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16. Abstract

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This report documents the status of current legislation of each state with respect to laws governing truck size and weight. Emphasis was placed on laws pertinent to the operation of larger motor carriers such as "doubles" and "triples," overall vehicle length, width, axle weight, and gross vehicle weight. A survey of all states was made to ascertain the current status of truck size and weight studies and highway cost allocation studies. The survey results as well as details of the studies are summarized herein.

Ten states were found to have conducted studies for which reports, papers, or some documentation was available. The documents were analyzed to determine the objective and scope, methodology, data sources, findings, and summary. Efforts were made to gain insight into national implications from the aggregated findings of the individual studies. Many interesting findings surfaced regarding pavement and bridge costs aspects of increased truck size and weight.

Other pertinent findings regarding data sources and methodology were found to be useful in furthering aspects of the comprehensive Texas study.

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AN ASSESSMENT OF RECENT STATE TRUCK SIZE AND WEIGHT STUDIES

by

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Paul Ng
Susan Tobias

Research Report Number 241-4

Truck Use of Highways in Texas
Research Study Number 3-18-78-241

conducted for

Texas State Department of Highways and Public Transportation

by the

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

July 1982

PREFACE

This is an interim report on Research Project 3-8-78-241, "Truck Use of Highways in Texas." This report represents another aspect of the comprehensive study to adequately assess the various issues and effects of an increase in truck size and/or weight on the intercity highway network of Texas. Previous or programmed reports from this study are

- 241-1 Effects of Heavy Trucks on Texas Highways
- 241-2 An Assessment of Changes in Truck Dimensions on Highway Geometric Design Principles and Practices
- 241-3 Evaluation of Selected Operational Issues of Increased Truck Size and Weights
- 241-5 Modeling and Forecasting Selected Effects of Motor Vehicle Size and Weight Laws
- 241-6 An Assessment of the Enforcement of Truck Size and Weight Limitations in Texas

The authors wish to express their appreciation to the Association of American Railroads, Inc., for their support of and assistance with this study. In addition, the authors would like to thank the Motor Vehicle Manufacturers Association and American Trucking Association for information pertaining to the legal limits in various states.

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Chairman, Byron C. Blaschke, Chief Engineer of Maintenance and Operations
Robert L. Lewis, Chief Engineer of Highway Design
Wayne Henneberger, Bridge Engineer
Phillip L. Wilson, State Planning Engineer for Transportation
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ABSTRACT

With the growing interest nationally in the effects of increased size and weight of motor carriers on the existing highway infrastructure, there is a need to remain current on the various studies being conducted by the various states.

This report documents the status of current legislation of each state with respect to laws governing truck size and weight. Emphasis was placed on laws pertinent to the operation of larger motor carriers such as "doubles" and "triples," overall vehicle length, width, axle weight, and gross vehicle weight. A survey of all states was made to ascertain the current status of truck size and weight studies and highway cost allocation studies. The survey results as well as details of the studies are summarized herein.

Ten states were found to have conducted studies for which reports, papers, or some documentation was available. The documents were analyzed to determine the objective and scope, methodology, data sources, findings, and summary. Efforts were made to gain insight into national implications from the aggregated findings of the individual studies. Many interesting findings surfaced regarding pavement and bridge costs aspects of increased truck size and weight.

Other pertinent findings regarding data sources and methodology were found to be useful in advancing certain aspects of the comprehensive Texas study.

KEY WORDS: truck, size, weight, motor carrier, tractor/trailer, rural highways, intercity carriers, interstate commerce, truck laws and regulations

SUMMARY

Since the inception of highway motor truck transportation, the effects of sizes and weights of trucks on highways and the need for a regulatory enforcement have become more accepted. Since the 1970's, particularly since 1974, when Congress raised the weight limits on Interstate highways, there has been a wave of interest among some states to study the truck size and weight problem in their own states. Among them are Arkansas, California, Illinois, Indiana, Iowa, Kentucky, Mississippi, Tennessee, Texas, and Utah. The objective, scope, and methodology, including data sources and findings of each state study, were received and summarized. While the California study was limited to triple trailer evaluation, Arkansas, Illincis, Mississippi, Indiana, and Kentucky dealt with the weight aspect of the issue. Four states——Iowa, Tennessee, Texas, and Utah——studied both the size and the weight aspects of the issue.

With respect to data sources, AASHO Road Test results and truck weight study data were the most frequently consulted in the study of increased weight on highway pavements. Other data sources, such as state road life records and state accident data, were used by some states.

Of the ten states, Arkansas, Illinois, Indiana, Iowa, Mississippi, and Tennessee conducted studies to determine if their weight limits should be raised to the current level. The states of Arkansas, Illinois, and Mississippi were not in favor of the increase, while Tennessee's study did not come up with a definite answer. Instead, Tennessee recommended that the decision be made after findings from the "Highway Cost Allocation Study" are available. Iowa came out in favor of the increase. The Indiana study was conducted by University researchers and, hence, did not develop any policy statement but did provide an estimate of the cost of raising size and weight limits to current Federal levels.

Both Utah and California studied the effects of triple trailer operations in their states. California found that triple operations could be allowed on Interstate highways but would create problems on local roads and metropolitan

area freeways. The Utah study found that an increase for certain combinations does increase productivity and reduce fuel consumption without sacrificing pavement performance. The study subsequently recommended the operation of triples on Interstate highways in Utah.

The Kentucky study dealt with the mechanics of weight distribution on highway pavement, and it came up with some suggestions as to how to reduce pavement damage due to truck loads. The Texas study evaluated the effects of four size and weight scenarios on the state. Scenario A was the status quo scenario. Scenario B has a maximum gvw of 120,000 lb, maximum single axle load of 26,000 lb, and a maximum tandem axle load of 44,000 lb. Scenario C has the same axle limit as the current one but allows the so-called "turnpike doubles" and triple trailer combinations to operate within the state. The maximum gross vehicle weight allowed is 105,500 lb. Scenario D is the same as C except that the maximum gvw's were governed by bridge formula. The Texas study found that Scenario C has the least overall cost to the state and has the second highest (next to Scenario D) overall benefit. It was emphasized that other factors, such as highway safety, would have to be more completely explored before a final judgment could be made with respect to larger and heavier motor carriers.

IMPLEMENTATION STATEMENT

The objective of this report was to review and assess the size and weight studies conducted by the states. Findings from Utah and California on triple trailer operations indicate that such vehicles may be allowed on Interstate highways with increased productivity and reduced fuel consumption. Scenario C in the Texas study showed that the introduction of triple trailer combinations, as well as the so-called "turnpike doubles," into Texas may not create serious additional pavement damage or require extensive geometric redesign cost if these large combinations are confined to the Interstate system. Allowing these combinations on other main rural highways would bring in considerable income, but allowing these vehicles on farm-to-market roads would be very impractical.

The Kentucky study found that certain vehicle configurations have a less damaging effect on the highway pavement than certain other vehicle configurations. The development of legislation or other measures to encourage these types of configurations and discourage those that are more damaging to the highway pavement has considerable merit.

DEFINITION OF TERMS AND ACRONYMS

AAA	The American Automobile Association
AASHTO	The American Association of State Highway and Transportation Officials (formerly AASHO, the American Association of State Highway Officials)
BMCS	The Bureau of Motor Carrier Safety
DOT	The Department of Transportation
FHWA	The Federal Highway Administration (formerly BPR, the Bureau of Public Roads)
GAO	The U.S. Government Accounting Office
NCHRP	The National Cooperative Highway Research Program
SDHPT	The Texas State Department of Highways and Public Transportation
TRB	The Transportation Research Board (formerly HRB, the Highway Research Board)
VMT	Vehicle miles of travel
3R Program	Interstate Resurfacing, Restoration, and Rehabilitation Program
18 KSAL	18-kip single axle load

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CHAPTER 1. INTRODUCTION

During the past several years many states have had studies conducted on a variety of issues associated with changes in the legal limits governing the operation of motor carriers on highways within their respective state boundaries. In many cases these studies have been used to support or defend various legislative positions affecting laws governing truck size and weight limits. In addition to the documented studies reviewed herein a number of states have current or pending legislative action or studies, some of which will ultimately impact the legal limits within their respective states. In essence, therefore, the U.S. is characterized by a patchwork of individual state truck size and weight limits.

At the Federal level, the national truck size and weight study may suggest changes for certain highway classes, such as the Interstate System, which could alter further the role of states in governing trucks operating within their jurisdiction.

The purpose of this study, therefore, is to review the published studies or other information available on states' truck size and/or weight matters. Figure 1 shows the states from which published information was obtained and included in this assessment. The primary emphasis of this study is to provide an overview of each state's information as to the objective, scope, methodology including data acquisition and analysis, findings, and conclusions. A summary of the findings is provided.

BACKGROUND

To characterize the variety of basic legal limits governing the operation of trucks within the states, a series of illustrations has been assembled. These illustrations represent the legal status within the individual states as of 1980 and do not include changes debated, pending, or passed thereafter.

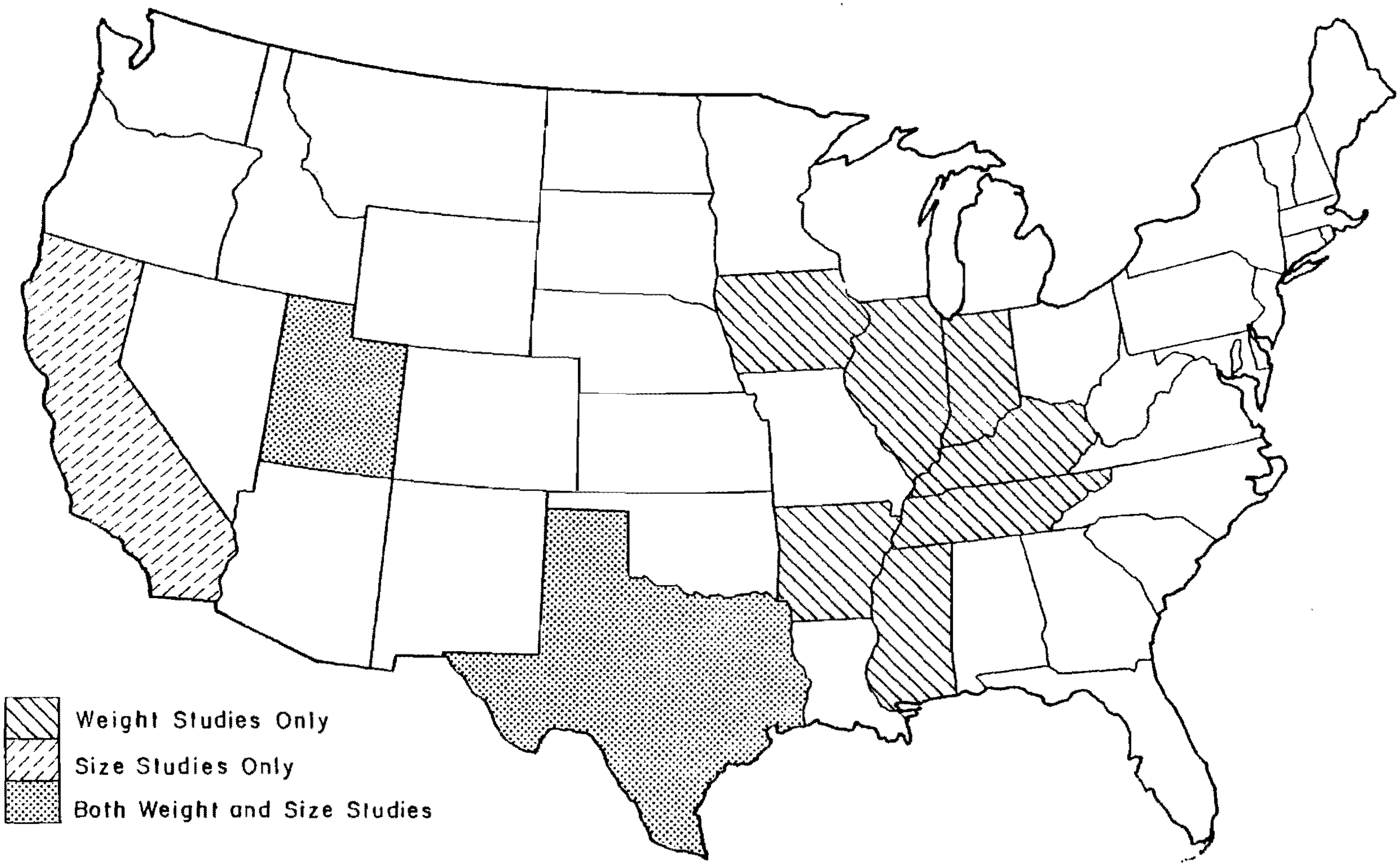

Fig 1. States conducting size and/or weight studies.

With respect to truck weight, the most common measurement is the gross vehicle weight (GVW), which is shown in Figure 2. The most significant change not reflected in this figure is the U.S. Supreme Court decision against the position taken by the State of Iowa. This case, reviewed in this study, could establish a precedent for action in other states as well. Since the Interstate Highway System represents the highest order of design and operational safety and the most likely routing for major interstate motor carrier operations, Figure 3 was developed to show the limits imposed by the states.

Although GVW is an important aspect of the overall size and weight issues, the highway engineer concerned with pavement design, maintenance, and general serviceability is more interested in axle weight limits and anticipated load applications. Figures 4 and 5 provide the vehicle weight limits per single axle and the maximum tandem axle vehicle weight, respectively.

The size of trucks, specifically overall length and width, is a pertinent issue in terms of productivity. In many instances, an increase in vehicle length while retaining axle weight limits is advocated as a means of enhancing the cost of operations. Figure 6 indicates the maximum vehicle lengths for the tractor-semitrailer (3-S2) permitted by individual states. The tractor-semitrailer represents the "workhorse" of the motor carrier fleet operating on the national highway network. More and more attention is being given to the operation of "doubles" and "triples" as a means of increasing long haul productivity and flexibility. Since the large doubles represent the critical design vehicle (Ref 25) in terms of highway geometric design policy and procedures, it is likely that they will be limited for most of their operations to the Interstate Highway System, with "reasonable access" to and from, which in the Iowa case is five miles. Figure 7 provides a status report on the operation of these larger vehicles. It shows that several states which allow the operation of doubles and triples limit the overall length of these units, which, in effect, eliminates the operation of these large vehicle units. Therefore, to gain a proper perspective it should be noted that the states where laws allow the operation of the larger doubles and triples have an overall length authorization of approximately 95 ft or more. Smaller doubles are possible with length restrictions of 60 or 65 ft.

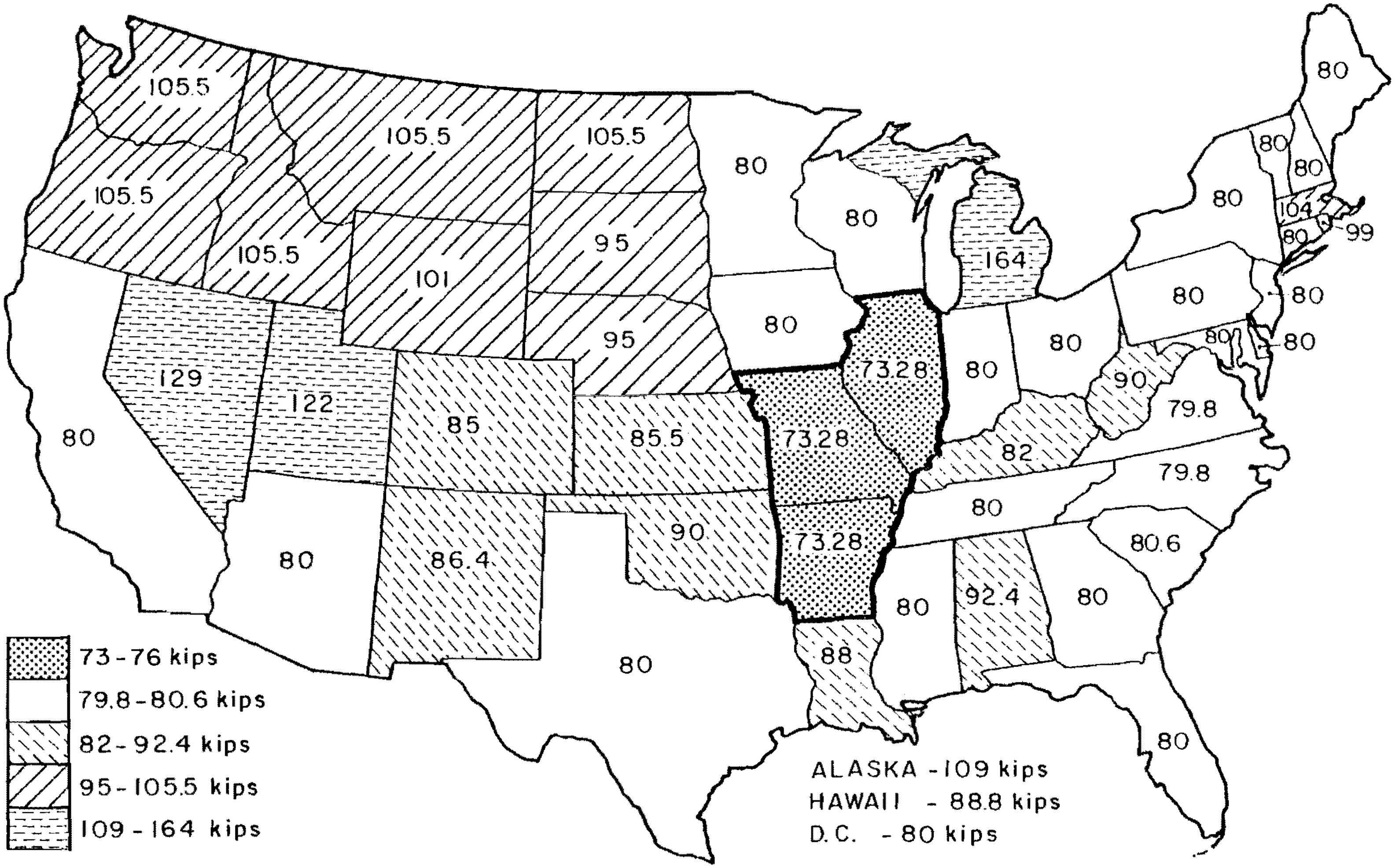

Fig 2. Maximum GVWs permitted on state highways.

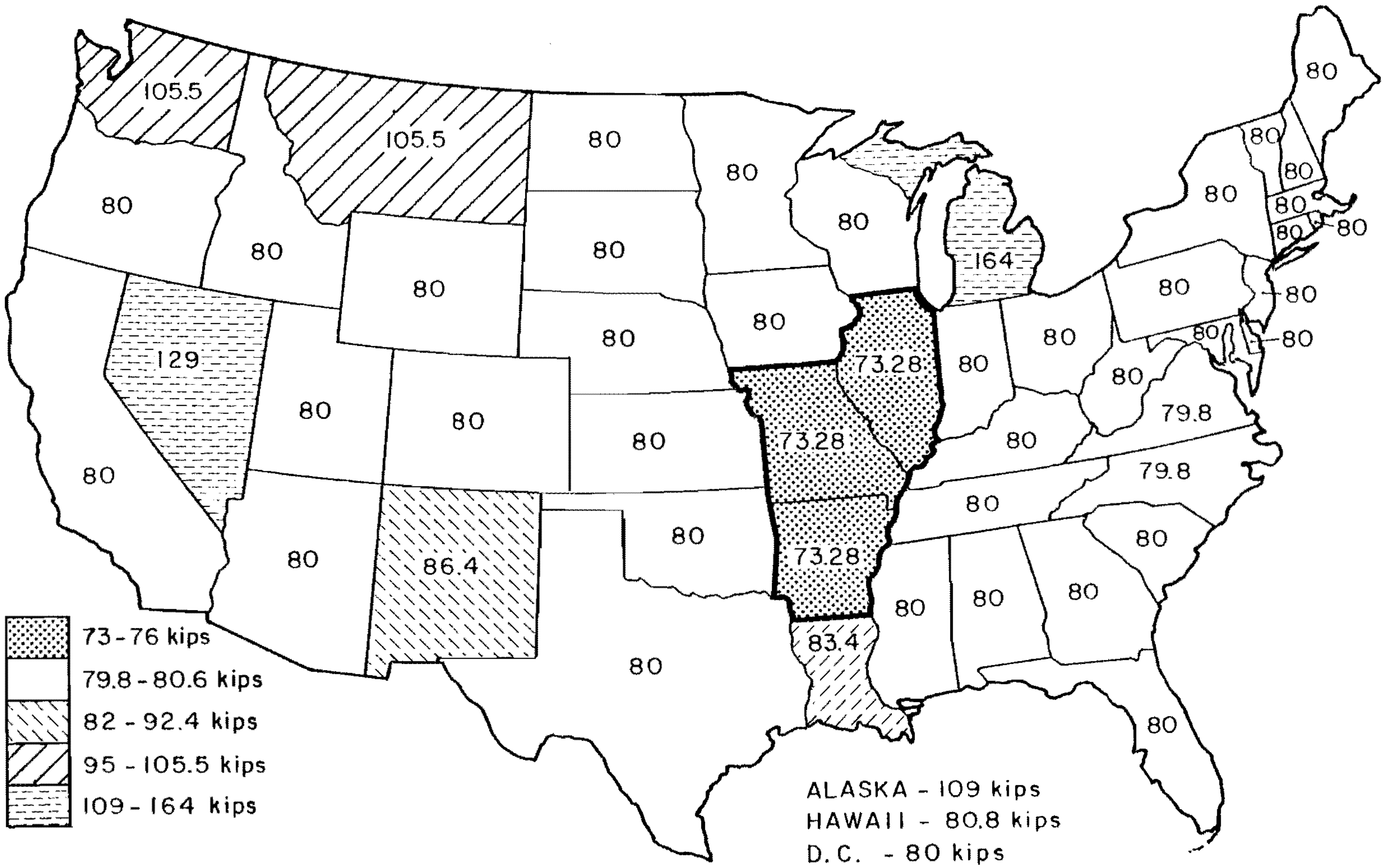

Fig 3. Maximum GVWs permitted on interstate highways.

