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Federal Maritime
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National Highway Traffic
Safety Administration

Bureau of
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1997 Comprehensive Truck Size and Weight Study

DRAFT

Volume II
Issues and Background

June 1997

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CHAPTER 1

BACKGROUND AND OVERVIEW

INTRODUCTION

Historically, Truck Size and Weight (TS&W) laws have been driven by concerns for National uniformity and good highway system stewardship. Over time, new pavement and bridge design standards have been adopted by the States to better match the weights and dimensions of vehicles permitted to operate on their highways. However, the potential of premature degradation of the infrastructure with its attendant strain on public resources continues to be a major concern. Further, technology and marketplace demand have contributed to the pressure for larger and heavier trucks, raising concerns about highway safety as well as diversion of rail freight to trucks. Underlying this concern is the role of the Federal government in the private sector economy. To the extent that government subsidizes any mode of transport, this will result in a misallocation of resources as users over-consume under-priced facilities.

Clearly, questions related to determining appropriate TS&W limits are difficult to resolve. The issue involves differing views of State and Federal authorities, rival economic interests, and uncertainty as to the operational safety of various types of trucks. Shippers and carriers understandably want to improve the efficiency of their operations, while public agencies and interest groups are also concerned about highway safety and preserving highway infrastructure and the environment. TS&W policy affects not only highway safety and stewardship, but also local, State, and National economic performance.

It has been 16 years since the Department's last comprehensive study of TS&W limits. In recent years, the Transportation Research Board and General Accounting Office have conducted studies looking at various proposals, including the potential impacts of "longer combination vehicles" (LCVs) which are combination vehicles with two or more trailing units that have gross weights of more than 80,000 pounds. While LVCs have received considerable attention in recent years, of perhaps greater consequence are policy issues affecting conventional single unit trucks and tractor-trailer combinations that operate much more widely than LCVs. These issues include changes to the bridge formula, axle load limits, gross vehicle weight limits (GVWs), and trailer lengths.

Overall, this effort is intended to provide a fact based framework within which alternative policy actions may be addressed. The outcome will assist decision makers in determining what legislative action, if any, may be indicated. The analytical framework is designed as a structure for gathering information related to the potential size and weight impacts of alternative truck configurations. The study offers a "policy architecture" for considering alternative TS&W options. As the Study effort progresses, a wide range of TS&W options, from more restrictive to more liberal, may be evaluated. With periodic updates in data or methodologies, this framework will ensure that the Department can respond to significant TS&W proposals without embarking on a separate, new Study for each proposal.

This Study represents a cooperative effort among the Office of the Secretary, the Federal Highway Administration (FHWA) as staff, and the other Department modal administrations with freight responsibilities. A companion document, the 1997 Highway Cost Allocation (HCA) Study, will be transmitted to Congress shortly. Taken together, this material will provide the policy and factual framework for Congressional deliberations regarding Federal TS&W limits and associated Federal user fees.

It should be noted that this volume is a draft work in progress and will be revised before the final report is released in the fall. This is a preliminary analysis of current TS&W issues and does not present findings from the evaluation of alternative policy scenarios. These analytical results will, however, be addressed in the final report.

PURPOSE

The objectives of the CTS&W Study are to: (1) identify the range of issues impacting TS&W considerations; (2) assess current characteristics of the transportation of various commodities including modes used, the predominant types of vehicles used, the length of hauls, payloads, regional differences in transportation characteristics, and other factors that affect the sensitivity of different market segments of the freight transportation industry to changes in TS&W limits; and (3) evaluate the full range of impacts associated with alternative configurations having different sizes and weights.

The analytical tools developed under the Study umbrella can be used to: (1) estimate the effects of various TS&W policy options upon the transport system; (2) evaluate the system's capacity to respond in the global economy; (3) evaluate the capabilities and opportunities created by new vehicles, new technology, and distribution systems for transport logistics; (4) estimate the diverse impacts on rail and truck shippers, carriers, consumers, and the traveling public; and (5) evaluate safety impacts.

The TS&W analysis considers the safety and efficiency of the total transportation system from the point of view of both the public and private sectors. Specifically, the Study addresses:

- Safety of truck operations, including the enforceability of safety regulations across North America;
- Infrastructure impacts (pavements, bridges, and geometric design) and how the costs of these impacts are recovered;
- Effects on productivity and efficiency for shippers and carriers;
- Federal and State roles in regulating traffic and equipment, as well as interstate and international commerce;
- Differences in transportation requirements across regions and commodities;
- Consistency with trends in overall domestic and international freight transportation;
- Impacts on freight shippers, other modes and intermodal movements;
- Equity among user fees for various classes of users;
- Environmental and other social costs;
- Effects on efficiency of automobile travel; and
- Net productivity and efficiency for combined rail and truck freight shipments.

APPROACH

This CTS&W Study was developed along four distinct tracks. The first focused on producing background studies to identify current issues and trends related to freight markets and motor carrier vehicle impacts. The second track involved the development of databases describing truck weights, body types, commodities and truck flows. The third major component of this effort will be the development and/or refinement of tools and models designed to analyze a broad range of impacts associated with truck configurations of different sizes and weights. Finally, the fourth track will bring together the products resulting from the earlier work to evaluate alternative illustrative TS&W policy scenarios.

IMPACT AREAS ASSESSED

Nine impact areas were included in the analysis: (1) safety; (2) infrastructure; (3) traffic operations; (4) environment; (5) energy; (6) modal considerations; (7) economic performance; (8) compliance and enforcement; and (9) intergovernmental issues. These areas of interest were identified through the extensive literature review conducted during the first phase (Track 1) of this Study. The impact measures for each area were identified and grouped into one or more of three categories, qualitative, quantitative, or cost and are summarized in Table I-1. The impact models and the analysis results, will be described in Volume III of this CTS&W Study.

TABLE I-1
STUDY EVALUATION AND IMPACT MEASURES

Impact Area	General Discussion of Impact Area Issues	Impacts	Impact Measures		
			Qualitative (Technical Discussion)	Quantitative	Cost
Safety	Accident Causation Accident Severity Vehicle Performance Rollover Transient Offtracking Braking Speed Limit Changes Driver Fatigue Public Perception—Outreach Meetings, Focus Group Results, Docket Comments and Polls	Accidents: Fatal Personal Injury Property Damage Only Vehicle Stability and Control		Number of Accidents: Fatal Personal Injury Property Damage Only Engineering Performance Index	Change in Accident Costs
Infrastructure	Bridge Stress Bridge Fatigue Load Equivalency Steady-State Offtracking Cost Recovery	Bridges Pavement Interchanges Intersections Grades		Bridge Overstress Bridge Fatigue Load Equivalency Factors Interchange and Intersection Improvement Needs	Bridge Costs Pavement Costs Costs of Geometric Improvements
Traffic Operations	Effects of TS&W Factors on Traffic operations Public Perception	Congestion Passing Speed Maintenance	Passing Speed Maintenance	Passenger Car Equivalents	Congestion Costs
Environment	Air Quality Noise and Vibration Effects	Air Quality Noise	Noise Effects and Exposure	Pollutant Emission Burden	Air Pollution Costs Noise Costs
Energy	Modal Use Rates Truck Use Rates	Energy Use		Change in Truck Fuel Consumption	(In operating costs)
Modal Considerations	Shipper Needs Freight Diversion Modal Equity—"Level playing field"	Effects on Rail and Waterborne Modes Amount of Truck Travel	Effects on Waterborne Mode	Changes in Payload Ton-Miles or Truck and Rail Change in Truck VMT	Future Rail Revenue
Economy	Changes in Production and Distribution Patterns International Trade Resource Markets Market Areas Container Transportation	Truck Operating Costs per Unit of Payload Logistics Costs Production Costs Truck and Rail Total Cost Trade facilitation		Truck VMT by Body Type, Configuration, and Length of Haul Rail Payload Ton-Miles by Car Type Container Use	Truck Operating Costs for Short Haul Total Logistics Costs for Long Haul Total Truck and Rail Logistics Costs
Compliance and Enforcement	Permit Use Administrative Burden Resource Needs	State Administration and Enforcement Requirements	Institutional Issues and Barriers	Permit Issuance Needs Vehicle Inspections Needs File Audit Needs	State Administrative and Enforcement Costs
Intergovernmental Issues	Federal and State Roles Federal-State Relationship Uniformity State Flexibility Grandfather Rights				

ALTERNATIVES EVALUATION

BUILDING BLOCKS: CONFIGURATION, SYSTEM AND GEOGRAPHY

Technical building blocks analyzing a broad range of truck configurations at varying GVWs provide the foundation for the analytical framework. These configurations include three- and four-axle single unit trucks, five- and seven-axle truck trailers, five- and six-axle semitrailers, 28-foot doubles, intermediate length (31-foot to 33-foot) doubles, and LCVs. They are illustrated in Figure I-1.

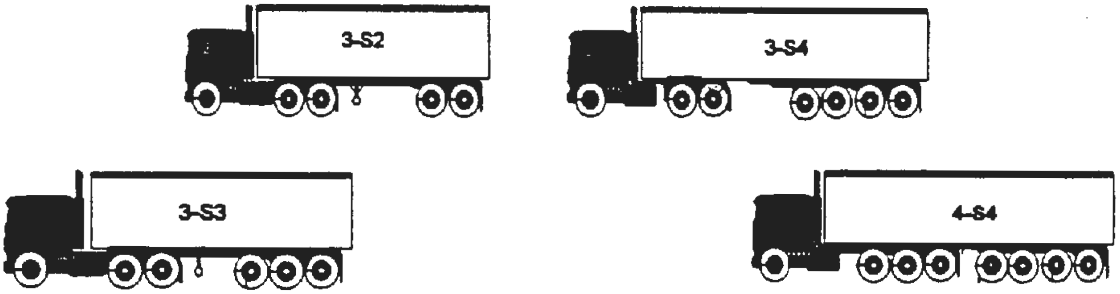
An evaluation of each configuration will be conducted in relation to various highway system(s)—the Eisenhower National System of Interstate and Defense Highways (Interstate System), the National Network (NN) for trucks, the National Highway System (NHS), and a limited system of highways tailored for the operation of longer combination vehicles on which these configurations now operate or might be proposed to operate.

FIGURE I-1
BUILDING BLOCK VEHICLES

Single Unit Trucks

Truck-Trailer Combinations

Tractor-Semitrailer Combinations

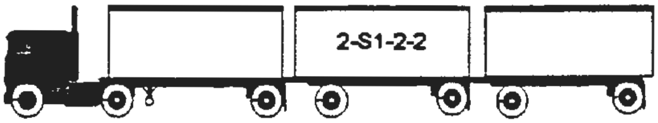


STAA Double-Trailer Combination

Longer Combination Vehicles (LCVs)

Double-Trailer Combinations

Triple-Trailer Combination



Operations of each configuration also are to be examined in relation to major geographic considerations for that configuration–National, regional, and State. In addition, configurations are analyzed at operating weights which vary according to different assumptions about axle weight and bridge formula restrictions. These analytical building blocks are represented in Table I-2 below:

TABLE I-2
ANALYTICAL BUILDING BLOCKS BY CONFIGURATION, SYSTEM, AND GEOGRAPHY

Configuration	Max. GVW range (000 lbs.)	Highway System				Geography		
		Interstate Restricted*	NN	NHS	Restricted	National	Regional	State
Single Unit Truck	54-68	X	X	X	——	——	X	X
Semitrailer	80-97	X	X	X	——	X	X	X
Double 28 - 28.5 ft. Trailers	80-111	X	X	X	——	X	X	X
Intermediate Length Double (31-33 ft.)	105.5-128	X	——	X	——	X	X	——
Longer Combination Vehicles	105.5-148	——	——	——	X	X	X	——

*Highways on which LCVs currently operate or might be proposed to operate.

ILLUSTRATIVE SCENARIO OPTIONS

Evaluation of possible regulations pertaining to a variety of configurations, such as elimination of grandfather provisions, freezing weight limits on the NHS, limiting trailer and semitrailer lengths to 53 feet, and lifting the LCV freeze will also be examined. The inclusion of a configuration at a GVW limit or on a certain network in the building blocks for analysis does not imply a predisposition of the DOT toward its adoption. In an effort to conduct a thorough and comprehensive study, a wide range of options will be evaluated to (1) test the analytical tools and (2) provide an assessment of the full range of alternativeTS&W impacts. The scenarios selected for full analysis are intended to establish representative benchmarks delineating the full range of potential impacts.

GUIDING PRINCIPLES, OVERSIGHT AND OUTREACH

GUIDING PRINCIPLES

NATIONAL FREIGHT TRANSPORTATION POLICY STATEMENT

On January 6, 1997, the Office of the Secretary of Transportation published a statement of National Freight Transportation Policy. The statement "establishes the most important principles that will guide Federal decisions affecting freight transportation across all modes. The aim . . . is to direct decisions to improve the Nation's freight transportation systems to serve its citizens better by supporting economic growth, enhancing international competitiveness and ensuring the system's continued safety, efficiency and reliability while protecting the environment."[1] The policy establishes eight principles to guide freight transportation policy development:

- *Provide funding and a planning framework* that establishes priorities for allocation of Federal resources to cost-effective infrastructure investments that support broad national goals;
- *Promote economic growth* by removing unwise or unnecessary regulation and through the efficient pricing of publicly financed transportation infrastructure;
- *Ensure a safe transportation system*;
- *Protect the environment and conserve energy;*
- *Use advances in transportation technology* to promote transportation efficiency and safety;
- *Effectively meet our defense and emergency transportation requirements*;
- *Facilitate international trade and commerce*; and
- *Promote effective and equitable joint utilization* of transportation infrastructure for freight and passenger service.

These eight principles provide the framework for evaluation of the various scenarios under review in this Study.

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[1] "National Freight Transportation Policy," Office of the Secretary of Transportation, Federal Register, Vol. 62, No. 3, January 6, 1997, pp. 785-790.

COORDINATION WITH HIGHWAY COST ALLOCATION STUDY

The first Federal Highway Cost Allocation (HCA) Study since 1982 was undertaken in 1995 for two key reasons: (1) to determine how changes in the Federal highway program, including user fees which support the program, have affected the equity of Federal highway user fees; and (2) to provide complementary information to the CTS&W Study. These two studies, when taken together, will provide information on how alternative TS&W limits might affect highway infrastructure and social costs and what impact those changes would have on assignment of cost responsibilities and user fees to different truck configurations. This approach is consistent with the role of DOT evolving to include establishment of policy architecture for use by all levels of decision makers.

OVERSIGHT

INTERNAL DEPARTMENTAL: POLICY OVERSIGHT GROUP

In June 1995, the Secretary of Transportation established a Policy Oversight Group (POG) chaired by the Assistant Secretary for Transportation Policy to provide overall policy direction, ensure that major decisions guiding the CTS&W Study would be made on an intermodal basis and assist the FHWA team effort by providing guidance and early review of draft documents associated with the final Study document.

The POG also provided policy guidance for the HCA Study. The group included policy-level representatives from the Office of the Secretary, FHWA, Federal Railroad Administration, National Highway Traffic Safety Administration, Maritime Administration, and the Bureau of Transportation Statistics.

PUBLIC OUTREACH

Underlying this CTS&W Study has been an extensive outreach effort. Outreach activities included: (1) a Federal Register[2] notice requesting public comment; (2) public meetings; (3) regional focus sessions aimed at reaching out to major constituencies and experts; and (4) special teleconference sessions with our partners at the State-level in addressing their issues of importance.

Federal Register Notice

A February, 1995, Federal Register notice (Docket 95-5) requested comments on 23 questions and the 13 working papers produced in the initial phase of the study. The comments submitted to the docket addressed one or more of the following areas:

- Safety (enforcement, driver fatigue and overall issues)
- Infrastructure damage
- Truck productivity
- Modal diversion
- Study plan
- Changes in TS&W limits (particularly the LCV freeze)
- Performance based standards
- Federal versus State roles
- Enforcement
- Cost responsibility.

Respondents to the docket may be grouped into the following categories: (1) State government agencies; (2) local government agencies; (3) industry associations; (4) public interest groups; (5) shippers; (6) motor carriers; (7) other organizations; and (8) private citizens. Table I-3 shows the number of comments received by respondent category.

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[2] Federal Register, February 2, 1995, Docket No. 95-5.

TABLE I-3
RESPONSE TO FEDERAL REGISTER

Respondent Category	Number of Responses
State Government Agency	29
Local Government Agency	5
Industry Associations	32
Lobbying Groups	5
Shippers	3
Motor Carriers	26
Other Organizations	10
Private Citizens	13,042
Total	13,152

Of the comments received, a selection of ten are summarized in Table I-4. Respondents represented in Table I-4 include: (1) California Department of Transportation; (2) Association of American Railroads; (3) Policy Services, Inc.; (4) American Automobile Association; (5) United Parcel Service; (6) A petition signed by 45 private citizens; (7) National Private Truck Council; (8) Citizens for Reliable and Safe Highways (CRASH); (9) Advocates for Highway and Auto Safety; and (10) Regular Common Carrier Conference.

Public Meetings

Public meetings were held in Denver and Washington D.C. They were attended by representatives of large and small carriers, trucking industry associations, safety advocates, and representatives from State and local governments. Testimony of the carriers focused primarily on the operation of LCVs and individual company operations and safety history. The carriers testified that the operation of Rocky Mountain doubles, twin 28-foot trailers, and triple trailers had not resulted in a deterioration of safety. The carriers generally supported restricted operation of LCVs and lifting of the ISTEA freeze.

The safety advocates, represented by CRASH, argued that continuation of the LCV freeze was necessary based on their experience that longer and heavier trucks are inherently more dangerous, irrespective of accident history. Further, they believe that trucks designed to carry heavier loads are more dangerous when they travel empty because of the potential for jackknifing.[3]

Regional Focus Sessions

Regional focus sessions were held in April and May 1996 in four locations (Detroit, Salt Lake City, Houston and Philadelphia) and were intended to (1) provide information on how the Study was being conducted, (2) obtain input from private citizens and interest groups, and (3) develop an improved understanding of special or regional concerns.

Each of the sessions resulted in a list of issues or concerns that the participants believed should be addressed prior to any consideration of TS&W policy changes. Two significant points of concern were: (1) safety and safety enforcement to attain "complete compliance," with no particular concern for TS&W enforcement; and (2) regional differences on proper Federal/State roles ranging from advocating States' rights to supporting a strong Federal role which would enhance safety compliance by the States and prevent the States from liberally interpreting any future changes to Federal vehicle requirements. Detailed summaries of these meeting are provided in Appendix __.

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[3] Excerpted from testimony of Mr. Jack Rendler, CRASH, presented at Public Meeting on the Comprehensive Truck Size and Weight Study at Lakewood, Colorado, March 21, 1995.

TABLE I-4
SUMMARY OF DOCKET COMMENTS

ISSUE AREA	PRO RESPONDENTS	CON RESPONDENTS
TS&W Study plan	Pro respondents feel study is needed and should focus on facts rather than emotionally or politically-based appeals.	The study is biased towards increases in TS&W limits, ignores safety concerns, underestimates rail diversion, lacks sufficient data and modeling capabilities, too narrow in scope and should be expanded to include other important issues.
Safety : Enforcement	Not addressed by any of the ten	Advocates maintain increasing TS&W limits will aggravate problem of enforcement of driver violation of hours of service, falsifying log books, overweight trucks, increasing number of State issued permits for weight.
Safety : General	Pro respondents point out that trucking industry has made large improvements in safety over last decade and potential for further improvements with improved vehicle and driver standards.	Note that heavier trucks are inherently more dangerous, improvements in truck designs might be lost after placed in operation and larger trucks are more dangerous under congested driving conditions. Also note, even if trucks are made safe, the general public fears trucks and these fears can lead to safety risks. Increasing TS&W limits will aggravate safety concerns.
Safety : Driver Fatigue	Not addressed by any of the ten	Advocates raise concern over potential increase in driver hours of service and falsifying log books, will increase risk of accidents, problems exist now and will increase the risk of and damage levels from accidents with bigger trucks.
Cost Responsibility	RCCC states that permit programs should allow heavier vehicles if appropriate fee structures are put in place. Not addressed by other nine.	Noted that under current user charge structures, heavy trucks pay less in user fees than the total costs that they create, permits do not capture the full cost of heavy truck travel.
Truck Productivity	Pro respondents indicate increased TS&W limits would lead to reduced operating costs and improved truck productivity.	Agreed that increased TS&W limits would increase truck productivity but would occur only because trucks do not pay their fair share of highway use and are outweighed by the societal costs imposed by truck travel. Improved truck productivity would severely impact railroads.
Infrastructure Damage	Argue that productivity improvements can be made that are not damaging to infrastructure and numerous techniques available to strengthen infrastructure to sustain increased TS&W limits.	Increased TS&W limits will damage infrastructure, current user fees will not collect sufficient revenue to rebuild infrastructure.
Modal Diversion	RCCC stated transportation providers and consumers should determine future use of transportation systems, not Federal rules governing TS&W, should not seek to protect or enhance railroad profits by TS&W restrictions.	AAR commented on impact to railroad industry if TS&W limits change, elimination of freeze would not reduce VMT, diversion from rail offset any anticipated reduction in truck VMT, trucks pay far less than costs they impose and can reduce rates to divert freight from railroads, would cause serious traffic and revenue loss to railroads, would be devastating since large proportion of rail traffic is potentially truck competitive, existing rail diversion models are flawed.
Elimination of LCV Freeze	Favor elimination because of substantial savings to consumers from reduced transportation costs, have a proven safety record in Western States, some restrictions on operations are needed and should be set at the State level.	Support continuing LCV freeze, citing a variety of safety concerns and lack of adequate safety research on LCVs, and heavy trucks do not pay their full cost responsibility.
Performance-Based Standards	Will allow flexibility in equipment design while minimizing the impact on the infrastructure and would reduce the need for permitting.	Performance-based standards are a validation of current practices by setting standards sufficiently low, using ideal vehicles in development of standards and unknown effects of wear and maintenance leave large gap in determing real performance-based standards and no one knows how to implement and enforce these types of standards.

Source: Comments to the Docket from (1) California Department of Transportation (CALTRANS), (2) American Association of Railroads (AAR), (3) Policy Services Inc., (4) American Automobile Association (AAA), (5) United Parcel Service (UPS), (6) A petition signed by 45 private citizens, (7) National Private Truck Council (NPTC), (8) Citizens for Reliable and Safe Highways (CRASH), (9) Advocates for Highway and Auto Safety and (10) Regular Common Carrier Conference (RCCC)

CONTEXT

THE TRANSPORTATION ENVIRONMENT

The U.S. freight transportation industry has undergone enormous changes in the last few decades. In the late 1970s, Congress reevaluated the body of transportation regulation that had been developed since the Interstate Commerce Commission (ICC) was created in 1887. Congress acknowledged that there were vast inefficiencies, caused by both rate and entry-exit regulation. The belief was that the Nation's transportation system could perform better with less regulation and more competition. Numerous pieces of Federal legislation--including the Motor Carrier Act of 1980, the Staggers Rail Act of 1980, the Surface Transportation Assistance Act of 1982, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the Trucking Industry Regulatory Reform Act of 1994. Title VI of the Federal Aviation Administration Authorization Act of 1994, and finally, the ICC Termination Act of 1995--played major roles in the deregulation of the surface freight industry.

Freight transportation has become more complex since deregulation and the evolution toward a global marketplace. The complexity of TS&W issues has also increased, especially with the advent of integrated, multi-modal transportation, increased international container movements, and the enactment of the North American Free Trade Agreement (NAFTA). Evolving logistics requirements are changing the way that many goods are transported. Speed and reliability are becoming increasingly important to the business community replacing the traditional emphasis on moving the largest volumes at the absolute lowest rates.

The highway environment also has changed significantly over the last few decades. Congestion in major metropolitan areas has increased dramatically. Concerns about highway safety have grown as trucks have gotten bigger and automobiles smaller. Vocal opposition to further increases in TS&W limits has arisen, not just from safety interest groups, but from large segments of the general public. Accidents involving trucks on congested urban Interstate highways often result in large traffic jams and receive significant media attention, especially when hazardous materials are spilled.

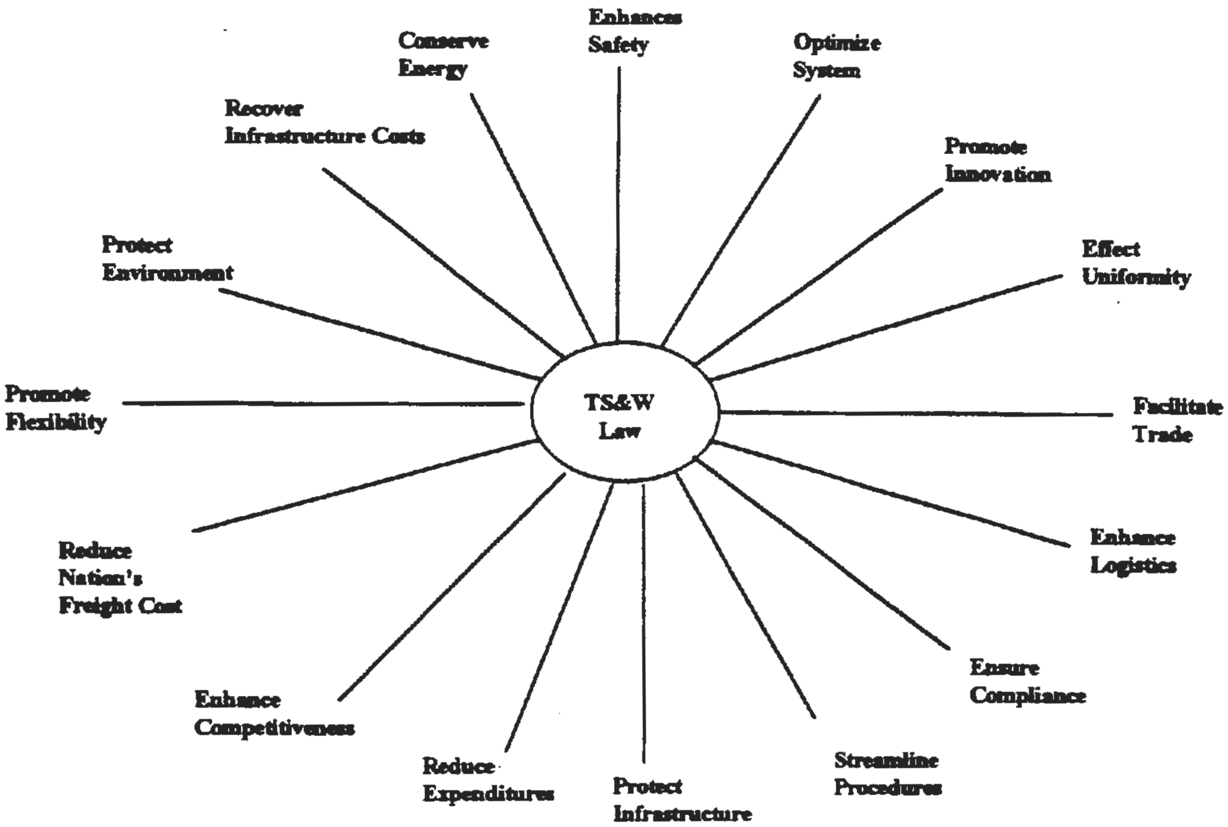
A number of relatively recent legislative developments are important considerations in TS&W discussions. First, the 1991 passage of the ISTEA established a National Highway System (NHS). This network includes all Interstate routes and major connecting principal arterials. It was established to focus Federal resources on the roads that are most critical to interstate travel and National defense; that connect with other modes of transportation; and that are essential for international commerce. The ISTEA also included a freeze on expansion of LCV operations beyond those allowed when ISTEA was passed.

Second, the signings of the NAFTA with Canada and Mexico in 1993 and the General Agreement on Tariffs and Trade (GATT) in 1995, have increased traffic related to the movement of international freight for export and import. The increase in international traffic underlies continued efforts at harmonization of TS&W limits between trading partners, particularly in North America. Also, increased movement of containerized cargo stemming from international transportation creates impacts for the U.S. highway system.

In summary, there have been many changes in the factors interrelated with TS&W laws over the past 20 years. These include growth in freight traffic, changes in freight characteristics and origin-destination patterns, global economics and trade, containerization of freight and intermodalism, economic deregulation, enhanced motor carrier safety programs, and improvements to truck equipment.

These developments suggest important new policy questions concerning Federal TS&W laws. For example, how should Federal TS&W provisions relate to the NHS; and how should harmonization goals for NAFTA be approached? Figure I-2 portrays the environment within which this Study was conducted and highlights the issues that influence and/or impact changes to the Nation's TS&W limits.

FIGURE I-2
FORCES AFFECTING FEDERAL TRUCK SIZE AND WEIGHT LAW



CURRENT FEDERAL TRUCK SIZE AND WEIGHT REGULATIONS

Federal law now regulates TS&W limits by specifying basic standards and excepting certain situations from those standards by grandfather right and provision for special permits. Federal laws governing truck weights apply to the Interstate System while Federal laws governing vehicle size apply to a legislated National Network (NN) which includes the Interstate System. The NN was designated under the authority of the same 1982 Act[4] that established the size limits. Current U.S. Federal TS&W law establishes the following limits:

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[4] Surface Transportation Assistance Act of 1982.

- 20,000 pounds for single axles on the Interstate;
- 34,000 pounds for tandem axes axles on the Interstate;
- Application of Bridge Formula B for other axle groups, up to the maximum of 80,000 pounds for GVW on the Interstate;
- 102 inches for vehicle width on the NN;
- 48 foot (minimum) for semitrailers in a semitrailer combination on the NN; and
- 28 foot (minimum) for trailers in a twin-trailer combination on the NN.

Underlying Federal regulation of TS&W are a myriad of State and local regulations (see Appendix __). The sizes and weights of vehicles have been regulated by State and local law since the early part of this century. Over the years, these regulations have been changed many times in response to needs and circumstances. Change continues--often without Federal involvement or influence. The importance of State TS&W regulations cannot be over-stated since they govern trucking on the vast majority of U.S. roads.

Broadly speaking: (1) many State provisions differ from Federal provisions, (2) there are many regulatory differences among the States, and (3) these differences are increasing over time. These disparities exist because of differences in local and/or regional political choices that have been made balancing economic activities; freight movements; infrastructure design characteristics and status; traffic densities; mode options; engineering philosophies. Table I-5 provides an overview of the areas where either Federal or State laws specify limits.

TABLE I-5
TRUCK SIZE AND WEIGHT LIMITS SPECIFIED IN LAW

Area	Federal Law	State Law
Vehicle Weight Limits		
Tire related		
Number of tires	No	Some
Tire load limit	No	Some
Load distribution between tires	No	No
Axle related		
Load limits by axle type	Yes	All
Load distribution between axles in a group	No	Some
Suspensions	No	No
Lift axles	No	No
Gross vehicle weight		
Bridge formula	Yes	All
Cap	Yes	All
Vehicle Dimension Limits		
Height	No	All
Width	Yes	All
Length		
Single unit	No	All
Semitrailer	Yes	All
Trailer	Yes	All
Combination	Yes	Some
Vehicle Specifications		
Configuration	No	Some
Body type	No	No
Equipment Specifications		
Safety-related		
Hitching	Yes	No
Weight distribution	No	Some
Power/weight	No	Some
Off-tracking-related		
Kingpin	No	Many
Hitching	No	No

WEIGHT

Federal Law

The Federal Government first became involved in TS&W regulation in the 1950's when truck axle and vehicle gross weight and width limits were established for the Interstate system. The Federal-Aid Highway Act of 1956 placed limits on the weight of vehicles operating on the Interstate System to protect the substantial Federal investment in its construction. The limits were 18,000 pounds for single axles, and 32,000 pounds for tandem axles. The allowable gross weight of each vehicle was determined as the sum of the allowable axle weights, up to a maximum allowable GVW of 73,280 pounds.

In 1975, weight limits were raised and "Bridge Formula B" was imposed to insure that the vehicle load was distributed so as to avoid excessive overstressing of bridges. The Federal-Aid Highway Amendments of 1974 increased the allowable maximums on the Interstate System to 20,000 pounds for single axles, 34,000 pounds for tandem axles, and 80,000 pounds for the gross weight. This legislation also requires vehicles to comply with the Federal bridge formula, which limits weights allowed on groups of axles at different spacings, whereas, groupings of two or more axles (except tandems) and the distances between them are checked against the weight allowed by this formula.

State Laws and Grandfather Rights

The Federal-Aid Highway Act of 1956 also contained a provision that allowed States to retain vehicle weight limits exceeding the Federal limits if the State's weight laws or regulations were in effect in 1956. Some states have elected to retain these higher weight limits because of the transportation savings they afford to industries important to their economies.

There are 14 States in which vehicles on Interstate highways can exceed the Federal axle weight limits or gross weight limits without special permits. At least 30 States permit exceptions to the Interstate System axle load limits or gross weight limits for divisible loads. Such special permits are an exercise of grandfathered permit rights. Special permits sometimes stipulate specific routes, equipment components, driver qualifications, and operating restrictions as conditions for vehicle operations.

The regional characteristics of trucking operations are determined, to a large extent, by the existence of grandfather rights. In the western States, LCVs with multiple trailer units operate at high gross weights while meeting Federal axle load and bridge formula requirements. In many Eastern States, heavy trucks with short wheelbases such as concrete mixers and dump trucks operate below the 80,000 pound limit, but with axle loads that exceed the Federal axle load and bridge formula limits. These vehicles are of particular concern since they can cause relatively more pavement and bridge damage than differently configured vehicles traveling at comparable GVWs.

SIZE

Federal Law

In the STAA of 1982, Congress extended the Federal interest to length issues and to highways beyond the Interstate System by requiring all States to permit the operation of 48-foot long semitrailers and twin-trailer combinations with trailing units up to 28 feet long (commonly referred to as "STAA Doubles"[5]) on the Interstate System and on other non-Interstate, Federal-aid, primary system highways to be designated by the Secretary of Transportation. Just before passage of the STAA of 1982, length laws in 14 Eastern States from Maine to Florida prohibited operation of 48-foot long semitrailers. STAA doubles had operated in States west of the Mississippi River for many years, but were not permitted on any roads in 12 States before the STAA of 1982 was enacted. Also, in 1982, minimum length dimensions were enacted for semitrailers. The width limit was increased from 96 inches to 102 inches.

State Laws and Grandfather Rights

As noted above 14 Western States have grandfathered permit authority created by ISTEA and therefore may operate vehicles weighing more than 80,000 pounds on their Interstate highways. In addition, six other States allow limited LCV operations on certain turnpikes. The ISTEA legislation included a freeze limiting LCV routes to those in existence as of June 1991.

Overall Length Limit

The 1982 STAA prohibited States from setting limits on the overall length of single- and twin-trailers combination vehicles on Interstates and other designated Primary highways. However, several States have overall length limits on lower class roads. The reason States were prohibited from limiting the overall length of these combinations was due to safety concerns. To meet such limits, some equipment manufacturers were reducing the size of cabs so that trailer length (and thus cubic capacity) could be increased. When limits on the overall length of combinations on some highways were prohibited, many States instituted limits on the length of cargo-carrying trailers.

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[5] Also referred to as "Western Doubles"

Kingpin to Rear Axle Distance

Several States regulate kingpin setting[6] to rear axle distances for combinations, as a means for controlling vehicle off-tracking. The exact definitions of these limits vary: some measure the distance from the kingpin to the center of the rearmost axle, while others measure the distance from the kingpin to the center of the rear tandem.

STUDY PRESENTATION

OVERVIEW

The 1997 CTS&W Study is to be provided in four volumes. Volume I, Executive Summary, will consolidate and distill the Study findings into an user friendly summary; Volume II identifies and provides background material on the critical issues (see following section); Volume III will describe the illustrative scenarios in detail, provides a detailed overview of the evaluation process to present the analytical findings. Volume IV is to be a guide to the documentation supporting the CTS&W Study.

ORGANIZATION OF VOLUME II: BACKGROUND AND ISSUES

Volume II, Background and Issues, is organized into seven chapters.

TRUCK SIZE AND WEIGHT REGULATIONS

Chapter 2 provides a historical perspective of TS&W regulation in the United States during two time periods, pre- and post-1956. An overview of Federal and State regulation for each period is provided, describing roles and responsibilities at each level of government. Landmark Federal legislation in the post-1956 period is discussed and important highlights noted. Current TS&W laws, at both the State and Federal levels, are discussed.

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[6] Kingpin setting refers to the truck-tractor fifth wheel connection point for the kingpin which is located to the front of the semitrailer.

TRUCKING

Chapter 3 describes the truck fleet and trucking industry in the United States, with special emphasis on those aspects that have important implications for TS&W issues. Questions related to the impact of size and weight regulations on trucking and truck characteristics are examined, including the use of split tandems, super single tires, and lift axles.

TRUCK/RAIL COMPETITION

Chapter 4 examines truck-rail competition and how the competitive balance is likely to be affected by possible changes in TS&W limits. The predominant variables affecting shipper selection of mode are identified, given the type of freight, distance hauled, and freight traffic lane density. Emphasis is placed on identifying the commodities that might shift from rail to truck or truck to rail if limits are changed, and on estimating the magnitude of these shifts.

SAFETY AND TRAFFIC OPERATIONS

Chapter 5 examines the role of TS&W factors in highway safety and traffic operations. Results of past studies linking truck characteristics to crash rates are presented. Stability and control related to various truck configurations at different weights is detailed. Traffic operations impacts, including traffic congestion, acceleration capability, and braking efficiency also are described.

HIGHWAY INFRASTRUCTURE IMPACTS

Chapter 6 examines highway infrastructure costs, including bridges, pavements, and roadway geometric features in the context that (1) bridge stress may not be adequately controlled by Bridge Formula B, (2) adverse pavement impacts may be reduced with the introduction of additional axles, and (3) longer and heavier trucks, in general, require changes to such geometric features as sharp curves (interchange ramps), intersections, hill climbing lanes, vertical curves, intersection clearance, and passing sight distance. The relationship of weight limits to bridge stresses are described. Pavement impacts are discussed, including the effects of axle weight limits, tire regulations, lift axles, road-friendly suspensions, and overweight containers.

ENFORCEMENT ISSUES

Chapter 7 examines enforcement and implementation issues related to changes in Federal TS&W provisions. Evolution of the Federal-State partnership in enforcement is described. Contributions of intelligent transportation systems, vehicle inspections, permit programs, and relevant evidence are considered.

CHAPTER 2

TRUCK SIZE AND WEIGHT LIMITS

EVOLUTION AND CONTEXT

The second issue of *Public Roads* magazine published in 1918 focused on the problems State highway departments were encountering as the result of truck traffic.[1] The lead article, "The Highways of the Country and the Burden They Must Carry," summarized the issues of that era, many of which are still familiar today:

> Apparently the point has been reached where the demands of traffic have exceeded the strength of the average road to meet them. Highways designed to withstand the pounding of ordinary loads, that have stood up under imposts they were intended to sustain, no longer appear to be adequate to meet the present-day conditions. Widespread failure is demonstrative of the fact the roads can not carry unlimited loadings. Their capacity is limited.

A review of past Federal and State regulatory roles and responsibilities for highways provides a sense of how the current regulatory environment evolved.

PRE-1956

FEDERAL REGULATION

Federal government regulation of all transportation modes prior to 1956 was directed at economic regulation. First to be regulated were railroads in the mid- and late-1800s, then steamship lines in the early 1900s, followed by pipelines, motor carriers and airlines in the mid-1930s. Size and

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[1] Transportation Research Board (TRB) *Special Report 225, Truck Weight Limits: Issues and Options*, 1990.

weight regulation was controlled by the individual States and developed in response to increasing motor carriage of freight on a developing highway system. Direct Federal involvement in regulation of TS&W did not occur until the passage of the Federal-Aid Highway Act of 1956.

STATE REGULATION

The first truck weight limits were enacted in 1913: Maine [18,000 pounds gross vehicle weight (GVW)], Massachusetts (28,000 pounds GVW), Pennsylvania (24,000 pounds GVW) and Washington (24,000 pounds GVW). Early State truck weight laws were passed to limit damage to the earth- and gravel-surfaced roads caused by the iron and solid rubber wheels of heavy trucks.[2] The limits included tire load limits in Maine, Massachusetts and Pennsylvania. Further, in Pennsylvania the first axle weight limit was set at 18,000 pounds.[3]

Limits on length, width, and height were generally adopted somewhat later in most States. By 1929, the majority of States regulated all dimensions. The most common form of early State size regulation was a width restriction that remained fairly uniform among the States at 96 inches until the 1982 Federally mandated increase to 102 inches on the National Network (NN). By 1933, all States had passed some form of TS&W regulation.[4]

The American Association of State Highway Officials (AASHO), organized in 1914, developed a model used by many States in adopting TS&W limits. Beginning with its first policy statement in 1932, AASHO (subsequently renamed American Association of State Highway and Transportation Officials, AASHTO) advocated State adoption of uniform regulations. While AASHO/AASHTO policy has significantly influenced State and Federal regulations, the call for State uniformity has produced limited results.[5]

The first Federal study that examined the need for Federal regulation of TS&W was published in 1941 by the Interstate Commerce Commission (ICC).[6] The Study found

> . . . wide and inconsistent variations in the limitations imposed by the . . . States . . . [and that]. . . limitations imposed by a single State may and often do have an influence and effect which extend, so far as interstate commerce is concerned, far beyond the borders of that State, nullifying or impairing the effectiveness of more liberal limitations imposed by neighboring States.

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[2] TRB Special Report 223, *Providing Access for Large Trucks*, 1989.

[3] Interstate Commerce Commission (ICC), 1941.

[4] TRB Special Report 211.

[5] TRB Special Report 211.

[6] ICC, *Federal Regulation of the Sizes and Weight of Motor Vehicles*.

The study concluded that a need existed for Federal intervention and establishment of Federal standards on the sizes and weights of motor vehicles. Since the study also concluded that national uniformity of standards would be impossible, the recommendation for Federal intervention was confined to cases where State laws were determined to be an unreasonable obstruction to interstate commerce.

POST-1956

FEDERAL REGULATION

The Federal-Aid Highway Act of 1956

The first Federal TS&W limits were enacted in the Federal-Aid Highway Act of 1956 as part of the new Federal highway program for construction of the Interstate and Defense Highway System. The Act established Federal limits for the Interstate System that were based an AASHO policy adopted in 1946 that recommended:

- Maximum width limit of 96 inches;
- Single-axle weight limit of 18,000 pounds;
- Tandem-axle weight limit of 32,000 pounds; and
- GVW of 73,280 pounds.

The Federal limits were qualified by a "grandfather clause" (see subsequent section) that allowed continued operation of heavier trucks on the new Interstate System consistent with State limits in effect on July 1, 1956.

In the decades leading to the 1956 Act, Federal highway funding to the States increased from an equal 50/50 partnership to a 75/25 Federal/State match, and in 1956 to 90/10 and 80/20 for the Interstate System and State system, respectively. The new Interstate System was to be designed and constructed to higher, uniform standard than the State and local highway system. The substantial degree of Federal financial participation motivated increased Federal involvement in setting Interstate TS&W limits.[7] In the words of the House of Representatives' Committee on Public Works and Transportation, Congress

> . . . recognizes the maximum weight limitations are fundamentally a problem of State regulations, but feels that if the Federal government is going to pay 90 percent of the cost of the Interstate System improvements, it is entitled to protection of the investment against damage caused by heavy loads on the highway.

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[7] U.S. DOT, 1981, *An Investigation of Truck Size and Weight Limits*. Final Report.

Table II-1 provides a time line depicting Federal and State roles in highway funding and TS&W regulation from 1916 through 1991.

TABLE II-1
FEDERAL/STATE ROLES AND RESPONSIBILITIES FOR HIGHWAYS: EMPHASIS AREAS[8]

	Federal-Aid for Highways	Weight Regulation	Size Regulation
Federal-Aid Road Act 1916	Rural Post Road construction 50/50 match		
Federal-Aid Road Act 1944	Post-war highway construction: Federal Aid Primary, Federal Aid Secondary and inter- regional system 75/25 match		
Federal-Aid Highway Act 1956	Interstate construction, 90/10 match; other State system, 80/20 match	Interstate: maximum axle and gross vehicle weight (GVW) limits 18,000/32,000/ 73,280 pounds(a)	
Federal-Aid Highway Act Amendments 1974	Interstate construction, Federal Aid Primary and Federal Aid Secondary	Interstate: axle and minimum GVW limits 20,000/34,000/80,000 pounds under Federal Bridge Formula B(b)	
Surface Transportation Assistance Act (STAA) 1982	Interstate construction, Federal Aid Primary and Federal Aid Secondary	Interstate: Mandated maximum limits on Interstate(c)	STAA vehicle mandate on Interstate and Designated System(d)
Intermodal Surface Transportation Efficiency Act (ISTEA) 1991	Interstate completion, National Highway System designation	Longer Combination Vehicle freeze	Longer Combination Vehicle freeze imposed by Congress(e)

(a) First "grandfather clause" allowed operation on Interstate at higher limits in States where higher weights were legal prior to July 1, 1956.

(b) Adopted new BFB with new "grandfather" provisions to allow previously enacted axle spacing tables to exceed new bridge formula on Interstate.

(c) Congress mandated the Federal weight limits be allowed by the States on the Interstate to resolve problems of "barrier" States that had not adopted the 1975 Federal limits.

(d) Required States to allow 48' semitrailers and 28' twin-trailer combinations without length restriction (plus auto carriers and household goods movers). Created designated system for operation off the Interstate and access provisions to terminals and service facilities.

(e) Froze weight of LCVs on the Interstate and cargo box length of double- and triple-trailer combinations on the National Network. as of June 1, 1991.

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[8] *Pub.No.156, Chap.241, 1916; Federal-Aid Road Act, 1944; Federal-Aid Highway Act, 1956;*

The 1956 Act directed the U.S. Secretary of Commerce to provide information to Congress regarding maximum desirable vehicle size and weight. In response, extensive field tests of pavement and bridges were conducted by the Highway Research Board under sponsorship of AASHO.[9] The 1964 Report to Congress recommended the following changes:

- Single- and tandem-axle weight limits should be increased to 20,000 pounds and 34,000 pounds, respectively;
- The maximum GVW limit of 73,280 pounds should be replaced by a table of axle group weight limits, depending on the length of the axle group and the number of axles in the group. The look-up table would be based on Bridge Formula B.[10]
- The maximum width limit should be 102 inches;
- Maximum lengths should be: 40 feet for single unit trucks and buses, 40 feet for a semitrailer or full trailer, 55 feet overall length for a tractor-semitrailer, and 65 feet overall length for other combinations;
- Performance standards should be specified for weight-to-horsepower ratio, vehicle braking systems, and linkages between combinations; and
- Grandfather exemptions should not be eliminated immediately, but should be phased out.

The Federal-Aid Highway Act Amendments of 1974

The Federal-Aid Highway Amendments of 1974 adopted several recommendations from the 1964 Report. The 1974 Act established maximum single- and tandem-axle limits of 20,000 and 34,000 pounds, respectively. It also set the maximum GVW limit at 80,000 pounds, disregarding the recommendation from the 1964 Report that GVW be limited solely by the bridge formula. Further, Congress expanded the grandfather exemptions from the 1956 Act to include provisions for State weight tables or axle spacing formulas not meeting the new bridge formula.[11]

Although the 1974 legislation provided for increases in the maximum axle weight limits and the GVW limit, it did not mandate State adoption of these weights. In fact, when six contiguous States in the Mississippi Valley, collectively referred to as the "barrier States," refused to increase their Interstate GVWs to 80,000 pounds, the trucking industry effectively faced a barrier to cross-country interstate commerce. This situation contributed to Congressional action in 1982.

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[9] TRB Special Report 225.

[10] Description of Bridge Formula B

[11] TRB Special Report 225.

The Surface Transportation Assistance Act of 1982

The 1982 Surface Transportation Assistance Act (STAA) substantially expanded Federal regulation and authority over both vehicle size and weight, overriding the more restrictive barrier States and establishing minimum, and maximum standards for weight, width, and minimum standards for length on the Interstate system and many Federal-aid highways.[12] The Federal size limits included two dimensions, trailer length and vehicle width. Congress also made the previous single-and tandem-axle and GVW maximum the States could allow, the minimums they must allow on the Interstate highways.

In addition, the new dimensional restrictions barred States from limiting the overall length of a tractor and 48-foot semitrailer in combination, or the overall length of a tractor and two 28-foot semi-trailers or trailers in combination on the Interstate and portions of the Federal-aid primary system. The width limit established in STAA was 102 inches, providing the highway lane width was 12 feet.

The motor vehicle size limits established in the STAA covered roads other than Interstate highways. The Act directed the Secretary of Transportation to designate a network of highways that would include Federal-Aid Primary (FAP) system roads that could safely accommodate STAA vehicles. This network is commonly referred to as the "National Network" (NN) and includes the Interstate in addition to designated sections of the FAP system.

The intent of Congress in expanding the Federal role was to improve carrier productivity through liberalizing restrictive State limits and to create a uniform national minimum standard.[13] However, some State and local transportation officials maintained that the majority of the non-Interstate highway system could not accommodate larger trucks and, therefore, restricted access beyond the Interstate.[14] The extent of restrictions on large trucks varied from slight to extensive. For example, nine States in the West had virtually no restriction on 48-foot trailers and STAA doubles[15] on the major highways connecting urban centers (the FAP system). By comparison, 17 primarily Eastern States and the District of Columbia restricted the larger trucks to fewer than one-third of their FAP highways.

Access restrictions imposed by the States following passage of STAA initiated litigation by the trucking industry. The result was court rulings that: (1) a State was prohibited from enacting or enforcing laws that denied reasonable access; and (2) congressional intent was not to preempt the

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[12] TRB Special Report 221.

[13] TRB Special Report 211 and U.S. Senate Report No. 97-298 1981.2.

[14] "Access for Large Trucks," TR News, Transportation Research Board, Jan-Feb 1990.

[15] Also referred to as Western Doubles

reasonable exercise by a State of its police powers to protect public safety on roads within its jurisdiction. In other words, the States could not deny reasonable access, but what was reasonable would be defined by the States.

The STAA of 1982 included provisions to address increasing concerns of States over the deteriorating conditions of the Nation's highways, bridges and mass-transit infrastructure. The STAA increased and restructured Federal highway taxes for the first time in over two decades and authorized increased Federal spending to finance several major transportation programs. The STAA also initiated two primary tax increases affected by vehicle-weight: a five-cent-per-gallon increase in motor-fuel excise taxes and an increase in the GVW-based annual heavy vehicle use tax.

Significant TS&W highlights from the 1982 STAA are:

- Combinations consisting of a tractor and two trailing units were allowed on Interstates and other primary highways to be designated by the Secretary of Transportation (creation of the NN). For these combinations (often referred to as "STAA doubles" or "twin-trailers"), States were prohibited from limiting the length of each trailing unit to less than 28 feet or imposing an overall length limit.
- States were prohibited from limiting the length of semitrailers in tractor-semitrailer combinations to less than 48 feet and from placing any limits on the overall length of combinations.
- States were required to allow 102 inch wide vehicles on Interstates and other Federal-aid highways with 12-foot lanes.
- States were prohibited from denying reasonable access to twin-trailer trucks and 48-foot semitrailers to terminals; facilities for food, fuel, repairs, and rest; and points of loading and unloading for household goods carriers.
- States were prohibited from enforcing any reduction of trailer size limits that would have the effect of banning trailers that were legal and actually in use on December 1, 1982. This restriction *required* states to keep higher limits.[16]

The 1982 legislation also addressed the issue of State permit practices and grandfather provisions. Permit practices in place in 1956 rarely specified absolute limits, as many States did not maintain records of weights actually allowed before 1956. Some States contended that the grandfather provision applied to their power to issue permits, not the specific permits themselves. Hence, these States claimed that they could issue permits for overweight vehicles that weighed more than those that might have been permitted before 1956. The 1982 STAA resolved this dispute, by

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[16] TRB Special Report 211.

allowing States to permit vehicles "which the State determines could be lawfully" operated in 1956 or 1975.[17] Subsequent litigation over an FHWA regulation requiring States to seek approval for permits for divisible loads resulted in a court ruling affirming the States' rights.[18]

The Intermodal Surface Transportation Efficiency Act of 1991

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) froze the weight of longer combination vehicles (LCVs) and limited them to routes that were allowed by the States on June 1, 1991. ISTEA defined LCVs as "any combination of a truck tractor and two or more trailers or semitrailers which operate on the National System of Interstate and Defense Highways with a GVW greater than 80,000 pounds."

A second ISTEA freeze applied to the length of trailers and semitrailers, specifically cargo carrying units and stated

> . . . no State shall allow by statute, regulation, permit, or any other means the operation on any segment of the National System of Interstate and Defense Highways and those classes of qualifying Federal-aid primary system highways as designated by the Secretary . . . . any commercial motor vehicle combination (except those vehicles and loads which cannot be easily dismantled or divided and which have been issued special permits in accordance with applicable State laws) with 2 or more cargo carrying units (not including the truck tractor) whose cargo carrying units exceed--the maximum combination trailer, semitrailer, or other type of length limitation authorized by statute or regulation of that State on or before June 1, 1991; or the length of the cargo carrying units of those commercial motor vehicle combinations, by specific configuration, in actual lawful operation on a regular or periodic basis (including seasonal operation) in that State on or before June 1, 1991.

Further, ISTEA prohibits all States from expanding routes or removing restrictions related to LCV or longer double operations after that date. Congress required each State to submit information on LCV and longer double restrictions and requirements to the FHWA by December 1, 1991, and to certify annually to FHWA in their size and weight certification that they are enforcing the freeze.

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[17] TRB Special report 225.

[18] TRB Special Report 211 and Janklow v. Dole, D.S.D. June 17, 1985.

STATE REGULATION

In the first 20 years following passage of the 1956 Highway Act, and the beginning of Federal regulation of TS&W, States continued to control size and weight limits on State highways and Interstate highways under grandfather rights. As the Federal investment in the Interstate system grew and Interstate construction neared completion, Federal regulations and control increased, often putting the State and Federal governments in adversarial positions. One issue that continues to emerge in the TS&W debate is grandfather rights exercised by a growing number of States as the result of the STAA of 1982 and ISTEA of 1991.

Grandfather Rights[19]

In the 40 years following enactment of the Federal-Aid Highway Act of 1956 the extension of grandfather rights to the States has grown more controversial. At the State level, truck weight limits are influenced by three different grandfather rights provisions. The first was enacted in 1956 and deals primarily with axle weights, gross weights, and permit practices. The second was adopted in 1975 and applies to bridge formula and axle spacing tables. Finally, the third enacted in 1991, ratifies State practices regarding LCVs.

The First Grandfather Clause

Before enactment of the Federal-Aid Highway Act of 1956, some States permitted motor carriers to operate with axle weights or GVWs in excess of the limits specified in the 1956 Act (18,000 pounds on a single axle, 32,000 pounds on a tandem axle, and 73,280 pounds GVW). To avoid a rollback of vehicle weights in those States where the higher limits were permitted, Congress included a "grandfather clause" in the 1956 legislation.

The FHWA had the authority to determine whether specific grandfather claims would be permitted. Although no formal approval process was established, informal procedures soon evolved. In general, a State seeking to establish grandfather rights would submit copies of the appropriate 1956 statue to the FHWA. The Agency would review the claim and if it determined the documentation was ambiguous or otherwise arguable, FHWA would request an Attorney General's opinion. Claims that were not legally defensible were rejected.

During the 1960s and 1970s, most grandfather issues related to the interpretation of State laws in effect in 1956. While these have been largely resolved, States occasionally make new claims, mostly for exemptions from Federal weight limits. However, most grandfather rights were established decades ago.

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[19] The material presented in this section was excerpted from the personal papers of Charles Medalen, Office of Chief Counsel, Federal Highway Administration.

