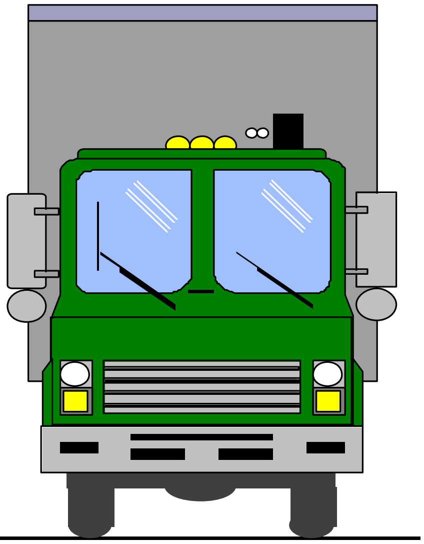
U.S. Department of
Transportation

The U.S. Department of Transportation's

Comprehensive Truck Size and Weight Study



Volume II

Issues and Background

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List of Acronyms

ANPRM	Advanced Notice of Proposed Rulemaking
AAR	Association of American Railroads
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
AAA	American Automobile Association
ATA	American Trucking Association
AVC	Automatic Vehicle Classification
AVI	Automated Vehicle Identification
CALTRANS	California Department of Transportation
CRASH	Citizens for Reliable and Safe Highways
CVISN	Commercial Vehicle Information Systems and Networks
CFS	Commodity Flow Survey
CTS&W	Comprehensive Truck Size and Weight
COFC	Container-On-Flat-Car
DOT	Department of Transportation
DST	Double Stack Train
DIVINE	Dynamic Interaction Vehicle Infrastructure Experiment
DLC	Dynamic Loading Coefficient
EDI	Electronic Data Interchange
ESAL	Equivalent Single Axle Loads
EWS	Extended Weight System
FAP	Federal-Aid Primary
FBF	Federal Bridge Formula
FHWA	Federal Highway Administration
GAO	General Accounting Office
GIS	Geographic Information System
GVW	Gross Vehicle Weight
HCA	Highway Cost Allocation
ITS-CVO	Intelligent Transportation Systems-Commercial Vehicle Operations
ICC	Interstate Commerce Commission
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
JIT	Just-In-Time
LTL	Less-Than-Truckload
LTSA	Land Transport Safety Authority
LRFD	Load and Resistance Factor Design
LCV	Longer Combination Vehicle
MRI	Midwest Research Institute
MCA	Motor Carrier Act of 1980
MCSAP	Motor Carrier Safety Assistance Program
NHTSA	National Highway Traffic Safety Administration

NHS	National Highway System
NN	National Network
NPTC	National Private Truck Council
NAFTA	North American Free Trade Agreement
OIG	Office of Inspector General
OECD	Organization for Economic Cooperation and Development
PSI	Per Square Inch
POG	Policy Oversight Group
PPI	Producer Price Index
QR	Quick Response
RF	Rating Factor
RPL	Reduction of Pavement Life
RCCC	Regular Common Carrier Conference
RTAC	Road Transport Association of Canada
RMD	Rocky Mountain Double
SHV	Specialized Hauling Vehicle
SEP	State Enforcement Plan
STAA	Surface Transportation Assistance Act
TTI	Texas Transportation Institute
TOFC	Trailer-On-Flat-Car
TRB	Transportation Research Board
TS&W	Truck Size and Weight
TIRRA	Trucking Industry Regulatory Reform Act of 1994
TL	Truckload
TPD	Turnpike Double
UPS	United Parcel Service
VMT	Vehicle Miles of Travel
VS&C	Vehicle Stability and Control
WIM	Weigh-In-Motion

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 issues involve differing views of State and Federal authorities, competing 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. The 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 (TRB) and General Accounting Office (GAO) 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 and policy architecture are designed as a structure for gathering and evaluating information related to the potential impacts of alternative truck size and weight options. 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 of Transportation, Federal Highway Administration (FHWA) as staff, and other Department modal administrations with freight responsibilities. A companion document, the 1997 Federal Highway Cost Allocation (HCA) Study, was transmitted to Congress in August 1997. Taken together, this material will provide the policy and factual framework for congressional deliberations regarding Federal TS&W limits and associated Federal user fees.

PURPOSE

The objectives of the Comprehensive Truck Size and Weight (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, are 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				

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 3- and 4-axle single unit trucks, 5- and 7-axle truck trailers, 5- and 6-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), National Network (NN) for trucks, National Highway System (NHS), and a limited system of highways tailored for the operation of LCVs on which these configurations now operate or might be proposed to operate.

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 pounds)	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 feet Trailers	80-111	X	X	X	....	X	X	X
Intermediate Length Double (31 - 33 feet)	105.5-128	X	....	X	....	X	X	....
LCVs	105.5-148	....	....	....	X	X	X	....

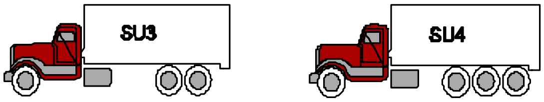
*****Highways on which LCVs currently operate or might be proposed to operate.

ILLUSTRATIVE SCENARIO OPTIONS

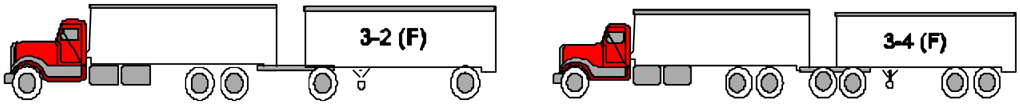
Evaluation of possible regulations pertaining to a variety of configurations, such as elimination of grandfather provisions, freezing weight limits on the NHS, limiting trailer and semitrailer lengths to 53 feet, and lifting the LCV freeze are also examined. The inclusion of a configuration at a GVW limit or on a certain network does not imply a predisposition of the Department of Transportation (DOT) toward its adoption.

FIGURE I-1
BUILDING BLOCK VEHICLES

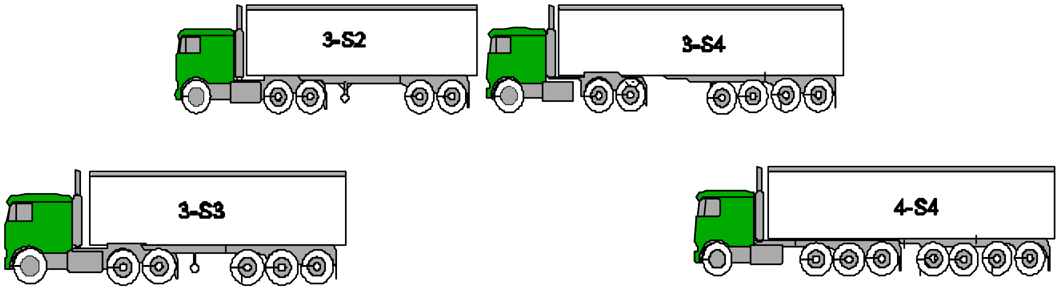
Single Unit Trucks



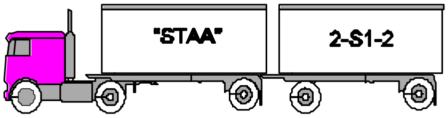
Truck-Trailer Combinations



Truck-Semitrailer Combinations

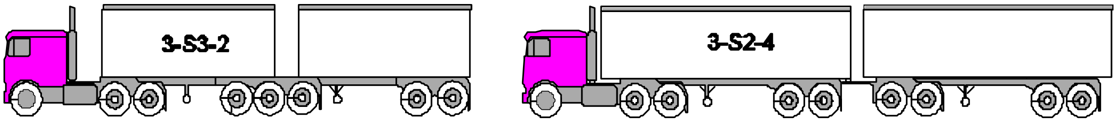


STAA Double-Trailer Combination

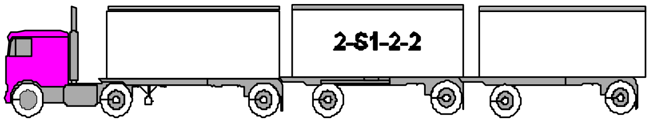


Longer Combination Vehicles (LCVs)

Double Trailer Combinations



Triple-Trailer Combinations



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 alternative TS&W impacts. The scenarios selected for full analysis are intended to establish representative benchmarks delineating the 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.

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[1] "National Freight Transportation Policy," Office of the Secretary of Transportation, Federal Register, Volume 62, Number 3, January 6, 1997, pp. 785-790.

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

COORDINATION WITH THE HIGHWAY COST ALLOCATION STUDY

The first Federal 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.

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 of Transportation, FHWA, Federal Railroad Administration (FRA), National Highway Traffic Safety Administration (NHTSA), Maritime Administration (MARAD), and Bureau of Transportation Statistics (BTS).

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 concerning truck size and weight limits and on 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:

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[2] Federal Register, February 2, 1995, Docket Number 95-5.

- 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; and
- 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.

TABLE I-3
RESPONSE TO FEDERAL REGISTER NOTICE

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 10 are summarized in Table I-4. Respondents represented in Table I-4 include: (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).

Public Meetings

Public meetings were held in Denver, Colorado; 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 (RMDs), 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 Intermodal Surface Transportation Efficiency Act of 1991 (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, Michigan; Salt Lake City, Utah; Houston, Texas; and Philadelphia, Pennsylvania) 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.

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[3] Excerpted from testimony of Mr. Jack Rendler, CRASH, presented at Public Meeting on the CTS&W 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 determining real performance-based standards and no one knows how to implement and enforce these types of standards.**

Source: Comments to the Docket from (1) CALTRANS, (2) AAR, (3) Policy Services Inc., (4) AAA, (5) UPS, (6) A petition signed by 45 private citizens, (7) NPTC, (8) CRASH, (9) Advocates for Highway and Auto Safety and (10) RCCC

CONTEXT

THE TRANSPORTATION ENVIRONMENT

The U.S. freight transportation industry has experienced 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, Staggers Rail Act of 1980, Surface Transportation Assistance Act (STAA) of 1982, ISTEA, 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 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 truck 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.

CURRENT FEDERAL TS&W 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 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:

- 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.

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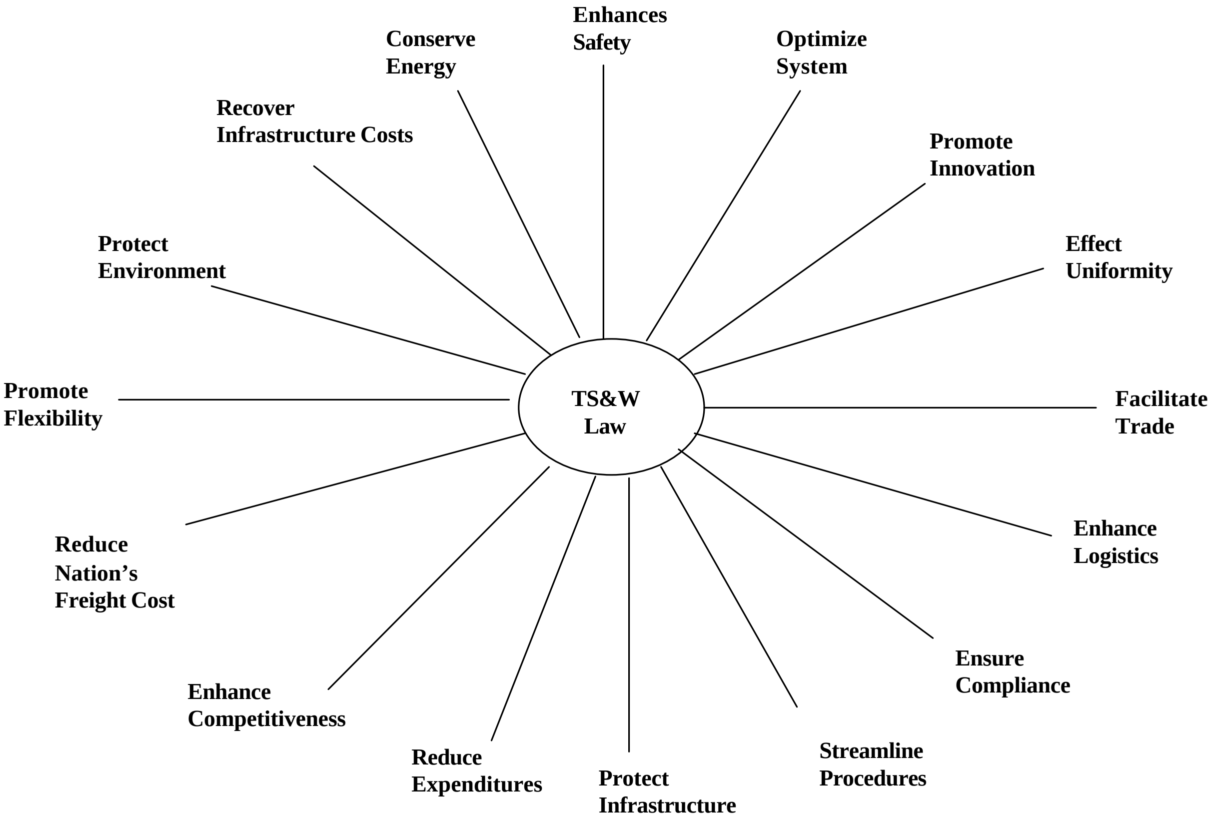
[4] STAA of 1982.

FIGURE I-2
FORCES AFFECTING FEDERAL TS&W LAW



Underlying Federal regulation of TS&W are a myriad of State and local regulations. 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
TS&W 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**
GVW		
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 (FBF), which limits weights allowed on groups of axles at different spacings, whereas, groupings of 2- 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. The 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 STAA of 1982 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.

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.

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[5] Also referred to as "Western Doubles."

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

ORGANIZATION OF VOLUME II: BACKGROUND AND ISSUES

Volume II, Background and Issues, is organized into seven chapters, including this introductory chapter. Brief descriptions of the remaining chapters follow.

TS&W 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.

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 weight regulation was controlled by the individual States and developed in response to increasing motor carriage of freight on a developing highway system. Direct

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

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 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 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 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 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.

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

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

[3] ICC, 1941.

[4] TRB Special Report 211.

[5] TRB Special Report 211.

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

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 standards 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.

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

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

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 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 FBF B(b)	
Surface Transportation Assistance Act of 19982 (STAA)	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 of 1991 (ISTEA)	Interstate completion, NHS designation	LCV freeze	LCV 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 NN as of June 1, 1991.

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:

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[8] *Publication Number 156, Chapter 241, 1916; Federal-Aid Road Act, 1944; Federal-Aid Highway Act, 1956.*

[9] TRB Special Report 225.

- 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.

- 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.

The Surface Transportation Assistance Act of 1982

The STAA of 1982 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

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[10] Description of Bridge Formula B.

[11] TRB Special Report 225.

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" 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 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

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[12] TRB Special Report 221.

[13] TRB Special Report 211 and U.S. Senate Report Number 97-298 1981.

[14] "Access for Large Trucks," TR News, TRB, January - February 1990.

[15] Also referred to as Western Doubles.

and authorized increased Federal spending to finance several major transportation programs. The STAA also initiated two primary tax increases affected by vehicle-weight: a 5-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 STAA of 1982 resolved this dispute, by 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]

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[16] TRB Special Report 211.

[17] TRB Special Report 225.

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

The Intermodal Surface Transportation Efficiency Act of 1991

The ISTEA froze the weight of LCVs and limited them to routes that were allowed by the States on June 1, 1991. The 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 the FHWA in their size and weight certification that they are enforcing the freeze.

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.

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.

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. The 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.

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

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.

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.

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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).

ISTEA: The Third Grandfather Clause

The 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 3 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 2 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 10 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		FBF “B”		“Routine” Permit		
	“I”	Other Highways	“I”	Other Highways	“I”	Other Highways	“I”	Other Highways	GVW	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	80	80 (18)	20	20(18)	34	34(18)	Yes	Yes(18)	92/120	20	40

State	Gross Vehicle		Single Axle		Tandem Axle		FBF “B”		“Routine” Permit		
	“I”	Other Highways	“I”	Other Highways	“I”	Other Highways	“I”	Other Highways	GVW	Single Axle	Tandem Axle
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
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	100(22)/150(22)	25(22)	40(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	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	80	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 GVW: 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 FBF 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) FBF applies if GVW exceeds 73.28K.

(7) If GVW 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) 6- or 7-axle combinations are allowed 83.4K on the Interstate System, and 88K on other State highways.

(13) A 3-axle tractor hauling a tri-axle semitrailer has a maximum GVW of 90K.

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

(15) If the GVW 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 GVW is 80K or less. For other vehicles and GVWs 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 GVW maximum is 73.28K.

(19) The maximum is directly controlled by the FBF. 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 GVW 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 GVW 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 GVW 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 GVW 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, 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

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
D.C.	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(4)		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	

NN			Other State Highways		
State	**Length**	**Kingpin**	**Length**	**Kingpin**	**Overall**
New Mexico	57-6		No Limit		65-0
New York	53-0(4)	41-0 KCRT	48-0		65-0
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
LCVS 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[21]	
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.

OVERSIZE AND OVERWEIGHT PERMITS

State administration of TS&W regulations includes issuing permits for nondivisible 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 II-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.

