' or greater ___________ (specify length of longest units ______________ ft.)

- Number of two axle semitrailers

  a. less than 25' in length ______________
  b. from 25' to 27' in length ______________
  c. greater than 27' but less than 30' in length ______________
  d. equal to or greater than 30' but less than 40' in length ________
  e. equal to or greater than 40' but less than 45' in length ________
  f. 45' or greater ___________ (specify length of longest units ______________ ft.)

- Number of two axle full trailers

  a. less than 25' in length ______________
  b. from 25' to 27' in length ______________
  c. greater than 27' but less than 30' in length ______________
  d. equal to or greater than 30' but less than 40' in length ________
  e. equal to or greater than 40' but less than 45' in length ________
  f. 45' or greater ___________ (specify length of longest units ______________ ft.)

- Other (specify) ____

13. Which of the following do you use for transporting goods between two or more states? (Please provide your best estimate the mileage driven per year for each possible selection. Write the number 0 beside any combinations you did not use.)

single unit straight truck ______________ miles
tractor semitrailer combination equal to or less than 55' ______________ miles
tractor semitrailer combination greater than 55' ______________ miles
truck towing full trailer ______________ miles
tractor semitrailer towing 2nd trailer (doubles or twins) less than or equal to 65' ______________ miles
tractor semitrailer towing 2nd trailer (doubles or twins) greater than 65' ______________ miles
truck towing two trailers ______________ miles
tractor semitrailer towing 2 trailers (triples) ______________ miles
other ______________ miles (specify combination ____

TERMINALS

14. How many terminals do you own exclusively (including those owned by a parent holding company or a subsidiary)? _____
How many do you own jointly with other trucking operations? _______________ How many do you lease? ____________

15. How many of your terminals are major breakbulk terminals? _______________. Primarily pick up and delivery? _____
Used equally for both breakbulk and pickup and delivery _______________?

16. Are any of your terminals located at intervals designed to allow your drivers to rest after a certain amount of driving time on a line haul ____________.
(yes or no)
If yes, answer the following: a) length of driving time allowed? _______________ hours
b) speed limit upon which terminal location was based? _______________ MPH
c) Number of terminals located on this basis? _______________

INTERMODAL

17. What percent of your trips between two or more states involve any of the following:

a. TOFC (Piggyback Trailers) _______________%
b. COFC (Piggyback Containers) _______________%
c. TOS (Fishyback Trailers) _______________
d. COS (Sea-containers) _______________%
e. Air Freight _______________%

LOADING CHARACTERISTICS

18. Assume that you are operating a 5 axle tractor semitrailer combination 55' long. If maximum weight permitted for this combination is 73,280 lbs., on how many of your trips would your vehicle cube out (to cube out is to be fully loaded with no more loading space before getting to the maximum weight permitted)? (check one)

all trips ___________
more than three quarters (75%) of your trips ___________
more than half of your trips ___________
more than one quarter of your trips ___________
less than one quarter of your trips ___________
none ___________

If the same conditions as above apply, but you are permitted a maximum weight of 80,000 lbs, then on how many of your trips would your vehicle cube out? (check one)

all trips ___________
more than three quarters (75%) of your trips ___________
more than half of your trips ___________
more than one quarter of your trips ___________
less than one quarter of your trips ___________
none ___________

19. Now assume that you are operating a five axle vehicle combination consisting of a tractor semitrailer and trailer (twins or doubles) 65' long and you are permitted to carry 80,000 lbs. On how many of your trips would you now cube out before getting to that maximum weight? (check one)

all trips ___________
more than three quarters (75%) of your trips ___________
more than half of your trips ___________
more than one quarter of your trips ___________
less than one quarter of your trips ___________
none ___________

20. Are the legal vehicle width limitations in some states in which you operate such that they prevent efficient loading of standard dimension containers or articles you normally carry? _______________
(yes or no)
If yes, what is the legal width limitation which you are referring to? _______________ inches.

What are the standard dimensions of the containers or articles? (list the standard dimensions for the three most common size containers or articles which you carry and describe the container or article.

dimension	container or article
_______________	_______________
_______________	_______________
_______________	_______________

DECISIONS BASED ON DIMENSIONS & WEIGHTS

1. What percentage, if any, of your trips between two or more states involve scheduled equipment or load changes enroute solely to meet state laws and regulations on size and weight? ________%

2. List the most restrictive legal size, weight and speed law of any state in which you are now operating (least weight allowed, least length allowed, etc.)

width ________ inches
height ________ feet
single axle weight ________ lbs.
tandem axle weight ________ lbs.
gross vehicle weight ________ lbs.
truck length ________ ft.
semitrailer length ________ ft.
full trailer length ________ ft.
tractor semitrailer length ________ ft.
number of units that can be towed ________
maximum length of vehicle combination ________ ft.
speed ________ MPH

23. The provisions of the Federal-Aid Highway Act of 1956, as amended January, 1975, contain the following maximum size and weight limits:

Width __96"__
single axle weight __20,000 lbs.__
tandem axle weight __34,000 lbs__
gross vehicle weight __80,000 lbs.__
vehicle weight determination formula $w = 500 \left(\frac{LN}{N-1} + 12N + 36\right)$

In addition, the American Association of State Highway and Transportation officials recommends that the following be permit

height __13'6"__
tractor semitrailer length __55'__
tractor semitrailer towing 2nd trailer (twins or doubles) __65'__

Assume that every state in which you travel had the maximum limits listed above. Would you be likely to make any of the following changes? (Answer yes or no)

change routing to add/subtract (circle one) ________ miles per trip
change terminal location ________ (how many ________ and in which state(s)? ________
elimination of terminal(s) ________ (how many? ________ and in which state(s)? ________
add terminal(s) ________ (how many? ________ and in which state(s)? ________
reduce number of breakbulks ________ (how many ________ and in which state(s)? ________
increase number of breakbulks ________ (how many ________ and in which state(s)? ________
reduce no. of breakbulk points ________ (how many? ________ and in which state(s)? ________
increase no. of breakbulk points ________ (how many? ________ and in which state(s)? ________
increase fleet size ________ by ________%
decrease fleet size ________ by ________%
change the equipment you presently use to different types of combinations and sizes ________.
decrease number of trips ________ (by what percent? ________)
increase number of trips ________ (by what percent? ________)
increase hauling in certain states ________ (if so, list the state(s) ________
decrease hauling in certain states ________ (if so, list the state(s) ________
other (specify) ________

24. If you answered in question 23 above that you would change your equipment selection to different combinations and sizes, specify what changes you would make. Change from ________

____

to ________

____

25. Not exceeding the most liberal (heaviest weight, longest length, etc.) law or regulation of any state in which you now oper list the legal sizes, and weights that would permit you to operate most efficiently and economically (include operations allowable under regular, multiple trip permits--not single trip or limited trip permits--for hauling reducible loads. Write the letter "P" beside any limits selected on this basis.)

width ________
height ________
single axle weight ________
tandem axle weight ________
gross vehicle weight ________
truck length ________
semitrailer length ________
full trailer length ________
tractor semitrailer length ________

maximum number of units permitted in vehicle combination (tractor, trailer and semitrailer each considered a separate u
maximum length for combination vehicle __________
speed __________

26. If every state had the same maximum limits as those you listed in your answers to question 25 above, would you be like make any of the following changes? (answer yes or no)

change routing to add/subtract (circle one) __________ miles per trip
change terminal location __________ (how many __________ and in which state(s)? __________
elimination of terminal(s) __________ (how many? __________ and in which state(s)? __________
add terminal(s) __________ (how many? __________ and in which state(s)? __________
reduce number of breakbulks __________ (how many? __________ and in which state(s)? __________
increase number of breakbulks __________ (how many? __________ and in which state(s)? __________
reduce no. of breakbulk points __________ (how many? __________ and in which state(s)? __________
increase no. of breakbulk points __________ (how many? __________ and in which state(s)? __________
increase fleet size __________ by __________%
decrease fleet size __________ by __________%
change the equipment you presently use to different types of combinations and sizes __________.
decrease number of trips __________ (by what percent? __________)
increase number of trips __________ (by what percent? __________)
increase hauling in certain states __________ (if so, list the state(s) __________
decrease hauling in certain states __________ (if so, list the state(s) __________
other (specify) __________

(continue on back)

27. If you answered in question 26 that you would change your equipment type and size, specify what changes you would m
from __________

to __________

28. If the conditions of uniformity you listed above in question 25 could be created, would you change your routing to make (ch appropriate choices)

more __________ or less __________ use of the National System of Interstate & Defense Highways? (by how much? __________%)
more __________ or less __________ use of state primary roads? (by how much __________%)
more __________ or less __________ use of toll roads? (by how much? __________%)

SPEED

29. In the fall of 1973, the maximum legal speed limit was reduced to 55 MPH in every state.

a) Prior to that time, what was the fastest allowable speed for trucks in any of the states in which you do business? __________ MPH and what was the maximum speed that you would travel? __________ MPH
What is the maximum speed that you will travel now? __________ MPH

b) Since the speed limit was reduced to 55 MPH, what changes, if any, have you experienced in any of the categories listed below? (check appropriate column)

	no change	more	less	by how much
av. time of trip				
av. no. of trips per vehicle				
av. amount of maintenance per 100,000 vehicle miles				
no. of accidents per 100,000 miles of travel				
other (specify) __________				
__________				
__________				

c) Based upon your past and present experience, what gas mileage would your equipment average at the following spee

at 55 MPH	at 60 MPH	at 65 MPH	at 70 MPH
__________ MPG	__________ MPG	__________ MPG	__________ MPG

PART II
SPECIFIC TRIP INFORMATION

This section of the questionnaire asks you to describe an actual recent or typical trip between two or more states in which you fe your operation was affected by lack of uniformity in size and weight laws (if you wish to do more than one trip, you may make additional copies of this section of the questionnaire & fill them out). If you employed the leased operators, you may make copies of this portion of the questionnaire and have some of your leased operators fill them out.

1. What was your trip origin? ____________ (city or county) (state)

2. Where did you pickup the cargo?

   factory ______ warehouse ______ dealer ______ pickup/delivery terminal ______
   breakbulk terminal ______ non-industrial site ______ railroad yard ______ dockside ______
   farm, forest or mining site ______ other (specify) ______

3. Through which states did your truck or vehicle combination pass, including the origin and destination states?

   1 ______ 2 ______ 3 ______ 4 ______ 5 ______ 6 ______
   7 ______ 8 ______ 9 ______ 10 ______ 11 ______ 12 ______
   13 ______ 14 ______ 15 ______ 16 ______

4. What were the highway route numbers used by your truck or vehicle combination. Indicate highways of the National Syster of Interstate and Defence Highways by the letter "I" and the highway number, and other highway by the U.S. or state designation and route number. List in sequence.