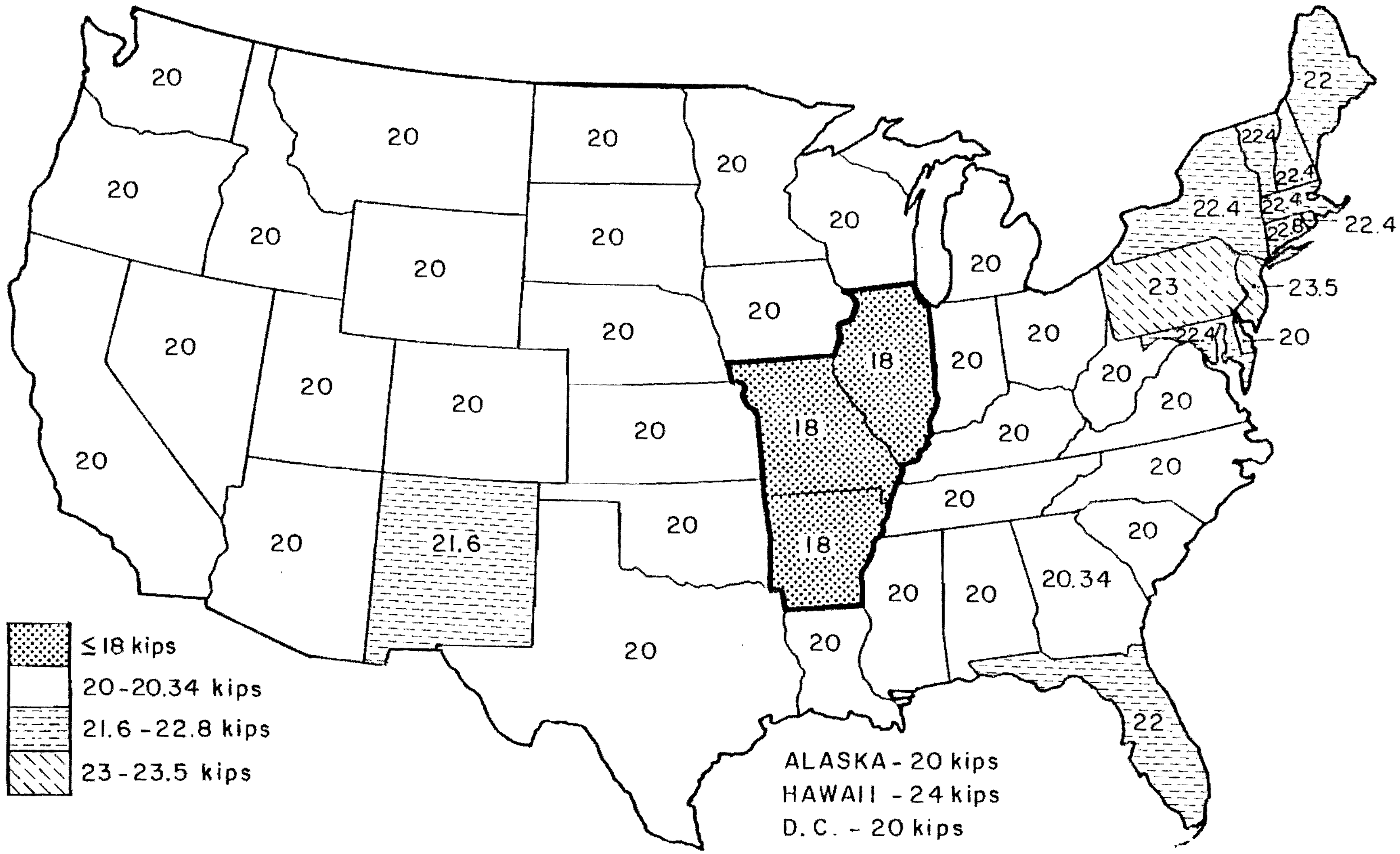

Fig 4. Vehicle weight limits per single axle.

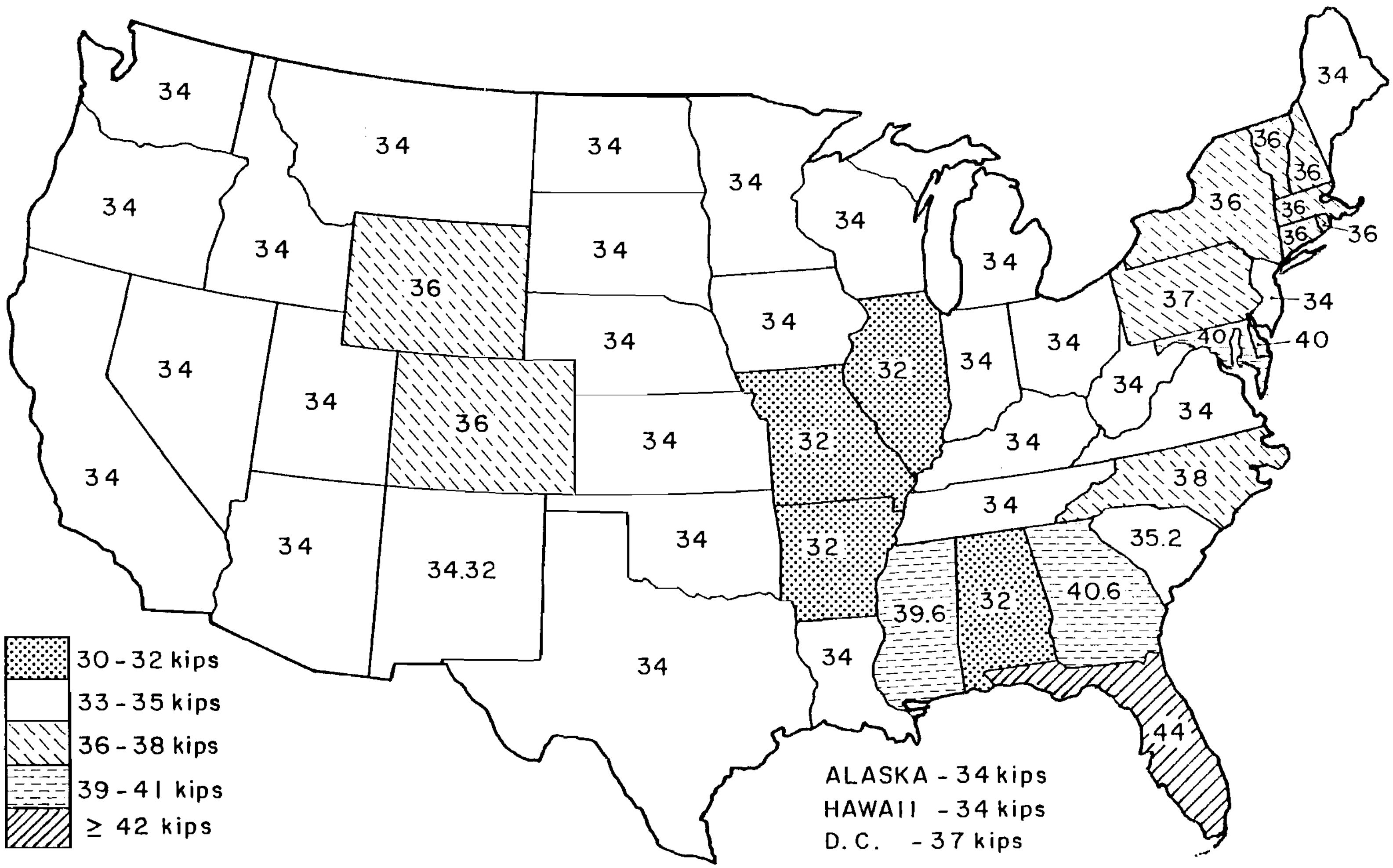

Fig 5. Maximum tandem axle vehicle weights permitted by states.

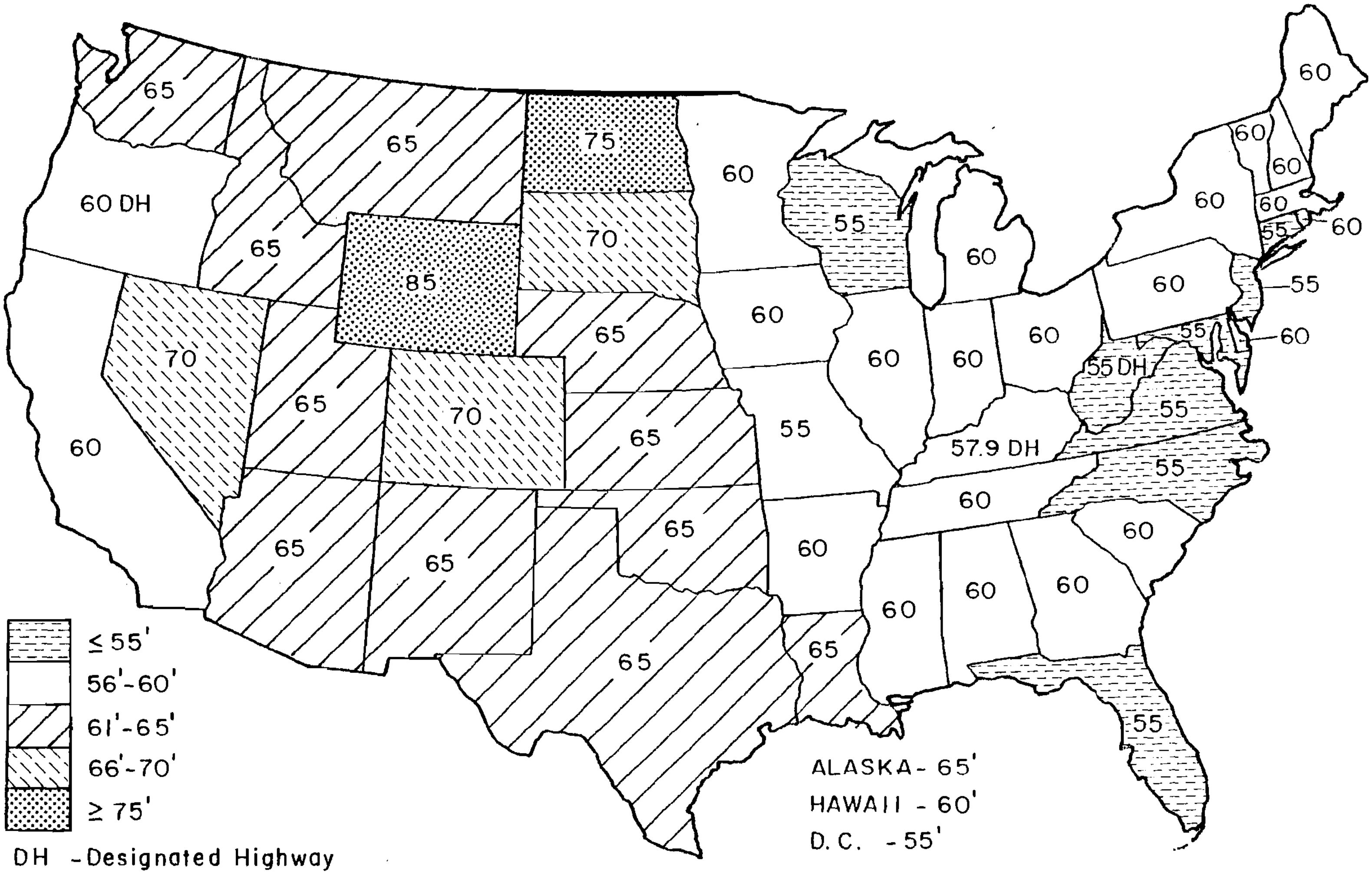

Fig 6. Maximum vehicle lengths for tractor-semitrailer (3-S2) permitted by states, in feet.

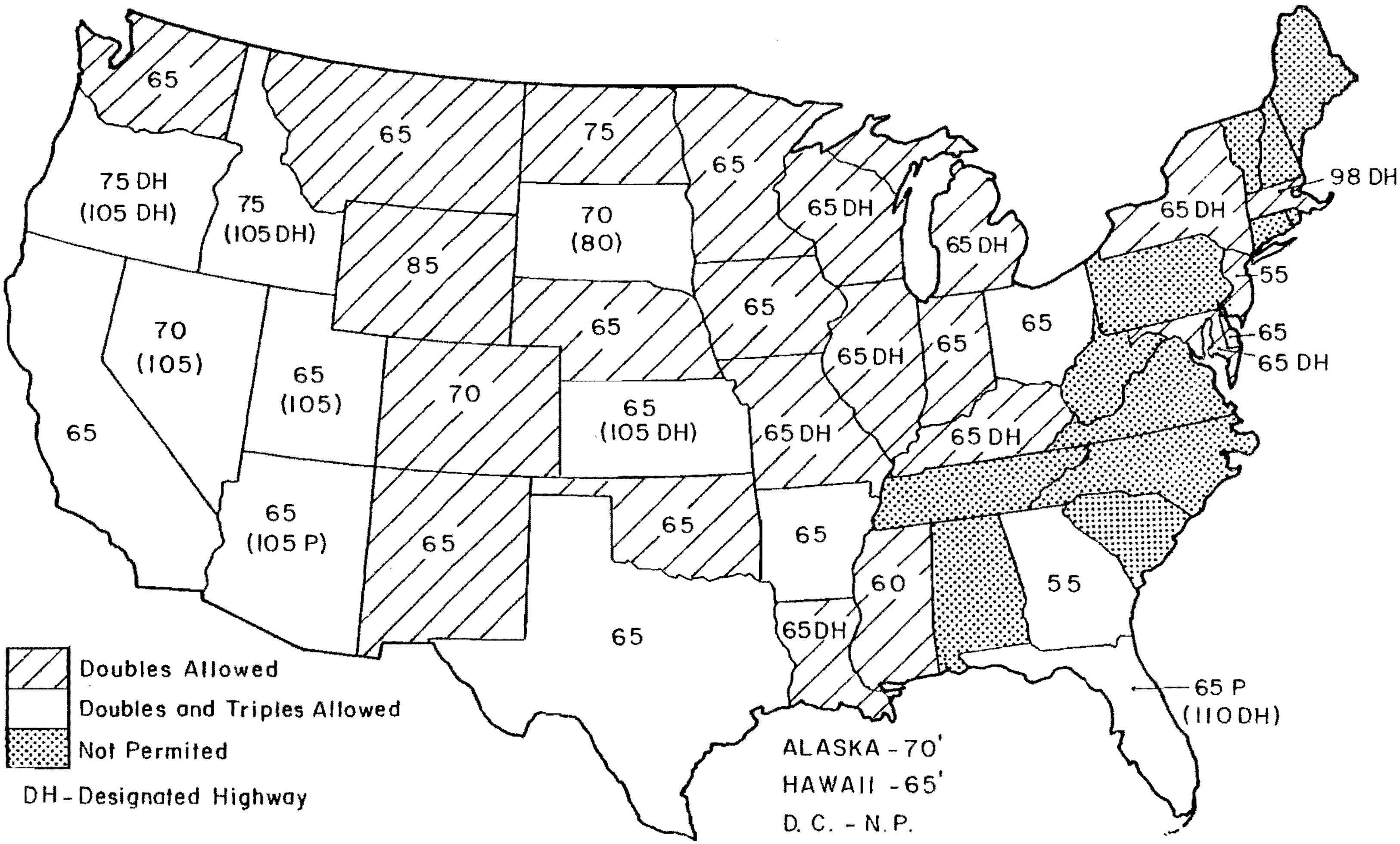

Fig 7. States which allow doubles (triples) and maximum allowable vehicle unit lengths, in feet.

The maximum widths of vehicles permitted to operate on the highways of the individual states are shown in Figure 8. As seen, most states have retained limits of 96 inches; however, there is a bill introduced in the U.S. Senate (S.B. 402) forwarding the notion of increased productivity which some industries could expect from an increase of 96 inches to 102 inches. Most states which allow 102 inches in width, limit the width of units on the Interstate System to 96 inches. Although some attention has been given to increasing vehicle height to 14 ft or more, the limit of 13.5 ft is more universally accepted. Obviously any change in vehicle height would represent an expensive modification to the highway system, given the number of critical obstacles, such as bridges, tunnels, etc.

Because many state legislatures are still considering or will consider bills affecting truck size and weight, these status summaries will, in all likelihood, change. In addition to the published reports, a survey of all states was conducted to gain insight into action contemplated or programmed with respect to truck size and weight and highway cost allocation. These findings are summarized in the following section.

SURVEY OF THE STATES

To obtain the most current information available, it was important for each State Department of Transportation to respond directly to certain questions. Therefore, a survey was composed to obtain facts concerning not only allowable vehicle size and weight, but predicted trends in each state toward vehicle size and weight limits. The states were also asked about their research of the effects of vehicle size and weight to pavement wear, bridge damage, operating capability, energy/fuel consumption, vehicle operation costs, highway/motor carrier safety, air quality, noise level, and truck route systems. A second survey concerning Highway Cost Allocation Studies presently being conducted or completed by the states was included. Since there are many different ways of researching these areas, it was also important to know something about methodology of research, where the research proposal originated, and the report publication date. The surveys established contact between researchers and clarified the type of information available.

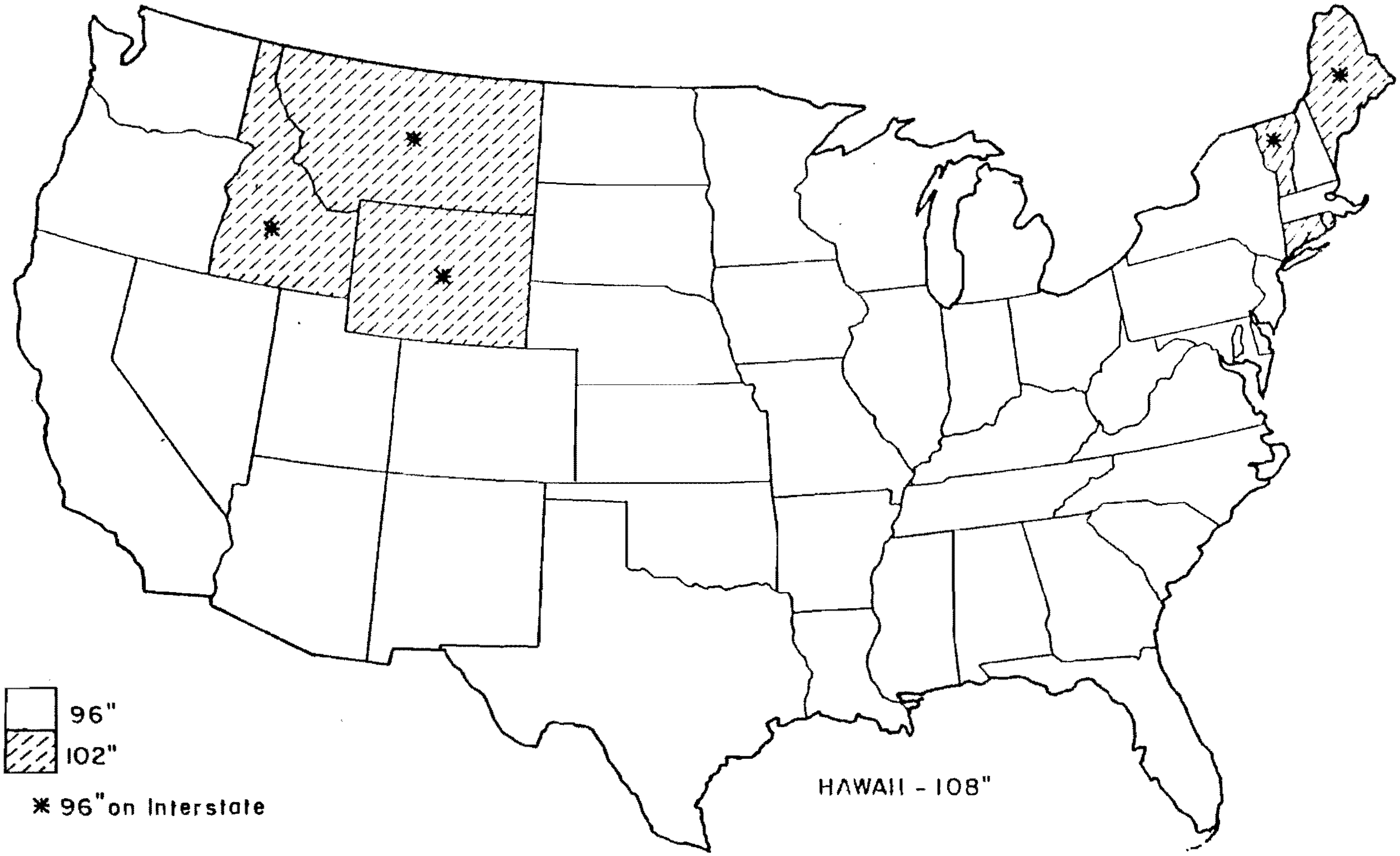

Fig 8. Maximum vehicle widths permitted by states.