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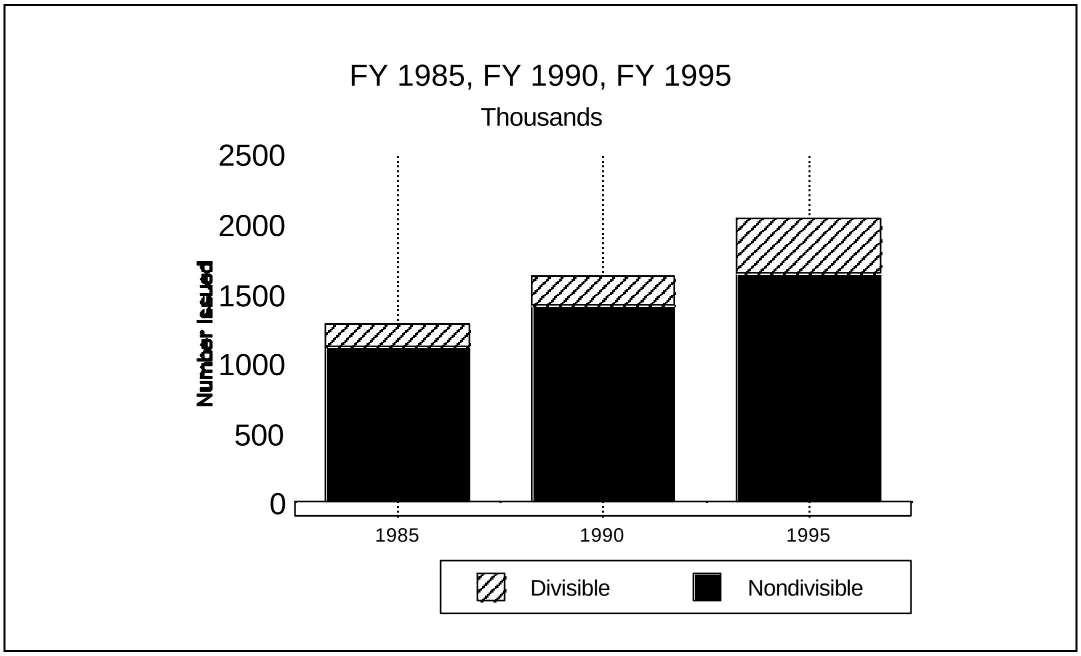
[21] From Kansas, within 20 miles of border.

FIGURE II-1
OVERWEIGHT PERMITS ISSUED BY STATES



The details of these trends are shown in Table II-5. In the 11-year period the total number of overweight permits issued annually (divisible and nondivisible) 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 "multitrip" 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 nondivisible) are often insufficient and unrelated to damage imposed and associated costs.

Table II-6 compares data for 1983, 1989 and 1995 from the 40 States that issued divisible load permits. During that time, there was significant growth in the number of multitrip 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 multitrip[22] permits essentially allow

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[22] This includes monthly, "blanket," and "annual" permits.

unlimited operation with no accounting for mileage or routes for a greater length of time, generally a year.

TABLE II-5
STATE PERMITTING OF OVERWEIGHT LOADS, FY 1985 - FY 1995

Year	Divisible Trip	Divisible Multitrip	Divisible Total	Nondivisible Trip	Nondivisible Multitrip	Nondivisibe 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, FY 1985 - FY 1994; and FY 1995 Annual State Certifications

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,[23] Tennessee, and Virginia).

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[23] This was reversed in 1996 when Pennsylvania implemented legislation mandating permits for milk.

TABLE II-6
DIVISIBLE LOAD PERMITS ISSUED BY STATES

STATE	SINGLE TRIP			MULTIPLE TRIP		
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
D.C.	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

STATE	SINGLE TRIP			MULTIPLE TRIP		
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) 7,476 oversize/overweight permits on toll road.

(C) 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, FY 1983 (Table 12), FY 1989; and Annual State Certifications (FY 1995)

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.[24]

In 1989, State permit fees for an 84,000-pound overweight vehicle ranged from $6 to $61.[25] Although there has been little significant change to the 1989 fees, case studies conducted for this Study (see page VII-32) indicate that States are considering increases that would take into account damage costs; none are considering elimination of the “multitrip” 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 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.”[26]

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

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[24] Confirmed in case study interviews and comments to Docket 93-28.

[25] Source: FHWA “Inventory of State Practices.”

[26] “Performance Audit Report of the Department of Transportation,” Commonwealth of Pennsylvania Legislative Budget and Finance Committee, 1996.

wear for axle groups on an Equivalent Single Axle (ESAL) basis.[27] 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.[28]

Table II-7 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 2-axle group; (2) 18,000 pounds for a 3-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 calculated damage cost per mile fee.

TABLE II-7
MINNESOTA OVERWEIGHT AXLE GROUP COST FACTORS ($ PER MILE) SINGLE TRIP PERMITS

Number of Pounds	2 Axles at 8 Feet Or Less	3 Axles at 9 Feet Or Less	4 Axles at 14 Feet Or Less
0 - 2,000 Pounds	0.12	0.05	0.04
2,001 - 4,000 Pounds	0.14	0.06	0.05
4,001 - 6,000 Pounds	0.18	0.07	0.06
6,001 - 8,000 Pounds	0.21	0.09	0.07
8,001 - 10,000 Pounds	0.26	0.1	0.08
10,001 - 12,000 Pounds	0.3	0.12	0.09
12,001 - 14,000 Pounds	Not Permitted	0.14	0.11
14,001 - 16,000 Pounds	Not Permitted	0.17	0.12
16,001 - 18,000 Pounds	Not Permitted	0.19	0.15
18,001 - 20,000 Pounds	Not Permitted	Not Permitted	0.16
20,001 - 22,000 Pounds	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

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[27] 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.

[28] Comments to Docket 93-28, Minnesota DOT, FHWA Docket 93-28-17, March 14, 1994.

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 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, most States presently set permit fees well below levels that would cover infrastructure costs caused by vehicles operating under overweight permits. 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.

CHAPTER 3

TRUCK FLEET AND OPERATIONS

INTRODUCTION

The Nation's truck fleet characteristics and operations are highly varied as trucking evolves within a dynamic environment that includes multi jurisdictional TS&W regulations, safety regulations, freight characteristics, shipper and customer needs, economic forces, international trade, and truck and trailer manufacturer innovation. The truck fleet and use are described in the following sections: (1) trucking industry structure, (2) equipment characteristics, (3) relationship between TS&W policy and truck characteristics, and (4) trucking operations (truck flows, commodity case studies, cross-border trucking, and container use).

TRUCKING INDUSTRY STRUCTURE

As trucking serves many different markets, it has become highly segmented in order to respond efficiently to these markets. 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) and 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 businesses have internalized all aspects of their logistics including owning and operating their own truck fleet. Common examples of private carriers include grocery stores, retail chains, and food processing companies. Information on the operations of private carriers is limited, partially because these carriers traditionally have been less subject to government reporting requirements. Table III-1 indicates that private carrier operations constitute a large share of trucking in the Nation.

Table III-1
Private Carrier Profile - 1993

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.
- The average length of haul for private carriers is 51 miles, resulting in 240 billion ton-miles handled.
- The value of freight handled by private carriers was $1.8 trillion, $1.0 trillion lower than the for-hire carriers.

REVENUE

- 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.

Source: 1993 CFS 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 - 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.

REVENUE

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

TL VERSUS LTL OPERATIONS

The TL carriers 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. The TL operations are categorized according to the type of freight handled, either general or specialized. General freight is transported in enclosed van trailers; 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 than general freight carriers in 1993, the revenue generated from general freight was slightly higher than that generated by specialized freight carriers ($11.7 billion versus $11.4 billion). In the late 1980s, a small number of “megacarriers” emerged from within the large TL carriers. These megacarriers 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.

The LTL carriers specialize in transporting small shipments of freight, generally in units of between 250 pounds and 12,000 pounds. An LTL shipment is comprised of general freight from several shippers and has many different destinations. An example of an 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 an LTL carrier that transports international containers from a port to a break-bulk terminal. Often these potentially overweight containers are moved to a terminal under special permit, emptied, and their cargo reloaded for line-haul movements at 80,000 pounds or less. To reduce line-haul miles and handling of freight, LTL carriers use strategically located terminals and operate truck combinations between them on regularly scheduled line-haul routes.

SHORT-HAUL VERSUS LONG-HAUL OPERATIONS

Short-haul operations are defined for this Study as freight movements of 200 miles or less from origin to 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).

Typically, trucks operating in local, short-haul operations have lower annual VMT than those in long-haul, which varies greatly according to type of truck configuration. In general, single-unit trucks have average VMT much lower than truck combinations. For example, average VMT for 2-axle single-unit trucks is 11,000 miles, or about 30 miles per day. The 3- and 4-axle single-unit trucks are slightly higher at about 40 miles and 60 miles per day, respectively.

Annual average VMT for long-haul operators is substantially higher. For example, 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 mounted on the same chassis as the engine, or whether they are combination vehicles that have separate cargo-carrying trailers or semitrailers that are pulled by a truck or truck-tractor. Nationally, the distribution of the trucking fleet by configuration is approximately as follows:

Single-unit trucks - 68 percent;
Truck-trailer combinations - 4 percent;
Tractor-semitrailer combinations (primarily 5-axle combinations) - 26 percent;
Double-trailer combinations - 2 percent; and
Triple-trailer combinations - less than one-tenth of 1 percent.

The distribution of large truck configurations, combinations with 5 or more axles, varies among States and regions. For example, in California 18 percent of the truck fleet are truck-trailer combinations and 39 percent are STAA twin-trailer combinations; in Florida, only 2 percent of the truck fleet are truck-trailer combinations and 1.6 percent are double-trailer combinations.[1] Figure III-1 presents the different types of configurations in the national truck fleet.

The U.S. trailer fleet increased significantly 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 LCVs (that is, double- and triple-trailer combinations).

SINGLE-UNIT TRUCKS

The most common single-unit trucks in the commercial fleet with three or more axles are dump trucks, transit mixers, tank trucks, and trash trucks. These vehicles are designed to provide specialized services and are commonly referred to as specialized hauling vehicles (SHVs). They have from 2- and 4-axles. The SHVs represent approximately 46 percent of the single-unit trucks operating in the United States with 3 or more axles. They are typically used in local and intrastate, short-haul operations. The most common commodities that they haul are construction materials, gravel, ready-mix cement, grain, milk, petroleum products, and garbage or waste.

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 2-axle single-unit trucks decreased over this period by about 14 percent. During that same period of time, the number of 4-axle single-unit trucks more than doubled to approximately 84,000 due to the substitution of 3-axle trash, dump and concrete trucks with 4-axle units.

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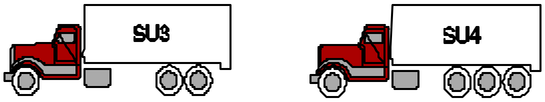
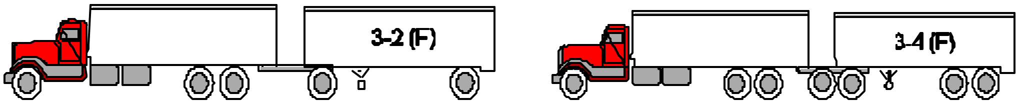
[1] 1992 TIUS Database.

Figure III-1
Illustrative Truck Configurations of U.S. Fleet

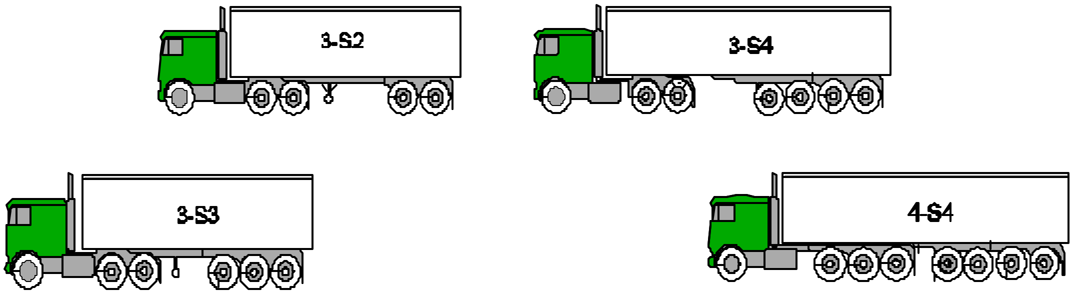
Single-Unit Trucks



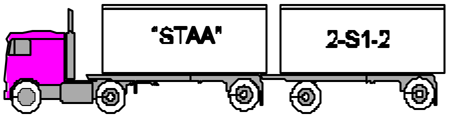
Truck-Trailer Combinations



Tractor-Semitrailer Combinations

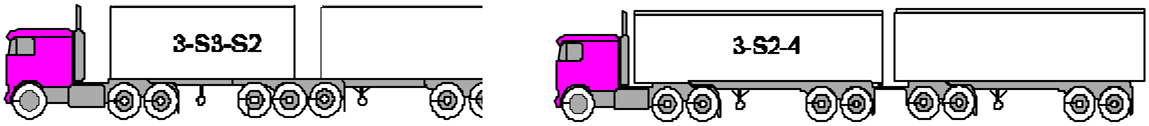


STAA Double-Trailer Combination



LCVs

Double-Trailer Combinations



Triple-Trailer Combination

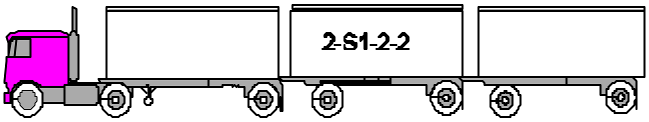
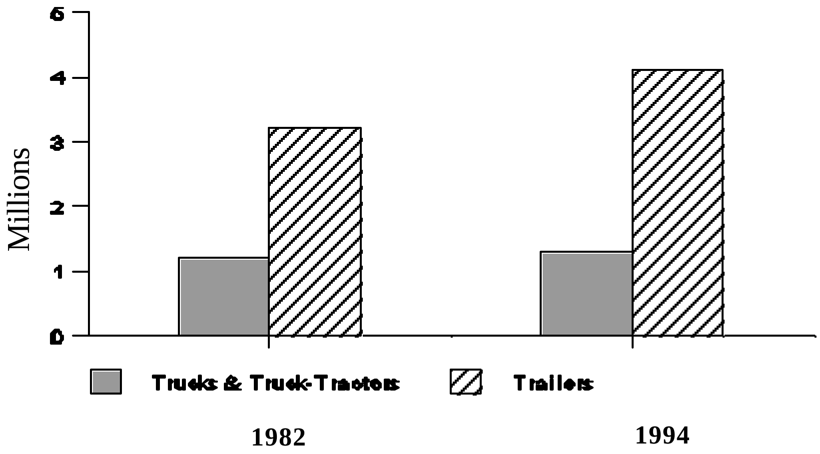


Figure III-2
Fleet Size And Growth: 1982-1994



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.

TRACTOR-SEMITRAILERS

Tractor-semitrailer combinations account for more than 82 percent of all combination trucks on U.S. highways. The number of 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 2-axle tractors, such as the cab-over models of the early 1980s, toward longer wheelbase 3- and 4-axle tractors.

MULTITRAILER

The more typical multitrailer combinations operating in the United States are: STAA doubles (twin 28-foot trailers), RMDs, turnpike doubles (TPDs), and triples. The LCV are the RMD, TPD, and triple-trailer combinations. LCVs represent a very small number in relation to the total truck combination fleet, approximately 20,000 in 1994 or 0.5 percent. Like single-unit trucks and other combinations, multitrailer combinations are used to haul a variety of commodities, and their trailers are specialized for the commodities being carried.

STAA DOUBLES

The STAA of 1982 provided for the unrestricted use of two-trailer combinations (two 28-foot to 28.5-foot trailers) on the NN. The NN consists of the Interstate System and routes designated by the 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 has been relatively small nationwide, except for those States in the East where they had been previously prohibited. Nationwide, STAA doubles represent approximately 2.5 percent of all truck combinations. Generally, STAA doubles are most important to the LTL industry.

LCVs

Figure III-3 illustrates the common types of LCVs: RMD, TPD, and triples. The RMDs consist 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 6 States and on other routes in 17 States. (Some States like Iowa and Missouri limit the access of LCVs to specific terminals within the State).

The TPD combinations consist of a truck-tractor towing two long trailers of equal length, typically two 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 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 15 States under permit with restrictions. Triple-trailer combinations have been operating in Idaho, Nevada, Oregon, and Kansas since the 1960s.

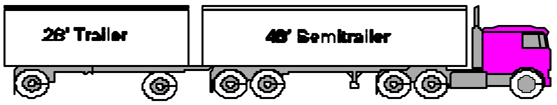
Figure III-3 provides a list of the States where LCVs are allowed to operate, by configuration. Also indicated is the first year of operation

RELATIONSHIP BETWEEN SIZE AND WEIGHT POLICY AND TRUCK CHARACTERISTICS

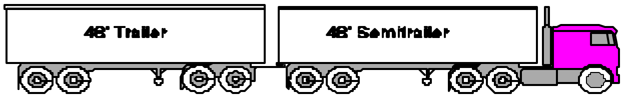
Federal and State TS&W regulations define the weight and dimension envelopes into which loaded trucks must fit. Other influencing factors are the freight hauled and associated logistical considerations (shipment size, packaging, fragility, temperature control, origin-destination patterns, delivery time requirements); infrastructure considerations (terminals and route options between origin-destination pairs); truck economic considerations (replacement cycles, resale

Figure III-3
LCVS

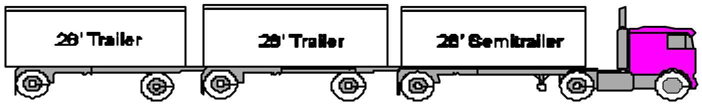
RMD



Turnpike Double



Triple-Trailer



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markets, fuel economy, driver flexibility); truck operating strategies and company structures; special permitting policies and practices; regulation enforcement; and intermodal considerations.

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

Interestingly, beginning in the late 1980s an industry trend began to emerge; the mean average loaded weights (tare weights plus payload weights) 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. Note that: (1) on average, none of these combinations uses the maximum weight allowed, and (2) 5-axle tractor-semitrailer combinations with specialized body types (dump, tank, grain) for hauling bulk commodities use about 93 percent of the allowed 80,000 pounds GVW.