   1 ______ 2 ______ 3 ______ 4 ______ 5 ______ 6 ______
   7 ______ 8 ______ 9 ______ 10 ______ 11 ______ 12 ______
   13 ______ 14 ______ 15 ______ 16 ______

5. Which of the following commodities were you carrying? (list weight of payload)

   general freight ______ lbs
   household goods ______ lbs
   heavy machinery ______ lbs
   liquid petroleum products ______ lbs
   refrigerated liquid products ______ lbs
   refrigerated solid products ______ lbs
   dump trucking ______ lbs.
   Specify commodity ______
   agricultural commodities ______ lbs
   motor vehicles ______ lbs
   armored truck service ______ lbs
   building materials ______ lbs
   films and associated commodities ______ lbs
   forest products ______
   mine ore, not including coal ______ lbs
   retail store delivery service ______ lbs
   explosives or dangerous articles ______ lbs
   specific commodities, not subgrouped ______ lbs

6. Please list the following in regards to the truck or vehicle combination you were using on this trip:

   type of vehicle or combination (truck, tractor semi-trailer, truck trailer, etc.) ______
   total length of vehicle or combination (ft.) ______
   length of semitrailer(s) (ft.) ______
   length of full trailer(s) (ft.) ______
   width (inches) ______
   height (inches) ______
   single axle weight ______
   tandem axle weight ______
   gross vehicle weight ______

7. Did you stop at any terminals enroute? Yes ______ No ______

8. If yes, how many? ______ (specify locations in trip sequence ______

9. Did you make a scheduled equipment change or load modification enroute? ______

10. If your answer to question 9 is yes, which of the following is the reason for your equipment or load change (check appropri. reason(s))

   state length limit ______
   state gross vehicle weight limit ______
   state single axle limit ______
   state tandem axle limit ______
   state restriction on permissible vehicle combinations ______
   other reason(s) related to differences between states in size and weight limits ______ (if so, specify reason ______
   for reasons not related to differences in size and weight laws and regulations ______. (if so, specify reasons ______

11. If your answer to Question 9 is yes and your reasons for changing equipment or load were related to differences in state laws and regulations on sizes and weights, specify what equipment you changed to and where?

type of vehicle or combination ____________
total length of vehicle or combination ____________
length of semitrailer(s) ____________
length of trailer(s) ____________
width ____________
height ____________
single axle weight ____________
tandem axle weight ____________
gross vehicle weight ____________
where did change take place? ____________________________
(city or county) (state)

(if there was more than one scheduled change on the same trip, please check box and repeat information asked in this question for the other change(s) on the reverse side) ☐

12. What was your final destination ______________________________
(city or county) (state)

13. Where did you deliver the cargo?

Fatory ________ warehouse ________ dealer ________ pickup/delivery terminal ________
breakbulk terminal ________ non-industrial site ________ railroad yard ________ dockside ________
farm, forest or mining site ________ other ________

14. Who owns the tractor? Operator ________, leasing company ________, trucking company ________, private manufacturer, wholesaler or retailer ________, other ________.

15. Who owns the trailer(s)? Operator ________, leasing company ________, trucking company ________, private manufacturer, wholesaler or retrailer ________, other ________.

16. If all states had exactly the same size, weight and speed laws,would you have taken the same routes? ____________
(yes or no)

17. If your answer to question 16 is "no", specify the routes you would have taken if all size and weight laws were the same.

________ ________ ________ ________ ________ ________ ________ ________
________ ________ ________ ________ ________ ________ ________ ________

Would this result in less mileage ____________ (if yes, how much ____________)
(yes or no)

18. Assume that the most liberal law or regulation (heaviest weight, longest length, etc.) of any state on the logical routing this trip was applied to all of the states along the trip route. Which, if any, of the following changes would you be likely to make:

Vehicle combination (tractor semi-trailer, tractor semi-trailer and full trailer, etc.) from ____________ to ____________
total vehicle combination length from ____________ (ft.) to ____________ (ft.)
length of semitrailer(s) from ____________(ft.) to ____________ (ft.)
length of full trailer(s) from ____________ (ft.) to ____________ (ft.)
width from ________ (inches) to ________ (inches)
height from ________ (inches) to ________ (inches)
single axle weight from ________ lbs to ________ lbs
tandem axle weight from ________ lbs to ________ lbs
gross vehicle weight from ________ lbs to ________ lbs
other ____

19. If your answers to the above questions show that you made equipment or load changes because of non-uniformity in state laws and regulations on sizes and weights, and/or that you would have made different route selections, by what percent if any, would the total cost of the trip be reduced under circumstances of uniformity?

reduce fuel cost by ________%
reduce driver cost by ________%
reduce terminal costs by ________%

Other costs reductions (specify below)
a) ____________________ by ________%
specify
b) ____________________ by ________%
specify
c) ____________________ by ________%
specify

total trip cost decreased by ____________%

20. Assume the most liberal law or regulation of any state on the logical routing for this trip was applied to all the states on the trip route. How much more weight, if any, would you have carried? ____________ lbs. If you charge a shipper specific rates for carrying that shippers commodity, would you have charged a lower rate per pound for carrying a greater weight of payload? (answer yes or no) ________. By what percentage would the rate differ? ________%.

21. How many trips do you make along this route per year? ______________

Thank you for answering this questionnaire. If your company has analyzed average operating costs on a per mile or per ton-mile basis for different sizes of equipment and different weights of payload which may reflect advantages or disadvantages to be gained through more uniformity in sizes and weight laws and regulations in the states in which you operate, we would appreciate receiving specific data from you as a supplement to this questionnaire.

CHECK BOX IF YOU WOULD LIKE A SUMMARY OF THE RESULTS OF THIS QUESTIONNAIRE and give us your name and address ☐

____
company

____
street or box no.

____
city or town, state and zip code

____
attention of

____
position

R. J. Hansen Associates, Inc.

MANAGEMENT AND INFORMATION SYSTEMS CONSULTANTS

6110 EXECUTIVE BLVD., SUITE 200
ROCKVILLE, MARYLAND 20852
Telephone (301) 468-1330

A QUESTIONNAIRE
ABOUT THE EFFECTS OF DIFFERENCES IN
TRUCK SIZE, WEIGHT & SPEED LAWS

IF UNIFORMITY IN STATE LAWS AND REGULATIONS ON TRUCK SIZES AND WEIGHTS IS IMPORTANT TO YOU, THEN YOU ARE URGED TO ANSWER THIS QUESTIONNAIRE.

As you know, each and every state has its own laws and regulations for maximum allowable truck sizes and weights, and these may vary greatly from state to state. This questionnaire asks for information from you which will present the facts necessary to determine how you are actually affected by these differences in size, weight and speed laws.

This research is being sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, under the National Cooperative Highway Research Program.

THE CONCLUSIONS WHICH WILL BE REACHED AS A RESULT OF THIS STUDY DEPEND UPON YOUR RESPONSE TO THIS QUESTIONNAIRE. ONLY YOU CAN PROVIDE THE KIND OF INFORMATION NEEDED. WE NEED YOUR HELP. We honestly believe your response will make a significant contribution towards greater uniformity.

If you would like to receive a summary of the response to this questionnaire, check the box on the last page.

PLEASE ANSWER THE QUESTIONNAIRE PROMPTLY AND RETURN IT IN THE ENCLOSED ENVELOPE. NO POSTAGE IS NECESSARY.

TRUCKER'S QUESTIONNAIRE ON SIZE, WEIGHT & SPEED LAWS

1. Are you an owner-operator? ______________ (answer yes or no) If you answered no, how would you describe your operation? ______________________________

2. Which of the following would best describe your classification? (check one)

   You haul exempt commodities __________ You are under lease to a certified carrier __________
   Other __________
   If you checked "other", what is your classification? ____________________

3. In how many states do you operate trucks? __________

4. What would you estimate is your average length of haul? __________ miles

Think of a recent trip which you have taken in which the states through which you traveled or wanted to travel had different size and/or weight laws. Describe that trip by answering the following questions:

5. Where did your trip start? ____________ (City or county) ______________ (State)

6. Where did you pick up the cargo? (for example, from a factory? warehouse? farm site? etc.) __________ (Where)

7. What were you carrying? ______________ (type of cargo)

8. Where did you have to take the load? ______________ (City or county) ______________ (State)

9. List the states you went through to get to your deliver points ______________________________
   ____
   ____

10. List the numbers of the highway routes you traveled on. Identify whether they were highways of the National System of Interstate and Defense Highways by the letter "I" and the route number or other highways by the "U.S." or state letters and route number. (for example, I-80 or U.S. 73, etc.) ______________________________
    ____
    ____

11. What were you driving? (truck, tractor semitrailer, doubles, etc.) ______________________ (describe vehicle)
    and list the following in regards to it: (if pulling more than one semitrailer or trailer, list length for each)

    length of truck or overall vehicle combination __________ ft.
    length of tractor wheel base __________ inches
    length of semitrailer(s) __________ ft.
    length of full trailer(s) __________ ft.
    width __________ ft.
    height __________ ft.

12. Which of the following best describes how you were loaded? (check one)

    Fully loaded with no more room to load more cargo __________
    Loaded to maximum weight allowed by law __________
    Both of the above __________
    None of the above __________

13. How much weight were you carrying on each of the following?

    Steering axle __________ lbs.
    Other single axle __________ lbs. (if more than one, list weights for each additional single axle here __________ lbs. __________ lbs.)
    Tandem axle __________ lbs. (if more than one, list weights for each additional tandem axle here __________ lbs.)
    Gross weight __________ lbs.

(over)

14. List below in the left hand column the smallest of any legal maximum size, weight or speed limit among the states in which you traveled on this trip. List the largest in the right hand column. Leave those blank which you do not know. (For example, if the smallest maximum amount you were allowed to weigh by any of the states on your trip was 73,280 lbs. and the largest maximum amount allowed by any of the other states on your trip was 80,000 lbs, enter 73,280 lbs in the left hand column and 80,000 lbs in the right hand column).

<u>Smallest Maximum Limits Allowed</u>

truck length __________ ft.
tractor semitrailer length __________ ft.
semitrailer or trailer length __________ ft.
length for other vehicle combinations (doubles, etc.) __________ ft.
height __________ ft.
width __________ ft.
single axle weight __________ lbs.
tandem axle weight __________ lbs.
gross vehicle weight loaded __________ lbs.
doubles allowed? __________ (yes or no)
triples allowed? __________ (yes or no)
speed __________ mph

<u>Largest Maximum Limits Allowed</u>

truck length __________ ft.
tractor semitrailer length __________ ft.
semitrailer or trailer length __________ ft.
length for other vehicle combinations (doubles, etc.) __________ ft.
height __________ ft.
width __________ ft.
single axle weight __________ lbs.
tandem axle weight __________ lbs.
gross vehicle weight loaded __________ lbs.
doubles allowed? __________ (yes or no)
triples allowed? __________ (yes or no)
speed __________ mph

If all of the states had the same limits as those you listed in the right hand column--"Largest Limits Allowed"--of question 14, would you have made any of the following changes on this trip?