All states returned completed surveys yielding a 100 percent sample. In all cases the surveys were completed by representatives, or directors, of the state departments of transportation. All responses were very prompt and informative. The following provides an overview of the findings:

1. Colorado, Indiana, Iowa, Kentucky, Maryland, Mississippi, Pennsylvania, and South Dakota indicated that they all used analytical techniques performed by engineers, such as highway road testing and analysis, and computer modeling, in addition to theoretical research or information based upon other available technical reports (National Bridge Inventory, AASHTO pavement design data, HPMS, NHIPS, TIUS, truck weight data summarized by FHWA).
2. Pavement wear was researched by Indiana, Iowa, Kentucky, Maryland, Mississippi, Pennsylvania, and South Dakota.
3. Bridge Damage Data is available in Indiana, Iowa, Maryland, Mississippi, and Pennsylvania.
4. The effects of increased vehicle weight and/or size to decreased operating capability and possible lack of ability to operate under certain highway geometric conditions was researched by engineers in Colorado, Indiana, Iowa, and Pennsylvania.
5. Energy and fuel consumption research was performed in Colorado, Indiana, and Iowa.
6. Vehicle operating costs were estimated by Colorado, Indiana, Iowa, and Pennsylvania.
7. The effects to vehicle safety were researched in Colorado, Indiana, Iowa, and Mississippi.
8. Air quality and noise level were researched in Indiana and Pennsylvania.
9. Colorado and Indiana also researched a possible truck route system for heavier vehicles.
10. The economic implications of allowing heavier vehicles on roads were researched by Indiana and Pennsylvania.
11. Indiana was also concerned with soil strength as it relates to pavement wear from heavy vehicles.
12. Arizona, Arkansas, Florida, and Georgia used data from sources outside of laboratory and road testing to research the effects of heavy vehicles to the transportation system, primarily as related to pavement/bridge damage. Arkansas used previously published technical literature to research energy and fuel consumption by heavier trucks. These states indicated their research is based upon previously recognized research rather than the type of data compiled by engineers in the previously mentioned states.

Table 1 provides another perspective of the results gleaned from the surveys of those 13 states which seem to be more involved in various truck size and weight studies. Table 2 is a summary of the findings from the surveys received which indicated involvement in highway cost allocation studies.

APPROACH

There are a number of published state truck size and/or weight studies (see Fig 1). The approach pursued in this study was to review each identified report or other information available from each state on its particular study. The purpose was to examine the objective, scope, methodology, findings, and conclusions of each. A review of each study is provided in the appendices. The final section of this paper summarizes the findings and conclusions of these studies and makes an assessment of the results.

TABLE 1. STATE RESEARCH ON EFFECTS OF INCREASING ALLOWABLE SIZE AND WEIGHT LIMITS OF VEHICLES

Research Subject		Arizona*	Arkansas	Colorado	Florida	Georgia	Indiana*	Iowa***	Kentucky	Maryland*	Mississippi*	Pennsylvania***	South Dakota	Texas
Structural Analysis	Pavement wear	●	●				●	●	●	●	●	●	●	●
	Bridge damage	●	●				●	●		●	●	●		●
	Soil testing						●							
Economical Analysis	Economical effects						●					●		●
	Operating costs			●			●	●				●		●
	Energy/fuel consumption		●	●			●	●						●
	Effects on rail			●										●
Operational Issues	Safety			●			●	●			●			●
	Operating capability			●			●	●						●
Environmental Aspects	Air quality						●					●		●
	Noise level						●					●		●
Other	Truck route			●			●							●
	Remarks				Specific areas not defined	Informal studies								

NOTES:

Research using actual road or highway testing, computer modeling, theoretical and based upon available technical reports

* Report available

** Report available, revisions underway

*** Proposed research not yet underway

\+ All data above are based on survey responses

TABLE 2. STATE HIGHWAY COST ALLOCATION STUDIES: SURVEY FINDINGS

Research Subject \ State	Arizona*[3]	Colorado[3]	Connecticut[3]	Florida*[3]	Georgia*[3]	Illinois*[3]	Indiana*[4]	Iowa*[3]	Kentucky[4]	Maine[3]	Maryland[4]	Minnesota[3]
Pavement costs	●	●		●	●	●	●	●	●	●	●	●
Bridge costs	●	●		●	●	●	●	●	●	●	●	●
Right-of-way costs								●				
Economic effects				●		●						
Level of service/ capacity		●		●	●		●	●		●	●	●
Energy/fuel consumption		●		●	●		●	●	●			●
Equitability of tax structure			●			●						
Safety		●		●	●		●	●			●	●
Vehicle operating costs		●		●	●	●	●	●	●	●		
Environmental aspects		●			●			●				
Consumption approach								●				
Incremental cost study method	5	●		●	●	●	6		●	●[7]	●	●
Year/Comment	1981	1981	1982	1979	1979, 1981 (update)	1981	1976, 1979	1980, 1982	1981	1982–1983	1982	1983

NOTES:

[1]report/research conducted by: legislative committee

[2]report/research conducted by: engineering consulting firm

[3]report/research conducted by: state agency

[4]report/research conducted by: university

[5]weight distance study method

[6]earnings credit/standard cost method/predominant use method/relative use method

[7]several study techniques being considered

[8]report from CALTRANS

[9]gross ton mile analysis/cost function analysis/earnings credit analysis

*Study complete

**Pennsylvania, Massachusetts, and Kansas have also done some research in the area of highway cost allocation.

(continued)

TABLE 2. (continued)

Research Subject \ State	Mississippi*[3]	Michigan[3]	New Hampshire*[3]	New Mexico*[2]	North Carolina*[3]	Ohio[3,4]	Oregon*[3]	South Dakota*[3]	Virginia[1,3]	West Virginia[3]	Wisconsin	Wyoming*[2]
Pavement costs	●	●	●	●	●	●	●	●	●		●	●
Bridge costs	●	●			●	●	●	●	●		●	●
Right-of-way costs					●		●					
Economic effects		●			●					●		
Level of service/ capacity		●	●		●		●	●	●		●	●
Energy/fuel consumption		●	●		●	●	●		●		●	
Equitability of tax structure					●							
Safety		●	●		●	●	●	●	●		●	●
Vehicle operating costs			●	●	●							
Environmental aspects		●			●	●			●			●
Consumption approach		●			●	●			●		●	
Incremental cost study method	8	●	●	9	●	●	●	●	●		●	●
Year/Comment	1980	1982	Jan 1981	Feb 1972	1983	July 1, 1982	I, 1981 II, pends	1980	1981	1982	1982	1981

NOTES:

[1]report/research conducted by: legislative committee

[2]report/research conducted by: engineering consulting firm

[3]report/research conducted by: state agency

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*Study complete

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CHAPTER 2. SUMMARY OF THE VARIOUS STATES' STUDIES

The concept of motor vehicle size and weight laws was first introduced in 1913 when tire manufacturers recommended 800 pounds per inch of width as the maximum economic tire loading (Ref 1). As a result of this recommendation, three states—Maine, Massachusetts, and Pennsylvania—adopted regulations in 1913 which limited the maximum load per inch of tire width, and maximum load on either the axle or the whole vehicle (Ref 2). The motor vehicle weight limitation spread at a rapid rate within the United States. By 1925 about half of the states had some limitation on vehicle loadings; and, by 1950, all of the 48 contiguous states had motor vehicle size and weight limits in effect (Ref 3).

The need for a detailed technical study of the motor vehicle size and weight issue was first recognized by the formation of the Committee on Highway Transport of the American Association of State Highway Officials (AASHO, now AASHTO) which has in its charter as part of its purpose the study of the size and weight issue and the formulation of a policy that can be applied nationally. The first recommended AASHO national policy on motor vehicle size and weight limitations on highways was adopted by AASHO in 1932 (Ref 4).

In 1956 the Congress of the United States, through the Federal Highway Act, authorized the construction of 41,000 miles of the Interstate Highway System. In the same Act, the Congress, in order to protect its huge investment in highways, set the legal limits on maximum motor vehicle size and weight. The limits set were 18,000 pounds for single axles, 32,000 pounds for tandem axles, and 73,000 pounds for GVW. These limitations were eventually adopted by most states, with the few exceptions being the states that retained their old law through the grandfather clause. Through the Act, the Congress also directed the Bureau of Public Roads (BPR) to study the size and weight impacts on highways. A series of studies on the desirable limits of motor vehicle sizes and weights on highways were subsequently conducted during the sixties and the early seventies. In 1974 the U.S. Congress again enacted legislation, in the form of the Federal Highway Amendment, which authorized the increase of size and weight limits on highways to 20,000 pounds for single axles, 34,000 pounds for tandem axles, and 80,000 pounds for GVW. After the passage of the Federal Aid Highway Amendment, all but six states adopted the new size and weight limitations.

During the early seventies, two states—Utah and California—conducted studies on the operations of triple-trailer combinations (Refs 6, 7). Since 1979 there has been a fresh wave of interest in the study of motor vehicle size and weight limitations. In the past the FHWA (or its predecessor, BPR) and AASHO conducted studies on the motor vehicle size and weight issues; however, the renewed interest resulted in a number of states conducting studies to determine the appropriate size and weight limitations for their own states. The Utah Department of Transportation prepared two papers explaining some aspects of the truck size and weight issues (Refs 8, 9). States that did not increase their size and weight limits to the Federal maximums were under pressure from various interest groups to increase their existing limits. The special interest groups representing the motor carrier industry pressured for an increase in size and/or weight limits, while various interest groups representing the rail industry and the automobile industry, and environmental conservationist groups argued for the retention of the existing laws or for a "roll back." Among the states that retained the 1956 Federal maximums, six states were along the Mississippi River. With the exception of Missouri, each had conducted studies to determine the effects of increasing size and weight limits (Refs 5, 10-16, 19). The Kentucky Department of Transportation had also conducted several studies to determine the impact of truck design and operations on pavement performance (Refs 20-22).

The studies conducted by each state often vary in scope, methodology, and level of detail. Some states have a well-rounded treatment of major aspects of the size and weight issues and employ rather stringent analytical techniques while others are less analytical.

The study done for the State of Indiana (Ref 17) emphasized the cost aspects of increasing size and weight limits but did not address any beneficial aspects of increasing vehicle weight limits. The study is thorough in its treatment of pavement maintenance costs and it also considers bridge costs. The State of Kentucky (Refs 20-22) concentrated on the study of the interaction of truck design and pavement performance and presents some interesting relationships. It did not address other issues to the same level of detail as the truck design and pavement performance aspects. The Tennessee study (Ref 16) applied the NCHRP 141 methodology in estimating the direct highway costs but did not estimate any benefits of increasing size and weight limits.

The Iowa study (Refs 10-14) is relatively more complete than most studies reviewed. It covered aspects of pavement wear, benefit/cost ratios, highway cost responsibility methodology and shortfalls, travel forecasts, options for increased truck taxes, vehicle lengths, and intermodal competition; however, it did not address the size issues of increasing size and weight limits—such as the issue of the impact of larger trucks on highway geometrics.

The Texas study (Refs 20-26) is the most comprehensive in its treatment among all states since it has covered selected costs and benefits. The Texas study also dealt with issues of the effect of larger trucks on highway geometrics and pavement life, impact on noise and environment, etc. However, the aspect of bridge structure design and life as affected by changes in size and weight of vehicles were not as thoroughly analyzed.

Table 3 gives a summary of the types of studies that have been conducted by these states, and Table 4 shows a brief view of the data sources used by each state, as well as the methodology employed. The findings of each state are summarized in Table 5. The reports published by each state as a result of each study are listed in detail in the appendices.

All the values in Table 6 are based on cost figures published by each state. Because no uniform study format was given to each state, comparison of the figures is difficult. The figures published in the Mississippi report are the highest; however, these figures may have been computed over a number of years, thus increasing the magnitude of these costs. Among other states, the figures published in the Arkansas and Tennessee reports are quite high, whereas the figures published in the Iowa and Indiana reports are comparable. The Indiana study is considered a reliable base for comparison with other studies. The Iowa figures also appear to be reasonable. The Texas figures are not included in Table 6 since the Texas study was not concerned with raising size and weight limits to current Federal maximum limits. However, Texas figures are shown here in Table 7 for information purposes.

A few states also computed the cost of upgrading bridges to current Federal maximum limits. The converted unit bridge upgrading costs are as shown in Table 8. Overall, states devote more time and effort to the study of increased size and weight limits on pavement than on bridges; hence, the emphasis on pavements in this report.

TABLE 3. STATES CONDUCTING WEIGHT AND SIZE STUDIES

	Weight Studies			Size Studies		
	Pavements	Structures	Safety	Geometric Design	Operational Issues	Safety Aspects
Arkansas	x	x	●			
California				x	x	x
Illinois	x					
Indiana	x	x				
Iowa	x	x	x	●	●	●
Kentucky	x	●	●			
Mississippi	x	x	x			
Tennessee	x		●	●		●
Texas	x	x	●	x	x	x
Utah	x			x	x	x

x = detailed studies conducted in states

● = reviewed in study reports

TABLE 4. DATA SOURCES AND METHODOLOGIES USED BY STATES IN TRUCK SIZE AND WEIGHT STUDY

States	Data Sources	Methodologies
Arkansas	FHWA size and weight research studies, GAO Report, 1975 Truck Characteristics Report, Arkansas accident data, BMCS accident data, size and weight studies by Central State Resource Center, AAA, DOT, etc.	For pavements, "Asphalt Overlay and Pavement Rehabilitation," Asphalt Institute Manual Seires #17 and "AASHO Road Test: St. Louis Conference Proceedings" were used. Other aspects of the study were done by literature review.
California	Field test of doubles and triples; data received from Oregon, Nevada, Idaho, Wyoming, Montana, and Utah.	Field testing of triples on California highways to obtain operational characteristics of triples; experiences of other states were also considered.
Illinois	AASHO Road Test and Illinois Loadometer and Traffic Count Data.	Estimates of the reduction in pavement service life were based on AASHO Road Test results and Illinois Loadometer and Traffic Count Data.
Indiana	Indiana Road Life Records, soil information and performance data, truck weight and traffic count study data, AASHO Road Test results.	For impact on pavements, the NULOAD program, AASHTO Interim Guide, NCHRP 141, and other local methodologies were used. For bridges, a literature review was conducted. NCHRP 141 was consulted extensively for its findings on bridges.
Iowa	AASHO Road Test results; opinions from representatives of Teamsters Union, insurance industry, truck industry; National Highway Traffic Safety Administration; National Accident Data; Iowa Accident Data; and truck weight study data.	AASHO Road Test results were used in estimating impact on pavements. "Incremental Cost Concept" was used in allocating cost responsibility. Benefit-cost ratios were computed for increasing size and weight limits for various classes of highways.

(continued)

TABLE 4. (continued)

States	Data Sources	Methodologies
Kentucky	AASHO Road Test results, Kentucky truck weight study data	The modified Chevron N-layer computer program provided the basis for most of the computation. Equivalent axle load concept was used to calculate the damage factors. Elastic theory and work concept were used to predict the number of ESALS a given pavement system can support.
Mississippi	State economic data, AASHO Road Test results, "Commodity Flow Analysis" by W. Rush of Mississippi State University, 1973 FHWA Truck Commodity Flow Study, special weight limit questionnaire by the Mississippi R&D Center in 1976	AASHTO Interim Guide and AASHO Standard Specification for Highway Bridges were followed in the study of pavement and bridge. Pavement PSI ratings were obtained through National Highway Functional Classification and Needs Study and the 1976 National Highway Inventory and Performance Study Manual.
Tennessee	1976 and 1978 truck weight study data, Tennessee pavement records, AASHTO Interim Guide, and Tennessee State Traffic Data	New truck weight distribution was predicted using the NCHRP Shifting methodology and Tennessee weight data. For estimating effects of weight increase on remaining service life, the methodology by Conci and Bullard was used. On safety issues, findings based on NCHRP 141 and research work done by FHWA were utilized.
Texas	1954-1979 Texas truck weight study data; Texas Road Life Record, Texas traffic data, accident data, national truck weight study data, NCHRP 141 and 198 reports, size and weight studies conducted by other states, fuel consumption rates from data published in TRB publications,	AASHTO Interim Guide was followed in estimating pavement damage and REHAB computer model was used to calculate pavement cost. SDHPT procedure was used to predict future weight distribution. NCHRP 198 data on truck commodity tonnage and mileage were utilized to predict future truck

(continued)

TABLE 4. (continued)

States	Data Sources	Methodologies
Texas (continued)	National size and weight studies, AASHTO Policy for Design of Highways, AASHTO Interim Guide, Western Highway Institute research reports	mix with the introduction of turnpike doubles and triples into the traffic stream. Four scenarios were developed and tested. The first representing current limits, the second an increase in weight limit, and the third and fourth an increase in size limit. Effects on vehicle emission were estimated from models developed for EPA. Regarding effects of larger trucks on highway geometrics, AASHTO policy was reviewed and provided the basis for additional cost needed to upgrade highway geometrics. A new shifting procedure was developed.
Utah	Field test of triple trailer combinations; triple trailer studies done in California, Idaho, and Alberta, Canada; AASHTO Interim Guide; Western Highway Institute research findings on fuel consumption; Claffey's work on vehicle running cost and truck cost data in HRB Bulletin 301; major coal user records; highway patrol data; opinion survey; Utah accident data	Triples were allowed to operate on highways and observed. Utah accident data were evaluated to determine safety of larger trucks. Other Utah data and national data were used to evaluate other aspects of allowing triples. The opinions of the general public, drivers, and trucking companies were surveyed and evaluated. Regarding the costs and benefits of increasing size and weight limits, AASHO Road Test results have been used extensively.

TABLE 5. SUMMARY OF THE FINDINGS OF THE TRUCK SIZE AND WEIGHT STUDIES

State	Findings
Arkansas	The operation of heavier trucks on Arkansas highways will require $934.5 million to upgrade pavements and structures. An additional maintenance cost of $59 million per year is also required.
California	The use of triples is allowable on interstate highways. Triples create operational problems on local roads and metropolitan area freeways.
Illinois	Increase of maximum GVW limit from 73,280 to 80,000 lb reduces Interstate pavement life and increases the rehabilitation cost by $36 million over the next 4 years and requires an extra $3 million for annual maintenance. Fatal accidents may increase with a greater number of heavier trucks on highways and with automobiles becoming smaller and lighter.
Indiana	The Interstate Highways have the highest increase in maintenance cost per lane-mile, but the lowest total increased maintenance costs as compared to primary and secondary roads. It is estimated the increased annual pavement maintenance costs will vary between $10.43 and 12.15 million annually. The study also concluded that it is difficult for Indiana to retain its current weight limits equal to or higher than the Federal weight limit established in 1974.
	Changes in axle spacing and axle loads have a much greater effect on bridges than changes in GVW. Increased loads have a greater effect on short spans than on long spans; however, the bridges designed to safely carry the 1956 load limits should be adequate to carry the 1974 load with no additional strengthening. Hence there will be no strength-related upgrading costs for bridge structures due to changes in truck size and weight limits.
	Damage due to fatigue is cumulative in nature and is not evident until some future time. Maintenance costs can be expected to increase with loads, e.g., an 11 percent load increase may boost maintenance costs up by 10 percent. In terms of present costs, maintenance ranges from $2 to 3 million.