Table III-3
Permitted LCVs by State and Configuration

State	Triples	Turnpike Doubles	RMDs
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
State Turnpike Authority	**Triples**	**Turnpike Doubles**	**RMDs**
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: U.S. GAO, *Longer Combination Trucks* (Washington, D.C., 1994).

Table III-4
Average Payload and Loaded Weight of Common Truck Types (Pounds)

	5-Axle Truck-Trailer		5-Axle Tractor-Semitrailer		STAA Double	
Body Type	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.

GVW LIMITS

Most trucks and combinations operate at or below the GVW limits, as they do not reach their weight limit because the available space in the truck becomes filled first, that is, it “cubes out.” Tank trucks and trailers operate at average load levels that reach their maximum weight limit and “weigh-out” over 80 percent of the time; this occurs less than 20 percent of the time for enclosed van trailer combinations. Enclosed van trailers, in many instances, are used to transport commodities that have low density.

The 1975 FBF mandate led to a variety of vehicle configurations and characteristics not initially envisioned. These new configurations are typically directed at increasing the potential payload. Examples of such “bridge formula” trucks are: (1) 4-axle tractors with a lift axle; (2) very long “tongues” on truck-trailer and double-trailer combinations (to increase axle spacing, and therefore, allow a higher gross weight limit); and (3) split tandem axles, now a common feature of 5-axle tractor-semitrailers carrying heavy commodities.

AXLE WEIGHT LIMITS

One or both of the Federal axle limits (20,000 pounds for a single axle and 34,000 pounds for tandem axles) are surpassed through the exercise of grandfather rights for Interstate highways in 12 States, and permit policies in others. Weight limits for other axle groups are determined through the application of the FBF or State regulation in some cases.

Current Federal axle weight limits were established to minimize pavement damage and the FBF, a formula specifying a maximum gross weight given a vehicles wheelbase and the number of axles it has. The Federal provision also has a maximum GVW of 80,000 pounds. 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 (within 3- and 4-axle groups -- tridems and quadrems).

The increasing use of wide-base super single tires instead of dual tires in the United States is an innovation that originated in Europe. Federal law and most State laws do not prohibit the use of wide-base single tires. Benefits to industry include reduced energy use, tare weights, 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 configurations frequently observed on single-unit trucks, especially SHVs, include tridem axles, lift axles, split tandem axles, and quadrem axles. Use of these configurations has evolved over the last two decades as industry adapted to Federal and State weight policies.

TRIDEM AXLES

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. On tractor-semitrailers, tridem axles offer the advantage of 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 building materials and heavy machinery on tractor-semitrailer combinations.

LIFT AXLES

Throughout the country, lift axles are routinely used on single-unit trucks, such as dump trucks and cement mixers, as well as on semitrailers operating where GVWs over 80,000 pounds are permitted. Lift axles are used on over 70 percent of all 4-axle, single-unit trucks. In several States, 5-, 6-, and 7-axle single-unit trucks with two to four lift axles are used. Federal TS&W laws, as well as most State laws, do not address the use of lift axles.

Generally, a truck operates with the lift axle down when loaded to increase its weight limit, and up when empty to improve vehicle maneuverability and handling. On the other hand, lift axles allow the driver to raise the axle of a loaded truck during operation on the highway, which redistributes the loaded weight over fewer axles.

SPLIT TANDEM AXLES

A split tandem axle is created by increasing the spacing between the 2-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. Their operational advantages are: (1) they increase GVW within the allowable limit, and (2) they provide increased flexibility in load distribution. By increasing the spacing, the split tandem, rather than being considered a tandem axle with an axle weight limit of 34,000 pounds, is considered as two single axles with a total allowable weight governed by the FBF. The combined weights allowed on a split tandem axle are 38,000 pounds for a spread of more than 8 feet, 39,000 pounds for 9 feet, and 40,000 pounds for 10 feet or more.

DIMENSIONAL LIMITS

SEMITRAILER LENGTH

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

Van 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 the available length or width. In certain States semitrailer lengths and operating properties are also influenced by kingpin requirements. Such laws set a specified distance from the trailer kingpin connection to a specified axle or the center of the semitrailer axle group.

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 53-foot semitrailers. The historic trend has been incremental growth in the length of semitrailers, 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; This semitrailer offers an 18 percent increase in cubic capacity over the 45-foot semitrailer.

The distribution of 53-foot semitrailers by trailer body type is: (1) 30 percent to 40 percent of all types of van trailers; (2) 15 percent to 20 percent of the flatbed fleet; and (3) less than 10 percent of specialized truck body types. Currently, semitrailers longer than 53 feet are permitted to operate in 10 States (on most State NN facilities) -- Alabama, Arkansas, Arizona (Interstate only), Colorado, Kansas, Louisiana, New Mexico, Oklahoma, Texas, and 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 provided for the free movement of 102-inch wide equipment on the NN. Although the law provided for uniformity on Interstate and NN highways, several States have a 96-inch-width limit for commercial vehicles on non-NN routes. As a consequence, 96-inch wide equipment remains commonplace, especially for trucks that meet the maximum weight limits before using the allowed cubic space.

HEIGHT

Height limits have been established over the years to ensure clearance of vehicles under rail or highway overpasses. The clearance standard for bridges constructed over the Interstate System is a minimum of 14 feet in urban areas, where space is limited, and 16 feet in rural areas. 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; while the Eastern States, except Maine, limit vehicle and load heights to 13.5 feet.

TRUCKING OPERATIONS

The relative intensity of truck traffic throughout the Nation can be measured by the volume of truck flows on major highways and truck VMT in each State.

TRUCK FLOWS

Truck flows on the NHS are illustrated in Figure III-4. These flows range from fewer than 100 trucks per day on rural corridor highways to over 25,000 trucks per day on Interstate highways in and around major urban centers. General observations regarding these flows are:

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

- Truck volume on most of the NHS 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 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 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 VMT

Total truck VMT in 1994 was approximately 168 billion, which is distributed among the States as shown in Table III-5. California had the highest truck VMT (16.8 billion), equal to 10 percent of the 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 Northeast region.

SINGLE-UNIT TRUCKS

Single-unit trucks account for approximately 42 percent of total truck VMT. The 2- and 3-axle trucks account for the majority of the single-unit truck VMT, approximately 85 percent and 12 percent, respectively. Although the number of 4 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.

SINGLE-TRAILER COMBINATIONS

Tractor-semitrailer combinations are the most common combination operating in the country, accounting for over 25 percent of all registered trucks and 82 percent of all truck combinations. They include combinations of a 2-, 3-, or 4-axle tractor with a semitrailer having 1 or more axles (up to 8 in Michigan). In 1994, tractor-semitrailers accounted for approximately 53 percent of total truck VMT, or 89.6 billion VMT.

Truck-trailer combinations are the second most common combination in the country, accounting for approximately 14 percent of the truck combination fleet. Their use increased significantly since 1982, primarily in the North Central region. With 3.1 billion VMT, however, truck-trailer combinations account for less than 2 percent of total truck VMT. Over 50 percent of this VMT is attributed to the 5-axle combination.

MULTITRAILER COMBINATIONS

STAA Doubles

The VMT for the STAA double (twin 28-foot) in 1994 was approximately 4.5 billion miles per year, or 2.6 percent of all truck VMT. It accounted for 4.5 percent of all truck combinations VMT, and 71 percent of all VMT by double-trailers.

LCVs

The LCVs are permitted in 21 States and include RMD, TPD, and triple-trailer combinations (see Table III-3 for a listing of where these vehicles are permitted to operate). Total VMT for the longer double-trailer combinations was 1.8 billion VMT in 1994, or approximately 1 percent of all truck VMT and less than 2 percent of all combination VMT.

The number of triple-trailer combinations is relatively small compared to the total truck combination fleet. In 1994, total VMT for triple-trailer combinations was 108 million distributed among the 14 States in which they operate. On average each triple combination travels approximately 90,000 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 occurring in Oregon and Utah.

Figure III-4
Truck Flows on the NHS

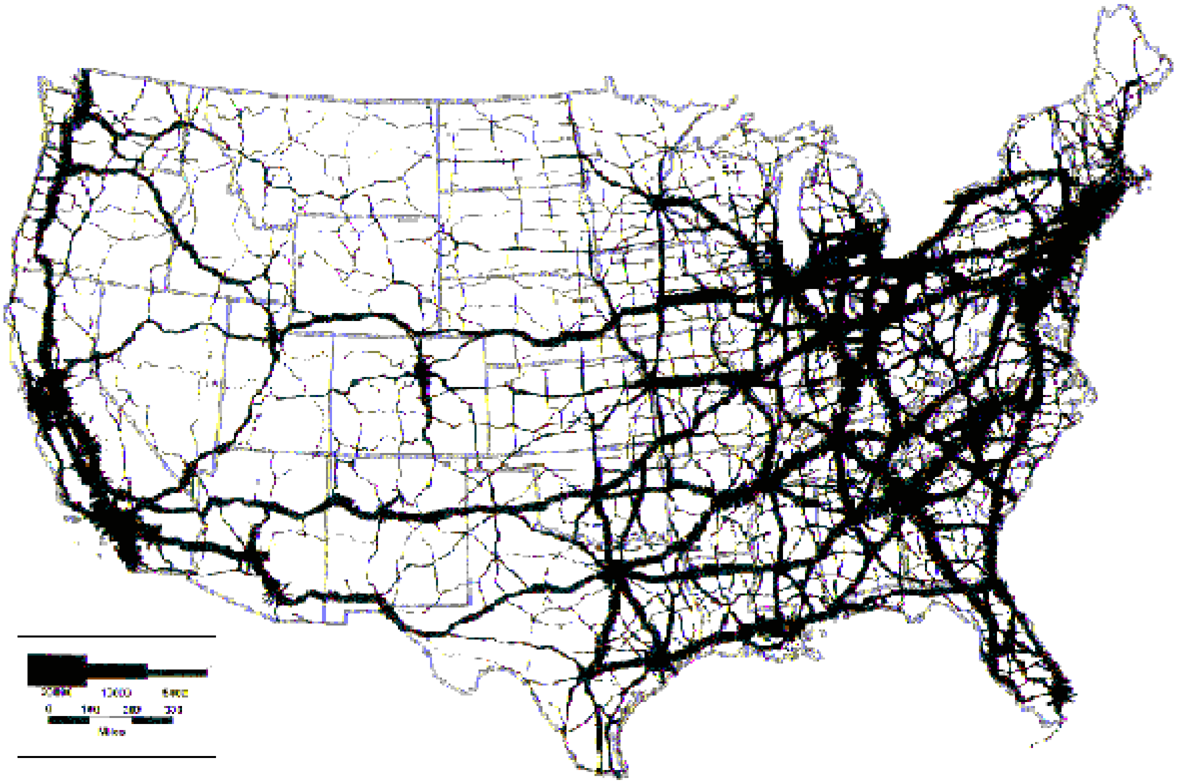


Table III-5
Truck VMT by State: 1994
(Thousands)

State	Total VMT	Total Truck VMT	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 U.S. DOT, HCA Study (Washington, D.C., 1997)

HIGHWAY NETWORKS FOR MULTITRAILER COMBINATIONS

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. While STAA doubles are allowed in all States, doubles combinations longer than 28.5 feet are only allowed in 21 States. Indeed, the ISTEA 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 included in the 1991 grandfather provision are summarized in Table III-6. Of the 21 States allowing longer combination doubles, all but five are west of the Mississippi River. Figures III-5 and III-6 provide maps of the RMD and TPD highway networks.

Table III-6
Operation of Vehicles Subject to the ISTEA Freeze Maximum Size and Weight Limits

State	Truck Tractor and Two Trailing Units	Truck Tractor and Three Trailing Units	Other
	Length in Feet (‘)/Weight in 1,000 Pounds (K)		
Alaska	95'	110'	83'
Arizona	95' 129K	95' 129K	69' - 98'
Colorado	111' 110K	115.5' 110K	78'
Florida	106' (1)	No	No
Idaho	95' 105.5K	95' 105.5K	78' - 98'
Indiana	106' 127.4K	104.5' 127.4K	58'
Iowa	100' 129K	100' 129K	78'
Kansas	109' 120K	109' 120K	No
Massachusetts	104' 127.4K	No	No
Michigan	58' 164K	No	No
Missouri	110' 120K	109' 120K	No
Montana	93' 137.8K	100' 131.06K	88' - 103'
Nebraska	95' 95K	95' (1)	68'
Nevada	95' 129K	95' 129K	98'
New Mexico	86.4K (2)	No	No
New York	102' 143K	No	No
North Dakota	103' 105.5K	100' 105.5K	103'
Ohio	102' 127.4K	95' 115K	No
Oklahoma	110' 90K	95' 90K	No
Oregon	68' 105.5K	96' 105.5K	70'5"
South Dakota	100' 129K	100' 129K	73' - 78'
Utah	95' 129K	95' 129K	88' - 105'
Washington	68' 105.5K	No	68'
Wyoming	81' 117K	No	78' - 85'

(1) No maximum weight is established as this vehicle combination is not considered an “LCV” per the ISTEA definition. Florida’s combinations not allowed to operate on the Interstate System..

(2) No maximum cargo-carrying length is established for this combination. Because State law limits each trailing unit to not more than 28.5 feet in length, this combination is allowed to operate on all NN routes under the authority of the STAA of 1982, regardless of actual cargo-carrying length. The maximum weight listed is New Mexico’s maximum allowable gross weight on the Interstate System under the grandfather authority of 23 U.S.C. 127.

Source: FHWA Publication Number FHWA-MC-96-03

Figure III-5
Highways Available for Turnpike Doubles

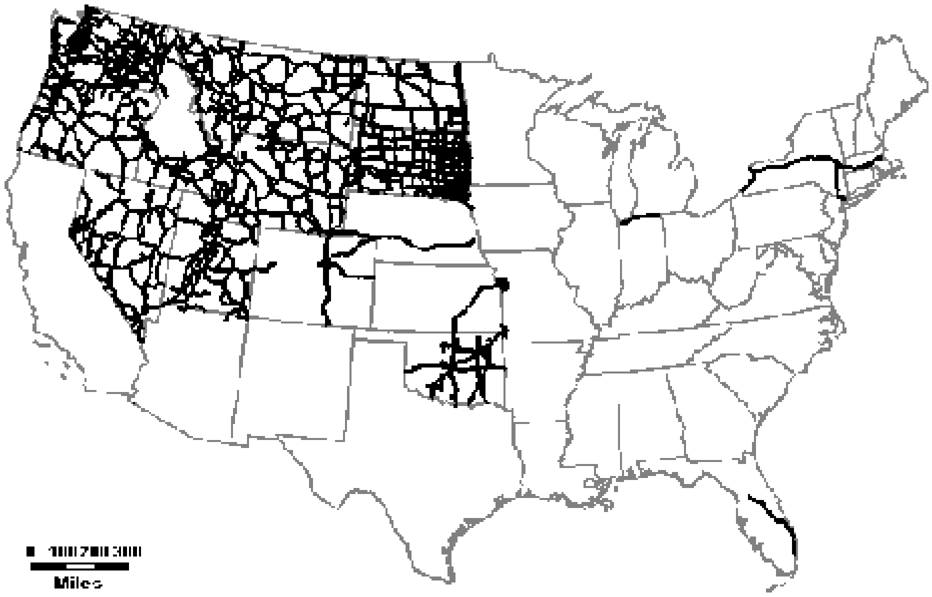
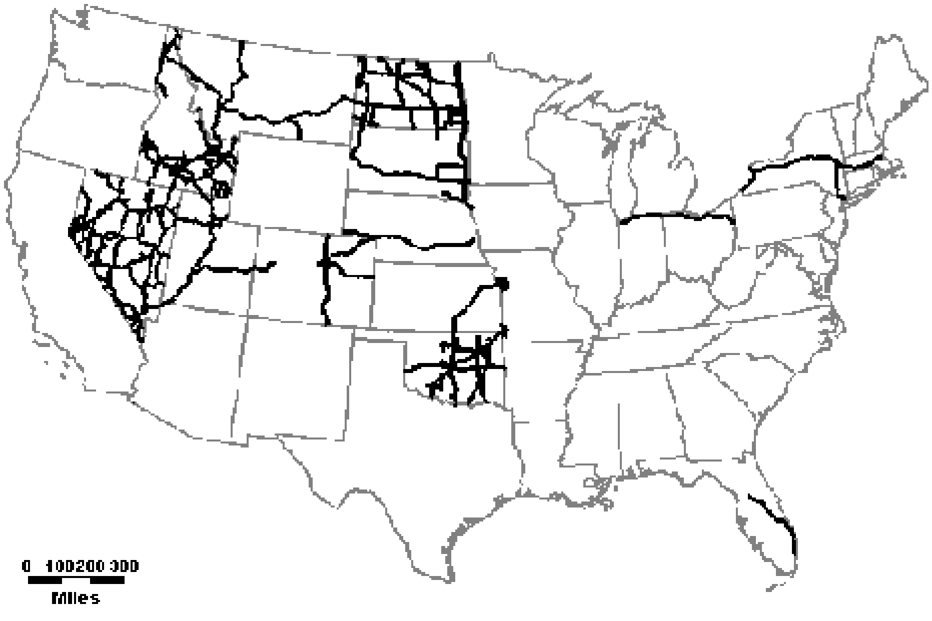
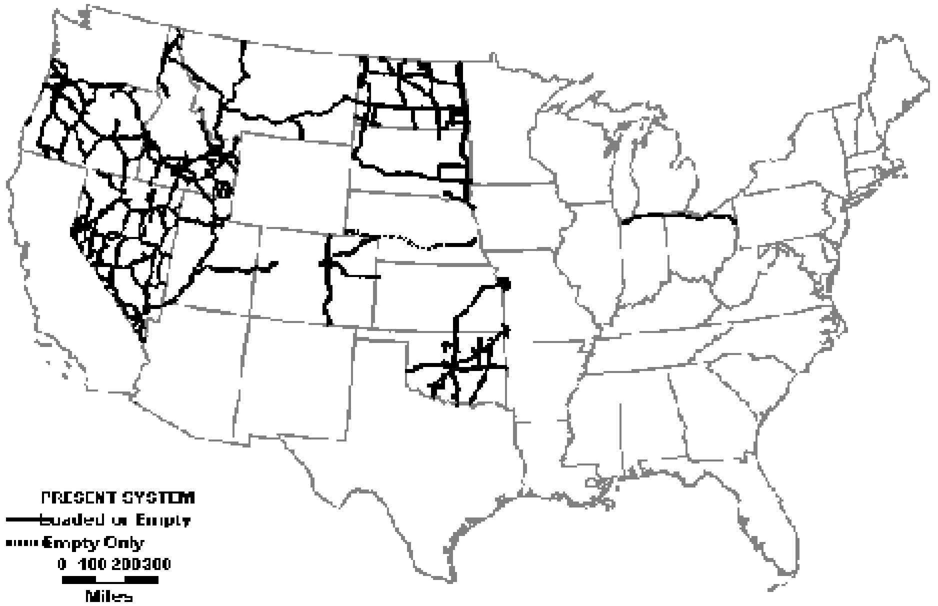


Figure III-6 **Highways Available for RMDS**



A triple-trailer combination consists of a tractor and typically three 28- to 28.5-foot trailers. Triple-trailer combinations are permitted to operate in 13 States under restrictive circumstances and on limited networks. Figure III-7 provides a map of the highways available for triple-trailer combinations.