After the mid-1970's, the meaning and intent of the grandfather clause itself came into dispute. At issue was the use of divisible load permits for overweight vehicles. A strict interpretation of the 1956 Act would prohibit use of divisible load permits today for weights in excess of the weight allowed under permit in 1956. FHWA has held that the grandfather clause allowed States to issue permits only if the same circumstances and conditions are present today as were present in 1956. Problems arose with this reading of the Act because many States did not specify the weight allowed under permit and most were unable to document the weight limits or other conditions imposed in 1956.

State courts[20] have supported a more permissive interpretation of the grandfather clause, requiring only proof that certain weights could have been operated under divisible/nondivisible permits in 1956, rather than proof that they were in actual operation. This interpretation of the grandfather clause essentially repealed the Federal 80,000 pound GVW. Today, many States issue divisible load permits allowing vehicles weighing over 110,000 pounds to routinely operate on the Interstate Systems.

The Second Grandfather Clause

Interstate single axle, tandem axle, and GVW limits were increased with passage of the Federal-Aid Highway Amendments of 1974. In addition, the bridge formula was added. Also provided was a grandfather clause which would allow States to retain any bridge formula or axle spacing tables governing motor vehicle operations as of January 4, 1975, which allowed higher weights than Bridge Formula B.

However, in 1975 few States had specified bridge formulas or axle-spacing tables. In fact, it was common for State law to be silent on axle spacing requirements. Because short-wheelbase trucks (that were nonconforming with respect to the bridge formula) were permitted in a number of States before 1975, the absence of a regulation was grandfathered. Therefore, many State motor vehicle operations are exempt from the bridge formula up to the highest GVW allowed in 1975, typically 73,280 pounds. Not all States take advantage of their grandfather exemption.

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[20] State ex rel. Dick Irvin, Inc., v. Anderson 525 P. 2d. 564 (1974) and South Dakota Trucking Association v. South Dakota Department of Transportation, 305 N.W. 2d 682 (1981).

The Symms Amendment

The STAA of 1982 included language to amend the then current provisions addressing the withholding of Federal-aid funds (revised language underlined):

> This section shall not be construed to deny apportionment to any State allowing the operation within such State of any vehicles or combinations thereof which the State determines could be lawfully operated within such State on July 1, 1956, except in the case of the overall gross weight on any group of two or more consecutive axles (i.e., the bridge formula), on the date of enactment of the Federal-Aid Highway Amendments of 1974.

The amendment was introduced by Senator Symms (hence, it is commonly referred to as the "Symms Amendment") and was intended to resolve disputes about grandfather rights between the FHWA and certain States. However, it had the opposite effect since some States began to make unrealistic claims for grandfather rights that went well beyond rights that had previously been claimed.

ISTEA: The Third Grandfather Clause

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) placed a freeze on the operation of LCVs. An LCV was defined as a tractor and two or more trailers or semitrailers operating on the Interstate with a GVWs exceeding 80,000 pounds. The legislation allowed LCV combinations which were in actual and lawful operation under State law on June 1, 1991 to continue in operation, if the State so desired. Thus, the grandfather date for LCVs is 1991.

Permits

Many States allow exemptions for certain classes of vehicles or commodities, with or without permits. For example, dump trucks in many States in the Northeast are allowed higher weight limits either through a special truck registration or permit.

States continue to issue permits for divisible loads under grandfather authority. Thirty-seven States issued divisible load permits in 1985 and 1995 totaling 153,642 and 380,511, respectively. The number of permits available for specific commodities continues to increase. For example, in 1995 Pennsylvania added two new overweight permits for 94,000 pounds GVW and 21,000 pounds per axle, on State highways only, for steel coils and milk; in 1996 the Pennsylvania legislature added bulk animal feed. State authority to control vehicles that operate off the Interstate continues to be an important issue.

CURRENT ENVIRONMENT

FEDERAL

Federal truck weight law applies to the Interstate System while Federal vehicle size law applies to the NN which includes the Interstate System. Current Federal TS&W law establishes the following limits:

- 20,000 pounds for single axles on the Interstate;
- 34,000 pounds for tandem axes on the Interstate;
- Application of Bridge Formula B for other axle groups up to the maximum of 80,000 pounds GVW on the Interstate;
- 102 inches for vehicle width on the NN;
- 48-foot (minimum) for semitrailers in a semitrailer combination on the NN; and
- 28-foot (minimum) for trailers in a twin-trailer combination on the NN.

Federal law regulates trucks by specifying basic TS&W standards and excepting certain situations from those standards by recognizing State grandfather rights and special permits.

STATE APPLICATION

WEIGHT

There are four basic weight limits: single axle, tandem axle, bridge formula and gross vehicle. These limits generally apply both on and off the Interstate system. When taken together, the 50 States and the District of Columbia have created 40 different combinations of these eight limits. Only seven States apply the Federal limits Statewide without modification or "grandfather right" adjustment. Even in these seven, however, the upper limits for routine permits are all different. In a sense, each State has a different weight limit "package." Table II-2 provides vehicle weight limits for each of the States.

Single Axle, Tandem Axle and Gross Weight Limits

Fourteen States have a single axle limit greater than the Federal standard of 20,000 pounds on the Interstate. Off the Interstate, 17 States have limits greater than the Federal limit and three States are below the Federal limit.

Fifteen States have a tandem axle limit greater than the Federal limit of 34,000 pounds on the Interstate. On the non-Interstate State system, 21 States have limits greater than 34,000 pounds and two states are below the Federal limit.

Four States have grandfather rights to exceed 80,000 pounds on the Interstate. On non-Interstate State highways, 18 States have a GVW limit higher than 80,000 pounds. Alternatively, five States have GVWs less than 80,000 pounds on some of their non-Interstate highways.

"Routine" Permit Limits

For a 5-axle unit there are 28 different permitted maximum GVW limits ranging from 80,000 pounds to 155,000 pounds. The mode value (the value that occurs most frequently) is 100,000 pounds and occurs in seven States. For any number of axles there are 25 different maximum permitted GVW limits (the mode value is 120,000 pounds and occurs in ten States).

For single axles there are 16 different limits ranging from 13,000 pounds to 32,000 pounds. For tandem axles there are 17 different limits ranging form 26,000 pounds to 64,000 pounds.

TABLE II-2
1994 VEHICLE WEIGHT LIMITS
(In 1,000 Pounds)

State	Gross Vehicle		Single Axle		Tandem Axle		Federal Bridge Formula "B"		"Routine" Permit		
	"I"	Other Hwys.	"I"	Other Hwys.	"I"	Other Hwys.	"I"	Other Hwys.	Gross Vehicle Weight	Single Axle	Tandem Axle
Alabama	80	84	20	20	34	40	Yes	No-WT	110/150	22	44
Alaska	–	90(2)	–	20	–	38	—	Yes	88.6(2)/150	30	50
Arizona	80	80	20	20	34	34	Yes	No-WT	106.5(3)/250	28	46
Arkansas	80	80	20	20	34	34	Yes	Yes	102/134	20	40
California	80	80	20	20	34	34	Yes-mod	Yes-mod	119.8(4)/(5)	30	60
Colorado	80	85	20	20	36	40	Yes	No	127/164	27	50
Connecticut	80	80	22.4	22.4	36	36	Yes	Yes	120/160	22.4	NS
Delaware	80	80	20	20	34	40	Yes	No-WT	120/120	20	40
D.C.	80	80	22	22	38	38	Yes-mod	Yes-mod	155-248	31	62
Florida	80	80	22	22	44	44	Yes (6)	No-WT	112/172	27.5	55
Georgia	80	80	20.34	20.34	34(7)	37.34	Yes	Yes(6)	100/175	23	46
Hawaii	80.8	88	22.5	22.5	34	34	Yes	No Case-by-case above normal limits			
Idaho	80	105.5	20	20	34	34	Yes	Yes Case-by-case above normal limits			
Illinois	80	80(8)	20	20(9)	34	34(9)	Yes	Yes(9)	100/120	20	48
Indiana (10)	80	80	20	20	34	34	Yes	Yes	108/120	28	48
Iowa	80	80	20	20	34	34	Yes	Yes	100/160	20	40
Kansas	80	85.5	20	20	34	34	Yes	Yes	95/120	22	45
Kentucky	80	80(11)	20	20	34	34	Yes	Yes	96/140	24	48
Louisiana	80(12)	80(12)	20	22	34	37	Yes	No	108/120	24	48
Maine	80	80(13)	20(14)	22.4	34	38	Yes-mod	No	130/167	25	50
Maryland	80	80	20(15)	20(15)	34(15)	34(15)	Yes	Yes	110/110	30	60
Massachusetts	80	80	22.4	22.4	36	36	Yes	Yes	99/130	NS	NS
Michigan (16)	80	80	20	20	34	34	Yes	Yes	80/164	13	26
Minnesota	80	80(17)	20	18	34	34	Yes	Yes-mod	92/144	20	40
Mississippi	80	80	20	20	34	34	Yes	Yes	113/190	24	48
Missouri	90	80 (18)	20	20(18)	34	34(18)	Yes	Yes(18)	92/120	20	40
Montana	80	80	20	20	34	34	Yes	Yes	105.5/126	20	48
Nebraska	80	95	20	20	34	34	Yes	Yes	99/110	20	40
Nevada	80	129(19)	20	20	34	34	Yes	Yes	110(20)/(21)	28	50.4

State	Gross Vehicle		Single Axle		Tandem Axle		Federal Bridge Formula "B"		"Routine" Permit		
	"I"	Other Hwys.	"I"	Other Hwys.	"I"	Other Hwys.	"I"	Other Hwys.	Gross Vehicle Weight	Single Axle	Tandem Axle
New Hampshire	80	80	20(15)	22.4	34(15)	36	Yes	No	130/150	25	50
New Jersey	80	80	22.4	22.4	34	34	Yes	No	144(22)/240(22)	32(22)	64(22)
New Mexico	86.4	86.4	21.6	21.6	34.32	34.32	Yes-mod	Yes-mod	104(23)/120	26	46
New York	80	80	20(24)	22.4	34(24)	36	Yes(24)	Yes(24)	100/150	25	42.5
North Carolina	80	80	20	20	38	38	Yes-mod	Yes-mod	94.5/122	25	50
North Dakota	80	105.5	20	20	34	34	Yes	Yes	103/136	20	45
Ohio	80	80	20	20	34	34	Yes	No	120/120	29	46
Oklahoma	80	90	20	20	34	34	Yes	Yes	95/140	20	40
Oregon	80	80	20	20	34	34	Yes/mod	Yes-mod	90/105.5	21.5	43
Pennsylvania	80	80	20(25)	20(25)	34(25)	34(25)	Yes(25)	Yes(25)	116/136	27	52
Rhode Island	80	80	22.4	22.4	36	36	Yes-mod	Yes-mod	104.8/(21)	22.4	44.8
South Carolina	80	80.6	20	22	34(26)	39.6	Yes(26)	No	90/120	20	40
South Dakota	80	129(19)	20	20	34	34	Yes	Yes	116(27)/(21)	31	52
Tennessee	80	80	20	20	34	34	Yes	Yes	100/160	20	40
Texas	80	80	20	20	34	34	Yes-mod	Yes-mod	106.1(28)/200	25	48.125
Utah	80	80	20	20	34	34	Yes	Yes	100/123.5	20	40
Vermont	80	84	20	22.4	34	36	Yes	Yes	108(29)/120	24	48
Virginia	80	80	20	20	34	34	Yes	Yes	110/150	25	50
Washington	80	105.5	20	20	34	34	Yes	Yes	103/156	22	43
West Virginia	80	80(30)	20	20	34	34	Yes	Yes	104/110	20	45
Wisconsin	80	80	20	20	34	34	Yes-mod	Yes-mod	100/191	20	60
Wyoming	117	117	20	20	36	36	Yes	No	85/135	25	55

NS...Not specified
WT...Weight table

(1) "Routine" Permit Gross Vehicle Weight: the first number (left) is the highest weight a 5-axle unit can gross before special (other than routine) review and analysis of an individual movement is required. The second number (right) is the highest gross weight any unit with sufficient axles can gross before special review is required.

(2) State rules allow the more restrictive of the Federal Bridge Formula B or axle summation. The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with a 65' outer bridge (based on a 48' semitrailer).

(3) The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with two 5' tandems @ 47.25K each + a 12K steering axle.

(4) Estimate based on State weight table values for a 4' tandem (drive) @ 46.2K, a rear tandem at the 60K maximum, and a 12.5K steering axle.

(5) Maximum based on the number of axles in the combination.

(6) Federal Bridge Formula applies if gross vehicle weight exceeds 73.28K.

(7) If gross vehicle weight is less than 73.28K, the tandem axle maximum is 40.68K.

(8) On class III and non-designated highways the maximum is 73.28K.

(9) On non-designated highways the single axle maximum is 18K, the tandem axle maximum is 32K, and the Bridge formula does not apply.

(10) On the Indiana Toll Road the single axle maximum is 22.4K, the tandem axle maximum is 36K, and the maximum practical gross is 90K.

(11) The maximum gross weight on class AA highways is 62K, on class A highways 44K.

(12) Six or seven axle combinations are allowed 83.4K on the Interstate System, and 88K on other State highways.

(13) A three axle tractor hauling a tri-axle semitrailer has a maximum gross vehicle weight of 90K.

(14) If the gross vehicle weight is less than 73.28K, the single axle maximum is 22K.

(15) If the gross vehicle weight is 73K or less, the single axle maximum is 22.4K, and the tandem axle maximum 36K.

(16) Federal axle, gross and Bridge formula limits apply to 5-axle combinations if the gross vehicle weight is 80K or less. For other vehicles and gross vehicle weights over 80K other limits apply. State law sets axle weight controls which allow vehicles of legal overall length to gross a maximum of 164K.

(17) Most city, county and township roads are considered "9-Ton Routes" with a maximum gross vehicle of 73.28K.

(18) On highways other than Interstate, Primary, or other designated, the single axle maximum is 18K, the tandem axle maximum 32K, the Bridge formula is modified, and the gross vehicle weight maximum is 73.28K.

(19) The maximum is directly controlled by the Federal Bridge Formula. Given the State's length laws, the maximum practical gross is 129K.

(20) The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with a 12.5K steering axle, a 47.25K drive tandem (5' spacing from State weight table), and a 50.4K spread tandem (8' spacing from the State weight table).

(21) A determination is made on a case-by-case basis.

(22) All "routine" permit values are calculated using 10" wide tires and a maximum 800 pounds/inch of tire width loading value.

(23) The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with two 46K tandems + a 12K steering axle.

(24) If the gross vehicle weight is less than 71K, the single axle maximum is 22.4K, the tandem axle maximum 36K, and a modified Bridge formula applies.

(25) If the gross vehicle weight is 73.28K or less, the single axle maximum is 22.4K, the tandem axle maximum 36K, and the Bridge formula does not apply.

(26) If the gross vehicle weight is 75.185K or less, the tandem axle maximum is 35.2K, and the Bridge formula does not apply.

(27) The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with two 52K tandems + a 12K steering axle.

(28) The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with a 13K steering axle, a 45K drive tandem, and a 48.125K spread tandem. Both tandem weight values are from the State weight chart.

(29) The 5-axle "routine" permit value is estimated using a truck tractor-semitrailer with two 48K tandems + a 12K steering axle.

(30) The maximum gross vehicle weight on non-designated State highways is 73.5K, and on county roads 65K.

Information sources:

J. J. Keller & Associates, Vehicle Sizes and Weights Manual. July 1, 1994.

Specialized Carriers & Rigging Association (SC&RA), Permit Manual. July 19, 1994.

Western Association of State Highway and Transportation Officials (WASHTO), Guide for Uniform Laws and Regulations Governing Truck Size and Weight. June 26, 1993.

LENGTH

Ten States allow semitrailers over 53 feet in length. See Table II-3 for a state-by-state presentation of maximum semitrailer lengths.

TABLE II-3
1994 MAXIMUM SEMITRAILER LENGTHS BY STATE

National Network (NN)			Other State Highways		
State	**Length**	**Kingpin**	**Length**	**Kingpin**	**Overall**
Alabama	57-0	41-0 KCRA(1)	53-0		
Alaska	48-0		45-0		70-0
Arizona	57-6(7)		53-0		65-0
Arkansas	53-6		53-6		
California	53-0	40-0 KCRTA(8) 38-0 KCSRA(9)	53-0	Same as NN	
Colorado	57-4		57-4		
Connecticut	53-0		48-0		
Delaware	53-0		53-0		60-0
Dist. of Col.	48-0		48-0		55-0
Florida	53-0	41-0 KCRT(2)	53-0	41-0 KCRT	
Georgia	53-0	41-0 KCRT	53-0	41-0 KCRT	67-6
Hawaii	No Limit		45-0		60-0
Idaho	53-0		48-0	39-0 KCRA	
Illinois	53-0	42-6 KCRA	53-0	42-0 KCRA	
Indiana	53-0	40-6 KCRA	53-0	40-6 KCRA	
Iowa	53-0		53-0	40-0 KCRA	60-0
Kansas	59-6		59-6		
Kentucky	53-0		No Limit		57-9
Louisiana	59-6		No Limit		65-0
Maine	53-0(3)	43-0	53-0		65-0
Maryland	53-0(4)	41-0 KCRT	53-0	41-0 KCRT	
Massachusetts	53-0(5)		53-0		
Michigan	53-0	41-0 KCRT	50-0		
Minnesota	53-0	41-0 KCRT	53-0	41-0 KCRT	
Mississippi	53-0		53-0		
Missouri	53-0		No Limit		60-0
Montana	53-0		53-0		
Nebraska	53-0		53-0		
Nevada	53-0		53-0		70-0
New Hampshire	53-0(6)	41-0 KCRT	53-0	41-0 KCRT	
New Jersey	53-0	41-0 KCRT	53-0	41-0 KCRT	
New Mexico	57-6		No Limit		65-0
New York	53-0(4)	41-0 KCRT	48-0		65-0

National Network (NN)			Other State Highways		
State	**Length**	**Kingpin**	**Length**	**Kingpin**	**Overall**
North Carolina	53-0	41-0 KCRT	No Limit		60-0
North Dakota	53-0		53-0		
Ohio	53-0		53-0		
Oklahoma	59-6		59-6		
Oregon	53-0		Varies		
Pennsylvania	53-0		No Limit		60-0
Puerto Rico	48-0				
Rhode Island	48-6		48-6		
South Carolina	53-0	41-0 KCRT	48-0		
South Dakota	53-0		53-0		
Tennessee	53-0	41-0 KCRT	53-0	41-0 KCRT	
Texas	59-0		59-0		
Utah	53-0	40-6 KCRT	53-0	40-6 KCRT	
Vermont	53-0(4)	41-0 KCRT	48-0		60-0
Virginia	53-0	37-0 Last tractor axle to first trailer axle.	No Limit		60-0
Washington	53-0		53-0		
West Virginia	53-0	Same as VA	No Limit		60-0
Wisconsin	53-0	41-0 KCRT	No Limit		60-0
Wyoming	60-0		60-0		

(1) KCRA = Kingpin to center of rear axle
(2) KCRT = Kingpin to center of rear tandem
(3) permit may be required
(4) Interstate and designated State routes
(5) Requires annual letter of authorization. Does not apply on the Massachusetts Turnpike
(6) Designated routes
(7) Only on Interstate System
(8) KCRTA = Kingpin to center of rearmost tandem axle
(9) KCSRA = Kingpin to center of single rear axle.

The ISTEA froze the maximum GVW for LCVs in 16 States. Table II-4 provides the State LCV weight limits.

TABLE II-4
LONGER COMBINATION VEHICLES WEIGHT LIMITS BY STATE
(1994)

Pounds	Truck Tractor and 2 Trailing Units	Truck Tractor and 3 Trailing Units
86.4	NM	
90	OK	OK
95	NE	
105.5	ID, ND, OR, WA	ID, ND,OR
110	CO	CO
111	AZ	
115		OH
117	WY	
120	KS, MO	
123.5		AZ
127.4	IN, MA, OH	IN
129	NV, SD, UT	NV, SD, UT
131.06		MT
137.8	MT	
143	NY	
164	MI	

Source: Final Rule on LCVs published in the Federal Register at 59 FR 30392 on June 13, 1994.

CHAPTER 3

TRUCKING FLEET AND OPERATIONS

INTRODUCTION

The Nation's truck fleet may be described as non-homogenous, with truck configurations and operations evolving within a dynamic environment that includes: multi-jurisdictional TS&W regulations, safety regulations, freight characteristics, shipper and customer needs, economic forces, international trade and the innovation of truck and trailer manufacturers.

TRUCKING INDUSTRY STRUCTURE

The trucking industry serves many different markets. Each segment of the industry is characterized by different operating features and equipment utilization practices. Broadly, the industry may be divided into either private or for-hire carriers. In the for-hire sector, two types of services are provided: Truckload (TL) or less-than-truckload (LTL). Additionally, TL and LTL services can be segmented into either short-haul or long-haul.

PRIVATE VERSUS FOR-HIRE CARRIERS

Many private business have internalized all aspects of the logistics function; they own and operate their own fleet of trucks. Common examples of private carriers include grocery stores, retail chains, and food processing companies. Information concerning the operations of private carriers is limited, partially because these carriers have been traditionally less subject to government reporting regulations. The following table (Table III-1) indicates that private carrier operations constitute a large share of trucking in the Nation.

TABLE III-1
PRIVATE CARRIER PROFILE

TONNAGE AND VALUE OF SHIPMENTS

- Private carriers handled approximately 3.56 billion tons of the total 6.5 billion tons (55 percent) handled by the trucking industry in 1993.
- The average length of haul for private carriers is 51 miles, resulting in 240 billion ton-miles handled in 1993.
- The value of freight handled by private carriers was $1.8 trillion in 1993, $1.0 trillion lower than the for-hire carriers.

REVENUE

- In 1994 private carriers captured approximately 54 percent ($178 billion) of total truck revenue in the Nation.
- The $178 billion in revenue was split between intercity and local freight movements, approximately $90/$88 billion, respectively.
- Overall, private carriers captured 70 percent of local revenues.

*1993 Commodity Flow Survey database

For-hire carriers transport goods for others as their primary business. This segment of the trucking industry includes a large and growing number of single vehicle owner/operators. Information on share of freight handled by the for-hire segment in 1993 is provided in Table III-2.

TABLE III-2
FOR-HIRE CARRIER PROFILE

REVENUE HIGHLIGHTS

- For-hire carriers captured approximately 56 percent of total intercity market revenues in 1993.

TONNAGE AND VALUE OF SHIPMENTS

- The for-hire carriers' share of total truck freight movements (6.5 billion tons) was 2.9 billion tons—45 percent.
- The average length of haul of for-hire carriers is 470 miles.
- The value of shipments for for-hire carriers equaled $2.8 trillion in 1993.

TRUCKLOAD VERSUS LESS-THAN-TRUCKLOAD

TRUCKLOAD OPERATIONS

Carriers with TL operations generally pick up a load in a truck or truck combination at the shipper's dock and transport it directly to the consignee in the same vehicle. TL operations may be categorized according to the type of freight handled, either general or specialized. General freight is transported in enclosed van trailers and specialized freight is transported by specialized equipment, such as refrigerated van trailers, automobile transporters, tank trailers, dump trucks, and hopper-bottom grain trailers. Many TL carriers depend on the services of owner-operators for equipment and drivers.

While there were more specialized carriers (613) than general freight carriers (547) in 1993, the revenue generated from general freight ($11.7 billion) was slightly higher than that generated by specialized freight carriers ($11.4 billion). It is notable that in the late 1980s, a small number of "mega" carriers emerged from within the large TL carriers. These mega carriers now dominate the general freight segment of TL operations. Additionally, since the early 1990s, some of the general freight TL carriers have become major intermodal carriers with large domestic container fleets.

LESS-THAN-TRUCKLOAD OPERATIONS

LTL carriers specialize in transporting small shipments of freight, generally in units of between 250 pounds and 12,000 pounds. A LTL shipment is generally composed of general freight from several shippers and has many different destinations. An example of a LTL carrier is a package delivery service provider. In most instances, LTL carriers are constrained more by cubic capacity than weight limitations. One exception is the LTL carrier that transports international containers from a port to a break-bulk terminal. These potentially overweight containers, often are moved to the terminal under special permit, are then stripped and replaced for line-haul movements at 80,000 pounds or less.

To reduce line-haul miles and handling of freight, LTL carriers generally maintain extensive networks of strategically located terminals, operating truck combinations between terminals on regularly scheduled line-haul routes.

SHORT-HAUL VERSUS LONG-HAUL OPERATIONS

Short-haul operations are defined in this Study as freight movements of 200 miles or less from point of origin to point of destination. Consequently, the majority of truck operations, on a Nationwide basis, are considered short-haul, being regional or local in nature. Single unit trucks operate almost exclusively within their home State (intrastate), as do truck combinations where approximately 80 percent of their VMT is within the State of registration. This also applies to the operation of LCVs.

Typically, trucks and truck combinations operating in local, short-haul operations tend to have lower annual VMT than those in long-haul. However, this varies greatly according to type of truck configuration. In general, single unit trucks average much lower VMT than truck combinations. For example, average VMT for two-axle single unit trucks is 11,000 miles, or about 30 miles per day. Three- and four-axle single unit trucks are slightly higher at about 40 miles and 60 miles per day, respectively. This low VMT for single unit trucks reflects the local, short-haul, intrastate nature of their operations.

Annual average VMT for long-haul operators is substantially higher. For example, large tractor-semitrailer combinations average between 100 miles and 200 miles per day. The STAA double-trailer combinations average 220 miles per day, or about 80,000 miles per year.

EQUIPMENT CHARACTERISTICS

The most general distinction among truck configurations is whether they are single unit trucks whose cargo carrying units are part of the same chassis as the engine, or whether they are combination vehicles that have separate cargo carrying trailers or semi-trailers that are pulled by a truck or truck-tractor. Nationally, the distribution of the fleet by configuration is approximately:

- Single unit trucks - 68 percent
- Truck-trailer combinations - 4 percent
- Tractor-semitrailer combinations (primarily 5-axle combinations) - 26 percent
- Double-trailer combinations - 2 percent
- Triple-trailer combinations - less than one tenth of one percent

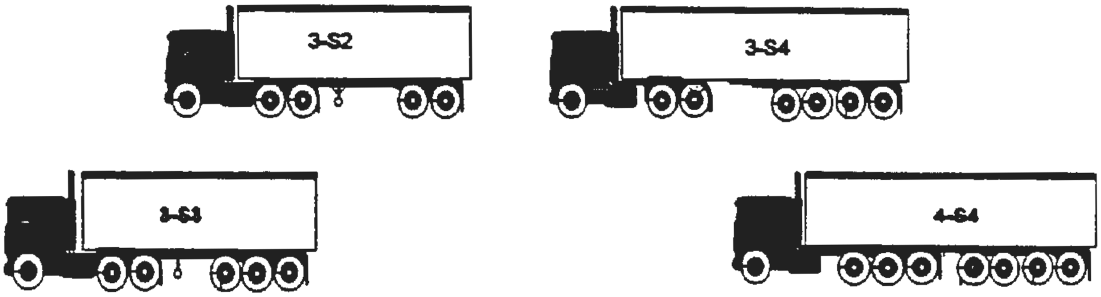
The distribution of large truck configurations, those combinations with five- or more axles, varies between States and regions of the Nation. For example, in California 18 percent of the truck fleet are truck-trailer combinations and 39 percent are STAA twin-trailer combinations, whereas in Florida, only 2 percent of the truck fleet are truck-trailer combinations and 2 percent are double-trailer combinations. Figure III-1 presents the different types of configurations in the National fleet.

FIGURE III-1
ILLUSTRATIVE TRUCK CONFIGURATIONS OF U.S. FLEET

Single Unit Trucks

Truck-Trailer Combinations

Tractor-Semitrailer Combinations

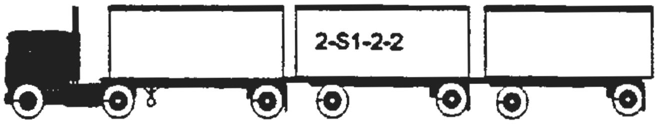


STAA Double-Trailer Combination

Longer Combination Vehicles (LCVs)

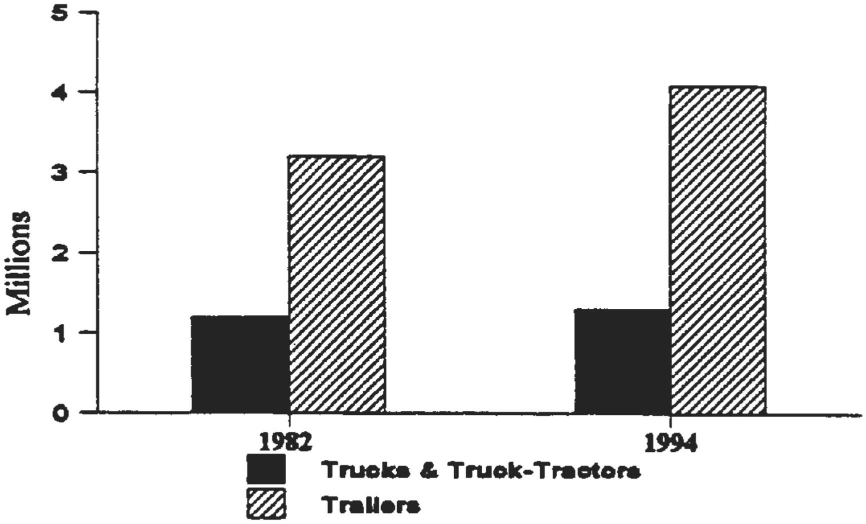
Double-Trailer Combinations

Triple-Trailer Combination



The size of the Nation's trailer fleet increased significantly during the decade following passage of the STAA of 1982. The number of trucks and truck-tractors increased only marginally (see Figure III-2). In 1994, the total commercial truck fleet consisted of approximately 1.3 million truck-tractors and 4.1 million trailers, including semitrailers. The increase in the number of trailers was commensurate with an increase in the number of STAA doubles and longer combination vehicles (LCVs) (that is, double- and triple-trailer combinations).

FIGURE III-2
FLEET SIZE AND GROWTH
1982 TO 1994



SINGLE UNIT TRUCKS

The most common single unit trucks in the commercial fleet are dump trucks, cement mixer trucks, tank trucks, and waste hauling trucks. These vehicles are designed to provide specialized services and are commonly referred to as specialized hauling vehicles (SHVs), having between two and four axles. SHVs represent approximately 46 percent of single unit trucks operating in the United States with three or more axles.

SHVs are typically used in local and intrastate, short-haul operations. The most common commodities that are hauled Nationally include construction materials, gravel, ready-mix cement, grain, milk, petroleum products, and garbage or waste. Dump trucks are primarily used to transport construction materials and tank trucks are primarily used to transport liquids or gases.

The total number of commercial single unit trucks (10,000 pounds or more) remained constant at approximately 2.75 million between 1982 and 1994. However, the number of two-axle single unit trucks decreased over this period by about 14 percent. During that same period of time, the number of four-axle single unit trucks more than doubled to approximately 84,000 due to the substitution of three-axle garbage, dump and concrete trucks with four-axle units.

TRUCK-TRAILER AND TRACTOR-SEMITRAILER COMBINATIONS

Combination vehicles in the National truck fleet consist of a towing unit, either a truck or tractor, and one or more trailers or semitrailers. Truck-trailer combinations account for approximately 14 percent of all combination vehicles. Approximately 33 percent of the truck-trailer combinations are five-axle combinations.

TRACTOR-SEMITRAILERS

Tractor-semitrailer combinations are the most common combination truck configuration operating on U.S. highways. They account for more than 82 percent of all combinations trucks. The most common combination, constituting 90 percent of the tractor-semitrailer combinations, is the so-called "18-wheeler," a three-axle tractor with a two-axle semitrailer. Tractor-semitrailer combinations vary in size and configuration depending on axle configurations, State semitrailer length limits, and State kingpin setting laws.

The number of tractor-semitrailer combinations has increased an average of 2.5 percent per year between 1982 and 1994. Increases in long-haul operations following the STAA of 1982, and the market for sleeper cab tractors resulted in a shift away from two-axle tractors, such as the cab-over models of the early 1980s, toward longer wheelbase three- and four-axle tractors.

A number of tractor-semitrailer combinations are considered SHVs, in that the semitrailer is designed to transport a specific commodity in one direction and is operated empty on the return trip. End-dump trailers, cargo tank trailer, bottom-dump trailers, and automobile transporters are all examples of SHV trailers.

MULTI-TRAILER COMBINATIONS

There are four types of multi-trailer combinations operating in the United States: (1) STAA doubles (twin 28-foot trailers); (2) Rocky Mountain doubles (RMD); (3) turnpike doubles (TPD); and (4) triples. The RMD, TPD, and triple-trailer combinations are generally grouped together under a common category referred to as longer combination vehicles (LCVs). In aggregate, double- and triple-trailer combinations represent a very small number in relation to the total truck combination fleet, approximately 20,000 in 1994 or 0.05 percent. Like single unit trucks and other combinations, multi-trailer combinations are used to haul a variety of commodities and trailers are specialized for the commodities being carried.

Surface Transportation Assistance Act Doubles

The 1982 STAA provided for the unrestricted use of two-trailer combinations (two 28 foot to 28.5-foot trailers) on the National Network (NN). The NN consists of the Interstate System and routes designated by FHWA in consultation with the States. Prior to 1982 the operation of double trailers of any length was primarily limited to States West of the Mississippi River and turnpikes in a few Eastern States.

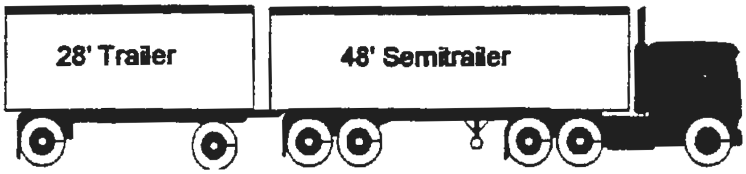
Since 1982, growth in the use of STAA doubles in relation to the size of the total truck fleet as been relatively small Nationwide, with the exception of California and many States in the East where they were prohibited prior to 1982. Nationwide, STAA doubles represent approximately 2.5 percent of all truck combinations. Generally, the industry segment where the STAA double is important is the LTL segment where tare weight is not a consideration.

Longer Combination Vehicles

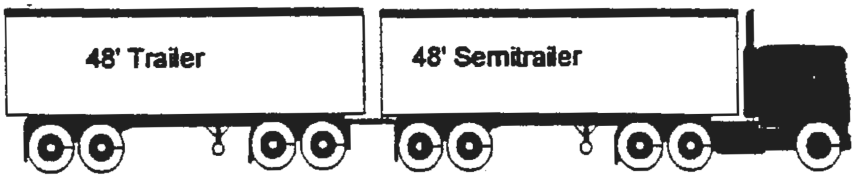
Figure III-3 illustrates the common LCV combinations: RMD, TPD and triples. The RMD consists of a truck-tractor and one long front trailer, ranging in length from 40 feet to 48 feet, towing a shorter 20-foot to 28-foot trailer. The RMD combinations are currently allowed to operate on turnpikes in six States and on other routes in 14 States and since the mid-1950s on three of the six turnpikes (Indiana, Massachusetts and New York).

FIGURE III-3
LONGER COMBINATION VEHICLES

ROCKY MOUNTAIN DOUBLE



TURNPIKE DOUBLE



TRIPLES

The TPD combinations consist of a truck-tractor towing two long trailers of equal length, typically two 40-foot, 45-foot, 48-foot or 53-foot trailers. The TPD combination is allowed in all but three (Oregon, Washington, and Wyoming) of the States in which RMDs are allowed to operate. However, the allowable weights and the extent of highway networks upon which these vehicles may operate vary among the States.

A triple-trailer combination consists of a truck-tractor and three trailers in tow--typically three 28-foot to 28.5-foot trailers. Triple-trailer combinations are allowed to operate on limited highway networks in fourteen States under permit with restrictions. Triple-trailer combinations have been operating in four States since the 1960s (Idaho, Nevada, Oregon, and Kansas).

Table III-3 provides a list of the States where LCVs are allowed to operate, by configuration. Also indicated is the first year of operation.

TABLE III-3
LONGER COMBINATION VEHICLES
STATES AND CONFIGURATIONS PERMITTED

States	Triples	Turnpike Doubles	Rocky Mtn. Doubles
Alaska	Not permitted	1984	1984
Arizona	1976	1976	1976
Colorado	1983	1983	1983
Idaho	1968	1968	1968
Montana	1987	1972	1968
Nebraska	1984	1984	1984
Nevada	1969	1969	1969
North Dakota	1983	1983	1983
Oklahoma	1987	1986	1986
Oregon	1967	Not permitted	1982
South Dakota	1988	1984	1981
Utah	1975	1974	1974
Washington	Not permitted	Not permitted	1983
Wyoming	Not permitted	Not permitted	1983
Turnpike Authority			
Florida	Not permitted	1968	1968
Indiana	1986	1956	1956
Kansas	1960	1960	1960
Massachusetts	Not permitted	1959	1959
New York	Not permitted	1959	1959
Ohio	1990	1960	1960

Source: GAO *Longer Combination Trucks*, 1994

INFLUENCE OF SIZE AND WEIGHT POLICY ON FLEET CHARACTERISTICS

Federal and State TS&W regulations define the weight and dimensional envelope into which the truck fleet must fit, and this influences the characteristics of the National fleet. Other factors also influence truck characteristics, such as: freight and logistical considerations (commodity, shipment size, package, fragility, temperature control, origin-destination patterns, delivery time requirements); infrastructure considerations (terminals and route options between origin-destination pairs); truck economic considerations (replacement cycles, re-sale markets, fuel economy, driver flexibility); truck operating strategies and company structures; special permitting policies and practices; regulation enforcement; and intermodal requirements.

Sometimes a truck is operated within only one TS&W regulatory regime or envelope, typically however, the envelope is a composite of various limits established by Federal and State regulations. Additionally, for trucks operating across international borders with Canada and Mexico, Canadian provincial law and Mexican Federal law applies. A trucker confronted with multiple TS&W regimes and interested in operating at one or all of the boundaries of the composite envelope must either select a "least common denominator" vehicle and operating strategy, or a vehicle and operating strategy that can be modified in route (for example, removing a trailer, reducing the load, moving an axle).

The primary commodity groups transported by combination trucks are processed foods; building materials, logs and forest products, and petroleum and farm products. It is interesting to note that beginning in the late 1980s an industry trend began to emerge: the mean average loaded weights (tare weight plus payload) were decreasing while the tare weights of trucks increased. Commodities transported, such as electronic equipment and more highly processed goods, are becoming lighter.

Table III-4 provides information on average payload and loaded weights for the five major truck and combination body types operating Nationwide in 1994.

TABLE III-4[1]
MEAN AVERAGE PAYLOAD AND LOADED WEIGHT OF COMMON TRUCK TYPES
(pounds)

Body Type	5-Axle Truck-Trailer		5-Axle Tractor-Semitrailer		STAA Double	
	Payload	Loaded	Payload	Loaded	Payload	Loaded
Platform/Flatbed	30,715	56,900	36,780	65,350	45,330	64,470
Van	34,890	60,340	30,555	61,550	33,935	65,100
Grain Body	48,970	63,340	48,030	74,570	56,380	80,140
Dump Truck	34,760	59,460	42,580	72,160	*	*
Tank Body	47,980	72,390	46,410	74,490	*	*

* Indicates very small sample size.

Under the current 80,000 pound Federal GVW limit the following observations are noted:

- On average, none of these combinations utilizes the maximum weight allowed; and
- Five-axle tractor-semitrailer combinations with specialized body types (dump, tank, grain) use about 93 percent of available GVW.

WEIGHT LIMITS

Current Federal weight limits apply to GVW and axle weights. The GVW limit is 80,000 pounds and axle weight limits are 20,000 pounds for single axles and 34,000 pounds for tandem axles. One or both of the Federal axle limits are surpassed by the laws of 25 States, through the exercise of grandfather rights on the Interstate in 12 States, and permit policies in most. Weight limits for other axle groupings are determined through the application of the Federal bridge formula and/or State regulation.

Current Federal axle weight limits were established to minimize infrastructure damage under a Federal bridge formula with a maximum GVW limit. Consequently, various innovative arrangements of axles and tires have evolved to increase load capacity within the GVW limit and not exceed axle limits. Three of these innovative arrangements are "super-single" tires, split tandem axles, and lift axles.

TIRE LOAD LIMITS

The increasing use of wide-base "super-single" tires in the United States is an innovation that originated in Europe. Federal law and most State laws do not discourage or prohibit the use of wide-base single tires. Benefits to industry include reduced energy use, emissions, tare weights,

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[1] TIUS 1992 database.

and truck operating costs. As with tire pressure and tire loads, there are conflicting views concerning the public benefits and costs and whether the use of wide-base tires should be regulated.

AXLE CONFIGURATIONS

Axle types and configurations frequently observed on single unit trucks, particularly SHVs include lift axles, split-tandem axles, tridem axles and quadrem axles. Use of these axles and configurations have evolved over the last two decades as the industry adapted to Federal and State TS&W limits.

Split Tandem Axles

A split tandem axle is created by increasing the spacing between the two axles in a tandem axle group from a typical standard of approximately 4 feet to 8 feet, 9 feet or 10 feet. Split tandem axles are an increasingly common feature of trucking throughout the United States. The operational advantage to the carrier of split tandems is two-fold: (1) increasing GVW within the allowable limit; and (2) increased flexibility in load distribution. By increasing the spacing, rather than being considered a tandem axle with an axle weight limit of 34,000 pounds, the split tandem is considered as two single axles with a total weight limit of between 38,000 pounds and 40,000 pounds depending on the spacing. Under Federal Bridge Formula B, the combined weights allowed on a split tandem axle are: (1) 38,000 pounds at more than 8 feet; (2) 39,000 pounds at 9 feet; and (3) 40,000 pounds at 10 feet or more.

Tridem Axles

Tractor-semitrailer combinations with a tridem axle on the semitrailer are operating in all States, as are single unit trucks with tridem axles. Tridem axle semitrailers are used in about 5 percent of the truck combinations operating Nationwide and are most common in the Northeast region and least common in the South Atlantic region. On tractor-semitrailers, tridem axles offer the same advantages offered by split tandem axles, namely higher gross loads (especially in those States not limited by the 80,000-pound Federal weight limit). This is particularly important for movement of commodities such as heavy machinery and transportation equipment on tractor-semitrailer combinations.

Lift Axles

Lift axles are one innovation utilized by carriers to allow maximum use of capacity without exceeding weight limits. Generally, a truck operates with the axle down when the truck is loaded to increase its weight limit, and up when empty to increase maneuverability and handling of the vehicle. The concern with lift axles arises when a truck is loaded and the lift axle is raised by the driver during operation on the highway resulting in redistribution of the weight over fewer axles.

Throughout the country, lift axles are routinely used on single unit trucks such as dump trucks and cement mixers throughout the country, as well as on semitrailers and trailers operating where GVWs over 80,000 pounds are permitted. Lift axles are used on 6 percent of all three-axle and 77 percent of all four-axle single unit trucks. In a number of States five-, six- and seven-axle single unit trucks with two to four lift axles are operated. Federal TS&W laws, as well as most State laws, do not address the use of lift axles.

GROSS VEHICLE WEIGHT AND IMPACT OF THE BRIDGE FORMULA

Nationally, the average loaded weight for five-axle tractor-semitrailers operating on the Interstate System between 57,000 pounds and 75,000 pounds depending on trailer body type. Most trucks and combinations operate at or below the GVW limits, although many do not reach their weight limit because of volume capacity. Tank trucks and trailers operate at average load levels that reach their maximum weight limit and "weigh-out" over 80 percent of the time, while this occurs less than 20 percent of the time for enclosed van trailer combinations. Enclosed van trailers, in may instances, are used to transport commodities that have low density and as a consequence the cubic capacity of the trailer is filled before the maximum weight allowed is reached. This is referred to as "cube-out."

The mandated implementation of the Federal bridge formula in 1982 led to the creation of a variety of vehicle configurations and characteristics not initially envisioned. Such configurations and characteristics are typically directed at increasing the potential payload weight for configurations.

Examples of "bridge formula" trucks and truck characteristics that have emerged are: (1) four-axle tractors with a pusher lift axle (to provide more axles within a given outer bridge limit); (2) very long "tongues" on truck-trailer and double-trailer combinations (to increase the distance from the first axle to the last axle, and therefor a higher gross weight limit); and (3) split tandem axles--a now common feature of five-axle tractor-semitrailers, carrying heavy commodities.

DIMENSIONAL LIMITS

SEMITRAILER LENGTH

Federal law concerning semitrailer length (48 feet) and trailer length for standard STAA doubles (28 feet to 28.5 feet) is a facilitating law, specifying the minimum lengths that States must permit on the NN for trucks. As a result, semitrailer lengths throughout the country are largely controlled by State laws specifying maximum semitrailer lengths and/or tractor-semitrailer combination lengths.

Van body trailers are designed to maximize payload within the length limits of the States in which the vehicle will be operating. For example, van trailers for hauling grain are often designed with drop-bottoms to increase cubic capacity without exceeding State height limits. On the other hand, flatbed trailers often do not need to utilize the entire available length or width limits. In certain States semitrailer lengths and operating properties are also influenced by kingpin requirements. Such laws set a specified distance from the kingpin trailer connection to specified axles(s).

Semitrailers have undergone major changes in the last 30 years in response to changes in Federal and State regulations, such as the shift from the industry standard 45-foot semitrailers to current use of many 53-foot semitrailers. The historic trend has been incremental growth in the length of the semitrailer fleet with each new length taking about 10 years to 12 years to become the new standard. For example, the 45-foot semitrailers introduced in 1970 were the industry standard for van trailers until the 1980s when the 48-foot semitrailer became the standard. The new market share for the 53-foot semitrailer in 1994 was 30 percent. The 53-foot semitrailer offer an 18 percent increase in volumetric capacity over the 45-foot semitrailer.

The distribution of 53-foot semitrailers by trailer body type is: (1) 90 percent of the automobile transporter fleet; (2) 30 percent to 40 percent of all types of van trailers; (3) 15 percent to 20 percent of the flatbed fleet; and (4) less than 10 percent of specialized truck body types. Currently, semitrailers longer than 53 feet are permitted to operate in 11 States (on most State NN facilities)--Alabama, Arkansas, Arizona (Interstate only), Colorado, Kansas, Louisiana, Montana (under a readily available permit), New Mexico, Oklahoma, Texas Wyoming. The extent of their use is unknown, although it is believed to be relatively small at the present time.

WIDTH

The STAA of 1982 was a facilitating law providing for the free movement of 102-inch wide equipment on the NN. Although the STAA of 1982 provided for uniformity on the Interstate and NN, several States have a 96-inch width limit for commercial vehicles on non-NN routes. As a consequence, 96-inch wide equipment remains common place.

HEIGHT

Height limits have been established over the years to assure clearance of vehicles under rail or highway overpasses. The clearance standard for bridges constructed over the Interstate System is a minimum of 14 feet. Some State constructed turnpikes built prior to 1956 do not meet the Federal standard and the clearances must be posted. Most Western States limit vehicle and load heights to 14 feet or more, while the Eastern States, except Maine, limit vehicle and load heights to 13.5 feet.

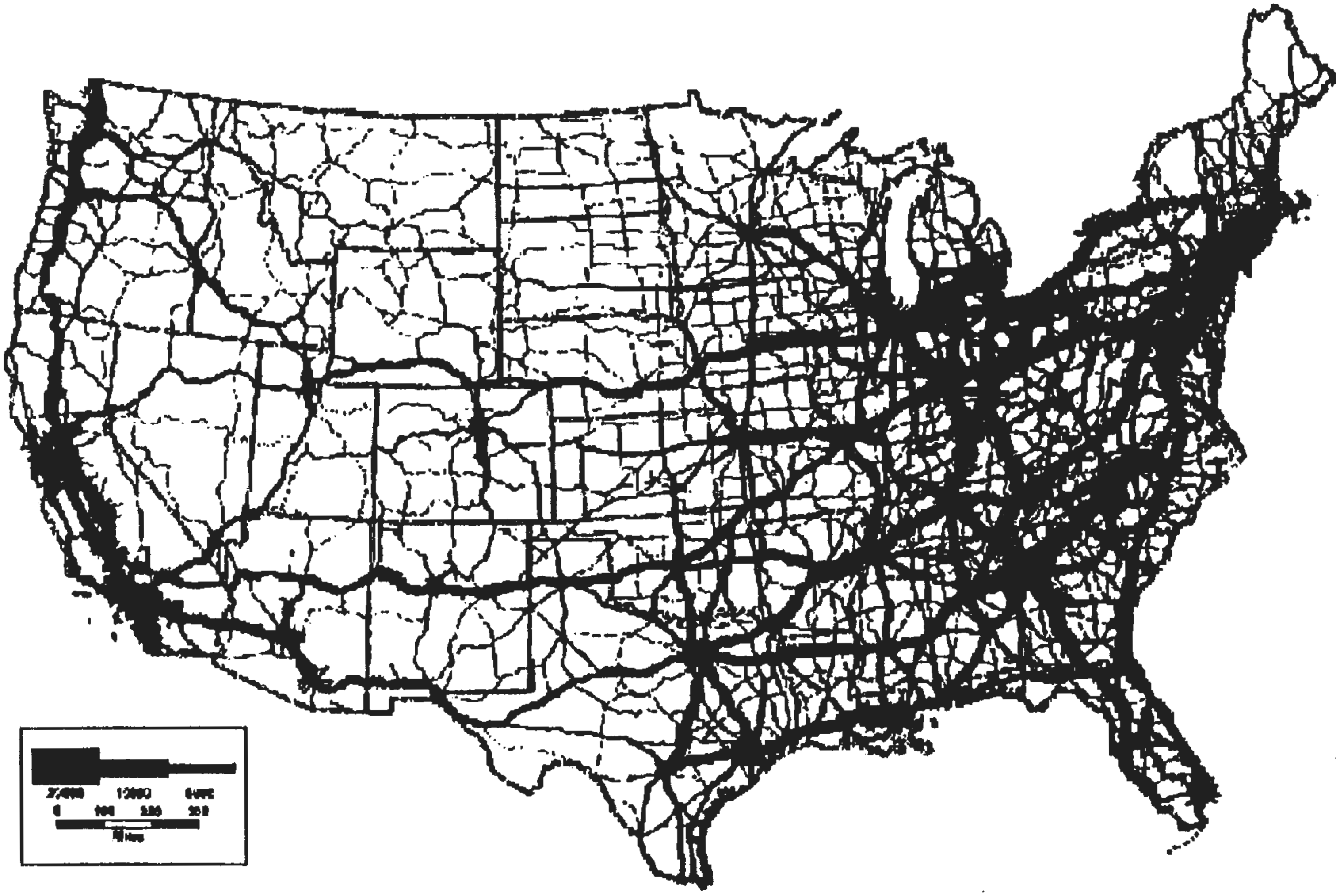
DOMESTIC FLEET OPERATIONS

The relative intensity of trucking traffic, as well as traffic patterns and activity throughout the Nation, can be measured by: the volume of truck flows on major highways and the truck vehicle-miles-of-travel (VMT) in each State.

TRUCK FLOWS

Truck volumes operating on the National Highway System (NHS) are illustrated in Figure III-4. Flows range from fewer than 100 trucks per day on rural corridor highways to over 25,000 trucks per day on the Interstate in and around major urban centers.

FIGURE III-4
TRUCK TRAFFIC FLOW ON THE NATIONAL HIGHWAY SYSTEM BY STATE



General observations regarding the flow of trucks include:

- Truck traffic per mile of NHS highway varies widely throughout the country--ranging from an annual average of one truck or two trucks per hour in each direction to more than 500 trucks per hour.

- Truck volume on most of the NHS mileage in the Western region is relatively low. Exceptions include major North-South routes in the Interstate Route 5 coastal corridor, and major East-West corridors associated with Interstate Route 80, Route 40, Route 10 and Route 20.

- Truck volumes east of the Mississippi on much of the NHS mileage range from modest in the New England States to very high in the mid-Atlantic region.

- Many of the highways in the North-South, mid-Continent I-35 corridor have relatively low to modest truck volumes. The lowest truck volumes in this corridor are at the Northern and Southern ends, and in the middle of the corridor through Kansas. Dominant trucking activity in the corridor includes East-West trips, and travel between most corridor States and the North Central region of the United States.

TRUCK VEHICLE MILES OF TRAVEL

Total truck VMT in 1994 was approximately 168 billion; distribution as measured by VMT in each State, is shown in Table III-5. As indicated, California had the highest truck VMT (16.8 billion), equal to approximately ten percent of National truck VMT. Regional distribution of total truck VMT is approximately 25 percent in the North Central region, 20 percent in each of the South Atlantic, South Gulf and Western regions and 15 percent in the Northeastern region as previously shown in Figure III-4.

TABLE III-5
1994 TRUCK VMT BY STATE
(000s)

STATE	TOTAL VMT	TOTAL TRUCK VMT[2]	STATE	TOTAL VMT	TOTAL TRUCK VMT
Alabama	48,955,998	3,618,154	Montana	9,116,001	764,175
Alaska	4,149,989	195,239	Nebraska	15,465,999	1,572,777
Arizona	38,773,999	3,932,615	Nevada	13,019,000	1,224,392
Arkansas	24,947,997	3,015,746	New Hampshire	10,501,000	598,353
California	271,942,998	16,769,280	New Jersey	60,465,998	3,584,790
Colorado	33,704,999	2,484,491	New Mexico	20,479,999	1,758,453
Connecticut	27,138,000	1,195,570	New York	112,970,002	5,235,286
Delaware	7,025,000	396,163	North Carolina	71,928,001	8,874,775
Dist of Col	3,448,000	114,106	North Dakota	6,337,999	583,377
Florida	121,989,000	6,282,027	Ohio	98,199,997	7,208,332
Georgia	82,821,999	5,490,345	Oklahoma	36,979,997	3,151,269
Hawaii	7,934,999	279,371	Oregon	29,453,000	2,116,079
Idaho	11,652,000	907,409	Pennsylvania	92,347,001	8,104,688
Illinois	92,316,001	6,200,093	Rhode Island	7,095,000	326,770
Indiana	62,108,001	5,740,501	South Carolina	37,245,001	2,033,429
Iowa	25,736,997	3,004,366	South Dakota	7,630,998	551,802
Kansas	24,678,000	1,714,820	Tennessee	54,524,001	3,699,589
Kentucky	39,822,001	2,894,242	Texas	178,347,999	14,471,141
Louisiana	37,430,000	4,875,763	Utah	18,078,002	1,376,369
Maine	12,469,001	779,987	Vermont	6,152,000	405,991
Maryland	44,164,999	3,291,562	Virginia	67,608,999	4,988,220
Massachusetts	46,989,999	1,723,840	Washington	47,428,000	3,444,500
Michigan	85,182,998	4,551,583	West Virginia	17,112,001	1,569,653
Minnesota	43,317,002	2,444,670	Wisconsin	50,273,000	3,175,214
Mississippi	28,548,000	2,313,672	Wyoming	6,688,998	827,671
Missouri	57,288,000	4,534,102	TOTAL	23,599,983,970	170,396,812

Source: 1997 DOT Highway Cost Allocation Study

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[2] Excluded: auto, bus and light trucks

SINGLE UNIT TRUCK VEHICLE MILES OF TRAVEL

Single unit trucks account for approximately 42 percent of the total truck VMT. Two- and three-axle trucks account for the majority of the single unit truck VMT, approximately 85 percent and 12 percent, respectively. Although the number of four- or more axle single unit trucks has more than doubled since 1982, their share of the annual VMT, 3 percent, is an indication that their use is primarily short-haul or interstate.