(continued)

TABLE 5. (continued)

State	Findings
Iowa	The benefit/cost ratios for increasing truck weight limits to 21/34 and 80,000 lbs are as follows:

System	Percentage Ratio
Primary Interstate	9.8
Other Primary	4.4
Total Primary	5.9
Secondary	0.8
Municipal	3.5
Total	4.2

The cost responsibility is as follows:

	Automobile	Truck	Landowner
Year	Ratio of Auto User Tax Collections to Auto Responsibility	Ratio of Truck User Tax Collections to Truck Responsibility	Ratio of Local Landowner Taxation to Landowner Responsibility
1972	1.36	1.09	0.59
1973	0.87	0.87	0.63
1974	0.89	0.81	0.74
1977	1.04	0.90	0.74
1978	0.90	0.71	0.46
1979	0.81	0.79	0.42
1980	0.69	0.69	0.41

A cost responsibility update reflects the following 1980 costs and revenues:

	Revenue	Cost	Percentage of Revenue-Cost
Autos	$366 M	$528 M	69%
Trucks	164 M	237 M	69%
TOTAL	$530 M	$765 M	69%

(continued)

TABLE 5. (continued)

State	Findings
Kentucky	In the Kentucky report, damage factors computed by the strain energy method were compared to AASHO results. The load distributions of trucks were found to have significant effects on pavement damage. Pavement life could be extended considerably if a triaxle group were used on the trailer instead of a tandem group. Vehicle configurations should be specified to minimize fatigue damage. It was recommended that statutes dealing with limitations on truck weights might be reviewed for consistency with the mechanics of pavement performance and efforts to be made through the use of statutes to encourage the use of those vehicles which are less damaging to highway pavements.
Mississippi	A total of $182.6 million is required to bring the Mississippi highway pavements to the standard sufficient for the present Federal weight limits. It is estimated to cost $76.8 million to replace 306 bridges which were designed according to the H-10 standard and $196.7 million to replace 296 bridges which were designed according to the H-15 standard. Regarding enforcement, the report recommends increasing the number of truck weight inspectors, the number of portable scales, and the authority of the weight inspectors.
Tennessee	Estimated additional costs for new pavement designs due to increased truck weight limits are (1) $17 million/year (or $4,000/lane-mile/year) for 4,108 lane-miles of Interstate Highway; (2) $16 million/year (or $3,000/lane-mile/year) for 20,708 lane miles of state highway; and (3) $4 million/year for the 500 lane miles of new pavement that was let to contract in 1978. An increase in truck weights would raise the fatal accident rate while an increase in truck size could reduce potential accidents. The study states that trucks are underpaying by 17.3 percent their share of highway costs. Based on NCHRP 141 methodology, an annual saving of $6 million in fuel cost is expected.
Texas	In Texas four scenarios were analyzed with respect to the truck size and weight studies. A summary of the scenarios, and the estimated highway costs and the savings that would result from implementing the various scenarios are given in the following table. Based on these estimates, scenario C was found to have some interesting results among all future scenarios (i.e., B, C, and D). The savings in operating costs are highest with D, followed by C, and then B. If the criterion for selecting

(continued)

TABLE 5 (continued)

WEIGHT AND LENGTH LIMITS BY SCENARIO

	Max. Single Axle Weight, Kips	Max. Tandem Axle Weight, Kips	Max. Gross Vehicle Weight		Length, feet	Operations of Doubles and Triples
			I, Kips	II, Kips		
Scenario A	20	34	80		65	N.P.
Scenario B	36	44	120		65	N.P.
Scenario C	20	34	80	105.5	105	All Highway Classes
Scenario D	20	34	80	BF	105	All Highway Classes

NOTE: I - for vehicle and combinations 19.81 m. or shorter
II - for Eastern double and triple trailer combinations
N.P. - Not Permitted
BF - Bridge Formula Governs

4.44 kips = 1 kn.
.3048 m. = 1 ft.

(continued)

TABLE 5. (continued)

DIFFERENTIAL HIGHWAY COSTS, SAVINGS IN TRUCK OPERATING COSTS AND FUEL SAVINGS OVER 20 YEARS, BY HIGHWAY CLASSES AND SCENARIOS

	Total for Highway Systems			Interstate Highways			Farm-to-Market Roads			Other State Highways		
	B/A	C/A	D/A	B/A	C/A	D/A	B/A	C/A	D/A	B/A	C/A	D/A
Additional Highway Costs (in billions of 1979 dollars)												
(1) Pavements	3.69	0.29	1.08	0.81	0.13	0.38	0.64	0.018	0.11	2.24	0.14	0.59
(2) Bridges	1.42	0.008	0.48	0.25	0	0.06	0.44	0.005	0.11	0.74	0.003	0.31
(3) Geometrics	2.86	3.04	3.04	0.94×10^{-3}	1.91×10^{-3}	1.91×10^{-3}	1.79	1.96	1.96	1.068	1.074	1.074
Savings in Truck Operating Costs (in billions of 1979 Dollars)	10.93	13.30	15.15	5.48	7.95	8.87	0.85	0.60	0.71	4.60	4.75	5.57
Fuel Savings* (in billions of gallons)	2.40	2.96	3.47	1.21	1.76	2.03	0.18	0.14	0.16	1.03	1.06	1.28

*Fuel cost savings are included in Truck Operating Costs

TABLE 5. (continued)

SUMMARY OF ADDITIONAL COSTS TO ALLOW FOR SCENARIOS B, C, OR D
(IN THOUSANDS OF DOLLARS)

	Case 1			Case 2		
Item	Interstate Highways	U.S. and State Highways	Farm to Market Highways	Interstate Highways	All Principal Arterials	"All Systems"
Scenario B	939	1,068,212	1,791,562	939	329,139	2,860,713
Scenario C	1,908	1,073,727	1,964,388	1,908	336,581	3,040,023
Scenario D	1,908	1,073,727	1,964,388	1,908	336,581	3,040,023

(continued)

TABLE 5. (continued)

State	Findings
Texas (continued)	future alternatives is the cost required to maintain existing systems, scenario C would be the most viable. The various highway geometric elements affected by turnpike doubles and triples, and the additional costs required for implementation of the scenarios are summarized in the following tables. It was found that air quality and noise pollution would not be significantly affected by any of the scenarios considered.

Highway Geometric Elements	Changes Required Due to Scenario		
Items	B	C	D
1. Stopping sight distance			
2. Passing sight distance	x	x	x
3. Pavement widening on curves		x	x
4. Critical lengths of grades			
5. Lane width	x	x	x
6. Width of shoulder	x	x	x
7. Minimum design for the sharpest turns		x	x
8. Width for turning roadways		x	x
9. Sight distance for at-grade intersections		x	x
10. Median openings		x	x

State	Findings
Utah	With respect to the performance of triples, research showed that for certain combinations an increase in productivity and reduced fuel consumption could be achieved without sacrificing pavement performance. Current Utah overweight fines and overweight permit fees are too low and need upgrading. Additional portable scales are required to improve enforcement.

TABLE 6. SUMMARY OF ESTIMATED COST FIGURES FOR INCREASING WEIGHT LIMIT TO CURRENT FEDERAL MAXIMUM

Arkansas	Interstate	$ 771/lane-mile/year	
	Primary	$3927/lane-mile	Immediate cost
		$2678/lane-mile/year	Annual cost
	Other highways on the state highway system	$1308/lane-mile/year	
Indiana	Flexible pavements on state highway system	$ 215/lane-mile/year	System carrying less than 4000 veh/day (4% trucks)
	All pavements on the state highway system	$ 475/lane-mile/year	Both figures computed by study staff and refer to increased maintenance cost
Tennessee	Interstate (new contracts)	$4000/lane-mile/year	
	State highway system	$3000/lane-mile/year	
Illinois	Interstate	$4662/lane-mile	Increased rehabilitation cost (1st 4 years)
		$ 388/lane-mile/year	Maintenance cost
Mississippi	Federal-aid Primary		The report did not specify if these costs were annual or total
	Corridor system	$14,970/lane-mile	
	Non-corridor system	$30,350/lane-mile	
Iowa	Interstate	$ 620/lane-mile/year	The cost refers to annual construction and maintenance cost increases
	Rural primary	$ 201/lane-mile/year	
	Urban primary	$ 298/lane-mile/year	
	County	$ 18/lane-mile/year	
	City	$ 24/lane-mile/year	

TABLE 7. ADDITIONAL COSTS OF SCENARIOS B, C, AND D OVER SCENARIO A IN TEXAS

Scenarios Compared With Scenario A	Interstate Highways	Farm-to-Market Roads	Other State Highways	Total State Systems
Scenario B				
Pavement maintenance and seal costs	0	0	0	0
Pavement rehabilitation ($/lane-mile)	2026.0	399.2	1660.1	1098.5
Bridges (in millions of 1979 dollars)	245.4	438.2	736.1	1419.2
Scenario C				
Pavement maintenance and seal costs	0	0	0	0
Pavement rehabilitation ($/lane-mile)	336.4	10.9	101.7	86.0
Bridges (in millions of 1979 dollars)	0	4.4	2.9	7.3
Scenario D				
Pavement maintenance and seal costs	0	0	0	0
Pavement rehabilitation ($/lane-mile)	954.5	70.6	580.0	321.4
Bridges (in millions of 1979 dollars)	61.3	11.0	312.6	484.9

TABLE 8. UNIT BRIDGE COST COMPARISONS

State	Highway System	Unit Bridge Cost	Remarks
Arkansas	Primary system	$314,900/bridge	Immediate cost required to upgrade bridge to current Federal standard to allow heavier trucks
	Other highways on the state system	$183,045/bridge	
Mississippi	Federal-aid Primary		
	Of H-10 design	$250,990/bridge	
	Remaining bridges	$455,075/bridge	

CHAPTER 3. OVERALL SUMMARY

All studies performed conclude that an increase in truck weights will result in additional cost per mile or lane-mile; however, there is no uniform agreement as to the magnitude of the costs or the procedure for estimating the costs. Most states used the AASHTO Interim Guide and available truck weight study data. Some used the methodologies contained in the Report 141. Although the methodology used varied, an effort was made in most studies to incorporate local data.

As a group, pavement costs were given more attention and emphasis than bridges and other costs. This reflects, to a large degree, the information and knowledge about the analysis procedures and techniques available for each. As a result, only three states considered bridge effects.

Some areas of concern with respect to change in truck size and weight and related effects remain:

- application of the AASHTO Road Test results without local adjustments;
- lack of detailed data and road life histories;
- analytical techniques for estimating bridge life effects; and
- load shifting procedures with respect to modal shares, truck configurations, commodity flows, and the like.

The study reports provide guidance to the problem areas whose enhanced analytical techniques are needed. These are being documented and will be presented in the future.

In conclusion, the state truck studies, in general, were fostered by state government officials to assess the need for, and results to be expected from, an increase in truck size and/or weight to the maximum allowable federal limits. Only five studies considered size changes and most of these did not consider size with the same level of detail as that for weight changes. It is likely that future efforts may indicate emphasis on increasing the vehicle unit length and, possibly, vehicle width while retaining the

Federal Bridge Formula B, the Federal GVW and axle limits, and vehicle height. It is likely that future efforts may consider such legislative proposals as a national truck and/or state truck route networks and tax policies, which are designed to encourage vehicle configurations, conducive to extending pavement and bridge life.

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APPENDIX A

ARKANSAS

APPENDIX A

ARKANSAS

BACKGROUND OF STUDY

Arkansas is one of the few states that retained the 1956 truck load limits after passage of the Federal Aid Highway Amendments in 1974. It is one of the "delta states" lying within the Mississippi valley. The deltaic soils of Arkansas are cited for causing enormous and costly problems in highway and bridge design, construction, and maintenance.

With respect to increased truck weights to 80,000 lb GVW, a compromise was reached on March 4, 1981. The compromise, HB 964, provides that haulers of Arkansas agricultural products only, including poultry and livestock, may apply to the Highway and Transportation Department for individual permits for GVW of 80,000 lb. The Highway and Transportation Department has the authority to approve or deny each request and to approve routes. This compromise is effective for one year, or until July 1, 1982.

The following is a summary of the report prepared by the Arkansas State Highway and Transportation Department regarding the effect of increased truck weights on highways, roads, and streets in Arkansas. The report was prepared before the compromise was reached.

Title: Response to Interim Study Proposal 79-34 by Representative Doug Wood Regarding the Effects of Increased Truck Weights on Highways, Roads and Streets in Arkansas

Date of Publication: December 12, 1980

Performing Organization: Arkansas State Highway and Transportation Department

Purpose of Study: To assess the maintenance costs on Arkansas highways related to the change in truck weight laws

Scope: The report covers the economical aspects related to the changes in truck sizes and weights. The economical aspects include

- pavement costs, and
- bridge costs.

The findings are given in terms of three highway systems:

1. Interstate system,
2. Primary system, and
3. Other highways on the state highway system.

Methodology: There is no direct technical research on truck size and weight issues contained in this report. The results and findings are based on a review of the literature, including technical reports. Local pavement design data were referenced in the computation of remaining service life. In predicting the remaining service life of pavement, the Asphalt Institute Manual Series #17, "Asphalt Overlays and Pavement Rehabilitation," was used.

Findings: The additional costs related to increasing truck loads can be summarized as follows:

Interstate System - Pavement life would be reduced by approximately one-tenth. An annual expenditure of $2.0

million in addition to the regular $21 million would be required in order to maintain the integrity of the 530-mile system.

Primary system - Pavement life would be reduced approximately by 1/3 on the 5203-mile system. An additional $44 million for roadways and $414.4 million for bridge structures (1,316) would be immediately required to meet the design criteria corresponding to the 80,000-lb GVW limit. Also, an additional $30 million/yr would be necessary to maintain and improve the remainder of this system. This is in addition to $191 million in immediate expenditures required to improve 2,750 miles of primary system to adequately accommodate the current legal load of 73,280 lb.

Other highways on the state highway system - Pavement life would be reduced by approximately 1/2. An estimated additional $27 million/yr would be required to assure continued serviceability for the 10,360 miles of secondary and non-federal-aid highways on the state highway system. An estimated $476.1 million would be required to upgrade 2,601 bridges.

Total highway system - (funds required to accommodate the change in GVW)

- Initial expenditure - $ 934.5 million
- Annual expenditure - $ 59.0 million

SUMMARY

The major concerns considered in the report include:

- pavement life and maintenance,
- bridges and highway structures,
- safety, and
- energy conservation.

Since a change in size was not an issue, no attention was given to operational issues such as geometric design criteria for heavier (usually larger) trucks.

All the cost figures given in the findings are based on a technical report, A Study of the Effects of Proposed Weight Limit Increase on Arkansas Highways, prepared by the Division of Planning and Research of the Arkansas State Highway and Transportation Department. In that report, it is stated that the percentages of loss of remaining pavement service life due to increased loads are 35.4 and 53.6 percent for primary and secondary highways, respectively. However, based on actual data from Florida and Texas instead of assumptions[1] used by the authors of the Arkansas paper, these values were computed to be approximately 32 and 41 percent, respectively. The discrepancy is probably a result of using the maximum GVW instead of the average GVW in the computations. Therefore, the estimated additional highway maintenance costs for accommodating heavier trucks may be higher than the actual amount since it is unlikely that all trucks will carry the maximum gross weight allowable.

[1] Truck weight data on Texas and Florida highways were used to compute the average truck weight; and the design indexes given in the Manual Series #17 published by the Asphalt Institute were also used.

No reference was made to the operation of doubles or other specific truck classifications.

The study was basically concerned with the direct cost effects on pavement and bridge structures without reference to any benefits resulting from allowing heavier trucks on state highways.

APPENDIX B

CALIFORNIA

APPENDIX B

CALIFORNIA

BACKGROUND OF STUDY

The operation of triple trailers in California was requested by representatives of the motor carrier industry in 1968 and again in 1969. Triple trailer operations are permitted on designated routes in some western states, including Nevada and Oregon which border on California. Several bills regarding the operation of these longer units with increased load limits on the Interstate Highway System have been introduced at the Federal level over the past few years.

In view of the above, the Assembly Transportation Committee of the 1971 California Legislative Session requested the Department of Public Works, in cooperation with the California Highway Patrol, to conduct a study of the operation of triple trailers and truck tractor combinations. The study included a road test of triple trailers under various conditions so that an assessment of their effects on operational aspects and geometric design could be made.

The following is a summary of the report regarding the demonstration.

Title: Triple Trailer Study in California

Date of Publication: March 1972

Author(s): Department of Public Works, State of California

Performing Organization: Business and Transportation Agency, Department of Public Works, and the California Highway Patrol

Purpose of Study: To study the effects of triple trailers on traffic safety, traffic congestion, geometric design standards, and maintenance of streets, roads and highways in California.

Scope: The report discusses the demonstration of a triple trailer operation in California. The demonstration took place in 1971 over approximately 1,800 miles. The mileage included multilane rural highways, metropolitan area freeways, and local roads between truck terminals and major highways. The factors considered in the test included

- stopping distance,
- backing,
- acceleration,
- off-tracking, and
- environment.

Methodology: The demonstration, which involved a truck combination operated by one driver, included operations during off-peak periods on metropolitan freeways and local roads. Two different GVWs were used to test the performance of triple trailers.

Findings:

A. Operational Issues

1. Stopping distance: Stopping distances were all within Federal and State standards. The triples loaded with 90,000 lb stopped in approximately the same distance as triples loaded with 76,800 lb. Triples were found

to stop safely in distances less than those required for doubles.

2. Backing: Backing distances varied from 47 ft to 65 ft. When placed on a 60-ft radius curve, the triple was able to back approximately 30 ft. The backing ability was adequate to allow the triple to negotiate around obstacles used during the test.

3. Acceleration: Ability of large-engine tractors to accelerate was slightly above average when compared with trucks of equal weight/horsepower ratio. In the passing maneuver, triples required more time and distances than doubles.

4. Off-tracking: The maximum legal size tractor-semitrailer combination operating in California has worse off-tracking characteristics than the triples.

5. Environment: No exhaust smoke was recorded as visible at any time. The noise level did not exceed legal limits.

6. Operation on grades: The 475 hp tractor performed better on grades pulling triples with 90 kips than the 335 hp tractor pulling legal loads.

7. Operation on local roads: Triples were found to have problems common to all large tractor-semitrailer combinations:

   (a) use of extra lanes when turning;

   (b) failure to activate signal detectors in left-turn pockets because triples did not use turn pockets;

(c) running over curbs, channelization, and violating double yellow stripes; and

(d) use of an inordinate amount of signal time when turning at an intersection.

With respect to the above, triples led other vehicles in operating in the intersection during a red phase signal indication. Since triples are longer than most left-turn pockets, they often used a second lane when anticipating a turn.

8. Operation on metropolitan area freeways: Triples did not create measurable congestion but caused conflicts with merging traffic due to their overall length. Merging conflicts resulted in excessive speed adjustment and lane changing.

9. Operation on multilane rural highways: The rear of the trailer "whipped" from side to side for a lateral movement recorded to be more than 8 inches. The magnitude of the lateral movement and frequency of the whipping action were found to increase with an increase in speed.

B. Economic Issues

1. From a general freight standpoint there would be little economic advantage in using triples with a 76,800-90,000 lb GVW bracket.

2. Triples provide economic advantages as the maximum GVW is increased to 115,000 lb. The amount of the estimated decrease in total per hundred weight cost will vary in

the range from one to ten percent, depending upon the shipment weight, route, and length of haul.

3. Some rail traffic is expected to divert to highway transportation, but the amount of diversion is limited.

4. It cannot be predicted whether or not the operation of triples would reduce the total number of trucks on highways.

C. Road System Costs: If the GVW of triple trailers remains 76,800 lb, there would be no reduction in bridge or pavement life; indeed, there could be some increase in life since axle loads could conceivably decrease. If GVW were increased to 90,000 lb, no reduction to pavement or bridge life would be expected, if enforcement were exercized.

D. Enforcement: Enforcement is required to prohibit truckers from overloading the doubles and triples. It would be necessary to develop and execute (1) authorization (permit) procedures and (2) enforcement to regulate the operation of triple trailers.