Figure III-7
Highway Network Available for Triple-Trailers



COMMODITY CASE STUDIES

The use of trucking in the production and distribution of the four commodities: coal (in Kentucky), forest products (in the Northwest), farm products (in the upper-Midwest), and automobiles is discussed in this section.

COAL

Kentucky is a major producer of coal with more than three-quarters of its production used by electric utilities. Until the early 1950s, most coal was retrieved from underground coal mines, and rail was the principal mode for moving it. Underground mining and railroading complimented each other because large quantities of coal were brought to the surface at relatively few locations, thereby, permitting the development of large loading facilities and concentrated rail lines.

Strip mining increased in the 1960s with increasing coal prices. Because this type of mining leads to the production of relatively small quantities of coal in many locations, usually at some distance from a rail line, it encouraged the use of trucks to haul coal, and the trucks used have increased in size and weight over the years.

Through the 1960s, 2- and 3-axle dump trucks were the standard means of haul. Some operators added lift axles to facilitate handling larger payloads. Because of the relatively low density of coal compared to stone and dirt normally handled in the dump trucks, coal truckers added side boards of as much as 2 feet in height to their dump boxes to permit handling larger payloads. This practice raised the center of mass of loads, leading to increasing problems with vehicle stability. Longer and heavier straight frame trucks continued to dominate the coal haul until into the late 1970s. By this time, to help accommodate the heavy loads being handled, many operators were inflating their tires to pressures as high as 150 to 200 psi -- as much as double the inflation pressures of many trucking operations, and a harmful practice for pavements.

Five-axle tractor-semitrailers were introduced in the late 1970s. This equipment generally used 20-foot boxes with 12- to 16-inch side boards. By the late 1980s, these units were being replaced with 6-axle tractor-semitrailers using a tridem axle semitrailer with 28-foot boxes. These longer trailers allow the loads to be placed over a longer distance with a lower center of gravity and enhanced stability. Air-lift axles started to be used in the tridem groups, first on the lead axle in the group, and most recently on both the lead and rear axle in the tridem. Tridem-axle semitrailer units are allowed to operate at GVWs up to 120,000 pounds on selected highways designated as the "Extended Weight System (EWS)."

Surveys at coal sites throughout Kentucky in 1988 and 1992 demonstrate that: (1) tractor-semitrailers dominate coal haul in the State; (2) 5-axle tractor-semitrailers are being replaced by 6-axle units; (3) the use of both 3- and 4-axle straight trucks is declining. Coal haulers have indicated that their vehicles have to be replaced about every 7 years. In 1992-1993, Kentucky issued EWS decals for 3,471 units.

FOREST PRODUCTS

The high concentration of natural forest production in the Pacific Northwest has generated an array of forest product industries involved in the harvesting, manufacturing and distribution of wood products. The harvested timber is used for: lumber, plywood, poles, shingles, paper, and raw logs for export. Lumber and plywood production dominate.

The growth and success of these industries has been promoted by an efficient transportation network comprised of truck, rail, and barge transport. However, trucks are the prime mode used for transporting timber from the harvest area, due to their flexibility and reliability in accessing remote forest areas. Typical maximum haul lengths are about 100 miles.

Sawmill products, mostly in the form of lumber, from the Pacific Northwest are distributed to all regions of the United States and exported abroad. However, the primary destinations (one-half to two-thirds) for sawmill products in Washington, Idaho and Oregon are in the West. About one-third of Montana products are shipped to the Midwest and another roughly one-third to western markets. Ten to 15 percent of Washington/Oregon production is exported, while only a small proportion of Montana/Idaho production is exported.

There is substantial modal competition for the movement of sawmill products (mostly lumber). Trucking dominates in Washington and Oregon, accounting for nearly 60 percent of sawmill product moves. On average, rail handles about one-third of the product in these two States, and water handles about 10 percent. Water movements are typically export-bound. For Idaho, rail and truck share equally in the handling of sawmill products. For Montana, rail handles 60 percent and trucks handle 40 percent.

There is also substantial modal competition for moving of plywood. Plywood from the western region (west of the Cascade mountains) is handled equally by truck and rail. About two-thirds of plywood originating in the inland region (principally Eastern Washington and Oregon, Northern Idaho, and Western Montana) is handled by rail. Less than 1 percent of the plywood is moved by water, reflecting the small percentage of plywood that is exported.

Log production for export is concentrated in Washington at 73 log export sites and Oregon at 13 sites. Practically all movement of logs destined for export is by truck to either an ocean port for ship loading, or to the Snake or Columbia Rivers for barge transport to ocean ports. Generally, logs for export from Eastern Washington move down river, whereas the majority of log export movements originating west of the Cascades are done by truck.

Markets and movements of sawmill products in the Pacific Northwest involve either comparatively short hauls dominated by truck, or comparatively long hauls dominated by rail. Only about 10 to 20 percent of the movements operate over distances which could be considered competitive between truck and rail.

FARM PRODUCTS

Before the 1980s, the Midwest agricultural economy was primarily based on production of raw agricultural goods with some food processing. Transportation needs centered on the efficient movement of raw agricultural products. Except for short moves from farms to railheads, grain was primarily moved by rail to processing facilities across the country and to barge facilities for export. Meat was primarily moved by truck as either live animals to slaughter facilities or hanging carcasses to retailers throughout the country.

In the last 20 years, changes in farm production, transportation, and other technologies have combined to alter the Midwest agricultural economy from primarily a raw agricultural goods economy to include a large processed grain and meat sector. Production of farm products has increased as farms have become more efficient. At the same time the agricultural and food industries have diversified; instead of shipping farm products from the Midwest for processing, today more of the processing is done in the region close to the source of raw materials. Examples of value-added products that have emerged as a mainstay of the Midwest agricultural economy are: ethanol, cooking oils from both corn and soybeans, animal feeds, cereals, and corn sweeteners, and processed meat products. This has resulted in transportation requirements shifting from the movement of raw farm products out of the region to the movement of farm products locally and the movement of processed food and grain milling products to regional markets or to more distant domestic and international markets.

There is a high level of integration of the agribusiness economies of the States in the Midwest. Much of the associated traffic moves within and among the Midwestern States. State boundaries are rather transparent to the agribusinesses. Recent surveys show that 70 percent of Iowa's agribusiness truck traffic is involved in movements within Iowa and between it and neighboring States.

Grain

The transportation of raw and bulk grain products is dominated by the need for efficient movement of large amounts of dense corn and soybean products. These movements are primarily served by rail. However, with grain processing moving closer to the location of raw production, some of the localized transportation needs of raw grain products are handled by trucks. These truck movements primarily involve short hauls of grain from farms to railheads, and the trucking of dry bulk products such as flour and sugar to food processors not served by rail.

The transportation of processed grain products is served primarily by truck. High-cube, low weight products like cereals do not require the large quantity, high-weight service capability provided by rail. In addition, these products are most often destined for retailers not easily served by rail. Other processed grain products such as baked goods have a relatively short shelf-life and may be somewhat fragile, thus requiring the quick, high-level service provided by truck to maintain product quality.

Widespread acceptance of 53-foot long, 102-inch wide semitrailers has allowed shippers of low density boxed breakfast cereal to increase their transportation efficiency (a 25 percent payload advantage over the 45-foot, 96-inch semitrailers of the early 1980s). This has encouraged cereal producers to locate their manufacturing facilities in smaller Midwestern communities close to raw material sources. For example, General Mills, Quaker Oats, Cargill Inc., and Archer Daniels Midland all have major grain milling facilities located in the Cedar Rapids, Iowa area.

The development of sealed pneumatic trailers has provided for greater efficiency in the transportation of bulk flour and sugar used in other value-added products such as baked goods, and bulk feed ingredients such as soybean meal and corn gluten. The aluminum construction of these trailers allows for more cargo capacity due to reduced tare weight of the trailer. These trailers have provided two types of efficiencies: (1) a reduction in manufacturing and manpower requirements for the packaging of the commodity because the product is shipped in bulk rather than bag, and (2) an increase in payload capacity through elimination of packaging materials and the use of lighter materials. Through a combination of lighter materials and using an extended-bridge mounting of rear tandem axles to lengthen the interior bridge dimension, pneumatic trailers carry payloads of 52,000 pounds (a 13 percent payload advantage over van trailers handling packaged goods). Bagged shipments of these processed grain products are generally limited to 46,000-pound payloads.

Refrigerated trailers have experienced increases in productivity as a result of decreased tare weights. Because of the increased use of aluminum and composite components in trailer body construction and light, more fuel efficient refrigeration units that utilize smaller fuel tanks, today's 48-foot refrigerated trailers commonly have tare weight of 15,000 pounds or less (including the refrigeration unit) versus approximately 17,000 pounds for older trailers. Using these light trailers and properly specified tractors, carriers can routinely handle 46,000-pound payloads (a 2,000-pound increase over the common payloads available in the early 1980s). Fifty-three-foot trailers are not used because the cargo capacity of the vehicle is limited by maximum gross weight requirements rather than by a lack of volumetric capacity.

Livestock and Processed Meat

The most significant changes in the beef and pork industries over the past two decades are: (1) a shift in pork production from smaller, independent producers to large corporate hog finishing facilities and contracted hog finishing for meat packers; (2) relocation of meat processing facilities to the Midwest to be nearer beef and pork supplies; (3) large increases in meat exports to eastern markets due to improvements in refrigeration and transportation. These shifts have impacted the grain market in the Midwest with areas near large hog finishing facilities in the heart of high corn production territory actually importing corn to meet the demand for feed. Improvements in sanitation, meat processing, and packaging have changed the product being shipped longer distances from hanging carcasses to meat packaged for retail.

The transportation of livestock and processed meat products is served almost exclusively by trucks. Transport of livestock cannot be accommodated by the longer service intervals and unsupervised (no driver) nature of rail and intermodal container transportation. Market demands for high-quality meats require the fast, high-service available through truck transportation to ensure livestock arrives for processing in the best condition possible. Similarly, processed meats require high-level service (short delivery intervals and monitoring of refrigerated temperatures) that is not readily available through rail car service. A very small portion of processed meat freight is transported via intermodal container.

AUTOMOBILE INDUSTRY

Much of the in-bound transportation of auto parts and materials to assembly plants has been out-sourced to for-hire carriers. Also, there is a growing dependence on third party logistics providers, just-in-time delivery systems, and information technology. Other factors include containerization, intermodal moves, and international sources. Intermodal is a small but growing industry-wide trend that may be more pronounced in the auto parts sector of the trucking industry due to the international character of automobile production.

The sector of the trucking industry that moves the finished product from the assembly plants (an $1.8 billion per year business with approximately 13,000 power units and trailers) is significantly different from the sector of the trucking industry involved in inbound transport. The number of outbound carriers used by each of the Big Three is small compared to the number of inbound carriers. Information technology is being deployed slowly by the outbound carriers, and the outbound carriers typically use trailers that have little use outside of auto hauling. Lastly, it is widely, but incorrectly, assumed that auto transporters cube out. Cars are getting heavier, and as a result, auto transporters are weighing out more and more.

CROSS-BORDER TRUCKING

Eleven of the 77 highway border crossings between Canada and the United States are Interstate highways. Four of the 38 highway crossings between Mexico and the U.S. Southwest are Interstate highways. 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. 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, truck traffic from Canada grew by 9 percent per year and traffic from Mexico grew 11 percent per year.

WEIGHT LIMITS

Weight limits governing trucking operations across the two borders are very different. In crossing to Canada, all but 1 crossing for NHS highways have a GVW limit of more than 99,000 pounds; 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 a GVW of 80,000 pounds, and six of nine other crossings on the NHS have a GVW of 84,000 pounds (with a permit from Texas).

TRUCK CHARACTERISTICS

The majority of trucking across the Canadian border is conducted with 5-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) 7- and 8-axle combinations moving containers between British Columbia and Washington; (2) 7- and 8-axle A-train and B-train doubles, RMD, and triple-trailer combinations between the Western provinces and Northern Plains States; and (4) various heavy multiaxle combinations operating under Michigan and Ontario bridge formulas.

Differing TS&W limits between Canada and the United States result in unique situations. For example, an 8-axle tractor-semitrailer crossing into British Columbia from Washington converts to a 6-axle by lifting axles on the tractor and semitrailer, which is required; a wide variety of combinations have as many as 11-axles for operations between Michigan and Ontario.

A large portion of truck traffic between Mexico and the United States is dominated by the 2- and 3-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

Several new types of containers came into usage in the 1980s including refrigerated, ventilated, bulk cargo, intermediate bulk, and other specialized containers. It is anticipated that the search for improved productivity through increasing the size and capacity of containers, container equipment, and container facilities will effect truck movements. Two-thirds of the container loads handled in 1992 were international. The 1.2 million domestic loads were transported equally in reloaded marine containers and domestic containers.

Very few ports are capable of directly transferring maritime containers to the rail mode, and the railroads generally do not have direct access to container destinations. Consequently, as containerized freight transportation has grown rapidly in recent years, it has resulted in an increased number of maritime shipping containers traveling on the highways. These containers may be loaded at weights that cause trucks to exceed Federal, State, or local vehicle weight limits.

The increasing size and capacity of marine containers may add to problems of overweight transport on U.S. highways. The impact may differ by State. In California most container movements are less than 50 miles, but on the East Coast most movements are considerably longer. Thus, East Coast movements are more likely to be impacted by non-uniform State TS&W regulations, while movements in California are not.

Standard dimensions for international marine containers are: lengths of 20 and 40 feet; width of 8 feet; and heights of 8, 9 and 9.5 feet. Container lengths of 24 and 45 feet are rarely used for international transport, 24-foot containers are being phased out, and 45-foot containers are used only on limited trade routes. Domestic containers can be 102 inches wide, but international marine containers are limited to a width of 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 been developed to take full advantage of the opportunities available from vehicle size regulations.

United States. These dimensions have been developed to take full advantage of the opportunities available from vehicle size regulations.

CHAPTER 4

SHIPPER CONCERNS AND MODAL COMPETITION

INTRODUCTION

In evaluating TS&W policy options, it is important to consider shipper concerns and competitive advantages of the 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. The 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 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 before price

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

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 changes 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.

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

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[2] 1993 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 CTS&W Study.

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.

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

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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.

Table IV-1
Deregulation of Surface Transportation

Mode	1980	1982	1984	1991	1994	1995
Trucking	Motor Carrier Act	STAA		ISTEA	TIRRA	ICCTA
Rail	Staggers Rail Act			ISTEA		ICCTA
Rivers/Canals				ISTEA		ICCTA
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
Selected Years By Mode (Billions)[5]

	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	**36.8**	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 10-15 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 LTL sector that were substantially higher than they would be in a fully competitive environment.[7] To remedy this situation, Congress passed the MCA, 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 MCA 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 MCA 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 MCA. 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 truckload 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 faster service.[11] In 1975, there were 73 Class I[12] railroads; by 1988, the number

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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 Company, Inc. 128 ICC 873, March 24, 1978.

[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*, Volume 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 AAR. Note: The operating level is adjusted annually for inflation.

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 10 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 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 MCA. 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. The 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.

FEDERAL AVIATION ACT OF 1994: TITLE VI

The MCA 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 MCA. Shippers found themselves paying more to move freight within large States than for cross-country hauls.

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[13] AAR, *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).

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 ICC 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 MCA, 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 TS&W REGULATION

Federal trucking deregulation has had a profound effect on all aspects of the industry since the passage of the most significant legislation, the MCA.[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 in many changes, such as established carriers expanding into new services, and private 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. The TL carriers account for 80 to 90 percent of all combination truck traffic.

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

[16] Harris, op cit.

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.

> “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

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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.

> 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 NPTC and American Trucking Associations, Inc. (ATA), 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 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.

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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, pg. 24.

> . . . 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.

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. As indicated in Figure IV-1, 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

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

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

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

$600 billion. Expenditures for inventory costs ($221 billion) almost equaled transportation costs. Outlays for other transportation modes and administrative activities were small in comparison.