SINGLE-TRAILER COMBINATIONS VEHICLE MILES OF TRAVEL

Tractor-semitrailer combinations are the most common combination operation in the Nation, accounting for over 25 percent of all registered trucks and 82 percent of all truck combinations. They include combinations of a two-, three- or four-axle tractor with a semitrailer having one or more axles. In some instances, as many as eleven axles are seen on semitrailers. In 1994, tractor-semitrailers accounted for approximately 53 percent of the total truck VMT, or 89.6 billion VMT.

Truck-trailer combinations are the second most common combination in the Nation, accounting for approximately 14 percent of the truck combination fleet. This use increased significantly since 1982, primarily in the North Central region of the Nation. Truck-trailer combinations however, with 3.1 billion VMT, account for less than 2 percent of the total truck VMT. Over 50 percent of this VMT is attributed to the five-axle combination.

MULTI-TRAILER COMBINATIONS VEHICLE MILES OF TRAVEL

Surface Transportation Assistance Act Doubles

Total annual VMT for the STAA double (twin 28-foot) is approximately 4.5 billion mile per year, or 2.6 percent of all truck VMT. It accounts for 4.5 percent of all truck combinations VMT, and 71.3 percent of all VMT operated by double trailers.

Longer Combination Vehicles

LCVs are permitted in 20 States and include RMD, TPD and triple-trailer combinations (See Table III-6 for a listing of where these vehicles are permitted to operate).

Rocky Mountain and Turnpike Doubles

Total VMT by longer double-trailer combinations was 1.8 billion VMT in 1994, equal to approximately one percent of all truck VMT and less than two percent of truck combinations VMT.

Triple-Trailer Combinations

The number of triple-trailer combinations is relatively small in comparison to the total truck combination fleet. In 1994, total VMT for triple-trailer combinations was 108 million distributed among the 14 States where they operate. On average each triple combination travels approximately 89,701 miles per year. Total triple-trailer VMT was approximately 0.1 percent of the total VMT for all combinations, with approximately half of the VMT split between two States, Utah and Oregon.

MULTI-TRAILER HIGHWAY NETWORK

The highway network for operation of STAA doubles and LCVs is limited when taken as a percentage of the total public road mileage in each State. This is in contrast to total public road mileage of 3,906,544. Table III-6, Table III-7, and Table III-8 summarize the network mileage for STAA doubles, RMD and TPD, and triple-trailers by State of operation.

TABLE III-6
NETWORK MILES BY STATE FOR STAA DOUBLES[3]

State	Miles	% of Total State Miles[4]	State	Miles	% of Total State Miles	State	Miles	% of Total State Miles
Alabama	2,182	2.34	Kentucky	2,714	3.72	North Dakota	2,230	2.57
Alaska	481	3.36	Louisiana	3,984	6.64	Ohio	8,138	7.11
Arizona	4,482	8.24	Maine	378	1.68	Oklahoma	6,238	5.55
Arkansas	5,777	7.49	Maryland	788	2.68	Oregon	4,970	5.92
California	9,141	5.41	Massachusetts	653	2.13	Pennsylvania	3,307	2.79
Colorado	5,400	6.41	Michigan	6,608	5.62	Rhode Island	95	1.59
Connecticut	470	2.31	Minnesota	4,841	3.32	South Carolina	2,035	3.17
Delaware	225	4.02	Mississippi	6,456	8.85	South Dakota	6,472	7.77
Dist. of Col	16	1.45	Missouri	3,998	3.27	Tennessee	7,254	8.68
Florida	9,470	8.36	Montana	6,610	9.53	Texas	20,029	6.80
Georgia	1,844	1.66	Nebraska	7,670	8.27	Utah	3,553	8.70
Hawaii	544	13.25	Nevada	2,370	5.13	Vermont	350	2.47
Idaho	2,744	4.60	New Hampshire	234	1.56	Virginia	3,121	4.53
Illinois	2,104	1.54	New Jersey	439	1.24	Washington	5,786	7.25
Indiana	6,145	6.64	New Mexico	3,645	5.95	West Virginia	1,093	3.14
Iowa	8,006	7.10	New York	3,933	3.51	Wisconsin	6,191	5.58
Kansas	8,913	6.69	North Carolina	3,213	3.33	Wyoming	3,901	10.68
						TOTAL	211,241	5.41

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[3] Table HM-43, National Network for Trucks, *Highway Statistics 1991*.

[4] Public Road Mileage, from Table HM-14, *1994 Highway Statistics*.

TABLE III-7
NETWORK MILES BY STATE FOR ROCKY MOUNTAIN AND TURNPIKE DOUBLES

State	RMD	TPD	% of Total State Miles[5]		State	RMD	TPD	% of Total State Miles	
			RMD	TPD				RMD	TPD
Arizona	139	29	0.3	0.1	Nevada	4,152	4,152	9.0	9.0
Colorado	814	814	1.0	1.0	New York	562	562	0.5	0.5
Florida	256	256	0.2	0.2	North Dakota	2,487	2,487	2.9	2.9
Idaho	303	3,030	0.5	5.1	Ohio	242	242	0.2	0.2
Indiana	135	135	0.2	0.2	Oklahoma	1,878	1,878	1.7	1.7
Iowa	36	36	0.03	0.03	Oregon	4,584	0	5.5	0
Kansas	256	256	0.2	0.2	South Dakota	6,471	1,037	7.8	1.2
Massachusetts	134	134	0.4	0.4	Utah	3,563	949	8.7	2.3
Missouri	243	243	0.2	0.2	Washington	5,616	0	7.8	0
Montana	6,711	1,192	9.7	1.7	Wyoming	4,098	0	11.2	0
Nebraska	443	443	0.5	0.5	TOTAL	43,123	17,875	2.45	1.0

TABLE III-8
NETWORK MILES BY STATE FOR TRIPLE-TRAILER COMBINATIONS[6]

State	Miles	% of Total State Miles[7]	State	Miles	% of Total State Miles
Arizonr	$ 25	0.05	Oklahoma	1,828	1.70
Colorado	$ 650	0.80	Oregon	3,500	4.20
Idaho	$ 612	1.00	South Dakota	997	1.20
Montana	$ 1,191	1.70	Utah	951	2.30
Nebraska[8]	$ 481	0.50	Indiana	157	0.20
Nevada	$ 4,872	10.60	Kansas	247	0.20
North Dakota	$ 2,170	2.50	Ohio	242	0.20
			TOTAL	17,923	1.60

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[5] Public Road Mileage, Table HM-14, 1994 *Highway Statistics*.

[6] "Report of the Subcommittee on Truck Size and Weight of the AASHTO Joint Committee on Domestic Freight Policy," 1995 and Strate contact.

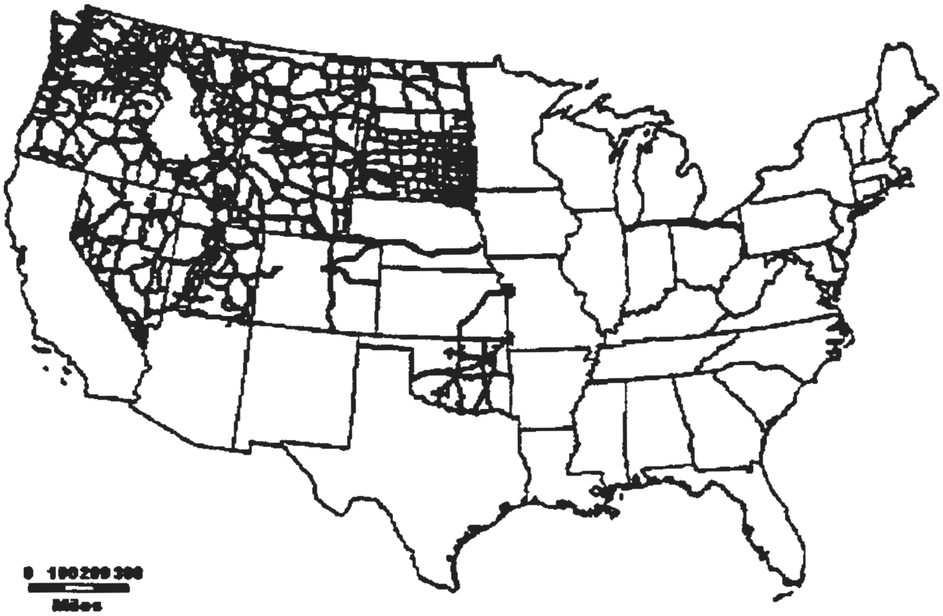
[7] Public Road Mileage, Table HM-14, 1994 *Highway Statistics*.

[8] Nebraska allows triples only when trailers are empty.

While STAA doubles are allowed in all States, longer combination doubles in excess of 28 feet are only allowed in only 21 States. Indeed, ISTEA of 1991 enforced a freeze limiting the use of the longer, heavier double- and triple-trailer combinations to those States in which they were already operating in 1991. The TS&W limits that were included in the 1991 grandfather provision are summarized in Appendix __. Consequently, two-thirds of all double-trailer combinations are STAA doubles. Of the 21 States allowing longer combination doubles, all but five are West of the Mississippi River. Figure III-5 and Figure III-6 provide maps of the Turnpike and Rocky Mountain Double highway networks.

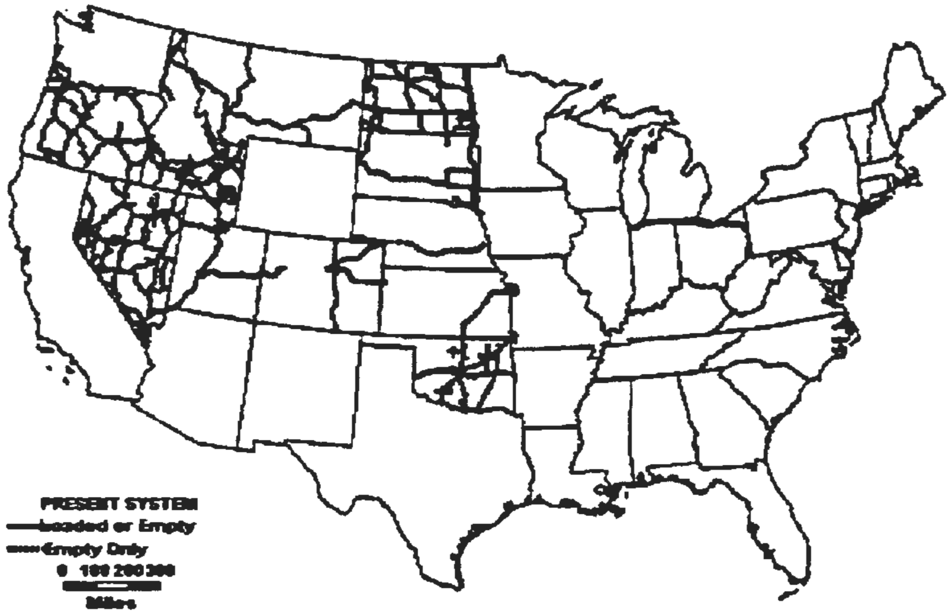
FIGURE III-5
HIGHWAY NETWORK MAP FOR DOUBLE-TRAILERS
Turnpike Doubles

FIGURE III-6
HIGHWAY NETWORK MAP FOR DOUBLE-TRAILERS
Rocky Mountain Doubles



A triple-trailer combination consists of a tractor and three trailers in tow--typically three 28- to 28.5 foot trailers. Triple-trailer combinations are permitted to operate in thirteen States under restrictive circumstances and on limited networks. The total network miles available for triple-trailer combinations is shown in Table III-11. Figure III-7 provides a map of the triple-trailer highway network.

FIGURE III-7
HIGHWAY NETWORK MAP FOR TRIPLE-TRAILERS



CROSS-BORDER TRUCKING AND INTERNATIONAL COMMERCE

There are 77 highway crossings between Canada and the ten border States in the contiguous United States--11 of the highway crossings are Interstate, 15 are on other NHS routes, and 51 are on other highways. There are 38 highway crossings between Mexico and four Southwestern States--four are Interstate, nine are on other NHS routes, and 25 are on other highways.

The volume of truck traffic from Canada into the United States is twice as high as truck traffic from Mexico into the United States. In 1995, an average of 14,008 trucks entered the United States every day from Canada compared with 7,943 trucks per day from Mexico. Between 1991 and 1995, inbound truck traffic from Canada grew by 9 percent per year and traffic from Mexico grew 11 percent per year.

The four States experiencing the highest volume of truck traffic from Canada, in descending order of number of trucks per day are: Michigan, New York, Washington and Maine. The two States experiencing the highest volume of truck traffic per day from Mexico are Texas and California.

SIZE AND WEIGHT LIMITS DIFFER

TS&W limits governing trucking operations across the two borders are very different. In crossing to Canada all but one crossing involving the NHS has GVW limits of more than 99,000 pounds and 9 of the 11 Interstate crossings have GVW limits of more than 105,000 pounds. In crossing to Mexico, all four Interstate crossings are limited to GVWs of 80,000 pounds and six of nine other crossings on the NHS have a GVW of 84,000 pounds (with a permit from the State of Texas).

TRUCK CHARACTERISTICS

The characteristics of trucks operating across the U.S. borders are affected by: type of trade, commodity, and the TS&W regulations of three countries. The majority of trucking across the Canadian border is conducted with five-axle tractor-semitrailer combinations, although a few single unit trucks are used. Commonly used tractor-semitrailer combinations in the cross-border operations on the Canadian border include: (1) seven- and eight-axle combinations with lift axles moving containers between British Columbia and Washington; (2) seven- and eight-axle A-train and B-train doubles, RMD and triple-trailer combinations between the Western provinces and Northwestern States; and (4) various heavy combinations with multiple axle groups limited by Michigan and Ontario bridge formulas.

Different TS&W limits between Canada and the Untied States result in unique situations. For example, an eight-axle tractor-semitrailer crossing into British Columbia from Washington converts to a six-axle by lifting axles on the tractor and semitrailer) and a wide variety of combinations having as many as 11 axles with one or more being liftable, operate between Michigan and Ontario.

A large portion of truck traffic between Mexico and the Untied States is dominated by the two- and three-axle single unit truck, and tractor-semitrailer combinations limited to 80,000 pounds. Very few double-trailer combinations are used.

DOMESTIC AND INTERNATIONAL CONTAINER TRANSPORT

Very few ports and rail facilities are capable of direct intermodal transfer of maritime containers. As a consequence, containerized freight transportation has grown rapidly in recent years, resulting in an increased number of maritime shipping containers traveling on the transportation system. These containers may be loaded at weights that cause trucks to exceed Federal, State, or local vehicle weight limits. Additional information on container characteristics and trends is included in Appendix __.

In general, containerized cargo refers to freight being transported in either domestic or international (maritime) containers. The significant difference between domestic and international marine containers is the structural standard for stacking endurance. Domestic containers are only required to have the structural strength to be stacked two high such as on a train, whereas international marine containers are required to have the strength to be stacked up to seven containers high. Another difference, domestic containers can be 102 inches wide, but international containers are limited to 96 inches.

The dimensions of standard dry domestic containers in the United States are lengths of 45-feet, 48-feet, and 53-feet, width of 8.5 feet and height of 9.5 feet. The 28-foot container is also common in the United States. These dimensions have developed to take full advantage of the dimensional opportunities available from TS&W regulations.

CHAPTER 4

SHIPPER CONCERNS AND MODAL COMPETITION

INTRODUCTION

In evaluating truck size and weight (TS&W) policy options, it is important to consider shipper concerns and the competitive advantages of truck, rail, water, and air modes. Shippers are a widely varying group who define freight transportation services by identifying customer needs, procuring necessary materials, and ultimately delivering goods to meet customer needs. Shippers are impacted directly by TS&W limits, as in the case of privately operated truck fleets, or indirectly affected because the carriers they select must comply with TS&W laws and regulations.

Shipper decisions regarding freight transportation are based on total logistics costs, customer requirements, and other corporate goals. Total logistics costs include inventory, capital cost of that inventory, warehousing, and transportation costs. These costs can vary between industries and among firms within the same industry. TS&W policies contribute to total logistics costs, but each shipper must evaluate their transportation options against potential tradeoffs with other logistics costs.

Shippers are not a homogeneous group and the freight transportation market is dynamic with changing customer requirements, new transportation opportunities, technological advances and interrelated services. An example is satellite tracking of a shipment's location. These factors also influence how much freight moves by truck or by type of truck, even if no change is made in TS&W policies.

The 1997 Comprehensive TS&W (CTS&W) Study included a number of activities designed to understand the heterogeneous shipper interests and issues, and assess how shipper decisions relate to TS&W issues[1]. Primary findings are: (1) shippers will optimize their logistics operations in response to TS&W policies; (2) service requirements of freight transportation must be met

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[1] These activities and findings are discussed in Report #10 of the 1997 U.S.DOT Comprehensive TS&W Study, *A Post Deregulation Perspective on Shipper Decision Making.*

before price decisions can be made; (3) transportation efficiency has increased in recent years as a result of transportation industry consolidations, technological advances, and development of closer shipper/carrier/ third-party relationships; and (4) shippers consider transportation system safety to be important.

The last two decades have seen remarkable change in the freight transportation industry. Major deregulation has occurred in truck, rail, and air transportation businesses. As a result, there have been considerable consolidations in the trucking and rail industries, blurring the boundaries between traditional business entities. Consequently, intermodal transportation services have improved. These changes have supported the development of integrated supply chains and technological advances that have improved the efficiency with which freight is moved.

Nearly 56 percent of all freight shipped (measured in tons) travels less than 50 miles, and more than 75 percent travels less than 250 miles. In 1993, the trucking industry handled about 66 percent of all freight tons and about 75 percent of the market value of all freight shipments.[2] However, trucks constituted a far smaller portion of freight movements in terms of ton-miles traveled (about 36 percent) whereas rail accounted for 39 percent and water modes accounted for 11 percent of the total in 1993 with the balance made up by intermodal and other forms of transport. The value, travel distance, time-sensitivity, and density of freight combine ultimately to determine the means and mode of freight transportation.[3]

RECENT CHANGES AFFECTING SHIPPERS AND FREIGHT TRANSPORTATION

Since 1980, there have been significant changes in United States and global freight transportation. A number of common issues have prompted cross-industry (transportation) change that has had an impact on both the structure of the transportation systems and how shippers use these transportation systems. The most important factors influencing these changes are: (1) global markets; (2) deregulation; (3) technological advances; (4) merger, acquisitions, and alliances; and, (5) shipper process change. These factors, including TS&W limits, and other issues directly impact shipper logistics costs and how freight is moved.

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[2] 1993 Commodity Flow Survey (CFS) data.

[3] A description of the models used to estimate the diversion of freight from one mode to another is provided in the Volume III Report of the 1997 Comprehensive TS&W Study.

GLOBAL MARKETS

Shippers and carriers have an increasing interest in globalization. For example, rather than being solely concerned with a Chicago-New York transportation move, a company may now have to consider inbound flow from Asia and outbound flow to Europe and South America. This increases the complexity of the transportation network — and of the entire supply chain — and provides new challenges to effectively manage a combined global and domestic goods flow network.

> . . . globalization of U.S. business has been a double edged sword providing both a threat and an opportunity. There is no doubt, however, that it is no longer business as usual, and companies have responded, in part, by copying some foreign business practices, e.g., "just-in-time" (JIT) inventory control and flexible manufacturing systems, as well as instituting other changes in their organization structures to remain competitive.
>
> [Global]. . . markets include foreign purchasing (sourcing) of raw materials and supplies and selective sales in international markets with extensive use of intermediaries to multi-faceted international manufacturing and marketing strategies encompassing international production sites, multi-staging inventory, and counter trading product sales. The growing international dimension of both the inbound and outbound logistics channels has had and will continue to have a major impact upon the logistics and transportation requirements of companies.[4]

ECONOMIC DEREGULATION OF TRANSPORTATION

An overview of economic deregulation of transportation is relevant to TS&W for many reasons, including: changes to TS&W regulations have been stimulated by increasing markets for the trucking sector, growth in the number of carriers and trucks following deregulation is significant and has contributed to capacity problems faced by the States, and changes to TS&W limits can either stimulate or stifle efficient commodity flow, impacting both domestic and international commerce.

SURFACE TRANSPORTATION INDUSTRY DEREGULATION

The freight transportation industry in the United States has experienced enormous changes since 1980. In the late 1970s, advocates for deregulation of transportation began to argue for elimination of Federal economic regulation and Congress began to reevaluate the body of transportation regulation that had been developed since the Interstate Commerce Commission (ICC) was created in 1887. Under the belief that inefficiencies existed, caused by rate and entry-exit regulation, Congress determined that the Nation's transportation system could perform better

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[4] "Future Manufacturing, Markets, and Logistics needs," John J. Coyle, Conference Proceedings 3: International Symposium on Motor Carrier Transportation, National Academy Press, 1994, pg 21.

with less regulation and more competition. A number of Federal deregulatory laws— including the Motor Carrier Act of 1980, the Staggers Rail Act of 1980, the Surface Transportation Assistance Act (STAA) of 1982, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the Trucking Industry Regulatory Reform Act (TIRRA) of 1994, Title VI of the Federal Aviation Administration Authorization Act of 1994, and, the Termination of the ICC Act (TICCA) of 1995—followed as Table IV-1 shows.

TABLE IV-1
DEREGULATION OF SURFACE TRANSPORTATION

Mode	1980	1982	1984	1991	1994	1995
Trucking	Motor Carrier Act	STAA		ISTEA	TIRRA	TICCA
Rail	Staggers Rail Act			ISTEA		TICCA
Rivers/Canals				ISTEA		TICCA
Shipping			Shipping Act			

Under the deregulated market, each freight transportation mode experienced significant business volume growth in the 15 years that followed the 1980 and 1982 legislation. Although each mode had a rise in ton-miles (Table IV-2), the greatest gains were made by air freight and non-ICC regulated trucking. The Eno Foundation's estimate of domestic intercity ton-miles show the variance in relative shares as the industry has evolved during deregulation. In the early 1980s rail lost share to trucking, but it recovered somewhat in the 1990s with new operations and services.

TABLE IV-2
HISTORICAL DOMESTIC INTERCITY TON-MILES OF FREIGHT BY MODE (Billions)[5]
Selected Years

	Rail		ICC Truck		Non-ICC Truck		Rivers/Canals		Air	
	Ton-miles	%	Ton-miles	%	Ton-miles	%	Ton-miles	%	Ton-miles	%
1980	932	37.5	242	9.7	313	12.6	227	12.5	4.84	0.19
1982	810	36.0	218	9.7	302	13.4	217	12.8	5.14	0.23
1987	972	36.6	276	10.4	387	14.6	257	12.8	8.67	0.33
1991	1100	37.7	320	11.0	438	15.0	290	13.3	9.96	0.34
1992	1138	37.6	342	11.3	473	15.6	298	13.1	10.99	0.36
1993	1183	38.1	365	11.7	496	15.9	284	12.2	11.54	0.37
1994	1275	39.1	391	11.9	517	15.8	290	11.8	12.70	0.39

Source: Eno Transportation Foundation, Inc.

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[5] Percents are based on totals which include oil pipelines and all Rivers/Canals not just domestic.

THE STAGGERS RAIL ACT OF 1980

The Staggers Rail Act of 1980 limited ICC authority over maximum rail rates to movements where railroads had market dominance over the specific traffic at issue.[6] The Act also allowed carriers and shippers to enter into confidential, unreviewable rate and service contracts, and broadened the ICC's authority to exempt specific traffic segments or services from all regulation, if competition is sufficient to protect shippers. As a result of all these changes, today, only approximately 10 percent to15 percent of rail traffic is subject to maximum rate regulation. The ICC's maximum rate guidelines are designed to stimulate a competitive rate level in cases where market forces are weak or absent.

The Staggers Act set minimum rates at "a reasonable minimum," which the ICC interpreted as not below directly variable costs. By prohibiting most collective ratemaking as collusive, the Act significantly stimulated intramodal competition and encouraged rail-barge and rail-truck intermodal movements (the Act did retain permission for railroads that participated in joint line movements to work together to set rates).

The Act extended 1976 legislation and ICC administrative actions to allow railroads to abandon lines where traffic did not support the cost of providing service. By allowing any financially responsible party to acquire an abandoned line at low cost, the Act preserved local rail service in many areas and stimulated the growth of the shortline railroad industry. The Staggers Act also placed time deadlines on ICC determinations in abandonment and merger proceedings, and set slightly easier approval criteria for mergers and acquisitions that did not involve at least two Class I (major) railroads.

THE MOTOR CARRIER ACT OF 1980

The goal of Congress and the ICC in deregulating the trucking industry was to lower rates, particularly in the less-than-truckload sector. Various studies concluded that the trucking industry's collective rate-making system, composed of regional rate bureaus, resulted in rates in the less-than-truckload (LTL) sector that were substantially higher than they would be in a fully competitive environment.[7] To remedy this situation, Congress passed the Motor Carrier Act of 1980, which significantly affected the structure and functioning of the trucking industry by limiting collective rate making, easing entry restrictions, and encouraging pricing freedom.

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[6] For a railroad to have market dominance over a specific movement, the rate to variable cost ratio for the traffic has to exceed a statutory threshold (originally set at 160 percent and rising by increments to 180 percent, the level today). Additionally, there must be no effective intermodal, intramodal, product or geographic competition for the movement.

[7] For one example, see John W. Snow, "The Problem of Motor Carrier Regulation and the Ford Administration's Proposal Reform," in Paul W. MacAvoy and John W. Snow, eds., *Regulation of Entry and Pricing in Truck Transportation*. American Enterprise Institute, 1977.

The Motor Carrier Act of 1980 directed the ICC to eliminate gateway and circuitous route restrictions, as well as some other operating restrictions, for the common carrier segment of the industry and for contract carriers of property, the Act eliminated restrictions on the number of shippers they could serve. Of particular importance, the Act phased-out antitrust immunity for collusive rate-setting activities, which resulted in increased price competition.

A significant provision of the Motor Carrier Act was the relaxation of entry restrictions for new carriers, making it easier to obtain certificates of operating authority. Unless the ICC found the proposed new service to be inconsistent with public convenience and necessity, the ICC was required to grant certificates. Prior to the act, applicants had to prove that their proposed new service was in the public interest. Existing carriers serving the market now had to prove that the new service was not in the public interest.

INDUSTRY CHANGES

Deregulation of the surface freight transportation industry allowed the transportation system to grow in size and to become more efficient. Industry figures suggest that a huge influx of new entrants into the trucking business followed the Motor Carrier Act of 1980. In the period from 1978 to 1987 the number of for-hire carriers increased from 67,038 to 89,677; the number of local carriers increased from 41,069 to 50,091; intercity carriers increased from 21,426 to 33,547; and household goods carriers increased from 4,543 to 6,039. The largest increase in number was the ICC-regulated carriers, doubling from 16,874 in 1978 to 36,948 by 1986.[8] The largest increase in operating authority came primarily from small Class III[9] carriers, which almost exclusively provide TL service. These carriers increased from 14,610 in 1980 to 33,903 in 1986. The main source of this increase was from private carriers that took advantage of their ability to obtain backhaul authority.[10] Other sources of growth were in owner-operators, who previously leased their services to common carriers, and carriers that operated in intrastate or exempt markets.

Rail and motor-carrier operations changed dramatically in response to the movement toward deregulation. Railroads and shippers negotiated thousands of contract rates for regulated and unregulated commodities. Consolidation and abandonment reduced excess capacity and improved yard and linehaul operations, enabling railroads to lower their costs and to offer substantially

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[8] "Trends and Statistics," *Commercial Carrier Journal, July 1987.*

[9] Class III carriers are those carriers receiving annual gross operating revenues less than $3 million from property motor carrier operations.

[10] Toto Purchasing and Supply Co., Inc. 128 ICC 873, March 24, 1978.

faster service.[11] In 1975, there were 73 Class I[12] railroads; by 1988, the number had dropped to 17, operating 82 percent of the system mileage and employing 90 percent of the industry's labor force. By 1995, the number had decreased to ten Class I railroads.[13]

An important outcome of deregulation of motor carrier and rail that is relevant to TS&W regulations is the shipper advantage gained. For example, the average rail rate per ton declined 38 percent between 1980 and 1995 (after adjusted for inflation).[14] From a shipper's point of view, the improvements in rail and motor carrier service have also been beneficial because they have coincided with efforts to reduce inventory costs. There has been a shift to JIT production and inventory management, which attempts to minimize inventories by bringing in raw materials and components JIT for production. Companies are achieving substantial savings in the lower cost of warehousing, insurance, interest expense, taxes, loss, and damage. Deregulation aided the development of this policy because shippers were freer to enter into contracts and to specify service standards that carriers had greater incentive and ability to meet.

Deregulation of transportation services has allowed carriers to focus on providing flexible service that responds to changing market conditions and is not dependent on a lengthy approval process by a regulatory agency. Carriers operate more efficiently, with more direct routes and fewer empty backhauls, and offer more service options with greater pricing flexibility.

TRUCKING INDUSTRY REGULATORY REFORM ACT OF 1994

With the passage of the TIRRA in August 1994, the domestic trucking industry became almost entirely deregulated, finishing the work that Congress started with the Motor Carrier Act of 1980. The catalyst for change contained in the TIRRA was a provision that eliminated the long-standing requirement that interstate motor common carriers file their rates with the ICC.

Before TIRRA, 41 States exercised some degree of control over truck movements within their borders through regulation of operation authority. TIRRA prompted many LTL carriers to expand their territorial coverage to include intrastate service. Further, large, well-financed regional carriers expanded into once-protected markets like California and Texas. Relevant to TS&W regulation was the provision in TIRRA that established the minimum entry requirements for motor carrier applications to safety, fitness, and financial responsibility with revocation of a carriers' authority limited to a carriers' failure to maintain safety standards and insurance.

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[11] "Potential Benefits of Rail Mergers: An Econometric Analysis of Network Effects on Service Quality," G. Harris and Clifford Winston, *Review of Economics and Statistics*, Vol. 65, February 1983, pp. 32-40.

[12] For 1994, Class I railroads are those railroads with operating revenue of $255.9 million or more. According to Railroad Facts published by the Association of American Railroads. Note: The operating level is adjusted annually for inflation.

[13] Association of American Railroads, *Railroad 10 Year Trend*, 1985-1994. Washington, D.C., November 1995

[14] ICC Office of Economic and Environmental Analysis, Rail Rates Continue Multi-Year Decline (1995).

FEDERAL AVIATION ACT OF 1994: TITLE VI

The Motor Carrier Act and TIRRA deregulated interstate commerce among States, permitting shippers to negotiate with truckers on rates, however some States exercised tight controls over intrastate operating authority—preventing carriers from reaching the full potential of the Motor Carrier Act of 1980. Shippers found themselves paying more to move freight within large States than for cross-country hauls. Restricted competition allowed intrastate rates to rise to levels about 40 percent higher than interstate rates for the same distances.[15]

On January 1, 1995, Title VI of the Federal Aviation Act of 1994, the section that preempts State economic regulation of motor carriers transporting property intrastate, became effective. The Act bars all States from enacting or enforcing a law, regulation, or other provision having the force and effect of a law related to price, route or service of any motor carrier (other than a carrier affiliated with a direct air carrier) or any motor private carrier with respect to the transportation of property.

THE INTERSTATE COMMERCE COMMISSION TERMINATION ACT OF 1995

The deregulation of the rail and trucking industries diminished much of the ICC regulation in these industries; constraints on rates and entry into these industries were largely eliminated. After the Motor Carrier Act, in addition to some residual rate and entry regulations, the ICC continued to enforce several kinds of ancillary trucking regulations on matters other than rates and entry. One of the "fitness" regulations the ICC continued to enforce was safety, requiring ICC-regulated motor carriers to have insurance coverage, in the amount of $750,000 in 1980.

In December 1995, the ICC Termination Act was signed into law. The act eliminated dozens of ICC functions, with the remaining responsibilities transferred to a new Surface Transportation Board. The Board will continue to render decisions on undercharge claims, rate reasonableness, and adequacy of service. Specifically, it retained almost all its authority over rail regulation under the Staggers Act (including maximum rates, abandonments, mergers, etc.).

IMPACT OF DEREGULATION AND TRUCK SIZE & WEIGHT REGULATION

Federal trucking deregulation has had a profound effect on all aspects of the industry since passage of the most significant legislation, the Motor Carrier Act of 1980.[16] Simplified entry into the industry, greater pricing freedom, expanded classification of exempt commodities, provisions of for-hire services by private fleets, and easing of territorial restrictions have all contributed to stimulating industry and market competition.

During the mid- to late-1980s the trucking industry underwent a significant reorganization that resulted many changes, such as established carriers expanding into new services, and private

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[15] "The Brave New World of Tariff-Free Pricing," Ray Bohman, *Traffic Management*, June 1995

[16] Harris, op cit.

carriers and owner-operators operating independently as for-hire interstate carriers. Economic deregulation eroded the relevance of many traditional distinctions between trucking companies and carriers are now described more by the market segment they serve, TL or LTL. TL carriers account for 80 to 90 percent of all combination truck traffic.

Increased use of larger trucks following enactment of the STAA of 1982 and changes in the trucking industry that evolved from economic deregulation coincided. A strong economic incentive influenced the trucking industry conversion to the STAA trucks. Carriers select trailers largely on the basis of the characteristics of the commodities they haul, therefore increases in truck size limits is of lesser importance to TL carriers than the LTL carriers.[17]

Consequently, any policy scenario that increases size limits, but not weight limits, would benefit one segment of the industry, the LTL carriers, but not TL carriers. The expanded use of twin trailers provided for in STAA is primarily concentrated within the LTL segment of the industry, whereas the longer semitrailers are favored by the TL carriers.

The 1980 deregulation of the rail and trucking industries strongly affected shipper decisions. Deregulation has given greater freedom to both shippers and carriers in meeting the requirements of the market place for both a cost-effective and service-effective system. However, deregulation has not been without its casualties. The industry changes in the mid 1980s found over a thousand truck lines a year ceasing operations. Many short-line railroads also ceased operations. Carriers which were not able to adapt to new shipper requirements were the first casualties of deregulation. However, many more thousands of motor carriers entered the market, as did about 300 short line railroads.

TECHNOLOGICAL ADVANCES

New technology has provided the platform for many pervasive and continuing changes in transportation supply which have improved communication between shippers and carriers. Examples of technologies include bar coding, advanced material-handling systems, and sophisticated carrier routing and scheduling programs. Movement-related equipment, such as double-stack trains, RoadRailer[18], and other advanced rail car designs, has also provided technology applications that have a direct impact on the economics of both shippers and carriers. Electronic Data Interchange (EDI) and more broadly electronic commerce is linking together the shipper, carrier, and customer in real time. Additionally, reduced costs and increased capabilities of personal computers contributed to improvements in shipper and carrier communications.

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[17] Harris, op cit.

[18] A type of rail-highway vehicle developed in the late 1950s by the Chesapeake and Ohio Railroad consisting of a conventional highway semi-trailer with a pair of steel railroad wheels that could be lowered so the trailer could also ride on railroad tracks. The evolution of the RoadRailer is summarized in *Intermodal Freight Transportation*, 3rd edition, Gerhardt Muller, 1995, pg.62.

> The impact of . . . computer technology on logistical practices has been far reaching. Complex tasks such as truck routing and scheduling are now much more routine using desktop computers. Simulations of entire logistical systems can be developed to determine the optimal approach to achieving desired customer service performance. It is possible to simulate the knowledge of logistics experts and combine it with current data to develop new strategic alternatives. Such systems offer the promise of linking status and control information from material procurement to finished product customer delivery. The development and management of such a huge data base would not have been possible a few short years ago.
>
> Current available systems such as bar coding are being improved and combined with data communication transmission to improve logistical control and manage inventory more effectively. With the advent of satellite transmission, a shipper/carrier can pinpoint the exact location and schedule of an individual package at any time throughout the entire logistical supply chain. Throughout the logistics infrastructure, carriers, warehouses, and special service providers are introducing much better information and control systems.
>
> The information transmission part of the technological revolution is worthy of special note. EDI and bar coding have played a major role in the more efficient and effective management of the distribution process, but there is much more that can be done to integrate the systems of vendors, customers and transportation companies.[19]

MERGERS, ACQUISITIONS, ALLIANCES

The high level of merger activity within and between the traditional modes of transportation during the past decade created new transportation capability for shippers. Several recent mergers of large Class I rail lines have been initiated for improving rail service and making it more competitive with trucks. Similarly, other mergers, acquisitions, and alliances within and between the modes have created a new menu of enhanced carrier and third-party service capabilities for the shipper. Even with this enhanced menu, according to the National Private Truck Council and the American Trucking Associations, Inc., private carriers continue to represent a 52 percent share of interstate freight movement. At the same time that these mergers, acquisitions, and new alliances are taking place, some carriers have emerged to aggressively take a new role in the transportation network.

> A key trend in organizational restructuring has been the flattening or leaning of organizations with layers of middle management being eliminated and the span of control being increased. The logistics and transportation function has frequently

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[19] "Future Manufacturing, Markets, and Logistics Needs," John J. Coyle, Conference Proceedings 3: International Symposium on Motor Carrier Transportation, National Academy Press, 1994, p. 24.

> been a primary area for economies to be implemented with less staff. With mergers, one company's department of logistics and transportation is often eliminated, or in some instances both, and the function is outsourced to a third party company in whole or in part.
>
> ...The outsourcing of logistics and transportation has created a niche for transportation companies to add services that will add value for their customers. Some transportation companies have established subsidiaries to offer broad based logistical services for their customers including warehousing, inventory control, order processing, delivery, . . . and so forth.[20]

SHIPPER PROCESS CHANGES

There is strong evidence in almost every industry sector that forward-thinking shippers have changed the way they go to market. It is difficult to find an industry meeting where one is not bombarded by the relative merits of a new alphabet of acronyms: JIT, Quick Response (QR), Efficient Consumer Response (ECR), Distribution Requirements Planning (DRP), and a host of others. Most of these in one way or another deal with connecting the supply chain with a unified operation, eliminating safety stock, duplicating inventory in the system, shortening freight ordering and transit times, and bringing more value to the consumer or user.

Along with these changes have come changes in buyer-seller relationships in the transportation network. Most of the freight moving today in the United States moves under contract rates—where the price of an individual shipment is set by an overall contractual relationship between a shipper and carrier. Shippers project that contract rate shipments could climb to over 75 percent of total shipments by the turn of the century[21]. This trend suggests a changing set of relationships in the supply chain, and a set of relationships which may provide a more stable, predictable, and productive base for forecasting future transportation requirements.

These five factors, along with other industry-specific factors, have a significant impact on costs, productivity, and strategy of the entire logistics supply chain. For a number of firms, the total logistics costs in 1996 on a cost-per-unit basis are lower than they were in 1980 (inflation adjusted). The savings come from elimination of duplicate inventory in the system, lower overall transportation costs, and reduced transaction costs in the supply chain.

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[20] Coyle, op cit., p. 25

[21] Based on findings of Report #10 of TS&W Study previously cited.

ANALYSIS OF MARKETPLACE CHANGES IN DISTRIBUTION[22]

Logistics costs have been increasing since 1983 in the United States and are projected to exceed $600 billion annually during the 1990s. Logistics costs as a percentage of gross national product (GNP) declined from about 15 percent in 1981 to 11 percent in 1990. This decline is expected to continue through the 1990s.

Table IV-3 presents the components of total National logistics costs in 1990. Of the major categories listed, motor carrier transportation costs accounted for $277 billion out of the total $600 billion. Expenditures for inventory costs ($221 billion) almost equaled transportation costs. Outlays for other transportation modes and administrative activities were small in comparison.

Figure IV-1 indicates an overall decline in total expenditures for logistics, transportation and inventory carrying costs as a percentage of GNP from 1970 through 1990. During the 1980s, total business logistics costs declined by about $65 billion. About $35 billion of this savings is attributed to reductions in transportation costs; savings in inventory carrying costs accounts for the remaining $30 billion. Figure IV-2 demonstrates the dramatic decrease in inventory levels during the period 1980 through 1990.

TABLE IV-3
COMPONENTS OF 1990 LOGISTICS COST

COMPONENT	COST ($ Billions)
Inventory Carrying Costs	76
Interest	84
Taxes, obsolescence, depreciation	61
Warehousing	221
Transportation Costs	
Motor Carriers	
Public and for hire	77
Private and for own account	87
Local freight services	113
	277
Other Carriers	
Railroads	32
Water carriers	21
Oil pipelines	9
Air carriers	13
	75
Shipper-Related Costs	4
Distribution Administration	23
Total	600

Source: John J. Coyle, "Future Manufacturing, Markets, and Logistics Needs," 1994

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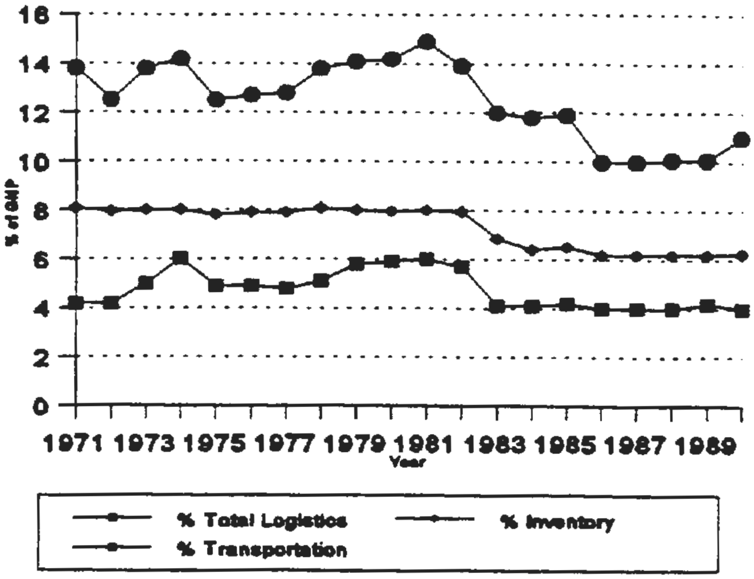
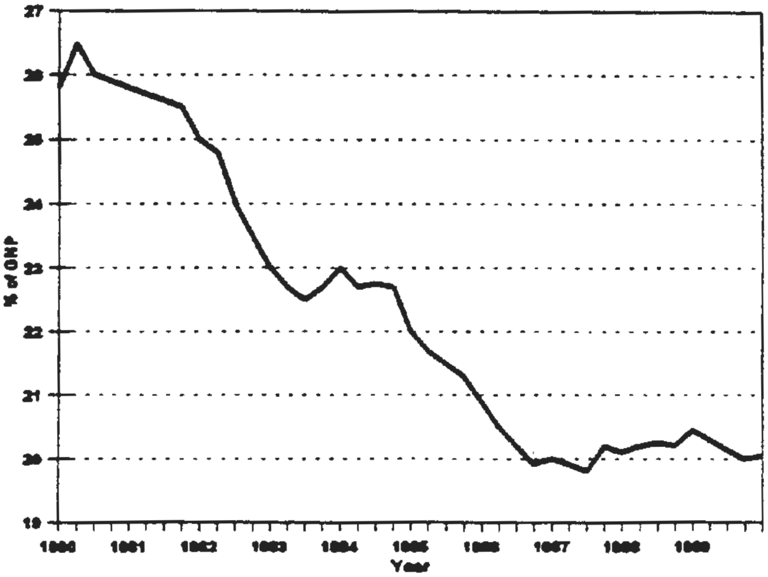
[22] The material in this section is based on Coyle, op cit.

FIGURE IV-1
BUSINESS LOGISTICS, TRANSPORTATION, AND INVENTORY CARRYING COSTS AS A PERCENTAGE OF GNP



Source: Robert D. Delaney, Cass Logistics, Inc., reprinted with permission.

FIGURE IV-2
NOMINAL RATIO OF BUSINESS INVENTORIES TO FINAL SALES: 1980-1989

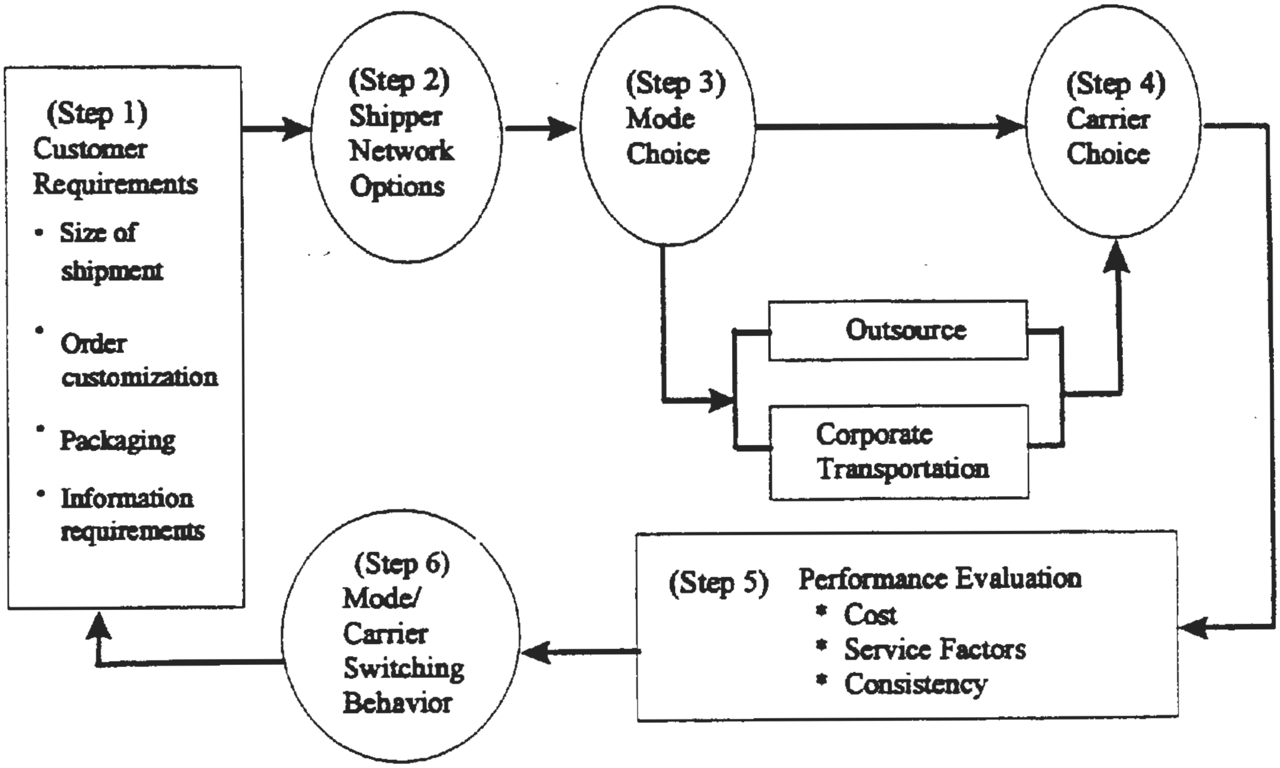


Source: Federal Reserve Board

SHIPPER DECISION MAKING PROCESS

The complexity of the shipper transportation decision process is shown in Figure IV-3. The process begins with understanding customer requirements, then flows into network shipping options, modal choice, carrier choice, and post-choice evaluation processes. The process is continual because shippers select a transportation strategy to meet customer needs and continually evaluate customer requirements which may lead to further changes in the shipping process. TS&W limits affect all cells in the shipper transportation decision-making process diagram. For example, TS&W limits may effect a carrier's delivery schedule for customers with a time-definite production process. On the other hand, a shipper who has opted to use private trucks may be less likely to purchase new equipment or to switch modes of transport that may be more cost-effective following a change in TS&W limits, given the substantial investment in their existing private truck fleet. This entire process may be noticeably different for a shipper that has outsourced their traffic management or is using for-hire carriers.

FIGURE IV-3
THE SHIPPER TRANSPORTATION DECISION MAKING PROCESS



STEP 1: CUSTOMER REQUIREMENTS

A shipper deciding on a "go-to-market" strategy must tie its transportation decisions to customer requirements. A number of factors have had an impact on this part of the shipper decision process. For example, from 1950 to 1980 most inventory systems in the United States were "push" systems in which the shipper decided when to ship, where to ship, and what packaging to use. During the decade of the 1980s, the large mass merchants grew to maturity. A number of retailers grew very rapidly, and as they did, power shifted away from the shipper downstream to large upstream customers. The inventory systems shifted from the classic "push" system to a "pull" system, in which the customer decided the size of shipment and when and where it would be delivered.

Customer requirements today are multifaceted, and increasingly more diverse. It is no longer satisfactory to simply provide quick transit time for most of the shipments. Customized shipments—specialized packaging, shipment tracking, and progress reporting—is the rule for many customers. There is a growing use of "time-definite" shipments, meaning that the customer is not concerned with how long the shipment takes in transit but rather the exact time that it arrives. This, of course, allows the shipper and carrier greater latitude in designing their logistics network in that they are able to manage transit time in the most economical way, using a variety of transportation modes, providing they are able to deliver to the customer on a time-definite basis.

The long-running debate over the relative importance of cost-versus-service quality continues today. There is no doubt that some freight—due to its low value and high density—is cost sensitive and, therefore, generally moves by rail, and generally by the lowest costing carrier. At the other end of the scale is a range of products that are service sensitive and, therefore, generally move by truck, not air. However, in between price-sensitive and service-sensitive freight are a range of goods that can move either by rail or truck depending on the service requirements, distance traveled, and total logistics costs to the shipper.

STEP 2: SHIPPER NETWORK OPTIONS

From 1950 to 1980 most firms buffered uncertainty with inventory. This approach involved a network of multiple distribution centers and duplicate inventory throughout the United States and the world. With costs decreasing and the capability of information resources increasing in the 1980s and 1990s, a significant shift took place in logistics architecture. Instead of multiple inventories, forward-thinking companies replaced physical inventories with information resources describing the location and arrival time of new shipments. There is also a trend toward logistics architecture which emphasizes product flow directly to the customer. In these types of systems, product flows from the end of the production line to the ultimate customer or user. If this is not possible, then a process of cross-docking or flow-through distribution is adopted which keeps the goods moving with short delays for sorting and switching.

Recent improvements to material supply processes, such as JIT inventory practices where needed inputs are not stockpiled but arrive as needed, have supported the shift from traditional flows to "flow-through" systems. These changes, along with the enabling power of information, allowed the shipper to rethink network options in terms of efficiency and effectiveness. The resulting changes, which include everything from global sourcing to direct store delivery, have and will continue to shape future transportation network options.

STEP 3: MODE CHOICE

After defining the shipments' requirements a shipper must select a mode. Transportation choice used to focus on freight rates and inventory costs. Today, service variables (speed, reliability, and dependability) are more important than just low rates.

A firm needs to choose between managing its own shipping needs or outsourcing the transportation function. If the firm decides to manage its own shipping it may need to purchase, or lease, a trucking fleet. In the United States, private carriers command a 52 percent share of interstate freight movements.[23] However, nationwide, transportation logistics executives are seeking the best mix of service quality options for their companies, which often leads to a combination of private fleet operation and outsourcing. Many third parties not only provide transportation but also logistics services. A single vendor manages the warehousing of a manufacturer's finished goods, transporting them to retailers, and tying together the process with information systems. These parties often combine multiple carriers and modes, taking full advantage of TS&W limits and other factors.

A shipping firm may choose to use a third party for its transportation needs for several reasons. For example, using a third-party logistics provider can support a shipper's overall strategy by allowing it to concentrate on its core competency (such as manufacturing) rather than on transporting freight. In addition, logistics providers may offer better services at lower prices by specializing in transportation and developing superior expertise. Other reasons for choosing contract logistics include avoiding labor problems, removing/keeping assets off balance sheets, and ensuring more flexibility than available with private operations. However, some shippers may choose not to outsource thereby retaining control of freight operations or avoiding dependencies on outside firms.

STEP 4: CARRIER CHOICE

Factors motivating a decision to use an outside carrier or third-party logistics provider cannot be generalized. As a result, shippers find that a detailed analysis on a case-by-case basis is usually the best decision-making approach. Initially, the shipper must question if there is a better way to obtain necessary freight transportation services. To address this question, the shipper identifies alternative methods, including transportation modes and carriers, and gathers service and cost data to evaluate the alternatives. Relevant data includes freight rates; reliability; transit time; over,

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[23] Source: National Private Truck Council and the American Trucking Associations, Inc.

short, and damaged shipments; shipper market considerations (including customer service, user satisfaction, market competitiveness, and market influences); and carrier considerations (such as transport modes and equipment). Usually performance and quality requirements must be satisfied before rates.

STEP 5: PERFORMANCE EVALUATION

The next step is an ongoing performance evaluation for the mode and carrier choice. This is a dynamic and complex process often involving an analysis of multiple modes and carriers. Most firms treat the performance evaluation phase of the selection process as a quality process. Both the shipper and the customer have quality expectations which are expressed in terms of specific metrics. Carriers are usually evaluated on several variables including service quality consistency, on-time pickup and delivery performance, customer complaints, claims experience, prompt shipment tracing, and prices.

Depending upon the relationship between shipper and carrier, the carrier is usually offered an opportunity to correct a variance from shipper or customer expectations. Continued variance can lead to shipper actions ranging from a reduction in the proportion of freight handled by any given mode or carrier to switching carriers completely. Because this is not an unusual action, the carrier evaluation process usually includes the identification of other qualified carriers.

STEP 6: MODE AND CARRIER SWITCHING BEHAVIOR

At some point, a shipper may decide to switch carriers. However, switching carriers may be a high cost action. Switching costs include specialized assets acquired by the carrier for the shipper, shared information systems, and long-term contracts. A carrier may increase potential switching costs by creating proprietary information systems and using dedicated assets. The shipper can decrease these costs by using more than one carrier and using its own accounting/ information systems in addition to that of the third party.

The shipper decision process is continuous. After completing the performance evaluation and making any mode or carrier changes, the shipper evaluates its customers' requirements, which repeats the process.

SHIPPER ISSUES AND TRUCK SIZE AND WEIGHT POLICY

Shipper and carrier transportation decisions are not made in a vacuum and vary considerably between and within different industries. Transportation costs are one component of total logistics costs, and these costs vary significantly by industry- and company-specific situations. In addition, the number of transportation options available and differences in TS&W limits further complicate quantitative assessment. However, a number of conclusions may be drawn regarding shipper and carrier considerations and TS&W limits. These conclusions are based on a review of relevant transportation literature, four regional shipper focus group meetings, direct interviews with shippers and carriers, detailed case studies of freight movements in six major corridors, investigations into selected commodities, and other data collection activities. Table IV-4, Shipper and Carrier Considerations Regarding TS&W Policy, summarizes these conclusions.

Shippers will respond in different ways to changes in a TS&W policy. In general, shippers and carriers who typically fill up the cubic capacity of trailers, before reaching truck weight limits will utilize size increases but not increased weight limits. Similarly, shippers and carriers that typically have heavy freight will benefit from increases in truck weight, but not size limits. Many other factors often dictate the mode for freight travel, including time sensitivity, product value and density, non-transportation logistics costs, facility and capacity constraints, and cost and availability of transportation alternatives. Each of these combine in a unique way which complicates accurate freight forecasting of nationwide impacts of TS&W policy changes.

TABLE IV-4
SHIPPER AND CARRIER CONSIDERATIONS REGARDING TS&W POLICY

- √ Shippers consider total logistics systems costs, and will optimize their operations to existing TS&W policies and respond to any TS&W policy changes.
- √ Shippers prefer simplified supply chains, which will increase the use of third party logistics firms and global alliances between shippers and carriers. Some transportation modes are integrated, and further integration is likely .
- √ Transportation safety is important to shippers. Safety cannot be compromised by TS&W changes.
- √ In general, more liberal and more uniform TS&W limits would improve shipper productivity. The amount of improvement is dependent on unique characteristics for each freight shipment and customer's needs.
- √ Service and quality considerations are a prerequisite to mode selection. Rail is the least expensive mode, but transit time and service consistency limit its use. Rail-truck intermodal services help to bridge the transit time/service quality gap.