SUMMARY

The demonstration of triple trailers in California was carefully and thoroughly planned and implemented. The important operational aspects were well covered in the demonstration. The results and findings of each aspect are useful in assessing the effects of triples in California and elsewhere. However, the following aspects require some attention:

- magnitude and direction of lateral movement of the trailers during emergency braking;
- geometric design of rest areas to accommodate triples;
- blockage of traffic signs;
- lane changing operations, i.e., time and distance required;
- passing by other vehicles, i.e., other vehicles passing triples; and
- operations on non-multilane highways.

APPENDIX C

ILLINOIS

APPENDIX C

ILLINOIS

BACKGROUND OF STUDY

Illinois is one of the few states that still retain the 1956 Federal maximum limits. In a public meeting that was held by the U.S. Department of Transportation (DOT) for the National Truck Size and Weight Study, the Illinois Secretary of Transportation, John Kramer, presented his view on the uniform size and weight limits as well as on the issue of raising the size and weight limit to 80,000 lb maximum GVW. The paper, representing his testimony, does not provide specific technical details or data; nevertheless, it does lend insight into the position of the Illinois DOT with respect to the truck weight issue.

Title: Testimony by John D. Kramer, Illinois Secretary of Transportation, to the U.S. DOT Truck Size and Weight Study Public Meeting

Date of Publication: July 13, 1979

Author: John D. Kramer

Performing Organization: Illinois Department of Transportation

Purpose of Study: To outline the Illinois Department of Transportation position in opposition to increasing truck GVW to 80,000 lb.

Scope: Covers Illinois DOT's position regarding uniformity in national size and weight limits, the raising of truck weight limits to 80,000 lb maximum GVW, the effects of current national size and weight limits on highway pavement, and the highway funding question.

Data Source: AASHO Road Test and Illinois loadometer and traffic count data

Methodology: The Illinois DOT estimates the reduction in pavement service life due to higher weight limits from its loadometer and traffic count data. AASHO Road Test results also aided in the estimation.

Findings: The Illinois DOT finds that an increase in maximum gross truck weight from 73,280 to 80,000 lb would reduce interstate pavement service life in Illinois by at least 17 percent. Due to the need to increase pavement thickness to accommodate heavier trucks, Interstate rehabilitation cost would also be driven up by $36 million over the next four years. In addition, the Interstate maintenance cost would also rise nearly $3 million annually over present levels as a result of heavier trucks. At present, Federal funding available to Illinois under the 3R program amounts to only $7 million annually, while Illinois' own estimate of Interstate rehabilitation needs for the 185 miles of deteriorated pavement under the current truck weight law is about $275 million over the next four years. In addition, the failure to meet new federal Interstate maintenance standards may also cut highway apportionments by 10 percent. The non-Interstate system is even less capable of carrying the heavier vehicles and would be even more susceptible to deterioration. Secretary Kramer noted some potential safety problems that might result, such as more accidents due to the decreasing size of automobiles, and less vehicle stability and more driver fatigue due to higher steering axle weights.

The Illinois DOT fully endorses the concept of uniform truck weight limits nationwide; however, it opposes the concept of Federal government mandating standards for states. Further, if the Federal government does mandate Federal limits for all states, the Federal government should increase funding or funding flexibility to help states pay for the increased pavement and structural damages carried by heavier trucks.

SUMMARY

Since the paper represented a brief position paper presented at the U.S. DOT public meeting, the Secretary did not provide insight as to the methodology, the assumptions, or pertinent data used to arrive at the estimates.

The paper presented aspects of the direct costs associated with increasing size and weight limits and did not reference any benefits——direct or otherwise. It is not clear from the material reviewed whether bridge effects were considered in the costs.

Based on highway lane-mileage data, the cost figures obtained in the Illinois study were converted to a cost per lane-mile. The results show that (assuming that tollroads on the Illinois interstate system are also included in the Illinois DOT's cost estimate) rehabilitation cost in the first four years would be $4,662 per lane-mile and the increase in maintenance cost would be $388 per lane-mile. These figures, when compared with those prepared by Iowa, appear to be very high. The Iowa study estimated construction and resurfacing costs to increase by $32,000 per mile of a 4-lane interstate highway or $800 per one lane-mile, and maintenance cost to increase by $13.5 per one lane-mile. Although the Iowa study was released in 1978 and the Illinois study in 1979, the difference represents a range of values for comparable highway cost elements. The difference may be attributable to estimating procedures and data which were not available for replication. The importance of the comparison rests with capturing similar estimates prepared by other states to gain a perspective of the positions taken by the various states and the data presented as supporting documentation for that position.

APPENDIX D

INDIANA

APPENDIX D

INDIANA

BACKGROUND OF STUDY

Indiana is one of the states that changed their weight laws recently. Before it adopted the Federal Aid Highway Amendments of 1974 weight limits, it used 18,000 lb SAL, 32,000 lb TAW, and 73,280 lb GVW.

Research into the effects of increased truck weight on pavements and bridges was conducted by a Joint Highway Research Project at Purdue University. The findings of the evaluation of maintenance costs related to increased loads given in the reports are summarized as follows.

Title: Effects of Raising Load Limits on Pavements and Bridges in Indiana

Date of Publication: December 17, 1979

Authors: Eldon Y. Yoder, Benjamin Colucci-Rios, John Fraczek, and James A. Skees

Performing Organizations: Purdue University and the Indiana State Highway Commission

Purpose of Study: To determine the economic impact on maintenance costs on Indiana highways if load limits were to be raised from those in the 1956 Act to those authorized in the 1974 Federal Aid Highway Amendments.

Scope: The study is subdivided into two parts. Part I deals with the effects of increased load limits on pavement costs, and Part II deals with the effects of increased axle load limits on bridge costs. The report emphasizes maintenance costs alone.

Data Source: The data used in this research include the following items:

- road life records of the Indiana State Highway Commission,
- truck weight information from the weight stations, and
- soil information and performance data on file in the Joint Highway Research Project offices.

Methodology: The evaluation of increased pavement maintenance costs used the NULOAD computer program developed for the Federal Highway Administration (Refs 27 and 28). The computer program evaluates the effect of legal load limit changes on maintenance costs for flexible, rigid, and overlay pavements. Figure D.1 shows the basic methodology followed in the analysis. Traffic data under the present and increased load limits were coupled with climate, soils, pavement property data, and the AASHTO equations to predict the pavement structure life cycle performance (Ref 30).

In the evaluation of bridge cost, the study concentrated on a review of the literature. The NCHRP 141 methodology for evaluating existing bridges with respect to possible load increases was used extensively.

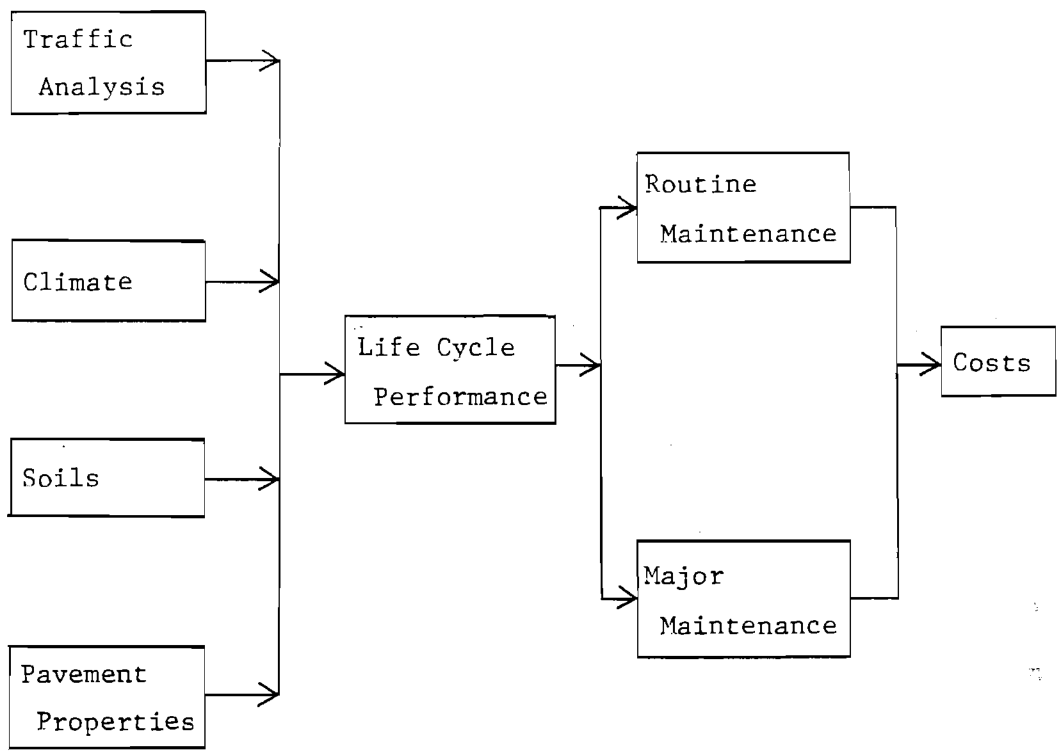

Fig D.1. Methodology of cost analysis.

Findings in the studies of Goodpasture (Ref 31), Heins (Ref 32), Kosten (Ref 33), Agarwal (Refs 34, and 35), Moses (Ref 36), and Cudney (Ref 37) provided some criteria for the analysis.

Findings:

Part I. Effects of Increased Loads on Pavement Maintenance Cost.

The estimates of increased costs are shown in Table D.1. These values are presented for two cases:

A. resurfacing costs assuming no appreciable increase in routine costs in the interim, and

B. resurfacing costs along with accelerated routine maintenance costs.

The report concluded that the Interstate highways have the highest pavement maintenance cost per lane-mile because the Interstate System carries the highest percent of heavy trucks in the State. Overweight trucks decrease pavement life as well as increase the routine maintenance costs (see Table D.1). The annual increased costs for county roads is $215/per lane-mile. The overall average for all pavements on the state system is approximately $476/lane-mile/yr.

. The report also concluded that it would be difficult "to enforce the weight limits adopted from the Federal Aid Highway Act of 1956 since three out of the four states that surround Indiana have adopted those weight limits established by the Federal Aid Highway Amendments of 1974."

TABLE D.1. ESTIMATED INCREASED ANNUAL PAVEMENT MAINTENANCE COSTS*

Road Type	Increased Costs (Millions Dollars) Resurface Only	Resurface Plus Routine Maintenance
Interstate	2.88	3.15
U.S. and State Routes		
ADT > 4,000	3.29	3.68
ADT < 4,000	4.50	5.41
TOTAL	10.67	12.24

*NOTES: (1) All cost values are increased costs resulting from increased load limits.

(2) Costs based on 1978 dollars.

(3) Asphalt concrete price of $25 per ton in-place. Resurfacing costs increase in direct proportion to asphalt concrete costs.

In addition, one state is protected under the "grandfather clause" which permits loads in excess of those specified by the Act."

Part II. Effects of Increased Loads on Bridge Maintenance Costs.

The costs associated with the increased weight limits are classified as upgrading costs and routine maintenance costs.

A. Upgrading costs are directly related to the strengthening of existing structures, replacing structures that cannot be adequately strengthened and repairing or replacing structural elements which fail prematurely due to fatigue.

Most bridges in the United States are designed in accordance with AASHTO specifications. AASHTO suggests the following permissible overstress factors:

reinforced concrete, flexure = 0.35, shear = 0.3

structural steel, flexure = 0.25, shear = 0.23

prestressed concrete, flexure = 0.12, shear = 0.30

A bridge with an overstress factor less than the permissible overstress factor is considered to be serviceable. The increase in axle loads and GVW produces an overstress factor less than 0.11. Since the factor is smaller than any of the permissible overstress factors, the report concluded that "bridges designed to safely carry the present load limits (1956 limits) are adequate to carry an 11 percent increase in live load with no additional strenthening." Thus, raising maximum loads from 1956 limits to the 1974 limits will produce no strength-related upgrading costs in structures designed for 1956 limits.

The damage due to fatigue is not immediate and is typically corrected by periodic major rehabilitation.

Based on the NCHRP 141 findings, the report stated that "the proposed 11 percent weight increase will have no effect on fatigue related costs."

B. Routine load-related maintenance costs can be expected to be associated with concrete bridge deck deterioration. There is no evidence to suggest that deck deterioration is uniquely associated with loads; nevertheless, increased loads can cause widespread distress to decks.

Based on NCHRP 141 suggestion (i.e., structure maintenance costs are linearly related to maximum permitted GVW), the estimated structural maintenance costs range from $2 to $3 million per year.

SUMMARY

The Indiana report presents a very thorough study on the effects of increased loads on pavements. The researchers used many standard procedures to arrive at the estimate of the increase in maintenance costs resulting from heavier loads. AASHO Road Test findings, NCHRP Report 141, and the NULOAD program were used in the study. The authors considered the effects of soils, climate, and pavement properties on pavement performance. Most studies conducted by other states did not consider climatic or other environmental conditions nor did they consider the range of different pavement types. The Indiana study presented a more detailed documentation of the study methodology, which is a noteworthy aspect of the overall study.

With respect to the bridge cost analysis, a couple of points may be worth mentioning. The report states that "assuming that axle spacings remain unchanged, and 11 percent increase in axle loads and GVW would produce an overstress factor of less than 0.11. Since this factor is smaller than any of the specified permissible overstress factors, it can be concluded that bridges designed to safely carry the present load limits are adequate to carry an 11 percent increase in live load with no additional strengthening." This conclusion may not consider illegal overloading beyond the new weight limits. The AASHTO bridge design manual suggests .012 for the flexural overstress factor for prestressed concrete. Any overweight trucks operating on Indiana bridges may make the prestressed structure unsafe.

This analysis did not include other economic aspects such as fuel savings, reduction in operation costs, and the costs related to more severe truck-related accidents due to increases in truck weights.

APPENDIX E

IOWA

APPENDIX E

IOWA

BACKGROUND OF STUDY

The State of Iowa is one of the states close to the Mississippi River that had retained the 1956 Federal maximum size and weight limits until very recently. The State of Iowa has conducted a study on the size and weight issues, the results of which were presented in three separate reports. The reports deal with (1) the implication of allowing heavier loaded trucks, (2) various aspects of allowing the heavier loaded trucks to operate within the State, and (3) the size and weight issues in Iowa in 1978. Each of the reports is reviewed separately.

Title: Implications of Allowing Heavier Trucks in Iowa

Date of Publication: January 10, 1978

Author: Jim Charlier

Performing Organization: Office of Policy Analysis, Planning and Research Division, Iowa Department of Transportation

Purpose of Study: To address the question, "What would allowing heavier truck weights mean to Iowa?"

Scope: The following topics were covered:

- truck length,
- pavement wear costs,
- designated routes/embargos,
- 60-ton trucks in Iowa, and
- safety.

Data Source: AASHO Road Design Data was used for pavement analysis. For the safety issue, opinions of the Teamster's Union, the insurance industry, and the National Highway Traffic Safety Administration were considered. National and Iowa accident data, as well as truck weight survey data, were examined.

Methodology: The report reviews various aspects of allowing heavier trucks in Iowa. The report did not discuss in any detail how some figures were computed, though it is evident the AASHO Road Test results were very much utilized in the pavement part of the study.

Findings: The Iowa study utilized the AASHO Road Test results to estimate the effect of change in GVW on pavement damage. The example shown indicates that the increase in pavement damage clearly outpaces the increase in GVW change. In a typical Interstate Highway, the study found that allowing 20,000/34,000 lb axles (single and tandem, respectfully) would increase the cost for construction and surfacing of one mile of 4-lane sections by $3200, and increase maintenance cost by $54/mile.

The report recommended that "significant weight increases ... should be accomplished only after a carefully controlled transition period during which highway upgrading necessary to accept the changes is funded and is performed." The report also recommended that "if weight increases are adopted, highway use taxes should be increased for the heavier classes of commercial vehicles during such transition period to defray the costs of improvements to the highway system."

Regarding steering axle, the report found that there is no problem with steering as long as the load rating of the steering axle is not exceeded. Both the steering axle and the tires are designed to carry specified loads, and such loads should not be exceeded. The study anticipated the following direct impacts of increased truck weights:

Safety - Annual Reduction in Number of Accidents

Fatal	Injury	All
1	14	49

Wear - Annual Construction and Maintenance Cost Increase for All Systems

Roadway	Structure	Total
$6.5 million	$0.5 million	$7.0 million

Energy - Annual Fuel Savings, All Systems: 7.8 million gallons

Truck Travel - Annual Vehicle Miles of Travel Reduction 52 million miles: 2.2 percent of total truck travel

SUMMARY

The report is one of the earlier results of an Iowa size and weight study. Several of the cost figures appearing in this report were later modified; therefore, except for technical information, later reports provide more current cost data.

Title: Final Technical Review: Allowing Heavier Trucks in Iowa

Date of Publication: March 7, 1978

Author: Jim Charlier

Performing Organization: Office of Policy Analysis, Planning and Research Division, Iowa Department of Transportation

Purpose of Study: A final technical review of the implications of allowing heavier trucks in Iowa

Scope:

- Increased pavement wear cost,
- benefits and benefit/cost ratios,
- review of cost responsibility methodology and short falls,
- travel forecasts,
- options for increased truck taxes,
- vehicle length, and
- intermodal competition.

Data Source: Primarily Iowa data

Methodology: In calculating pavement wear cost, the study made the following assumptions:

- For interstate and primary highways, the original slab plus one resurfacing is assumed in calculating pavement wear cost for both portland cement concrete (PCC) and asphaltic concrete (AC) pavements.
- For county roads the actual pavement condition was used.

- For city roads the original slab plus one resurfacing is assumed for PCC pavement as well as AC pavement.

For benefit/cost ratios, the study staff defines benefit to be savings in truck operating cost due to increased capacity. The net benefit is assumed to be

Net Benefits = Lower trucking costs due to fewer trips - higher cost per mile due to heavy trucks.

The study staff also employs the "incremental cost concept" to determine the cost responsibility for different classes of highway users. The "incremental cost concept" assigns responsibility for each element of highway cost to the vehicles which occasion the cost.

In allocating construction costs, the following assumptions were cited:

Right-of-way (ROW) - to all vehicles on basis of VMT

Grading - 8.5% to trucks, 91.5% to all other vehicles based on VMT

Pavement - 4.5-in. thick pavement to all vehicles on basis of axle miles - remaining costs allocated to trucks

Bridges - Primary: 25% to trucks, 75% to all vehicles on basis of VMT

County and city: 15% to trucks, 85% to all vehicles on basis of VMT

The following amortization periods were assumed:

ROW	100 years
Grading	50 years
Bridges	50 years
Pavement	20 years

No information was available as to discount rate employed or discount concept (e.g., present worth or annual cost) used in computing B/C ratios. To forecast growth in motor vehicle travel and the impact on increased pavement wear costs, a simple extrapolation of past trend was assumed. The last part of the report is concerned with rail/truck competition. The rail/truck competition analysis seems to be based on comparisons of the percent of each commodity currently shipped by rail or truck.

Fingings: With respect to raising vehicle size and weight limits to 20,000 lb single axle/34,000 lb tandem axle, the report has the following findings:

Type of Road	Annual Construction and Maintenance Cost Increase
Interstate	$ 1.8 million
Rural Primary	3.4 million
Urban Primary	1.0 million
County	3.2 million
City	0.6
TOTAL	$10.0 million

The benefits for different highway classes were estimated as follows:

System	Benefits
Primary	
Interstate	$ 17.3 million
Other Primary	$ 19.4 million
Total Primary	$ 36.7 million
Secondary	$ 2.6 million
Municipal	$ 2.0 million
TOTAL	$ 41.3 million

Benefit/cost ratios were estimated as follows:

System	Benefits/Costs
Primary	
Interstate	9.8
Other primary	4.4
Total Primary	5.9
Secondary	0.8
Municipal	3.5
TOTAL	4.2

Concerning rail/truck competition, the study found that due to the inherent advantages and differences between rail and truck an increase in truck size and weight limits to current Federal maximum limits would not have a major impact on the railroads operating in the State.

SUMMARY

Because the report contained only the important findings of the Iowa study, the methodologies were not readily apparent or of sufficient detail to replicate the findings. Nevertheless, the study covered many of the truck size and weight issues. and contained some explicit findings.

Title: 1978 Iowa Truck Issues

Date of Publication: March 21, 1978

Author: Jim Charlier

Performing Organization: Office of Policy Analysis, Planning and Research Division, Iowa Department of Transportation

Purpose of Study: To review the important truck issues before the Iowa Legislature in 1978

Scope: The paper reviewed two important issues.