15. Would you have taken a different route? __________ (yes or no) If yes, list the new route numbers ______________

____

____

How many miles would this have saved? __________ miles. How many gallons of fuel? __________ gallons. What different states, if any, would you have traveled through? ______________________

16. Would you have carried more weight? __________ (yes or no) If yes, how much more weight would you have carried before reaching the maximum legal weight or being loaded to capacity? __________ lbs. How much more would this have meant in revenue to you? __________

17. How many trips the same as this one do you make per year? __________

18. If all of the states that you travel in now changed to the same limits that you listed in the right hand column--"Largest Limits Allowed"--in question 14, when it comes time to replace your equipment would you stay with the same size equipment that you have now? __________ (yes or no)

If you answered no, describe what changes would you make? ______________________

____

____

19. In the fall of 1973, the speed limit was reduced to 55 MPH. Before that time, what was the average speed that you traveled? __________ MPH. What is the average speed that you travel now? __________ MPH.

20. Would you like to have the speed limit changed from 55 MPH to some other speed? __________ (yes or no). If yes, to what speed limit? __________ MPH. How would this help you? ______________________

____

____

Thank you for answering this questionnaire. If you would like us to send you back a summary of everyone's response to this questionnaire, check this box . . . . ☐ and give us your name and address below.

____

____

____

Appendix C. Continued

May 27, 1977

Mr.
Highway Director
State of Highway Department

Re: NCHRP 20-16, FY '77
State Laws and Regulations on Truck Size, Weight and Speed

Dear Mr.

We are currently engaged in a study which is sponsored by the American Association of State Highway and Transportation officials, in cooperation with the Federal Highway Administration, under the National Cooperative Highway Research Program. The objectives of the study are to:

- Identify and describe the effects of current state size, weight, and speed laws, regulations, and interstate agreements on trucks and the highway systems they use.

- Investigate the potential benefits and disadvantages of increased uniformity in truck size, weight, and speed limits among states.

- List and evaluate the available alternatives for eliminating or minimizing the differences in truck size, weight, and speed limits among states.

The enclosed questionnaire was designed to obtain certain basic information relative to size, weight and speed restrictions in your state and to obtain your estimate of the effects of different levels of size and weight limits. Some of the questions ask you to make some basic assumptions and provide us with rough calculations in the event you have not yet conducted studies in those areas. Where possible, we ask that you respond to those questions if you have the base information and can do so without the expenditure of a great deal of effort. Your answers will help us to satisfy the objectives listed above.

We have also sent questionnaires to 7,500 truckers throughout the country to obtain information pertinent to the objectives.

Mr.
May 27, 1977
Page 2

Your response is essential if impacts arising from non-uniformity are to be clearly defined and feasible solutions developed.

Although space has not been provided, please feel free to include a discussion of any current situations related to non-uniformity in size and weight laws and regulations which are causing you problems or increasing your costs of administration and which may not otherwise be covered in your answers to the questionnaire.

We will appreciate receiving your response by July 1, 1977. If you have any questions, please feel free to call us at 301-468-1330.

Sincerely,

Ralph D. Johnson
Principal

RDJ/dkt

Enclosure

A QUESTIONNAIRE TO STATE HIGHWAY AND REGULATORY AUTHORITIES CONCERNING SIZES, WEIGHTS AND SPEEDS OF COMMERCIAL MOTOR VEHICLES

I. BASIC DOCUMENTS

In addition to answering the questions on the ensuing pages, please provide us with one copy of each of the following documents:

a. Your state's laws governing truck sizes, weights and speeds.

b. Any regulations on size, weight and speed promulgated under administrative authority granted by your legislature or constitution (except for regulations concerning single trip special permit operations, which are not an issue of consideration in this project).

c. State highway system maps or listings showing sections or locations on the system that are restricted to or designated for specific size or weight limits.

d. Any historical trends in 18 kip equivalent axle loadings or other measures of vehicle weight loading on highways, average daily truck traffic (ADTT) and other related data.

e. Your procedures for designing rigid and flexible pavements.

f. Variances from AASHTO standard bridge design procedures.

II. LEGAL LIMITS

1. Please indicate the maximum vehicle size, weight and speed limits established on the various highway systems in your state by law or regulation. Write the letter "R" beside any limit which is established by regulation. Where applicable, include limits for operations allowed under regular multiple trip permits FN/ available to carriers of all types of commodities and write the letter "P" beside any such limit. If limits are the same on all systems, fill in only the FAI column. Where limits are not specified in your laws and regulations, insert the letters "NS".

Dimensions	(FAI) Interstate System	Other (Please specify) ______	Other (Please specify ______
width (inches)	______	______	______
height (inches)	______	______	______
single unit truck length (ft.)	______	______	______
tractor semi-trailer length (ft.)	______	______	______
semi-trailer length (ft.)	______	______	______
full trailer length (ft.)	______	______	______
length of other combinations (ft.)	______	______	______
number of units permitted in a vehicle combination **	______	______	______

** Please count the tractor as a single unit and each trailer or semi-trailer as a separate unit. If fifth wheel converter dollies are specifically considered to be separate units in your state, please so indicate by checking this box ☐

Weights

Maximum number of axles			
lb.s per inch of tire width			
steering axle weight			
other single axle weight			
% legal tolerance on single axle			
tandem axle weight (lbs)			
% legal tolerance on tandem axles			
minimum tandem axle spacing (inch)			
maximum gross vehicle weight (lbs.)			
% legal tolerance on gross weight			
minimum % of gross weight on a single axle			

Truck Speed Limits	(FAI) Interstate System	Other (Please specify)	Other (Please specify)
Day (in mph)			
Night (in mph)			

FN/ Regular multiple trip permits refer to those applicable generally to interstate movements which serve to practically increase size and weight limits for common vehicle movements--not those specifically accommodating one industry.

2. Gross vehicle weights (loaded) are determined in different ways, including the following methods:

   a. by Bridge Formula B--$W = 500 \left(\frac{LN}{N-1} + 12N + 36\right)$--or by a table based on this formula

   b. by a formula other than Bridge Formula B

   c. by a table other than one based on Bridge Formula B

   d. by specified maximums for specific vehicles or vehicle combinations, and

   e. by tire wheel or axle limits up to a specified maximum.

   Please indicate which of these methods or which combination of methods are used in your state by listing the corresponding letter or letters (a thru e) for your:

   FAI Interstate System ______________________

   State Primary System ______________________

   Other Systems ______________________ ______________________ (specify system)

3. If there are exceptions in your truck size and weight laws or regulations, which significantly affect the interstate movement of commodities by truck, please describe the nature of the exception and/or indicate the section(s) of your laws or regulations where the exceptions may be found ______________________

4. Is there legislation pending that could change your truck size & weight limits? If yes, please describe the nature of the change, the position of your agency toward the bill, and the probability of passage. If any documents in support of your agency's position have been developed, please attach a copy.

____

III. BRIDGES

1. Please provide the following data concerning bridges on your state highway systems.

	FAI System	State Primary System	Other State Systems	Toll Authorities
Design designation (H or HS loading)	______	______	______	______
Number of bridges	______	______	______	______
Percent evaluated for load capability *	______	______	______	______
Number posted	______	______	______	______
At what percent of yield stress?	______	______	______	______
Lowest posted limits (tons)	______	______	______	______
Number posted at lowest limits	______	______	______	______

* This means an actual analysis of the ability of the bridge structural members to sustain particular loads based on surveys of bridge structural characteristics and conditions--AASHTO or equivalent methods.

2. Can you cite any bridge failures attributable to continuous overstressing of an FAI or State Primary bridge? ______ If so, please give details.
____
____
____
____

3. Can you cite any bridge failures attributable to overstressing of local system roads by interstate trucks? ______ If so, please give details.
____
____
____
____

IV. PAVEMENT DESIGN

1. Please show by appropriate letter the basic nature of your pavement design procedures for flexible and rigid pavements as follows: A--Based on 18 kip equivalent axle loads (including Design Numbers and similar procedures); B--Based on other axle or wheel loadings (Describe ______________________________________); C--Based on standardized designs related to functional classification or traffic volume groups; D--other (please specify ____________________).

	Design Procedure	Maximum Anticipated Axle Load *
Flexible pavement	______	______
Rigid Pavement	______	______

* used in your design formula.

2. If heavier axle loads were permitted on your systems without increase in the total annual loading in terms of the number of 18 Kip equivalent axle load repetitions, would you change your design procedure to account for the heavier axle load? If yes, explain why ______
____
____
____

V. ACCIDENT EXPERIENCE

1. Please provide the accident data requested below, if it is readily available, for the most current year possible (indicate which year ______). If it is obtainable from your record but would require special programming, please indicate so with a "Y" in the appropriate blanks.

RURAL ACCIDENTS

Type of Vehicle Accident	Vehicle* Miles	Fatal Accidents	Non-fatal Injury Accidents	Property Damage on Accidents
All accidents				
One vehicle only				
One truck only **				
One auto only				
Truck auto collision **				
Involving semi-trailer combination(s)				
Involving Truck and Trailer Combination(s)				
Involving twin-trailer combination(s)				
Involving triple-trailer combination(s)				
Involving semi-trailer(s) on dry pavement				
Involving twin-trailer(s) on dry pavement				
Involving semi-trailer(s) on dry FAI pavement				
Involving twin-trailer(s) on dry FAI pavement				

URBAN ACCIDENTS

All accidents				
One vehicle only				
One truck only				
One auto only				
Truck auto collision				
Involving semi-trailer combination(s)				
Involving Truck and Trailer Combinations				
Involving twin-trailer combination(s)				
Involving triple-trailer combination(s)				
Involving semi-trailer(s) on dry pavement				
Involving twin-trailer(s) on dry pavement				
Involving semi-trailer(s) on dry FAI pavemant				
Involving twin -trailer(s) on dry FAI pavement				

* Vehicle mile base for which accidents are reported.

** Trucks are those vehicles having an empty weight of 10,000 lbs or more.

VI. IMPACTS OF VARIOUS LEVELS OF UNIFORMITY

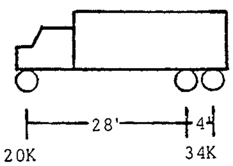
Three levels of dimension and weight limits are presented on the ensuing pages. For each level, assume that it was adopted as the desired level of national uniformity and estimate the impacts to your Interstate and State Primary systems by answering the set of questions accompanying each level.

CASE A

The following maximums are permitted in case A:

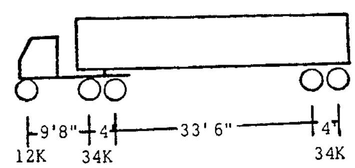
width 96"
height 13' 6"
length of tractor-semitrailer (trailer 45') 55'
length of tractor-semitrailer towing 2nd trailer (doubles or twins) 65'
single axle weight 20,000 lbs
tandem axle weight 34,000 lbs
gross vehicle weight 80,000 lbs
weight determination formula $W = 500 \left(\frac{LN}{N-1} + 12N + 36\right)$

Vehicle #1



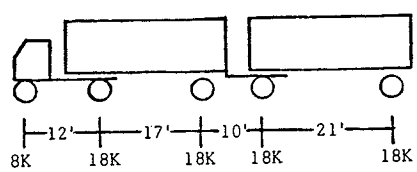
GVW = 54K
Length = 37'

Vehicle #2



GVW = 80K
Length = 55'

Vehicle #3



GVW = 80K
Length = 65'

1. Estimate the miles and % of your state's FAI system pavement structure that would immediately require strengthening outside of your present program as follows:

   Overlay: _______ miles; _______% of system; $ _______ estimated cost
   Reconstruction:_______ miles; _______% of system; $ _______ estimated cost

   (An overlay is an added increment of surface material, regardless of thickness, without major reprocessing of underlying courses. Reconstruction includes major processing or reprocessing of surface and base materials.)