This research suggests that the tremendous changes of the last 15 years in the freight transportation industry are likely to continue into the next century. The continuing trends are intermodal service, third party logistics providers, shipper/carrier alliances, technology applications, and the use of contracted and preferred carriers. Each of these affect how freight is transported, and many create obstacles to carrier- and mode-switching behavior. For example, more shippers and carriers are developing integrated shipment-tracking systems to monitor product inventory. Once these information systems are installed and linked between shippers and carriers, changing carriers or modes would require an additional investment to develop new information sources and integrate them into shippers' logistics systems. TS&W regulations are an important aspect, but certainly not the only factor, in how freight is shipped. Even without changes in TS&W policies, shippers will continue to operate in a changing freight transportation environment and will optimize shipments within existing TS&W policies.

There is a consensus in the shipper and carrier communities that safety is a high priority and any changes to TS&W limits have to at least maintain, if not improve, public safety. Shippers said that they were concerned for safety for several reasons, including good community citizenship, protection of the public and freight from harm, and minimization of costs. Several shippers said that preservation of safety justified a Federal role in TS&W regulation to ensure that nationwide protections are in place. Shippers at the group meetings felt that the Federal Government should not delegate TS&W policy and the corresponding safety responsibility entirely to the States.

In general, shippers and motor carriers believe that higher or more uniform TS&W limits would increase productivity. The degree of improvement depends on a number of unique factors which vary for each individual freight movement. However, some shippers felt that higher limits would not improve productivity. For example, many shippers face facility constraints, such as older warehouses, which are not large enough to accommodate longer trailers or longer combination vehicles (LCVs). Another limitation may be insufficient warehouse space to accommodate larger, less frequent, quantities of freight deliveries.

FACTORS AFFECTING SHIPPER MODE CHOICE[24]

Shippers and carriers believe that few commodities are competitive between truck and rail service. However, transportation modes are interrelated and impact each other. Many factors influence the decision between truck and rail shipments, including service quality consistency, transit time, cost, complexity of supply chain, truck driver availability, union agreements, and other factors. The present research supports the contention that service quality issues are as important as cost issues for most freight shipments.

TRANSIT TIME

Companies recognize that time is a critical variable that can determine success in the marketplace. In the past, firms attempted to reduce the lead time required to introduce new products, controlling factors related to product design and manufacturing. In recent years, efforts to compress time have broadened to include other areas, particularly distribution activities. Transportation is an increasingly important component of the new "quick-response" logistics systems. Among the modes, motor carriers have traditionally held the competitive advantage in terms of speed of service relative to cost. However, as companies continue efforts to reduce inventory and lead times, products for which air is competitive with truck may expand.

SERVICE QUALITY

Recent trends to improve overall quality, particularly through total quality management (TQM) initiatives, have been extended to include distribution programs. Shipper demands related to transportation service levels, especially consistency, have become more intense. Companies recognize that transportation is a visible and important part of their relationship with the consumer.

Carriers have responded to expectations for time sensitive, high quality and responsive service by providing deliveries and pickups to meet increasingly narrow timeframes. The trucking industry

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[24] The material in this section is based on Coyle, op cit.

is, at present, considered most conducive to supplying this high level of service. However, other modes are becoming more competitive. Technological advances will contribute to further improvements.

ASSET PRODUCTIVITY

As companies seek ways to improve on asset productivity, investments in fixed facilities such as warehouses and private carrier trucking fleets are being closely scrutinized. There is a definite trend toward lowering private warehousing requirements either by reducing inventory and/or increased reliance on public warehousing. Further, many larger companies are also reducing their use of private motor carrier operations.

CARRIER USE

The ways in which shippers interact with carriers are changing as shippers attempt to leverage their transportation buying power especially through reducing the number of carriers they contract with. These practices reflect deregulation as well as the increased emphasis on JIT practices. Shippers and carriers are forging partnerships consistent with requirements for lower rates and enhanced efficiency.

CUSTOMER SATISFACTION

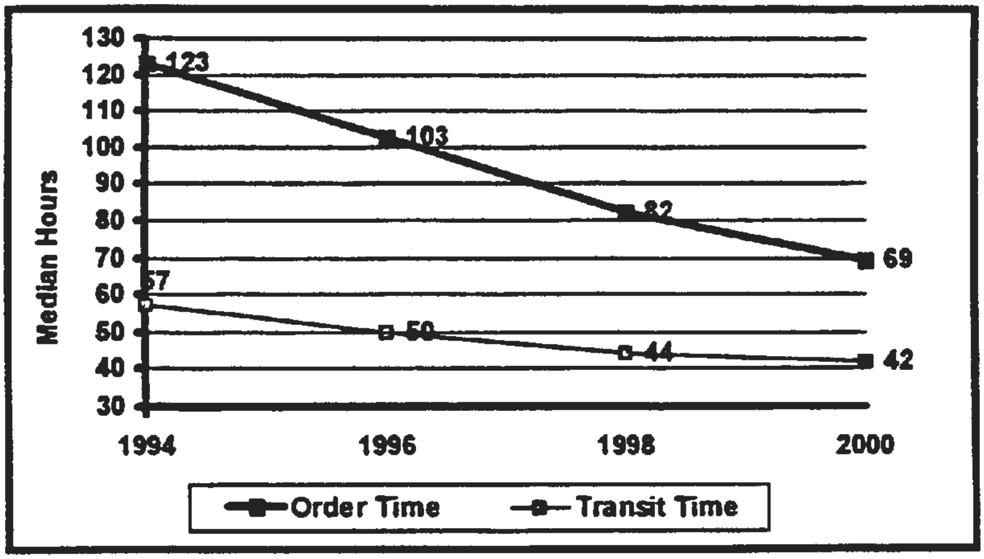
As indicated earlier, companies are emphasizing their relationship with the consumer. They are looking for ways to improve customer satisfaction and are tracking transportation related statistics such as delivery times and satisfaction in orders received (e.g., loss and damage considerations). Transportation companies are recognized as an integral component of efforts to achieve high levels of customer satisfaction. Frequently, shippers and carriers are even sharing data as they build "win-win" partnerships.

CONTINUING TRENDS IN SHIPPER DECISION-MAKING

Significant transportation changes in the logistics functions of shippers over the last 15 years have reduced transportation costs in many industries. It appears that many changes, such as increased time-definite freight shipments, reduced overall transit times, and closer relationships in the supply chain will continue into the 21st century. This section presents the results of the Career Patterns Survey[25] participants, consisting of 200 chief logistics executives of large, Fortune-100 United States firms.

Quick movement of goods to market is a concern for shippers. This includes many shipper practices such as JIT, QR, and vendor-managed inventory, continuous replenishment and direct store delivery. The time from when an order for freight is placed and when it is received on the customers dock, has fallen sharply in recent years, and the trend is expected to continue. Figure IV-4 shows that in 1994, average order time was over five days; it is expected to be less than three days by the year 2000. Similarly, the time freight actually spent in transit has decreased, from 57 hours in 1994 to 50 hours in 1996 and is projected to decline to 42 hours in 2000.

FIGURE IV-4
FREIGHT ORDER AND TRANSIT TIMES



Source: Career Patterns Survey

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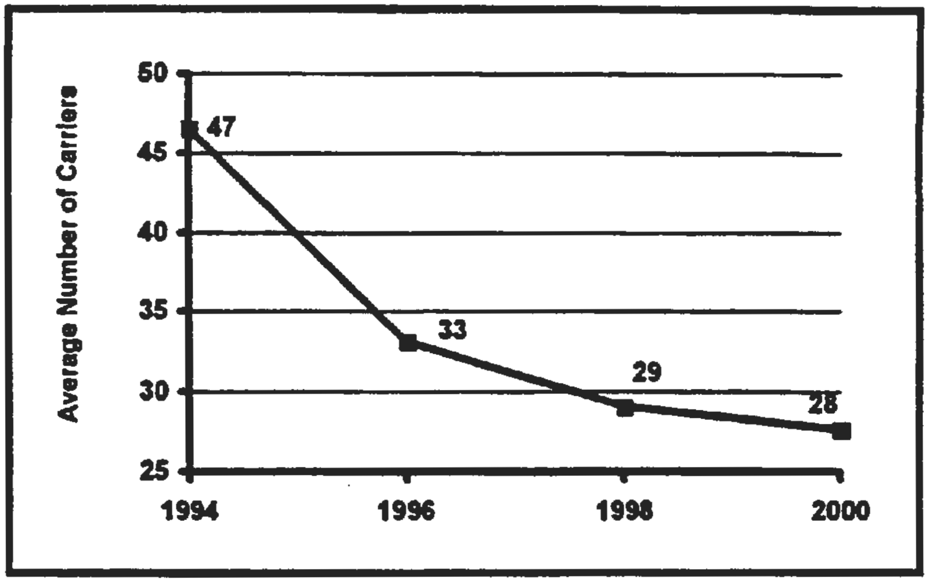
[25] From presentation of Bernard J. LaLonde and James M. Masters, Ohio State University Career Patterns-1996 at Council of Logistics Management Conference. Respondents were asked to provide actual company data for 1994 and 1996 and estimate changes for 1998 through 2000. Respondents represented a mixed group of large firms, including the food products, chemicals, electronics, pharmaceutical, and automotive industries.

There has been a clear trend among shippers toward the development of strong, long-term relationships with several preferred carriers. As illustrated in Figure IV-5 the average number of transportation carriers (excluding overnight/express deliveries) is expected to drop dramatically between 1994 and 2000. As contractual relationships develop, it is consistent that firms will do more business with fewer carriers and continue to "rationalize their carrier base." The practice of shippers doing business with fewer carriers and continually rationalizing their carrier base allows for greater learning on both sides of the partnership and presumably more efficient transportation results.

FIGURE IV-5
AVERAGE NUMBER OF CARRIERS USED REGULARLY BY SHIPPERS



Source: Career Patterns Survey

Communications technology will probably have the single most important impact on the transportation industry through EDI[26] usage. As indicated in Figure IV-6, a three-fold increase in the percent of shipments using EDI is anticipated between 1996 and 2000, with six of ten shipments being initiated and tracked using EDI capability. The flip side of the data would seem to suggest that carriers who are not able to "match up" with the shipper and the downstream

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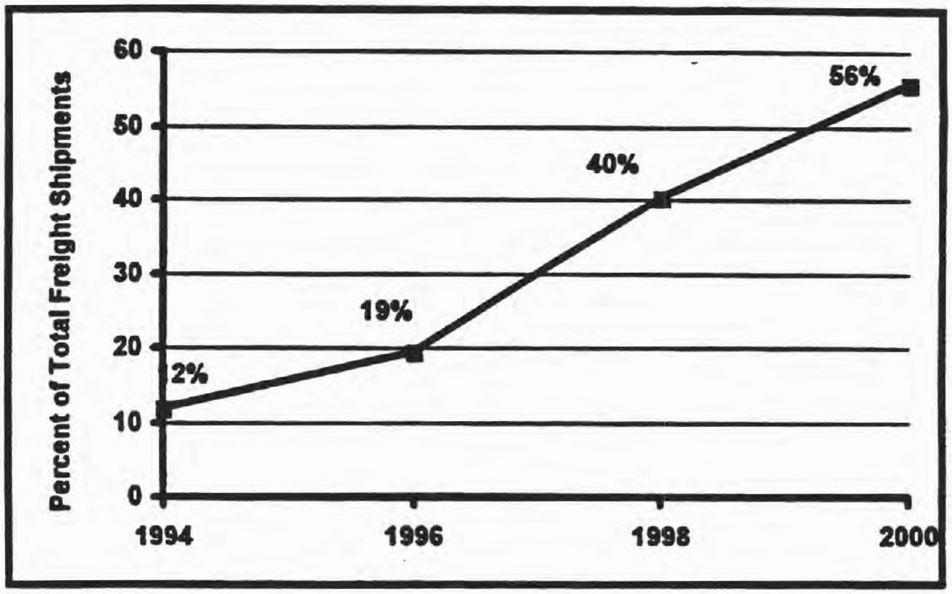
[26] Traditional communications systems, such as mail and telex, are quickly being replaced with systems such as facsimiles (faxes) and EDI. These changes are occurring in communication and information systems between carriers, shippers and ancillary services as well as within the operations of those entities. (*Intermodal Freight Transportation*, 3rd edition, Gerhardt Muller, 1995)

customer would be considered less competitive by an increasing number of shippers. It is interesting to note that the same profile emerges for vendors and customers, indicating that the vendor, customer, and third parties will be part of a rapidly expanding EDI or electronic commerce network.

FIGURE IV-6
PERCENT OF SHIPMENTS USING EDI



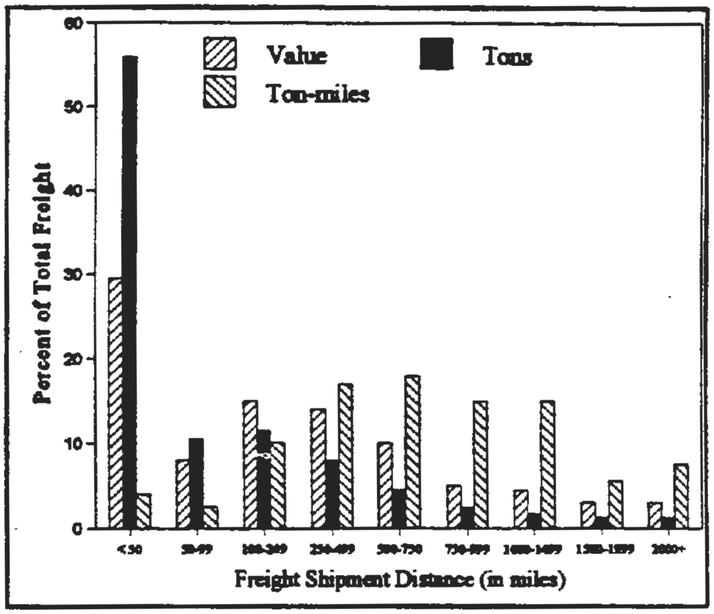
Source: Career Patterns Survey

The indicators just highlighted suggest continued increases in transportation efficiency. The data suggest that creative solutions to lowering transportation costs and providing higher service capability to the customers will continue into the 21st century. Further, the data suggest that consumers will have increasing service requirements.

MODALLY COMPETITIVE AND NON-COMPETITIVE FREIGHT COMMODITIES

To understand why different modes are competitive for transporting various commodities, one should understand how freight generally moves in this country. Local and regional transportation are important segments of the Nation's commerce, as reflected in the distribution of freight shipments by distance. About 30 percent of the value and 56 percent of the commodity tonnage are shipped between places less than 50 miles apart. This is highlighted in Figure IV-7.

FIGURE IV-7
TOTAL 1993 FREIGHT VALUE, TONS, AND TON-MILES BY DISTANCE OF HAUL



Source: 1993 Commodity Flow Survey (CFS), Conducted by the Bureau of the Census and Bureau of Transportation Statistics

Given that over half of all freight, by weight, is transported less than 50 miles, it is not surprising that trucks are the dominant mode of freight transportation. This is because the other modes face considerable competitive difficulties hauling freight short distances. About two-thirds of all freight moved in the United States, measured in gross tons, is moved by truck, with rail moving about 16 percent of all freight tonnage. However, rail shipments typically travel much farther distances—nearly twice as far as the average truck shipment. Consequently, rail accounts for the highest proportion of total ton miles of freight transportation—almost 39 percent of all freight ton miles, with trucks accounting for over 36 percent.[27]

Table IV-8 shows the distribution of the total freight movements in the United States, measured in dollar value, tons and ton-miles, for each mode: truck, air, rail, water, pipeline, multimodal (combination of two or more modes), and other (mode not specified).

TABLE IV-5
1993 UNITED STATES SHIPMENT CHARACTERISTICS BY TRANSPORTATION MODE

Transportation Mode	Freight Value		Tons		Ton-miles		Average miles per shipment
	Dollars (millions)	Percent	Tons (thousands)	Percent	Ton-miles (millions)	Percent	
Truck[1]	4,966,772	85.0	6,404,807	66.2	882,687	36.4	362
Air	5,200	–	148	–	139	–	1,180
Rail	247,394	4.2	1,544,148	15.9	942,561	38.9	766
Water	64,077	1.1	518,912	5.4	271,981	11.2	1,744
Pipeline[2]	89,849	1.5	483,645	5.0	–	–	–
Multimodal	230,346	3.9	190,832	1.9	152,374	6.4	1,049
Other	242,691	4.2	544,335	5.6	96,972	4.0	229
Total[3]	5,846,334	100.0	9,688,493	100.0	2,420,915	100.0	424

[1] Includes mail and parcel services.

– Represents zero or less than 1 unit of measure

[2] Excludes most shipments of crude oil.

[3] Some data may be included in the total, but is excluded from the modal categories, due to CFS publishing standards.

Source: 1993 Commodity Flow Survey for the United States (Bureau of the Census)

COMPETITIVE AND NON-COMPETITIVE COMMODITIES IDENTIFIED IN FREIGHT DATABASES

One approach to the truck and rail competition issue is to examine the traffic lanes (by miles) and their density (by tons) by selected/popular vehicle equipment or by value. Five factors, which bear on the service and total cost profile involved in modal selection, are examined in detail:

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[27] These numbers are from the Commodity Flow Survey which does not include imports, a greater percentage of which is moved by rail, but comparable data is not available.

- *Mileage* - bears directly on transport cost;
- *Product Value* - factor in logistics cost and influences service requirements;
- *Product Density* - affects loading characteristics and thus transport cost;
- *Lane Density* - affects operating cost and service levels, especially in rail; and
- *Equipment* - incorporates multiple characteristics influencing service and cost.

Data that highlights truck-dominated freight, rail-dominated freight, and modally competitive freight is summarized in Tables IV-6 through IV-11. In general, shorter trip lengths with lower lane densities are dominated by trucks, while longer trip lengths with higher lane densities are dominated by rail. Lower value products that must travel longer distances are dominated by rail, whereas higher value products traveling shorter distances are dominated by truck.

TABLE IV-6
FREIGHT MODAL SHIPMENTS
BY DISTANCE AND PRODUCT DENSITY
(thousands of 1994 tons)

HIGHWAY MILES	Product Density: >60 pounds/cu.ft.			Product Density: 36-60 pounds/cu.ft.			Product Density: 1-35 pounds/cu.ft.		
	ALL	TRUCK	RAIL	ALL	TRUCK	RAIL	ALL	TRUCK	RAIL
<100	521,941	502,670	19,271	500,523	340,327	160,195	188,047	170,535	17,512
100-200	211,292	188,139	23,153	395,492	282,498	112,995	150,750	139,894	10,855
201-300	138,868	114,758	22,110	246,030	135,889	110,141	96,872	83,574	13,298
301-500	128,622	104,735	23,887	290,486	133,158	157,327	124,266	103,973	20,294
501-700	73,564	54,966	18,599	139,237	62,136	77,101	86,086	64,739	21,347
701-1000	61,386	38,400	22,986	205,522	55,051	150,470	92,144	63,987	28,157
1001-1500	36,268	16,494	19,774	172,123	45,910	126,213	58,605	40,938	17,667
>1500	26,326	14,656	11,670	46,674	24,608	22,066	53,719	30,951	22,768
TOTAL	1,198,268	1,034,817	161,450	1,996,086	1,079,577	916,509	850,489	698,591	151,899

Source: Reebie Associates

TABLE IV-7
FREIGHT MODAL SHIPMENTS
BY DISTANCE, PRODUCT VALUE, AND PRODUCT DENSITY
TRUCK (shaded columns) and RAIL (in thousands of 1994 tons)

HIGHWAY MILES	VALUE PER POUND										I-MODAL FAK
	<$0.05		$0.05-0.14		$0.15-0.39		$0.40-0.99		$1.00 or more		
	PRODUCT DENSITY: > 60 POUNDS/CUBIC FOOT										
<100	382,626	2,194	55,346	2,112	45,181	10,077	14,855	4,887	4,663	2	
100-200	98,619	10,497	30,829	2,406	41,856	8,511	11,659	1,711	5,186	27	
201-300	65,195	7,034	16,233	2,469	21,550	11,017	7,799	1,533	3,979	58	
301-500	52,589	7,723	17,592	3,141	20,004	9,315	9,256	3,27	3,294	182	
501-700	22,688	4,393	8,761	2,902	11,826	7,743	5,539	3,482	5,781	79	
701-1000	8,017	4,144	6,777	2,555	13,064	10,080	5,905	6,015	4,637	192	
1001-1500	3,653	3,897	2,636	1,324	4,616	8,182	3,547	6,036	2,043	334	
>1500	1,162	935	1,697	875	7,434	5,408	2,665	4,150	1,699	303	
TOTAL	634,549	40,816	139,878	17,782	165,531	70,333	61,615	31,340	13,252	1,178	
	PRODUCT DENSITY: 36-60 POUNDS/CUBIC FOOT										
<100	182,179	146,563	81,041	9,991	43,218	3,330	25,257	179	8,633	133	
100-200	178,288	97,371	45,761	10,647	32,471	4,643	18,648	286	7,330	47	
201-300	70,045	93,546	29,143	10,211	16,385	5,978	13,969	314	6,346	92	
301-500	57,842	128,032	33,232	17,852	15,530	10,317	18,487	667	8,868	460	
501-700	25,080	53,688	10,279	12,580	9,985	9,486	9,771	1,149	7,893	199	
701-1000	14,364	120,777	11,530	13,868	9,836	13,504	11,617	1,838	7,705	484	
1001-1500	14,194	107,126	10,459	10,071	5,007	6,684	8,756	2,098	7,495	234	
>1500	7,636	2,734	2,457	6,623	4,198	4,706	6,208	7,181	4,118	820	
TOTAL	548,754	749,838	223,983	91,842	136,629	58,648	112,713	13,711	57,579	2,469	
	PRODUCT DENSITY: 1-35 POUNDS/CUBIC FOOT										
<100	N/A	N/A	43,295	11,414	18,871	1,721	46,952	2,321	61,416	2,057	222
100-200	N/A	N/A	42,668	5,735	16,672	1,804	35,965	2,365	44,589	952	1,679
201-300	N/A	N/A	24,968	5,053	10,179	2,173	22,583	2,200	25,923	3,872	2,078
301-500	N/A	N/A	23,023	7,903	13,077	2,963	29,453	3,432	38,419	5,996	13,362
501-700	N/A	N/A	11,955	6,527	4,733	2,780	18,511	3,902	29,548	8,138	8,750
701-1000	N/A	N/A	11,856	9,665	2,961	4,138	16,481	5,412	30,690	8,941	18,081
1001-1500	N/A	N/A	8,629	5,547	2,184	3,270	11,155	3,773	18,970	5,077	7,516
>1500	N/A	N/A	3,782	6,403	847	3,573	8,430	4,400	17,893	8,393	38,062
TOTAL	N/A	N/A	170,176	58,246	69,523	22,422	191,449	27,805	267,442	43,425	89,750

Source: Reebie Associates

TABLE IV-8
FREIGHT MODAL SHARES
BY DISTANCE, PRODUCT VALUE, AND PRODUCT DENSITY
TRUCK/RAIL RATIO (shaded cells=competitive)

HIGHWAY MILES	VALUE PER POUND					INTERMODAL FAK
	<$0.05	$0.05-0.14	$0.15-0.39	$0.40-0.99	$1.00 or more	
	PRODUCT DENSITY: > 60 POUNDS/CUBIC FOOT					
<100	99/1	96/4	82/18	75/25	100/0	
100-200	90/10	93/7	83/17	87/13	99/1	
201-300	90/10	87/13	66/34	84/16	99/1	
301-500	87/13	85/15	68/32	72/28	97/3	
501-700	84/16	75/25	60/40	63/37	99/1	
701-1000	66/34	72/27	56/44	50/50	96/4	
1001-1500	48/52	67/33	36/64	37/63	86/14	
>1500	55/45	66/34	58/42	39/61	85/15	
	PRODUCT DENSITY: 36-60 POUNDS/CUBIC FOOT					
<100	55/45	89/11	93/7	99/1	98/2	
100-200	65/35	81/19	87/13	98/2	99/1	
201-300	43/57	74/26	73/27	98/2	99/1	
301-500	31/69	65/35	60/40	97/3	95/5	
501-700	32/68	45/55	51/49	89/11	97/3	
701-1000	11/89	45/55	42/58	86/14	94/6	
1001-1500	12/88	51/49	43/57	81/19	97/3	
>1500	74/26	27/73	47/53	46/54	83/17	
	PRODUCT DENSITY: 1-35 POUNDS/CUBIC FOOT					
<100	N/A	79/21	92/8	95/5	97/3	0%
100-200	N/A	88/12	90/10	94/6	98/2	2%
201-300	N/A	83/17	82/18	91/9	87/13	2%
301-500	N/A	74/26	82/18	90/10	87/13	15%
501-700	N/A	65/35	63/37	83/17	78/22	10%
701-1000	N/A	55/45	42/58	77/23	77/23	20%
1001-1500	N/A	61/39	40/60	75/25	79/21	8%
>1500	N/A	37/63	19/81	66/34	68/32	42%

Source: Reebie Associates

TABLE IV-9
MODAL FREIGHT SHIPMENTS BY DISTANCE, LANE DENSITY, AND EQUIPMENT GROUP
TRUCK/RAIL RATIO (shaded cells =competitive)

HIGHWAY MILES	LANE DENSITY (Thousands of Annual 1994 Tons)				
	<25	25-100	101-500	501-2000	>2000
EQUIPMENT CLASS: BULKS					
<100	86/14	96/4	92/8	92/8	73/27
100-200	97/3	89/11	78/22	78/22	56/44
201-300	94/6	85/15	69/31	59/41	43/57
301-500	92/8	77/23	63/37	57/43	17/83
501-700	81/19	64/36	54/46	47/53	1/99
701-1000	75/25	54/46	50/50	29/71	3/97
1001-1500	72/28	47/53	44/56	19/81	4/96
>1500	61/39	42/58	37/63	50/50	18/82
EQUIPMENT CLASS: DRY VAN					
<100	99/1	99/1	96/4	93/7	95/5
100-200	99/1	96/4	92/8	92/8	92/8
201-300	97/3	92/8	87/13	86/14	85/15
301-500	96/4	87/13	82/18	76/24	72/28
501-700	93/7	82/18	73/27	69/31	28/72
701-1000	90/10	74/26	67/33	52/48	32/68
1001-1500	88/12	71/29	66/34	58/42	29/71
>1500	79/21	64/36	50/50	33/67	9/91
EQUIPMENT CLASS: FLATBED					
<100	100/0	100/0	85/15	84/16	89/11
100-200	97/3	93/7	87/13	84/16	90/10
201-300	97/3	92/8	85/15	81/19	79/21
301-500	96/4	86/14	80/20	83/17	71/29

Source: Reebie Associates Transearch Database

TABLE IV-10
MODAL FREIGHT SHIPMENTS
BY DISTANCE, LANE DENSITY, AND EQUIPMENT GROUP
Truck (shaded columns) and Rail

HIGHWAY MILES	LANE DENSITY (Thousands of Annual 1994 Tons)									
	<25		25-100		101-500		501-2000		>2000	
EQUIPMENT CLASS: BULKS										
<100	20	3	761	34	7,844	699	58,929	4,786	396,436	148,059
100-200	229	8	2,979	366	19,894	5,432	64,158	17,973	107,914	85,071
201-300	990	54	5,142	940	28,796	9,437	30,098	20,552	39,738	79,083
301-500	2,835	248	10,831	3,197	30,678	17,900	38,923	27,775	21,888	105,984
501-700	3,255	759	8,349	4,755	17,135	14,660	14,943	17,159	337	38,844
701-1000	3,854	1,274	6,950	5,838	12,289	12,345	6,637	18,471	3,322	113,848
1001-1500	3,323	1,305	4,418	5,024	6,768	8,879	2,694	11,785	4,633	102,861
>1500	1,948	1,176	2,338	3,219	2,775	4,749	3,079	3,039	956	4,289
Total	16,303	4,826	41,760	23,373	117,342	73,900	217,462	119,540	594,284	677,839
EQUIPMENT CLASS: DRY VAN										
<100	118	1	1,800	14	9,368	350	42,565	3,163	255,432	12,612
100-200	565	7	5,682	236	32,848	2,872	78,116	6,945	108,084	9,022
201-300	1,643	42	10,051	830	36,886	5,243	41,779	6,754	36,089	6,457
301-500	7,875	320	21,361	3,067	55,921	12,476	38,009	12,045	31,867	12,540
501-700	10,449	831	22,486	5,007	38,836	13,995	24,466	11,071	1,641	4,326
701-1000	15,372	1,771	20,352	6,996	31,108	15,278	14,595	13,637	6,568	13,779
1001-1500	13,227	1,844	15,299	6,309	39,443	10,018	18,836	7,887	1,732	4,277
>1500	9,363	2,475	10,922	6,165	12,719	12,686	6,789	13,598	2,478	26,014
Total	57,805	7,291	107,153	28,623	234,721	72,918	257,874	75,101	443,878	89,027
EQUIPMENT CLASS: FLATBED										
<100	16	-	266	1	4,862	719	26,074	4,811	171,752	20,258
100-200	163	5	1,850	135	13,493	2,093	40,626	7,752	96,668	10,328
201-300	466	15	3,847	346	15,958	2,722	23,774	5,711	23,896	6,337
301-500	1,809	81	6,879	1,074	17,617	4,291	19,185	3,842	11,845	4,884
501-700	2,452	220	5,250	1,357	8,531	3,869	5,987	2,676	777	1,753
701-1000	2,821	502	4,881	1,715	5,848	3,449	2,233	3,469	3,828	3,309
1001-1500	2,216	660	2,134	1,648	2,532	2,432	1,189	2,574	167	405
>1500	1,892	912	1,664	1,929	1,694	2,990	1,078	1,832	1,816	1,804
Total	11,833	2,397	25,891	8,204	68,926	22,565	128,867	32,667	309,942	49,077

Source: Reebie Associates

TABLE IV-11
MODAL FREIGHT SHIPMENTS BY DISTANCE, LANE DENSITY, AND EQUIPMENT GROUP

HIGHWAY MILES	TOTAL TONS			DISTRIBUTION BY MILES			TRUCK % ALL
	ALL	TRUCK	RAIL	ALL	TRUCK	RAIL	
	EQUIPMENT CLASS: BULKS						
<100	617,571	463,989	153,582	33%	47%	17%	75%
101-200	302,924	194,074	108,851	16%	20%	12%	64%
201-300	226,730	116,663	110,057	12%	12%	12%	51%
301-500	258,242	103,139	155,104	14%	10%	17%	40%
501-700	119,975	43,998	75,976	6%	4%	8%	37%
701-1000	182,827	33,052	149,775	10%	3%	17%	18%
1001-1500	150,895	21,241	129,654	8%	2%	14%	14%
>1500	27,466	10,995	16,471	1%	1%	2%	40%
TOTAL	1,886,629	987,151	899,479	100%	100%	100%	52%
	EQUIPMENT CLASS: DRY VAN						
<100	324,607	308,467	16,139	24%	28%	6%	95%
101-200	243,578	224,648	19,082	18%	20%	7%	92%
201-300	144,681	125,648	19,327	11%	11%	7%	87%
301-500	194,681	154,233	40,448	14%	14%	15%	79%
501-700	132,308	97,078	35,230	10%	9%	13%	73%
701-1000	139,448	87,988	51,460	10%	8%	19%	63%
1001-1500	90,871	60,535	30,336	7%	6%	11%	67%
>1500	103,122	42,184	60,938	8%	4%	22%	41%
TOTAL	1,373,590	1,100,629	272,960	100%	100%	100%	80%
	EQUIPMENT CLASS: FLATBED						
<100	227,959	202,171	25,788	35%	38%	22%	89%
101-200	173,113	152,800	20,313	27%	28%	18%	88%
201-300	83,065	67,934	15,131	13%	13%	13%	82%
301-500	71,430	57,256	14,173	11%	11%	12%	80%
501-700	32,873	22,998	9,875	5%	4%	9%	70%
701-1000	30,366	17,923	12,444	5%	3%	11%	59%
1001-1500	15,954	8,235	7,718	2%	2%	7%	52%
>1500	16,811	7,343	9,468	3%	1%	8%	44%
TOTAL	651,570	536,659	114,911	100%	100%	100%	82%

Source: Reebie Associates

INSIGHTS FROM THE CORRIDOR AND COMMODITY CASE STUDIES

The TS&W Study includes a number of case studies reflecting selected commodities, regional freight movements, and major traffic corridor movements. The purpose of the case studies is to provide specific insight and first-hand knowledge of how freight is moved and the decision-making considerations by a variety of freight players: shippers, carriers, third parties, and regulators. Table IV-12 highlights insights regarding modal competitiveness or lack of competitiveness from the case studies.

TABLE IV-12
INSIGHTS ON MODAL COMPETITIVENESS FROM CASE STUDIES
(See Chapter 3 for details)

Regional Freight	✓	Along the western United States/Canadian border, trucks dominate freight movements, usually operating above 80,000 pounds gross vehicle weight. These heavier weights are allowed by Canadian laws and the border States' regulations. Common configurations include three-axle tractors with three-axle semitrailers.
	✓	In the eastern states, LCVs are only allowed to operate on a few turnpikes. On these limited routes, LCVs are a small portion of all traffic, but LCV trips tend to be longer than average non-LCV truck trips.
Major Traffic Corridors	✓	Some traffic corridors have good rail-intermodal service, for example the Chicago-Seattle and Chicago-Los Angeles corridor.
	✓	Rail-intermodal has a lower share in other traffic lanes, including Michigan-Florida (Interstate 75 corridor) and Minnesota-New Orleans (Mississippi River corridor).
	✓	Shippers and carriers frequently customize their equipment to take advantage of TS&W limits within their immediate region (including permitted operations).

PERSPECTIVES FROM THE TRUCK SIZE AND WEIGHT STUDY DOCKET COMMENTS

Thousands of comments to the docket were received in response to three separate notices placed in the Federal Register concerning this study. One of the many purposes of a docket is to gather insights and points of view from a variety of sources. The major docket comments on modal competitiveness are summarized in Table IV-13.

TABLE IV-13
PERSPECTIVES ON MODAL COMPETITIVENESS FROM TS&W DOCKET COMMENTS

- ✓ Several organizations, many affiliated with the railroad industry, said that increased TS&W limits would lower truck operating costs, which would thus divert freight traffic from rail to trucks for long haul transport. This diversion would increase the cost of the remaining rail operations which would lead to even further losses of rail shipments and increased rates for captive shippers.
- ✓ Some motor carrier and other industry associations claimed that freight diversion would not occur, and suggest that rail shipments could not possibly decrease, because the rail industry has been extremely competitive (as evidenced by significant improvements in service quality and reliability in recent years). For example, carriers could more easily utilize rail for shipping intermodal containers if trucks were able to legally carry higher container loads for drayage operations.
- ✓ Several industry associations stated that the Federal Government should not be concerned about the diversion of freight from rail to truck--market forces should determine the mode that is best suited for each freight shipment.

RECENT TRENDS IN MODAL COMPETITION

During the past 15 years, there have been tremendous changes in the transportation of freight in the United States. Although all modes of freight transportation have been affected, significant changes have occurred in truck and rail freight transportation. Truck and rail changes have been national and international in nature, with some structural and some operational changes. The consequences of deregulation of the truck, rail, and air transportation industries include: (1) blurring the line between separate types of trucking, such as TL, LTL, and parcel services; (2) reorganization of the rail freight industry with improved financial performance and concentration among the Class 1 railroads, and the proliferation of short rail lines; and (3) the restructuring of air freight systems in favor of integrated operations. Much of the discussion and analysis in the balance of this chapter has been excerpted from a background report and analysis prepared for this CTS&W Study by DRI/McGraw-Hill, including a forecasting model for freight and modal shares. It was prepared in 1996 and has not been updated. It is intended to provide general background on freight trends as of that date.

RAIL INDUSTRY TRENDS

In 1995, Class I railroads turned-in their best performance in recent history. Indeed, excluding grain and coal; the 6.8 percent rise in primary rail tonnage surpassed the rise in manufacturing output (excluding computers and semiconductors). This is a turnaround from the 1980s, when railroads lost modal share in terms of freight tons handled. However, in terms of ton-miles, the railroads had a turnaround in the 1980s and the industry has continued to gain mode share since that time.

Rail freight is projected to post steady gains into the next century; however, there could be varying degrees of growth in the three primary rail sectors--bulk freight, general freight, and intermodal shipments. Moreover, growth should differ according to the railroad class, with non-

Class I railroads enjoying most of the growth. In all, total rail shipments are expected to rise slightly from 16 percent of domestic primary shipments (tons) in 1994 to 16.4 percent in 2000.

The majority (about two-thirds) of rail shipments are bulk commodities. These are expected to grow an average of 2.1 percent annually from 1994 to 2000 (see Table IV-14). In Class I primary tonnage growth through 2000, nonmetallic minerals, coal, petroleum products, and crude petroleum are expected to rank among the lower growth commodities, averaging 0.5-1.5 percent annual gains. Faster growth in manufacturing commodities (e.g., transportation equipment, printed matter, and non-electrical machinery) is projected to spur general freight somewhat faster. General freight, which constitutes a smaller share of rail traffic, is anticipated to grow 2.2 percent per year through 2000.

TABLE IV-14
RAIL SHIPMENTS BY MAJOR COMMODITY GROUPING
(MILLIONS OF TONS)

	1994	2000	Average Annual Growth 1994-2000
Bulk	1,083.6	1,225.7	2.1%
General Freight	530.7	610.7	2.2%
Total	1,614.3	1,836.4	2.2%

Note: Bulk commodities are constituted by STCC 1,8-14, and 29.

Class I railroads, which originate about 75 percent of total volume of rail shipments, are projected to grow 1.8 percent per year between 1994 to 2000. Non-Class I railroads are expected to continue to grow in importance through a focus on specialized niche markets where they are extremely aggressive in marketing their services and capturing freight. Shipments handled by non-Class I railroads are forecast to grow at a significantly higher rate—6.1 percent per year. Non-Class I railroads carry significant volumes of only a few specialized commodities: metallic ores is among the fastest-growing (except for pulp).

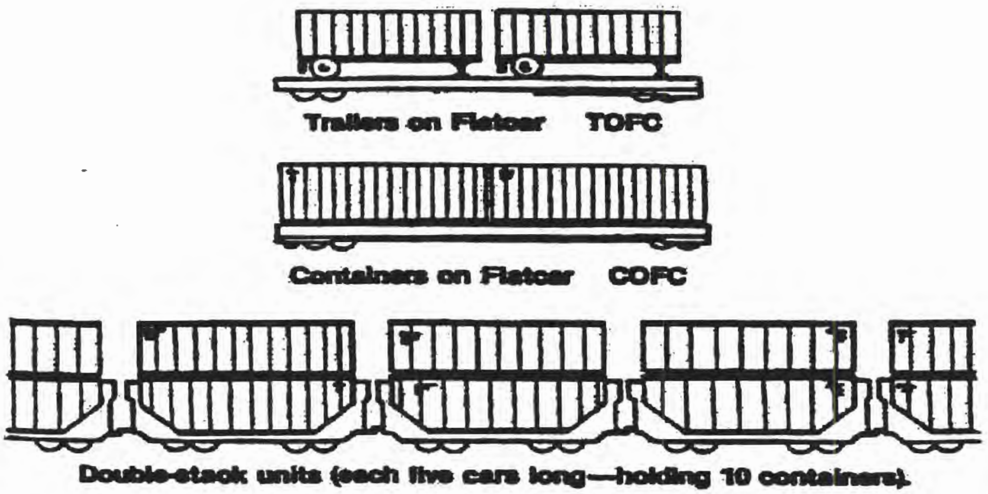
The 1990s are shaping up as a transitional period for railroads—from the traffic losses of the 1980s to rising tonnage and improving industry fundamentals, which should make for stable growth in the future. Furthermore, this is projected to be accomplished with only a slight increase in the size of the rail fleet, as railroads continue to make equipment improvements and productivity gains, holding down rail costs.

The future is, however not certain. Unsettled labor negotiations, competition from other modes, and the difficulty of railroads to achieve a return-on-investment equal to the industry cost of capital are potential risks. On the other hand, the opening up of Mexico, the strong outlook for global trade, faster-than-expected cost and productivity improvements, and strong projected growth in intermodal traffic all argue for a healthy future.

TRENDS IN RAIL INTERMODAL FREIGHT[28]

"Rail intermodal" refers to a broad range of services, the most common being: Trailer-On-Flat-Car (TOFC) commonly referred to as "piggyback", Container-On-Flat-Car (COFC), Double-Stack Train (DST) and carless technologies such as the best known example, RoadRailer.[29] Figure IV-8 illustrates the services noted above.

FIGURE IV-8
RAIL INTERMODAL SERVICES IN USE



Source: Vickerman, Zachary, & Miller

In recent years railroads have responded to the increased emphasis on intermodal and past criticisms that rail intermodal service was slow, difficult to work with, and prone to damage. Establishment of separate intermodal train operations for the movement of traffic on dedicated intermodal trains has improved on-time performance and significantly reduced damage. Railroads

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[28] This discussion illustrates the complexity of forecasting freight shares and the constrained role of TS&W limits in influencing the distribution of freight among modes.

[29] TOFC refers to movement of highway trailers on rail flatcars, COFC refers to containers moving on flatcars without chassis, DST refers to containers moving on equipment that can be loaded with one container placed on top of another in single cars, multiple platform cars or groups of such cars, and carless technologies generally refers to equipment consisting of a highway semi-trailer with attached rail wheels or a separate specially modified rail truck that can be placed on railroad tracks (Source: *Intermodal Freight Transportation*, 1995 previously cited).

have increased the use of automated systems, improving billing and customer service. The use of new types of equipment, such as multiple platform articulated intermodal rail cars, has contributed to reduced loss and damage claims. Consequently, the rail intermodal business has grown rapidly and annual growth rates continue to increase.[30]

Over the next ten years, based on current TS&W limits, strong growth in rail intermodal traffic is projected.[31] Intermodal volume is expected to rise an average 5.5 percent per year, through 2000. Recent years, particularly 1994, saw much higher growth; however, it occurred as a result of several factors that have since reversed; a surge in domestic economic growth, equipment and labor capacity problems in the trucking sector, movement of LTL truck traffic to rail, and strong export traffic to Mexico. Railroads raised some intermodal rates just as significant truck equipment purchases were being delivered to motor carriers. The reduction in cross-border freight volumes resulting from the devaluation of the peso prompted some trucking capacity to re-enter the domestic market. Rail intermodal growth was further dampened by deteriorating service levels, which caused some freight to shift back to truck. Finally, the trucking labor shortage, although somewhat eased during the economic soft landing, is likely to reemerge as economic expansion resumes.

In large part, worries about equipment capacity constraints in rail intermodal have disappeared. Despite the rapid growth in 1994 (up 14 percent from 1993), the increased production by rail equipment manufacturers actually created a surplus of equipment.[32]

Although there are no long-term constraints to growth, short-term local capacity and terminal constraints exist. As a result of mergers, some railroads are not in a financial position to invest in remedying the problem as fast as they would like to. They are being conservative about substantial capital expenditures and are waiting for the traffic before changing investment strategies. In the near future, this will dampen the growth of rail intermodal traffic on routes directly affected by line and terminal constraints.

Table IV-15 presents a forecast for rail intermodal traffic volume, with a breakout of international, TL, LTL, and empty rail car segments of the market. International container traffic is expected to grow at a strong 5.4 percent per year. This growth will sustain the international share of total intermodal, accounting for around half of total intermodal tonnage.

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[30] Summarized from *Intermodal Freight Transportation*, previously cited, page 47.

[31] DRI/McGraw-Hill and Reebie Associates analysis for this CTS&W Study.

[32] The DRI analysis assumes availability of equipment will not be a limiting factor in the growth of rail intermodal during the forecast period.

TABLE IV-15
RAIL INTERMODAL TRAFFIC BY VOLUME
(MILLION OF TONS)

	1994	2000	Annual Growth Projected to 2000
International	59.4	77.3	5.4%
TL	54.6	66.4	4.0%
LTL	7.3	11.2	8.9%
Empty Rail Cars	6.4	7.7	3.7%
Total	127.8	162.6	5.5%

The LTL intermodal freight is forecast to grow by about 9 percent per year. A recent labor agreement allows carriers to send up to 28 percent of their shipments via intermodal. Because most carriers are currently utilizing intermodal traffic to a much smaller degree, the agreements yield significant room for growth in intermodal volumes. Although conservative estimates indicate that carriers will remain below the 28 percent ceiling, an increase is expected. This will raise LTL rail intermodal volumes from 7.3 million tons in 1994 to 11.2 million in 2000. Non-union LTL carriers, especially the regional LTL carriers, were never subject to the ceiling so their use of rail intermodal may go higher.

Use of rail intermodal by TL carriers is forecast to increase an average 4 percent per year. Many of the major TL carriers have already shifted to moving long haul TL shipments via rail intermodal. These TL carriers will not sustain their recent annual increases in rail intermodal that were partially caused by driver shortages and are currently being attenuated by equipment surpluses. Still, the forecasts predict that TL use of rail intermodal will grow faster than the overall TL freight volume.

MOTOR CARRIER INDUSTRY TRENDS

Overall, trucking is expected to continue to experience steady, if moderate, growth during the next decade. Bolstering profits, however, will depend on absorbing excess capacity and shoring up prices. Furthermore, traditional truck industry boundaries are changing, and intra-industry shifts are occurring. Indeed, about 10 percent of private truck tonnage will be transferred to the for-hire truck sector during the forecast period.

Trucking remains by far the largest freight transportation mode, carrying two-thirds of the tonnage for all primary goods shipments. The importance of trucking is magnified even further when intermodal traffic, ground package, and air freight—a significant percentage of air freight actually travels by truck—are included.

The analysis below presents projections for truck freight through 2000 with separate forecasts for the private and for-hire segments[33]. Due to data availability, this discussion will emphasize primary manufactured goods shipments. Nonetheless, these findings should assist in the analysis of modal market shares. In addition, industry dynamics, equipment sales, revenue, and costs are discussed.

THE RECENT PAST

From 1993 and 1994 (the last available data), rapid growth in motor carriers occurred primarily in the area of manufactured shipments. It climbed 6.2 percent in 1993, to 2,558 million tons. In 1994, a 5.2 percent rise in manufactured goods output (its best gain since 1987) propelled truck tonnage a further 6 percent.[34] Tonnage reached a strong 2,712 million tons, the result was total for-hire and overall trucking volumes rose. All told, TL traffic climbed almost 9 percent in 1994 and saw its share of total traffic rise 2.5 percent. In contrast, LTL carriers managed a below-average 4.5 percent increase and a 1.4 percent drop in their market share.

At the time of this report historical trucking activity data were not available for 1995. Nevertheless, it is clear that the industry was beset by slower growth in end-markets, excess capacity, and rate discounting. As the economic soft-landing took hold in the spring, last year saw more trucks chasing fewer shipments. A record 201,000 Class 8 trucks (with a gross vehicle weight rating above 33,000 pounds) were purchased in 1995. Meanwhile, for-hire volumes shrank, despite beginning the year with double-digit gains. Since proposed rate hikes could not be enforced, prices and revenues tumbled. This was particularly true in the LTL sector, though weakness was not confined to it. TL carriers, which had managed steady growth throughout 1994, saw revenue and prices plateau in the first few months of 1995, and then fall. Producer price index (PPI) growth for LTL general freight steadily declined, while the TL PPI stabilized at 2 percent. For 1995 as a whole, LTL PPI slid, from its 3.6 percent run up in 1994, to 2.0 percent. TL rates actually accelerated from a 1.0 percent gain in 1994 to a 2.6 percent rise in 1995.

THE FUTURE

Transportation of freight for United States manufacturers, construction firms, and mining businesses is highly sensitive to the business cycle in the United States. The long-term trend forecast commissioned for this study[35] assumes gains consistent with the economy's "trend" rate of growth. Thus, the forecasts do not fully reflect peaks or troughs. The forecast captures long-run trends affecting truck volumes. Truck tonnage should be consistent with these long-run factors. The freight transportation outlook is for potential growth in the freight market. The United States economy is not expected to match its robust 1994-1995 pace over the next ten years. Instead, real GDP growth should downshift into its 2.5 percent trend rate. This steady,

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[33] This is based on the DRI model.

[34] It is noted that the truck gain surpassed the rise in manufactured output.

[35] DRI and Reebie Associates analysis.

albeit less spectacular, overall growth is forecast to permit trucking volumes to post a 1.4 percent average annual gain through 2000. This compares with the forecast of 1.6 percent anticipated growth in manufactured goods shipments by railroads.

Along with potential market growth, truck shipments will be shaped by their composition. Primary general freight shipments make up around half of total movements. Six sectors—food, lumber, paper, chemicals, petroleum, and stone, clay and glass—comprise more than 80 percent of all manufactured shipments. Indeed, these six commodities determine overall freight growth. In combination, they are expected to post average annual growth of only 1.3 percent over the forecast period, placing them among the low-growth performers. Only one of the six components, chemicals, will experience high growth during the next ten years. The relatively slow pace of growth in most shipment categories will constrain the growth of total shipments.

Food, the second-largest truck commodity, is expected to post an average annual gain of less than 1 percent over the forecast period. Last year, the trucking industry transported about 520 million tons of food products. This represented 20 percent of total general freight shipments. About one-half of the food movements are made by private carriers that retain their own fleets for transporting merchandise. Typically, food demand is determined by domestic population growth and export prospects. Over the forecast interval, real United States food exports are expected to rise an average 2.0 percent annually (in billions of 1987 dollars), below their pace of the past decade. Moreover, domestic demographics will limit gains in this category to only 0.9 percent a year. Excluding chemicals, the high-growth sectors are forecast to be rubber, machinery, and transportation equipment. They constitute only about 4 percent of total manufactured shipments, limiting their ability to boost overall growth.

Trucking industry advances are forecasted to be in line with those of their rail counterparts. Trucks and railroads do not compete head-to-head for each commodity. Typically, trucks have a higher concentration of high-value items. The rise of truck/rail joint ventures and the use of new intermodal technology has changed the playing field. In many areas, truck and rail traffic can grow in unison, taking advantage of new opportunities in a dynamic marketplace.

SHIFTS

New means of transport are not limited to inter-industry changes; intra-industry shifts are also underway. During the past several years, the trend among manufacturers to out source distribution and logistics functions has resulted in a decline in private carrier tonnage and a rise in for-hire tonnage. Companies are placing greater emphasis on their core businesses and paring costs. This trend toward a few "core" for-hire carriers is projected to accelerate over the next ten years. The shift will be particularly noticeable in the food, primary metals, and transportation equipment markets, which currently have a high concentration of private tonnage.

EQUIPMENT, REVENUE, AND COSTS

The trucking industry should be well-equipped to handle the modest pace of freight gains. The 1995 heavy truck sales figure of 201,000 units was a record high. Indeed, as mentioned, these equipment purchases gave rise to excess capacity. As the economic soft landing took hold and over-supply became apparent, orders and sales softened. Indeed, the forecast is that heavy truck sales have peaked. Although sharp, this drop would be in line with prior downturns. Thereafter, sales should stabilize at about 169,000 vehicles per year.

Two important areas influencing the bottom line should be emphasized: fuel and labor costs. The trucking industry uses almost 17 percent of the petroleum consumed in the United States[36]. Also, many industry experts agree that the shortage of drivers is a major risk facing the industry. Although somewhat offset during the economic slowdown, the shortage is likely to reemerge during economic growth. To help ease the shortage, some motor carriers are operating driver training schools. But finding and training drivers is only half the battle; driver retention is also necessary for motor carriers. Relatively low salaries and few benefits encourage veteran long-haul drivers to leave. To combat this, companies commonly attempt to arrange routes to ensure that drivers are able to return home frequently. While reducing driver turnover is necessary for the long-term health of the industry, it also affects costs, profits, and competitiveness.

SUMMARY

There is growing evidence that the productivity improvement of U.S. businesses through reduced logistics cost will continue. The reduced logistics costs are realized through reductions in inventories, reduced interest rates, lower transportation costs, and warehousing costs. Reduced inventory and warehousing costs are attributed to better logistics management and transportation services, which allow reduced stock levels and stocking points, warehouses and distribution centers.

Carriers will need to continue being responsive to shipper requirements. They will need to provide more value-added services and cooperate more with other modes to meet shipper demands for reduced warehousing costs and enhanced service reliability with reduced rates for freight traffic.

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[36] Bureau of Transportation Statistics, *1996 National Transportation Statistics*

CHAPTER 5

SAFETY AND TRAFFIC OPERATIONS

INTRODUCTION

Many factors influence truck safety. Driver performance, roadway design and condition, weather, and vehicle performance directly affects the ability to safely complete a trip. Motor carrier regulations and enforcement affect safety by determining conditions within which drivers and vehicles operate. Within this broad context, however, truck size and weights (TS&W) also directly affects truck safety and traffic congestion, especially in major metropolitan areas. TS&W limits directly impact motor carrers' choices as to the type and configuration of vehicles they operate, as well as the network of roads on which the vehicles are operated. These choices, in turn, determine truck travel patterns and the control and stability properties of the vehicles operated.

There is a shortage of data directly correlating TS&W with the type, frequency, and casualties of roadway crashes. However, available evidence does point to a number of trends relevant to truck safety. Numerous analyses of crash data bases have noted that truck travel on lower performance roads, (e.g., undivided, higher speed-limit roads with numerous intersections and entrances), significantly increases crash risks compared to travel on Interstates and other higher quality roads. Higher traffic densities, which are common in urban and populous areas, exacerbate this problem. The majority of fatal crashes involving trucks occur on non-Interstate, U.S. and State routes, many of which are undivided and have high posted speed limits. For this reason, review of potential TS&W changes should especially focus on truck travel patterns and truck performance capabilities in terms of use on roads of this type.

Further, numerous vehicle performance tests and engineering analyses have frequently highlighted significant differences in the stability and control properties of different sizes and configurations of trucks. Some larger and heavier trucks are more prone to roll over than other, smaller trucks; some are less capable of successfully avoiding an unforeseen obstacle, when traveling at highway speeds; some negotiate tight turns and exit ramps better than others; and some can be stably stopped in shorter distances than others; some climb hills and maneuver in traffic better than others. The effects of these differences on crash likelihoods are subtle, but become more evident when traffic conflict opportunities increase. Some of these concerns can be addressed through judicious designs. Others can only be addressed by matching and restricting use to certain roadways and traffic density conditions. Attention to these inherent properties of trucks is critical when TS&W options are being considered.