1. Funding truck and auto cost responsibility short falls, and
2. Allowing heavier trucks in Iowa.

Methodology: Since this paper is a summary of the important findings of the Iowa size and weight study, no methodology is presented.

Findings: On the issue of allowing heavier trucks in Iowa, the Iowa study found the following alternatives to be the most favorable.

- Increase truck weights to 20/34/80 on designated roads;
- Do not increase truck length and restrict trailer length to 45 ft;

- Adopt the Federal modified bridge formula;
- Leave current law(s) on seasonal embargoes unchanged; and
- Increase registration fees 13 percent and collect and additional 2.4¢ fuel tax from trucks registered at 20 tons and above.

SUMMARY

The Iowa study is one of the more complete studies reviewed. The results of the study, particularly the cost figures, are comparable with those obtained in the Indiana study. The following is the converted annual construction and maintenance cost increase based on the Iowa study:

Type of Road	Annual Construction and Maintenance Cost Increase	Annual Construction and Maintenance Cost Increase/Lane-Mile
Interstate	$ 1.8 million	$ 620/lane-mile
Rural Primary	3.4 million	201/lane-mile
Urban Primary	1.0 million	298/lane-mile
County	3.2 million	18/lane-mile
City	0.6 million	24/lane-mile

With respect to the cost figures provided, it could not be determined if the values reflected current 1978 dollars or another base; therefore, caution is warranted in the use of these figures.

The impact of heavier trucks on highway bridges was not comprehensively presented.

APPENDIX F

KENTUCKY

APPENDIX F

KENTUCKY

BACKGROUND OF STUDY

The State of Kentucky was among the first of the states along the Mississippi River to adopt the current Federal maximum limits. The Bureau of Highways of the Kentucky Department of Transportation has published a number of reports dealing with the effects of heavy and large trucks on highways. The reports concentrate on the various aspects of pavement design and do not consider in any detail other areas. These reports are herein reviewed.

Title: Fatigue Damage of Flexible Pavements Under Heavy Loads

Date of Publication: April 1979

Authors: James H. Havens, Robert C. Deen, and Herbert F. Southgate

Performing Organization: Division of Research, Bureau of Highways, Department of Transportation, Commonwealth of Kentucky

Purpose of Study:

- To develop damage factors for given load groups based on concept of equal work,
- To compare the results with those in the 1972 AASHTO Interim Guide, and
- To evaluate the effect of the distribution of loads on pavement damage.

Scope: The report covered seven axle groups, namely, two-tire and four-tire single axles, tandems, triaxles, and four-axle, five-axle, and six-axle groups. Damage factors for AASHO Test Vehicles were developed, and the results compared with the 1972 Interim Guide. The effect of the distribution of loads on a given vehicle was also evaluated.

Data Sources: AASHO Road Test Results, Kentucky truck weight data

Methodology: The author used a modified Chevron N-layer computer program which has the capability of calculating the "work" done by the load on a given axle group. The Chevron program was modified to perform the strain energy density calculations for specified depths and radial distances from the center of the load. Superposition principles were applied and layer thickness of the asphaltic concrete pavement sections used at the AASHO Road Test were employed in the analysis. The effect of load distribution on pavement damage was also evaluated using the same program by varying the load distribution in a vehicle.

Findings: Previous analysis indicated that the location of the most severe strain is under the center of a single tire or the center of the inside tire of a dual arrangement and at the top of the subgrade; however, strain energy density calculations indicate that the most severe location is at the bottom of the asphaltic concrete layer beneath the outer edge of the inside tire. Thus, the location is shifted from the center of the inner tire to the outside edge.

Damage factors computed by the strain energy method were compared with AASHO results, and presented in the report. It was also found that additional load is placed on the front axle when the kingpin assembly is shifted forward of the center of the tandem of the tractor. Weight shifted to the front axle can be two times more damaging than that placed on the tandem axles. Approximately 80 percent of the three-axle tractors have the kingpin assemblies located forward of the center of the tandem. The pavement life could be extended considerably if a tractor used a tri-axle group instead of a tandem group. If the proposed GVW is raised to 120 kips, the authors recommended that the configuration of the vehicle should be specified to minimize the fatigue damage.

SUMMARY

This paper is well-written and the research methodology as well as the findings are clearly presented. It has contributed toward knowledge and understanding of the interaction between truck loads and fatigue damage of flexible pavement, as well as of the effect of load distribution on pavement damage.

Title: Truck Design and Usage and Highway Pavement Performance
Date of Publication: October 1979
Authors: Robert C. Deen and Herbert F. Southgate
Performing Organization: Bureau of Highways, Department of Transportation, Commonwealth of Kentucky

Purpose of the Study: To inform the public of the nature and background of the problem of truck design and usage, highway pavement performance, and other factors related to an increase in truck weight limits.

Scope: The paper discusses in detail truck design and usage and the principles of pavement design. Other truck weight related factors and issues such as bridges, operating costs, safety, other economic considerations, and enforcement were only briefly introduced.

Date Source: AASHO Road Test Results, Kentucky truck weight data

Methodology: The equivalent axle load concept was used to calculate the damage factors caused by different vehicle types on the highway pavement. Elastic theory and work concept were used to predict the number of ESALs a given pavement system can support over its design life. On other size and weight issues, such as bridge effects, operating cost, and safety, the report provided little, if any, information.

Findings: The mechanics of pavement performance in response to vehicular loadings is "reasonably well understood" and a reliable mathematical model has been developed. However, "a comprehensive modeling of the economic factors has not been satisfactorily accomplished." The authors hoped that the highway cost allocation studies could provide more insight into this subject.

The report indicates through mathematical models and calculations that pavement damage factors increase more rapidly than incremental increases in payload; however, this will vary with vehicle type. Hence it was recommended that "statutes dealing with limitations on truck weights might be reviewed for consistency with the mechanics of pavement performance." The authors also recommended that statutes be devised which would encourage the use of those vehicles which are less damaging to highway pavements.

Finally, the authors encouraged wide dissemination of the information contained in the report to convince the public of the importance of vehicle design and the importance of vehicle load distribution to highway life.

SUMMARY

The report is well-written, particularly the discussions on pavement design principles and truck design and usage. The later sections dealing with bridges, safety, and other economic factors are not presented in any detail.

In the report, figures showing that pavement damage factors increased at a faster rate than payload for all vehicle types studied are worth noting. Hence the report states that "costs of increased maintenance increased at a much faster rate than the economic benefits from increased payload." This statement, however, may lead to misleading conclusions. While the statement may be true for increase of payload at any level, it is also true that within certain levels, the economic benefits in absolute terms may still be higher than the cost of increased maintenance; such was demonstrated by the findings in the Texas study where increases in weight limit yield substantial economic benefits. It would be of interest to compare the methods used in computing maintenance costs; however, the Kentucky methodology was not included in their report.

Title: The Effect of Truck Design on Pavement Performance

Date of Publication: January 1980

Authors: Robert C. Deen, Herbert F. Southgate, and Jesse G. Mayes

Performing Organization: Division of Research, Bureau of Highways, Department of Transportation, Commonwealth of Kentucky

Purpose of the Study: To assess the effect of truck design on pavement performance

Scope: The first part of the report summarizes the development of classical equations for superpositioning of stresses, strains, and deflections under various load configurations. The concept of work or strain energy is introduced and the controlling equations for strain energy density are presented. The second part of the paper covers truck design and usage, the principles of pavement design, and other issues and factors related to the increase in truck weight.

Data Source: AASHO Road Test Results, 1976 W-6 Tables for Kentucky

Methodology: The Kentucky DOT uses the modified Chevron N-layer program for calculations of work strain in pavement in response to vehicle loadings. The second part of the report was informative and qualitative.

Findings: The strain energy concepts permit modifications to thickness design systems to account for the net effect of all components of strains and stresses. Previously, however, pavement thickness design systems have been developed using a single component of strain at the bottom of the asphaltic concrete layer or at the top of the subgrade. The study also found through inspections of tandem axle suspensions on semitrailer trucks that most tandem groups do not distribute the load equally to the axles. Using pavement structures identical to those in the AASHO Road Test and the W-6 Table for Kentucky, it was found through preliminary analyses of tandem groups for 3-S2 vehicles that there is a 40 percent increase in EAL over that calculated for EAL assuming the total load on each tandem group had been uniformly distributed to the axles. Other findings and conclusions are similar to those contained in the Kentucky DOT Report 530, entitled "Truck Design and Usage and Highway Pavement Performance."

SUMMARY

The pavement part of the report is interesting and well written, but other aspects are not as complete. The finding that actual pavement damage from 3-S2 vehicles in Kentucky was about 40 percent higher than that calculated, assuming that total loads on tandem groups are equally distributed, is rather significant. This would mean that assumptions of equal distribution of total loads over tandem groups could underestimate pavement damage by 40 percent. This finding supports the need for developing a vehicle weight shifting methodology that could predict axle weight distribution accurately.

The Kentucky study emphasized the weight aspect and not size, and stressed pavement effects with little, if any, attention devoted to bridge structure, geometric design, of other related highway elements. Their findings on the pavement wide are noteworthy.

APPENDIX G

MISSISSIPPI

APPENDIX G

MISSISSIPPI

BACKGROUND OF STUDY

The Mississippi State Highway Commission, as early as 1976, prepared a special report on the highway weight limit for the Mississippi Legislature as directed by Senate Resolution Number 31.

Title: A Special Report on the Highway Weight Limit

Date of Publication: November 1976

Author: Mississippi State Highway Commission

Performing Organization: Mississippi State Highway Commission

Purpose of the Study:

- To study the state's highway system with regard to movement of goods, safety of all motorists, stress and damage to roads and bridges, and applicable enforcement of increased weight limit; and
- To make specific recommendations to the Mississippi Legislature as to an acceptable and practically enforceable weight limit.

Scope: The report covers the following areas

- Overall economy situation in the state;
- Goods movement in the state;
- The positive effects of increasing the allowable truck weights on the movement of goods and the state economy;

- The negative effects of increasing the maximum allowable truck weight including pertinent factors of highway pavement and bridge design, stress, and damage caused by increased loading and the safety of the motoring public;
- A review of the state highway system, and additional reconstruction and maintenance funds that will be required immediately; and
- Weight limit enforcement.

Data Source:

- State economic data;
- AASHO Road Test Results;
- "Commodity Flow Analysis" conducted by Dr. William Rush of Mississippi State University. (The study is based on motor carrier waybill sample.)
- Data obtained from a 1973 Federal Highway Administration Truck Commodity Flow Study; and
- Special weight limit questionnaire conducted by the Mississippi Research and Development Center in 1976.

Methodology: For pavement design, the AASHTO Design Method contained in the AASHTO Interim Guide was used. For bridge design, the AASHTO Standard Specifications for highway bridges were followed. To obtain the PSI ratings, the Mississippi study used the procedure set by the Federal Highway Administration in the National Highway Functional Classification and Needs Study Manual and the 1976 National Highway Inventory and Performance Study Manual.

The AASHO Road Test results were used to establish the relationship between performance of pavement and traffic loading.

Regarding the aspect of heavier trucks and highway safety, findings from the National Highway Traffic Safety Administration were used. The same approach was used for analysis of the noise issue. It was stated that the additional cost of maintaining highways from increased weights has not been determined from the records. The Mississippi State Highway Department used engineering judgement and studies conducted by other states to determine the increase in percentage of maintenance activities.

Type of Maintenance	Percentage
Bituminous Surface	60
Concrete Surface	50
Gravel or Shell Surface	10
Shoulder and Approach	45
Drainage	10
Roadside	6
Structure	30
General Physical	10
Traffic Service	20
Other Service	5
General Functions	40
Average	26

Findings: The study found that to raise the single/tandem axle limits from 18/32 to 20/34 kips and the gross weights to 80,000 lb, an additional cost of $10,000 per mile would be needed for highways constructed at new locations, $25,000 per mile for upgrading existing pavements in good condition, and $50,000 per mile for upgrading existing pavements in poor condition. (All cost figures are assumed to be in 1975-76 fiscal year dollars.)

The State of Mississippi has 6,017 lane-miles of Federal-Aid Primary System, of which 2,680 lane-miles are the Corridor System designated by the Mississippi Legislature in 1972. To bring them to the standard under the current Federal size and weight limit, an additional fund of $40,120,000 is needed. To bring the remaining 3,800 lane-miles to current Federal weight limit, an estimated $142,500,000 will be needed. Thus a total of $182,620,000 will be required.

Of the 1,883 bridges on the Federal-Aid Primary System in Mississippi, some 601 bridges are overstressed. Of these 601 bridges, 306 are of the H-10 design and must be replaced. It will cost $76,803,000 to replace all these bridges. It will also cost $196,697,000 to replace the remaining 295 bridges that are of the H-15 standard. Thus, it is estimated that an annual increase of 26 percent in maintenance expenditures would be needed to allow the highway department to conduct the necessary preventive maintenance if the load limit increase is allowed. Using the fiscal 1976 Highway

Department Maintenance Expenditure as the base, the load limit increase means an additional annual maintenance expenditure of about $5 million. The $76,803,000 to replace the critically overstressed H-10 bridges would still be needed. Regarding enforcement, the report recommended more stringent enforcement, with an increase of 12 truck weight inspectors and 24 portable scales. The report recommended that the inspectors be given the authority to go to plant sites or other loading sites and weigh trucks before they access the highway system. It was recommended that enforcement officers be authorized to require off-loading of illegally overweighed vehicles. It was also recommended that the Motor Vehicle Comptroller's Office be given the authority to suspend the operating privilege of a truck operator for a given period of time as a result of repeated violations.

SUMMARY

The Mississippi report provides an overview of the state's economy and a characterization of goods movement in the state. With respect to the technical aspects such as highway pavement and bridge costs, the report provided few details as to the methodology or procedure used in computing the findings.

The cost figures have been converted into per-lane-mile figures for comparison purposes. These figures, based on additional funds needed, were divided by the total lane-miles of the particular roadway class. The results show that Mississippi would need $14,970 per lane-mile to raise the 2,680 lane-miles of the Corridor System in the Federal-Aid Primary highways to the standard sufficient to allow the increase in weight limits to the current

Federal maximum limits; and, it will take an additional $37,500 per lane-mile to do the same for the remaining part of the Federal-Aid Primary System.

These figures are much higher than those computed from the Indiana and Iowa studies. Such difference may be due to methodologies used and assumptions made.

APPENDIX H

TENNESSEE

APPENDIX H

TENNESSEE

BACKGROUND OF STUDY

Tennessee is one of the states that, until recently, had not adopted an increase in weight limits allowed by the 1974 Federal Aid Highway Amendments. Since most states bordering Tennessee allowed the 80,000 GVW, Tennessee was considered by some as a "barrier state" to interstate commerce. Opponents to increasing GVW from 73,260 lb to 80,000 lb maintain that trucks are not paying for their fair share of the cost of highways, while the proponents argue that an increase in weight limits is an economic necessity without which the state industry would be placed at a competitive disadvantage. The following is a summary of a report conducted to study various aspects related to an increase in truck weight and length.

Title: Special Report——Truck Weights and Length

Date of Publication: January 1980

Author: Tennessee Department of Transportation

Performing Organization: Tennessee Department of Transportation

Purpose of Study: To examine various aspects related to an increase in truck size and weight in the State of Tennessee

Scope: The aspects include

- Economic factors,
- Weight limits related to damage of pavement and highway structures,
- Size issues related to operations,

- Safety issues,
- Revenue, and
- Energy savings.

Data Source: The data used in the report include the following:

- 1976 and 1978 truck weight study data,
- Tennessee pavement records,
- AASHTO Interim Guide, and
- Tennessee traffic data.

Methodology: The new axle weight distribution was estimated from the truck weight data in Tennessee collected under the current weight laws. The "prediction" utilizing the NCHRP 141 shifting methodology was based on multiple-unit trucks operating on the Interstate Rural System.

The methodology used to analyze the effects of the weight increase on the remaining service life of existing pavements was based on the methodology presented by Corui and Bullard and found in "A System for Estimating Present Surface Condition and Remaining Service Life of Existing Pavement Sections," (Public Roads, Vol. 36, No. 5).

With respect to the safety issues, no physical tests were conducted. Findings were based on NCHRP 141 and research work done by FHWA.

Findings:

1. Economic Aspects

   A. Estimated Additional Costs for New Pavement Designs Due to Increased Truck Weight Limits

(1) 4,108 lane-miles of Interstate Highway will require an additional $17 million/yr or $4,000/lane-mile/yr.

(2) 20,708 lane-miles of State Highway System will require an additional $16 million/yr or $3,000/lane-mile/yr.

B. Design for New Pavements

Tennessee DOT records for 1978 show that 500 lane-miles of new pavement were let to contract for a cost of $60 million. If the pavement were to be redesigned and constructed for the new proposed truck weight limits, the additional cost would be $4 million.

C. Total Estimated Costs

Pavement cost related to increased truck weight limits for the whole state would total $37 million/yr.

If enforcement were strengthened to eliminate all overweight vehicles, the annual pavement cost increase would be reduced by $15 million, leaving the additional $22 million to be offset by increased registration and overload permit fees.

The report stated that the adoption of the federal weight limits could possibly result in added cost to the state which could not be offset by additional tax revenue. However, there are potential benefits to the state, as a whole, if uniform weights and dimensions are adopted by all the states.

2. Safety

The report stated that, based on the literature review, increased weights would require longer stopping distances and thus would increase accident potential. When smaller cars are involved in an accident with a larger truck, the chance of injury or fatalities is increased; however, further research indicates that the truck involvement rate may decrease as truck weights increase. This reflects the assumption of a decrease in exposure rates since fewer trucks will be required to carry the same annual payload.

An increase in truck sizes would allow an increase in cab lengths, which would improve the unit handling ability and operator comfort, and thus reduce potential accidents.

3. Revenue

Based on the study of design costs and safety issues, the report states that the heavier trucks should be paying a higher portion of the cost of maintaining highways than they are presently paying. The following is a summary of the fair portion for three kinds of vehicles:

(1) passenger vehicles - 45.2%
(2) pickups - 15.5%
(3) trucks - 39.3%

The study reveals that trucks are underpaying by about 17 percent.

4. Energy Saving

Based on the vehicle cost-data taken from NCHRP 141 (Ref. 4), the increase in truck size and weight in Tennessee will produce an annual decrease in fuel cost of approximately $6 million.

5. Enforcement

The report recommended a strict enforcement program including realistic penalties. It suggests that overload permits should not be issued for loads that can be divided.

SUMMARY

The shifting methodology used in the study was based upon NCHRP 141. Truck weight data obtained from weighing stations in the State of Tennessee were used in the computation.

The report, which covers a wide range of aspects, including weight, length, safety, energy saving, and revenues, provides a good overview of the effects of changing truck size and weight limits in Tennessee.

The safety issue relied heavily upon secondary information, namely a national study. No local statistics were used for the analysis. Costs related to changes in highway geometric design policy and practice due to increase in truck size and weight limits were not considered in the report, and environmental aspects were not mentioned in the report.

APPENDIX I

TEXAS

APPENDIX I

TEXAS

BACKGROUND OF STUDY

The Texas study is divided into four phases. The first phase started in June 1977 in response to Texas Senate Resolution 589, which directed "the Texas State Department of Highways and Public Transportation to tell the people of Texas what weight loads the Texas highway system could safely tolerate without excessive maintenance and repair costs." The first phase of the study emphasized the effects of heavy trucks on Texas highways by assessing weight limits suggested by an FHWA study[1] (maximum single axle load = 26,000 lb, maximum tandem axle load = 44,000 lb, and maximum GVW = 120,000 lb). The proposed limits, scenario B, were contrasted with scenario A, which uses the existing size and weight limits in Texas. The first phase of the study was concluded at the end of August 1978 and a report, "Effects of Heavy Trucks on Texas Highways," reflects the findings of the first phase.

The second phase of the Texas study was started in September 1978 and ended in August 1979. During this phase, two more scenarios were added to the study. Scenario C allows the operation of turnpike doubles and triples, but limits the maximum GVW for these two vehicle types to 105,500 lb and limits maximum length to 105 ft. Scenario D is the same as scenario C except the maximum GVW for turnpike doubles and triples is governed by the

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[1] Economics of Maximum Limits of Motor Vehicle Dimensions and Weights, Vol. 182, by R. Winfrey and others, FHWA, 1968.

bridge formula. The results of the second phase were published in a paper titled "Aspects of Truck Sizes and Weights: A Scenario Analysis."

The third phase of the study began in September 1979 and was divided into two phases. One phase dealt with the influence on highway geometric design principles and practices of increased truck sizes and weights, and the other phase dealt with modeling the effects of increased size and weight laws. The former was completed by August 1980, and the latter is still undergoing investigation.