2. Estimate the miles and % of your state's primary system pavement structure that would immediately require strengthening outside of your present program as follows:

   Overlay: ________miles; _______% of system; $_______ estimated cost
   Reconstruction:________miles; _______% of system; $_______ estimated cost

   (Use same definitions for overlay and reconstruction as in preceding question.)

3. Of the three vehicles diagramed, list the relative responsibility attributable to each for the need to strengthen the pavement systems:

	Vehicle Number
most responsible	________
2nd most responsible	________
least responsible	________

4. Do the above estimates represent (a) rough calculations <u>or</u> (b) the results of recent studies of increased sizes and weights? _______ Please attach copies of calculations or studies.

5. Estimate the number of bridges requiring strengthening or replacement on:

   The FAI System ______ strengthened ______replaced _________est. cost
   State Primary System______ strengthened ______replaced _________est. cost

6. List the relative responsibility attributable to each of the three vehicles diagramed for the need to strengthen the bridges:

	Vehicle Number
most responsible	________
2nd most responsible	________
least responsible	________

7. Do the above estimates represent (a) rough estimates or (b) the results of recent studies of increased sizes and weights? ________ Please attach copies of calculations or studies.

8. With respect to the geometric design of your FAI system, indicate whether or not it will readily accommodate the vehicles diagrammed:

Vehicle	System will Accommodate Readily	Moderate System Changes Required	Extensive System Changes * Required
1			
2			
3			

* Extensive costs to improve geometrics such as ramps, curves and gradients. For entries in this column describe briefly the type of changes which would be required on your system ____________
____
____

9. Please indicate whether or not your State Primary System will readily accommodate the vehicles diagrammed:

Vehicle	System will Accommodate Readily		Moderate System Changes Required		Extensive * System Changes Required	
	4 lane	2 lane	4 lane	2 lane	4 lane	2 lane
1						
2						
3						

* Extensive costs to improve geometrics such as ramps, curves and gradients. For entries in this column describe briefly the type of changes which would be required on your system ____________
____
____

10. Estimate the number and % increase or decrease in truck accidents assuming your states laws are changed to permit the vehicles diagrammed. (Indicate increase with a plus sign, decrease with a minus sign.) If vehicles diagrammed are presently permitted, leave answer blank.

	Change in truck accidents on:			
	FAI		State Primary	
	No.	% change	No.	% change
Truck Only				
Other Vehicle Involved				

(If there is no available basis for these estimates, skip this question.)

11. Which of the vehicles diagramed, in your estimation, would be most responsible for any increase in the number of accidents on:

a. the FAI system? (indicate vehicle diagram number) ________
The least? ________

b. the State Primary system? (indicate vehicle diagram number) _____
The least? ________

12. Please enclose or briefly discuss any studies which have a bearing on your responses in connection with accidents. ____________
____
____
____

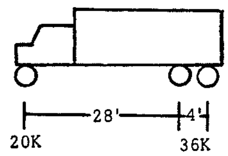
CASE B

The following maximums are permitted in Case B:

width* 96"
height 13'6"
length of tractor-semitrailer (trailer 45') 60'
length of tractor-semitrailer towing 2nd trailer (doubles or twins)* 65'
length of tractor-semitrailer towing 2 additional trailers (triples) 98'
single axle weight * 20,000 lbs
tandem axle weight 36,000 lbs
gross vehicle weight 95,000 lbs
weight determination formula $W = 500\left(\frac{LN}{N-1} + 12N + 36\right)$

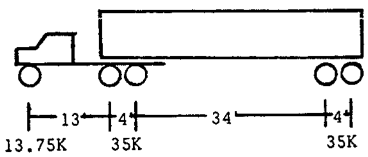
* Same as in previous case.

Vehicle #1



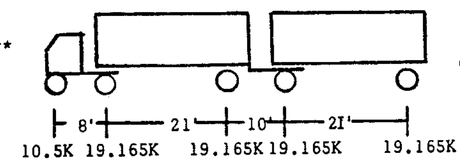
GVW = 56K
Length = 37'

Vehicle #2 **



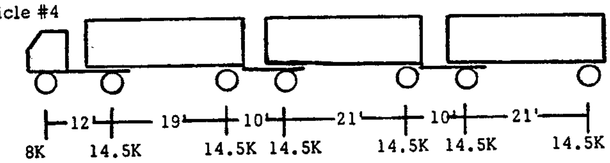
GVW = 83.75K
Length = 60'

Vehicle #3 **



GVW = 87.16K
Length = 65'

Vehicle #4



GVW = 95K
Length = 98'

** weights limited by bridge formula as applied to consecutive axles

13. Estimate the miles and % of your State's FAI system pavement structure that would immediately require strengthening outside of your present program as follows:

Overlay: ______ miles; ______% of system; $ ______ estimated cost
Reconstruction: ______ miles; ______% of system; $ ______ estimated cost

(An overlay is an added increment of surface material, regardless of thickness, without major reprocessing of underlying courses. Reconstruction includes major processing or reprocessing of surface and base materials.)

14. Estimate the miles and % of your state's primary system pavement structure that would immediately require strengthening outside of your present program as follows:

Overlay: ______ miles; ______ % of system; $______ estimated cost
Reconstruction: ______ miles; ______ % of system; $ ______ estimated cost

(An overlay is an added increment of surface material, regardless of thickness, without major reprocessing of underlying courses. Reconstruction includes major processing or reprocessing of surface and base materials.)

15. Of the four vehicles diagramed, list the relative responsibility attributable to each for the need to strengthen the pavement systems:

	Vehicle number
most responsible	________
2nd most responsible	________
3rd most responsible	________
least responsible	________

16. Do the above estimates represent (a) rough calculations or (b) the results of recent studies of increased sizes and weights? ______ Please attach copies of calculations or studies.

17. Estimate the number of bridges requiring strengthening on:

The FAI System ________ strengthened ________ replaced ________ est. cost
State Primary System ________ strengthened ________ replaced ________ est. cost

18. List the relative responsibility attributable to each of the four vehicles diagramed for the need to strengthen the bridges:

	Vehicle number
most responsible	________
2nd most responsible	________
3rd most responsible	________
least responsible	________

19. Do the above estim tes represent (a) rough estimates or (b) the results of recent studies of increased sizes and weights? ______ Please attach copies of calculations or studies.

20. With respect to the geometric design of your FAI system, indicate whether or not it will readily accommodate the vehicle diagrammed:

Vehicle	System will Accommodate Readily	Moderate System Changes Required	Extensive * System Changes Required
1			
2			
3			
4			

* Extensive costs to improve geometrics such as ramps, curves and gradients. For entries in this column describe briefly the type of changes which would be required on your system ________________
____
____

21. Please indicate whether or not your State Primary System will readily accommodate the vehicles diagrammed:

Vehicle	System will Accommodate Readily		Moderate System Changes Required		Extensive * System Changes Required	
	4 lane	2 lane	4 lane	2 lane	4 lane	2 lane
1						
2						
3						
4						

* Extensive costs to improve geometrics such as ramps, curves and gradients. For entries in this column describe briefly the type of changes which would be required on your system ________________
____
____

22. Estimate the number and % increase or decrease in truck accidents assuming your states laws are changed to permit the vehicles digramed. (Indicate increase with a plus sign, decrease with a minus sign). If vehicles diagrammed are presently permitted, leave answer blank.

	Change in truck accidents on:			
	FAI		State Primary	
	No.	% change	No.	% change
Truck Only				
Other Vehicle Involved				

(If there is no available basis for these estimates, skip this question.)

23. Which of the vehicles diagramed, in your estimation, would be most responsible for any increase in the number of accidents on:

a. the FAI system? (Indicate vehicle diagram number) ________
The least? ________

b. the State Primary system? (indicate vehicle diagram number) ________
The least? ________

24. Please enclose or briefly discuss any studies which have a bearing on your responses in connection with accidents. ________________
____
____
____

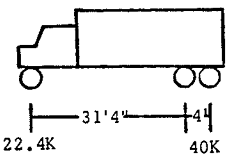
CASE C

The following are permitted in Case C:

width 102"
height * 13'6"
length of tractor-semitrailer (trailer 45') 65'
length of tractor-semitrailer towing 2nd trailer (doubles or twins) 105'
length of tractor-semitrailer towing 2 additional trailers (triples) 105'
single axle weight 22,400 lbs
tandem axle weight 40,000 lbs
gross vehicle weight 105,500 lbs
weight determination formula $W = 500 \left(\frac{LN}{N-1} + 12N + 36\right)$

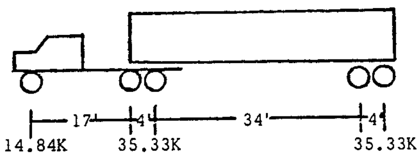
* Same as in previous case

Vehicle #1



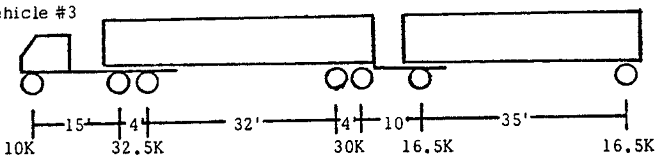
GVW = 62.4K
Length = 40'

Vehicle #2 **



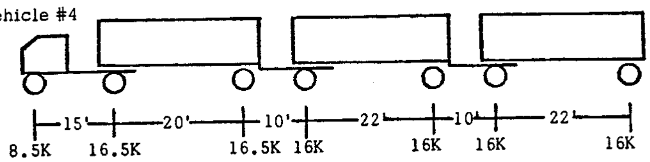
GVW = 85.5K
Length = 65'

Vehicle #3



GVW = 105.5K
Length = 105'

Vehicle #4



GVW = 105.5K
Length = 105'

** weights limited by bridge formula as applied to consecutive axles.

25. Estimate the miles and % of your state's FAI system pavement structure that would immediately require strengthening outside of your present program as follows:

Overlay: ________miles; ________% of system; $________ est. cost
Reconstruction: ________miles; ________% of system; $________ est. cost

(An overlay is an added increment of surface material, regardless of thickness, without major reprocessing of underlying courses. Reconstruction includes major processing or reprocessing of surface and base materials.)

26. Estimate the miles and % of your state's primary system pavement structure that would immediately require strengthening outside of your present program as follows:

Overlay: ________miles; ________% of system; $________ est. cost
Reconstruction: ________miles; ________% of system; $________ est. cost

(An overlay is an added increment of surface material, regardless of thickness, without major reprocessing of underlying courses. Reconstruction includes major processing or reprocessing of surface and base materials.)

27. Of the four vehicles diagramed, list the relative responsibility attributable to each for the need to strengthen the pavement systems:

	Vehicle number
most responsible	________
2nd most responsible	________
3rd most responsible	________
least responsible	________

28. Do the above estimates represent (a) rough calculations <u>or</u> (b) the results of recent studies of increased sizes and weights? ____ Please attach copies of calculations or studies.