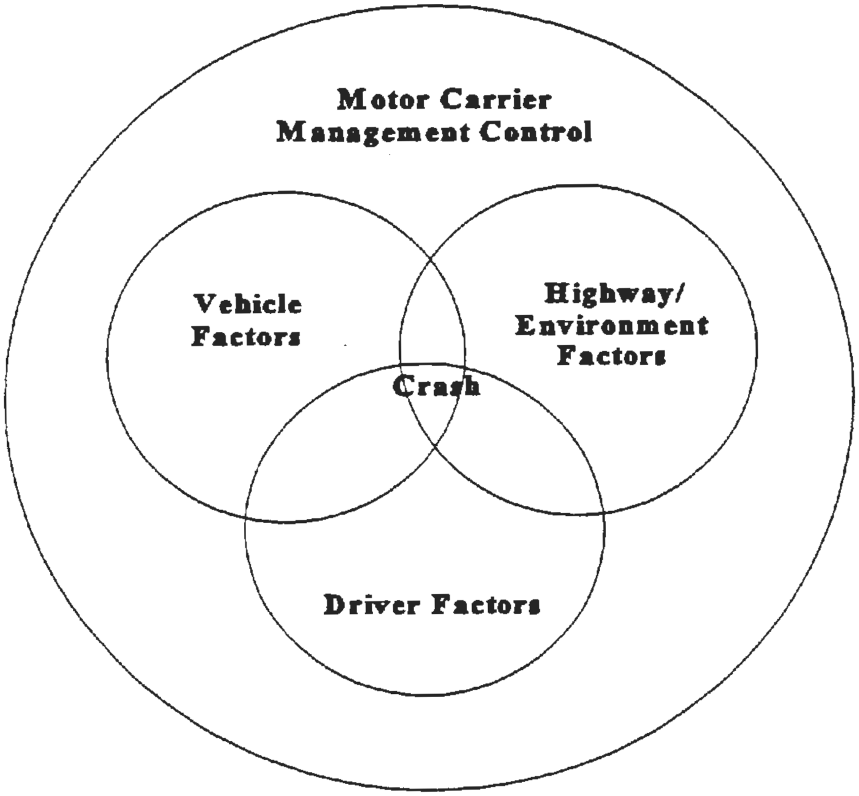
Moreover, notwithstanding any technical and analytical considerations, public perceptions of truck safety, and especially the safety of larger trucks, is uniformly negative. Public opinions on this issue are strongly held and must be heavily weighed when considering TS&W policies.

The following sections provide: additional details about the general causes of truck crashes and the role TS&W plays; more information about the public's and truck drivers' attitudes and opinions relative to large trucks; a summary of the key findings of crash data analyses, and; a summary discussion of the role that the design and performance properties of larger trucks plays in crash causation.

TRUCK CRASH CAUSATION FACTORS

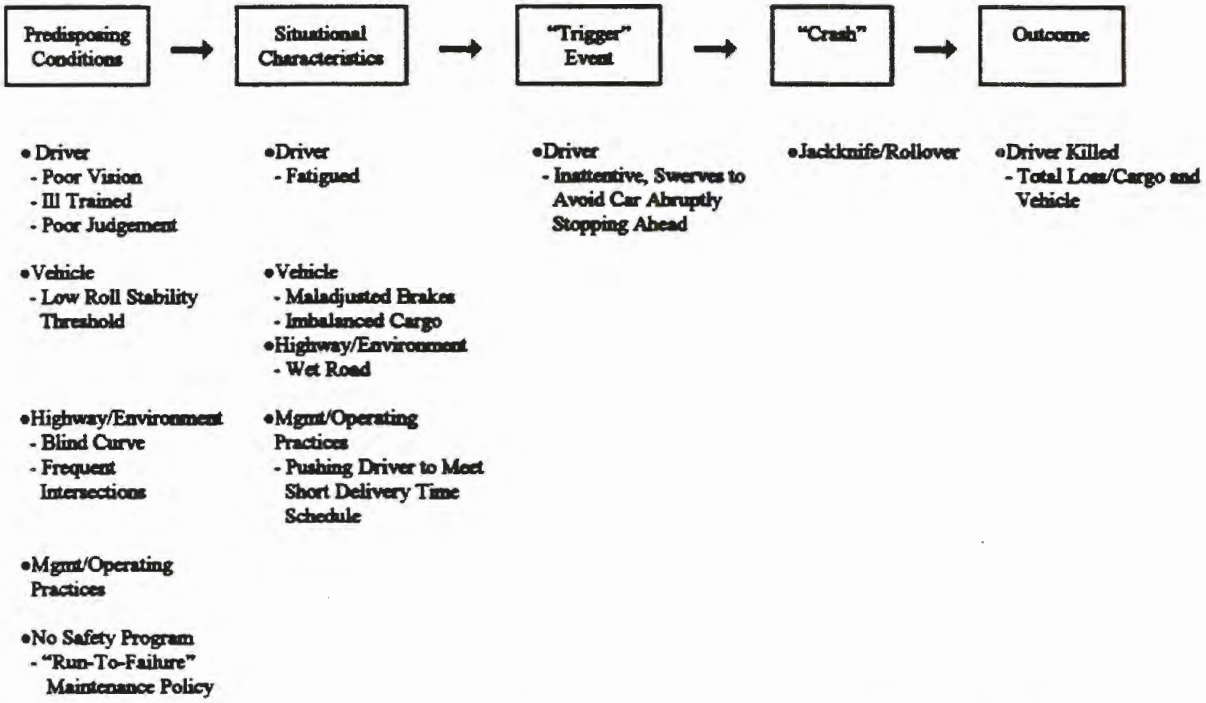
Variables influencing overall crash risk may be grouped into three broad categories: truck equipment, driver performance, operating environment (for example, roadway and weather conditions). Figure V-1 illustrates the complex interrelationship of these variables as they contribute to truck crashes. Almost every crash is initiated by some type of human error, typically a lapse of attention or a misjudgement of situational conditions. For this reason, driver behavior/ performance is overwhelming cited as the principal "cause" of crashes. Equipment considerations including vehicle size and weight as well as mechanical or operational failures play a role smaller than other factors and are very difficult to isolate in terms of crash causation. As the figure indicates, however, other operating environment and vehicle-related factors can diminish safety either by predisposing drivers to commit errors, or by preventing them from compensating or recovering from errors they commit. For these reasons it is important to address all the contributing factors to crashes.

FIGURE V-1
INTERRELATIONSHIP OF CONTRIBUTORY TRUCK CRASH FACTORS



Another way of looking at the relationship of the these various factors is to examine a hypothetical "crash causation chain" (see Figure V-2). The chain begins with predisposing conditions, these combine with situational characteristics to create an opportunity for a crash. In other words a set of factors either predispose or enable a crash to occur.

FIGURE V-2
HEAVY TRUCK CRASH CAUSATION "CHAIN"



Source: "Heavy Truck Safety Study," U.S. Department of Transportation (HS 807 109), March, 1987

CONTRIBUTORY FACTORS

TRUCK EQUIPMENT

Truck equipment issues include physical characteristics, such as the number of trailers, trailer length, and weight capacity; the dynamic performance of the vehicle under varying load conditions[1]; and other mechanical systems such as brakes and engine characteristics.

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[1] Includes steady-state roll stability, rearward amplification and load transfer ratio. These concepts are defined in a subsequent section.

The braking capability of combination trucks is a particularly important safety issue. Braking capability relates to achieving a safe stopping distance and maintaining vehicle control and stability during braking and is influenced by a number of factors, weight and size being one. Additionally, rollover propensity, the ability to negotiate turns and maneuver in traffic, and the ability to successfully maneuver when confronted with a potential crash threat are other performance concerns that warrant close attention. This issue is discussed in depth in a subsequent section.

DRIVERS

Driver performance issues, among other things, include skill level, experience, and fatigue. These are critical, regardless of the type or size of truck being driven. In the context of truck safety, the driver may be the most important element of the truck-driver-road-environment relationship. Driver experience and training have an effect on truck crash rates, and the drivers themselves report that inexperience is a significant contributory factor to loss-of-control crashes.

The FHWA Office of Motor Carriers recently sponsored[2] a study to investigate whether longer combination vehicles (LCVs), with their increased length, greater weight, and greater number of trailers, could significantly increase the amount of fatigue and stress experienced by the truck driver. Data were collected from 24 experienced LCV drivers, operating in a controlled test but under representative daytime driving schedules, on limited access highways. After a day of orientation and training, drivers operated three types of combination vehicles for two days each over a 6-day period: a single-trailer (48-foot trailer) combination, a triple-trailer combination equipped with standard A-dollies and a triple-trailer combination equipped with self-steering double-drawbar C-dollies.

Preliminary findings suggest that the most significant contribution to a given driver becoming fatigued were the characteristics of the individual driver, the number of hours since the last rest period, and the number of consecutive days of work. Trailer configuration type did contribute to changes in driver performance but these effects were small compared to the principal causative effects. The patterns in driving performance (specifically, lane-tracking) and in fatigue/ physiological recovery and subjective workload generally showed that drivers had the best performance when driving the single-trailer combination; next best was the triple with C-dollies, and poorest performance was with the triple combination with A-dollies.

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[2] The final report is expected to be completed by the summer of 1997.

OPERATING ENVIRONMENT

Environmental issues primarily include adverse weather, visibility conditions and roadway geometry and congestion. The environment also includes factors such as road class, region of the country, road condition and state of maintenance, and the presence or absence of traffic signals, intersections, guardrails and other barriers, and warning signs. For example, it has been observed that crash rates vary significantly by road class because of design characteristics.

ROADWAY GEOMETRY AND CONGESTION

Roadway geometry refers to the physical structures where trucks operate including road type, grades, and intersections, as well as the interaction of trucks with other users of the roadway and infrastructure. Longer and heavier trucks must contend with intersections, entrance/exit ramps, and highway grades with design elements that may not be suitable for current or alternative sizes, weights or configurations.

The interaction of truck design features with roadway geometry properties and visibility is accentuated as traffic volume increases. There is also a growing recognition that traffic congestion and driver behavior may be related--that congestion may cause more aggressive driving behavior.

ADVERSE WEATHER

Inclement weather, such as rain, sleet, snow and ice, creates road conditions that challenge the stability and control of vehicles during turning and braking maneuvers.

Visibility is a function of weather as well as time of day. Dawn, dusk and night place increased operating demands on the driver to safely control the vehicle. Crash profiles illustrated in Table V-1 show that approximately 35 percent of fatal crashes and about 26 percent of non-fatal crashes occur in visibility conditions other than normal daylight.

TABLE V-1
LARGE TRUCK OR BUS CRASHES (IN PERCENT)
BY WEATHER, ROAD SURFACE, AND LIGHT CONDITIONS

Weather Conditions	Fatal	Non-Fatal	Road Surface Conditions	Fatal	Non-Fatal	Light Conditions	Fatal	Non-Fatal
No Adverse Conditions	84.6	70.1	Dry	79.2	72.8	Daylight	64.3	73.7
Rain	9.5	17.0	Wet	15.1	11.4	Dark	22.7	14.5
Sleet	0.6	5.2	Snow/Slush	2.4	1.4	Dark/Lighted	8.9	7.3
Snow	2.6	6.0	Ice	2.8	5.7	Dawn	2.7	2.4
Fog	2.0	0.2	Sand, Oil, or Dirt	0.1	1.5	Dusk	1.4	1.4

A recent study[3] of truck crash rates reported that 53 percent of the crashes--and 51 percent of the VMT--occurred at night. Noted in the study were modest differences between daytime and nighttime crash rates, with the nighttime rate being marginally higher.

INTERACTION OF CONTRIBUTORY FACTORS

Clearly these variables, and their contribution to truck crashes, are not entirely separable. Further, crash data records do not typically delineate cause in terms of the three categories. Also, the boundary between environmental and roadway conditions is not always clear, since one may influence the other.

The driver is critical in initiating or preventing a crash. Experienced drivers can compensate, to some extent, for strenuous driving conditions or can overcome difficulties associated with vehicles that have inferior handling and stability properties, but with increased effort. On the other hand, inexperienced or unsafe drivers will be even more prone to incident involvement if the vehicles they are operating have inferior handling and stability characteristics. Further, fatigue, inattention, drug or alcohol impairment or traveling at excessive speeds--factors frequently cited as primary in contributing to incidents--exacerbate these concerns.

Figure V-3 illustrates the driver-truck equipment performance-operating environment demands relationship. Simply stated, as the operating environment performance demands (roadway, traffic and weather conditions) increase, driver-truck equipment performance must also increase to neutralize incident impacts.

FIGURE V-3
ILLUSTRATIVE RELATIONSHIP BETWEEN THE DRIVER/TRUCK EQUIPMENT PERFORMANCE AND OPERATING ENVIRONMENT DEMANDS

Driver/Truck Equipment Performance	Operating Environment Demands: Low	Operating Environment Demands: High
High	Low Crash Probability High performance Low demands	Moderate Crash Probability High performance High demands
Low	Moderate Crash Probability Low performance Low demands	High Crash Probability Low performance High demands

Source: Heavy Truck Safety Study, DOT HS 807 109, March 1987

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[3] Accident Rates for Longer Combination Vehicles, FHWA-MC-97-03, October 1996.

For example, perhaps the most prominent impact of environmental variables are the additional driver and equipment performance demands required for safe vehicle operation. As indicated earlier, conditions of poor visibility result in increased operating demands on the truck driver to safely control the vehicle. Sight distance, decision distances, and the time available for corrective or evasive action all are reduced resulting in a need for closer control of the vehicle.

MOTOR CARRIER SAFETY OBSERVATIONS

This section presents an overview of driver perceptions, both of automobiles and trucks.

DRIVER PERCEPTIONS

DATA COLLECTION APPROACH: FOCUS GROUPS

In 1996, as part of this CTS&W Study, FHWA held twelve focus group meetings to research the perceptions, concerns and reactions of the auto driving public and of over-the-road truck drivers[4] to operations in mixed auto and truck traffic. The focus group discussions were intended to generate an in-depth understanding of safety practices, experiences and perceptions among auto and truck drivers and to explore and assess how these groups are likely to react to possible changes in TS&W limits.

AUTO DRIVER CONCERNS

Auto drivers reported that they constantly worry about their safety when they are on the highway and perceive the greatest threat to come from other auto drivers--people who are impatient, aggressive, reckless, intoxicated or simply inattentive. But they also consistently cited large commercial trucks among their top three or four highway safety concerns.

Truck Size and Weight

Many auto drivers indicated that they feel outmatched by the size and weight of large commercial trucks. They indicated having seen or experienced dangerous and frightening interactions with large trucks on the highway, as well as news media reports of fatal truck crashes that stuck in their minds and reinforced their safety concerns.

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[4] FHWA Focus Groups with Auto Drivers and Truck Drivers on Size and Weight Issues, Draft Final Report, Apogee Research, Inc., February 24, 1997.

Sharing the Road

Many of the focus group participants believed that truckers drive too fast, too far and for too many hours to be safe. Truck speed and driver fatigue were among the greatest sources of auto driver concern. When the focus group participants see or hear examples of truck crash or unsafe driving by truck drivers, they begin to worry about the type of person behind the wheel. Motorists tended to attribute the truck safety problem to two sources--drivers with bad attitudes and/or economic forces in the trucking industry that place too much pressure on drivers and inadvertently create incentives for cutting corners and rewarding unsafe practices.

Road Conditions

Also cited as factors for concern were increased traffic congestion, bad weather and the mixing of truck and auto traffic under congested or inclement conditions.

Changes to Truck Size and Weight Limits

The vast majority of participants said they preferred the status quo on Federal TS&W standards, and a return to greater restrictions if any changes were actually made. At the same time, motorists-suggested that it made little difference whether truck weights were increased or decreased because in either case they were not likely to survive a collision with a truck.

Participants said they were opposed to allowing longer trucks and trailers because they perceive longer trucks to be less safe and harder to see or maneuver around. They commented that truck length is visible and therefore they can observe its impact on safety. With respect to LCVs, many participants said that they would not believe that doubles or triples can be operated safely. Others said doubles and triples should be used, but only under very strict limits and conditions.

Finally, the respondent auto drivers doubted they would realize any economic benefits from increased truck dimensions and felt that policy decisions would be based on narrow political or economic pressures and would undermine highway safety. Further, they indicated that they saw little evidence to suggest that current regulations were being adequately enforced, noting that they rarely saw trucks being inspected or pulled over for speeding.

TRUCK DRIVER CONCERNS

The truck drivers who participated in the focus groups generally felt that their jobs were potentially dangerous and required that they be ever vigilant against external threats to their safety.

Truck Size and Weight

Weight was considered a key variable in truck safety; it was seen as determining a driver's ability to maintain control under different conditions. However, according to the driver, a heavier truck is not necessarily a less safe truck. Trailers were reported as being too long for many city streets, and even some ramps and access roads along interstate highways.

They felt that experienced, responsible drivers are safely operating heavy trucks, but safe operation may be threatened by shippers, dispatchers and companies that tend not to allow sufficient time for deliveries. Economics was seen as the most fundamental determinant of truck safety because it is such a dominant factor in influencing driving conditions--truck weight, speed, fatigue, driver experience.

Sharing the Road

The truck drivers reported that automobile drivers are their biggest complaint. They indicated that, from their perspective, auto drivers are increasingly unpredictable. Further, increased traffic and traffic congestion have made potential safety problems worse, particularly around urban areas. The truck drivers indicated that better driver education--for automobile drivers--might improve the situation.

Road Conditions

Truck drivers perceive that traffic congestion is getting worse. They also perceive that the highways are less able to accommodate their larger, heavier trucks, creating more potential hazards. Road design, highway conditions and construction practices were seen as challenging maneuverability and safe operations.

Truck Driver Experience and Training

Truck drivers place a high premium on skill and experience. This makes veteran truck drivers leery of new drivers who they feel are being rushed through training which more experienced drivers perceive to be inadequate because it focuses on preparing them to obtain a Commercial Driver's License (CDL), not necessarily to be a safer driver.

Changes to Current TS&W Limits

The drivers said with considerable pride that they could operate anything and indicated confidence that they could handle any increase in TS&W that might occur. However, they were skeptical about the need or desirability of allowing longer or heavier trucks on the highways, and said that maintaining safety would require changes in highway conditions, training, equipment and economic incentives. They were skeptical that the necessary changes would be implemented.

Truck drivers generally opposed changing the TS&W standards. The majority prefer to maintain the status quo or return to a more restrictive set of standards, particularly if the latter would make the rules more uniform from State to State. Keeping up with the different and even contradictory rules was reported as a time-consuming distraction. Further, nonuniformity was reported as adding to stress, fatigue and costs. They also reported that, to ensure highway safety, special restrictions should be required in LCV operations.

If the regulations were made less restrictive the drivers said more skill, experience, effort and time would be required to maintain safety on the highway. The drivers were doubtful that these requirements would be met given the problems they previously cited.

SUMMARY

Automobile, and for that matter, truck drivers clearly have strongly held views about truck safety and larger truck safety and larger trucks. These concerns must be weighted heavily when considering TS&W policies.

CRASH DATA ANALYSES

Differentiating the crash involvement patterns of small subgroup populations of vehicles is problematic. Equally confounding is the effect of the interrelated variables previously discussed, which makes isolating crash rates as a function of TS&W variables a difficult task. The effects, attributable to truck size, weight or configuration, must be isolated from the impact of the driver, other equipment and environmental factors before definitive conclusions can be reached.

Crash data currently available are capable of ascertaining trends in overall truck safety, but are less capable of clearly differentiating trends by vehicle characteristics. Nonetheless, broad distinctions among vehicle types have been noted.

TRUCK-INVOLVED ACCIDENT RATES

Most recently, and illustrative of others that have been completed in the past, is a study of truck crashes in Michigan[5] which isolated differences between crash rates for singles and doubles (all doubles, not just LCVs) in terms of some key variables, such as day versus night, urban versus rural, and limited access versus other roadway types.

That study found that, based on police-reported accidents, singles and doubles have similar accident experience in terms of overall safety performance, but that other differences were apparent when the overall rates were disaggregated by road class, time of day and area type. Doubles had a statistically significant difference in casualty accident rates on lower road types. For doubles, the rate was 5.85; for singles, it was 3.72 accidents per million vehicle miles. Accidents involving doubles on lower type roads also were more likely to result in injury or death.

Differences were also found between rural and urban areas. When all accidents were considered, doubles performed better than singles in both urban and rural areas; but when only casualty accidents were considered, the doubles had similar rates in rural areas but slightly higher rates in urban areas. This was consistent with the usage pattern for doubles, which travel more on the safer limited-access roadways. Similarly for accidents occurring in the daytime versus nighttime, overall rates were lower for doubles than for singles, but for casualty accidents, the doubles had a worse rate during the day.

Doubles rates were higher than singles rates in some specific situations such as one-vehicle involvements on rural limited-access highways during the day, multi-vehicle involvements on rural major roadways during the day, and urban limited-access roadways during the day. The higher one-vehicle crash rate is primarily due to rollover crashes, a crash type for which, the author notes, doubles are well known.

SEVERITY OF TRUCK-INVOLVED CRASHES

Crash severity is generally measured in terms of whether the crash results in property damage only, injuries, or fatalities. Four factors influence the severity of an crash involving cars and trucks: the type of collision that occurs, the relative size and weight of the vehicles, the change in velocity of the car, and the type of truck involved in the collision.

Relationship of Truck Size and Weight to Crash Severity

Safety risk is significantly increased if truck traffic increases in operating environments with a higher risk of truck-car collisions, for example, undivided highways as compared to divided highways. Head-on traffic conflicts naturally create opportunities for higher closing velocities

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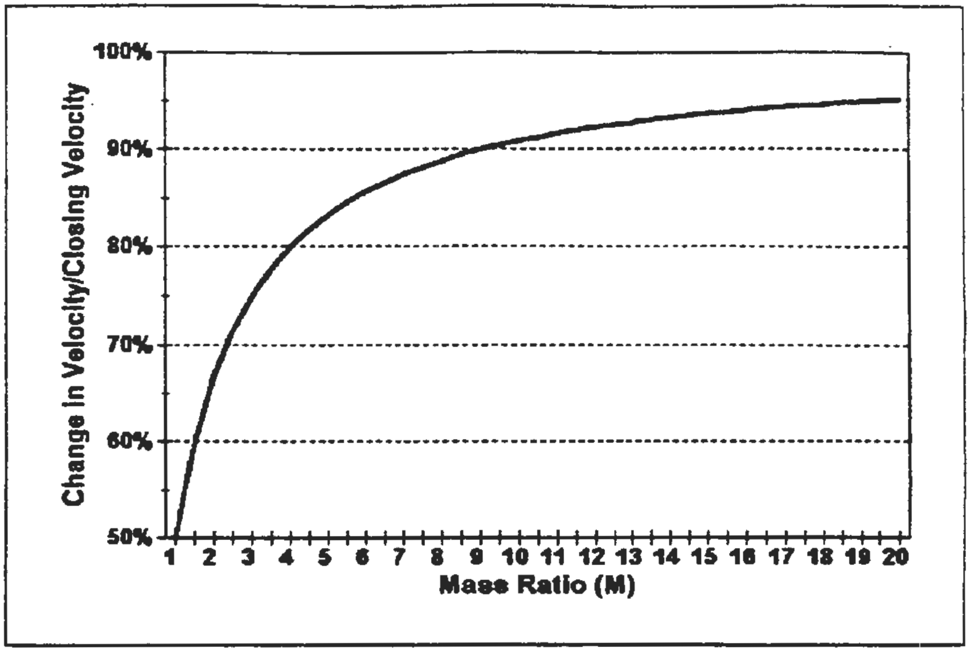
[5] Differential Truck Accident Rates for Michigan," Richard D. Lyles, Kenneth L. Campbell, Daniel F. Blower, and Polichrous Stamatiadis, Transportation Research Record 1322, Transportation Research Board, National Academy of Sciences, Washington, D.C., 1991.

(essentially the sum of the two vehicles' speeds) that result in higher changes in velocity for the automobile involved in the conflict. Divided highways are particularly effective for truck traffic because the near elimination of head-on collisions also reduces the number of car-truck collisions by about a factor of two.

When two vehicles collide, the speed at which they collide, the mass ratio of the two vehicles, and the vehicular orientation in the collision are the primary determinants of whether a fatality results. The effect of the difference in size between the two vehicles is large. For car-truck collisions, in comparison to car-car collisions, the effect of the difference in weight between the two vehicles increases the probability that fatalities which occur will be sustained by the occupant of the car. For car-truck collisions, the problem is also aggravated by vehicle geometric and structural stiffness mismatches. The relative closing speed at impact is the single largest predictor of the likelihood that a given crash will have a fatal outcome.

Figure V-4 illustrates the relationship between the difference in size between two vehicles involved in collision (mass ratio) and the relative change in velocity sustained by the smaller of the two vehicles. It assumes an impact between two vehicles of different mass traveling in opposite directions. The vertical axis is the change in velocity of the small vehicle as a fraction of the initial closing velocity of the two vehicles. The mass ratio, simply the weight of the larger vehicle divided by the weight of the smaller vehicle, is shown along the horizontal axis. As the mass ratio increases, the change in velocity as a fraction of the closing velocity, quickly rises to exceed 90 percent at a mass ratio of nine. The graph indicates that at mass ratio differences much above 10 to 1, the smaller of the two vehicles sustains virtually all the change of velocity resulting from the collision, while the larger of the two vehicles sustains little or no change in velocity. At the current 80,000 GVW limit, mass ratio differences between cars and trucks are already on the order of 25 to 1 or higher.

FIGURE V-4
MASS RATIO CHART



The significance of the change in velocity becomes more apparent as it is related to fatality rates in car-truck crashes. The fatality data[6] shown in Figure V-5 indicates the likelihood of a fatality as a function of the change in velocity of the vehicle. These data were compiled from over 19,000 crashes between cars and trucks. As can be seen in the Figure, the data are approximated by an exponential curve that estimates 100 percent fatalities for changes of velocity that exceed approximately 65 miles per hour. These data demonstrate why, when a car and a heavy truck are involved in a head-on collision at typical open highway operating speeds (e.g., above 45 miles-per-hour), car occupants are highly likely to be fatally injured.

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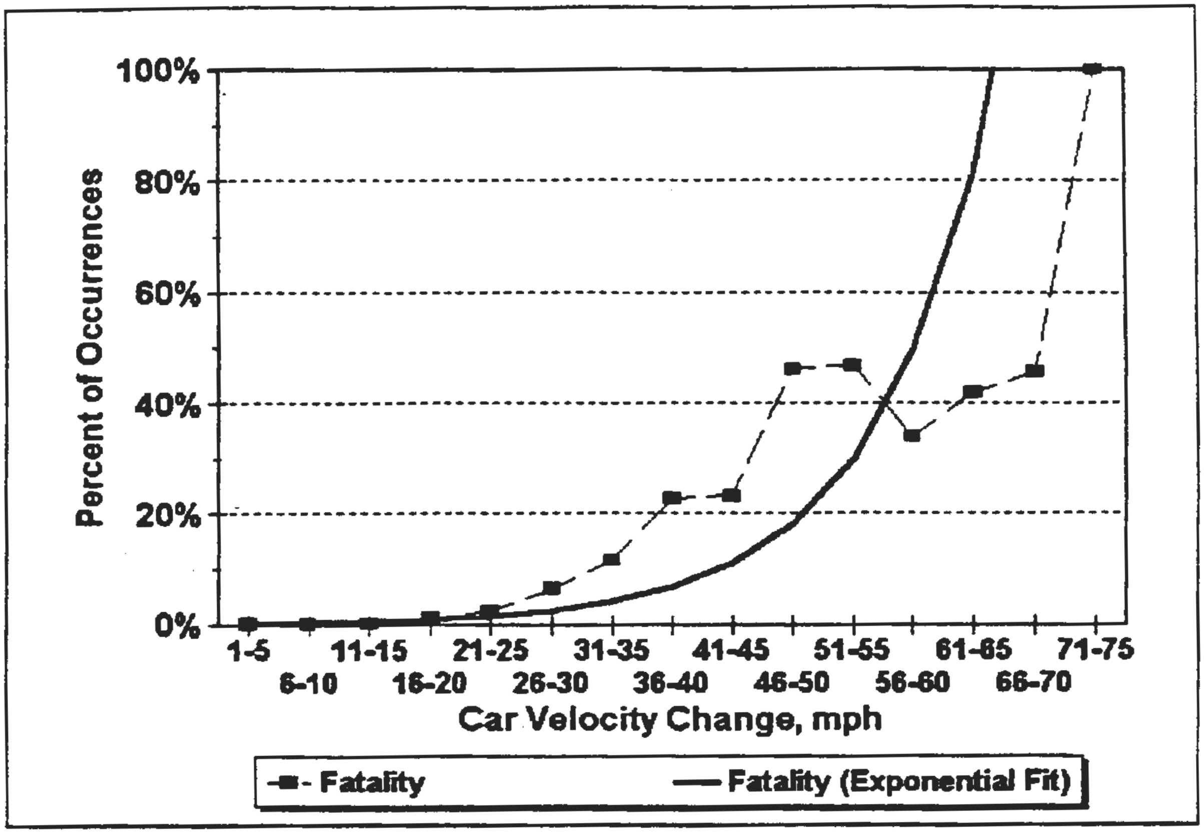
[6] "Large Trucks in Urban Areas: A Safety Problem?", James O'Day and Lidia P. Kostyniuk, Journal of Transportation Engineering, 111, 303, (1985).

FIGURE V-5
CHANCE OF FATALITY AS A FUNCTION OF CHANGE IN VELOCITY



Relationship of Crash Severity to Truck Configuration

An earlier study[7] (results shown in Table V-2) compared the overall distribution of crash outcomes (fatality, injury, or property damage only) between trucks with single trailers versus trucks with double trailers for both local and intercity trips. Distinctions were not made relative to the travel patterns of the two vehicle types. Crashes involving trucks with double trailers were more likely to result in a fatality, and more so for local trips than intercity trips.

TABLE V-2
DISTRIBUTION OF CRASH OUTCOMES BY TRIP TYPE FOR TRUCKS WITH SINGLE AND DOUBLE TRAILERS (IN PERCENT)

Trip Type	Single Trailer			Double Trailer		
	Fatal	Injury	Property Damage	Fatal	Injury	Property Damage
Local	3.13	73.51	23.35	11.11	48.15	40.74
Intercity	7.52	60.35	32.13	8.60	51.55	39.86
Total*	7.32	61.46	31.23	8.27	50.61	40.75

*Local and Intercity for van-type trailers only. Total includes data for other trailer types.

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[7] "Comparison of Accident Characteristics and Rates for Combination Vehicles with One or Two Trailers," Thipatai Chirachavala and James O'Day, UMTRI report UM-HSRI-81-41, August, 1981.

VEHICLE DYNAMICS ISSUES RELATED TO SAFETY AND TRAFFIC OPERATIONS

Rollovers, maneuverability, and the ability to avoid unanticipated crash threats are all affected by vehicle design characteristics. This section describes how those properties are related to TS&W.

Differing TS&W policies can affect the safety and traffic operations characteristics of heavy trucks because they lead carriers to make differing choices in the basic design properties and configurations of the vehicles they choose to operate. The following is a list of vehicle properties that typically differ as a direct result of differing size and weight allowances:

- Overall vehicle/unit length;
- Vehicle/unit wheelbase and track width;
- Overall vehicle/unit weight;
- Individual axle weights;
- Number of axles on vehicle/unit;
- Number of units in a combination unit vehicle;
- Number of articulation points in a combination unit vehicle;
- Number and type of tires;
- Suspension properties; and
- Brake system properties.

These vehicle design differences, in turn, affect vehicle braking, handling, and stability properties. In some cases, they can limit vehicle performance in traffic and/or incrementally reduce their ability to successfully execute abrupt or extreme maneuvers that tax the performance capability of the vehicle. Unless other compensatory changes in driver performance and/or operating environment demands are made to counteract the effects of vehicle performance differences, crash likelihoods and/or traffic disruption effects increase incrementally.

SAFETY RELATED EFFECTS

Vehicle handling and stability characteristics that can significantly affect the safety of heavy trucks, and which typically differ in relation to differing size and weight policies, include: static rollover threshold, braking efficiency, response of the rear trailer in a multiple trailer combination to rapid steering (rearward amplification), and high speed offtracking.

STATIC ROLLOVER THRESHOLD

Static rollover threshold is the level of lateral (sideward) acceleration that a truck can achieve during turning, without rolling over. Vehicles with low rollover thresholds are prone to rolling over when negotiating exit ramps from freeways, when making severe crash avoidance lane change maneuvers, or when they run off the road. The principal determinant of rollover threshold is the ratio of the center of gravity (COG) height of the vehicle's mass and cargo to one-half the vehicle's track width. Suspension and tire characteristics also influence this property, but to a lesser degree. Rollovers account for 8 percent to 12 percent of all combination-unit truck crashes, but are involved in approximately 60 percent of crashes fatal to heavy truck occupants. They greatly disrupt traffic when they occur in urban environments, especially if hazardous materials are involved.

Rollovers can be reduced by making vehicles more roll stable. Another solution would be for drivers never to exceed posted or reasonable speeds when traversing curves or exit ramps, but past experience indicates this does not always happen. Test procedures are available[8], which involve tilting a tractor and trailer either separately or together, to measure these vehicles' static rollover thresholds. Various minimum performance thresholds have been suggested for this test. Analytical methods of calculating rollover thresholds also exist which could minimize the need to perform tests in all but questionable cases.

Larger, heavier vehicles do not necessarily have poorer performance with respect to this metric than do smaller, lighter vehicles. However, loading more payload onto a given vehicle will in many cases worsen its rollover propensity. On the other hand, various design techniques, principally those that lower the COG of the vehicle's cargo hold, can substantially improve this performance characteristic, regardless of a vehicle's size or weight. The COG height can be reduced by lowering the trailer deck, the legal height limit or both. Also, the trailer could be widened. Other design techniques include adding one or more axles, stiffening suspensions, or specifying stiffer tires. Increasing the width of a typical trailer from 96 inches to 102 inches would improve roll stability 5 percent to 6 percent. Lowering the COG height would have even a more dramatic effect. Going from five to six axles on a 53-foot van semitrailer combination would improve roll stability by 5 percent. For a given freight commodity, decreasing the maximum GVW from 80,000 pounds to 73,280 pounds, the former Federal limit, would improve static roll stability by more than 6 percent.

BRAKING PERFORMANCE

The most straightforward metric of brake system performance is the distance required to stop the vehicle when fully loaded. Obviously, shorter distances are better in this regard. However, brakes must also be able to absorb and dissipate large amounts of kinetic energy when a fully loaded truck descends a grade. Also, trucks need to be able to stop in a stable manner, without jackknifing or otherwise losing directional control due to wheels locking and skidding. Past studies[9] have indicated that brake system performance plays a contributing role in approximately one-third of all medium/heavy truck crashes.

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[8] SAE J21280

[9] "Improved Brake Systems for Commercial Vehicles," U.S. Department of Transportation (HS 807 706), April, 1991.

The ability to stop in short distances is primarily dependent upon the size and number of brakes on the vehicle, their adjustment and state of maintenance, and tire properties. If the vehicle's brakes are adequately sized, and virtually all are as a result of Federal regulatory requirements, they are capable of generating enough force to lock most wheels on the vehicle when it is fully loaded. However, inadequately maintained or maladjusted brakes cannot generate needed braking power, which leads to longer stopping distances and poor brake balance. Improper brake balance can cause downhill runaways and braking instability. In addition, adding more load to a given vehicle, without adding axles and brakes, decreases stopping performance.

None of these problems are attributable to a truck's size or weight, they are generic truck safety issues. Properly designed larger trucks have more axles and, therefore brakes, to carry the heavier loads for which they are designed, but braking problems can be exacerbated if brake maintenance is lax.

Antilock braking systems are especially beneficial for heavier multiple trailer combinations because they have more axles/brakes which can be unevenly loaded or balanced, leading to incrementally increased risks of braking-induced instability and loss-of-control.

The National Highway Traffic Safety Administration recently finalized requirements that significantly upgrade the performance of trucks' brake systems and require antilock brake systems on all vehicles. These regulations follow others requiring trucks to be equipped with automatic brake adjusters and brake adjustment indicators. Permissive rules have been enacted to enable longer stroke brake chambers, which stay in adjustment longer than conventional brakes.
The collective effect of all these rule changes will be a significant overall improvement in both as-new and in-service brake system performance. All sizes and configurations of trucks could be expected to achieve these higher performance levels as well, if equipped and maintained as these new rules require.

REARWARD AMPLIFICATION

When a multiple-trailer combination is traveling at highway speeds (55 mph), it is susceptible to having its rear trailer roll over if an abrupt lane change crash avoidance maneuver becomes necessary. Lateral acceleration generated by the tractor, when the maneuver is initiated, is amplified in the trailing units being towed. This phenomenon (rearward amplification) is reduced primarily with increased trailer lengths and fewer articulation points. Other design factors, as well as the vehicle's weight, influence this characteristic to a lesser degree. Instances of these occurrences are rare, primarily because these vehicles (doubles and triples) accumulate less than 5 percent of the total truck mileage, and are typically operated in comparatively benign operating environments. Therefore, they experience comparatively little exposure to crash risk. The number of incidents could be expected to increase, however, if larger numbers of these vehicles were used, particularly in denser traffic that give rise to more frequent traffic conflicts.

The rearward amplification of multiple-trailer combinations can be substantially reduced through the use of double drawbar converter dollies, so-called C-dollies (see Figure V-6). C-dollies employ two connecting drawbars, instead of one, that couple to the preceding towing trailer. This effectively eliminates an articulation point in the combination, which damps out the rearward amplification characteristic. Thus, double combinations end up with two articulation points instead of three, and triples end up with three instead of five. C-dollies improve the rearward amplification of Western (STAA) doubles by 17 percent. Lengthening trailers also reduces the rearward amplification. For example, increasing trailer lengths in a B-train double from 28 feet to 33 feet improves its rearward amplification by 10 percent.

In order for the vehicle to have acceptable low speed offtracking characteristics, the C-dollies have self-steering axles which only move when the combination makes low speed turns. Combinations equipped with these dollies have better low speed offtracking properties than similar combinations equipped with conventional single drawbar A-dollies. Test procedures and minimum acceptability criteria for qualifying the performance of these dollies are available.

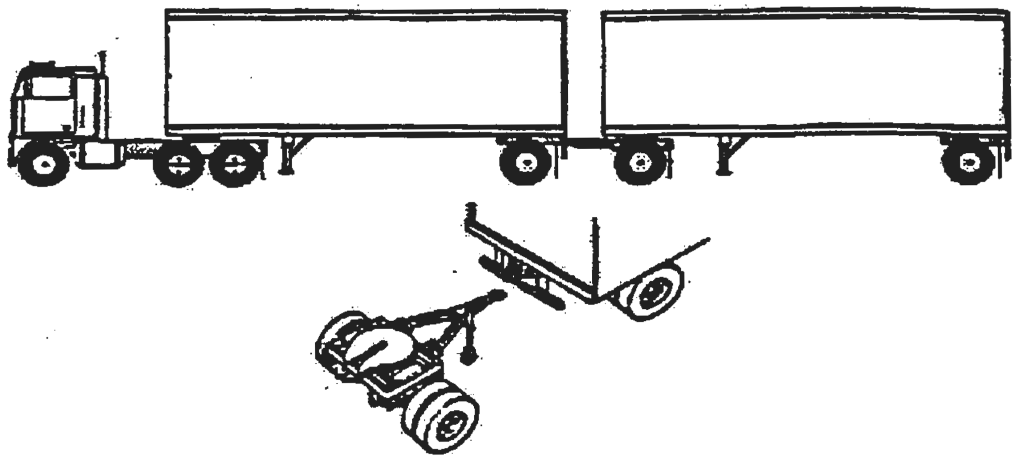
Control strategies involving "intelligent" differential braking have also been researched and show theoretical promise of being capable of effectively dealing with rearward amplification, but commercially viable systems are not currently available.

HIGH-SPEED OFFTRACKING

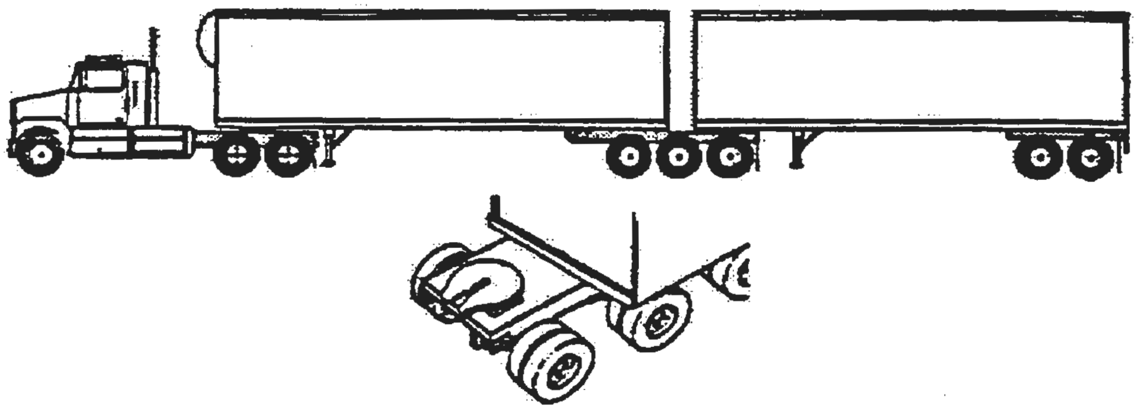
When a combination vehicle negotiates a sweeping (high radius of curvature), high-speed curve, as it would for example at some interchanges between freeways, the rearmost trailer axle can track outside the path of the tractor steering axle. For most truck configurations that have been analytically compared in this regard, this figure is 1.0-foot or less at 55 mph. This tendency is reduced on superelevated curves. Conceivably, if the trailer wheels were to strike the outside curb during negotiation of the curve, a rollover could occur, but this performance attribute has not been linked to any appreciable number of truck crashes. This performance attribute is related to a vehicle's rearward amplification tendencies and is indirectly addressed when rearward amplification is addressed. For a given freight commodity, decreasing the maximum GVW from 80,000 pounds to 73,280 pounds, and thereby the payload, decreases high-speed offtracking by more than 10 percent.

FIGURE V-6
ILLUSTRATIONS OF A, B, AND C TRAIN DOLLIES

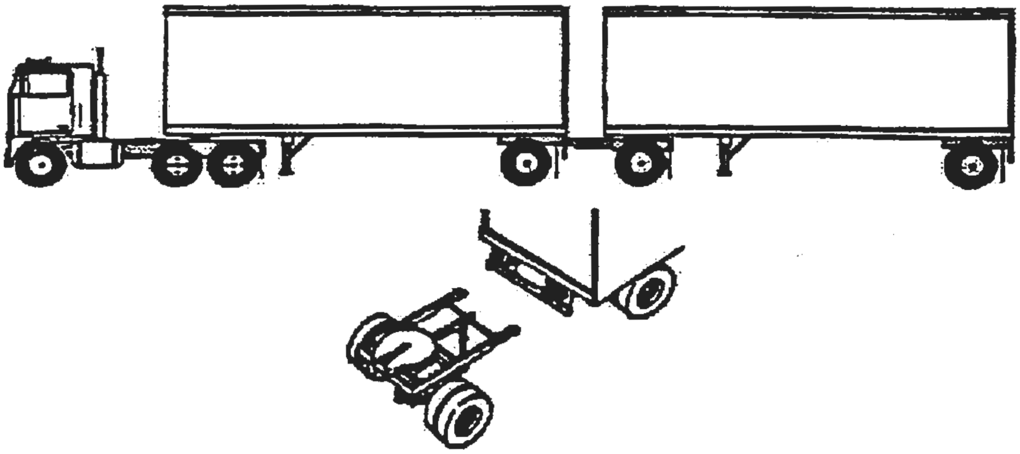
A Train - Second trailer connected with a type "A" converter dolly



B Train - Second semitrailer connects to extended frame of lead semitrailer



C Train - Second trailer connected by a type "C" converter dolly



TRAFFIC OPERATIONS EFFECTS

LOW-SPEED OFFTRACKING

When a combination-unit vehicle makes a low-speed turn, for example a 90 degree turn at an intersection, the wheels of the rearmost trailer axle follows a path several feet inboard of the path of the steering axle of the tractor. This is called low-speed offtracking and may, if excessive, force the driver to swing wide into adjacent lanes in order to execute the turn to avoid climbing inside curbs or striking curbside fixed objects or other vehicles. Also, when negotiating exit ramps, excessive offtracking can result in the truck tracking inboard onto the shoulder or up over inside curbs.

This performance attribute is affected primarily by the distance from the tractor kingpin to the center of the trailer's rear axle which, in the case of a semitrailer, is its effective wheelbase. In the case of multiple trailer combinations, the effective wheelbase(s) of all the trailers in the combination, along with the tracking characteristics of the converter dollies, dictate this property. In general, longer wheelbases worsen low-speed offtracking.

Standard STAA[10] double (two 28-foot trailers), and triple combinations (three 28-foot trailers) exhibit better performance in this regard, compared to a standard tractor/53-foot semitrailer combination, because they have more articulation points in the vehicle combination, and use trailers with shorter wheelbases than semitrailers.

Excessive offtracking can disrupt traffic operations and can result in pavement shoulder and/or inside curb damage at intersections or interchanges heavily used by trucks. Low speed offtracking is a readily measured and/or calculated metric and reasonable acceptability criteria exist with which to control this issue. The extent of offtracking is given in Chapter 6, Highway Infrastructure, for a variety of truck configurations and trailer lengths.

CHANGING LANES/MERGING

Compared to conventional tractor/semitrailer combinations, longer vehicles require incrementally larger gaps in traffic flows in order to merge into these flows. Lane changes in flowing traffic streams would likewise be affected. This could add incremental complexity and burdens to the drivers of these vehicles in these situations. Skilled drivers can compensate for this vehicle property by minimizing the number of lane changes they make and using extra caution when merging, but this may not always be possible. Concern about this performance metric is proportional to the traffic densities in which a given vehicle operates and vehicle length.

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[10] Also referred to Western doubles.

HILL CLIMBING/ACCELERATING

As a vehicle's weight increases, its ability to climb hills at prevailing traffic speeds and to accelerate quickly can be compromised if larger engines and/or different gearing arrangements are not used. When speed differentials between vehicles in flowing traffic streams exceed 20 mph, crash risks increase significantly. Table V-3 indicates that crash involvement may be from 15 times to 16 times more likely at a speed differential of 20 mph. On routes with steep grades that are frequently traveled by trucks, special truck climbing lanes have been built. However, these lanes are not always available, making it important that trucks be able to maintain reasonable performance in this regard. Concern about this aspect of truck performance is addressable with strategies combining judicious choices and matching of vehicles to suitable routes and vehicle hill climbing speed and acceleration performance minimums.

TABLE V-3
SPEED DIFFERENTIALS AND CRASH INVOLVEMENT

Speed Differential (mph)	Crash Involvement	Involvement Ratio (related to 0 speed differential)
0	247	1.00
5	481	1.95
10	913	3.70
15	2,193	8.88
20	3,825	15.49

Source: H.Douglas Robertson, David L. Harkey and Scott E. Davis, Analysis Group, Inc., "Safety Criteria for Longer Combination Vehicles," August 1987.

In the case of multiple-trailer combinations, if single drive axle tractors are used, a situation can arise where the tractor cannot generate enough tractive effort, under slippery road conditions, to pull the vehicle up the hill. Competent, responsible carriers who use routes susceptible to this problem, would not experience repeated incidents of this type without taking corrective actions.

In the past, ameliorative prescriptions for concern about hill climbing performance have centered on requiring larger trucks to be equipped with higher horsepower engines. However, this can be counterproductive, since larger engines tend to consume more fuel and, therefore, cause more gaseous emissions. While in some cases larger engines may be necessary to maintain reasonable performance in this regard, a more straightforward approach is performance standards specifying minimum acceptable speeds on grades and minimum acceptable times to accelerate from a stop to 50 mph, and/or to accelerate from 30 mph to 50 mph.

In cases where frequent truck/car conflicts could be anticipated, either because of the truck's speed maintenance or acceleration performance, or because the number of unsignalized intersections per mile of roadway was high, another countermeasure would be to restrict larger truck use altogether, or to limit their use to certain time periods. Also, in cases where insufficient uphill tractive effort could be a frequent concern, the use of either tandem-axle tractors, and/or tractors equipped with automatic traction control; would be indicated.

TURNS AT UNSIGNALIZED INTERSECTIONS

Heavier vehicles entering traffic streams, on two-lane roads, from unsignalized intersections could take a long time to accelerate up to the posted speed limit. If sight distances at the intersection were obstructed, it might be necessary for approaching vehicles to decelerate abruptly. This could cause crashes or disrupt traffic flows.

The degree to which larger or heavier vehicles perform worse in this regard, compared to smaller trucks, depends on their comparative acceleration performance characteristics. If equipped with appropriate powertrains that ensure adequate acceleration performance, or if routes were screened for suitability, concern about this issue would be minimized, regardless of the size or configuration of the vehicle.

CLEARING THROUGH SIGNALIZED INTERSECTIONS

Longer vehicles, crossing unsignalized intersections from a stopped position on a minor road could increase, by up to 10 percent, sight distances required by traffic on the major road being traversed.

PASSING / BEING PASSED ON TWO-LANE ROADS

Cars passing longer vehicles on two lane roads could need up to 8 percent longer passing sight distances compared to passing existing tractor semitrailers. Longer trucks would require incrementally longer passing sight distances to safely pass cars on two lane roads. In practice, safety conscious truck operators find it impractical to pass cars in these situations, except under the most ideal conditions. Operators of longer/heavier vehicles have to be even more diligent in this regard to avoid potential conflict situations. An alternative countermeasure would be to limit operations of vehicles that require comparatively long times to pass, to roadways with relatively light traffic densities. This issue is discussed further under Roadway Geometry Impacts and Limitations, Chapter 6, Highway Infrastructure.

AERODYNAMIC BUFFETING OF ADJACENT VEHICLES

Air turbulence around trucks does not increase if they are longer or heavier than currently used trucks. However, the gap between the tractor and the semitrailer it tows can be the source of a transient disturbance to adjacent vehicles, if they are operating in substantial crosswinds. Doubles combinations have two of these gaps, while triples have three. Thus, a passing car could experience this transient disturbance that many more times under these conditions. To the extent that motorists now find these occurrences disconcerting, they would experience that feeling incrementally more often if multiple trailer combinations were more widely used.

Truck generated splash and spray is primarily an aerodynamic phenomenon. Thus the incremental concerns that arise relative to buffeting and multiple trailer combinations, would be similar relative to incremental splash and spray concerns.

Efforts to improve truck aerodynamics are continual, since the fuel economy benefits they can yield are substantial. Both buffeting and splash and spray effects will be reduced as these market-driven product development efforts proceed.

SUMMARY

Notwithstanding driver, roadway and weather effects, vehicle size and weight can play a critical, if somewhat subtle role in truck crash causation. Only in cases of a component failure does vehicle performance directly cause a crash to occur, but more importantly, marginal or inferior stability and control performance can make it difficult, if not impossible for a driver to recover from an error, or avoid an unforseen conflict. Some configurations of larger trucks have comparatively inferior performance capabilities compared to other configurations of smaller trucks and these differences, especially if frequently challenged in traffic conflict situations, have been shown to result in incrementally higher crash likelihoods.

DRAFT

CHAPTER 6

HIGHWAY INFRASTRUCTURE

INTRODUCTION

Highway infrastructure protection has been an important consideration in determining the parameters of truck size and weight (TS&W) limits. Pavement wear increases with axle weight; the number of axle loadings; and the spacing within axle groups, such as a tandem or tridem groups. Truck weight also affects the design and fatigue life of bridges. As with pavements, the distribution of weight over the distance between truck axles also affects bridge design and fatigue life. Truck dimensions influence roadway design and vice versa: truck width affects lane widths, trailer or load height affects bridge and other overhead clearances, and length affects the degree of curvature and intersection design. Looking at truck design as determined by the existing roadway geometry, the reverse of the preceding points are true.

Alternative vehicle configurations, analyzed in terms of their interaction with highway infrastructure features include single-unit or straight trucks and single- and multi-trailer truck combinations. Pavement types analyzed include flexible, asphaltic concrete, and rigid, portland cement concrete. Bridge features included in the analysis are span length and clearances. The list of roadway geometry features analyzed is extensive and includes interchange ramps, intersections, and climbing lanes.

INFRASTRUCTURE IMPACTS OVERVIEW

TS&W characteristics--axle weights, gross vehicle weight (GVW), truck length, width, and height--impact of pavements, bridges, and roadway geometry in different ways as shown in Table VI-1.

TABLE VI-1
HIGHWAY INFRASTRUCTURE ELEMENTS AFFECTED BY TS&W LIMITS

Highway Infrastructure Element		Axle Weight	Gross Vehicle Weight	Truck Length	Truck Width	Truck Height
Pavement	Flexible	E				
	Rigid	E				
Bridge Features	Short Span	E		E		
	Long Span		E	E		
	Clearance				e	E
Roadway Geometric Features	Interchange Ramps		e	E	e	
	Intersections			E	e	
	Climbing Lanes		E			
	Horizontal Curvature		e	e		
	Vertical Curve Length		E			
	Intersection Clearance Time		E	E		
	Passing Sight Distance			e		

Key: E Significant effect
e Some effect

IMPACT OF WEIGHT

The relationship of weight to overall condition and performance of the highway system is indicated for each infrastructure element presented in Table VI-1: bridges, pavements, and roadway geometry. There are two aspects of weight that are dependent on each other and interact with the highway infrastructure, axle weight (loading) and GVW. As shown in Table VI-1, the effect of axle weight is more significant to pavements and short span bridges, whereas the GVW is of more significance to long span bridges.

Generally, highway pavements are stressed by axle and axle group loads directly in contact with the pavement rather than by GVW. The GVW, taking into account the number and types of axles and the spacing between axles, determines the axle loads. Over time, the accumulated strains (the pavement deformation from all the axle loads) deteriorate the pavement condition, eventually resulting in cracking of both rigid and flexible pavements, and permanent deformation or rutting in flexible pavements. Eventually, if the pavement is not routinely maintained, the axle loads, in combination with environmental effects, accelerate the cracking and deformation. Proper design of pavement relative to loading is a significant factor, and varies by highway system.

Axle groups, such as tandems or tridems, distribute the load along the pavement allowing greater weights to be carried, resulting in the same or less pavement distress than that occasioned by a single axle at a lower weight. The spread between two consecutive axles also affects pavement life or performance; the greater the spread the more each axle in a group acts as a single axle. For example, a spread of nine to ten feet results in no apparent interaction of one axle with another, and each axle is considered a separate loading for pavement impact analysis or design purposes. Conversely, the closer the axles in a group are, the greater the weight they may carry without increasing pavement wear beyond that occasioned by a single axle, dependent on the number of axles in the group. The benefit to pavements of adding axles to a group decreases rapidly beyond four axles.

Axle loads also have an effect on short span bridges, that is, bridge spans that are shorter than the wheelbase of the truck. This results in only one axle group, the front or rear axle group, being on the span at one time. In contrast to pavement impacts, spreading the axles in an axle group is beneficial to short span bridges.

As noted, it is not GVW but rather the distribution of the GVW over axles that impacts pavements. However, GVW is a factor for long span bridges, that is, bridge spans that are longer than the wheelbase of the truck. Bridge bending stress is more sensitive to the spread of axles than to the number of axles. Bridge Formula B takes into account both the number of axles and axle spreads in determining the GVW allowed.

In the context of roadway geometrics, increasing the GVW affects a truck's ability to accelerate from a stop, to enter a freeway, or to maintain speed on a long grade. Acceleration from a stop influences the time required to clear an intersection. Acceleration into a freeway affects the determination of acceleration lane length requirements. Inability to maintain speed on a long grade results in required construction of truck climbing lanes. Some of these effects can be ameliorated by changes in truck design, primarily engine and drive train components. GVW also has a second order effect on off-tracking. "Offtracking" refers to how the rear axle of a trailer tracks relative to the steering axle of the truck. Other truck characteristics that are impacted by roadway geometrics are discussed in more detail later in this chapter.

IMPACT OF DIMENSIONS

The dimensions of trucks and truck combinations have varied effects on the three elements of highway infrastructure. The most significant effects relate to length, particularly when combined with GVW. Width has a limited effect on swept path, the combination of off-tracking and vehicle width. The effect for highway geometrics of swept path is on ramp or intersection design which is based on mapping a maximum swept path that the truck encroaches on the shoulder, over the curb, or into another lane of traffic. Height regulations are intended to ensure trucks will clear overhead bridges, bridge members, overhead wires, traffic signals and other obstructions.