Four reports have been published so far, and each of them will be reviewed separately.

Title: Effects of Heavy Trucks on Texas Highways

Date of Publication: September 1, 1978

Authors: J. L. Brown, D. Burke, F. L. Roberts, and C. Michael Walton

Performing Organization: Joint effort by the Texas State Department of Highways and Public Transportation, the Texas Transportation Institute at Texas A&M University, and the Center for Transportation Research at The University of Texas at Austin

Purpose of the Study: To assess the effects of projected truck traffic on the highway system of Texas in consideration of the social and economic vitality of the State

Scope: The study included the evaluation of the costs and benefits for a twenty-year planning horizon. Alternative scenarios of future truck traffic were assessed. The study did not consider the effects of changes in the size of trucks, only an increase in the gross weights and axle loads. The study did not evaluate the effects that heavy trucks would have on county roads or city streets.

Methodology: The study was organized into three phases

1. The establishment of current and future truck traffic distributions that will most likely occur on the state highway system for each of two conditions or scenarios. The first, scenario A, was evaluated as the conditions that will develop under the present weight law (GVW of 80,000 lb, maximum single axle load of 20,000 lb, and maximum tandem axle load of 34,000 lb). The second, scenario B, was evaluated as the conditions developing under a possible future legal weight increase to a GVW of 120,000 lb, as suggested in an FHWA study (Ref 1) (maximum single axle load = 26,000 lb and maximum tandem axle load = 44,000 lb). The 120,000-lb GVW represents a maximum likely change and is sufficiently large that estimated results would not be overwhelmed by data inaccuracies. Figure I.1 schematically shows the maximum legal loading condition of the four trucks used to represent both scenarios. Figure I.2 shows the percentages of these trucks on the highways. Both

SCENARIO A	SCENARIO B
Max. Single Axle = 20,000	Max. Single Axle = 26,000
Max. Tandem Axle = 34,000	Max. Tandem Axle = 44,000
Max. GVW Axle = 80,000	Max. GVW Axle = 120,000
(Current Legal Limits)	

GVW = Gross Vehicle Weight
k (kips) = 1,000 lb

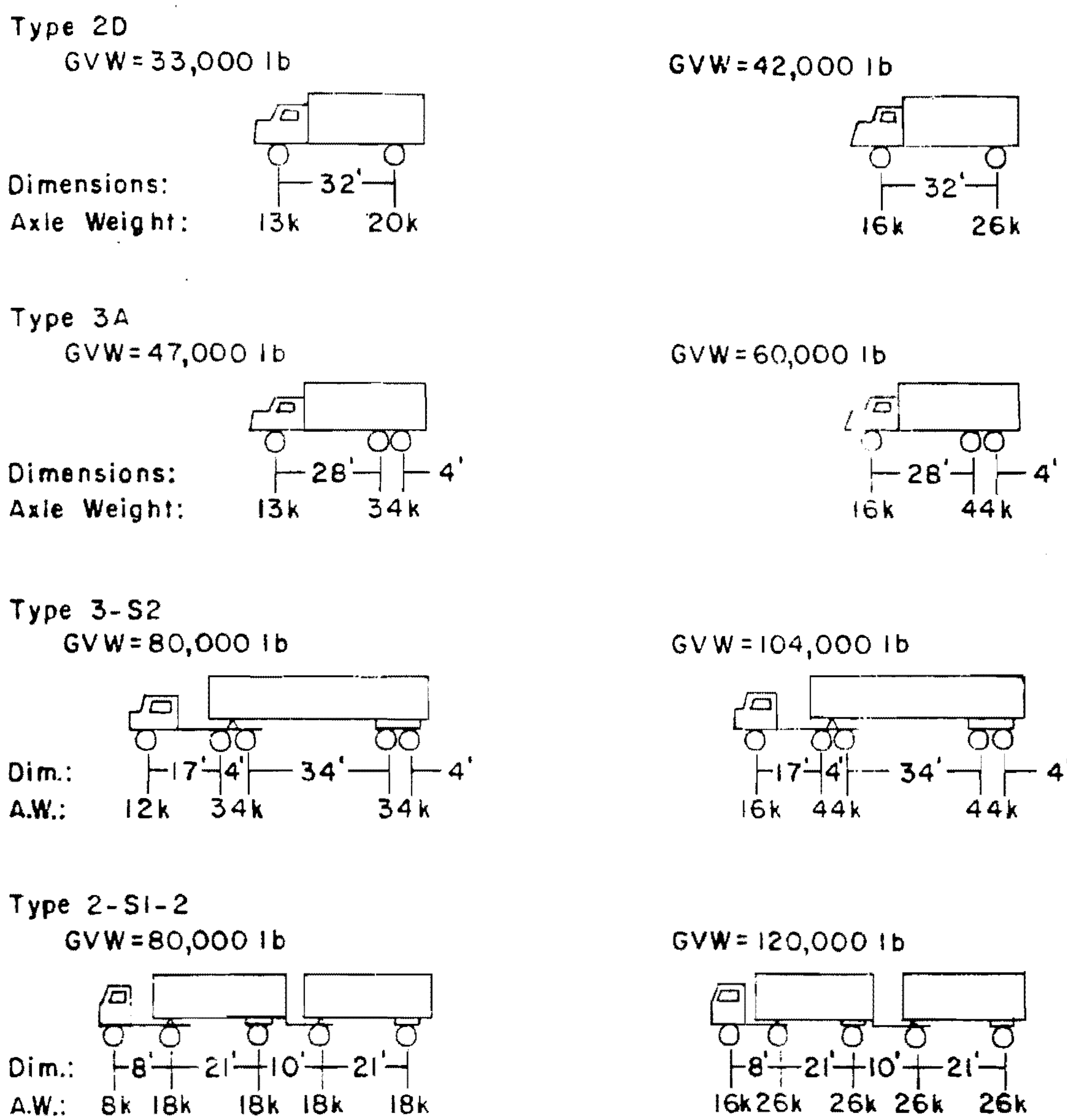


Fig I.1. Selected truck configurations for scenarios A and B.

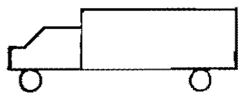
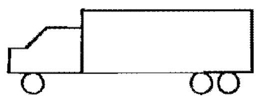
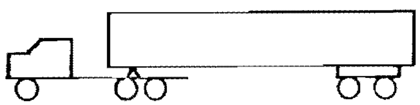
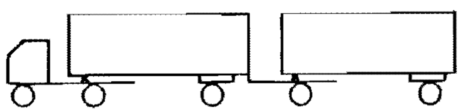
TRUCK TYPE		HIGHWAY TYPE			
		INTERSTATE HIGHWAYS	FARM TO MARKET ROADS	OTHER STATE HIGHWAYS	CITY STREETS / COUNTRY ROADS
2D		8%	23%	11%	Unknown
3A		3%	18%	7%	Unknown
3-S2		84%	59%	80%	Unknown
2-S1-2		5%	0%	2%	Unknown

Fig 1.2. Distribution of selected trucks by highway types.

scenarios considered distributions of all trucks including overloads.

2. An evaluation was made of the comparative tax dollar costs required to perpetuate the state highway system in an acceptable condition while carrying the traffic estimated for both scenarios. The basis for this evaluation was the general finding from the AASHO Road Test (Ref 9) that showed that heavier axle loads cause pavements to deteriorate at an accelerated rate. Figure 1-3 shows a typical relationship between the heavier axle loads and the equivalent damage as represented by an 18,000-lb single axle load (18 KSAL). The additional costs for scenario B were obtained by subtracting the cost of scenario A from scenario B.

3. An evaluation was made of the incremental benefits associated with the variation in conditions inherent in scenarios A and B. The benefits as defined in this study are associated with the increased payloads of scenario B over scenario A.

Data Source:

- AASHO Road Test Results,
- Texas Truck Weight Study Data, 1970-1974,
- Road Life Study published by the Texas State Department of Highways and Public Transportation (SDHPT),

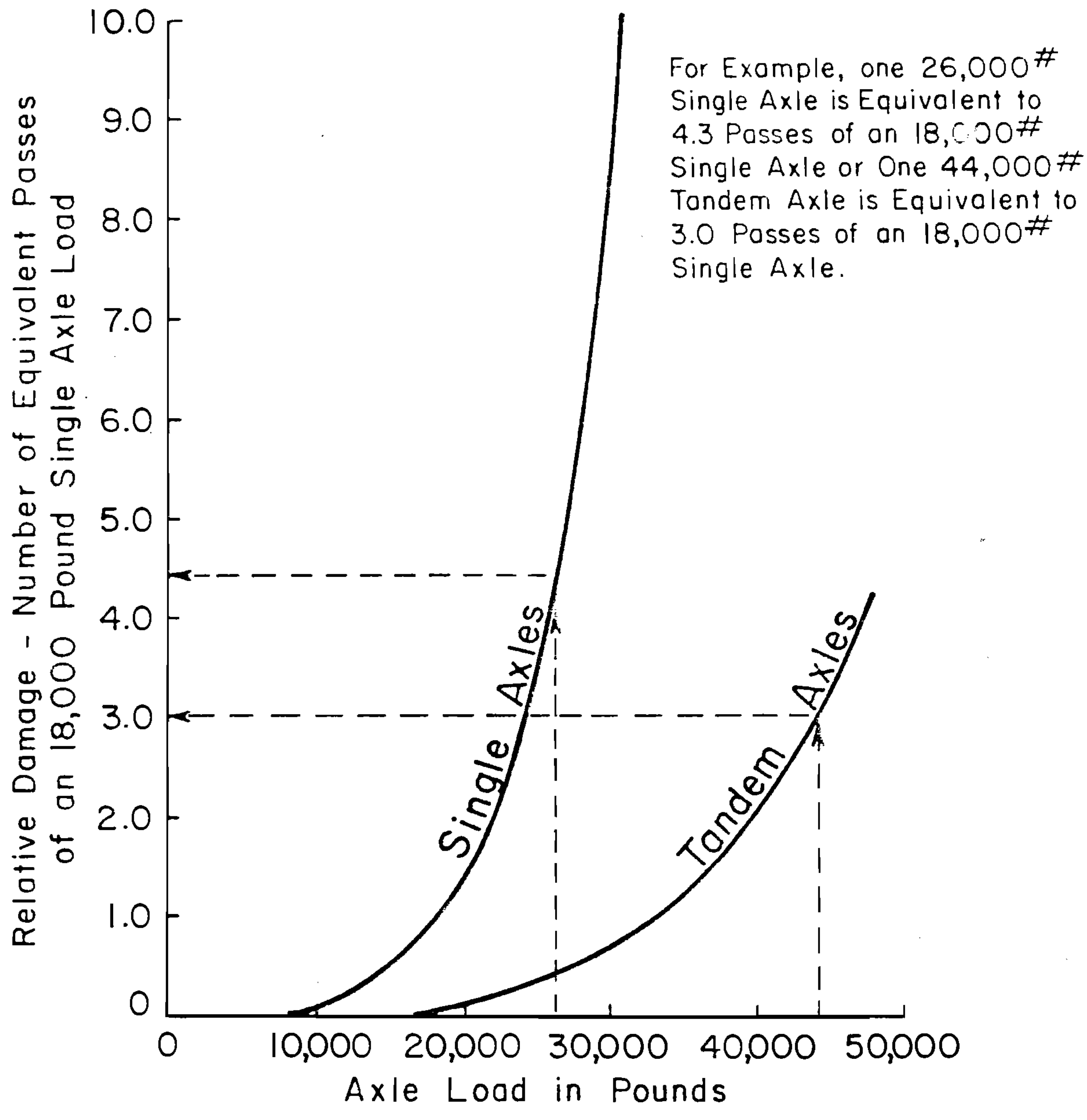


Fig I.3. Typical relative damage caused by different sized axles - from the AASHO Road Test (Ref 9).

- Truck fuel consumption rates and operating cost data from studies conducted for U.S. DOT and from TRB publications, and
- Vehicle Traffic Distribution Data from SDHPT.

Findings: The differential costs between scenarios A and B associated with heavier truck loads (subject to the limitations listed on page 2) and the corresponding savings in truck operating costs for the 20-year analysis period are presented in Table I.1. Figure I.4 shows the total costs for the various classes of highways. From the data contained in Table I.1 and Figure I.4, it appears that if weight law changes are undertaken, further analysis would be justified to select those routes that would carry relatively large freight tonnages and would cost relatively less to upgrade.

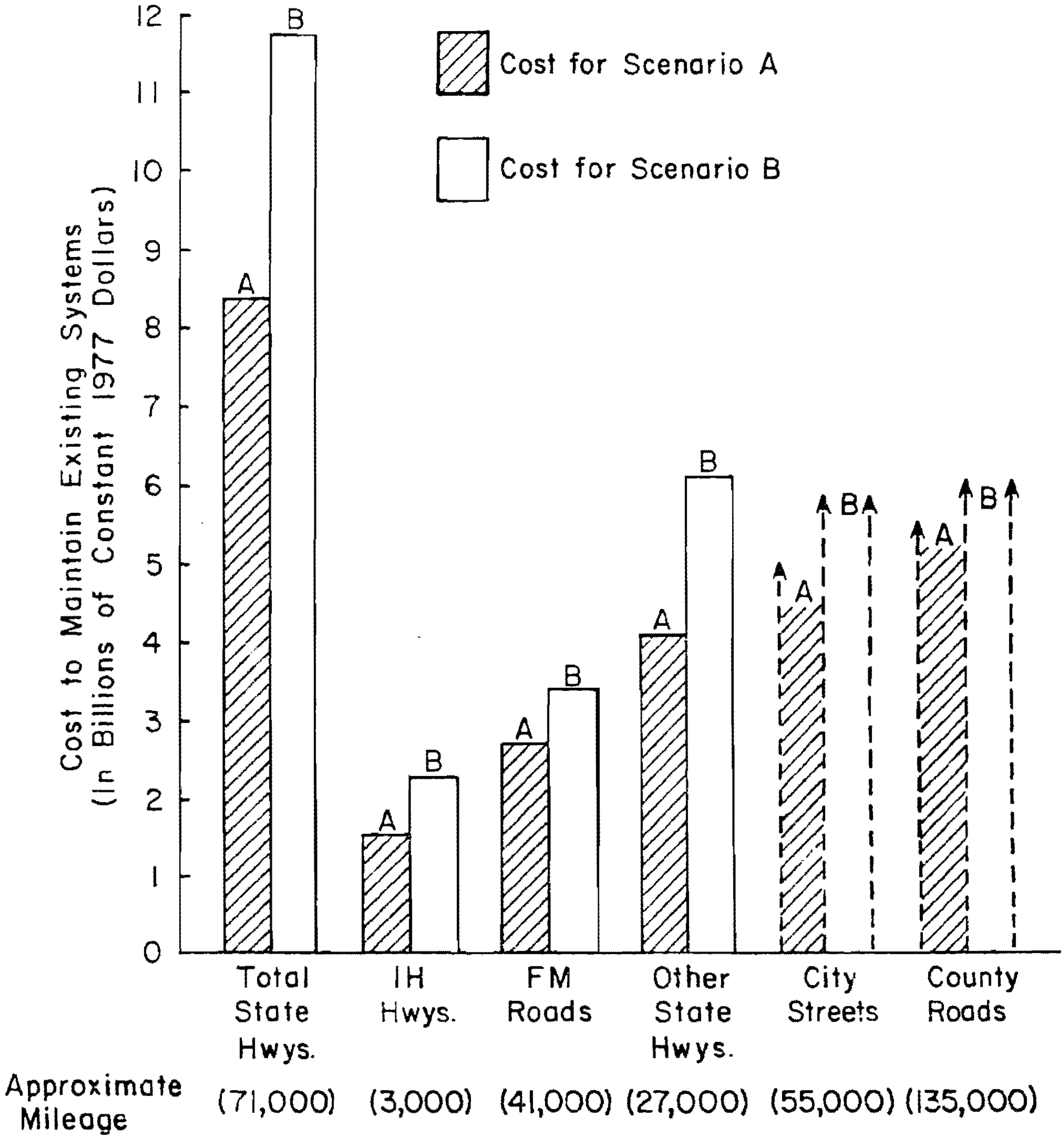
Figure I.5 indicates the annual cost to maintain the existing system for both scenarios A and B. From this data it can be inferred that once the highways have been upgraded to handle the heavier trucks, the additional cost to maintain the system for the heavier trucks will decrease. In other words, the additional costs beyond 1997 would be less than those costs occurring during upgrading.

A separate analysis was conducted to examine what, if any, fuel savings might result from an increase in truck weights. These calculations indicate that fuel saved would be about 1.8 percent of that needed to haul the same amount of truck freight under the present weight law.

TABLE I.1. COMPARISON OF COSTS AND BENEFITS FOR SCENARIO B OVER SCENARIO A

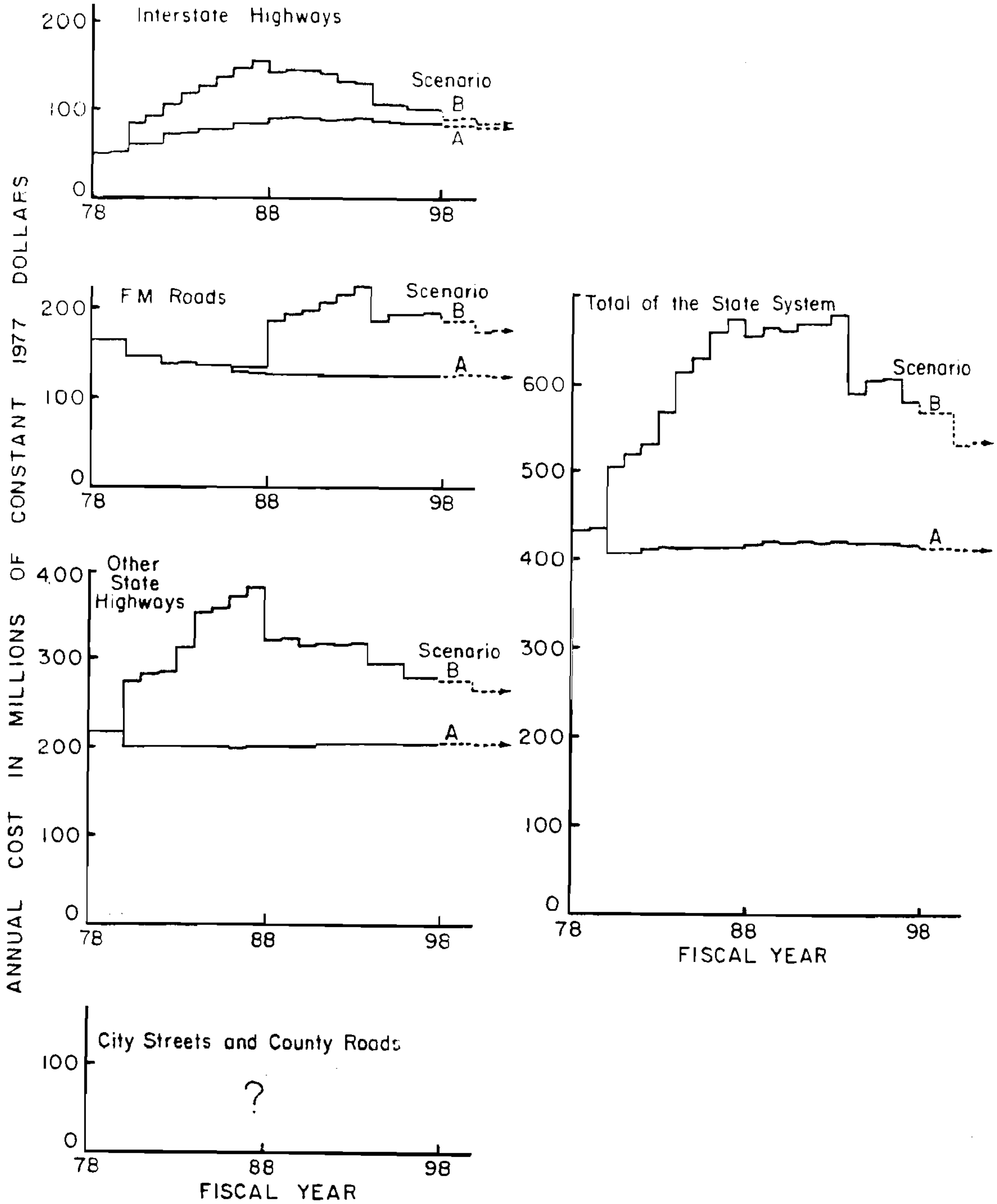
	Total for Hwy Systems	Interstate Highways	FM Roads	Other State Hwys	Co. Roads & City Streets
Add'l Hwy Costs (in billions of constant 1977 dollars)	3.50	.72	.74	2.04	unknown
Savings in Truck Operating Costs (in billions of constant 1977 dollars)	9.12	4.57	.71	3.84	unknown
Fuel Savings* (in billions of gallons)	2.42	1.21	.18	1.03	unknown

*Fuel cost savings are included in Savings in Truck Operating Costs



*Bridge costs included in totals reflect only expense of upgrading structurally deficient bridges to carry the loading of the respective scenarios. Not included are the costs of bridge maintenance, rehabilitation and replacement due to functional deficiencies and deterioration.