29. Estimate the number of bridges requiring strengthening or replacement on:

The FAI System ______strengthened______replaced __________est. cost
State Primary System ______strengthened______replaced __________est. cost

30. List the relative responsibility attributable to each of the four vehicles diagramed for the need to strengthen the bridges?

	Vehicle number
most responsible	________
2nd most responsible	________
3rd most responsible	________
least responsible	________

31. Do the above estimates represent (a) rough estimates or (b) the results of recent studies of increased sizes and weights? ________
Please attach copies of calculations or studies.

32. With respect to the geometric design of your FAI system, indicate whether or not it will readily accommodate the vehicles diagramed:

Vehicle	System will Accommodate Readily	Moderate System Changes Required	Extensive * System Changes Required
1			
2			
3			
4			

* Extensive costs to improve geometrics such as ramps, curves and gradients. For entries in this column describe briefly the type of changes which would be required on your system ____________
____
____

33. Please indicate whether or not your State Primary System will readily accommodate the vehicles diagramed:

Vehicle	System will Accommodate Readily		Moderate System Changes Required		Extensive * System Changes Required	
	4 lane	2 lane	4 lane	2 lane	4 lane	2 lane
1						
2						
3						
4						

* Extensive costs to improve geometrics such as ramps, curves and gradients. For entries in this column describe briefly the type of changes which would be required on your system ____________
____
____

34. Estimate the number and % increase or decrease in truck accidents assuming your states laws are changed to permit the vehicles diagramed. (Indicate increase with a plus sign, decrease with a minus sign). If vehicles diagramed are presently permitted, leave answer blank.

	Change in truck accidents on:			
	FAI		State Primary	
	No.	% change	No.	% change
Truck Only				
Other Vehicle Involved				

(If there is no available basis for these estimates, skip this question.)

35. Which of the vehicles diagramed, in your estimation, would be most responsible for any increase in the number of accidents on:

a. the FAI system? (indicate vehicle diagram number) __________
The least? ________

b. the State Primary system? (Indicate vehicle diagram number) ______
The least? ________

36. Please enclose or briefly discuss any studies which have a bearing on your responses in connection with accidents. ____________
____
____
____
____

VII. INTERSTATE COOPERATION

1. Does your state have any agreements or pacts with any other state or states specifically concerning:

   - truck dimensions, weights and/or speeds? _______
   - special over-size and/or overweight permits? ______

   If so, please attach copies of the agreement or pact or briefly describe it.
   ___
   ___
   ___

2. Has your state established any exceptions to maximum truck size and weight limits on selected routes or in specified areas in order to facilitate interstate movements between or through yours and neighboring states having higher limits? _______. If so, briefly provide the details. ___
   ___
   ___

3. Does your state periodically or regularly communicate with neighboring states concerning truck size and weight laws and regulations? _______. If so, by what means? ___
   ___
   ___
   ___

4. Has your state participated in any interstate efforts to achieve greater size and weight uniformity? ______ If so, briefly provide the details
   ___
   ___
   ___
   ___

VIII. PERSONNEL ASSIGNMENTS

With the exception of manpower devoted to enforcement of your state size and weight limits, can you identify any time expenditures by personnel of your agency that are solely a result of non-uniformity in truck size and weight limits between your state and other states? ______ If you answered yes, complete the following:

- nature of time expenditure (functions or duties performed) _________
  ___
  ___
- estimated 1976 effort expended ___________ man-months
- estimated 1976 total cost $ ____________

IX. ENFORCEMENT

Please refer this section to the appropriate agency(s)

1. Which of your state agencies are responsible, fully or in part, for enforcing size & weight laws? ___
   ___
   speed laws? ___
   ___

2. Please provide the following in regards to your size and weight operations:

   - number of ports of entry ______ responsible agency(s) _________
     ___
   - number of other permanent scales ______ responsible agency(s)
     ___

3. Are roving patrols with portable scales specializing in size and weight enforcement utilized in your state? _____ If yes, what is the average number of teams assigned? _____, and which is the responsible agency(s)? ___

4. Are off-road safety inspections (associated with Periodic Motor Vehicle Inspection) conducted in your state? ___________

5. Please provide estimates of the man-years and costs during the 1976 fiscal year devoted to enforcement of truck sizes and weights, as follows:

   fixed scale operations--man-years _________; costs $ ________
   roving operations--man-years _________; costs $ ________
   other _______________--man-years _________; costs $_________
   (specify nature)

6. If summary data are available, please provide the data showing number of vehicles weighed, number measured, etc. within the last year or two.

APPENDIX D

COMMODITY FLOW MODEL

THE NETWORK

The commodity flow network consisting of 54 nodes and 154 links is shown on Figure D-1. The nodes are population distribution centroids for the state or, in the case of California, New York, Ohio, Pennsylvania, and Texas, a region of the state. Average trip miles were assumed to be equal to the straight line distance between nodes.

DATA SOURCES

Many potential data sources were investigated and several were used. The Commodity Transportation Survey from the 1972 Census of Transportation was the most complete available data source. It supplied the necessary information for all manufactured or processed commodities. The information was available on magnetic computer tapes. These were obtained from the Bureau of Census.

Supplemental data sources were necessary for movements of unprocessed commodities. Raw agricultural products were among the commodities not covered by the Commodity Transportation Survey. Interviews were conducted with several sections of the U.S. Department of Agriculture and the two main USDA libraries were thoroughly investigated. No one source readily provided the needed data. However, aggregation of several sources provided a good picture of interstate truck movements of raw agricultural products. Movements of fruits and vegetables were obtained through USDA Market News monthly reports entitled "Fresh Fruit and Vegetable Unloads in 41 U.S. Cities," which the Department of Agriculture provided on magnetic computer tape, and which were expanded to the population. The USDA report entitled "Grain Movements between Southern and Cornbelt States" provided the needed data on the great majority of interstate truck movements of all types of grains. Requests for data were made individually to the few substantial grain exporting states not covered by this report. Livestock movements were obtained through the USDA report entitled

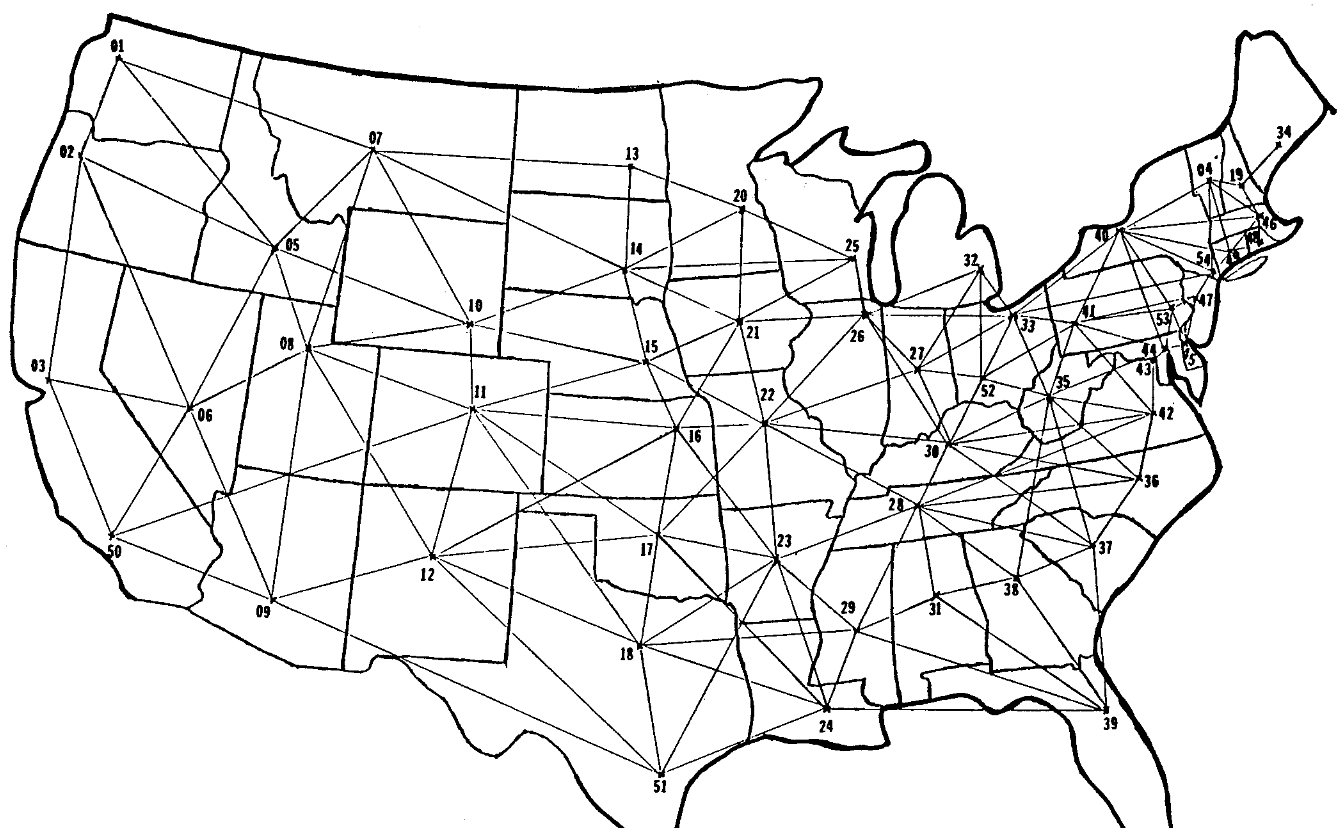


Figure D-1. NCHRP Project 20-16 link network.

"Livestock Trucking Services: Quality, Adequacy and Shipment Patterns," supplemented, where possible, by individual state inshipments/outshipments reports. Interstate cotton movements by truck are available through the USDA report entitled "Domestic Shipments of U.S. Cotton, 1970-71 Season." Use also was made of the USDA annual "Agricultural Statistics," "Crop Production," and "Meat Animal, Farm Production, Disposition & Income" reports.

Other nonprocessed products include raw coal, raw forest products, crude petroleum, metallic ores and nonmetallic minerals. Data on coal movements were available from the U.S. Department of Interior, Bureau of Mines annual publication entitled "Bituminous Coal and Lignite Distribution." Crude petroleum and national gas movements are discussed in the Congressional Research Service report entitled "National Energy Transportation" prepared for the U.S. Senate Committee on Energy and Natural Resources and the Senate Committee on Commerce, Science, and Transportation. In its tracing of petroleum movement by mode of transport, the report states that there is no significant interstate movement by truck (refined petroleum product movements are covered in the Commodity Transportation Survey). Likewise, discussions with the U.S. Forestry Service and other USDA sections did not reveal any significant interstate truck movements of raw forest products (milled products are covered by the Commodity Transportation Survey), and discussions with the Bureau of Mines did not reveal any significant interstate truck movement of raw minerals.