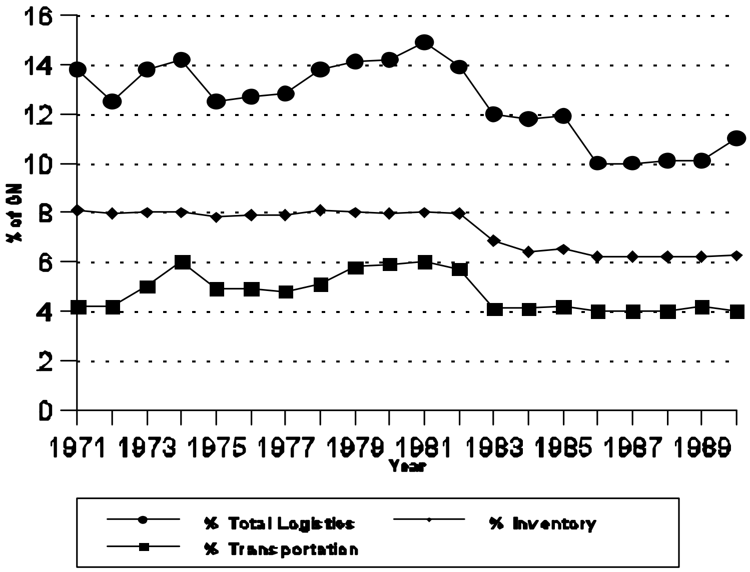
Figure IV-1 indicates an overall decline in total expenditures for logistics, transportation and inventory carrying costs as a percentage of GNP from 1970 through 1990. During the 1980s, total business logistics costs declined by about $65 billion. About $35 billion of this savings is attributed to reductions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

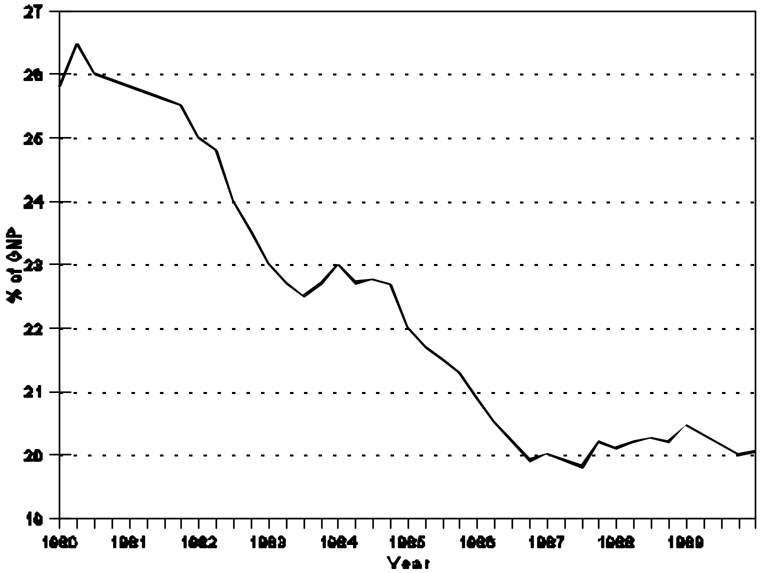
Source: John J. Coyle

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: 1980-1990

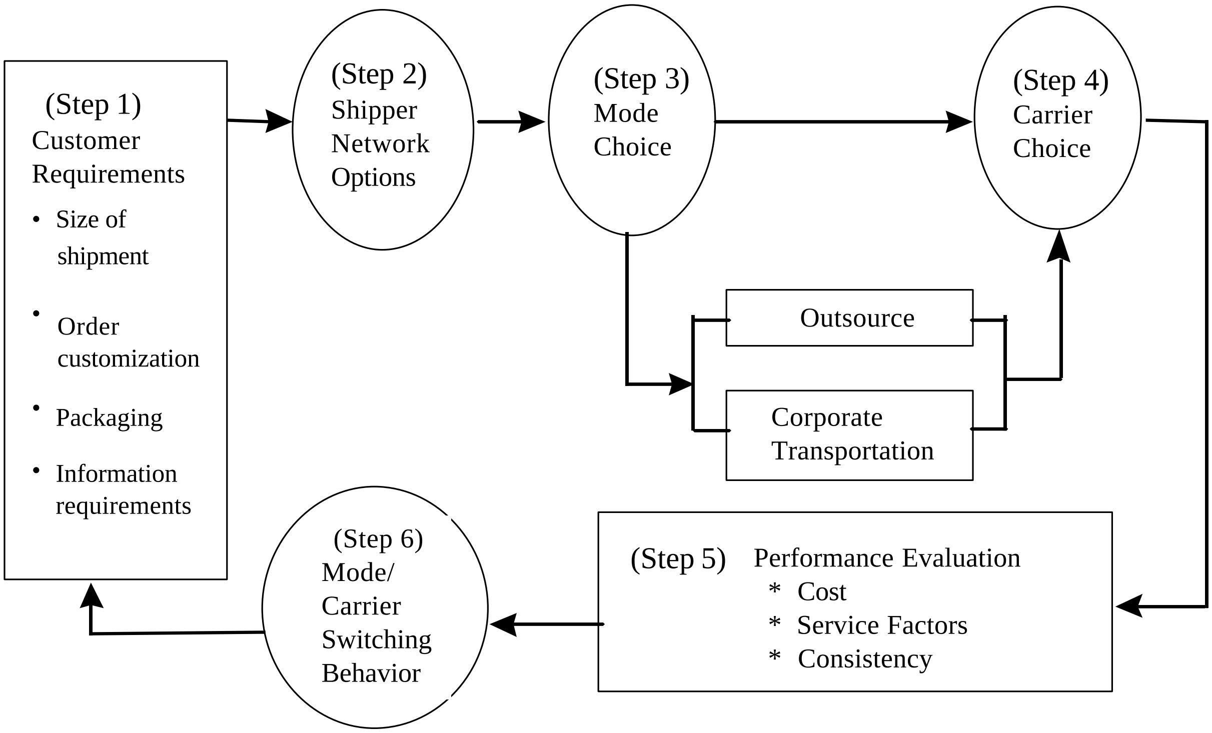


Source: Federal Reserve Board

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. The 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 factor s 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, short, and damaged shipments; shipper market considerations (including customer service, user satisfaction, market competitiveness, and market influences); and carrier considerations

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[23] Source: NPTC and ATA.

(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 TS&W 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

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.

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.

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. The 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 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.

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

SERVICE QUALITY

Recent trends to improve overall quality, particularly through total quality management 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.

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.

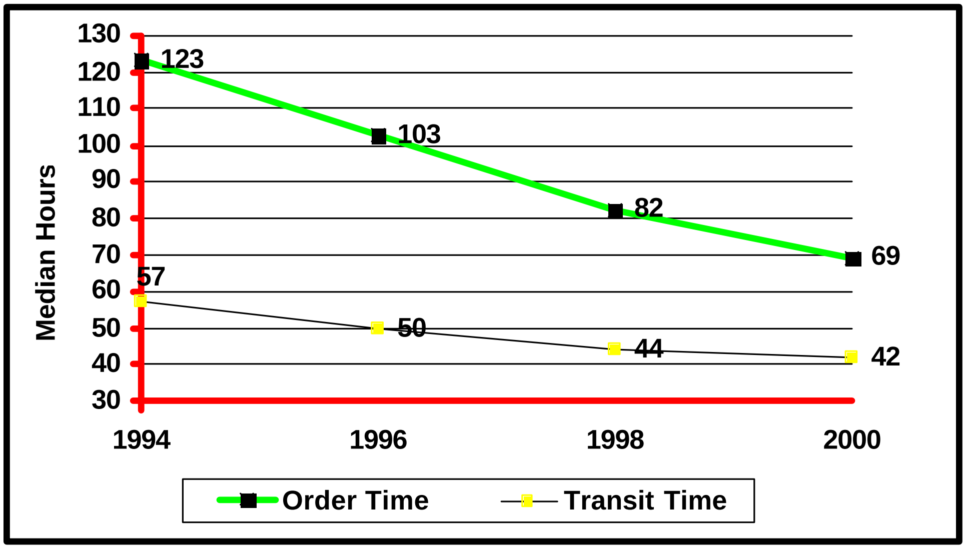
CONTINUING TRENDS IN SHIPPER DECISION-MAKING

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 5 days; it is expected to be less than 3 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

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

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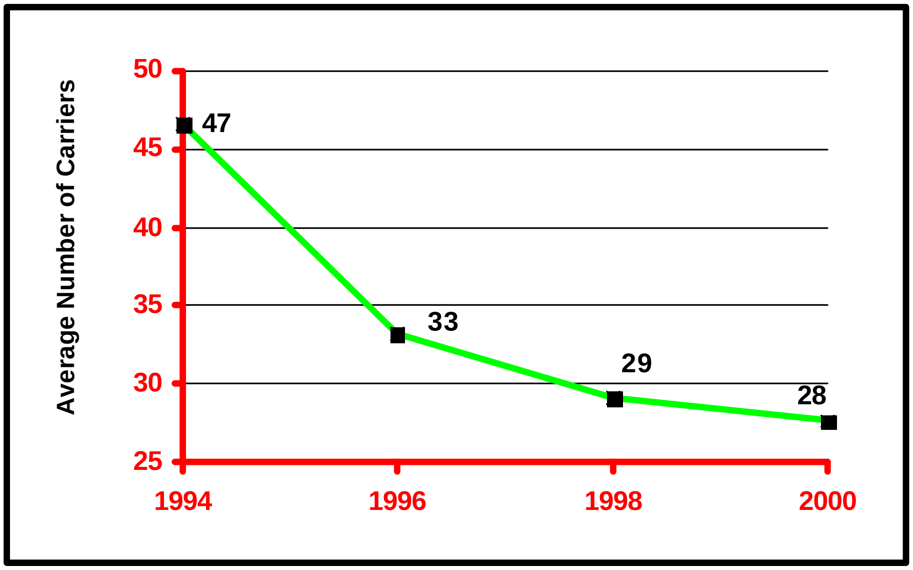
[25] From presentation of Bernard J. LaLonde and James M. Masters, Ohio State University Career Patterns -1996 at Council of Logistics Management Conference. Respondents were asked to provide actual company data for 1994 and 1996 and estimate changes for 1998 through 2000. Respondents represented a mixed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

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 3-fold increase in the percent of shipments using EDI is anticipated between 1996 and 2000, with 6 of 10 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 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.

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.

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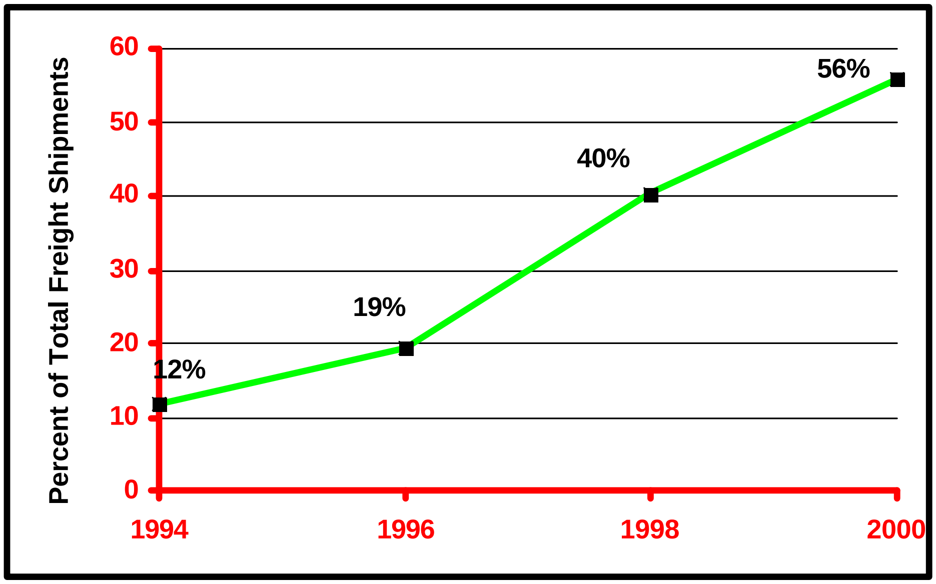
[26] Traditional communications systems, such as mail and telex, are quickly being replaced with systems such as facsimiles (faxes) and EDI. These changes are occurring in communication and information systems between carriers, shippers and ancillary services as well as within the operations of those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

Figure IV-6
Percent of Shipments Using EDI



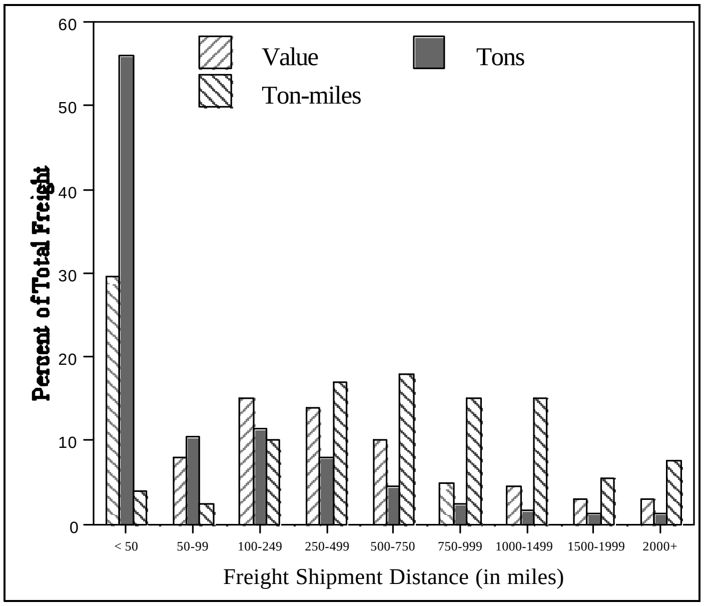
Source: Career Patterns Survey

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.

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]

Figure IV-7
Total 1993 Freight Value, Tons, and Ton-miles by Distance of Haul



Source: 1993 CFS, Conducted by the Bureau of the Census and Bureau of Transportation Statistics

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).

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 CFS which does not include imports, a greater percentage of which is moved by rail, but comparable data is not available.

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	**5.1**	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 CFS for the United States (Bureau of the Census)

- *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/ cubic feet			Product Density: 36-60 pounds/ cubic feet			Product Density: 1-35 pounds/ cubic feet		
	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										INTER-MODAL FAK [1]
	<$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	**382,62**	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	**11,650**	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	**5,294**	182	
501-700	**22,688**	4,393	**8,761**	2,902	**11,826**	7,743	**5,939**	3,482	**5,751**	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	**634,54**	40,816	**139,87**	17,782	**165,53**	70,333	**61,615**	31,340	**33,252**	1,178	
	PRODUCT DENSITY: 36-60 POUNDS/CUBIC FOOT										
<100	**182,17**	146,563	**81,041**	9,991	**43,218**	3,330	**25,257**	179	**8,633**	133	
100-200	**178,28**	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	**57,042**	128,032	**33,232**	17,852	**15,530**	10,317	**18,487**	667	**8,868**	460	
501-700	**25,008**	53,688	**10,279**	12,580	**9,985**	9,486	**9,771**	1,149	**7,093**	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	**4,110**	820	
TOTAL	**548,75**	749,838	**223,90**	91,842	**136,62**	58,648	**112,71**	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	**22,503**	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	**29,540**	8,138	8,750
701-1000	**N/A**	N/A	**11,8**	9,66	**2,96**	4,13	**18,4**	5,41	**30,6**	8,94	18,081
1001-	**N/A**	N/A	**8,62**	5,54	**2,18**	3,27	**11,1**	3,77	**18,9**	5,07	7,516
>1500	**N/A**	N/A	**3,78**	6,40	**847**	3,57	**8,43**	4,40	**17,8**	8,39	38,062
TOTAL	**N/A**	N/A	**170,**	58,2	**69,5**	22,4	**191,**	27,8	**267,**	43,4	89,750

[1] Freight, all kinds

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 FREIGHT ALL KINDS
	<$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**	**6535**	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**	4060	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	**396,43**	148,059
100-200	**229**	8	**2,979**	366	**19,094**	5,432	**64,158**	17,973	**107,81**	85,071
201-300	**890**	54	**5,142**	940	**20,796**	9,437	**30,098**	20,552	**59,738**	79,083
301-500	**2,835**	248	**10,831**	3,197	**30,670**	17,900	**38,923**	27,775	**21,880**	105,984
501-700	**3,255**	759	**8,349**	4,755	**17,115**	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	**4,410**	5,024	**6,760**	8,879	**2,694**	11,785	**4,033**	102,861
>1500	**1,848**	1,176	**2,338**	3,219	**2,775**	4,749	**3,079**	3,039	**955**	4,289
Total	**16,303**	4,826	**41,760**	23,373	**117,34**	73,900	**217,46**	119,540	**594,28**	677,839
EQUIPMENT CLASS: DRY VAN										
<100	**110**	1	**1,000**	14	**9,360**	350	**42,565**	3,163	**255,43**	12,612
100-200	**565**	7	**5,682**	236	**32,048**	2,872	**78,116**	6,945	**108,08**	9,022
201-300	**1,643**	42	**10,051**	830	**36,086**	5,243	**41,779**	6,754	**36,089**	6,457
301-500	**7,075**	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	**38,035**	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	**6,560**	13,779
1001-1500	**13,227**	1,844	**15,299**	6,309	**19,443**	10,018	**10,834**	7,887	**1,732**	4,277
>1500	**9,363**	2,475	**10,922**	6,165	**12,719**	12,686	**6,709**	13,598	**2,470**	26,014
Total	**57,805**	7,291	**107,15**	28,623	**234,72**	72,918	**257,07**	75,101	**443,87**	89,027
EQUIPMENT CLASS: FLATBED										
<100	**16**	-	**266**	1	**4,062**	719	**26,074**	4,811	**171,75**	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	**15,950**	2,722	**23,774**	5,711	**23,896**	6,337
301-500	**1,809**	81	**6,879**	1,074	**17,617**	4,291	**19,105**	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	**4,001**	1,715	**5,048**	3,449	**2,233**	3,469	**3,820**	3,309
1001-1500	**2,214**	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	**1,016**	1,804
Total	**11,833**	2,397	**25,891**	8,204	**68,926**	22,565	**120,06**	32,667	**309,94**	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	l Along the western United States/Canadian border, trucks dominate freight movements, usually operating above 80,000 pounds GVW. These heavier weights are allowed by Canadian laws and the border States' regulations. Common configurations include 3-axle tractors with 3-axle semitrailers. l 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	l Some traffic corridors have good rail-intermodal service, for example the Chicago-Seattle and Chicago-Los Angeles Corridor. l Rail-intermodal has a lower share in other traffic lanes, including Michigan-Florida (Interstate 75 Corridor) and Minnesota-New Orleans (Mississippi River Corridor). l Shippers and carriers frequently customize their equipment to take advantage of TS&W limits within their immediate region (including permitted operations).