In general, truck length, or more specifically wheelbase, has a strong effect on bridge bending stress for long span bridges.[1] A truck at mid-span is the loading condition for the maximum bending moment (stress) in a simple supported span. This is not the case for some continuous supported spans. When a truck is straddling the center pier of a continuous span, increasing the truck length can increase the bending moment in the span at the pier.

The effect of truck wheelbase on off-tracking is reduced considerably if the combination is articulated, especially in a multi-trailer combination. Low-speed off-tracking affects interchange and intersection design and high-speed off-tracking affects lane width.

BRIDGE IMPACTS

BRIDGE DESIGN[2]

Most highway bridges in the United States were designed according to the design manual guidelines of AASHTO. The AASHTO bridge specifications provide traffic-related loadings to be used in the development and testing of bridge designs, as well as other detailed requirements for bridge design and construction.

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[1] The longer the wheelbase the shorter the distance from the support member to where the load is being applied (the moment arm) when the truck is in the middle of the span. The shorter the truck the greater the concentration of load at the middle of the span, and the longer the distance (moment arm) to the support member for the bridge span member.

[2] A substantial amount of the background material is drawn from the TRB Special Report 225, *Truck Weight Limits: Issues and Options*, 1990 and from the 1981 U.S. DOT Report to Congress under Section 161, *An Investigation of Truck Size and Weight Limits.*

Dynamic effects can also be important, particularly for bridges carrying trucks operating at higher speeds. In bridge design, the static weight of design loadings are adjusted upward to account for dynamic effects. To minimize the dynamic effects of extra-heavy nondivisible loads on some bridges, permits often require the truck to cross at a very slow speed depending on the GVW.

A key task in bridge design is the selection of bridge members that are sufficiently sized to support the various loading combinations that the structure may carry during its service life. These include dead load (the weight of the bridge itself), live load (the weights of vehicles using the bridge), wind, seismic, and thermal forces. The relative importance of these loads is directly related to the type of materials used in construction, anticipated traffic, climate, and environmental conditions. For a short span bridge (for example, span length of 40 feet), about 70 percent of the load-bearing capacity of the main structural members may be required to support the traffic-related live load, with the remaining 30 percent of capacity supporting the weight of the bridge itself. For a long bridge (for example, span length of 1,000 feet), as much as 75 percent of the load-bearing capacity of the main structural members may be required to support the weight of the bridge.

For overstress, the loading event that governs bridge capacity in most instances is a design vehicle placed at the critical location on the bridge. In certain cases, a lane loading simulating the presence of multiple trucks on a bridge is the governing factor. Bridges are also affected by the dynamic impact and lateral distribution of weight of the trucks; dynamic impact is determined by speed and roadway roughness, and the lateral distribution of loads varies with the position of the truck(s) on the bridge and the girder spacing.

Planning for the rare loading event involves taking a design vehicle or lane loading and applying safety factors to accommodate variations in materials, deterioration, illegal loading, load distribution and dynamic loading conditions. This adjustment of the nominal legal loading is reflected in the safety factors, which are selected so that there is only a very small probability that a loading condition that exceeds its load capacity will be reached within the design life of a bridge.

The methods used to calculate stresses in bridges caused by a given loading are necessarily conservative, and therefore the actual measured stresses are generally much less than the calculated stresses. A margin of safety is necessary because:

- *The materials used in construction are not always completely consistent in size, shape,and quality,*
- *The effects of weather and the environment are not always predictable,*
- *Highway users on occasion violate vehicle weight laws,*
- *Legally allowed loads often increase during the design life of a structure, and*
- *Occasional overweight loading by permit.*

Some of the added margins of safety used by bridge engineers in the past have been eroded in recent bridge design and construction. Use of new design procedures and computer-aided engineering and design has enabled more precise analysis of load effects and the selection of lowest size bridge members and configurations. The competition between steel and concrete has led each group to foster lower costs for their own material. For example, many designs now proposed for steel reduce the safety factor by reducing the number of girders which increases their spacing. Good load models and regulations may need to be considered in the future to cover more load increases.

BRIDGE IMPACT MEASURES

Past studies of the impact of truck weight limit changes on bridges were based on various percentages of the yield stress for steel girder bridges, including 55 percent, 65 percent, and 75 percent of the yield stress. The yield stress, a property of the particular type of steel, is the stress at the upper limit of the elastic range for bridge strain. The elastic range of a structural member is the set of stresses over which the deformation, that is, the strain of the member is not permanent. In the elastic range the member returns to its former size and shape when the stress is removed. There is no permanent set in the structural member. For this discussion, strain is the elongation of a steel girder when: (1) a portion of the strain becomes permanent at a stress level above the yield stress; and (2) the girder continues to elongate, or stretch, under increasing load until it ruptures or fails. Beyond the elastic range, there is permanent elongation of the bridge girder, that is, for those stresses that are greater than the yield stress. However, in structural steel there is considerable strain before failure occurs. This is relative to the strains (elongations) that occur within the elastic range.

BRIDGE INVENTORY AND OPERATING RATINGS

States rate bridges, at their discretion, at either the inventory rating (55 percent of the yield stress), or the operating rating (75 percent of the yield stress)[3]. Of course, bridges are never intentionally loaded to yield stress in order to provide an adequate margin of safety. The design stress level for bridges is based on an operating rating of 55 percent of yield stress. These two ratings are also used for posting bridges; either may be used under the American Association of State Highway and Transportation Officials (AASHTO) guidelines, at the option of the State. A bridge is posted with a sign when it is determined that a vehicle above the specified weight would overstress the bridge. This weight could be that which stresses the bridge at the 55 percent or 75 percent level, whichever practice the State chooses to use.

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[3] According to the AASHTO *Manual for Maintenance Inspection of Highway Bridges* (1983) an operating rating is defined as $RF = 0.75-D/L(1+I)$ where RF= rating factor arrived at with the equation $0.55R= D + L (1 + I)$ where R= the limiting stress (often the stress at which steel will undergo permanent deformation, or "yield"), D= stress due to dead load (the effect of gravity on bridge components), L= stress due to live load (vehicles on the bridge), I= an adjustment to the static effect of live loads to account for dynamic effects. An inventory bridge rating is arrived at by selecting the most highly stressed bridge component and inserting the rating factor (RF) into the Equation, $RF= 0.55R- D/L(1 + I)$, as a multiplier on the live load of the rating truck.

As States have the option to use either rating for posting, both ratings have been used in past studies to assess the bridge impacts for illustrative TS&W scenarios (see Volume III). This is important as there are significant differences in costs that result from choice of rating. Use of the lower stress level (inventory rating) results in more bridges in need of upgrading and, therefore, more costs associated with an increased weight or decreased length limit.[4]

Following the reviews of TRB *Special Reports 225 and 227* (two studies of TS&W limit changes) the FHWA determined that the stress level most representative of all State bridge posting practices was the inventory rating (55 percent of the yield stress) plus 25 percent, which gives a level of 68.8 percent of yield stress. FHWA used this 68.8 percent of yield to estimate the bridge cost impacts of LCVs. The resulting cost estimate reported by FHWA in May 1991 was much closer to the estimate based on the 75 percent rating, the TRB findings in *Special Reports 225 and 227*.

For this current Study, two new stress levels based on the design loading for the bridge in question were chosen--inventory rating plus 5 percent for the HS-20 loading and the inventory rating plus 30 percent for the H-15 loading. These two bridge stress criteria are the same as used in the current Federal bridge formula. Bridges are not generally in need of replacement when trucks meet the Federal bridge formula, as long as they are properly maintained. Selection of bridge evaluation criteria affects the total number of bridges determined to be deficient and associated costs in the analysis of alternative TS&W scenarios (see CTS&W Study Volume III, forthcoming).

Codes developed by AASHTO specify vehicles to represent a broad range of trucks operating at legal weight limits. An H-15 bridge is designed to allow a two-axle truck with a total GVW of 15 tons (30,000 pounds), distributed with 6,000 pounds on the first axle and 24,000 pounds on the second, and axle spacing of 14 feet. An HS-20 bridge is designed to allow a semitrailer combination with a GVW of 36 tons (72,000 pounds) with 8,000 pounds on the tractor's steering axle and 32,000 pounds each on the tractor drive axle and trailer axle. The HS-20 load has a variable axle spacing of 14 feet to 30 feet from the drive to the trailer axle to better cover worst-case situations for continuous spans.

BRIDGE STRESS CRITERIA

Bridge stresses caused by vehicles depend on both the GVW and the distances between the axles which act as point loads. Trucks having equal weight but different wheelbases produce different bridge stresses. The shorter the wheelbase the greater the stress. On a simple span bridge The length of a truck relative to the length of bridge span is also important. For relatively short spans

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[4] The TRB *Special Reports 225, Truck Weight Limits: Issues and Options* and *227, New Trucks for Greater Productivity and Less Road Wear: an Evaluation of the Turner Proposal* estimated the bridge costs of the TS&W changes under study based on the operating rating of 75 percent of yield stress, whereas reviewers of those reports found much higher bridge costs resulting from the use of the inventory rating of 55 percent of yield stress.

(20 feet to 40 feet), all axles of a truck combination will not be on the bridge at the same time. The maximum bending moments determine stresses in the main load-carrying members of simple-span bridges.

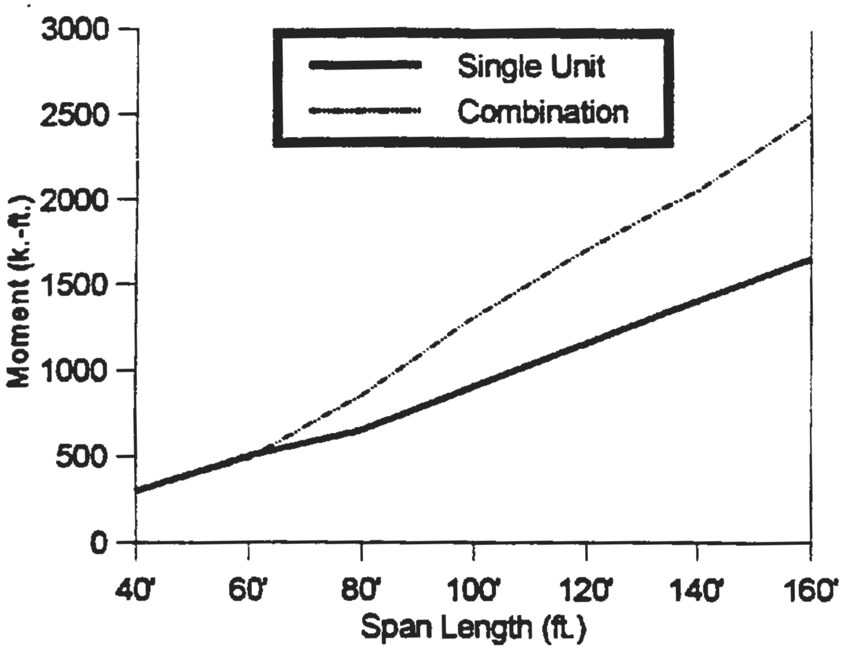
Figure VI-1 shows the maximum bending moments, by span lengths between 40 feet and 160 feet, for two trucks: a 50,000-pound single unit truck with a wheelbase of 19 feet, and an 80,000-pound combination with a wheelbase of 54 feet. For shorter bridges, the 50,000-pound single unit truck produces slightly higher stresses than the 80,000-pound combination; however, for longer bridges the combination produces higher stresses.

Also, estimates of bridge cost impacts of TS&W changes are very sensitive to assumptions regarding acceptable levels of stress on bridges. The inventory rating approach, used by some States, is considerably more conservative than the operating rating approach, used by other States. The inventory rating--equivalent to the design load, which produces a stress of 55 percent of the yield stress--results in no overstress. In comparison, the Federal bridge formula allows up to 5 percent overstresses on HS-20 bridges and 30 percent overstresses on H-15 bridges. The operating rating by allowing 75 percent of yield allows 36 percent more stress than the design load.

CONSIDERATIONS RELATED TO BRIDGE REGULATION

Only bridge overstress was considered in evaluating the effects of changes in TS&W limits on bridges; fatigue has not been evaluated (see Volume III). Overstress creates the possibility of severe damage and possible collapse caused by a single extreme loading event. Fatigue produces the cumulative damage caused by thousands and even millions of load passages, which can damage some of the more fragile elements of a bridge.

FIGURE VI-1
MAXIMUM BENDING MOMENTS ON A SIMPLE SPAN BRIDGE
50,000 pound Straight Truck vs. 80,000 pound Truck Combination



OVERSTRESS CRITERIA AND LEVEL OF RISK

The level of risk to accept in determining acceptable loadings for a given bridge, or acceptable bridge design requirements for given loadings, is an element of TS&W regulation. A less conservative bridge formula which did not preserve the underlying Bridge Formula B (BFB) criteria would reduce the margin of safety, thereby increasing somewhat the likelihood of bridge damage due to overstress. An overstress sufficient to damage a bridge would necessitate bridge repair and/or replacement sooner than anticipated.

BRIDGE FATIGUE

Another factor to be considered is fatigue life which is related to repetitive loadings. Each truck crossing produces one or more stress cycles in bridge components, which use up a portion of the components' fatigue lives. The magnitude of stress depends on vehicle weight and the size of the bridge component. The occurrence of a fatigue failure is signaled by cracks developing at points of high stress concentration.

Generally, only steel bridges are susceptible to fatigue, although some studies suggest that commonly used prestressed concrete spans, if overloaded, are also susceptible to fatigue damage. The governing damage law for steel components has a third-power relationship between stress and damage, so that a doubling of stress causes an eight-fold increase in damage.[5]

Bridge details that are particularly susceptible to fatigue include weld connections in tension zones, pin and hanger assemblies, and cover plates on the bottom flanges of steel beams.[6] Many fatigue failures result from stresses induced indirectly by the distortion of the structure due to poor design details or unforeseen restraints. Most steel cracks reported to date probably fall into the category of distortion induced. Some of the worst detailing can be corrected by repair and retrofit.

BRIDGE FORMULA B

In addition to axle and maximum GVW limits for Interstate highways, Federal law adopted Bridge Formula B (BFB) that restricts the maximum weight allowed on any group of consecutive axles based on the number of axles in the group and the distance from the first to the last axle.

AASHO proposed the formula concept in the 1940s. It was further developed and presented in a 1964 report to Congress from the Secretary of Commerce. The study[7] recommended a table of maximum weights for axle groups to protect bridges (see Appendix A). The values in the table are derived from the following formula, that is, BFB:

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

where:

W is the maximum weight in pounds carried on any group of two or more consecutive axles

L is the distance in feet between the extremes of the axle group

N is the number of axles in the axle group

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[5] Fisher, 1977.

[6] AASHTO specifications give different allowable fatigue stresses for different categories of detail. These fatigue rules were initiated in the mid-1960s, therefore many older bridges were never checked during their original design for fatigue life. Further, the AASHTO fatigue rules apply to welded and bolted details with stresses induced directly by load passages. (Moses, 1989)

[7] *Maximum Desirable Dimensions and Weights of Vehicles Operated on the Federal-Aid System*, 1964 Study Report to Congress, U.S. Department of Commerce.

Federal law specifies exceptions to BFB result given by the above formula: 68,000 pounds may be carried on tandem axles spaced at least 36 feet apart, and a single set of a tandem axle spread no more than 8 feet is limited to 34,000 pounds.

In 1974, Congress adopted BFB, when it increased the GVW limit to 80,000 pounds and the limits on single and tandem axles to 20,000 and 34,000 pounds, respectively. BFB is based on assumptions about the amount by which the design loading can be safely exceeded for different bridge designs. Specifically, this formula was designed to avoid overstressing HS-20 bridges by more than 5 percent and H-15 bridges by more than 30 percent.

The FHWA established a bridge stress level of not more than 5 percent over the design stress for HS-20 bridges to preserve the significantly large investment in HS-20 bridges by Federal, State, and local governments, and because these bridges carry high volumes of truck traffic. Although a level of up to 30 percent is considered to be a safe level for overstressing an H-15 bridge in good condition, the fatigue lives of these structures may be shortened by repeated loadings at this level.

BFB reflects the fact that increasing the spacing between axles generally results in less concentrated loadings and lower stresses in bridge members. For example, the bridge formula would allow a three-axle truck with a wheelbase of 20 feet to operate at 51,000 pounds. If the wheelbase of this truck is increased to 24 feet, then the maximum weight allowed under BFB would increase to 54,000 pounds.

BFB also allows more weight to be carried as the number of axles is increased. For example, if a fourth axle is added to a three-axle truck with a wheelbase of 20 feet, the maximum weight allowed under BFB is increased from 51,000 pounds to 55,500 pounds. Increasing the number of axles in an axle group without increasing the overall length of the group has very little benefit to reducing stress for bridges. However, more axles do provide substantial benefits to pavements.

POTENTIAL ALTERNATIVES TO BRIDGE FORMULA B

BFB is not just one formula but rather a series of formulas with the appropriate one chosen by a parameter, N, the number of axles in the group in question. However, bridge stress is affected more by the total amount of load than with the number of axles. Thus BFB is not effective in modeling the actual physical phenomenon and results in loads that overstress bridges by more than intended. More importantly, it encourages the addition of axles to obtain more payload even though one or both the bridge stress criteria are exceeded. At other times it inhibits the attainment of legitimate stress levels by the mathematical construct of the controlling equation. In summary, BFB actually results in overstressing some of the bridges it is intended to protect. BFB is not true to its own criteria.

Over the years, there have been a number of proposals to revise the Federal bridge formula. However, significant areas of concern have been identified with respect to the alternatives as well. The following discussion elaborates on three alternatives that have been proposed in recent years:

TRANSPORTATION RESEARCH BOARD ALTERNATIVE

In 1990, the Transportation Research Board (TRB)[8] recommended adoption of the formula developed by Texas Transportation Institute (TTI) that would allow a 5 percent overstress for HS-20 bridges, in conjunction with existing Federal axle limits for vehicles with GVWs of 80,000 pounds or less. The TRB report further recommended that the BFB continue to be applied to vehicles weighing more than 80,000 pounds. The effect of this proposal would be an increase in maximum weights allowed for shorter vehicles, while the maximum weight limits for the longer wheelbase trucks would remain unchanged. It was asserted that the TTI formula was overly conservative at heavier weights.

The TTI formula is in the form of two equations for straight lines that meet at a wheelbase length of 56 feet. For wheelbases less than 56 feet, it is:

$$W = 1{,}000(L + 34)$$

For wheelbases equal to or greater than 56 feet, it is:

$$W = 1{,}000(L + 62)$$

where: W = allowable weight
L = wheel base for the truck configuration.

AMERICAN ASSOCIATION OF STATE HIGHWAY & TRANSPORTATION OFFICIALS ALTERNATIVE

In 1993, AASHTO issued a report which recommended that its member committees: (1) evaluate Nationwide adoption of the TTI bridge formula as a replacement for Bridge Formula B;
(2) consider a limit on maximum extreme axle spacing of 73 feet in the short-term; (3) retain the existing single- and tandem-axle limits; (4) control tridem axle weights, and the special permitting

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[8] 1990 TRB *Special Report 225, Truck Weight Limits: Issues and Options.*

of vehicles with GVWs more than 80,000 pounds, with the original TTI Bridge Formula[9] which protects both H-15 and HS-20 bridges, as opposed to the TTI formula mentioned above, which protects only HS-20 bridges.

GHOSN ALTERNATIVE

In 1995 a research study for FHWA by Michael Ghosn et al.[10], City College of the City University of New York was published proposing a new formula based on structural reliability theory as a replacement for BFB. Structural reliability theory more explicitly accounts for the uncertainties associated with bridge design and load evaluation. The proposed formula, however is considerably more permissive than BFB, when applied to long vehicles. The proposed formula results in bridge stresses that are well above the criteria selected for this Study. Therefore, it was not considered.

DIRECT COMPUTATION OF ALLOWABLE WEIGHTS BASED ON BFB STRESS CRITERIA

Original research conducted for this Study suggests that a series of look-up tables may be developed that are based on the underlying stress criteria for BFB, that is: a maximum overstress of 5 percent for HS-20 bridges, and 30 percent for H-15 bridges. These stresses were computed for both simple and continuous spans for the most critical span lengths for the truck configuration. The BFB and TTI formulas are based only on simple spans. As a consequence, some continuous span bridges are stressed beyond the stress criteria on which the Federal and TTI formulas are based.

The look-up tables are generated through application of user friendly computer programs. The following discussion illustrates how this approach might be applied to three vehicles: (1) a tractor-semitrailer combination vehicle with a three-axle tractor and two-axle semitrailer; (2) a tractor-semitrailer combination vehicle with a three-axle tractor and a semitrailer with a tridem- axle group; and (3) a Rocky Mountain Double (RMD).

Illustrative Table VI-2 presents the weight values for the five-axle tractor-semitrailer with a three-axle tractor and two-axle semitrailer under the BFB, TTI and BFB Stress Criteria and Figure VI-2 graphically displays the maximum GVW.

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[9] The recommendation was reviewed by the AASHTO Highway Subcommittees on Bridges and Structures and Highway Transport, accepted in resolution form and approved by the Standing Committee on Highways. The AASHTO Board of Directors considered the recommendations at its 1996 Fall meeting. The Board expressed concern that the impact on pavements was not adequately addressed and remanded it for further consideration to the Subcommittees on Design and on Bridges and Structures. It is anticipated the Board will reconsider the recommendations in 1997.

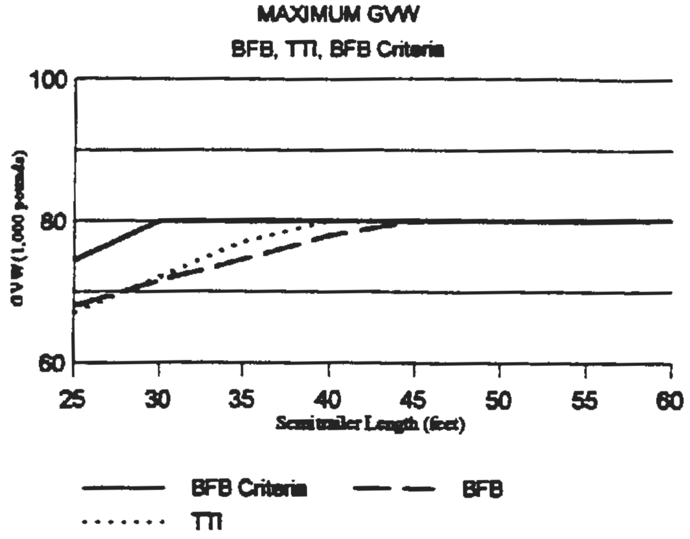
[10] "Bridge Overstress Criteria," Michael Goshn, Charles G Schilling, Fred Moses, and Gary Runco, The City College of the City University of New York for the Federal Highway Administration, Washington, D.C., May, 1995.

TABLE VI-2
MAXIMUM GVW FOR FIVE-AXLE SEMITRAILER COMBINATION APPLYING BFB, TTI, AND BFB STRESS CRITERIA

22.5' Tractor Wheelbase, 52" Tractor Tandem Spread, and 48" Trailer Tandem Spread

Semitrailer Length (feet)	Maximum GVW (1,000 Pounds)			Semitrailer Length (feet)	Maximum GVW (1,000 Pounds)		
	BFB	TTI	BFB Stress Criteria		BFB	TTI	BFB Stress Criteria
23.0'	66.5	65.1	71.4	42.0'	79.5	80.0	80.0
24.0'	67.0	66.1	72.9	43.0'	80.0	80.0	80.0
25.0'	68.0	67.1	74.4	44.0'	80.0	80.0	80.0
26.0'	68.0	68.1	75.7	45.0'	80.0	80.0	80.0
27.0'	69.0	69.1	77.1	46.0'	80.0	80.0	80.0
28.0'	70.0	70.1	78.4	47.0'	80.0	80.0	80.0
29.0'	71.0	71.1	79.7	48.0'	80.0	80.0	80.0
30.0'	71.5	72.1	80.0	49.0'	80.0	80.0	80.0
31.0'	72.0	73.1	80.0	50.0'	80.0	80.0	80.0
32.0'	72.0	74.1	80.0	51.0'	80.0	80.0	80.0
33.0'	73.5	75.1	80.0	52.0'	80.0	80.0	80.0
34.0'	74.0	76.1	80.0	53.0'	80.0	80.0	80.0
35.0'	74.5	77.1	80.0	54.0'	80.0	80.0	80.0
36.0'	75.0	78.1	80.0	55.0'	80.0	80.0	80.0
37.0'	76.0	79.1	80.0	56.0'	80.0	80.0	80.0
38.0'	76.5	80.0	80.0	57.0'	80.0	80.0	80.0
39.0'	77.5	80.0	80.0	57.5'	80.0	80.0	80.0
40.0'	78.0	80.0	80.0	58.0'	80.0	80.0	80.0
41.0'	78.0	80.0	80.0				

FIGURE VI-2
COMPARISON FOR FIVE-AXLE SEMITRAILER COMBINATION

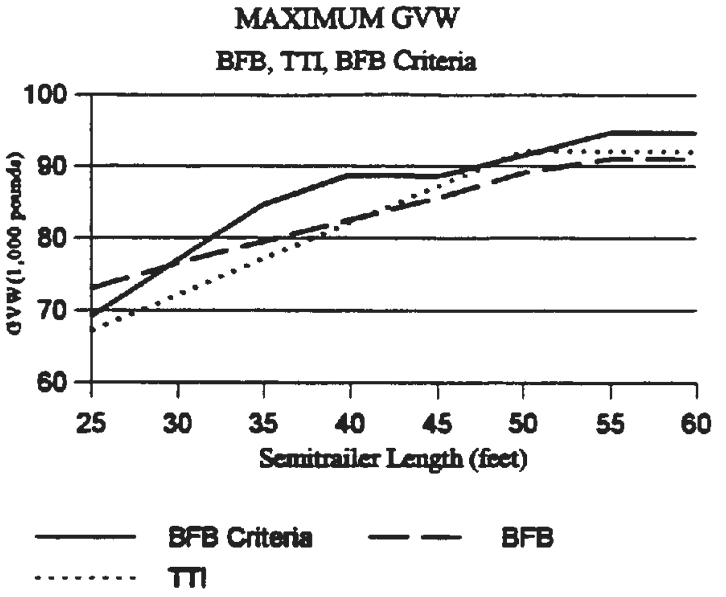


Illustrative Table VI-3 and Figure VI-3 have been created for a tractor-semitrailer combination vehicle with a three-axle tractor and a semitrailer supported at the rear by a tridem-axle group. In the case of the six-axle semitrailer, both the tractor wheelbase and semitrailer length are varied (common descriptive dimensions). Table VI-3 provides the GVW allowed under three formulas.

TABLE VI-3
MAXIMUM GVW FOR SIX-AXLE SEMITRAILER COMBINATION APPLYING BFB, TTI, AND BFB STRESS CRITERIA
22.5' TRACTOR WHEELBASE

Semitrailer Length (feet)	Maximum GVW (1,000 Pounds)			Semitrailer Length (feet)	Maximum GVW (1,000 Pounds)		
	BFB	TTI	BFB Stress Criteria		BFB	TTI	BFB Stress Criteria
23.0'	72.0	65.1	66.2	41.0'	83.5	83.1	88.4
24.0'	72.5	66.1	67.6	42.0'	84.0	84.1	88.2
25.0'	73.0	67.1	69.1	43.0'	84.5	85.1	88.3
26.0'	73.0	68.1	70.5	44.0'	85.0	86.1	88.5
27.0'	74.5	69.1	70.0	45.0'	85.5	87.1	88.6
28.0'	75.0	70.1	73.4	46.0'	86.0	88.1	89.0
29.0'	76.0	71.1	75.2	47.0'	87.0	89.1	89.5
30.0'	76.5	72.1	76.9	48.0'	87.5	90.1	90.0
31.0'	77.0	73.1	78.4	49.0'	88.5	92.0	90.7
32.0'	77.5	74.1	80.0	50.0'	89.0	92.0	91.4
33.0'	78.0	75.1	81.5	51.0'	89.5	92.0	92.3
34.0'	79.0	76.1	83.0	52.0'	90.0	92.0	93.3
35.0'	79.5	77.1	84.5	53.0'	90.5	92.0	94.2
36.0'	80.0	78.1	85.3	54.0'	91.0	92.0	94.6
37.0'	80.5	79.1	86.2	55.0'	91.0	92.0	94.6
38.0'	81.0	80.1	87.0	56.0'	91.0	92.0	94.6
39.0'	82.0	81.1	87.9	57.0'	91.0	92.0	94.6
40.0'	82.5	82.1	88.7	58.0'	91.0	92.0	94.6

FIGURE VI-3
COMPARISON FOR SIX-AXLE-SEMITRAILER COMBINATION
(22.5' Tractor-Wheelbase)



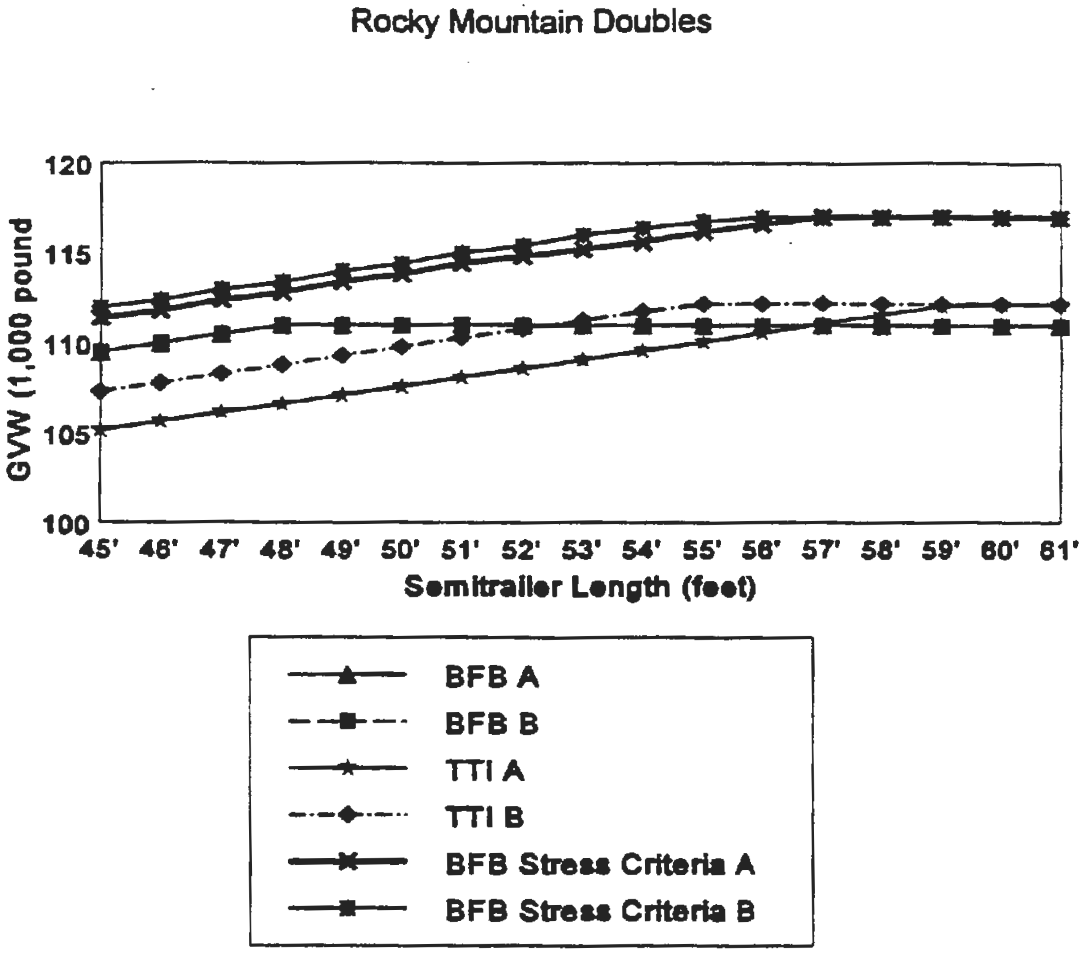
Illustrative Table VI-4 and Figure VI-4 present the values and charts the results for the Rocky Mountain double (RMD) combination which is a tractor-semitrailer combination with a three-axle tractor pulling a two-axle semitrailer and a two-axle full trailer. In the case of the RMD, the tractor and semitrailer length are varied, with the trailer remaining fixed at 28 feet. The limiting axle loads and maximum GVW for the entire vehicle are easily read from a table. This approach negates the need to compute the many axle group combinations inherent in the use of the existing and proposed formulas (which can amount to as many as 36 different combinations in the case of a nine-axle vehicle).

TABLE VI-4
MAXIMUM GVW FOR RMD WITH SEMITRAILER OF VARIABLE LENGTH AND 28' TRAILER APPLYING BFB, TTI, AND BFB STRESS CRITERIA

Tractor A = 18.2 feet or Tractor B = 22.5 feet

Semitrailer Length (feet)	BFB GVW (1,000 pounds)		TTI GVW (1,000 pounds)		BFB Stress Criteria GVW (1,000 pounds)	
	Tractor A	Tractor B	Tractor A	Tractor B	Tractor A	Tractor B
45'	109.5	109.5	105.16	107.3	111.4	112
46'	110	110	105.66	107.8	111.8	112.4
47'	110.5	110.5	106.16	108.3	112.4	113
48'	111	111	106.6	108.8	112.8	113.4
49'	111	111	107.1	109.3	113.4	114
50'	111	111	107.6	109.8	113.8	114.4
51'	111	111	108.1	110.3	114.4	115
52'	111	111	108.6	110.8	114.8	115.4
53'	111	111	109.1	111.3	115.2	116
54'	111	111	109.6	111.8	115.6	116.4
55'	111	111	110.1	112.2	116.2	116.8
56'	111	111	110.6	112.2	116.6	117
57'	111	111	111.1	112.2	117	117
58'	111	111	111.6	112.2	117	117
59'	111	111	112.1	112.2	117	117
60'	111	111	112.2	112.2	117	117
61'	111	111	112.2	112.2	117	117

FIGURE VI-4
RMD GVW COMPARISON CHART: BFB, TTI, BFB STRESS CRITERIA
Tractor A= 18.2 feet Tractor B= 22.5 feet



Combination with Tractor A designated with A or Tractor B designated with B

The preceding charts clearly indicate the relationship between the controls for BFB, TTI and BFB Stress formula. The degree to which BFB and TTI correlate with the criteria on which they are based is clearly seen. Table VI-5 summarizes the findings based on application of the BFB, TTI, and BFB Stress Criteria to the three illustrative truck configurations: (1) the five-axle tractor-semitrailer (3-S2); (2) the six-axle tractor-semitrailer (3-S3); and the RMD.

TABLE VI-5
APPLICATION OF BFB, TTI AND BFB STRESS CRITERIA

3-S2 Highlights
(3-axle tractor and 2-axle semitrailer)

- The BFB Stress Criteria curve is more permissive than either the BFB or TTI formula. This allows shorter vehicles to carry more payload without violating the stress criteria on which BFB is based.
- The TTI formula is less permissive than BFB for the 23- to 25-foot axle spacing.
- The TTI is more permissive than BFB for the 26- to 42-foot axle spacing.
- All curves are constrained by axle limits, not the 80,000-pound GVW limit. It is only coincidental if the sum of the axles equals 80,000 pounds.
- Linearity is evident in the BFB and TTI curves, and although it appears to be present in the BFB Stress Criteria curve it is not. The ascending part of the curve of the BFB Stress Criteria actually curves downward in a slightly concave manner.

3-S3 Highlights
(3-axle tractor and tridem-axle semitrailer)

- The BFB is more permissive than both the TTI and BFB Stress Criteria curve in the 25- to 29-foot axle spacing.
- The TTI formula is less permissive than both BFB and BFB Stress Criteria curve for axle spacing up to 41 feet, and more permissive than BFB for spacing greater than 41 feet.
- BFB Stress Criteria curve is more permissive than TTI and BFB for axle spacing over 30 feet as the curves indicate, with the exception of the 40- to 51-foot range where it is the same as the TTI formula.
- The maximum limits for the longer trailer lengths and axle spacings vary for all three formulas. The BFB maximum limit is 91,000 pounds; the TTI maximum limit is 92,000 pounds; and the BFB Stress Criteria maximum limit is 94,600 pounds. The reason for the differences in GVW is the different weights allowed by each for the tridem-axle: BFB is 45,000 pounds; TTI is 46,000 pounds; and BFB Stress Criteria is 48,600 pounds (constrained by simple beam stress levels). All curves are calculated using 12,000 pounds for the steering axle and 34,000 pounds for the tractor tandem-axle.
- The BFB Stress Criteria formula results in a curvilinear relationship that is pronounced. This is due to the variation in stress at the center pier of a two-span continuous bridge and shape of the influence line for that stress. The actual physical phenomenon occurring in bridges cannot be matched with linear curves with either the BFB or TTI formulas, although at the higher limits TTI comes closer than BFB .
- The 80,000 pound GVW limit is reached before the axle-limits are exceeded for this configuration with all three formulas.

RMD Highlights

- The BFB Stress Criteria curve results in a more liberal (permissive) curve than the BFB or TTI formulas.
- Two tractor lengths are used for the analysis resulting in increased payload for axle spacing up to 51 feet under the BFB Stress Criteria and TTI formulas. BFB is constrained by the inner axle groupings for both vehicle combinations with the steering axle limited at 12,000 pounds.
- The BFB formula is more permissive than the TTI formula for axle spacing up to 52 feet. Tractor B is more permissive with axle spacing up to 56 feet and Tractor B is more permissive for spacing more than 56 feet.
- For the maximum limits, the BFB Stress Criteria curve allows the greatest weight to be carried, followed by TTI and BFB in that order.
- The linearity of the BFB and TTI is strongly evident in the curves, whereas the BFB Stress Criteria formula relationship is curvilinear for spacing between 53 and 56 feet. The TTI formula curve is closer fit to the BFB Stress Criteria curve then the BFB curve.

In summary, there is significant variation in the results (curves) that is dependent on vehicle configuration. In general, the TTI formula is better match than the BFB formula for bridges and there is a significant amount of load capacity available before limits are exceeded for the three configurations. However, this is not the case for the largest vehicles–the BFB allows too much weight for turnpike doubles. The TTI curve for that vehicle is on the low side of the BFB Stress Criteria curve. Also, the BFB formula is too liberal for multi-axle short straight trucks.

There are demonstrative benefits to adhering to the criteria on which BFB is based, and incorporating the consideration of continuous beams into the control. Tools, such as user friendly computer programs can be used to assess allowable loading configurations for any vehicle, and standard (bridge formula) tables for the more common vehicles can be generated and made available.

The alternative described in this section squarely addresses the documented drawbacks of BFB and provides a basis for truck weight control that conforms to the criteria upon which both BFB and TTI are based but do not adhere to.

It should be noted that Federal BFB, by design, incorporates a degree of control for pavement damage by explicitly including the number of axles in the formula. The TTI and the BFB Stress Criteria formulas indirectly control for pavement damage by adhering to axle weight limits--the higher GVW limits, such as for LCVs, require more axles to avoid exceeding axle limits.

The quantitative analyses in CTS&W Study Volume III evaluate other options that are not constrained to the BFB stress criteria. Allowable weight for other stress levels could be easily developed using the same methods used to develop the BFB stress criteria weights.

PAVEMENT IMPACTS

The condition and performance of highway pavement is dependent on many factors, including: thickness of the various pavement layers, quality of construction materials and practices, maintenance, properties of the roadbed soil, environmental conditions (most importantly rainfall and temperature), and the number and weights of axle loads to which the pavements are subjected.[11]

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[11] TRB *Special Report 225, Truck Weight Limits: Issues and Options,* 1990.

IMPACT OF AXLES

WEIGHT

Load equivalency factors, such as equivalent single-axle loads (ESAL), measure the relative effects of different types of loadings on pavements. Pavement engineers generally use the concept of an ESAL to measure the effects of axle loads on pavement. By convention, an 18,000-pound single axle equals 1.0 ESAL. The ESAL values for other axles express their effect on pavement wear relative to the 18,000-pound single axle. The effect of a given vehicle on pavements can be estimated by calculating the number of ESALs for each axle, adding the ESALs to obtain the total ESALs for the vehicle. For example, if a given vehicle on a given type of pavement is 3.0 ESALs, then one pass by the vehicle has the same effect on that pavement as three passes by an 18,000-pound single axle.

AASHTO provides separate sets of ESAL values for flexible and rigid pavements. The principal difference between the flexible and rigid pavement ESAL values is that tandem axles were found to have a greater effect on rigid pavements as Figures VI-5 and VI-6 illustrate. For example, a 34,000-pound tandem axle is about 1.1 ESALs on flexible pavement and about 2.0 ESALs on rigid pavements. The same is true of single axles.

FIGURE VI-5
AXLE LOAD EFFECTS ON FLEXIBLE PAVEMENT

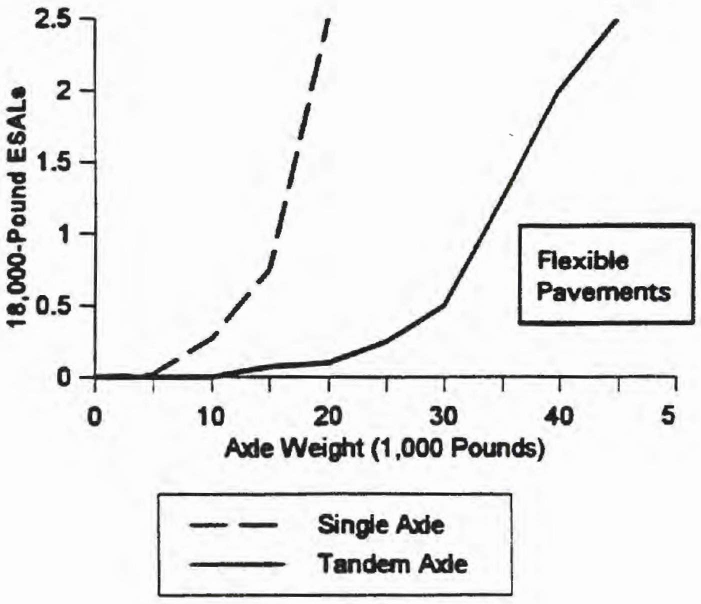
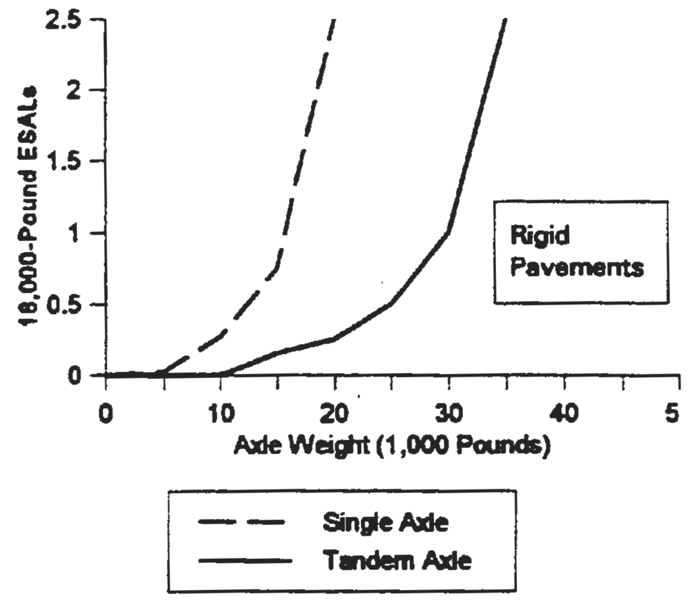


FIGURE VI-6
AXLE LOAD EFFECT ON RIGID PAVEMENT



While pavement engineers traditionally have used ESAL factors estimated from the AASHO Road Test as the basis for designing pavements, there is increasing recognition that better relationships between axle load and pavement wear are needed. Pavement distress models used in both the 1982 and the 1997 Federal HCA Study abandoned the use of ESALs to relate axle loading to pavement wear, and AASHTO will be replacing its ESAL-based pavement design formula with one that more directly relates axle loads to factors that determine pavement life. While ESALs are not used as the basis for estimating pavement costs associated with different TS&W scenarios, they are widely understood by highway administrators, pavement engineers, and others concerned about pavement impacts of TS&W scenarios and will be used as a benchmark for comparing relative pavement impacts among different truck configurations with different numbers and types of axles.

Pavement wear increases sharply with increases in axle load. On both flexible and rigid pavements, the load-equivalence factor for a 20,000-pound single axle is about 1.5. Thus, 100 passes across a pavement by a 20,000-pound axle would have the same effect on pavement life as 150 passes by an 18,000-pound axle.

The number of axles is also important in estimating pavement impact: other things being equal, a vehicle with more axles has less effect on pavements. For example, a nine-axle combination vehicle carrying 80,000 pounds has less of an effect on pavements than a five-axle combination vehicle carrying 80,000 pounds. A significant amount of additional weight can be carried by the nine-axle vehicle without causing greater pavement consumption relative to the five-axle vehicle. A comparison of vehicles in terms of ESALs provides information on load-related pavement impact, but it does not factor in an offsetting benefit gained by a reduction in the number of trips required to transport the same amount of freight. Vehicles are often compared in terms of ESALs per unit of freight carried as a means of factoring in the reduction in pavement wear from fewer trips.

The increase in pavement costs per added ESAL mile can vary by several orders of magnitude depending upon pavement thickness, quality of construction, and season of the year. Thinner pavements are much more vulnerable to traffic loadings than thicker pavements[12]. Additionally, pavements are much more vulnerable to traffic loadings during spring thaw in areas that are subject to freeze-thaw cycles.

AXLE SPACING

The primary load effect of axle spacing on flexible pavement performance is fatigue. Axle spacing is a major concern for fatigue. When widely separated loads are brought closer together, the stresses they impart to the pavement structure begin to overlap and they cease to act as separate entities. While the maximum deflection of the pavement surface continues to increase as axle spacing is reduced, maximum tensile stress at the underside of the surface layer (considered to be a primary cause of fatigue cracking) can actually decrease as axle spacing is reduced. However, effects of the overlapping stress contours also include increasing the duration of the loading period. Thus, the beneficial effects of stress reduction are offset to some largely unknown degree by an increase in the time or duration of loading. The net effect of changes in axle spacing on pavement wear is complex and highly dependent on the nature of the pavement structure.[13]

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[12] Results of a study by Hutchinson and Haas compare the average and marginal costs per ESAL on highways with 500,000 ESALs per year and 2,000,000 ESALs per year. They indicate the cost per ESAL for highways with 500,00 ESALs is almost four times as great as the cost per ESAL on highways designed for 2,000,000 ESALs. One important implication of this finding is that a policy that encourages heavy trucks to shift from highways with thicker pavements, such as the Interstate or NHS, to highways with thinner pavement can have a significant impact on pavement costs.

[13] TRB *Special Report 225, Truck Weight Limits: Issues and Options*, 1990.

TIRE CHARACTERISTICS

In recent years several studies on the impact of tire-characteristics on pavement have raised concern over the possibility of accelerated pavement wear, particularly rutting, caused by increasing tire pressures. The tires of the AASHO Road Test trucks of the 1950s were bias-ply construction with inflation pressures between 75 pounds and 80 pounds per square inch (psi). The replacement of bias-ply tires with radial tires and higher inflation pressures, averaging 100 psi[14], result in a smaller size tire "footprint" on the pavement and consequently concentration of weight over a smaller area. The increased pressures hasten the wear of flexible pavements, increasing both the rate of rutting and the rate of cracking.

The AASHTO load-equivalency factors strictly apply only to axles supported at each end by dual tires. Recent increases in steering-axle loadings and more extensive use of single tires on load-bearing axles have precipitated efforts to examine the effect on pavement wear of substituting single for dual tires. Both standard and wide-based tires have been considered. Past investigations of the pavement wear effects of single versus dual tires have found that single tires induce more pavement wear than dual tires, but that the differential wear effect diminishes with increases in pavement stiffness, in the width of the single tire, and in tire load.[15]

A general finding from the studies is that wide-base single tires appear to cause about 1.5 times more rutting than dual tires on roadways that do not possess good resistance qualities to rutting, such as flexible pavement, by far the most common type of pavement. Another finding is that one of the wheels in a dual tire assembly is frequently overloaded due to the road and that the average overload causes an increase in rutting similar to that caused by wide-based single and dual tire assemblies. Therefore, the real advantage of dual tire assemblies is undoubtedly lower than the theoretical advantage attributed to their use.[16]

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[14] A study by Bartholomew (1989) summarized surveys of tire pressure conducted in seven States between 1984 and 1986 and found that 70 to 80 percent of the truck tires used were radials and that average tire pressures were about 100 psi.

[15] Gillespie (1993) found that a steering axle carrying 12,000 pounds with conventional single tires is more damaging to flexible pavements than a 20,000-pound axle with conventional dual tires. Gillespie proposed that road damage from an 80,000-pound vehicle combination would be decreased by approximately 10 percent if a mandated load distribution of 10,000 pounds on the steering axle and 35,000 pounds on tandems. Since the operating weight distribution of a five-axle tractor-semitrailer at 80,000 pounds GVW generally has less than 11,000 pounds on the steering axle, the practical effect of the proposal would be to increase tandem axle weights without a compensating decrease in steering axle weights.

[16] Conflicting results were reported by Akram, et. al. They used multi-depth deflectometers to estimate the damage effects of dual versus wide-based tires. Deflections measures at several depths within the pavement under dual and wide-base single tires were used to calculate average vertical compressive strains. The Asphalt Institute's (AI) subgrade limiting strain criteria were then used to estimate the reduction in pavement life that will occur by using the wide-based single tires in place of duals. At a speed of 55 miles per hour, and equivalent axle loading, the AI found that the wide-based single tires (trailer axle) reduced the anticipated pavement life by a factor between 2.5 and 2.8 over that predicted for standard dual tires.

Based upon past studies single tires have more adverse effects on pavements than dual tires, it appears likely that past investigations have overstated the adverse effects of single tires[17] by neglecting two potentially important effects: (1) unbalanced loads between the two tires of a dual set, and (2) the effect of randomness in the lateral placement of the truck on the highway. Unbalanced loads between the tires of a dual set can occur as a result of unequal tire pressures, uneven tire wear, and pavement crown. As with unequal loads on axles within a multi-axle group, pavement wear increases as the loads on the two dual tires become more unbalanced.

The second neglected factor, sometimes termed "wander," is the effect of randomness in the lateral placement of trucks within and sometimes beyond lane boundaries. Less perfect tracking is beneficial to pavement wear, as the fatiguing effect is diminished because the repetitive traffic loads are distributed over wider areas of the pavement surface. Because the greater overall width of dual tires naturally subjects a greater width of pavement to destructive stresses, wander is expected to have a smaller beneficial effect for dual than for single tires. Once rutting begins, however, tires, especially radial tires, tend to remain in the rut, thereby greatly reducing the beneficial effects of wander for both single and dual tires[18] (see Figure VI-7).

The TRB *Special Report 225* found that without wander, the ESAL equivalent for an 18,000-pound axle with single tires was estimated to be 2.23. When wander with a standard deviation of 8 inches is assumed, the ESAL equivalent drops to 1.31. At least for the plus or minus 5 percent case considered in this study, the effects of imbalance in dual-tire sets on ESALs were found to be very small relative to the effect of wander.

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[17] Bauer (1994) summarized several recent studies on the effects of single versus dual tires: "Smith (1989), in a synthesis of several studies... evaluated at 1.5 on average the relationship of the damage caused by wide base single assemblies and that caused by traditional dual tire assemblies with identical loading at the axle. Sebaaly and Tabatace (1992) found rutting damage ratios between wide base and dual tire assemblies varying between 1.4 and 1.6....Bonaquist (1992), reporting on results obtained from a study ...on two types of roadway, using a dual tire assembly with 11 R 22.5 and a wide base with 425/65 R 22.5, indicates rutting damage ratios varying from 1.1 to 1.5, depending on the layers of the roadway."

[18] The TRB *Special Report 225* examined the importance of loading imbalance and wander. The TRB study examined two types of pavement wear: surface cracking due to fatigue and permanent deformation or rutting in the wheel tracks. Fatigue was found to be more sensitive to the differences between single and dual tires than rutting. Both balanced and unbalanced dual-tire loads were considered in analyzing the affect on wander. The analysis indicated that the adverse effects of single tires on pavement wear were reduced when wander was taken into account, although the effects were still significant.

Another consideration in evaluating wide-base single versus dual tires is dynamic loadings that arise from the vertical movement of the truck caused by surface roughness. Thus, peak loads are applied to the pavement that are greater than the average static load.[19] Signs of pavement damage from dynamic loadings are typically localized, at least initially. Because of the localized nature of the dynamic loading, its severity is much greater than previously thought.[20] A further note on wide-base single tires is that those having only two sidewalls are much more flexible than a pair of dual tires with four sidewalls, which means the tire absorbs more of the dynamic bouncing of the truck and less of the dynamic load is transmitted to the pavement.

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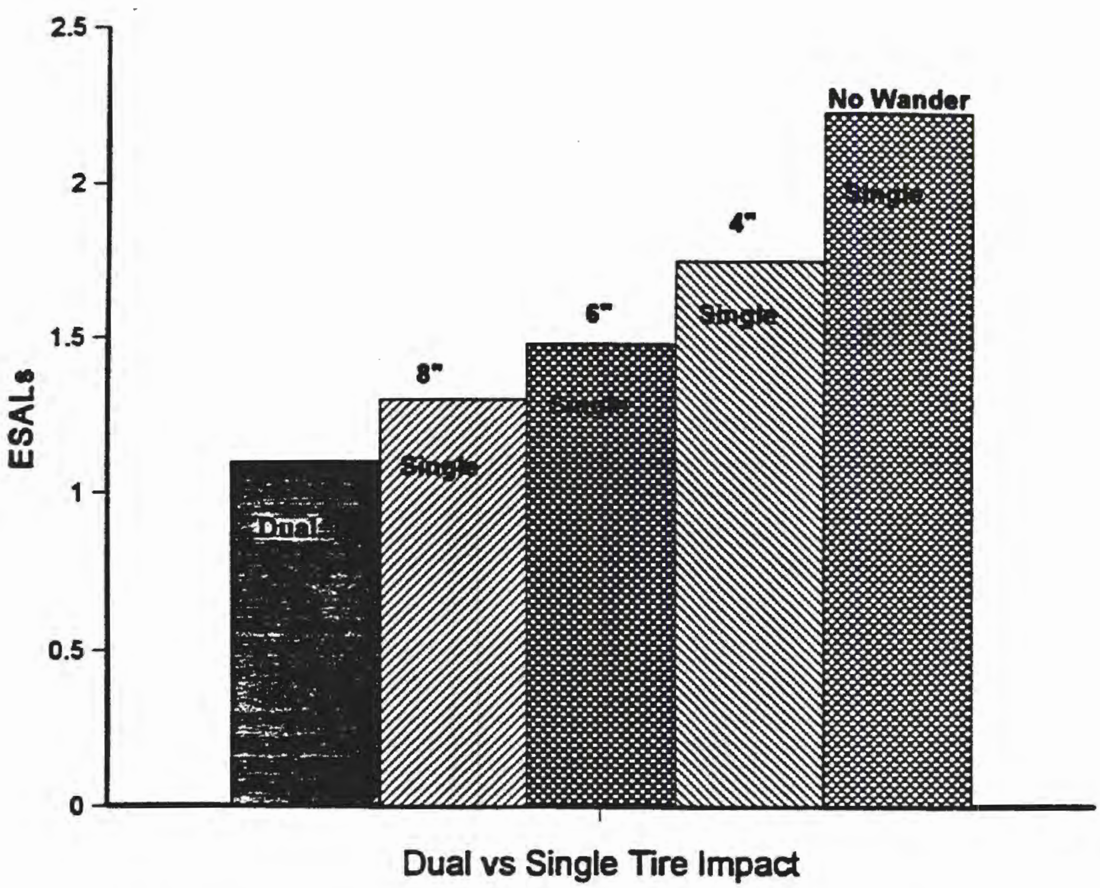
[19] From research summarized by the Midwest Research Institute (MRI) that suggests dynamic loadings are a consideration in assessing the relative merits of wide base single versus dual tires. Gyenes and Mitchell report that the magnitude of the added dynamic components was earlier thought to increase road damage over that of the static loading alone between 13 and 38 percent, according to research reported by Eisenmann. The MRI research noted that many recent studies have pointed out the fallacy in the earlier work, which assumed that the dynamic component of loading was distributed uniformly over the pavement in the direction of travel. The research found, however that the dynamic component is very localized, arising out of pavement surface irregularities and therefore is spatially correlated with these irregularities.