Some data sources were not usable because of difficulty in retrieving data in the proper format and for other reasons. Most notable of these sources were the "Nationwide Truck Commodity Flow Study" (FHWA) data and "Freight Commodity Statistics" (ICC) data. According to FHWA sources, the computer tapes in the NTCF study would be extremely difficult to work with because of poor data processing provided by a private contractor to the FHWA. The published data from that study also were not suitable for our purposes. The ICC study data were rejected because the origin/destination areas were too broad and the commodities surveyed too limited. The study covers commodities carried only by Class I regulated carriers. Further, it publishes data in terms of freight originated and freight terminated within regions without tracing the destinations or origins, respectively, of the movements.

NETWORK BUILDING

Figure D-2 is a flow diagram for the network building and link assignment component. Although the flow chart indicates that numerous programs were required, many of the complicated ones were taken from the Urban Transportation Planning System (UTPS). The Federal Highway Administration Office of Highway Planning, Technical Support Branch, was most helpful in applying the UTPS package to the national network.

Both the Commodity Transportation Survey and the Truck Weight Studies use 5-digit standard commodity codes. In reducing these to one of the 14 Project 20-16 codes, a complete review of the standard codes was made to ensure that each was assigned to a commodity group of like density and loading characteristics. All source tapes were recoded accordingly.

The network consists of 54 nodes—one per state except for California, New York, Ohio, Pennsylvania, and Texas. Each of these last states was divided into two nodes. When the nodes were connected, a total of 154 two-way links was established. The nodes were located as approximate demographic centroids, and link mileages were scaled.

In application, matrices are constructed through the computer programs illustrated in the flow charts. One set of matrices sums the tonnage moved for each commodity from each origin to destination pairing. The second matrix assigns the links to each node-to-node pairing and sums mileage. Adding the matrices together loads the commodity tonnage on the link.

TRUCK TYPE DISTRIBUTION

The flow chart for the component that assigns each truck to a truck type category and commodity type by network link is shown in Figure D-3. In order to accomplish this task it was necessary to recode the truck weight data from FHWA and to select and assign weigh stations to the network links. Some weigh stations were assigned to several links because of a shortage of stations and uniformity among contiguous states covered by the links.

Ten truck types were used in order to represent important differences in vehicle configuration. On the basis of these truck types and the kind of commodity, it was possible later to estimate the number of full trucks. The estimated number of full trucks was needed to determine the potential need for larger trucks.

COMMODITY FLOW DISAGGREGATION

The purpose of this component, as shown in Figure D-4, was to assign the tonnages of each commodity to various types of trucks based on the distributions of truck type and to convert these flows into a baseline estimate of vehicle mileage, 18-kip axle equivalents, and numbers of full trucks. The disaggregation was accomplished with a single FORTRAN program.

OUTPUT

Figure D-5 is a sample of the link output data. A similar table was generated for every link, four regions, and the nation. Links connecting two regions were assigned to both regions. Consequently, if the values from the four regions are totalled, they will exceed the national total.

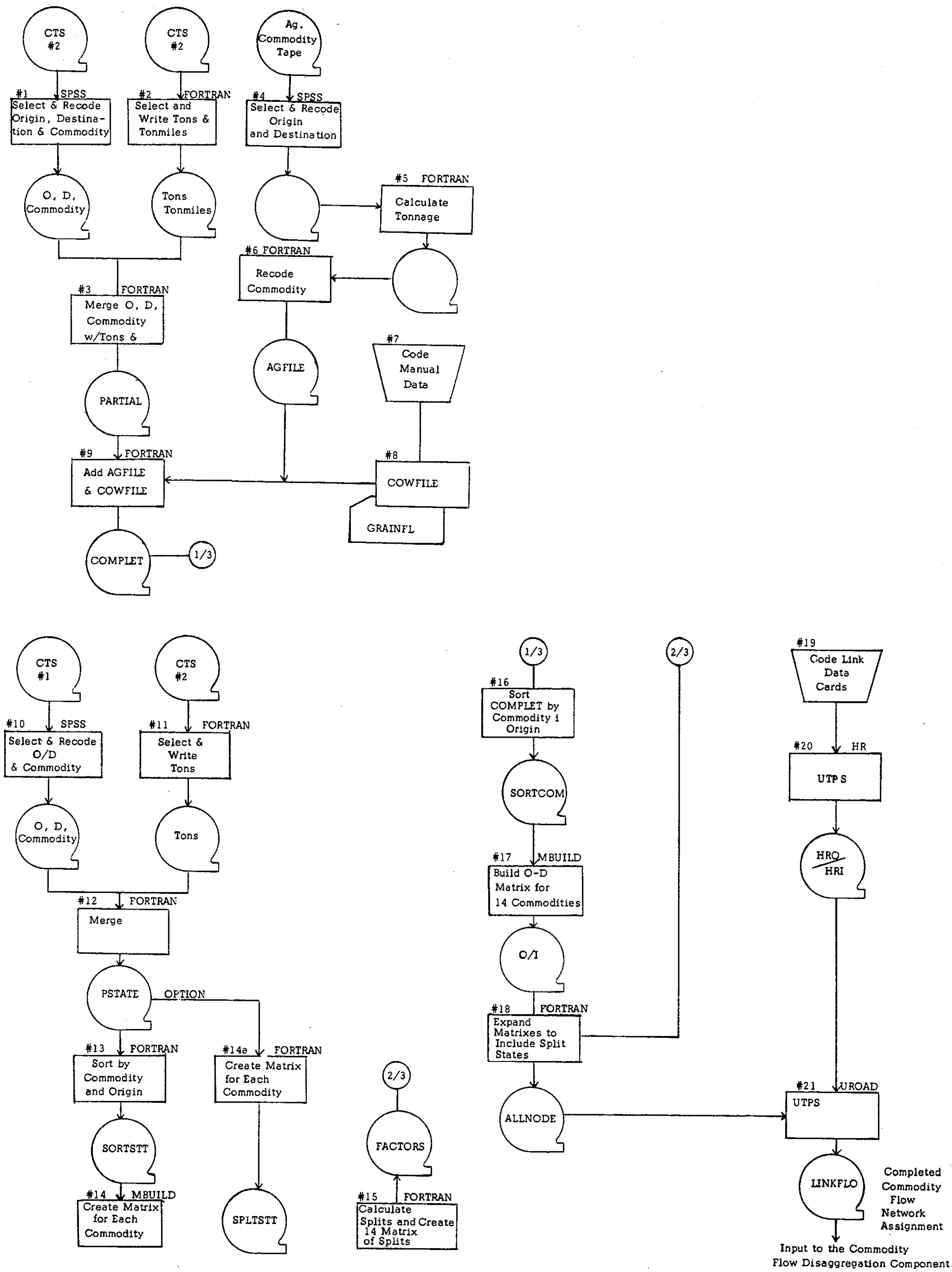


Figure D-2. Uniformity impact analysis model commodity flow network component.

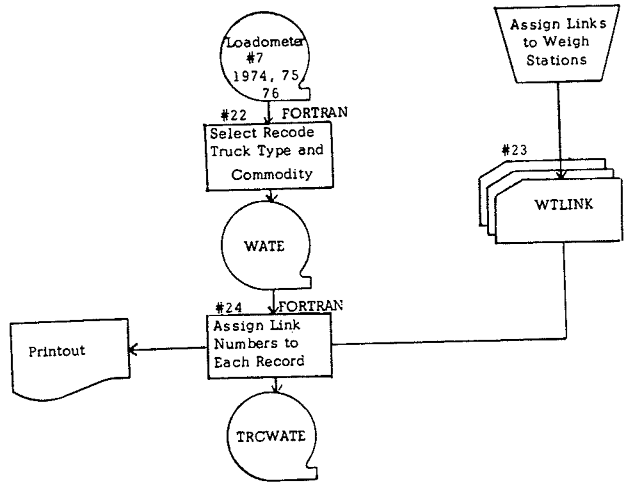


Figure D-3. Truck type distribution component.

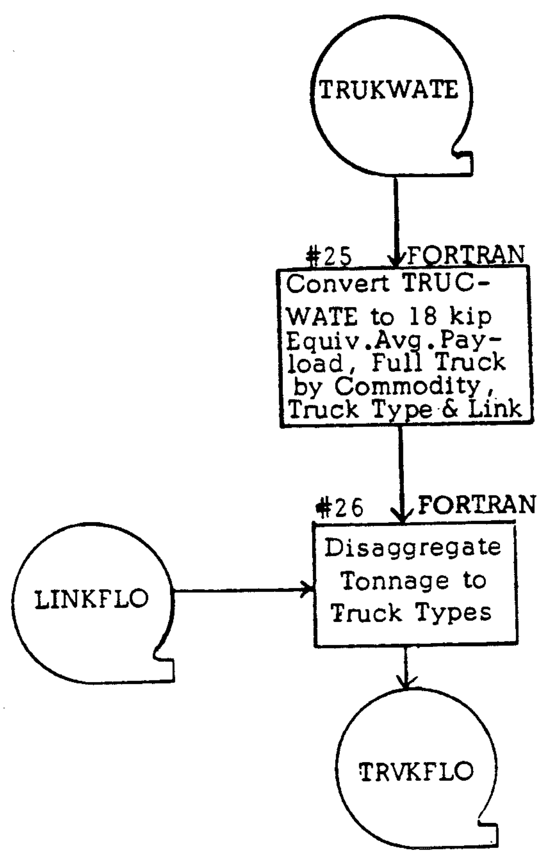


Figure D-4. Commodity flow disaggregation.

Commodity Types 1 - 14

Vehicle Types

TON (10^3)

Vehicle Type	LINK 157													
0	138.7	130.9	68.0	.0	126.6	25.1	53.4	81.8	10.2	72.6	71.9	87.1	192.7	203.7
1	67.7	31.7	36.7	.0	64.3	20.5	40.4	47.3	39.3	83.0	55.8	110.9	150.3	434.1
2	352.3	564.1	686.5	.0	259.8	33.5	96.0	72.1	5.5	92.8	119.5	118.4	603.2	916.8
3	899.9	380.1	999.9	.0	391.7	70.1	.0	112.7	.0	18.6	51.6	18.5	387.6	599.5
4	545.4	156.0	166.3	.0	374.4	38.5	.0	60.3	.0	.0	127.7	284.8	397.3	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	25.8	50.0	.0
6	405.9	24.3	43.6	.0	.0	11.4	35.2	74.2	.0	10.6	16.9	73.5	.0	3610.8
7	36.2	.0	.0	.0	33.5	.0	.0	13.7	.0	.0	.0	.0	.0	60.7
8	643.2	.0	274.0	.0	.0	57.8	.0	36.8	.0	28.4	253.5	2.9	6.9	180.4
9	22.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	129.9

TRIP

Vehicle Type	LINK 157													
0	1398.	1404.	713.	0.	1257.	256.	617.	945.	113.	847.	798.	1196.	1859.	2469.
1	1554.	520.	1188.	0.	943.	341.	926.	675.	564.	1440.	1043.	2116.	2366.	8356.
2	2097.	3275.	4278.	0.	1572.	171.	617.	405.	31.	593.	736.	736.	3380.	5507.
3	4272.	1819.	4753.	0.	1886.	341.	0.	540.	0.	85.	245.	92.	1859.	2849.
4	2330.	676.	713.	0.	1572.	171.	0.	270.	0.	0.	552.	1196.	1690.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	92.	169.	0.
6	2020.	156.	238.	0.	0.	171.	617.	270.	0.	85.	245.	368.	0.	26018.
7	155.	0.	0.	0.	314.	0.	0.	270.	0.	0.	0.	0.	0.	370.
8	3263.	0.	1901.	0.	0.	256.	0.	270.	0.	1610.	1227.	184.	507.	1899.
9	78.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	570.