PERSPECTIVES FROM THE TS&W 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.

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 I 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 the TS&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.

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.

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-l.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-

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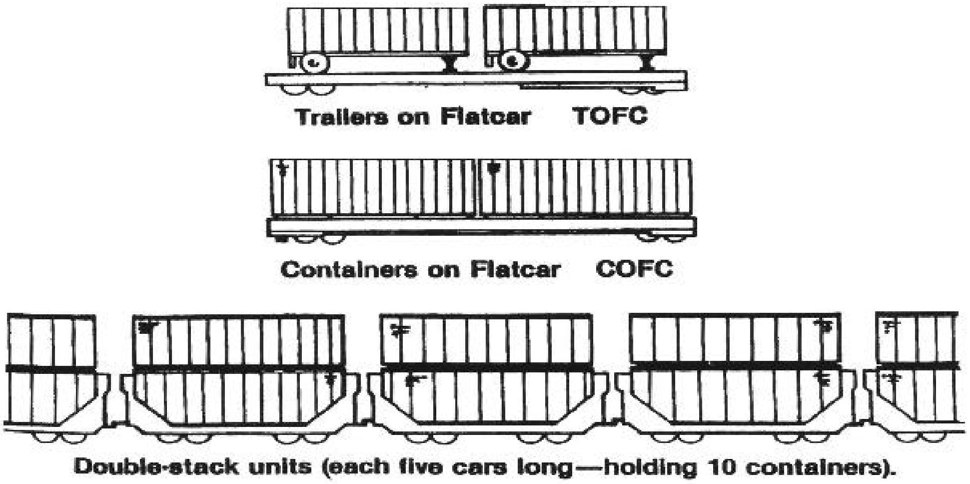
[28] This discussion illustrates the complexity of forecasting freight shares and the constrained role of TS&W limits in influencing the distribution of freight among modes.

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



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 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 10 years, assuming no change in 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

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[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).

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

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

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.

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

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

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

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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.

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 VIII trucks (with a GVW 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. The 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. The 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 10 years. Instead, real GDP growth should downshift into its 2.5 percent trend rate. This steady, 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 10 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

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[35] DRI and Reebie Associates analysis.

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 10 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 40 percent of the petroleum consumed in the United States. 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.

CHAPTER 5

SAFETY AND TRAFFIC OPERATIONS

INTRODUCTION

Safety was a primary consideration evaluated in this Study, which responds to the Department's enhanced priority on safety -- its preeminent goal -- as well as the considerable public concern about mixing larger trucks with passenger cars on our highways. The TS&W policies directly influence the stability and control characteristics of trucks when they operate at or near established size and/or weight limits. These characteristics influence how easily a truck driver can maintain control should operating conditions become challenging or regain control should it be lost in response to a precipitous event. Although to date safety has not been an explicit objective of TS&W policy in the United States, safety can be significantly affected either positively or negatively by changes in truck design features that result from policy changes. Table V-1 shows qualitatively the relative positive and negative effects of increases in dimensions, weights and loading conditions, and operations on crashes involving trucks and certain vehicle stability and control measures.

TRENDS IN MEDIUM TO HEAVY TRUCK CRASH EXPERIENCES

Medium to heavy trucks account for approximately 3 percent of vehicles in use on the Nation's highways and accumulate 7 percent of all the vehicle miles of travel (VMT), while being involved in 8 percent of all fatal crashes and 3 percent of all crashes (fatal, injury-producing, and property-damage-only crashes). Medium weight trucks have GVW ratings between 10,000 and 26,000 pounds, while heavy trucks weigh in excess of 26,000 pounds. The relative involvement of medium to heavy trucks in fatal crashes has decreased over the past 8 to 10 years.

In 1995, 4,903 people were killed (see Table V- 2) and 119,000 injured in crashes involving medium to heavy trucks, the majority (78 percent) of those killed were occupants of other vehicles involved in collisions with medium to heavy trucks. Most fatal crashes occur on rural roads (66 percent) and involve single-trailer combinations (68 percent) (see Figure V-1).

Table V-1
Safety Impacts of TS&W Limits and Truck Operation

Vehicle Features		Crash Occurrence		Vehicle Stability		Vehicle Control		
		Likelihood	**Severity**	**Static**	**Dynamic**	**Braking**	**Low Speed Offtracking**	**High Speed Offtracking**
Size	Length	- e	--	+ E	+ E	--	- E	+ E
	Width	- e	--	+ E	+ E	--	- e	+ e
	Height	--	--	- E	- E	--	--	- e
Design	Number of Units	- e	- E	--	- E	- e	+ E	- E
	Type of Hitching	--	+ e	+ E	+ E	+ e	+ e	+ E
	Number of Axles	--	--	+ e	+ e	+ E	+ e	+ e
Loading	GVW	- e	- E	- e	- E	- E	--	- E
	Weight Distribution	- e	- e	- e	- E	- E	--	- e
	Center of Gravity Height	- e	- e	- E	- E	- E	--	- e
Operation	Speed	- E	+ E	- e	- E	- E	+ E	- E
	Steering Input	- e	- e	- e	- E	- E	- E	- E

+ / - As parameter increases, the effect is positive or negative.
E = Large Effect. e = Small Effect. -- = No Effect.

Collisions between medium to heavy trucks and other, smaller vehicles (principally passenger cars and light trucks and minivans) can be particularly lethal to the occupants of the smaller vehicle, principally because of the difference in weight (mass) between the two vehicles, and for head-on collisions, the high vehicle closing speeds typically involved. In total, collisions with medium to heavy trucks account for 22 percent of all passenger car and light truck/van occupant fatalities sustained in collisions with other motor vehicles (see Figure V-2). Most fatal collisions (80 percent) involving a medium to heavy truck occur on non-Interstate roads, many of which are undivided roads and have comparatively high posted speed limits. Nevertheless, on a proportional basis, the number of other vehicle occupants killed in collisions with medium to heavy trucks, is significantly higher on Interstate highways (46 percent in rural settings, 28 percent in urban settings) than on other roadway types -- an indication, in many cases, of the relatively high proportion of medium to heavy trucks in the overall traffic flow on of these roads.

Table V-2
Fatalities and Injuries in Medium to Heavy Truck Crashes - 1995

Trauma Outcome	**Occupant of Other Vehicle Involved in Collision**	**Truck Occupant**	**Pedestrian, Cyclist, Other**	**Total**
Fatalities	3,835	644	424	4,903
Injuries	83,000	30,000	6,000	119,000

Source: FARS and GES, 1995

Both the number of people killed per year in medium to heavy truck crashes, and the crash fatality rate, have decreased markedly over the past 17 years. Figure V-3 depicts the trend in the annual number of fatalities occurring in crashes involving all medium to heavy trucks and, separately, for the two principal subclasses, single units and combinations, over the past 17 years. The patterns are distinctly different, with fatalities resulting from single-unit truck crashes virtually constant while those involving combination trucks have significantly decreased.

When these fatality trends are viewed in more detail, showing separately the fatality trends for other vehicle occupants and pedestrians, distinctly different patterns can be observed, especially when considering single-unit and combination trucks separately. Proportionally, there was a greater reduction in the annualized number of truck occupants fatally injured (nearly 5 percent per year reduction in the case of combinations and 4 percent per year reduction for single-unit trucks) than there were for occupants of other vehicles involved in collisions with heavy trucks (see Figure V-4 and Figure V-5). During that time period, seat belt use among heavy truck drivers increased significantly from a low of 6 percent in 1982 to 55 percent in 1991.[1]

When the fatality trend data are normalized for exposure (VMT), the trends in fatality rate reduction are also impressive. Figure V-6 depicts the travel mileage growth pattern of medium to heavy trucks over the past 17 years. Single-unit truck travel increased at an annual rate of 3.1 percent, while the comparable growth rate for combination trucks was 3.5 percent. These data result in the fatality rate trend data for all medium to heavy trucks, and for the two principal subclasses, as shown in Figure V-7. A strongly positive decreasing trend was evident until 1992, but since then, it has leveled off and remained essentially unchanged for the last 5 years.

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[1] M. Copenhaver and T. Wilkinson; *Heavy Truck Occupant Restraint Use,* U.S. DOT Report Number HS 807 752, August 1991.

FIGURE V-1

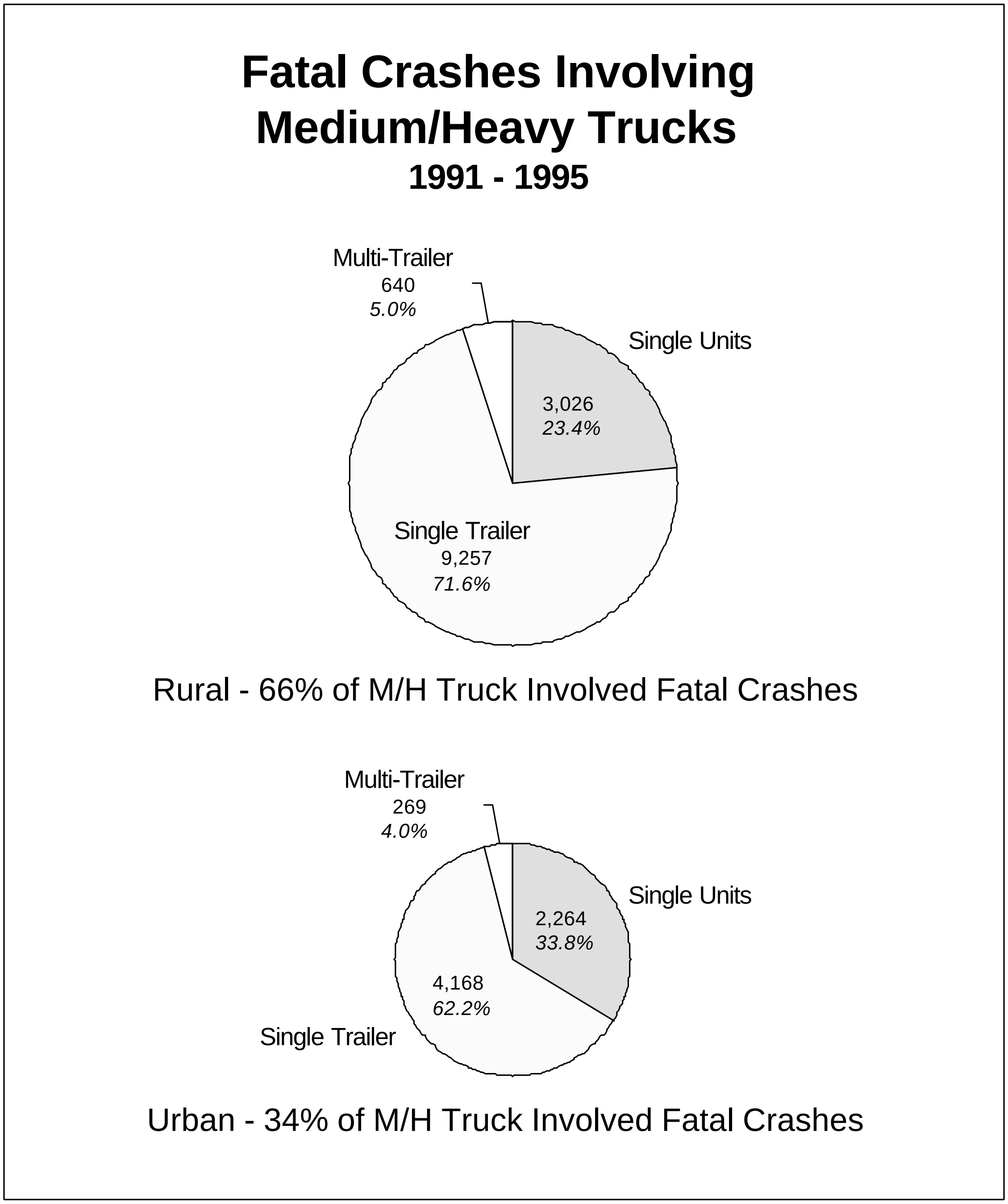
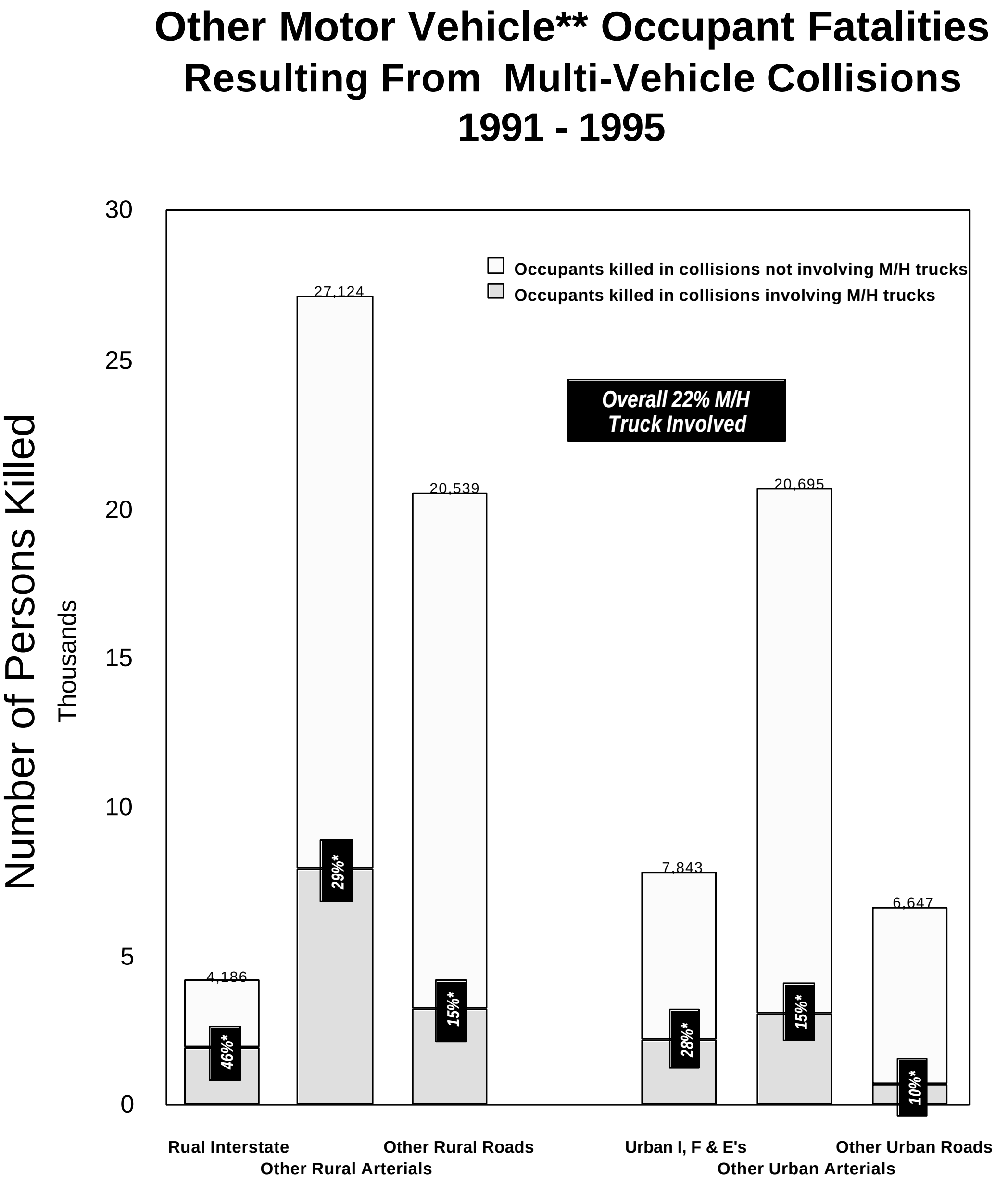

Fatal Crashes Involving
Medium/Heavy Trucks
1991 - 1995
Multi-Trailer
640
5.0%
Single Units
3,026
23.4%
Single Trailer
9,257
71.6%
Rural - 66% of M/H Truck Involved Fatal Crashes
Multi-Trailer
269
4.0%
Single Units
2,264
33.8%
4,168
62.2%
Single Trailer
Urban - 34% of M/H Truck Involved Fatal Crashes

FIGURE V-2



* Percent M/H truck involved.