[20] Gillespie, et.al. estimate that damage due to the combination of static and dynamic loading can be two to four times that due to static loading locally. Von Becker estimates the combined loading produces a "shock factor" between 1.3 and 1.55, depending upon suspension characteristics. Applying the fourth power law would translate these figures into relative damage estimates ranging from 2.8 to 4.8 times the static loading damage. Gyenes and Mitchell suggest impact factors in the range of 1.3 to 1.5 for relative damage estimates of 2.8 to 5.1.

FIGURE VI-7
THE EFFECT OF SINGLE TIRES VS DUAL TIRES ON PAVEMENT
18,000 pound Single Axle (wander is in standard deviations)



Source: TRB *Special Report 225, Truck Weight Limits: Issues and Options*

SUSPENSION SYSTEMS

The subject of road-friendly suspensions (within the context of the broader subject of vehicle-pavement interaction) is under intensive research by an Organization for Economic Cooperation and Development (OECD) project involving the United States and 16 other countries.[21] The work is focusing on: (1) how well different suspension systems can distribute load between axles in a group (the more evenly, the better); (2) how well different suspension systems dampen vertical dynamic loads (the more, the better); and (3) spatial repeatability of dynamic loads. Related considerations are examining how road and bridge characteristics act to excite a truck, and in turn influence the loads received by the road and bridge.

Recent research[22] on the role that suspension damping plays in enhancing the road friendliness of a heavy vehicle found that an increase in linear suspension damping tends to reduce the dynamic load coefficient and the dynamic tire forces, factors related to road wear. a conclusion was made that linear and air spring suspensions with light linear damping offer significant potentials to enhance the road friendliness of the vehicle with a slight deterioration in ride quality.[23] It is worth noting that approximately 90 percent of all truck tractors and 70 percent of all van trailers sold in the United States are equipped with air suspensions. Additional studies on various types of axle suspension systems include studies on: torsion suspensions, four-leaf suspensions, and walking-beam suspensions.[24]

The research has yet to produce any compelling argument to incorporate a suspension system determinant into United States regulations although some countries have done so. Mexico is in the final stages of preparing regulations that will allow up to 2,200 pounds of additional weight for each trailer axle equipped with an air suspension or its equivalent. For a drive axle, Mexico may allow up to an additional 3,300 pounds. The impacts of different suspension systems on pavement deterioration are of secondary importance compared to the static axle load levels

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[21] TRB *Special Report 225* noted that a heavy truck travels along the highway, axle loads applied to the pavement surface fluctuate above and below their average values. The degree of fluctuation depends on factors such as pavement roughness, speed, radial stiffness of the tires, mechanical properties of the suspension system, and overall configuration of the vehicle. On the assumption that the pavement wear effects of dynamic loads are similar to those of static loads and follow a fourth-power relationship, increases in the degrees of fluctuation increase pavement wear.

[22] Rakheja and Woodrooffe.

[23] In the Rakheja and Woodroofe model suspension effects are represented using a sprung mass, an unsprung mass, and restoring and dissipative effects due to suspension and tire. The tire is modeled assuming linear spring rate, viscous damping, and point contact with the road.

[24] Sousa, Lysmer and Monismith investigated the influence of dynamic effects on pavement life for different types of axle suspension systems. They calculated a Reduction of Pavement Life (RPL) index of 19 percent for torsion suspensions (an ideal suspension would have RPL of 0). Similar results were found by Peterson in a study for Road and Transport Association of Canada: under rough roads at 50 mph, air bag suspensions exhibited dynamic loading coefficients (DLC) of 16 percent, spring suspensions had a DLC of 24 percent, and rubber spring walking beam suspensions had a DLC of 39 percent. Problems with walking-beam suspensions were also noted by Gillespie, et.al. who state that on rough and moderately rough roads, walking-beam suspensions without shock absorbers are typically 50 percent more damaging than other suspension types.

themselves. Use of road-friendly suspensions is beneficial, particularly for large trucking operations with well-controlled axle loadings.

LIFT AXLES

The widespread use of lift axles in both Canada and the United States has raised concerns for pavement wear caused by a lift axle being in a raised position and the potential misuses that result when a driver, attempting to improve fuel consumption, fails to lower the axle when loaded. A survey conducted in Canada[25] in 1988 and 1989 in Ontario and Quebec found that approximately 17 percent and 21 percent, respectively, of trucks on highways in those provinces had lift axles. Lift axles have been adopted in response to GVW limits that are governed by the number of axles and because trucks with multiple, widely spaced axles have difficulty turning on dry roads and the lift axles can be raised by the driver prior to turns.

Lift axles make compliance with and enforcement of axle weight limits difficult. There are many concerns about the use of lift axles and damage to roads and bridges. Improperly adjusted lift axles can be damaging to pavements. The lift axle can be adjusted to any level by the driver. If the lift axle load is too high, the lift axle is overloaded. If it is too low, other axles may be overloaded. For example, under current Federal limits, a four-axle single-unit truck with a wheelbase of 30 feet can carry 62,000 pounds: 20,000 pounds on the steering axle and 42,000 pounds on the rear tridem. This vehicle would produce approximately 2.1 ESALs on flexible pavements. However, if the first axle of the tridem is a lift axle that is carrying little or no weight, this vehicle would produce approximately 4.0 ESALs.

PAVEMENT IMPACT

The pavement impacts for this study were estimated by using the Nationwide Pavement Cost Model (NAPCOM). NAPCOM incorporates 11 different pavement distress models. Together these models represent the state-of-the-art in predicting pavement responses to different axle loads and repetitions at the National level.

Pavement design parameters for each State, such as soil strength, terminal PSI value and other considerations are considered in this analysis. Design methods reflect the latest State specific and AASHTO design manuals and guidelines. Costs are estimated for traffic on each highway functional class based upon analyses and over 100,000 pavement sections in the HPMS database.

UNIT PAVEMENT COSTS

Unit pavement costs and pavement costs per unit of payload-mile by configuration are shown in Table VI-6 and Table VI-7. They illustrate how the addition of axles allows for increased payloads and at the same time reduces pavement wear. Particularly striking, are comparisons between the three- and four-axle single unit trucks, the five- and six-axle semitrailer combinations,

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[25] Billing, et.al.

and the five- and eight-axle doubles. The four-axle truck has costs per payload ton-mile about 75 percent of that for the three-axle truck even though its gross weight is 10,000 pounds more than the three-axle truck. The comparison of the six-axle semitrailer with the five-axle is very similar. The costs for the eight-axle double are less than half those for the five-axle double. Triples do not compare well with the doubles, however. It should be noted, however, that truck owners would be opposed to adding axles because it increases the tare weight of the vehicle and reduces payload capacity. The benefits of increased numbers of axles insofar as pavement damage is concerned, as shown in Table VI-6 and Table VI-7 assume increases in the allowable gross vehicle weight.

TABLE VI-6
UNIT PAVEMENT COST FOR VARIOUS TRUCK CONFIGURATIONS

Truck Configurations										
Area Type	Truck Type	Single Unit		Semitrailer		Double-Trailer			Triple	
	Axles	Three	Four	Five	Six	Five	Seven	Eight	Seven	
	GVW (pounds)	54,000	64,000	80,000	90,000	80,000	100,000	105,000	100,000	115,000
	$/1,000 miles									
	Functional Class									
Rural	Interstate	0.09	0.07	0.05	0.05	0.03	0.10	0.05	0.04	0.08
	Prin. Art.	0.17	0.16	0.12	0.11	0.07	0.15	0.10	0.17	0.31
	Min. Art.	0.37	0.33	0.29	0.22	0.32	0.41	0.21	0.39	0.75
	Maj. Col.	1.38	1.35	0.90	0.80	1.17	1.03	0.65	1.46	2.95
	Min. Col.	2.27	2.08	1.49	1.24	1.92	1.69	1.07	2.42	4.87
	Locals	5.90	5.63	3.87	3.23	4.99	4.40	2.79	6.27	12.60
Urban	Interstate	0.06	0.04	0.04	0.04	0.03	0.04	0.02	0.03	0.05
	Fwy&Ewy	0.09	0.06	0.06	0.05	0.04	0.07	0.04	0.09	0.18
	Prin. Art.	0.13	0.12	0.10	0.09	0.11	0.09	0.06	0.13	0.26
	Min. Art.	0.30	0.24	0.22	0.17	0.19	0.18	0.12	0.34	0.70
	Collectors	0.66	0.70	0.54	0.49	0.46	0.34	0.25	0.86	1.82
	Locals	2.34	2.53	1.91	1.75	1.64	1.19	0.88	3.06	6.45

TABLE VI-7
UNIT COST PER PAYLOAD-MILE FOR VARIOUS TRUCK CONFIGURATIONS

Truck Configuration										
Area Type	**Truck Type**	**Single Unit**		**Semitrailer**		**Double-Trailer**			**Triple**	
	Axles	**Three**	**Four**	**Five**	**Six**	**Five**	**Seven**	**Eight**	**Seven**	
	GVW (pounds)	54,000	64,000	80,000	90,000	80,000	100,000	105,000	100,000	115,000
	Tare Weight	22,600	26,400	30.490	31,530	29,320	38,600	33,470	41,700	41,700
	Payload Weight	31,400	37,600	49,510	58,470	50,680	61,400	71,530	58,300	73,300
	$/1,000 ton-miles									
	Functional Class									
Rural	**Interstate**	0.006	0.004	0.002	0.002	0.001	0.003	0.001	0.001	0.002
	Prin. Art.	0.011	0.009	0.005	0.004	0.003	0.005	0.003	0.006	0.008
	Min. Art.	0.024	0.018	0.012	0.008	0.013	0.013	0.006	0.013	0.020
	Maj. Col.	0.088	0.072	0.036	0.027	0.046	0.034	0.018	0.050	0.080
	Min. Col.	0.145	0.111	0.060	0.042	0.076	0.055	0.030	0.083	0.133
	Locals	0.376	0.299	0.156	0.110	0.197	0.143	0.078	0.215	0.344
Urban	**Interstate**	0.004	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
	Fwy&Ewy	0.006	0.003	0.002	0.002	0.002	0.002	0.001	0.003	0.005
	Prin. Art.	0.008	0.006	0.004	0.003	0.004	0.003	0.002	0.004	0.007
	Min. Art.	0.019	0.013	0.009	0.006	0.007	0.006	0.003	0.011	0.019
	Collectors	0.042	0.037	0.022	0.017	0.018	0.011	0.007	0.030	0.050
	Locals	0.149	0.136	0.077	0.060	0.065	0.039	0.024	0.105	0.176

CONSIDERATIONS RELATED TO PAVEMENT REGULATION

TIRE REGULATIONS

Federal law and most States laws do not address truck tire pressure. Tire pressure may have a large effect on fatigue of flexible pavements as discussed earlier (albeit a small to moderate effect on rigid pavements) and today's tire pressures are higher than in the 1950s--primarily the consequence of a change from bias to radial ply tires. Concern has been raised about accelerated pavement rutting as a result of increased tire pressures. The research in recent years gives conflicting views as to whether or not pressures should be regulated.[26]

Federal, and most State, laws do not discourage or prohibit the use of wide-base tires. The consensus of U.S. and international research is that these tires have substantially more adverse effects on pavements than dual tires because current designs employ smaller, overall tire-road contact patch sizes than equivalent dual tire sizes. Future tire designs could address this issue. Wide-base tires--widely used in Europe--are being increasingly adopted by U.S. trucking operations. The benefits of wide-base tires are reduced energy use, emissions, tare weights, and truck operating costs. The trade-off between changes in Federal pavement costs and operating benefits that would result from permitting or prohibiting extensive adoption of wide-base tires in the United States has not been analyzed.

Many State laws do specify some form of tire load regulation to control the damage effect of wide-base tires. They restrict the weight that can be carried on a tire based on its width. The limits range from 550 pounds per inch (in Alaska, Mississippi, and North Dakota) to 800 pounds per inch (in Indiana, Massachusetts, New Jersey, New York, and Pennsylvania). Such restrictions result in lower pavement costs; however, the size of the pavement cost savings (either in absolute terms or in relation to the increase in goods movement costs also resulting from these restrictions) have not been estimated. This type of approach does, however, hold promise.

SPLIT-TANDEM VERSUS TRIDEM-AXLE LOAD LIMITS

There is increasing use of wide-spread (up to 10 feet) "split-tandem" axle groups, particularly in flatbed heavy haul operations. These axles are allowed to be loaded at single axle limits--20,000 pounds on each of the two axles as opposed to 34,000 pounds on a closed tandem. They offer two key benefits to five-axle tractor-semitrailer usage: (1) flexibility in load distribution; and (2) full achievement of the 80,000-pound GVW cap, which is limited by the ability to distribute up to 12,000 pounds on the steering axle of a combination. But they do so with significant pavement cost. Their expanding use could be counteracted with a higher tridem-axle load to the benefit of pavements.

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[26] TRB *Special Report 225* (1990) suggested regulation could be warranted if the more pessimistic analyses proved to be correct. NCHRP study (1993) suggested limiting tire pressure to the recommended cold setting plus 15-psi; AASHTO (1993) suggested more research is required to answer all questions regarding the relationship of tire size, contact pressure, and contact area to pavement damage.

In the United States, the allowable load on a group of three axles connected through a common suspension system (a tridem) is determined by the Federal bridge formula rather than a limit set by law (or regulation). In Europe, Canada, Mexico and most other jurisdictions, tridem axles are given a unique load limit in the same way the United States specifies unique single- and tandem-axle limits without direct reference to a bridge formula. This is not to say that these unique tridem limits are not bridge-related. In Canada, for example, the tridem limits prescribed by the Road Transport Association of Canada (RTAC), which vary as a function of spacing, are based on bridge loading limitations--not pavement limitations.

THE GROSS VEHICLE WEIGHT LIMIT

The 80,000-pound GVW limit (cap) is the existing legal Federal maximum GVW limit for the Interstate Highway System, although some States allow truck combination weights above the cap under grandfather rights. Axle weight limits and BFB are designed to protect pavements and bridges respectively. As such, the cap may not be providing any additional protection to pavements and bridges. Nevertheless, it is important to consider such factors as bridge design vehicles and criteria, structural evaluation procedures, the age of the existing bridges and the extent to which increased GVWs would affect the fatigue life of bridges in the United States.

44,000-POUND TRIDEM-AXLE WEIGHT LIMIT

Original research, done for this study, on the pavement and bridge impacts of tridem axles showed how bridge stresses decrease as the axles in the tridem group are spread apart. This allows more weight to be carried on the tridem group as the axles are spread. The opposite is true for pavement damage. The more the axles are spread the greater the damage. Therefore, as the axles are spread within the group, the allowable weight must be reduced to hold pavement damage constant.

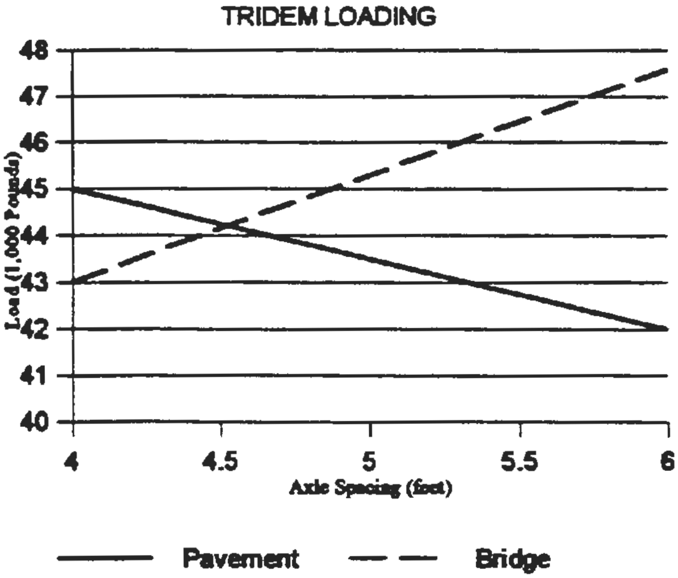
The tridem-axle weight limit of 44,000 pounds was determined by observing where the curve of the increasing bridge allowable load function crosses the curve of the decreasing pavement load equivalency function (see Figure VI-9). The two curves cross at a spread of 9 feet between the two outer axles which gives 44,000 pounds for both functions. To stop short of nine feet would require a lower load limit as bridge damage would be greater than at 44,000 pounds. To go beyond 9 feet would increase pavement damage over that at 44,000 pounds.

A six-axle semitrailer combination is more effective in reducing pavement damage than a five-axle semitrailer combination with a split-tandem (two trailer axles spread apart), which is allowed under the current Federal bridge formula. Table VI-8 provides the weight limits for a tridem axle between four and eight feet and Figure VI-8 illustrates the impact on pavement and bridges.

TABLE VI-8
TRIDEM AXLE WEIGHT LIMIT

Distance Between Adjacent Axles (feet)	Load at LEF=1	Allowable Bridge Load (1,000 pounds)
4	45	43
6	42	48.6
8	40	—

FIGURE VI-8
PAVEMENT AND BRIDGE IMPACT OF TRIDEM AXLE



USE OF TRIDEMS

Tridem axles could be considered as a way to increase truck load capacity while reducing pavement damage.[27] There already has been a switch from three-axle to four-axle single unit trucks by many heavy bulk freight haulers, and as noted above, significant pavement cost savings may be possible. The 80,000-pound GVW limit poses a constraint on adding axles to five-axle combinations because, under the GVW limit, the extra axle would reduce the payload.

When viewed using the AASHTO load-equivalence factors, combinations with tridem axles generally have much lower pavement costs per ton of freight carried than conventional five-axle combinations. To illustrate this, as shown in Figure VI-9, a six-axle tractor-semitrailer loaded to 90,000 pounds with a rear tridem carrying 44,000 pounds produces 2.00 ESALs on flexible pavements and 3.83 ESALs on rigid pavements. The corresponding ESAL values for a conventional five-axle tractor-semitrailer carrying 80,000 pounds are 2.37 (flexible) and 3.94 (rigid). However, as noted earlier, the reduced pavement costs of the tridem axle require increasing the allowable gross vehicle weight, in part because of the increased tare weight of the tridem axle.

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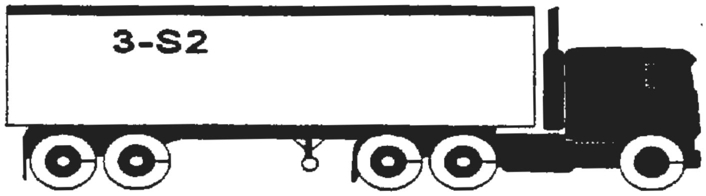
[27] Both the TRB *Special Report 225* and the AASHTO TS&W Subcommittee suggest consideration of the TTI bridge formula which could allow about 90,000 pounds for a six-axle tractor-semitrailer combination.

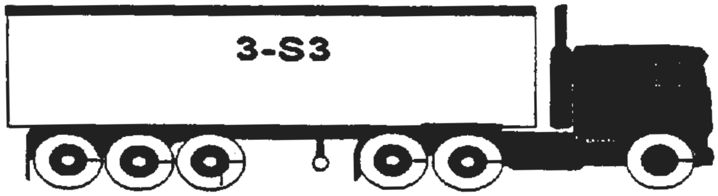
FIGURE VI-9
ESAL COMPARISON OF 5-AXLE AND 6-AXLE COMBINATIONS ON PAVEMENT

Five-Axle Tractor-Semitrailer



				Total
Weight (lbs)	34,000	34,000	12,000	80,000
ESALs				
Flexible	1.09	1.09	0.19	2.37
Rigid	1.88	1.88	0.18	3.94

Six-Axle Tractor-Semitrailer



				Total
Weight (lbs)	44,000	34,000	12,000	90,000
ESALs				
Flexible	0.72	1.09	0.19	2.00
Rigid	1.77	1.88	0.18	3.83

Assuming tare weights of 28,000 and 29,500 pounds for the five- and six-axle combinations, respectively, and using the AASHTO load equivalence factors, the ESALs per 100,000,000 pounds of payload for the trucks shown in Figure VI-9 are shown in Table VI-9. Research by others indicates a significantly smaller result in reduction of ESALs from increased payloads, for flexible pavements a reduction of 4 ESALs as opposed to 14 ESALs and for rigid pavements a reduction of 11 ESALs as opposed to 17 ESALs per million tons of payload.

TABLE VI-9
ESALs PER 100,000,000 POUNDS OF PAYLOAD FOR 5- AND 6-AXLE COMBINATION

	Flexible Pavement	**Rigid Pavement**
5-Axle Tractor-Semitrailer	46	76
6-Axle Tractor Semitrailer	33	63

ROADWAY GEOMETRY IMPACTS

ELEMENTS OF ROADWAY GEOMETRY IMPACTING TRUCK OPERATIONS

INTERCHANGE RAMPS

Access and exit ramps for controlled access highways are intended to accommodate design vehicles at certain design speeds, as well as for high speed and low speed offtracking by combination vehicles. AASHTO policy recommends widening to accommodate combination vehicles. For example, the width of a one-lane ramp, with no provision for passing a stalled vehicle, would be 15 feet on a tangent section.

The extreme case for design consideration occurs when traffic is congested and stop-and-go conditions are present. The speed component to the offtracking equation is negligible and maximum offtracking to the inside of the curve occurs. Under this condition, the turnpike doubles analyzed in this study offtrack 20 percent more than a five-axle, 53-foot semitrailer combination and as a result encroach on adjacent lanes or shoulders and necessitate widening beyond AASHTO standards.

INTERSECTIONS

Most trucks and truck combinations turning at intersections encroach on either the roadway shoulder or adjacent lanes. For example, the turning path of a truck making a right turn is generally controlled by the curb return radius, whereas the turning path in left turns is not constrained by roadway curbs, but may be constrained by median curbs and other traffic lanes. Combination vehicles with long semitrailers are critical in the determination of improvements to intersections required to accommodate offtracking requirements.

It is generally agreed that proper design and operation requires that no incursion into the path of vehicles traveling in opposing directions of flow be allowed. A higher standard is often used in design, especially in urban areas, where no incursion into any adjacent lane is allowed. This is particularly critical at signalized intersections where heavy traffic is a prevailing condition. A substantial number of intersections on the existing highway and street network cannot accommodate even a five-axle tractor semitrailer combination with a 48-foot semitrailer under the more stringent standard. Even more intersections would be inadequate to accommodate vehicles which offtrack more than the standard a 48-foot semitrailer.

Currently there are a substantial number of intersections on the highway and street network where improvements for combinations with semitrailers over 48 feet are not feasible and controls on vehicles, routing or travel times are required. Examples of common constraints to intersection improvements are bridges, buildings and sensitive environmental or historic plots. The use of permits in such cases can provide a desirable level of control, to the extent that they are enforced. Additionally, staging areas should be provided where routes and intersections have prohibitive constraints off the NN.

CLIMBING LANES

The ability of a truck to maintain speed on a grade is described by the term "gradeability" and the ability of a truck to start on a grade from a standstill is termed "startability." Truck "driveability" is defined as the percentage grade on which full throttle is required in top gear to maintain cruising speed. The ability of various trucks to start and to maintain speeds on grades is a complex subject which primarily depends on net engine horsepower, torque, gearing, drive train efficiency, friction, GVW and minimum allowable speed. Gradeability and startability are discussed more fully in Chapter 5, Safety and Traffic Operations. The AASHTO recommends that separate climbing lanes be provided on grades that have substantial truck traffic and that cause typical trucks to slow by more than 10 miles per hour.

CROSS SECTION

Cross section refers to the shape of the surface of the roadway transverse to the direction of traffic[28]. Under normal operating conditions, cross section is not a dominant factor in increased TS&W, but under extreme icing conditions, a superelevated cross slope can be a significant problem for vehicles which have greater off-tracking. The presence of cross slope discontinuities can also be a problem for vehicles more prone to rollover because of the dynamic forces which they tend to introduce.

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[28] The major determinants of the cross section are the number of lanes, the presence of curbing or shoulders, and cross slope. Generally, a slight cross slope is designed into the cross section to assist in proper drainage of precipitation. Often this slope breaks to a steeper slope at the shoulder line, on a divided multilane highway the cross slope is generally highest at the centerline.

HORIZONTAL CURVATURE

The rear wheels of trucks and truck combinations-traversing horizontal curves generally offtrack to one side or the other of the paths of the wheels on the steering axle. When a truck is traveling at higher speeds the rear wheels can follow a path outside that of the steering wheels. This effect is relatively small and virtually never results in the need to make geometric improvements beyond those normally made in the design process. On the other hand, when offtracking is to the inside of the curve at lower speeds and in stop-and-go traffic, it is usually more substantial and must be accommodated. Trucks in combination with longer trailers are often prone to producing relatively large amounts of offtracking beyond that provided for in AASHTO standards. On roadways not constructed to AASHTO standards more improvement would be required to accommodate longer combinations where offtracking would exceed normal lane width.

VERTICAL CURVE LENGTH

The height of the truck driver's eye is a distinct advantage of trucks over passenger vehicles for crest vertical curves which are designed to maximize stopping sight distance. Vertical curves are generally designed for passenger cars as the passenger car driver's eye is closer to the pavement than that of the truck driver. For a sag vertical curve going from a downgrade to an upgrade, headlight coverage and passenger comfort usually control. The vehicles considered in this study have braking distances similar to vehicles in common use at this time; therefore no geometric adjustments would be required.

SIGHT DISTANCES- STOPPING AND PASSING

Passing distances involving trucks can be significantly longer than when no trucks are present. Longer trucks increase the distance required for a car or truck to pass and require more care in order do so safely.

Drivers of passenger cars passing trucks, and drivers of trucks who desire to pass other vehicles, are expected to follow the rules of the road and exercise discretion, passing only where sight distance is adequate. On multi-lane highways passing is generally not as critical as passing on a two-lane highway with traffic in opposing directions. Sight distance criteria for marking passing and no-passing zones on two-lane highways are more appropriate for a passenger car passing another passenger car, and do not consider trucks, even the standard truck and 48-foot semitrailer combination vehicle at 80,000 pounds.

Increasing TS&W limits for LCVs could require as much as 8 percent more passing sight distance for cars passing LCVs on two-lane roads and longer and/or heavier trucks would require incrementally longer passing sight distances to safely pass cars on two-lane roads.

DIMENSIONAL LIMITS IMPACTING TRUCK MANEUVERS

LENGTH LIMITS OF SEMITRAILERS

The Surface Transportation Assistance Act (STAA) of 1982 established a minimum length limit that requires States to allow the operation of a semitrailer of at least 48 feet on the National Network (NN) for large trucks. All States now allow up to 53 feet on at least some highways. The majority of States prohibit semitrailers longer than 53 feet, the exceptions being Alabama, Arizona, Arkansas, Colorado, Kansas, Louisiana, New Mexico, Oklahoma, Texas, and Wyoming.[29] These States allow trailers in the 57- to 60-foot range to operate.

LENGTH LIMITS FOR DOUBLE-TRAILERS IN COMBINATION

The STAA of 1982 also established a requirement for States to allow, at a minimum, the operation of two 28-foot trailers (twins) in combination on the Interstate and NN. About one-fourth of the States prescribe 28 feet as a maximum; the others allow additional length up to 30 feet with 28.5 feet being the most common.

Prior to the Intermodal Surface Transportation Efficiency Act of 1991, Federal law allowed States to permit longer trailers in combination, commonly referred to as doubles, but did not require States to allow them.

OVERALL LENGTH LIMITS

The STAA of 1982 established a prohibition against State laws that specify a maximum length for tractor-semitrailer and STAA[30] double combinations operating on the Interstate and NN. Consequently, most States control total length on the NN by limiting semitrailer and trailer lengths. About two thirds of the States have some form of control of total combination length for non-NN highways. While there are no proposals that the Federal law prescribe a total length limit at this time, offtracking standards could effectively limit overall lengths for single- and double-trailer combinations.

VEHICLE WIDTH AND HEIGHT LIMITS

Vehicle widths and heights, although important from the standpoint of safety and traffic operations, have little effect on roadway geometric design except for lane width.

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[29] *Federal Size Regulations for Commercial Motor Vehicles*, U.S. DOT, Publication No. FHWA-MC-96-03.

[30] Also known as Western doubles

ROADWAY GEOMETRY AND TRUCK OPERATING CHARACTERISTICS

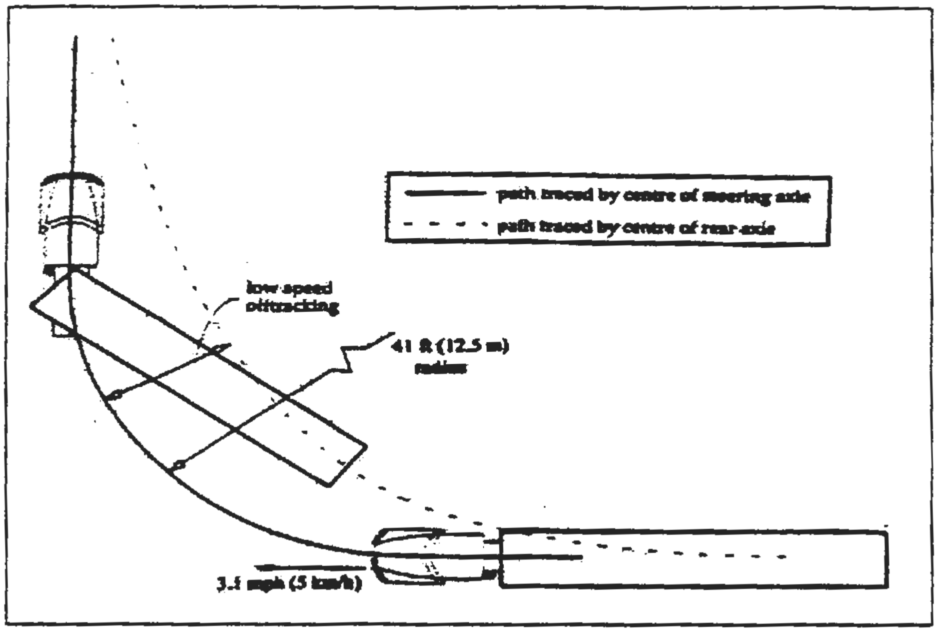
When a vehicle makes a turn, its rear wheels do not follow the same path as its front wheels. The magnitude of this difference in path, known as "offtracking", generally increases with the spacing between the axles of the vehicle and decreases for larger radius turns. Offtracking of passenger cars is minimal because of their relatively short wheel bases; however, many trucks offtrack substantially. The magnitude of the offtracking is often measured by the differences in the paths of the centerlines of the front and subsequent axles.

OFF-TRACKING AND INTERSECTION MANEUVERS

Low-Speed Off-Tracking

When a combination vehicle makes a low-speed turn--for example a 90 degree turn at an intersection--the wheels of the rearmost trailer axle follows a path several feet inside the path of the tractor steering axle. This is called low-speed offtracking. Excessive low-speed offtracking may make it necessary for the driver to swing wide into adjacent lanes to execute the turn (that is, to avoid climbing inside curbs or striking curbside fixed objects or other vehicles). When negotiating exit ramps, excessive offtracking can result in the truck tracking inboard onto the shoulder or up over inside curbs. This performance attribute is affected primarily by the distance from the tractor kingpin to the center of the trailer rear axle, or the wheelbase of the semitrailer. In the case of multiple-trailer combinations, the effective wheelbase(s) of all the trailers in the combination, along with the tracking characteristics of the converter dollies, dictate this property. In general, longer wheelbases worsen low-speed offtracking. Figure VI-10 illustrates low-speed off-tracking in a 90-degree turn for a tractor-semitrailer.

FIGURE VI-10
LOW-SPEED OFF-TRACKING



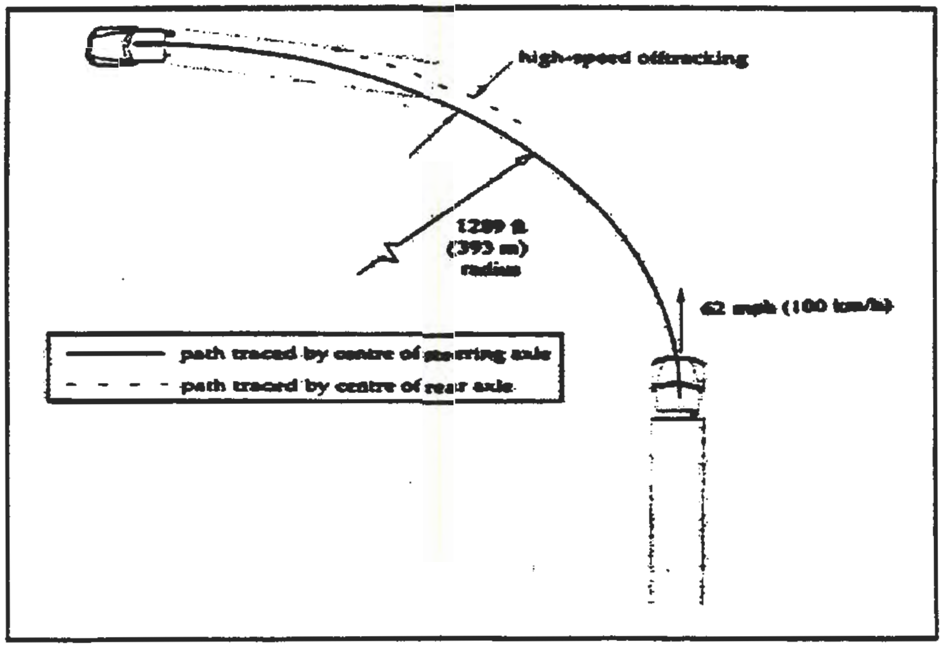
The standard double-trailer combination (two 28-foot trailers) and triple combinations (three 28-foot trailers) exhibit better low speed offtracking performance when compared to a standard tractor and 53-foot semitrailer combination. This is because they have more articulation points in the vehicle combination, and use trailers with shorter wheelbases.

High-Speed Off-Tracking

High-speed offtracking, on the other hand, is a dynamic, speed-dependent phenomenon. It results from the tendency of the rear of the truck to move outward due to the lateral acceleration of the vehicle as it makes a turn at higher speeds. High-speed offtracking is actually the

algebraic combination of the low-speed offtracking toward the inside of the turn and the outward displacement due to the lateral acceleration. As the speed of the truck increases, the total offtracking decreases until, at some particular speed, the rear trailer axles follow exactly the tractor steering axle. At still higher speeds, the rear trailer axles will track outside of the tractor steering axle. The speed-dependent component of offtracking is primarily a function of the spacing between truck axles, the speed of the truck, and the radius of the turn; it is also dependent on the loads carried by the truck axles and the truck suspension characteristics.
Figure VI-11 illustrates off-tracking maneuver for a standard tractor-semitrailer.

FIGURE VI-11
HIGH-SPEED OFF-TRACKING



OFF-TRACKING ON MAINLINE HORIZONTAL CURVES AND INTERCHANGE RAMPS

An analysis of offtracking and swept path width for horizontal curves designed in accordance with AASHTO's high-speed design criteria (1994) was completed for the vehicle configurations considered in this study. Such curves are typically found on mainline roadways and higher speed ramps. Alternative design criteria that permit higher unbalanced lateral acceleration and, thus, tighter radii can be used under AASHTO policies for horizontal curves with design speeds of 40 mph or less, which are typically found on ramps and turning roadways at intersections.

Under AASHTO policy, the minimum radius for a horizontal curve varies with the roadway design speed and the maximum super-elevation rate.[31] For horizontal curves with a maximum super-elevation rate of 0.06 ft/ft (the maximum super-elevation rate most commonly used by State highway agencies), the minimum radii permitted by the AASHTO high-speed design criteria vary with design speed, as shown in Table VI-10.

TABLE VI-10
AASHTO HIGH-SPEED DESIGN CRITERIA

Design Speed (MPH)	Minimum Radius (Feet)
30	273
40	509
50	849
60	1,348
70	2,083

AASHTO policy for horizontal curve design specifies pavement widening on sharp radius horizontal curves for which truck offtracking is a concern. For the minimum-radius curves listed above on a highway with a lane width of 12 feet on tangent sections, only the 273-foot radius curve (for a 30-mph design speed) would require widening. AASHTO criteria call for such a curve to be widened from 12 to 14.5 feet.

An analysis was conducted to determine whether minimum-radius curves with the widths described above, designed in accordance with AASHTO policies, would be capable of accommodating each of the vehicle configurations considered in this study. This analysis was conducted by comparing the lane or ramp width to the swept path width of the truck making a turn with the specified radius. Tables VI-11 and VI-12 present this comparison for selected truck configurations.

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[31] AASHTO, 1994.

The swept path widths in Table VI-11 are based on fully-developed offtracking determined with the Glauz and Harwood model for a truck traversing the curve with a travel speed equal to the roadway design speed. None of the swept path widths shown in Table VI-11 exceed the corresponding lane width for mainline roadways or the corresponding ramp widths, although the turnpike double with 53-foot trailers does require nearly all of the (widened) 14.5 feet of the 30-mph AASHTO horizontal curve. Thus, there is no indication that any of the Study vehicles, traveling at the roadway design speed, would necessarily offtrack into an adjacent lane or shoulder of the roadway or ramps designed in accordance with AASHTO policies.

Table VI-12 presents comparable results when the trucks travel at very slow speeds on these same curves, such as they may be required to do in congested traffic. The swept path widths at low speed in Table VI-12 are generally greater than those in Table VI-11, but except for the Turnpike Doubles, none of the study vehicles would encroach on adjacent lanes or shoulders. Both Turnpike Doubles would encroach on adjacent lanes or shoulders on 30-mph design speed horizontal curves, and the Turnpike Double with 53-ft trailers would low-speed off-track into adjacent lanes or shoulders on 40-mph design speed horizontal curves and on 30-mph design speed ramps.

TABLE VI-11
SWEPT PATH WIDTH FOR SELECTED TRUCKS ON HORIZONTAL CURVES AT AASHTO DESIGN SPEED CRITERIA

		Maximum Swept Path Width (feet) at the Design Speed on the Sharpest Horizontal Curve Allowed by AASHTO Design Policy		
	Design Speed (mph)	30	40	60
	Curve Radius (feet)	273	509	1,348
Truck Configuration	**Length (feet)**			
Three-Axle Single Unit Truck	39.5	8.12	8.00	8.00
Five-Axle Tractor Semitrailer	64.3	10.09	8.56	8.50
Five-Axle Tractor Semitrailer	76.8	11.88	9.43	8.50
Six-Axle Tractor Semitrailer	64.3	10.05	8.63	8.50
Six-Axle Tractor Semitrailer	76.8	11.79	9.48	8.50
Five-Axle Truck-Full Trailer	63.3	8.32	8.00	8.00
Seven-Axle Truck-Full Trailer	61.3	8.44	8.00	8.00
Six-Axle Western Double	74.3	9.02	8.50	8.50
Seven-Axle Rocky Mtn Double	99.3	11.62	9.21	8.50
Eight-Axle B-Train Double	84.3	10.39	8.70	8.50
Nine-Axle Turnpike Double	114.3	12.85	9.83	8.50
Nine-Axle Turnpike Double	124.3	14.29	10.54	8.50
Seven-Axle Triple	109.0	9.69	8.50	8.50

TABLE VI-12
SWEPT PATH WIDTH FOR SELECTED TRUCKS ON HORIZONTAL CURVES AT VERY LOW SPEED

		Maximum Swept Path Width (feet) at Very Low Speed on the Sharpest Horizontal Curve Allowed by AASHTO Design Policy		
	Design Speed (mph)	30	40	60
	Curve Radius (feet)	273	509	1,348
Truck Configuration	**Length (feet)**			
Three-Axle Single Unit Truck	39.5	8.80	8.26	8.00
Five-Axle Tractor Semitrailer	64.3	11.54	9.95	8.80
Five-Axle Tractor Semitrailer	76.8	13.65	11.12	9.30
Six-Axle Tractor Semitrailer	64.3	11.21	9.74	8.67
Six-Axle Tractor Semitrailer	76.8	13.22	10.85	9.14
Five-Axle Truck-Full Trailer	63.3	9.02	8.38	8.00
Seven-Axle Truck-Full Trailer	61.3	8.98	8.34	8.00
Six-Axle Western Double	74.3	10.38	9.31	8.55
Seven-Axle Rocky Mtn Double	99.3	13.65	11.15	9.35
Eight-Axle B-Train Double	84.3	11.92	10.16	8.89
Nine-Axle Turnpike Double	114.3	15.04	11.92	9.67
Nine-Axle Turnpike Double	124.3	16.69	12.83	10.05
Seven-Axle Triple	109.0	12.15	10.40	9.14

INTERSECTION MANEUVERS

Trucks turning at intersections have the potential to encroach on either the roadway shoulder or adjacent lanes. The turning path of a truck making a right turn is controlled by the curb return radius. Truck paths in left turns are not constrained by roadway curbs, but may be constrained by median curbs and other traffic lanes.

The analyses assume that the turn is made at the intersection of two two-lane or two four-lane streets and that the truck making the turn positions itself as far to the left as possible on the approach to the intersection without encroaching on the opposing lanes, and completes the turn as far to the left as possible without encroaching on the opposing lanes. In other words, the truck does encroach on adjacent lanes for traffic moving in the same direction (on four-lane roads), but does not encroach on lanes used by traffic moving in the opposing direction. The maneuver specified above requires a turning radius for the truck tractor which is 8 feet longer than the curb return radius on a two-lane road, and 20 feet longer than the curb return radius on a four-lane road, if all lanes are 12 feet wide.

Table VI-13 presents estimates of encroachment on the curb return for selected trucks for right turns at corners with curb return radii of 30, 60, and 100 feet. The data in these tables are based on the maximum value of the partially-developed offtracking because, in most cases, offtracking will not develop fully as a large truck proceeds through an intersection turning maneuver.

TABLE VI-13
CURB ENCROACHMENT FOR 90-DEGREE RIGHT-TURN MANEUVERS AT INTERSECTION OF FOUR-LANE ROADS

		Encroachment on Curb Return		
Truck Configuration	Length (feet)	30-foot Curb Return Radius	60-foot Curb Return Radius	100-foot Curb Return Radius
Three-Axle Single Unit Truck	39.5	-9.97	-12.07	-13.37
Five-Axle Tractor Semitrailer	64.3	-0.09	-4.47	-7.88
Five-Axle Tractor Semitrailer	76.8	6.42	1.11	-3.49
Six-Axle Tractor Semitrailer	64.3	-1.06	-5.27	-8.49
Six-Axle Tractor Semitrailer	76.8	5.34	0.16	-4.25
Five-Axle Truck-Full Trailer	63.3	-7.41	-10.29	-12.17
Seven-Axle Truck-Full Trailer	61.3	-8.10	-10.82	-12.54
Six-Axle Western Double	74.3	-4.06	-8.01	-10.37
Seven-Axle Rocky Mt. Double	99.3	6.73	1.23	-3.48
Eight-Axle B-Train Double	84.3	1.58	-3.23	-7.02
Nine-Axle Turnpike Double	114.3	11.02	4.91	-.057
Nine-Axle Turnpike Double	124.3	15.38	8.83	2.69
Seven-Axle Triple	109.0	1.97	-2.97	-6.87

The encroachment columns in Table VI-13 indicates the amount of encroachment on the curbline by the rear axles of the turning truck. a negative value for encroachment indicates that the truck does not encroach on the curbline. a positive value indicates that encroachment does occur and the magnitude of the value indicates the maximum encroachment distance. Where a positive value is shown for the encroachment distance, that particular truck could make the turn without encroaching on the curbline only if it encroached on an opposing lane(s) instead.

The turn from a four-lane street to another four-lane street was chosen as the case of interest because none of the trucks considered—baseline or study vehicles—are capable of making a short-radius turn from one two-lane street to another without encroaching on either the curbline or an opposing lane, unless the curb return radius is very large (100 feet, say), and then only by selected very short trucks.

With a 30-foot curb return radius (Table VI-13), many of the truck configurations will encroach on the curb return, with a few exceptions. The single unit trucks, the tractors with a 45-foot semitrailer, the truck-full trailers, and the western twins can successfully negotiate these turns. The encroachment of the five-axle semitrailer configuration with a 45-foot trailer is very marginal, however, as is the triple with 28-foot trailers.

By expanding the curb return radius to 60 feet (Table VI-13), nearly all configurations examined can negotiate the turn without encroaching on the curb return. The exceptions which can not successfully complete the turn are the tractors with 57.5-foot semitrailers, the longer Rocky Mountain double, and (particularly) the turnpike doubles.

At an even larger curb return radius of 100 feet (Table VI-13), all but the turnpike double with 53-foot trailers can properly negotiate the turn.

CURRENT REGULATIONS ON OFF-TRACKING

Federal law is silent on offtracking-related characteristics of trucks and combinations. In particular, it specifies no requirements on kingpin setting, kingpin setback, and rear overhang. In nearly one-half of the States regulations require a kingpin setting for semitrailers over 48 feet in length. Although there is no one uniform standard, the most common setting distance is 41 feet.

REGULATION ALTERNATIVES

Control of offtracking can be accomplished in one of two ways. The first requires considering the length limit(s) of the semitrailer(s) within the context of total combination length limit, restrictions on the kingpin setback, wheelbase, and effective rear overhang as in the Canadian regulations. a more straightforward alternative is a performance specification requiring that a truck be able to turn through a given angle, at a given speed, within a defined swept path as in the European regulations.

DRAFT

CHAPTER 7

ENFORCEMENT OF TRUCK SIZE AND WEIGHT REGULATIONS

INTRODUCTION

Identifying implementation issues associated with changes to truck size and weight (TS&W) regulations cannot be accomplished without first investigating the enforcement and administration of the existing size and weight regulations. This chapter provides a current "snapshot" of State TS&W enforcement and permitting practices. Also presented is historical data on enforcement and permit practices, resource allocation, initiatives to improve the effectiveness and efficiency of the program, as well as the Motor Carrier Safety Assistance Program (MCSAP). Federal and State roles are also discussed.

EVOLUTION OF FEDERAL/STATE ENFORCEMENT PRACTICE

PRE-SURFACE TRANSPORTATION ASSISTANCE ACT OF 1982

Federal size and weight regulation has evolved over time in response to changing National responsibilities, interests and needs, including the promotion of interstate commerce. A National highway system consisting of a network of "inter-regional" highways was envisioned as early as the 1921 Highway Act, and subsequently led to the designation of the Interstate System in 1956. Prior to the 1921 Act, individual States exercised sole responsibility for determining what roads were built and what improvements would be made with the Federal funds received under an apportionment formula. The 1956 Highway Act provided funding to the States from the newly created Highway Trust Fund financed by taxes on highway users under the "user pays" concept. With the exception of the Interstate System, States still decide what roads are improved and what improvements are made.

The Highway Act of 1956 also established the Federal involvement in weight regulation by enacting weight limits of 18,000 pounds for single axle, 32,000 pounds for tandem axle, and 73,280 pounds for gross vehicle weight (GVW) trucks and combination vehicles allowed on the new Interstate System. States which had weight limits in excess of the new Federal limits as of July 1, 1956 were given "grandfather rights." These "grandfather rights" were extended without any indication of a sunset date. The 1956 Federal weight limits remained in effect until the Federal-Aid Highway Act of 1974 when they were increased to the current limits of 20,000 pounds for a single axle, 34,000 pounds for tandem axle, and 80,000 pounds for GVW. States choosing to adopt the new 1974 weight limits were also required to adopt the new "bridge formula B." The provision of Federal-aid for highways carried with it a requirement that the States actively enforce both Federal and State weight limits.

Federal requirements for assurance of State enforcement of Federal weight limits evolved over time. Prior to 1974, the States typically sent a letter to the Federal Highway Administration (FHWA) each year stating that their laws were in compliance with the Federal laws. An annual statement (certification) of the Governor (or representative) was required starting in 1974. The Department of Transportation (DOT) adopted, through regulation, the requirement for an annual State Enforcement Plan (SEP). To assure full compliance with their certifications, the Surface Transportation Assistance Act (STAA) of 1978 authorized DOT to impose stricter requirements on the States. The annual SEP has become the measure of performance against which the certification is evaluated and compliance determined. A State which is deemed to be noncompliant may be penalized by withholding 10 percent of its Federal-aid highway funding.

Although States may be sanctioned for noncompliance with the enforcement requirement, funding of weight enforcement activities remained solely a State responsibility until 1992. State highway departments, as a rule, are authorized to construct and maintain the infrastructure, whereas State law enforcement departments are authorized and funded to enforce all laws, including TS&W. Consequently, the level of enforcement is, to a great extent, dependent on cooperation between two or more State agencies and a commitment of State resources for facilities and equipment (State highway or transportation department) and personnel (State law enforcement agency).

The 1979 General Accounting Office (GAO) report on State enforcement of weight limits cited a need for improvement of the State enforcement program administered by the FHWA. The report was critical of the DOT for failing to provide guidance and assistance to the States to improve programs. Other concerns raised by the GAO report included the States' expanded use of "grandfather" provisions for divisible loads, and the lack of uniformity in penalties, permit administration and enforcement among the States. The requirement of the annual SEP was one response by FHWA to the GAO report.

The 1981 Section 161 Report[1] by DOT to the Congress on TS&W noted that the Federal role and responsibility in the enforcement area was established by Congress in 1974 by requiring annual State certification. Evaluation of State enforcement and permit practices focused primarily on the use of an "apparent low level of activity" as the trigger for threatening sanctions in some States in the late 1970s. Measures cited in determining "low level of activity" were ratios of truck registrations to truck weighings, ratios of citations to weighings, and the number of scales per mile of Federal-aid highway. According to the 1981 Report, under these measures, 35 States were considered to be noncompliant or borderline and in need of some form of FHWA action.

POST-SURFACE TRANSPORTATION ASSISTANCE ACT OF 1982

Prior to the STAA of 1982 the Federal interest in enforcement was primarily in assuring that maximum axle and gross vehicle weight limits applicable to Interstate Highways and "Bridge Formula B" were enforced. Subsequent to the passage of STAA of 1982, the Federal preemption of State laws governing certain length limits and legal vehicle combinations expanded the Federal interest in size and weight regulation to include uniformity in dimensions for the highway movement of freight. The States establish the limits on size and weight for vehicles and loads on highway systems other than the Interstate (where weight, width, length and configurations are largely governed by Federal law) and the National Network (NN) for large trucks (where size and configuration of vehicles are partly governed by Federal law). The Interstate and NN total approximately 200,000 miles (44,000 Interstate and approximately 155,000 Non-Interstate Federal-Aid Primary system) which amounts to 5 percent of total public highway mileage.[2]

The impact of STAA preemption was significant for many States. Although FHWA solicited State input through a notice in the Federal Register, many States felt they did not have an opportunity to review the non-Interstate routes designated for the STAA vehicles in advance and as a consequence many narrow, winding, mountainous routes with insufficient standards were included in the initial FHWA designation. Subsequently, FHWA revised the routes based on the State review and submissions. Further, State enforcement and administrative issues had not been addressed, creating confusion for both enforcement personnel and carriers. Since access beyond the "designated system" was determined by the States, regulations and procedures needed to be developed for a route review process and/or issuing permits.

Enforcement of restricted routes for the 1982 STAA vehicles required information (such as maps or signs) including what routes were restricted and the vehicle configurations not allowed. The enforcement of the limits on the "non-designated" system was incorporated within State size and weight enforcement programs. FHWA rules to resolve and standardize reasonable access for STAA vehicles became effective in 1991 and since then, virtually all problems regarding access for STAA vehicles have been resolved.

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[1] *An Investigation of Truck Size and Weight Limits,* August 1981, Report of the Secretary of Transportation to the United States Congress.

[2] Highway Statistics 1990, Table HM-43, FHWA-PL-91-003.

ADMINISTRATION OF THE FEDERAL/STATE VEHICLE WEIGHT ENFORCEMENT PROGRAM

The mission of the Federal vehicle weight enforcement program is to administer FHWA's size and weight enforcement efforts as well as to monitor State compliance with Federal requirements.[3] As noted by FHWA "the need for truck weight enforcement must be balanced against other enforcement efforts including those for traffic law and criminal activity. The question is not, "are States enforcing truck weight laws, but rather how much enforcement is enough?"[4] In that regard, it was noted by FHWA in 1991, that since the requirement of SEPs in 1979, the State enforcement of truck weight limits improved from a national perspective. FHWA cited the significant number of trucks which were weighed and the citations issued, as well as the increasing use of technology [primarily weigh-in-motion (WIM)] for weight enforcement, as indicators of improvement. Although significant problems continue to exist.

CURRENT LEVEL OF STATE PERMITTING AND ENFORCEMENT

Both Federal and State governments are involved in TS&W enforcement. Generally speaking, the Federal role and responsibility can be described as monitoring the status and performance of the Nation's highway system and responding to Congressional intent specified in law. The State role and responsibility can be described as implementing Federal and State policy through enforcement of the size and weight laws (Federal and State) in a judicious manner for the purpose of preserving the Federal and State infrastructure investments.

The Federal TS&W program is administered by the Office of Motor Carriers (OMC) within the FHWA. The States are grouped into nine regions and each region is responsible for coordinating, reviewing, and providing recommendations on acceptance of the annual SEPs and certifications of the States in their region. The requirement for annual certification of enforcement has been in effect since 1974 and for the SEP since 1979. The SEPs provide the baseline for evaluation of the certifications, which in turn provide FHWA with a means of evaluating trends and identifying potential issues associated with State enforcement and permitting.

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[3] Stated in FHWA comments to the OIG's 1991 draft "Audit of the Vehicle Weight Program."

[4] This is a question that continues to be evaluated, however, as evidenced by the FHWA ANPRM 93-28 "Certification of Size and Weight Enforcement".

The State certifications provide the data which are summarized and published by FHWA in the annual "Inventory of State Practices." The State data reviewed for this chapter are summarized in Appendices __ and __, and analyzed in the aggregate as well as on a State or regional basis in the chapter. These data provide insight into trends, areas of State commonality and differences, the impact of various techniques or types of enforcement, and other factors which might influence the level of effort. Data and information obtained through nine State visits is discussed later in this chapter and interspersed throughout the various sections.

Efforts to improve weight enforcement and permit programs, at both the Federal and State level, are ongoing. The FHWA review of annual certifications may lead to changes in State laws which are determined to be "inconsistent" with Federal law, or which may be considered too lenient. For example, the State of Washington increased its permit fees in 1995 to incorporate damage costs following an FHWA review.

Additionally, actions are occurring at the State level to reduce incentives for overweight truck operations. Many States are in the process of reviewing the adequacy of fines and permit fees for overweight vehicles. Some have increased fines and/or fees to recover more of the damage costs. However, at the present time fees and fines in the majority of States are too low to recover costs. Weight enforcement officers provide seminars or educational sessions for State legislators and judicial officers as part of outreach. Many States participate in the national Commercial Vehicle Information and Systems Networks (CVISN) effort as "pilot or prototype" States. The CVISN effort and technology deployment are discussed later in the chapter. States are also moving toward computerization of their permit programs and adopting regionally uniform permit regulations for non-divisible loads.