TMILE (10^3)

Vehicle Type	LINK 157													
0	778.8	781.8	397.2	.0	700.4	142.5	343.8	526.1	62.8	471.9	444.4	666.3	1035.5	1375.2
1	865.4	289.6	661.9	.0	525.3	190.0	515.7	375.8	314.0	802.3	581.1	1178.8	1318.0	4654.4
2	1168.2	1824.2	2382.9	.0	875.5	95.0	343.8	225.5	17.1	330.4	410.2	410.0	1882.8	3067.7
3	2379.8	1013.5	2647.7	.0	1050.5	190.0	.0	300.6	.0	47.2	136.7	51.3	1035.5	1586.7
4	1298.1	376.4	397.2	.0	875.5	95.0	.0	150.3	.0	.0	307.6	666.3	941.4	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	51.3	94.1	.0
6	1125.0	86.9	132.4	.0	.0	95.0	343.8	150.3	.0	47.2	136.7	205.0	.0	14492.1
7	86.5	.0	.0	.0	175.1	.0	.0	150.3	.0	.0	.0	.0	.0	317.3
8	1817.3	.0	1059.1	.0	.0	142.5	.0	150.3	.0	896.7	683.6	102.5	282.4	1057.8
9	43.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	317.3

TNMILE (10^5)

Vehicle Type	LINK 157													
0	77.3	72.9	37.9	.0	70.4	14.0	29.7	45.6	5.7	40.4	40.0	48.5	107.3	113.5
1	37.7	17.6	20.5	.0	35.8	11.4	22.5	26.3	21.9	46.3	31.1	61.8	83.7	241.8
2	196.2	314.2	382.4	.0	144.7	18.7	53.5	40.2	3.1	51.7	66.6	65.9	336.0	310.7
3	501.3	211.7	556.9	.0	218.2	39.0	.0	62.8	.0	10.4	28.7	10.3	215.9	333.9
4	303.8	86.9	92.6	.0	208.5	21.5	.0	33.6	.0	.0	71.1	158.6	221.3	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	14.4	27.9	.0
6	226.1	13.5	24.3	.0	.0	6.4	19.6	41.3	.0	5.9	9.4	41.0	.0	2011.2
7	20.2	.0	.0	.0	18.6	.0	.0	7.6	.0	.0	.0	.0	.0	33.8
8	358.2	.0	152.6	.0	.0	32.2	.0	20.5	.0	15.8	141.2	1.6	3.9	100.5
9	12.6	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	72.4

EQUIVS

Vehicle Type	LINK 157													
0	525.	498.	290.	0.	453.	104.	136.	283.	42.	258.	320.	289.	740.	650.
1	785.	224.	511.	0.	456.	147.	398.	434.	307.	774.	449.	1048.	1271.	3897.
2	2416.	3946.	4516.	0.	1792.	222.	556.	472.	40.	568.	810.	810.	4124.	6248.
3	8118.	3457.	9032.	0.	3584.	648.	0.	1026.	0.	161.	466.	175.	3532.	5413.
4	4956.	1461.	1497.	0.	3301.	358.	0.	567.	0.	0.	1160.	2549.	3684.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	340.	625.	0.
6	5461.	220.	582.	0.	0.	43.	154.	1430.	0.	87.	169.	902.	0.	36655.
7	115.	0.	0.	0.	72.	0.	0.	59.	0.	0.	0.	0.	0.	129.
8	6267.	0.	2531.	0.	0.	580.	0.	313.	0.	179.	2252.	20.	56.	1348.
9	194.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	714.

AVGPLD (10^3)

Vehicle Type	LINK 157													
0	.099	.093	.095	.000	.100	.098	.087	.087	.091	.086	.090	.073	.104	.082
1	.044	.061	.031	.000	.068	.060	.044	.070	.070	.058	.054	.052	.063	.052
2	.168	.172	.160	.195	.165	.196	.156	.178	.178	.156	.162	.161	.178	.166
3	.211	.209	.210	.211	.208	.205	.000	.209	.000	.220	.210	.201	.208	.210
4	.234	.231	.233	.230	.238	.226	.000	.224	.000	.000	.231	.238	.235	.000
5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.280	.296	.000
6	.201	.156	.183	.000	.000	.067	.057	.275	.000	.125	.069	.200	.000	.139
7	.233	.000	.000	.000	.106	.000	.000	.051	.000	.000	.000	.000	.000	.106
8	.197	.000	.144	.043	.000	.226	.000	.136	.000	.018	.207	.016	.014	.095
9	.291	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.228

Figure D-5. Sample of NCHRP project 20-16 link output data.

APPENDIX E

UNIFORMITY IMPACT ANALYSIS PROCEDURE

The projections of future operating costs, fuel consumption, equivalent axle loads, and accidents were predicted on estimates of mileage for various types and weights of trucks. As noted in the body of the report two assumptions were used: (1) the distribution assumption and the full-truck assumption. This appendix presents the calculations used.

DISTRIBUTION METHOD

1. Current operating costs, fuel consumption, and EAL's were developed using the format shown in Table E-1.

   a. Unit operating line-haul vehicle costs (Col. 5 of Table E-1 and Col. 6 of Table E-2) for each type of truck combinations were obtained from the operating cost nomographs (Figs. 10 and 11 in Chapter Two), using average payload as input to the nomographs.

   b. Fuel consumption rates (Col. 8 of Table E-1 and Col. 9 of Table E-2) were determined for each type of truck combination using Figure 16 in Chapter Two, the average gross vehicle weight of the vehicle type, and the per gallon cost of $0.30 (to convert dollars into gallons).

   c. Equivalent axle loads were developed for each truck combination type by assigning 10 or 12 kip (4.5 t or 5.4 t) of the GVW to the steering axle and distributing the remainder evenly to the other sets of axles. The equivalencies were developed using the factors in Table 14 of Chapter Two. These factors were incorporated as a matrix in the commodity flow network programs. The EAL's per trip (Col.

TABLE E-1

TYPICAL CALCULATION TABLE (DISTRIBUTION METHOD—CURRENT)

Commodity ____________

(1) Vehicle Type	(2) Average Payload	(3) Tare Weight	(4) Gross Comb. Wgt.	(5) Vehicle Cost Per Mile	(6) Miles x 1000	(7) Cost x 1000	(8) Fuel Consumption Rate	(9) Fuel Consumption	(10) Trips	(11) EAL's Per Trip	(12) EAL's
	Tons	Tons	Tons	$000		$000	Gal/Mile	Thousand Gal			
0	From	14.75	Col.	From	From	Col.	From	Col.	From	From	Col.
1	Comm.	12.00	(2)	Oper.	Comm.	(5)	Fuel	(8)	Comm.	Comm.	(11)
2	Flow	14.75	Plus	Cost	Flow	times	Consump-	times	Flow	Flow	times
3	Net	14.75	Col.	Nomo-	Net	Col.	tion	Col.	Net	Net	Col.
4	Output	14.75	(3)	graph,	Output	(6)	Curves,	(6)	Output	Output	(10)
5		14.75		Chapter			Chapter				
6		16.25		Two			Two				
7		21.50									
8		15.00									
9		21.50									

Σ Tons = ____________ Σ EALs = ____________

Σ Trips = ____________

Average Link Trip Length = Σ Miles/Σ Trips = Trips

Metric Conversion Factors:
Tons x .907 = Metric Tons
Costs/Mile x .622 = Cost/Km
Miles x 1.609 = Kilometers
Gals/Mile x 2.352 = Liters/Km
Gallons x 3.785 = Liters

11 of Table E-1) were obtained from the output of the commodity flow network (see Fig. D-5). Most tare weights (Col. 3 of Table E-1) were determined from published summaries of loadometer data. Other tare weights were estimated on the basis of tare weights of other vehicles.

2. New distributions of tonnage (Col. 2 of Table E-2) and average payloads (Col. 3 of Table E-2) for the optimal uniformity level were obtained from distributions and payloads experienced on specific links or in regions where limits similar to the optimal uniformity level exist.

3. Operating costs, fuel consumption, and EAL's for the optimal uniformity limits were developed by completing the table in Table E-2.

4. Differences in operating cost, fuel consumption, and EAL's were determined by subtracting the optimal uniformity values from the current values.

5. Percent changes in EAL's relative to the current value were determined.

6. Changes in accident experience were determined by multiplying the accident rate per 1,000,000 veh-mi by the difference in million vehicle miles between the optimal uniformity and current size and weight limits. A conservative accident rate of 2.65 acc./1,000,000 veh-mi (1.65/10^6 km) was used in this study.

FULL-TRUCK METHOD

1. The calculations were basically the same as used in the distribution method, except only selected truck types were used. On the basis of the gross weight, the vehicle type, and the average density of the commodity, each cell of the 10 × 14 matrix shown in Appendix D (Fig. D-5) was tested to determine whether it could represent either cubed-out or weighted-out trucks.

TABLE E-2

TYPICAL CALCULATION TABLE (DISTRIBUTION METHOD—OPTIMAL UNIFORMITY)

Commodity ______________

(1) Vehicle Type	(2) Tonnage Distribution Factor	(3) Average Payload (Tons)	(4) Tonnage	(5) Number of Trips	(6) Vehicle Cost Per Mile	(7) Miles x 1000	(8) Cost	(9) Fuel Consumption Rates	(10) Fuel Consumption	(11) EAL's Per Trip	(12) EAL's
0	From	*	Col.	Col.	From	*	Col.	From	Col.	*	Col.
1	analysis		(2)	(4)	Oper.		(7)	Fuel	(9)		(5)
2	of		Σ tons	divided	Cost		times	Consumption	Times		Times
3	Comm.		from	by	Nomo-		Col.	Curves,	Col.		Col.
4	Flow		Table E-1	Col.	graph,		(6)	Chapter	(7)		(11)
5	Network		for	(3)	Chapter			Two			
6	Output		same		Two						
7			commo-								
8			dity								
9											

* From Commodity Flow Network Output

The following categories were assumed to be full trucks:

a. Vehicle types 3, 4, and 5—tractor-semitrailer combinations with GVW's in excess of 69,000 lb (31.3 t)—carrying commodities with average densities in excess of 15 lb/ft^3 (240 kg/m^3) were considered full in terms of being weighted-out. This included commodities 1, 2, 3, 4, 5, 6, 12, and 13.
b. Vehicle types 2, 3, 4, and 5—tractor-semitrailer combinations with GVW's in excess of 56,000 lb (25.4 t) carrying commodity 7.
c. Vehicle types 3 and 4 carrying commodity type 8.
d. Vehicle types 0, 1, 2, 3, and 4 carrying commodity 9.
e. Vehicle types 2, 3, and 4 carrying commodity 10.
f. Vehicle types 1, 2, 3, 4, and 5 carrying commodity 11.
g. Vehicle types 3, 4, and 5 carrying commodity 14.