** Occupants of all other motor vehicles, except M/H truck occupants.

FIGURE V-3

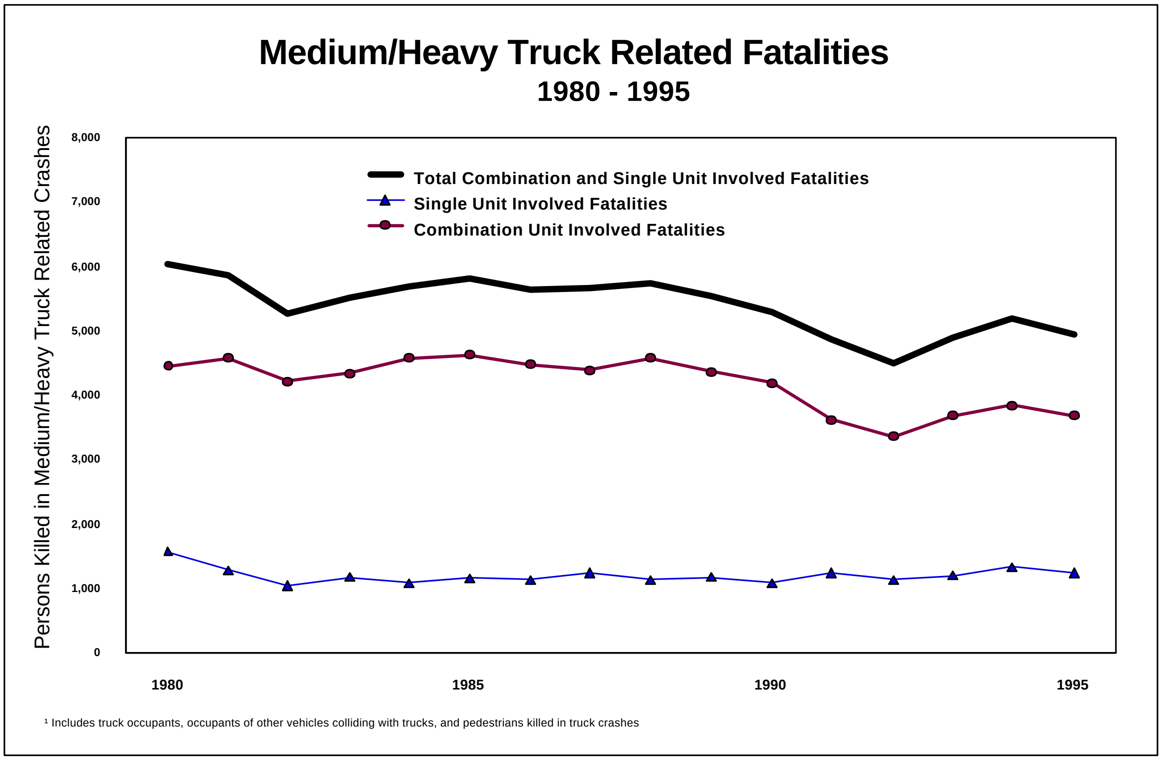


FIGURE V-4

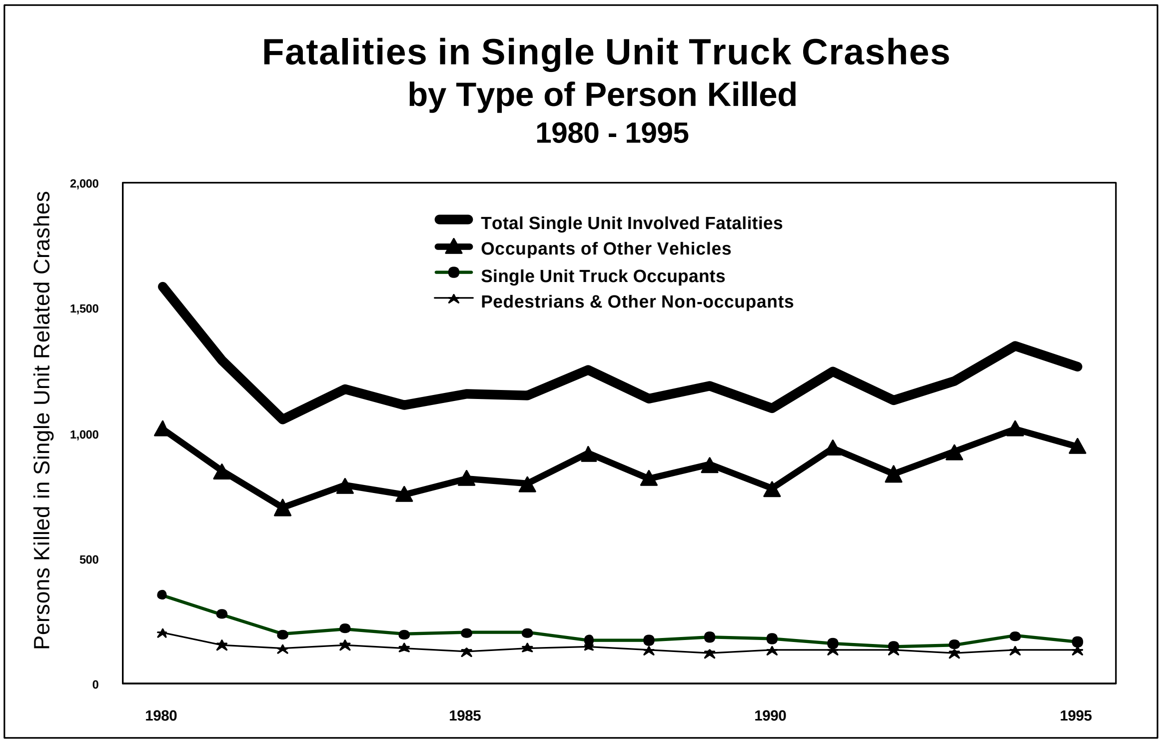


FIGURE V-5

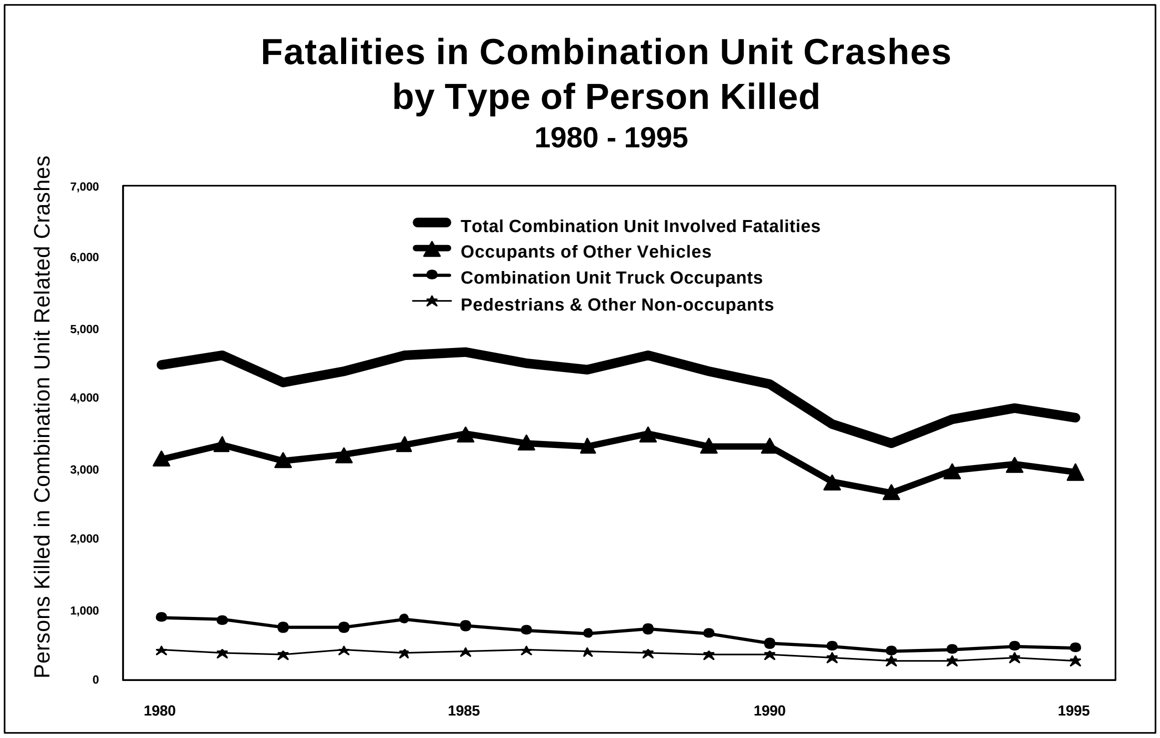
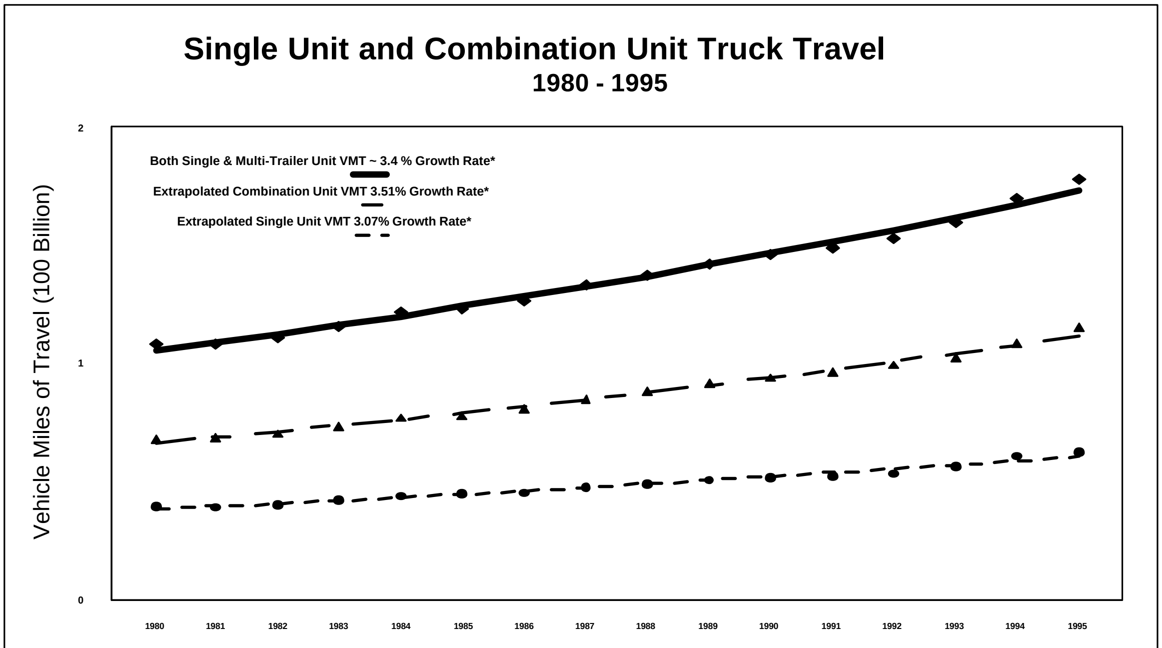
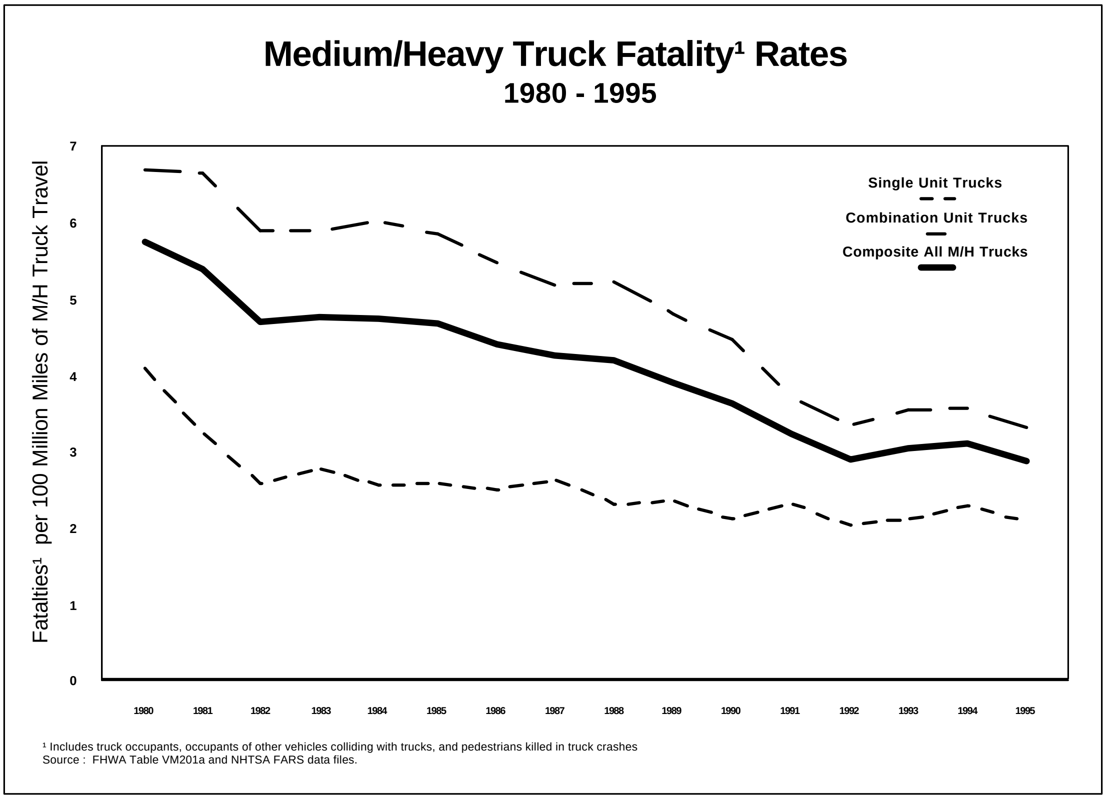


FIGURE V-6



* Growth rates based on logarithmic least squares regression on component vehicle travel for years 1980 - 1995 (1982-1995 for single unit trucks).
Source : FHWA Table VM201a.

FIGURE V-7



Medium/Heavy Truck Fatality[1] Rates

1980 - 1995

[1] Includes truck occupants, occupants of other vehicles colliding with trucks, and pedestrians killed in truck crashes

Source : FHWA Table VM201a and NHTSA FARS data files.

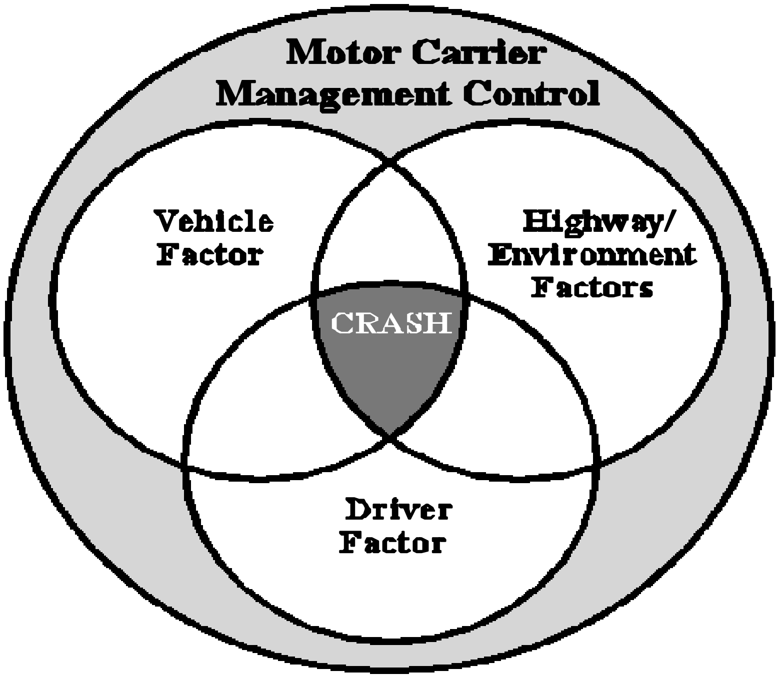
In summary, overall commercial truck safety has improved markedly in the past 17 years, a period during which the following motor carrier and vehicle safety initiatives have been implemented in the States.

- Introduction of uniform truck driver licensing and tracking of drivers' traffic violations and accident experiences under the Federal/State Commercial Driver's License Program;
- Increased Federal and State driver and vehicle inspections and motor carrier safety audits performed under the Motor Carrier Safety Assistance Program (MCSAP);
- Increased driving skill levels and safety awareness among truck drivers as a result of upgraded training received at institutions which adhere to the guidelines published by the industry-sponsored Professional Truck Driver Training Institute;
- Increased safety management effort and professionalism among motor carriers, and;
- Increased safety technology in truck designs, for example, improved seat belt designs and other truck occupant crash protection features, antilock braking systems, rear underride guards, and conspicuity treatment (reflecting tape) on trailers.

TRUCK CRASH CAUSATION AND SEVERITY FACTORS

Variables that influence the overall crash risk may be grouped into three broad categories: vehicle and equipment, driver performance, and operating environment (roadway and weather conditions). Figure V-8 illustrates the complex interrelationship of these variables as they contribute to truck crashes. Driver errors typically trigger crashes, and therefore, are overwhelmingly cited as their principal causes. Equipment considerations, which include vehicle size and weight and mechanical or operational failures, also play a role, but they are difficult to isolate. 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. Thus, it is important to address all the contributing factors to crashes.

Figure V-8
Interrelationship of Truck Crash Factors



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

Another way of looking at the relationship of these various factors is to examine a hypothetical crash causation chain (see Figure V-9). The chain begins with predisposing conditions that, when combined with situational characteristics, create an opportunity for a crash. In other words, there is a set of factors that either predisposes or enables a crash to occur.