Fig I-4. Twenty-year cost (1977-1997) to maintain existing systems*



*Bridge costs included in totals reflect only expense of upgrading structurally deficient bridges to carry the loading of the respective scenarios. Not included are the costs of bridge maintenance, rehabilitation and replacement due to functional deficiencies and deterioration.

Fig I.5. Costs to maintain the existing system (maintenance, replacement, and rehabilitation)*

Additional analyses were completed in an attempt to relate vehicular pollution and changes in vehicle weights. For the three major Texas metropolitan areas (Dallas-Ft. Worth, Houston-Galveston, and San Antonio), a decrease representing less than a 1 percent reduction in pollution generated by all urban transportation was computed. The available data and research on noise pollution indicated that the hypothesized increases in axle weight limits should generate only small increases in noise along highways.

SUMMARY

Comments are included in the summary of all four reports at the end of Appendix I.

Title: Aspects of Truck Sizes and Weights: A Scenario Analysis

Date of Publication: January 1980

Authors: C. Michael Walton and Dock Burke

Performing Organization: Joint effort by the Center for Transportation Research at The University of Texas at Austin and the Texas Transportation Institute at Texas A&M University

Purpose of Study: To evaluate the effects of allowing larger and heavier trucks on Texas highways (particularly turnpike doubles and triples)

Scope: Two additional scenarios, scenarios C and D, were evaluated and compared with findings from scenarios A and B. The types of vehicles examined and their maximum size and weight limitations are shown in Figures I.1 and I.6.

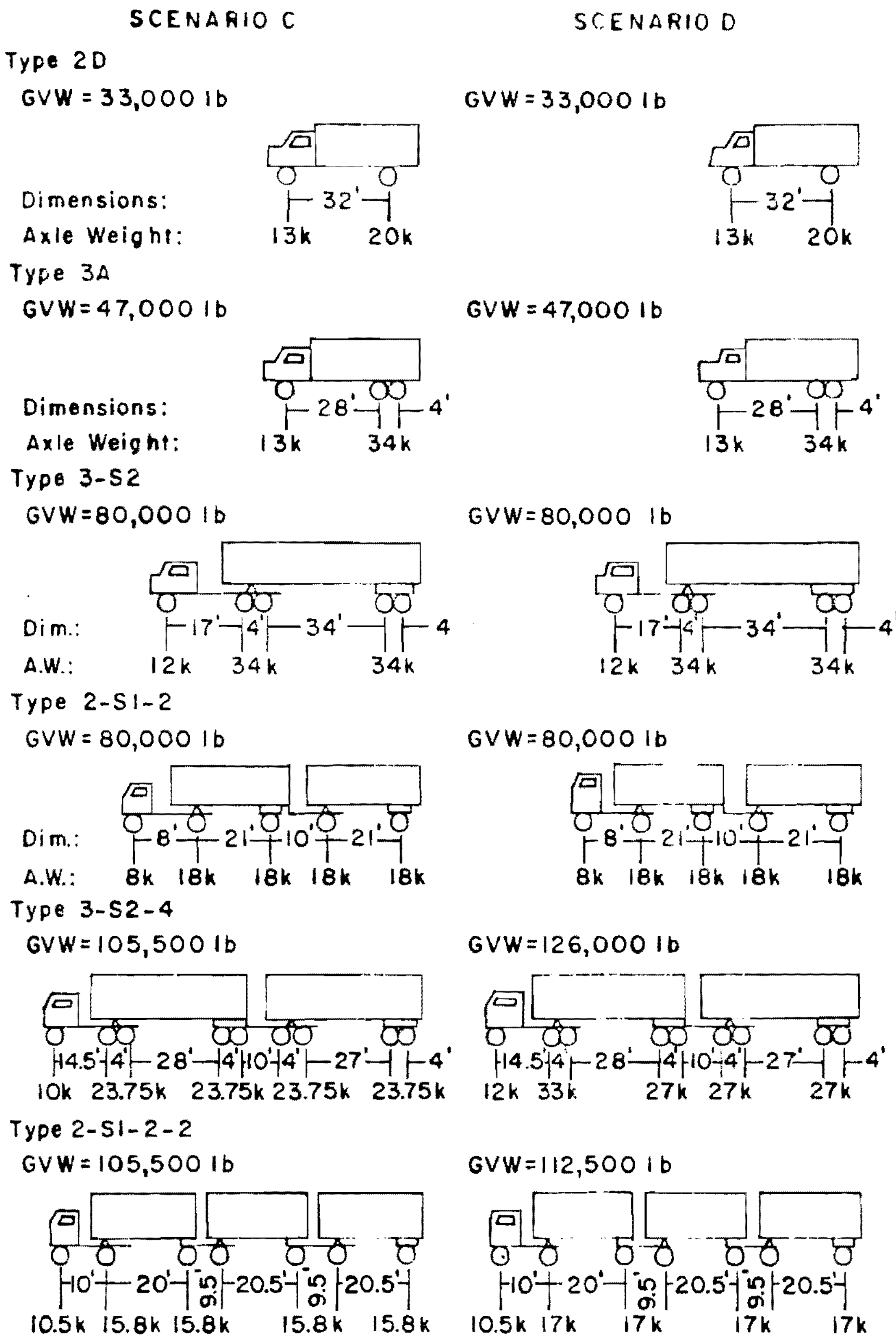


Fig I.6. Selected truck configurations for scenarios C and D.

Data Source: Besides those data used in phase one of the Texas study, national truck weight study data, national truck commodity tonnage and mileage data from NCHRP 198, and data on double bottoms from New York Thruway were also used.

Methodology: To estimate vehicle mix in scenarios C and D, a methodology was developed that uses the commodity tonnage as well as mileage data from NCHRP 198.

For estimating pavement damage, AASHO Road Test results were used. Some practical equations relating vehicle weight to fuel consumption and vehicle operating cost were also developed, based from data provided in national studies. (Vehicle operating cost data updated from NCHRP 141, and the fuel consumption equation was developed from results of several studies recently completed.)

Findings: The differential highway cost and corresponding savings in truck operating costs and fuel consumption by highway classes and scenarios are shown in Table I.2. From the comparisons rendered in the table it would appear that scenario C would offer significant savings. In fact, the analysis suggested that, based on the cost increases to pavements and bridges alone, scenario C would have minimal impact. However, the pavement and bridge effects do not represent the complete set of impacts associated with each scenario. The paper recommended further investigation into the highway geometric design and safety issues.

TABLE I.2. DIFFERENTIAL HIGHWAY COSTS, SAVINGS IN TRUCK OPERATING COSTS AND FUEL SAVINGS OVER 20 YEARS BY HIGHWAY CLASSES AND SCENARIOS

	Total for Highway Systems			Interstate Highways			Farm-to-Market Roads			Other State Highways			County Roads and City Streets
	B/A	C/A	D/A	B/A	C/A	D/A	B/A	C/A	D/A	B/A	C/A	D/A	
Additional Highway Cost (in billions of constant 1977 dollars)	3.50	0.20	1.07	0.72	0.09	0.30	0.74	0.02	0.15	2.04	0.10	0.62	Unknown
Savings in Truck Operating Costs (in billions of constant 1977 dollars)	9.12	14.81	16.86	4.57	8.84	9.87	0.71	0.69	0.79	3.84	5.28	6.20	Unknown
Fuel Savings* (in billions of gallons)	2.40	3.93	4.62	1.21	2.34	2.70	0.18	0.18	0.21	1.03	1.41	1.70	Unknown

*Fuel cost savings are included in Truck Operating Costs.

SUMMARY

Comments are included in the summary of all four reports at the end of Appendix I.

Title: Influence of Rural Highway Geometric Design (and Redesign) Principles and Practices of Increased Truck Size and Weights

Date of Publication: January 1981

Authors: Ogilvie F. Gericke and C. Michael Walton

Performing Organization: The Center for Transportation Research at The University of Texas at Austin

Purpose of Study: To summarize a study of the effects that an increase in legal truck limits would have on highway geometric design elements, and the cost implications, should various elements of the Texas highway system require redesign and modification to facilitate their safe and efficient operation.

Scope: The same types of vehicles that were used in scenarios A, B, C, and D were also used here. The study first considered the three functional rural highway systems which are

1. Interstate Highway System,
2. U.S. and State Highway System, and
3. Farm-to-Market Road System.

The study then considers the following rural functional classes or combination of classes.

- Interstate Highway System
- Principal Arterial System
- A combination of "all classes" (Interstate, other principal arterials, minor arterials, major collectors, and

minor collectors, excluding county roads that may be part of the above).

Highway upgrading costs according to the above rural systems were examined since the usage, the design standards, and vehicle composition differ from one to another.

City streets and county roads were excluded from the scope of the study.

Four alternative scenarios were developed to provide a framework for analyzing a significant change in truck dimension and weight patterns. Scenario A represents the current statutes and assumes that these weight and dimension limits will remain the same over the 20-yr analysis period. The other 3 scenarios represent an array of changes in GVW, single axle weights, tandem axle weights, lengths and widths.

Data Source:

- Highway geometrics and cost data on file at SDHPT,
- Design policies from SDHPT and AASHTO,
- Turnpike doubles and triples data from Utah, California, and Alberta, Canada, and
- Research findings from Western Highway Institute.

Methodology:

- A review of past and current research relating to the consequences of a possible change in legal vehicle dimensions and weights on the geometric design elements of rural roads,
- An identification of those geometric elements most affected by a change in truck dimension and weight,

- An assessment of the effects a change in legal truck size and weight will have on these geometric design elements for a variety of operation conditions, and
- An estimate of the cost required to redesign and modify the highway section.

Findings: The authors concluded that, if any one of scenarios B, C, and D is implemented, and the reasoning and assumptions made to establish the effect of these scenarios on the design elements, cross-section elements, and intersection design elements are reasonable, then the following can be expected:

- stopping sight distance - no change;
- passing sight distance - the implementation of any one of scenarios B, C, and D will require additional sight distance;
- pavement widening on curves - additional pavement width will be needed if scenario C or D is implemented;
- critical lengths of grades - no adverse effect on the climbing ability of trucks is expected should any one of scenarios B, C, and D be implemented;
- lane width - no change in SDHPT policy is expected, but a 6-inch increase in vehicle width will necessitate strict adherence to the current desirable standard;

- width of shoulder - strict adherence to SDHPT policy is recommended;
- due to the increased off-tracking characteristics and decreasing turning ability, additional pavement width will be needed in confined spaces to allow for the implementation of scenario C or D;
- width of turning roadways - additional pavement width will be needed to accommodate the 3-S2-4 vehicle if either of the scenarios C or D is implemented;
- sight distance for at-grade intersections - additional sight distance will be needed because of the increase in truck length and the additional time required to cross an intersection; and
- median openings - additional pavement area will be needed for scenarios C and D.

In conclusion it was stated that if any one of scenarios B, C, and D were implemented, some alterations to the Texas highway network may be necessary. While there is little difference in the cost of modifying geometrics of the highway system for any of the scenarios, other considerations such as pavement and bridge effects, will have a bearing on the evaluation of changes in the legal size and weight of motor vehicles.

It was recommended that there be further research in the areas of

- passing sight distance and passing maneuvers;

- the performance of trucks on grades; and
- the question of lane width, safety, and vehicle width.

SUMMARY

Comments are included in the summary of all four reports at the end of Appendix I.

Title: Estimating Vehicle Distribution Shifts Resulting from Changes in Size and Weight Laws

Date of Publication: Presented at the Annual TRB Meeting in January 1981

Authors: Chien-pei Yu and C. Michael Walton

Performing Organization: The Center for Transportation Research at The University of Texas at Austin

Purpose of Study: To evaluate existing methodologies for estimating vehicle weight distribution resulting from changes in size and weight laws

Scope: The paper evaluated four existing methodologies: the first FHWA methodology, the second FHWA methodology, the NCHRP 141 methodology, and the SDHPT methodology. The shifting methodologies were applied to Texas data and to the change in the size and weight law in Texas in 1975.

Data Source: Truck weight data collected in Texas from 1954-1979.

Methodology: Four methodologies were first introduced, and then the assumptions of NCHRP 141 and the SDHPT shifting methodologies were discussed in detail.

Actual data collected after the 1975 size and weight law change in Texas were compared with the predictions made by the NCHRP and the SDHPT procedures. A trucking firm was interviewed to gain insight into those operational aspects which would be affected by a size and weight law change.

Findings: The following observations were made at the end of the initial effort to modify existing methodologies:

- The historical shift pattern relied on by NCHRP 141 and the SDHPT methodologies were not observed for most vehicle types.
- The change in Texas weight limit in 1975 did not affect the distribution of steering axle weight.
- The volume- and demand-constraint concepts were observed in three vehicle types (2D, 3A, and 2-S1-2) but not in 3-S2.
- The NCHRP model's assumption that "the new distribution in axle weight for each type of axle may be assumed to retain the same ratio to gross weight under the new limit as was found in the roadside weighing" has merit.
- The assumption in current methodologies that truck weights will shift in proportion to the ratio of the proposed PMGVW limits to the present PMGVW limit is challenged.

- The historical and current usage patterns of the PMGVW under the proposed limits as compared to those of the PMGVW under the existing limit indicate that the redistribution of vehicle weight due to changes in size and weight laws varies from one vehicle class to another. Tire construction, trailer type, and terminal requirements must also be considered. A vehicle-type based methodology is preferred to a general one.

The authors finally recommended further research in the area of vehicle weight distribution shifting methodologies to obtain a better model for the future.

SUMMARY

Comments on all four reports on the Texas study appear at the end of Appendix I.

SUMMARY

Overall, the Texas size and weight study is the most comprehensive. It has addressed the effects of increased size and weight limits on pavement damage and cost, savings in vehicle operating cost and fuel consumption, environmental concerns, highway geometric design, and vehicle weight distribution shifting methodologies. The study has attempted to develop a more complete economic assessment of the various elements relating to an increase in size and weight limits than is in any of the other studies. However, the effect of larger and heavier trucks on urban streets and county roads has not been addressed. The review of existing methodologies which are used to make predictions of the outcome of changes in size and weight laws contained in the Texas study is considered an important aspect of the overall study.

While most other states have been examining the costs and benefits of raising size and/or weight limits to current Federal maximums, Texas is the only state that has done studies on the effects of both size and weight limits higher than current Federal maximums. Utah and California have examined the triple trailer operations, but not weight limits higher than the current Federal maximum.

APPENDIX J

UTAH

APPENDIX J

UTAH

BACKGROUND OF STUDY

The Utah study was issued in three reports. The first one, published in September 1975, was an evaluation of triple trailer operations in Utah. The second and third reports were published in April 1977 and January 1979, respectively. The second report was a descriptive report presenting truck characteristics and pavement effects. The third report, also a descriptive report, delineated the various costs and benefits of increased truck size and weight. All three reports are reviewed in the following pages.

Title: Triple Trailer Evaluation in Utah

Date of Publication: September 1975

Authors: D. E. Peterson and R. Gull

Performing Organization: Utah Department of Transportation

Purpose of the Study:

- To evaluate triple trailer combinations (for one year) against other truck combinations on highway routes in Utah designated by the State Road Commission, on aspects of safety, energy, and pavement effects;
- To determine the cost benefits of the various truck combinations, including triple trailers; and
- To make recommendations on the conditions for further use of triple trailers or their discontinuation.

Scope: The study covered eight areas of triple trailer combinations:

1. accident data
2. safety factors
3. truck operating costs
4. pavement life
5. State-of-the-Art
6. truck driver opinions
7. traveling public opinions
8. complaints

Data Source:

- Observations of triple trailer operations in Utah;
- Double or triple trailer studies conducted by California, Idaho, and Alberta, Canada;
- AASHO Road Test Results;
- WHI Research on fuel consumption;
- Claffey's study on motor vehicle running cost;
- HRB Bulletin 301;
- Utah truck weight study; and
- Utah motor vehicle accident data.

Surveys of drivers and the public were also conducted.

Methodology: The following data were collected from field tests and observations.

- braking distances,
- offtracking characteristics
- passing maneuvers
- minimum speed and the effect of grades,
- vehicle sway and swerve,
- splash and spray,
- effects of road condition on vehicle movements,
- effects of weather on vehicle movements,

- noise, and
- fuel consumption.

Effects of triple trailer operations on pavement life were evaluated using the AASHO Road Test results. Surveys were also conducted to determine opinions of truck drivers, trucking companies, and the public.

Findings: A brief summary of the conclusions and recommendations is provided. The evaluation showed that triples do reduce operating cost and fuel consumption. However, they do shorten pavement life in comparison with singles but not as much as doubles. The limited amount of accident data showed that triples were safe under the conditions in which they were operated. A questionnaire survey also showed that the traveling public became more favorable toward their operation with time. The characteristics of the triple trailer with respect to braking, offtracking, vehicle swerving, effects of road and weather conditions, and passing time were also discussed. The report eventually recommended the continued operation of triples under certain conditions.

SUMMARY

The report represents a commendable effort to study new vehicle type operations by actual field tests and observations. The results of the one-year observation of triple trailer operation in Utah and Nevada are valuable data for other states that are considering triples' operation.

Title: Truck Characteristics and Pavement Effects

Date of Publication: April 1977

Authors: Dale E. Peterson and L. Wayne Shepherd

Performing Organization: Utah Department of Transportation

Purpose of the Study: To discuss the various characteristics of trucks and their effects on pavement

Scope: The authors covered the following areas

- Truck axle weight and pavement performance;
- GVW of a vehicle and its corresponding 18,000-lb ESAL;
- Number of trucks required to transport a given amount of freight versus the amount of damage based on the effect of a given number of 80,000 lb gross loads;
- Effect of pavement thickness on pavement life;
- Cost savings resulting from various pavement design strategies;
- Payload and ton-mile haul per gallon of fuel;
- Increase in fuel consumption versus pavement condition for various operating speeds; and
- Weight limitations that could increase gross weights for certain types of combinations to increase productivity and reduce fuel consumption without sacrificing pavement performance.

Data Source:

- AASHO Road Test results, and
- Data on fuel consumption versus pavement condition for various operating speeds from research studies under NCHRP.

Methodology: In arriving at the recommended size and weight limit, the report documents the various aspects of truck characteristics on pavement performance. AASHO Road Text results were utilized.

Findings: The report states that "it ... appears desirable to consider increased gross weights for certain combinations for increased productivity and reduce fuel consumption without sacrificing pavement performance." The authors therefore recommended

> That gross weights be allowed to increase for combinations with more than five axles and with lengths of 75 feet or less in accordance with the bridge table and that six axle combinations be allowed to increase to a maximum of 90,000 lb and that seven axle combinations be allowed to increase to a maximum of 100,000 lb.

SUMMARY

This report serves as background material, or an informative source, on the effects of truck characteristics on pavement.

Title: Costs and Benefits of Increased Truck Size and Weight

Date of Publication: January 1979

Authors: D. E. Peterson, L. W. Shepherd, and E. D. Davenport

Performing Organization: Utah Department of Transportation

Purpose of the Study: To assess the costs and benefits of increased truck size and weight

Scope: The paper covers the following areas

- Benefits to the trucking industry,
- Pavement impact,
- Truck weight enforcement,
- Number of trips versus truck weight,
- Percentage change in pavement damage and vehicle operating cost for various truck types at different weight levels,
- Safety,
- Effect of load distribution, and
- Current Utah regulations.

Data Source:

- Utah goods movement data,
- AASHO Road Test results,
- Truck shipment records from major coal users in Utah,
- Highway Patrol data, and
- Triple trailer evaluation study.

Methodology: AASHO Road Test results were relied on extensively in evaluating pavement effects.

Findings: The authors felt that current overweight fines and overweight permit fees are too low and need upgrading. They also recommended procurement of additional portable scales for improved enforcement of the weight law.

SUMMARY

The strength of the Utah study is in the evaluation of triple trailer operations. In regard to the effect of increased vehicle weight on highway pavement, the State of Utah has not had any state-wide estimate of the effects of heavier trucks. The last two reports of the Utah study are qualitative and general.