Categories b through g were all considered cube-outs. Note that the vehicle type categories used designate gross weight in addition to other truck characteristics.

2. The present cube-out calculations also included a determination of the total cubic feet of cargo. This was based on the calculated cubic footage for each type of van. The average density also was determined.

3. When the cube-out tonnage was assigned to a new vehicle type, the following equation was used to determine the total number of future trips:

$$\text{Future Trips} = \frac{\Sigma \text{ Cube-Out Tonnage}}{\text{Density (Volume of New Vehicle)}} \qquad \text{(E-1)}$$

Multiplying the future trips times the average link trip length provided a new mileage figure from which new costs and fuel consumption were determined.

4. The determination of future changes in cost values due to changes in the truck mix carrying weight-out freight was conducted as shown in Table E-3, except fewer vehicle types were used. The following theoretical full-truck payloads were applied: (a) for 3-S2's—26.5 tons (24.0 t), (b) for 3-4's—30.5 tons (27.7 t), and (c) for turnpike doubles—40.0 tons (36.3 t).

5. Differences between optimal uniformity limits and current limits were determined as in the distribution method.

TABLE E-3

TYPICAL CALCULATIONS

Difference in Mileage	= Current Σ miles - future Σ miles
Difference in Fuel Consumption	= Gallons (current) - Gallons (future)
% Change in EAL's	$= \dfrac{\text{EALs (current) - EALs (future)}}{\text{EALs (current)}}$
Change in Accident Experience	$= \dfrac{\text{Difference in Mileage} \times 2.65}{1{,}000{,}000}$

APPENDIX F

A SAMPLE MULTISTATE AGREEMENT

This appendix contains a copy of a "Multistate Highway Transportation Agreement" currently in effect between the States of Idaho and Oregon.

MULTISTATE HIGHWAY TRANSPORTATION AGREEMENT

Pursuant to and in conformity with the laws of their respective jurisdictions, the participating jurisdictions, acting by and through their officials lawfully authorized to execute this agreement, do mutually agree as follows:

ARTICLE I
Findings and Purposes

SECTION 1. Findings. The participating jurisdictions find that:

(a) The expanding regional economy depends on expanding transportation capacity;

(b) Highway transportation is the major mode for movement of people and goods in the Western states;

(c) Uniform application in the West of more adequate standards will result in a reduction of pollution, congestion, fuel consumption and related transportation costs, and also permit increased productivity;

(d) A number of Western states have already, to the fullest extent possible, adopted substantially the 1964 Bureau of Public Roads recommended vehicle standards;

(e) The 1956 provision of federal law, (23 U.S.C. 127), though long outmoded, remains in effect depriving states of interstate matching money if weights and widths are increased, even though the Interstate System is more than 80 percent complete; and

(f) The participating jurisdictions are most capable of developing vehicle size and weight standards most appropriate for the regional economy and transportation requirements, consistent with and in recognition of principles of highway safety.

SECTION 2. Purposes. The purposes of this agreement are to:

(a) Adhere to the principle that each participating jurisdiction should have the freedom to develop size and weight standards that it determines to be most appropriate to its economy and highway system.

(b) Establish a system authorizing the operation of vehicles traveling between two or more participating jurisdictions at more adequate size and weight standards.

(c) Promote uniformity among participating jurisdictions in vehicle size and weight standards on the basis of the objectives set forth in this agreement.

(d) Secure uniformity insofar as possible, of administrative procedures in the enforcement of recommended size and weight standards.

(e) Provide means for the encouragement and utilization of research which will facilitate the achievement of the foregoing purposes, with due regard for the findings set forth in subdivision (a) of this article.

ARTICLE II
Definitions

SECTION 1. As used in this agreement:

(a) "Designated representative" means a legislator or other person authorized to represent the jurisdiction.

(b) "Jurisdiction" means a State of the United States or the District of Columbia.

(c) "Vehicle" means any vehicle as defined by statute to be subject to size and weight standards which operates in two or more participating jurisdictions.

ARTICLE III
General Provisions

SECTION 1. Qualifications for Membership. Participation in this agreement is open to contiguous jurisdictions which subscribe to the findings, purposes and objectives of this agreement and will seek legislation necessary to accomplish these objectives.

SECTION 2. Cooperation. The participating jurisdictions, working through their designated representatives, shall cooperate and assist each other in the enforcement of this agreement pursuant to appropriate statutory authority.

SECTION 3. Effect of Headings. Article and section headings contained herein shall not be deemed to govern, limit, modify, or in any manner affect the scope, meaning, or intent of the provisions of any article or section hereof.

SECTION 4. Vehicle Laws and Regulations. This agreement shall not authorize the operation of a vehicle in any participating jurisdiction contrary to the laws or regulations thereof.

SECTION 5. Interpretation. The final decision regarding interpretation of questions at issue relating to this agreement shall be reached by unanimous joint action of the participating jurisdictions, acting through the designated representatives. Results of all such actions shall be placed in writing.

SECTION 6. Amendment. This agreement may be amended by unanimous joint action of the participating jurisdictions, acting through the officials thereof authorized to enter into this agreement, subject to the requirements of Section 4, Article III. Any amendment shall be placed in writing and become a part hereof.

SECTION 7. Restrictions, Conditions or Limitations. Any jurisdiction entering this agreement shall provide each other participating jurisdiction with a list of any restriction, condition or limitation on the general terms of this agreement, if any. Such restrictions, conditions or limitations shall become effective upon approval by all other participating jurisdictions.

SECTION 8. Additional Jurisdictions. Additional jurisdictions may become members of this agreement by signing and accepting the terms of the agreement, subject to the acceptance by participating jurisdictions of any restriction, limitation, or condition requested by such additional jurisdiction.

ARTICLE IV
Cooperating Committee

SECTION 1. Pursuant to Section 2, Article III, the designated representatives of the participating jurisdictions shall constitute a committee which shall have the power to:

(a) Collect, correlate, analyze and evaluate information resulting or derivable from research and testing activities in relation to size and weight related matters.

(b) Recommend and encourage the undertaking of research and testing in any aspect of size and weight or related matter when, in their collective judgment, appropriate or sufficient research or testing has not been undertaken.

(c) Recommend changes in law or policy with emphasis on compatibility of laws and uniformity of administrative rules or regulations which would promote effective governmental action or coordination in the field of vehicle size and weight related matters.

SECTION 2. Each participating jurisdiction shall be entitled to one (1) vote only. No action of the committee shall be binding unless a majority of the total number of votes cast by participating jurisdictions are in favor thereof.

SECTION 3. The committee shall meet at least once annually and shall elect, from among its members, a chairman, a vice-chairman and a secretary.

SECTION 4. The committee shall submit annually to the legislature of each participating jurisdiction, no later than November 1, a report setting forth the work of the committee during the preceding year and including recommendations developed by the committee. The committee may submit such additional reports as it deems appropriate or desirable. Copies of all such reports shall be made available to the Transportation Committee of the Western Conference, Council of State Governments, and to the Western Association of State Highway Officials.

ARTICLE V
Objectives of the Participating Jurisdictions

SECTION 1. Objectives. The participating jurisdictions hereby declare that:

(a) It is the objective of the participating jurisdictions to obtain more efficient and more economical transportation by motor vehicles between and among the participating jurisdictions by encouraging the adoption of standards that will, as minimums, allow the operation of a vehicle or combination of vehicles in regular operation on all State highways, except those determined through engineering evaluation to be inadequate, with a single-axle weight not in excess of 20,000 pounds, a tandem-axle weight not in excess of 34,000 pounds, and a gross vehicle or combination weight not in excess of that resulting from application of the formula:

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

where W = Maximum weight in pounds carried on any group of two or more axles computed to nearest 500 pounds.

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

N = number of axles in group under consideration.

(b) It is the further objective of the participating jurisdictions that in the event the operation of a vehicle or combination of vehicles according to the provisions of subsection (a) of this section would result in withholding or forfeiture of Federal-aid funds pursuant to Section 127, Title 23, U.S. Code, the operation of such vehicle or combination of vehicles at axle and gross weights within the limits set forth in subsection (a) of this section will be authorized under special permit authority by each participating jurisdiction which could legally issue such permits prior to July 1, 1956, provided all regulations and procedures related to such issuance in effect as of July 1, 1956, are adhered to.

(c) The objectives of subsections (a) and (b) of this section relate to vehicles or combinations of vehicles in regular operation, and the authority of any participating jurisdiction to issue special permits for the movement of vehicles or combinations of vehicles having dimensions and/or weights in excess of the maximum statutory limits in each participating jurisdiction will not be affected.

(d) It is the further objective of the participating jurisdictions to facilitate and expedite the operation of any vehicle or combination of vehicles between and among the participating jurisdictions under the provisions of subsection (a) or (b) of this section, and to that end the participating jurisdictions hereby agree, through their designated representatives, to meet and cooperate in the consideration of vehicle size and weight related matters including, but not limited to, the development of: uniform enforcement procedures; additional size and weight standards; operational standards; agreements or compacts to facilitate regional application and administration of size and weight standards; uniform permit procedures; uniform application forms; rules and regulations for the operation of vehicles, including equipment requirements, driver qualifications, and operating practices; and such other matters as may be pertinent.

(e) In recognition of the limited prospects of Federal revision of Section 127, Title 23, U.S. Code, and in order to protect participating jurisdictions against any possibility of withholding or forfeiture of Federal-aid highway funds, it is the further objective of the participating jurisdictions to secure Congressional approval of this agreement and, specifically of the vehicle size and weight standards set forth in subsection (a) of this section.

ARTICLE VI

Entry Into Force and Withdrawal

SECTION 1. This agreement shall enter into force when enacted into law by any two (2) or more contiguous jurisdictions. Thereafter, this agreement shall become effective as to any other jurisdiction upon its enactment thereof, except as otherwise provided in Section 8, Article III.

SECTION 2. Any participating jurisdiction may withdraw from this agreement by cancelling the same but no such withdrawal shall take effect until thirty (30) days after the designated representative of the withdrawing jurisdiction has given notice in writing of the withdrawal to all other participating jurisdictions.

ARTICLE VII

Construction and Severability

SECTION 1. This agreement shall be liberally construed so as to effectuate the purposes thereof.

SECTION 2. The provisions of this agreement shall be severable and if any phrase, clause, sentence or provision of this agreement is declared to be contrary to the constitution of any participating jurisdiction or the applicability thereto to any government, agency, person or circumstance is held invalid, the validity of the remainder of this agreement shall not be affected thereby. If this agreement shall be held contrary to the constitution of any jurisdiction participating herein, the agreement shall remain in full force and effect as to the remaining jurisdictions and in full force and effect as to the jurisdictions affected as to all severable matters.

ARTICLE VIII

Filing of Documents

SECTION 1. A copy of this agreement, its amendments, and rules or regulations promulgated thereunder shall be filed in the highway department in each participating jurisdiction and shall be made available for review by interested parties.