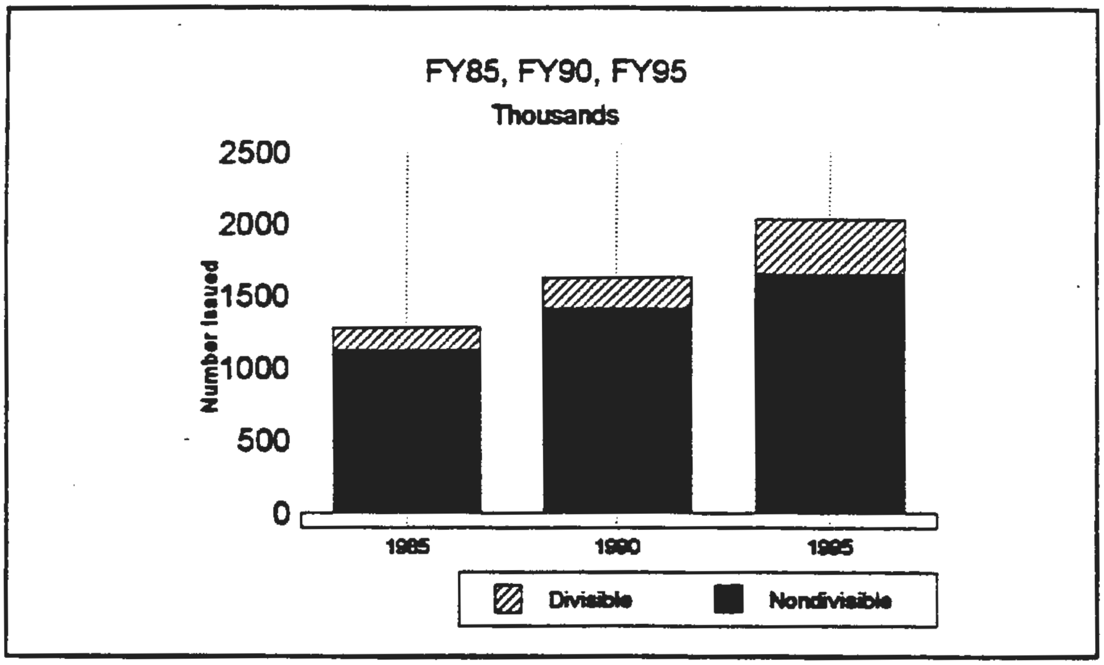
STATE PERMITTING OF TRUCK SIZE AND WEIGHT

State administration of TS&W regulations includes issuing permits for non-divisible and divisible loads that have been mandated by State legislatures or are protected by "grandfather rights." Prior to ISTEA there were 41 States which exercised Congressionally authorized "grandfather rights," with 34 issuing overweight permits for divisible loads.

PERMITS ISSUED

As Figure VII-1 shows, the most significant increase in overweight permitting has been in the number of divisible load permits issued. That number increased by 148 percent from FY 1985 through FY 1995 while nondivisible-load permits increased by 50 percent.

FIGURE VII-1
OVERWEIGHT PERMITS ISSUED BY STATES



The details of these trends are shown in Table VII-1. In the eleven-year period the total number of overweight permits issued annually (divisible and non-divisible) grew from 1.2 million in 1985 to 2.0 million in 1995, an increase of 60 percent.

Grandfathered gross weight and axle weight limits and overweight permits constitute "legally overweight" vehicles and result from Federal and State statutes allowing their use. From a cost recovery perspective the use of "multi-trip" permits is more problematic for at least two reasons: (1) they allow virtually unlimited operation of overweight vehicles on the highway system, and (2) fees for State permits (divisible and non-divisible) are often insufficient and unrelated to damage imposed and associated costs.

TABLE VII-1
STATE PERMITTING OF OVERWEIGHT LOADS, FY85-FY95

Year	Divisible Trip	Divisible Multi-trip	Divisible Total	Nondivis. Trip	Nondivis. Multi-trip	Nondivis. Total	Total Permits
1985	62,810	90,832	153,642	1,072,776	46,451	1,119,227	1,272,869
1986	53,976	96,193	150,169	1,149,625	59,274	1,208,899	1,359,068
1987	51,824	102,759	154,583	1,136,649	67,132	1,203,781	1,358,364
1988	64,955	112,801	177,756	1,151,732	61,222	1,212,954	1,390,710
1989	67,194	136,267	203,463	1,205,394	76,687	1,282,081	1,485,544
1990	73,270	140,697	213,967	1,321,261	88,362	1,409,623	1,623,590
1991	163,228	160,914	324,142	1,259,176	66,848	1,326,024	1,650,166
1992	184,711	162,040	346,751	1,347,773	92,734	1,440,507	1,787,258
1993	160,847	166,865	327,712	1,325,802	104,870	1,430,672	1,758,384
1994	157,114	198,236	355,350	1,426,143	116,934	1,543,077	1,898,427
1995	169,013	211,502	380,515	1,543,270	106,746	1,650,016	2,030,531

Source: FHWA Annual Inventory of State Practices, Overweight Vehicles—Penalties and Permits, FY85-FY94; and FY95 Annual State Certifications

Table VII-2 compares data for 1983, 1989 and 1995 from the 40 States that issued divisible load permits. During that period of time, there was significant growth in the number of multi-trip permits, with the exception of two States. Trip permits offer more control and information on routes and mileage of operation for the issuing agency, whereas the multi-trip[5] permits essentially allow unlimited operation with no accounting for mileage or routes for a greater length of time, generally a year.

Thirty-nine States and the District of Columbia issued divisible load permits in the period between 1983 and 1995 (see Table VII-2). Six States that issued divisible load permits in 1983 stopped issuing them by 1995 (Arizona, Hawaii, Illinois, Pennsylvania[6], Tennessee, and Virginia).

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[5] This includes monthly, "blanket," and "annual" permits.

[6] This was reversed in 1996 when Pennsylvania implemented legislation mandating permits for milk.

TABLE VII-2
DIVISIBLE LOAD PERMITS ISSUED BY STATES

STATE	SINGLE TRIP 1983	SINGLE TRIP 1989	SINGLE TRIP 1995	MULTIPLE TRIP 1983	MULTIPLE TRIP 1989	MULTIPLE TRIP 1995
Alaska	0	0	16	0	43	0
Arizona	1,286	0	0	8	0	0
Colorado	0	5	0.00	0	85	3,002
Connecticut	(a)	0	0	(a)	1,844	1,986
Dist of Col	0	0	161	646	954	563
Florida	0	0	0	1,256	0	0
Georgia	0	12,835	54,253	0	202	1,376
Hawaii	43	5	0	194	85	0
Idaho	0	139	0	4,866	15,165	16,262
Illinois	169	399	0	0	0	0
Indiana	0	18,130	53,982	(b)	6,182	0
Iowa	0	0	0	0	132	191
Kansas	0	0	0	0	0	1,807
Kentucky	0	0	0	382	4,035	3,831
Louisiana	0	0	0	0	0	8,591
Massachusetts	0	0	0	8,211	14,942	12,972
Michigan	61	0	0	657	540	968
Minnesota	1,257	0	0	1,076	1,722	3,260
Montana	0	2,275	5,246	0	5,468	11,846
Nebraska	3,296	0	20,816	0	837	84
Nevada	8	15	48	917	229	2,599
New Hampshire	0	0	0	0	NA	0
New Mexico	0	0	0	0	0	225
New York	©	0	0	©	37,122	54,038
North Carolina	0	0	640	0	0	0
North Dakota	25,136	30,330	21,446	0	0	0
Ohio	767	0	0	0	1,912	31,124
Oklahoma	0	0	0	2,890	3,005	388
Oregon	0	0	23	9,253	4,286	27,342
Pennsylvania	81	342	0	0	0	0
Rhode Island	0	0	0	2,118	4,473	3,571
South Carolina	0	81	1,908	0	243	1,797
South Dakota	17,517	278	1,162	0	0	297
Tennessee	0	0	0	1,117	0	0
Texas	0	0	0	0	411	13,042
Utah	17,458	2,320	8,569	22,995	8,814	858
Vermont	0	0	0	455	1,949	2,246
Virginia	0	0	0	5,579	7,581	0
Washington	17,458	0	0	3,566	4,286	2,480
Wisconsin	0	0	0	397	2,231	4,339
Wyoming	168	40	743	0	0	417
TOTAL	68,113	67,194	169,013	74,231	128,778	211,502

(a) 78 total permits, not stratified (included as single trip in total) (b) 7476 Oversize/Overweight permits on Toll Road
© 172 multiple trip permits, 788 single trip permits; not stratified as divisible or nondivisible (included as divisible in total)
Source: FHWA Annual Inventory of State Practices, FY83 (Table 12), FY89; and Annual State Certifications (FY95)

PERMIT FEES

While the number of overweight permits issued has increased dramatically, the fees assessed for permits appear to have changed little, if at all. Permit fees are established in either State laws or regulations. Historically, they have not been set on an infrastructure cost occasioned basis. The fees are usually established to recover the costs to administer the permit programs, and in some States enforcement is cited as an administrative cost[7].

In 1989, State permit fees for an 84,000 pound overweight vehicle ranged from $6 to $61.[8] Although there has been little significant change to the 1989 fees, case studies conducted for this Study (see page VII-18) indicate that States are considering increases that would take into account damage costs; none are considering elimination of the "multi-trip" permit. Oregon periodically conducts a cost-allocation study; based on the results its legislature makes adjustments to the various truck fees, including permits. Oregon officials noted that their most recent study indicated an overpayment by the industry, and permit fees were therefore adjusted downward. Pennsylvania DOT will be initiating a study following a legislative audit of the motor carrier program that found "truck weight waiver fees do not appear to cover the cost of the damage caused by overweight trucks."[9]

Minnesota and Washington have set permit fees that better reflect infrastructure damage. Minnesota revised its permit fees in 1993 to include damage cost per mile based on pavement wear for axle groups on an Equivalent Single Axle (ESAL) basis.[10] The cost assessed to a particular axle group increases for a given load as axles are added to the group. Pavement costs per ESAL are based on unit costs/ESAL for typical pavements. Bridge costs are not specifically accounted for in this fee, such costs were felt to be covered by registration and other taxes paid.[11]

Table VII-3 provides the cost factors that are based on weight and axle group within a defined axle spacing under the Minnesota formula. The maximum weights for which an overweight permit is available are: (1) 12,000 pounds for a two-axle group; (2) 18,000 pounds for a three-axle group; and (3) 22,000 pounds for a four-or more axle group. The permit fee is a combination of the base single trip fee plus the damage cost fee of xx cents per mile.

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[7] Confirmed in case study interviews and comments to docket 93-28.

[8] Source: FHWA "Inventory of State Practices"

[9] "Performance Audit Report of the Department of Transportation," Commonwealth of Pennsylvania Legislative Budget and Finance Committee, 1996.

[10] The formula is (AFxUC)xD+ADMIN where AF= Axle Group Factor, UC=Unit Cost, D= Distance increment, and ADMIN=minimum administrative fee. The cost factors adopted by Minnesota were based on a methodology developed by a Minnesota DOT research engineer.

[11] Comments to Docket 93-28, Minnesota Department of Transportation , FHWA Docket 93-28-17, March 14, 1994

TABLE VII-3
MINNESOTA
OVERWEIGHT AXLE GROUP COST FACTORS ($ per mile)
SINGLE TRIP PERMITS

Number of Pounds	2 Axles at 8 ft. Or less	3 Axles at 9 ft. Or less	4 Axles at 14 ft. Or less
0 - 2,000 lbs.	0.12	0.05	0.04
2,001 - 4,000 lbs.	0.14	0.06	0.05
4,001 - 6,000 lbs.	0.18	0.07	0.06
6,001 - 8,000 lbs.	0.21	0.09	0.07
8,001 - 10,000 lbs.	0.26	0.1	0.08
10,001 - 12,000 lbs.	0.3	0.12	0.09
12,001 - 14,000 lbs.	Not permitted	0.14	0.11
14,001 - 16,000 lbs.	Not permitted	0.17	0.12
16,001 - 18,000 lbs.	Not permitted	0.19	0.15
18,001 - 20,000 lbs.	Not permitted	Not permitted	0.16
20,001 - 22,000 lbs.	Not permitted	Not permitted	0.2

Washington State passed legislation in 1995 that increased the per mile overweight permit fees for nondivisible loads to reflect damage cost as well as administrative costs. Washington's action was in response to FHWA findings of inconsistencies in their law and a concern that the fees were insufficient. Washington has a two-tiered fee structure; in addition to a "flat fee" there is a per mile fee. Prior to the 1995 changes, the per mile fee was capped at $2.80 for 80,000 pounds or more overweight. The current fee increases from $2.82 per mile for 80,000 pounds to $4.25 per mile for 100,000 pounds plus $.50 per mile for each additional 5,000 pounds.

The FHWA Highway Cost Allocation (HCA) Study provides information on the overall cost recovery by States as well as by the Federal government. While several States are attempting to establish permit fees that recover damage to highways, the vast majority of States presently have permit fees that are insufficient and well below a realistic cost recovery level. Follow-up work on the HCA Study will provide the States with data and methodology to use in designing permit fees or developing their own HCA Study.

STATE ENFORCEMENT OF TRUCK SIZE AND WEIGHT REGULATIONS

The identification of possible State enforcement issues associated with changes to TS&W limits is dependent on understanding current practices and challenges. The baseline was established through reviewing previous studies, research, enforcement statistics, and personal interviews with the enforcement and permitting officials in nine States.

Development of the "snapshot" of State enforcement included review of the FY 1995 State Certifications of Size and Weight Enforcement and the FY 1995 SEPs submitted to the OMC. The information and data obtained from these documents pertained to enforcement strategy, State funding (budget) for the enforcement program, truck weighings and citations issued, off-loading, and number of permits issued for FY95. Inconsistencies in State interpretations of the FHWA guidelines often result from changes in personnel at the State level. When this occurs, FHWA often provides on-site training on preparation of the certifications and SEPs.

The role and importance of State enforcement in the management and control of State and Federal weight limits has been underscored in past studies.[12] The degree of compliance depends on numerous variables, many of which are beyond the control of State program administrators and enforcement officials, such as funding and State legislative mandates.

It is difficult to obtain accurate information on the degree of noncompliance with weight limits. Over the past 15 years FHWA review of the effectiveness of enforcement programs has primarily focused on changes in numbers from year to year. For example, number of trucks weighed, number of citations issued, and violation rates are tracked. Quantifying the degree of noncompliance with weight limits at the State and National level continues to be an unresolved issue for FHWA.[13]

While adequate fines and penalties are important elements in an effective program, judicial support is critical and beyond the control of State enforcement officials. The problem of judicial support was evaluated in a 1985 FHWA study. The report, "Administrative Adjudication of Overweight Violations," suggested alternative approaches and expanded use of the Minnesota Relevant Evidence model. Relevant evidence is discussed later in this chapter.

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[12] A previous study by Clayton, Nix, and Fepke noted that: (1) violation rates are an indication only of enforcement "ability to issue or impose sanctions" on those vehicles which are stopped and weighed, useful for comparison of one State to another in a given year but limited as a conclusive measure of effectiveness, and (2) that the number of citations issued as a percentage of the total truck population using the highways in a given State would likely be very small, probably minuscule. They also note that a minimum "measure of effectiveness" for enforcement is the perceived assurance of apprehension and penalties or sanctions that are severe enough to have a deterrent effect.

[13] Clayton, Nix, and Fepke in *Enforcement and Overweight Trucking*, presented at the Canadian Transportation Research Forum in June 1992 discuss the difficulty of measuring the "real" picture of overweight trucking and emphasize that regardless of this difficulty, without weight enforcement of limits the legal operators would be economically disadvantaged, road costs would be excessive and there would be no incentive for operators to control loading.

As noted earlier, perhaps the most important and difficult question to be answered by FHWA, prior to defining measures of effectiveness, is what is a reasonable level of enforcement given the uniqueness of each State's laws and available resources.

ANNUAL WEIGHT CERTIFICATIONS AND STATE ENFORCEMENT PLANS

Federal regulations detail the requirements for submittal of annual SEPs and certification of enforcement.[14] The certification must contain either the signature of the Governor or his official designee. The requirements specify the data and supplemental information which is required including a statement of enforcement of the ISTEA length and weight freeze (see Appendix __).

Failure to comply with the conditions, or provide the information required, may result in a withholding of Federal-aid highway funds. FHWA utilizes an incremental administrative procedure that gives States the opportunity to resolve discrepancies or problems and avoid sanction. Sanction proceedings may be initiated for one or more of the following reasons: (1) a State fails to submit the required certification (10 percent of highway funds); (2) FHWA determination of inadequate size and weight enforcement on the Federal-aid system following review of the annual certification and SEP (10 percent of highway funds); and (3) FHWA determines there is an inconsistency between State and Federal weight limits for the Interstate[15] (100 percent of NHS funds) (see Appendix __). The frequency of use over the 16 year period summarized in Appendix __, for each of the three reasons, is summarized in Table VII-4.

TABLE VII-4
FHWA REVIEW OF STATE ANNUAL SIZE AND WEIGHT CERTIFICATION[16]
CONDITIONAL APPROVALS 1978-1994
Number of States Receiving Conditional Approvals= 23

Reason Cited for Conditional Rating	Frequency of Use	Number of States
Inadequate Enforcement	15	11
Conflict in Laws	22	12
Inconsistency with Federal weight limits on Interstate	10	6

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[14] Part 657 of Title 23 CFR.

[15] 23 U.S.C. Section 127.

[16] See Appendix G

Since 1978, several States have received conditional approval of their annual certifications and SEPs; some frequently. Through 1995, conditional acceptance of certifications has occurred on forty occasions with sanctions threatened. Seven of the forty cases resulted in letters being sent to the Governor on the impending sanction. In fact, all conflicts were resolved and sanctions were not imposed. Appendix __ shows that in two (1979 and 1980) of the seven cases inadequate enforcement was given as a reason for the proposed sanction. As this illustrates, FHWA and the States make every effort to resolve conflicts administratively and through cooperative arrangements.

WEIGHT ENFORCEMENT

The FHWA's OMC extracts data from the annual certifications, which is then compiled into tables for the annual Inventory of State Practices on Overweight Permitting. Historic data from the past inventories and the certifications indicates a significant growth in enforcement activities from 1978 through 1985.

State size and weight enforcement, nationwide, has increased in the last 10 years, even with the additional demands on the States for safety inspections under the MCSAP. The increasing number of trucks operating in interstate commerce and the increased use of WIM technology for screening trucks is reflected in the increased number of vehicle weighings. In 1985, the States weighed 105.2 million trucks (including 7.9 million on WIM) on all types of scales (fixed, portable, semi-portable) with only four states using WIM. In 1995, the total number of trucks weighed (including 57.9 million on WIM) increased to 169.6 million with 28 States using WIM in some capacity. The increase in the number of vehicle weighings continued through 1993. A decrease occurred in 1994 and 1995 which reflects the inoperable condition of equipment (WIM or scales) in some States, as well as weather factors and personnel constraints.

During the same time period (1985 to 1995) the total number of overweight (axle, gross, and bridge formula) citations issued decreased slightly from 664,000 in 1985 to 655,000 in 1995 while the number of trucks weighed (excluding WIM) increased by 14.3 million. As the violation rates shown in Table VII-5 indicate, the percent of trucks weighed that are cited for weight violations is very small and deviates little over time.

In addition to citations, the requirement for an overweight vehicle either to off-load or shift the load until legal can be a strong incentive to comply. Off-loading and load shifting requirements are effective immediately, and the inconvenience and/or added cost which the violator incurs may contribute to increasing compliance. After decreasing from 1985 through 1991, off-loading and load shifting as enforcement tools appear to be increasing in use. The use of off-loading may be based on several factors including mandatory off-load parameters established by State legislatures, departmental guidelines or policy, prosecutor guidelines, or officer discretion.

TABLE VII-5
STATE WEIGHT ENFORCEMENT FY85-FY95

Year	Weighed (incl WIM) (000)	Weighed (excl WIM) (000)	Weight Citations	Violation Rate	Off Loaded	Load Shift Required
1985	105,234	97,330	664,033	0.007	106,618	371,104
1986	113,269	102,504	650,728	0.006	81,716	395,184
1987	117,900	104,452	671,259	0.006	85,949	432,598
1988	130,188	111,532	700,928	0.006	89,033	453,841
1989	146,950	124,687	692,673	0.006	79,309	438,584
1990	149,187	126,076	667,463	0.005	76,769	425,298
1991	150,428	116,759	663,204	0.006	85,935	396,913
1992	160,536	113,563	677,976	0.006	60,142	380,249
1993	162,615	111,889	653,492	0.006	76,611	451,643
1994	161,066	108,124	642,616	0.006	82,491	447,396
1995	169,568	111,620	654,903	0.006	105,948	472,614

Table VII-6 indicates that when the total number of trucks weighed is disaggregated by scale type, the distribution from 1985 through 1995 clearly indicates the significant influence of WIM as a screening tool on scale house efficiency. Enforcement strategies from year to year appear fairly constant, with the bulk of weighing occurring at fixed facilities. In 1995, only five States, four in the Northeast and Alabama, did not use fixed scales as part of their enforcement strategy.

TABLE VII-6
TRUCKS WEIGHED BY SCALE TYPE, FY85 THROUGH FY95 (000's)

Year	Fixed	Semi-Portable	Portable	WIM	Total
1985	94,685	1,152	1,494	7,903	105,234
1986	100,010	1,238	1,257	10,764	113,269
1987	101,801	1,444	1,206	13,449	117,900
1988	108,881	1,439	1,212	18,656	130,188
1989	122,188	1,312	1,187	22,263	146,950
1990	123,748	1,175	1,153	23,111	149,187
1991	114,271	1,233	1,255	33,669	150,428
1992	111,016	1,229	1,318	46,973	160,536
1993	109,347	1,238	1,304	50,726	162,615
1994	105,679	1,183	1,262	52,942	161,066
1995	109,275	1,107	1,237	57,948	169,568

Many of the measures of compliance (number of weighings, number of citations issued) are more input measures than output measures and offer limited information on the extent of illegal overweight activity in the State, and no information on legal overweight activity.

In general, there are three commercial vehicle enforcement functions which are performed during roadside and scale house inspections. These are credentials verification, vehicle size and weight enforcement, and driver/vehicle safety inspections.

A State's choice of enforcement strategies is dependent on many factors, including traffic patterns, resources, geography, and environment. Key factors influencing the choice between fixed facilities or mobile enforcement, as well as the advantages/disadvantages of each strategy, are noted in Table VII-7. The key physical elements of a fixed facility are stationary scales, space and lighting for safe inspections, voice and data communications, shelter, controlled highway and inspection facility signage, acceleration or deceleration lanes, washroom facilities, and use of technology such as WIM, Automated Vehicle Identification (AVI), and cameras.

Table VII-7 provides a summary of factors influencing the weight enforcement strategy a State might select. Generally, most States include all of the strategies, in varying degrees with mobile and portable scale teams patrolling on by-pass routes.[17]

TABLE VII-7
SELECTION CONSIDERATIONS FOR WEIGHT ENFORCEMENT STRATEGIES

Criteria	Fixed Facility	Mobile/portable + Weigh-in-Motion
Volumes of trucks weighed	700-800 per shift (2500 per day)	3-5 per hour
Facility and technology used	Best for space and technology use	Adequate to limited
Cost to construct[2]	Range from $1.7 million to over $5 million[1]	Cost of land, equipment and signage ($300,000 or more)
Staffing requirements[1]	24 hours (2) days a week operation: minimum staffing of 17	8 hours operation: minimum of 2 enforcement/inspectors[3]
Flexibility	Limited	Very flexible
Security and Safety for Officer, Driver and Vehicle	Excellent	Poor
Deterrence/Visibility	High for Specific System (primarily Interstate vehicles)	Low visibility, High deterrence for local traffic and weigh station avoidance

[1] Source: "Enhancing the Effectiveness of Commercial Motor Vehicle Inspections." Governor's Commission on Economy and Efficiency in State Government. November 1990. Montpelier, Vermont

[2] $1.7 million to construct St.Croix, Minnesota facility on I-94 in 1987; $2.4 million for Woodburn, Oregon on I-5 in 1986; $5.3 million (Arizona share) for joint port-of-entry at St.George, Utah on I-15 in 1990. Vermont Agency of Transportation

[3] Operation limited to daylight hours, weather is a serious consideration

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[17] As noted in annual SEPs submitted to FHWA.

Although the weight enforcement program has improved from a National perspective, there is need for continued improvement, both in Federal administration and oversight as well as State enforcement and administration. While positive steps have been taken at both levels, much remains to be done to correct outstanding issues in enforcement.

WEIGHT ENFORCEMENT AND MOTOR CARRIER SAFETY ASSISTANCE PROGRAM

Weight enforcement and MCSAP inspections are not mutually exclusive. The integration of weight enforcement with safety inspections without reducing the effectiveness of either program is an important issue. Therefore, it is essential to determining the current level of enforcement that data from both motor carrier programs administered by OMC and enforced by the States be included, that is certification of weight enforcement and MCSAP. Consequently, the data reviewed included resources dedicated by the States, weight and safety inspections performed (trucks weighed, citations issued, type of enforcement, weight enforcement personnel, trucks inspected, and vehicles placed out-of-service). The inclusion of the MCSAP inspection data is essential to providing a complete picture of State enforcement at weigh facilities, whether fixed or portable strategies are employed.

Currently the States provide the bulk of funding for enforcement of motor carrier related regulations. There is no Federal funding available for the weight enforcement program, except for those vehicles weighed incidental to MCSAP inspections. The States annually commit resources of approximately $281 million to enforce State and Federal weight laws and meet their SEP goals (see Appendix __). In FY95 the Federal and State MCSAP and State TS&W enforcement expenditures totaled $342 million, with 82 percent of this total from State funds as Table VII-8 shows. The Federal funding under MCSAP[18] was $49 million in FY95, distributed among the 51 States (and territories) under an 80/20 match, this represents a decrease of 12 percent ($7 million) from FY1994.

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[18] MCSAP funding to the States has been primarily for roadside inspections of vehicles. The FHWA/OMC inspectors continue to conduct the bulk of Compliance Reviews (CR) of registered carriers, although the States are being encouraged to perform CR audits to reduce the number of unrated carriers.

TABLE VII-8
FUNDING OF STATE MOTOR CARRIER ENFORCEMENT

Expenditures and Personnel for Enforcement of Weight and Motor Carrier Safety Assistance Programs, FY1995		
	Expenditures	Personnel
MCSAP Basic Grant	$ 61,267,000	1,069
Federal (80%)	$ 49,028,000	
State (20%)*	$ 12,239,000	
Weight Enforcement	$ 280,706,000	6,061
State (100%)		
TOTAL	$ 341,973,000	7,130

*The 20 percent represents only the required State match for MCSAP funds and not the total expenditure by the States for safety enforcement. All States were doing safety enforcement long before MCSAP and continue to place an emphasis on safety enforcement in such areas as speed limits, brake checks, vehicle equipment checks, and driver licensing checks.

In general, the numerical measures of enforcement (including expenditures) of size and weight laws and Federal safety regulations in the years since the STAA of 1982 have increased as Table VII-9 illustrates. It is apparent that some States support more comprehensive programs than others.

TABLE VII-9
COMPARISON OF STATE MOTOR CARRIER ENFORCEMENT ACTIVITY
(000's)

	FY85	FY95
Trucks Weighed (excl. WIM)	97,330	111,620
Trucks Inspected (MCSAP)	372	1,799
TOTAL	97,702	113,419

One problem for weight enforcement at fixed facilities is "scale avoidance."[19] Over the years it has been assumed that the only reason trucks avoid scales is because they are overweight. While this may have been the case in the early 1980s, it is probably less important in the 1990s. With forty-nine States and the District of Columbia participating in MCSAP, and an increasing emphasis on safety inspections, many trucks circumvent the scale houses to avoid a roadside inspection rather than to avoid being weighed. Therefore, mobile safety enforcement (as with weight enforcement) is part of a comprehensive safety enforcement program.

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[19] Cited as a problem by the GAO in "Excessive Truck Weight: An Expensive Burden We Can No Longer Support" in 1979 and the Florida DOT study, "Weigh Station Evasion by Trucks", 1994.

SAFETY ENFORCEMENT

In the 1982 Motor Carrier Safety Act, Congress created an Office of Motor Carrier Safety and established a Federal grant program for State enforcement of the Federal Motor Carrier Safety Regulations (FMCSRs), the MCSAP in STAA of 1982. Due to a significant increase in the number of commercial vehicles operating in interstate commerce, the resources of the FHWA's Bureau of Motor Carrier Safety (BMCS) program were insufficient to meet the enforcement demands of carrier audits and field safety inspections.[20]

MCSAP participation continues to be a voluntary commitment by States that accept a "basic" grant[21] to enforce the FMCSRs and conduct safety inspections. In FY84, the first year of the program, there were only 17 States participating, by FY 1995 this number had increased to 49 States and the District of Columbia. Only South Dakota remains outside MCSAP.[22]

As in the weight enforcement program, States that are determined by FHWA to have laws or regulations inconsistent or incompatible with Federal laws and regulations are subject to sanctions, in this case the withholding of up to 50 percent of their "basic" grant. As in the weight enforcement program, the majority of States facing MCSAP sanctions implement the necessary changes and avoid loss of funding.[23]

Until 1992 enforcement activities funded under MCSAP were limited to operations directly related to safety inspections, which did not include weight enforcement. Partially in recognition of the reality that enforcement of weight and safety regulations occur simultaneously or in conjunction with one another, ISTEA expanded the "flexibility" of States to use MCSAP funds for weight enforcement under certain conditions.

A comprehensive State commercial motor vehicle (CMV) enforcement program includes both weight and safety elements, and improvements to one should also serve to improve the other. Additional information on what the States are currently doing in their enforcement programs is useful in developing the base case on enforcement. An example of a State comprehensive weight enforcement and safety inspection plan was developed by Michigan DOT and State Police in 1992 and is included in Appendix __.

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[20] Prior to 1982 Federal BMCS inspectors coordinated field inspections with State weight enforcement personnel, since the Federal inspectors had no legal authority to stop vehicles.

[21] Since 1982, the MCSAP funding programs have increased beyond the "basic" grant to include a supplemental grant program. Supplemental program areas include: (1) Traffic Enforcement, (2) Hazardous Materials Training, (3) Drug Interdiction (DIAP), (4) Research & Development; and (5) Uniformity. Supplemental grants are not contingent on State participation in MCSAP, thus South Dakota is eligible for funding.

[22] South Dakota, by choice, does not participate in MCSAP as far as receiving funding under the "basic" grant. The State has adopted the FMCSRs and does enforce and perform safety inspections with 100% State funding.

[23] An exception occurred in FY95 when sanctions were imposed on two States, Maine and Pennsylvania, and 50 percent of the "basic" grant was withheld.

CASE STUDIES

Interviews and meetings with State size and weight enforcement and permit officials were conducted in nine States to obtain direct input and supplement information on file in the OMC. The selection of States was determined in consultation with the OMC which oversees both the size and weight program and MCSAP. The selection of States for interviews provided regional coverage for the six regions defined in the CTS&W Study:[24] Northeast, Southeast, South Central, Midwest, West, and California.

The criteria used included LCVs operating in State, States with no LCVs allowed, States with ports, high truck traffic corridors, use of Intelligent Transportation Systems-Commercial Vehicle Operations (ITS-CVO) in program, ranked in top 10 States for number of trucks weighed or weight citations issued, States using fixed facilities, and States with no fixed facilities for weighing. Table VII-10 provides descriptive information on the weight programs for each of the nine States.

TABLE VII-10
OVERVIEW OF CASE STUDY STATES

State	Region/1	Enforcement Agency	Enforcement Type	Grandfather Rights	LCVs Operate	Relevant Evidence Law/2
AZ	West	Dept. of Public Safety	Portable	No	Yes, by permit	Yes/ 3
CA	California	California Highway Patrol	Fixed, Portable	No	No	No
GA	Southeast	Georgia DOT	Fixed, Portable	Yes	No	No/4
MD	Northeast	Md State Police Md Trans Auth	Fixed, Portable	Yes	No	No
MA	Northeast	Ma State Police	Portable, Mobile Units	Yes	Yes, by permit	No
MN	Midwest	Mn State Patrol	Fixed POE, Portable	Yes	No	Yes
NH	Northeast	Dept. Of Safety	Portable	Yes	No	No
OR	West	Oregon DOT	Fixed POE, Portable	Yes	Yes, by permit	No
PA	Northeast	Pa State Police Pa DOT	Fixed, Portable	Yes	No	No

1 Regions: NE=CT,DE,DC,ME,MD,MA,NH,NJ,NY,PA,RI,VT,VA,WV; SE=AL,AR,FL,GA,LA,MS,NC,SC,TN, MW=IL,IN,IA,KY,MI,MN,MO,OH,WI; W=AK,AZ,CO,HI,ID,KS,MT,NE,NV,NM,ND,OK,OR,SD,TX,UT,WA,WY

2 See discussion on Page VII-23 describing Administrative Adjudication.

3 Arizona enforcement may use weight slips as basis for tickets on GVW violations without weighing trucks on scales

4 Georgia's fines for overweight violations are treated as administrative penalties and collected through an administrative adjudication process which could be an alternative for collection of fines.

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[24] The regions defined in the TS&W study are not the FHWA regions; however, the nine States selected represented six of the nine FHWA regions and five of the six TS&W study regions.

The case studies provided an opportunity to receive information directly from field enforcement and permit officials in the States on how the programs are operating. Key points of discussion that evolved from the case studies are noted below, and additional points are discussed in Appendix __.

PERMIT OPERATIONS

Refusing to Issue a Permit

In the case study States, issuance of overweight permits is generally not an automated process.[25] Although States screen applications for accuracy and compliance with minimum requirements, such as insurance, most do not check or consider carrier safety records or safety ratings issued by FHWA. A State's law may allow for the permit official to refuse to issue a permit, however it is unlikely that a permit will be refused for a poor safety record or rating. For example, Georgia law specifies that "For just cause, including, but not limited to, repeated and consistent past violations, . . . an official of the department designated . . . may refuse to issue or may cancel, suspend, or revoke the permit of an applicant or permittee." Since many of the permits issued are multi-trip or annual, screening would primarily be limited to the single-trip permit applicant without an automated system.

Vehicle Certifications for Weight versus Overweight Permits

In two of the case study States a certification appears to serve as a permit to operate over the GVW on State highways for certain vehicles. The certification is to verify that the vehicle does not exceed the truck manufacturer's GVW rating. The certification process in one State requires a visual inspection of the truck by an enforcement officer, whereas in the other State a clerk only verifies paperwork to see that it is in order. In both States the certification is a one-time requirement, as long as the owner remains the same.

Permitting of International Containers

Permitting of international containers is generally limited to those States that have marine ports, either coastal or on the Great Lakes. In the case study States, the GVW limits that are allowed for the container permits range from 80,000 pounds in Georgia to 105,500 pounds in Oregon. Table VII-11 summarizes the information on container permits for the nine case study States. The data that is collected by the States on the permits is limited as most are multi-trip (annual) permits and not vehicle specific.

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[25] With the exception of Minnesota and Oregon.

TABLE VII-11
CONTAINER PERMITTING IN CASE STUDY STATES

STATE	Permit Available Y/N Type:Trip/Annual	Permit Fee	Maximum GVW and Single/Tandem Axle Weight Limits	Conditions/Comments
Arizona	Not Available	NA	NA	NA
California	Yes Annual Permits	Yes $90 per vehicle	95,000 lbs.	Ports of Los Angeles and Long Beach, within specified distance of ports. Are vehicle and route specific. Oakland has its own permit program for the Port.
Georgia	Yes Trip and Annual Permits	Yes $20 trip $100 per vehicle	Trip: 100,000 lbs.; 22,000/40,680 lbs. Annual: to 80,000 lbs.; 20,340 per axle	Issue approximately 300 per day, second largest generator of permits.
Maryland	Yes Annual Permits	No Fee	90,000 lbs. 22,400/40,000 lbs.	To/From Port of Baltimore, route restrictions, not vehicle specific.
Massachusetts	Not Available	NA	NA	NA
Minnesota	Yes Trip Permits	Yes Base fee $15, plus damage assessment fee	No maximum GVW 46,000 lbs. tandem 60,000 lbs. tridem 80,000 lbs. quad	Available only since 1994, issued less than 50
New Hampshire	Not Available	NA	NA	NA
Oregon	Yes	Yes	105,500 lbs. 21,000/42,000 lbs.	
Pennsylvania	Yes Annual Permits	Yes based on number of truck-tractors*	90,000 lbs. 21,000/42,000 lbs.	Issued approximately, 3,200, routes restricted

* $100 for 15 or fewer truck-tractors; $150 for 16 to 50 truck-tractors; $250 for 51 to 100 truck-tractors; $350 for 101 to 150 truck-tractors; and $400 for more than 150 truck-tractors.

ENFORCEMENT OPERATIONS

Weigh Facilities and Equipment

Problems of inoperable or obsolete equipment, repair or maintenance work not completed expeditiously, and inconsistency between States and regions are common issues cited by FHWA in the review of the Annual State Certifications and confirmed in some of the case study States. States that are subjected to harsh winter weather conditions and have a very limited number of fixed weigh facilities, as with three of the case study States, contend with the problem of locating plowed roadside inspection areas for safely weighing trucks.

Roadside inspection facilities are often insufficient to provide a safe environment for the officer and vehicle being weighed, and limit the number of vehicles that can be safely stopped for weighing. The Minnesota State Patrol operates under written guidelines for enforcement in the selection of appropriate inspection areas for weight enforcement. Other State enforcement agencies may also consider implementing guidelines.[26]

Grandfather Rights and Nonuniformity Between States

Nonuniformity in weight limits and permits as the result of grandfather rights in contiguous States is an issue raised by enforcement in many of the case study States. The impact of different limits or exceptions in neighboring States often results in the addition of new permits or exceptions with each legislative session, resulting in the "ratcheting effect." The nonuniformity created by constant changes in limits and exceptions suggests that a uniform standard, whether Federal or regional, may be desirable. Uniformity, in this context, could be a means of "leveling the playing field" between States and the industries in those States. For instance, weight permits for milk in New York was cited by Pennsylvania officials as one reason legislation was passed for new overweight blanket permits for milk and steel coils, in 1995. In late 1995, the Pennsylvania permit law led to inquiries from the Maryland industry about pursuing a similar law.[27] This is an example of the process of "ratcheting" weight limits upward over time because of competitive pressure from neighboring States.

Complex Regulations Should be Avoided

State field enforcement personnel and officials interviewed during the case study process generally believed that complex regulations should be avoided.[28] National standards, particularly those that require field enforcement in the States, should be developed in full consultation with State enforcement officers. Regulations must be easily comprehended by enforcement personnel as well as by those expected to comply. Often the education of industry occurs when a ticket is written and the State enforcement officer must explain the law to the driver. A regulation that requires specialized equipment or facilities and technical expertise will be difficult to enforce.

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[26] The 1996 death of an Indiana State inspector and the truck driver of the vehicle he was inspecting led to calls by some enforcement and industry representatives at the 1996 Commercial Vehicle Safety Alliance annual meeting to end roadside inspections.

[27] The Pennsylvania permit is for 94,000 pounds, however the axle limits of 21,000 pounds (single axle) and 42,000 pounds (tandem axle) cannot be exceeded within the existing length limit. The permit is only valid off the Interstate. No law was introduced in Maryland in 1996.

[28] This observation confirms the findings presented in Transportation Research Board Report 225.

Interviews with representatives of the FHWA's OMC regarding the size and weight certification process and MCSAP indicate that activities are underway in both areas that may have an impact on operations of State enforcement. Of particular interest in the context of this discussion are the completion of "pilot projects" on implementation of relevant evidence legislation in four States: the Oregon study under way on size and weight violation data and carrier safety compliance history; and revisions to the certification and SEP process published under an Advanced Notice of Proposed Rulemaking (ANPRM) 93-28 in 1993.

ADMINISTRATIVE ADJUDICATION OPTIONS: RELEVANT EVIDENCE

In 1985, an FHWA Study was completed on the problem of administrative adjudication for weight enforcement in the States. The study identified various options for administrative adjudication that could be used to improve the effectiveness of State enforcement programs. One such option was "relevant evidence" as used in Minnesota since 1980. "Relevant evidence" allows the use of bills of lading, weight tickets, and other documents that indicate the weight of a truck to be used as evidence in a civil court proceeding to establish overweight violations."[29] Enforcement is accomplished through an audit, generally of the shipper or freight forwarder, and civil action can be taken against the driver, the shipper, the owner and/or the lessee for all or part of the fine, depending on the degree of responsibility for causing the overweight movement. The audits also provide a means to enforce the multiple trip permits and recover some of the damage costs as well as to determine frequency of use.[30]

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[29] "Effectiveness of Relevant Evidence in Reducing Truck Overweights," Report made through a cooperative effort of the Minnesota DOT and the Minnesota Department of Public Safety, p.2.

[30] Minnesota's weight enforcement personnel interviewed in the case studies believe the program has been a great success and are strong supporters of the approach. The findings of a 1985 program effectiveness audit by Minnesota DOT and State Police indicated that, as part of a comprehensive weight enforcement system, relevant evidence proved to be extremely successful in restricting the operation of illegally overweight vehicles.

In 1993 FHWA initiated a "pilot project" to assist a selected number of States[31] in adopting "relevant evidence" laws. The project was completed in 1996 with none of the States succeeding in passing legislation to implement relevant evidence. The preliminary observations from the relevant evidence project indicate that industry opposition to proposed legislation succeeded in defeating the bills. Renewed interest in "relevant evidence" laws has been expressed by several States; this may be a viable option in the future under what could be a new paradigm of weight enforcement.[32]

Another approach to administrative adjudication was reviewed in the discussion with the Georgia program administrator. Georgia adjudicates all weight citations through an administrative process within the DOT rather than through a court system which in theory should increase the probability of collecting fines. The process is quite similar to the way in which tax audits are processed, that is, the citation is issued, and the fine must be paid within a period of time or a hearing requested. Failure to pay results in initiation of a collection process by the DOT Investigative Unit. The result of the collection process may be impoundment of the vehicle, suspension of the registration or placement of a lien.

INCREASED TECHNOLOGY DEPLOYMENT

COMMERCIAL VEHICLE INFORMATION SYSTEMS AND NETWORKS; DEVELOPMENT AND OPPORTUNITIES

Commercial Vehicle Information Systems and Networks (CVISN) describes the ITS elements which support CVO. CVISN includes activity associated with commercial vehicle credentials and tax administration, roadside inspections, and freight and fleet management. It is a national effort to coordinate and integrate technologies in use or under development to improve efficient operation of motor carrier programs to benefit government, carriers, and other stakeholders.

Until recently, the use of technology for CVO has been more prevalent in the West and Northwestern States than East and Northeast. In its oversight role of the State weight enforcement programs, the Federal interest and involvement in technology use and deployment

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[31] The four states selected were Iowa, Louisiana, Mississippi, and Montana. Each state received $50,000 in funding from the Federal-Aid program as supplemental grants to MCSAP.

[32] Milan Krukar and Ken Evert described their view of a paradigm shift in TS&W enforcement at a 1993 conference, noting that ISTEA accelerated the shifts. The eleven paradigm shifts they observed are: (1) the traditional relationship between the motor carrier industry and enforcement has evolved from one of having to check all trucks to emphasis on potential violators; (2) a change in internal organization and attitude of transportation departments toward enforcement; (3) technology shifts toward combinations of WIM, AVI and other technologies to replace the traditional measurement methods; (4) use of relevant evidence laws to hold shippers/owners responsible for violations rather than drivers; (5) changes in weight citations toward a WIM standard; (6) metric conversion; (7) intermodal impacts and opportunities for enforcement, licensing, taxation of all modes; (8) infrastructure capacity control of truck traffic with technology; (9) integration of intermodal time schedules with technology; (10) weight overload citation changes from the criminal to the civil court system and the use of ESALs rather than pounds for weight violations; and (11) global enforcement needs for standardized limits.

for CVO has been most prominent in the advocacy of WIM and AVI. The ISTEA provisions for a Federal role in the deployment and testing of ITS technology, including a CVO element, has generated interest and support from many States.

Although CVISN technology holds some long-term promise in the identification of overweight vehicles and the enforcement and permitting of size and weight regulations, issues remain. The use of ITS technology holds promise for State administrative functions, such as permitting of vehicles and loads, and the collection of enforcement data into a "real-time" entry and access database. In fact, many States have either implemented computerized permit systems or are in the process in doing so.[33]

The technology discussed below has been in use, is currently being tested, or is available for use for State size and weight administration and enforcement. The Federal role in promoting the use of technology in the 1980's focused on the combination of WIM and AVI for monitoring and collecting data on vehicles and in encouraging States to use WIM for screening of vehicles. As new technologies evolve, additional opportunities for improving enforcement effectiveness may present themselves.

Weigh-In-Motion

The use of WIM for screening at fixed weigh facilities provides enforcement with a tool to improve the efficiency and effectiveness of operations[34]. Although WIM is excellent for screening purposes, it is not without its problems. WIM equipment has frequent maintenance requirements arising primarily from heavy use. Thus, this almost indispensable enforcement tool is often inoperable for extended periods of time.

A 1994 study conducted by the Florida DOT for the purpose of assessing the feasibility of using WIM for weight enforcement personnel, exemplifies the benefits to be gained from the use of WIM. The findings strongly support WIM use by enforcement for identifying areas in need of weight targeting. The findings also support conclusions of previous studies that lack of any enforcement results in high noncompliance and the highest enforcement results in complete, or near complete, compliance for those trucks weighed.[35]

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[33] Minnesota's computerized permit system was one of the first implemented and has served as a model for other States, reducing the time involved for carriers and the State agency for issuing a "routine" permit to approximately 30 seconds.

[34] "Weigh-In-Motion Technology Improves Highway Truck Weight Regulation," Laurita, Sellner, and DuPlessis discuss the benefits and problems, citing New Jersey and Delaware's incorporation into planning of weigh stations and uses in by-pass route monitoring.

[35] Periodic replication of this study methodology in other States could provide useful information for evaluating the extent of the overweight problem nationwide. One recommendation made by the study group was to require the States to report on weigh station bypass enforcement in the annual certifications. One limiting factor of the study is the vehicles weighed were exclusively 5-axle tractor trailers.

Other possible uses of WIM for enforcement exist, such as combining WIM with photo imaging and assessing civil penalties for violations. Another possibility within the scope of CVISN is to expand the use of high speed weigh-in-motion (HSWIM) off the Interstate System for enforcement in States not currently using WIM. This could increase the number of trucks that could be screened and weighed by portable scales.

Weigh-In-Motion and Photo Imaging

Photo imaging is a technique currently used for traffic enforcement in some States and large metropolitan areas where laws allow a citation to be issued for a violation (such as, stop sign or red light) based on a photograph or video reading of the vehicle plate. A combination of WIM and a camera plate reader to match up an overweight truck with the vehicle owner is being tested and evaluated in Minnesota. The impact of weather and speed on the photo image is one area being evaluated. This combination of technologies could provide a means to enforce weight limits on overweight vehicles by-passing scales if problems associated with climate can be resolved.

Automatic Vehicle Identification and Automatic Vehicle Classification Systems

Automatic Vehicle Identification (AVI) and Automatic Vehicle Classification (AVC) systems have been in use for many years, primarily by the private sector for such things as tracking intermodal containers, parking lot control, and fee assessment. The potential use of AVI for CVO and enforcement was tested in the Heavy Vehicle Electronic License Plate (HELP) Crescent Demonstration Project in the 1980s.[36] The HELP/Crescent evaluation team concluded that there were benefits to be derived if technical problems and barriers could be overcome. They concluded that the CVO services that are closest to being ready for deployment and implementation are the automated roadside dimension and weight screening technologies.

Bar Codes and Readers

Bar codes and readers may be used in the future to facilitate permitting and enforcement. This could potentially include checking credentials and data collection on registration, taxation and overweight permits. Since approximately 1990, bar codes have been in use by customs brokers on the Canadian border for international freight documents. This allows the documents to be scanned by customs officers providing a screen display of the data and entry into a database.

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[36] The HELP/Crescent project tested AVI, AVC and WIM in combination on the I-5 corridor and involved the States of Washington, Oregon, California, and Arizona and the province of British Columbia. The project was initiated in 1983, the demonstration element implemented in 1991 and concluded in 1993. The crescent shape of the I-5 corridor led to the project name.

Geographic Information Systems

Geographic information systems (GIS) is a technology currently in use by State transportation planners with potential for use in strategic weight enforcement planning. State DOT GIS databases could include information related to truck operations, such as known "generators of truck traffic" (i.e., asphalt plants, quarries, landfills) and access to the information could be provided to enforcement programs. Although individual enforcement officers may be familiar with the location of facilities in their patrol areas, a compilation of Statewide facilities is unlikely. Alone or coupled with WIM data, the GIS could provide a strong tool for enforcement planning.

Pilot Projects on Brake Testing Equipment

The FHWA's OMC is funding two States (Maryland and Minnesota) to evaluate brake testing equipment and its potential for use as a screening device for MCSAP inspections. The Minnesota brake testing equipment was installed in 1995 and has just completed a year in use. In addition to the braking data, a diagram is generated with weight distribution on axles and tires shown (see Appendix __). Therefore, not only can an axle weight be determined but the distribution of weight on each tire can be obtained.

COSTS OF TECHNOLOGY DEPLOYMENT AND MAINTENANCE

The use of ITS-CVO technology beyond the completion of Federal "prototype" and "pilot" State testing and evaluation will be contingent on overcoming barriers to include: (1) institutional; (2) legal; (3) industry acceptance; and (4) financial. Cost related to technology deployment and the required maintenance of the systems are two particularly important issues which remain to be resolved.

To illustrate the commitment of resources required to implement, Oregon developed a strategic plan for ITS-CVO in 1993. The State calculated the cost to implement and maintain such a system to be $23.3 million (1993 dollars) over a six-year period.[37] The technology included WIM & AVI (7 Interstate sites, 14 sites on the State primary system, and other sites on/off the State highway system) and dynamic warning systems. Federal funding for implementation of a portion of the plan as a National CVO project prototype was made available at an 80/20 match, with six million dollars appropriated for the Federal share.

The Oregon plan projected total costs over a 20-year period to be $48.2 million and the benefit to the State as $150.2 million due to reduced tax administrative costs, tax evasion and road damage. Motor carrier costs were also estimated over the same 20-year period to be $23.1 million, and benefits equal to $195.1 million from time savings, reduced procedures, and reduced tax administrative costs.

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[37] $13.2 million for construction, $4.6 million for operations and maintenance, $4.1 million for information systems, $0.9 million for research and development testing, and $0.5 million for planning and coordination.

Obviously costs and benefits vary from State to State, or region to region, an ongoing financial commitment of significant funds will be needed in order to realize the benefits.

CURRENT REGULATORY REGIME AND IMPLICATIONS OF CHANGES

The current National policy was established by Congress in 1982 when certain State laws pertaining to length and legal vehicle configurations were preempted for the Interstate Highway system and selected non-Interstate highways. Since that time FHWA has generally worked with the States one-on-one whenever a State fails adequately to enforce TS&W laws. The current relationship between the Federal and State administrators of the TS&W Enforcement Program is best characterized as Federally-guided and State-administered.[38]

The effectiveness of the relationship was questioned in a 1991 program audit by the Office of Inspector General which found that improvements are needed in the vehicle weight enforcement program and that FHWA should strengthen its administration of the program. How FHWA should proceed to strengthen its administration centered around the three elements shown in Table VII-12. The FHWA responded by clarifying several legal and operational misunderstandings and moved ahead to implement other suggested improvements in the program. Key recommendations from the OIG report follow.

TABLE VII-12
OIG PROGRAM EFFECTIVENESS MEASURES FOR STATE WEIGHT ENFORCEMENT

1. Quantification of Nature and Extent of Overweight Vehicles	2. Plans and Strategies to Combat Overweight Vehicles	3. Application and Evaluation of Enforcement Techniques
✓Expanded use of WIM to collect data for use in quantifying the magnitude of the problem ✓Increased use of WIM for planning enforcement details to be more effective ✓Improved calibration of WIM, New equipment purchases	✓Comprehensive criteria to evaluate the adequacy and effectiveness of State programs needs to be developed by FHWA ✓Current SEPs lacking required information needed to measure effectiveness ✓WIM data obtained from 4 states indicates increase in the percent of overweight tandem axles on non-interstate highways	✓Consideration of damage factor in permit fees ✓Adequacy of fines and penalties ✓No tolerances are acceptable ✓Off-loading usage ✓Use of "relevant evidence" laws

The specific recommendations for FHWA program administration improvements noted in the OIG audit report were:

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[38] Federal guidelines for annual certification and SEPs are specified in Part 657 of Title 23, CFR.

- Identify the nature and quantify the extent of overweight trucks;
- Direct FHWA Divisions to more actively promote, monitor, and evaluate the use of WIM;
- Direct FHWA Divisions to work with the States to evaluate existing fine structures;
- Analyze SEPs more critically;
- Initiate Congressional action to prohibit use of divisible load permits and multi-trip non-divisible load permits on the Interstate System;
- Promote use of nontraditional enforcement techniques; and
- Enforce prohibition of administrative weight tolerances.

FHWA RULEMAKING: "CERTIFICATION OF SIZE AND WEIGHT ENFORCEMENT"

In December 1993, the FHWA issued an ANPRM for the State Certification of Size and Weight Enforcement. Comments were requested on nine "problems" with the certification and SEP procedures identified by FHWA (see Appendix __):

- The magnitude and location of the overweight problem is unknown;
- Weight tolerances at scales are common despite Federal law;
- Preparation of SEPs and Certifications is time consuming;
- Not all states are taking advantage of improved data collection to enhance program management and effectiveness;
- The amount of pavement wear attributable to vehicles with special permits is unknown;
- Permit fees and overweight penalties do not always reflect true costs;
- Enforcement plans lack specific, measurable goals;
- There is inadequate vehicle size and weight enforcement in some urban areas; and
- Sanction procedures do not clearly identify State settlement options.

Comments to the docket were received from twenty-one State DOTs, nine State enforcement agencies, and twenty from other interested parties. Generally there was agreement among the States on the following:

- The magnitude of the overweight truck problem could possibly be measured with the use of WIM technology but only with an infusion of significant Federal funding to the States;
- Enforcement discretion on tolerances should be accepted as a given with less emphasis by FHWA, and if any tolerances are to be adopted by FHWA, they should not be percentage based;
- The process for preparation and submittal of the SEPs and certifications is time consuming (one estimate is 4,160 hours in the aggregate) and could be improved;
- The use of ITS will be limited until it has proven reliability and durability;
- Permit fees do not recover damage costs;
- There is no one model for enforcement that fits all States;
- "Relevant evidence" should not be mandated unless Federal funds are provided to implement;
- Certifications and SEPs should take into account "regional" enforcement performance; and
- The use of sanctions should be replaced with incentives such as a grant program for the States.

FHWA is considering all comments received, in depth.

The process for submittal and acceptance of the annual State certifications and SEPs is complex, time-consuming, and convoluted. Additionally, the process for review of the SEPs by the OMC is also time-consuming and complex (see Appendix __). The increasing demand for more detailed information from the States is not only the result of a need to measure program effectiveness for the Administration and Congress but also of a need to be able to provide comparative data on potential conflicts and inconsistencies in policies.

FUTURE ENFORCEMENT

The rulemaking has been temporarily suspended pending the completion of this CTS&W Study and potential Congressional revisions to TS&W regulation as part of ISTEA reauthorization. The rulemaking will be completed subsequent to this Study and necessary revisions made to ensure effective enforcement of the Federal law.