Figure V-9
Heavy Truck Crash Causation "Chain"

Predisposing Conditions	Situational Characteristics	"Trigger" Event	"Crash"	Outcome
! Driver **- Poor Vision** **- Ill Trained** **- Poor Judgement**	**! Driver** **- Fatigued**	**! Driver** **- Inattentive, Swerves to Avoid Car Abruptly Stopping Ahead**	**! Jackknife/ Rollover**	**! Driver Killed** **- Total Loss/Cargo and Vehicle**
! Vehicle **- Low Roll Stability Threshold**	**! Vehicle** **- Maladjusted Brakes** **- Imbalanced Cargo** **! Highway/Environment** **- Wet Road**			
! Highway/Environment **- Blind Curve** **- Frequent Intersections**	**! Management/ Operating Practices** **- Pushing Driver to Meet Short Delivery Time Schedule**			
! Management/ Operating Practices				
! No Safety Program **- "Run-To-Failure" Maintenance Policy**				

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

VEHICLE AND EQUIPMENT

Vehicle factors include physical characteristics, such as the number of trailers in a combination, trailer length, and weight capacity; the dynamic performance[2] of the vehicle under various loaded conditions; and mechanical systems such as brakes and engine characteristics.

The braking capability of combination trucks is particularly important. Braking capability relates to achieving a safe stopping distance and maintaining vehicle control and stability during braking. It is influenced by a number of factors including weight and the number of wheels on the vehicle. Additionally, rollover propensity, the ability to negotiate turns and maneuver in

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[2] Includes static roll stability, rearward amplification and load transfer ratio. These concepts are defined in a subsequent section.

traffic, and the ability to successfully maneuver when confronted with a potential crash threat are other performance concerns that warrant close attention. These issues are discussed in the section, “Effects of Vehicle Design on Stability, Control, and Operations.”

DRIVER PERFORMANCE

The driver is critical in preventing or initiating a crash. Driver performance factors include skill level, experience, and fatigue regardless of the type or size of truck being driven. 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 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 conditions.

The FHWA Office of Motor Carriers recently sponsored a study to investigate whether 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 combinations for 2 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.

Study findings suggest that, while the most significant contributions to driver fatigue were the characteristics of that individual driver, the number of hours since the last rest period, and the number of consecutive days of work, trailer configuration type contributed marginally to changes in driver performance. Patterns in driving performance (specifically, lane-tracking), in fatigue/physiological recovery, and subjective workload generally showed that drivers perform best when driving the single-trailer combination; next best when driving the triple-trailer combination equipped with C-dollies, and perform poorest when driving the triple-trailer combination equipped with A-dollies.

OPERATING ENVIRONMENT

Factors in the operating environment include roadway geometry, traffic congestion and adverse visibility and weather conditions. Roadway geometric features include roadway type, grades, interchanges, and intersections, as well as the interaction of trucks with other users of the highway. Longer and heavier trucks must contend with intersections, entrance and exit ramps, and highway grades with design elements that may not be suitable for all truck configurations.

The interaction of truck design features with both roadway features and visibility is accentuated as traffic volume increases. Visibility is a function of time of day as well as weather. Dawn, dusk, and night place increased operating demands on the driver to control the vehicle safely.

Crash profiles illustrated in Table V-3 show that approximately 35 percent of fatal crashes and about 26 percent of nonfatal crashes occur in visibility conditions other than normal daylight. 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.

Table V-3
Large Truck or Bus Crashes 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

INTERACTION OF CONTRIBUTORY FACTORS

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 result is that, although several truck crash data analysis reports were reviewed (see Appendix A) to assess their validity for establishing differential crash rates for LCVs and non-LCVs, none were identified as having applicability.

Figure V-10 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. As indicated earlier, conditions of poor visibility result in increased operating demands on the truck driver. Sight distance, decision distances, and the time available for corrective or evasive action are all reduced, resulting in a need for closer control of the vehicle.

Figure V-10
Illustrative Relationship Between the Driver-truck Equipment Performance and Operating Environment Demands

Driver/Truck Equipment Performance	Low	High
High	<u>Low Crash Probability</u> High Performance Low Demands	<u>Moderate Crash Probability</u> High Performance High Demands
Low	<u>Moderate Crash Probability</u> Low Performance Low Demands	<u>High Crash Probability</u> Low Performance High Demands

Operating Environment Demands

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

CRASH SEVERITY

Crash severity is generally stated in terms of whether the crash results in property damage only, injuries, or fatalities. Four factors influence the severity of a crash involving cars and trucks: the type of collision that occurs, the relative weights of the vehicles, the change in velocity (speed) of the car, and the type of truck configuration involved in the collision. Double-trailer combinations tend to have a trailer roll over more frequently than a single-trailer combination.

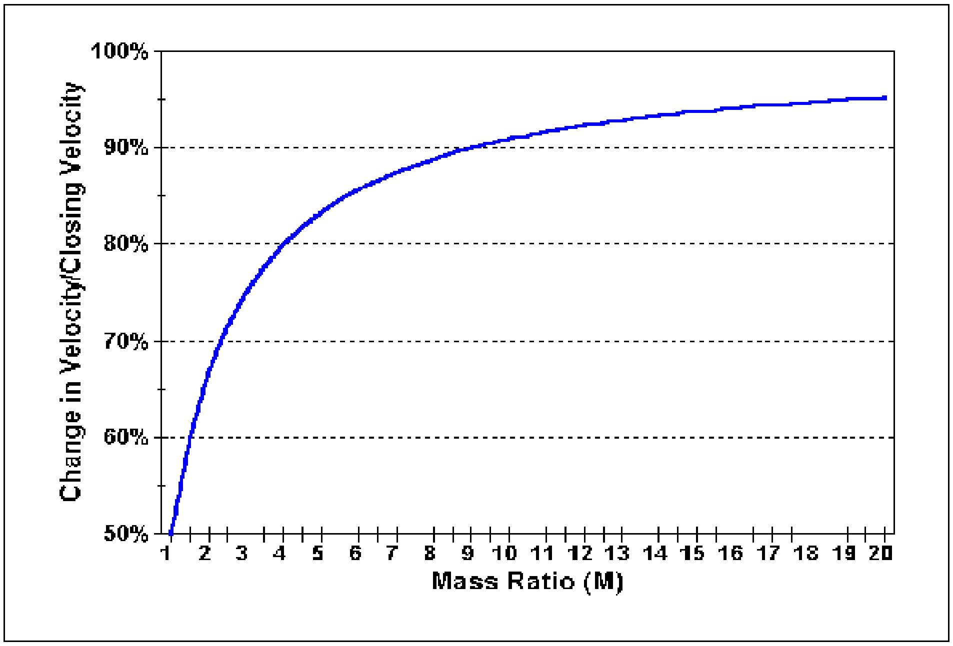
The likelihood of more severe crashes is significantly increased if truck traffic increases in operating environments with a higher risk of truck-car collisions, such as undivided highways rather than divided highways. Head-on traffic conflicts naturally create opportunities for higher closing velocities (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 as they eliminate head-on collisions and reduce the number of all types of car-truck collisions by about a factor of two.

SPEED AND WEIGHT

When two vehicles collide, the speed at which they collide, their mass ratio, and the vehicular orientations are the primary determinants of whether a fatality results. The effect of the difference in weight between the two vehicles is large. For car-truck collisions, as compared to car-car collisions, the effect of the difference in weight between the two vehicles increases the probability that fatalities will be sustained by the occupants of the car. In such collisions, the problem is 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.

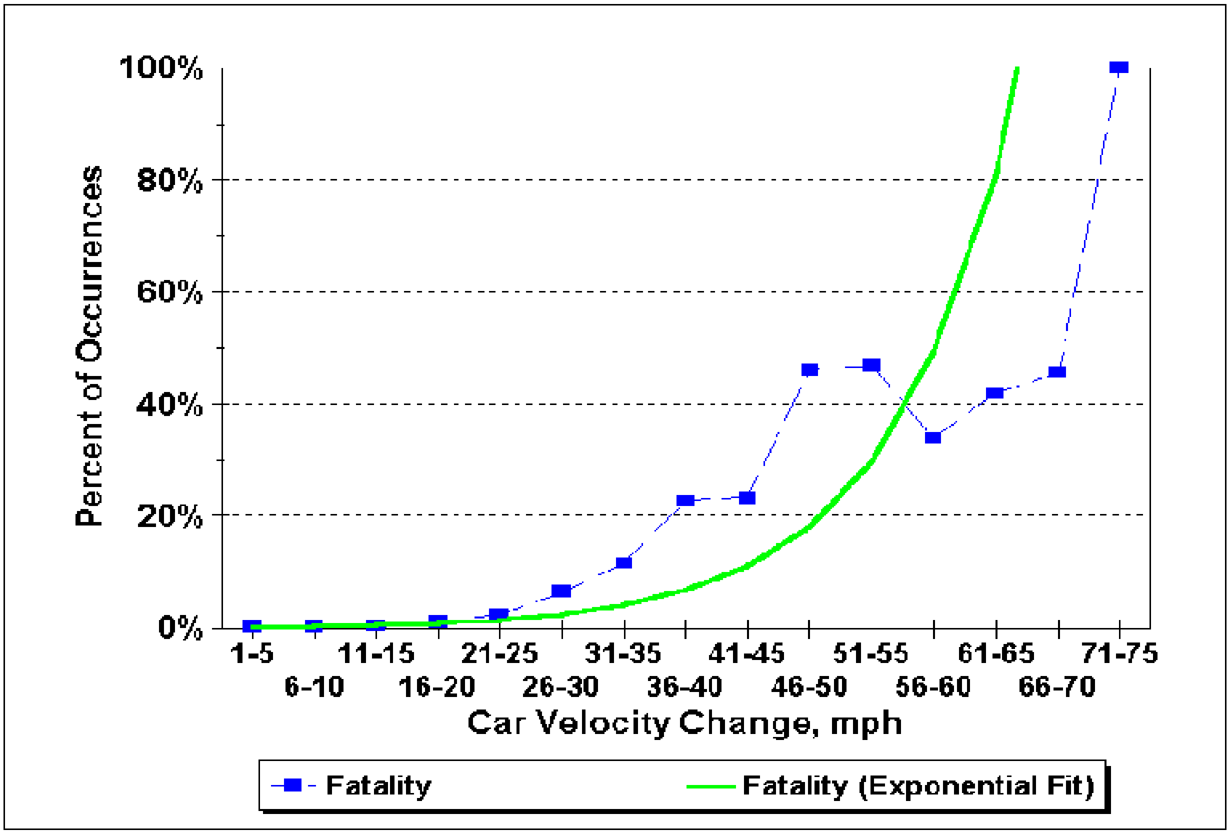
Figure V-11 illustrates the relationship between the difference in weight of two vehicles involved in collision (mass ratio) and the relative change in velocity sustained by the smaller vehicle. It assumes an impact between two vehicles of different mass traveling in opposite directions. The vertical axis represents 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, 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 ratios around 10:1 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. If a typical car is assumed to weigh 3,000 pounds, it can be seen that any truck weighing more than 30,000 pounds would result in ratio greater than 10:1. For a truck loaded to the current 80,000-pound limit, this ratio would be more than 25:1.

Figure V-11
Mass Ratio



The significance of the change in velocity becomes more apparent as it is related to fatality rates in car-truck crashes. The fatality data shown in Figure V-12 indicates the likelihood of a fatality as a function of the change in velocity of the vehicle. 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 speeds above 45 miles per hour, car occupants are highly likely to be fatally injured.

Figure V-12
Chance of Fatality as a Function of Change in Velocity



AUTO AND TRUCK DRIVER OBSERVATIONS

Twelve focus group meetings were held in 1996 to assess the perceptions, concerns, and reactions of the auto driving public and over-the-road truck drivers to operations in mixed auto and truck traffic.[3] The focus group discussions were intended to increase the 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. They perceive the greatest threat as coming from other auto drivers -- people who are impatient, aggressive, reckless, intoxicated, or simply inattentive. They also consistently cited large commercial trucks among their top three or four highway safety concerns.

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. The focus group participants said that when they see or hear examples of a 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: (1) drivers with bad attitudes, and (2) economic forces in the trucking industry that create incentives for cutting corners by inadvertently rewarding unsafe practices or placing too much pressure on drivers.

ROAD CONDITIONS

Auto drivers also cited increased traffic congestion, bad weather and the mixing of truck and auto traffic under congested or inclement conditions as factors of concern.

TS&W

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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[3] FHWA Focus Groups with Auto Drivers and Truck Drivers on Size and Weight Issues, Draft Final Report (Focus group findings are documented in Apogee Research, Inc., February 24, 1997).

CHANGES TO TS&W LIMITS

The vast majority of participants said they preferred the status quo regarding Federal TS&W standards or -- if changes were actually made -- a return to greater restrictions. 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 perceived such 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 responding auto drivers doubted that 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 constantly vigilant regarding external threats to their safety.

SHARING THE ROAD

The truck drivers cited automobile drivers as 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 felt that traffic congestion is getting worse. They also perceived that the highways are less able to accommodate their larger, heavier trucks, which creates 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 whom they feel are being rushed through training that they -- experienced drivers -- perceive to be inadequate because it focuses on preparing them to obtain a commercial driver's license and not necessarily to be a safer driver.

TS&W

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 for some ramps and access roads along Interstate highways.

Truck drivers 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, operating speed, and driver fatigue.

CHANGES TO CURRENT TS&W LIMITS

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

Truck drivers generally opposed changing the TS&W standards. The majority preferred 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. Truck drivers 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 had previously cited.

EFFECTS OF VEHICLE DESIGN ON STABILITY, CONTROL AND OPERATION

Differing TS&W policies can affect the safety and traffic operations characteristics of heavy trucks as they lead carriers to choose particular vehicle design features and configurations for their operations. The vehicle dynamic properties of rollover, maneuverability, and the ability to avoid unanticipated crash threats are directly affected by truck (especially for long and heavy trucks) weight, dimensions (including the height of the loaded truck's center of gravity, number of axles, and number of articulation points in combination trucks. The relevant design features and specifications include:

- Overall vehicle length and wheelbase;
- Vehicle track width;
- Overall vehicle weight;
- Individual axle weights;
- Number of axles and tires on vehicle;
- Number of units in a combination vehicle; and
- Number of articulation points in a combination vehicle.

Important vehicle equipment specifications also include the types of tires and braking and suspension systems.

In some cases, these vehicle design features and equipment limit vehicle performance in traffic, which reduces the driver's ability to successfully execute abrupt or extreme maneuvers. Unless other compensatory changes in driver performance and operating environment demands are made to counteract the effects of vehicle performance differences, crash likelihoods and traffic disruption effects increase somewhat.

Rollovers account for 8 to 12 percent of all combination 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, particularly when hazardous materials are involved. Rollovers can be reduced by making vehicles more roll stable through design changes such as lower deck heights, more axles, and stiffer suspensions. Another solution would be for drivers never to exceed posted or reasonable speeds when traversing curves or exit ramps. There are three performance measures that have evolved as being the principal indicators of crash risk due to vehicle design changes: static roll stability, rearward amplification, and load transfer ratio. All three describe aspects of a vehicle's basic or inherent propensity to roll over when turns or out-of-the-ordinary crash avoidance maneuvers are attempted.

BRAKING PERFORMANCE

Braking performance is a general concern that applies to all trucks and is not particularly influenced by changes in TS&Ws, if the requisite number of axles and brakes are added as the vehicle's weight increases and all the vehicle's brakes are well-maintained. Antilock braking systems, now required on all trucks, will greatly enhance their braking performance and will be especially beneficial to multitrailer combinations.

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 jack knifing or otherwise losing directional control due to wheels locking and skidding. Studies have indicated that brake system performance plays a contributing role in approximately one-third of all medium-to-heavy truck crashes.[4]

The ability to stop in short distances mostly depends on 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. Improper brake balance can cause downhill runaways and braking instability. Furthermore, adding more load to a given vehicle without adding axles and brakes degrades stopping performance.

HIGH-SPEED OFFTRACKING

When a combination vehicle negotiates a sweeping (long radius of curvature) high-speed curve, as it would at some interchanges between freeways, the rearmost trailer axle can track outside the path of the tractor steering axle. For most truck configurations analyzed, this offtracking is 1 foot or less at 55 miles per hour. This tendency is reduced on superelevated curves. Conceivably, if the trailer wheels were to strike any 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. High-speed offtracking is related to a vehicle's rearward amplification tendencies and is indirectly addressed when rearward amplification is addressed.

TRAFFIC OPERATIONS EFFECTS

There are other measures of a vehicle's ability to negotiate turns or otherwise "fit" within the dimensions of the existing highway system. The principle metric is low-speed offtracking, however, there is little, if any, link between this performance attribute and the likelihood of serious crashes (fatal or injury-producing), although excessive offtracking can disrupt traffic flow and damage infrastructure. This latter impact is discussed in Chapter 6, Highway Infrastructure.

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[4] "Improved Brake Systems for Commercial Vehicles," U.S. DOT (HS 807 706), April 1991.

Acceleration performance determines a truck's basic ability to blend well with other vehicles sharing the roadway with it; for example, hill climbing and acceleration ability, time to pass or be passed on a two lane road, merging at interchanges, which can be incrementally degraded as trucks increase in size or weight and, therefore, need to be addressed as well when considering the ability of a given segment of roadway to safely accommodate longer and heavier trucks.

LOW-SPEED OFFTRACKING

When a combination vehicle makes a low-speed turn -- for example at a 90-degree intersection -- the wheels of the rearmost trailer axle follow a path several feet inboard of the path of the steering axle. If excessive, this phenomenon (low-speed offtracking) may force the driver, when executing a turn, to swing wide into adjacent lanes to avoid climbing inside curbs or striking curbside objects. Excessive offtracking can disrupt traffic operations or result in shoulder or inside curb damage at intersections and interchange ramp terminals that are designed like intersections if they are heavily used by trucks.

Low-speed offtracking is affected primarily by the distance from the tractor kingpin to the center of the trailer’s rear axle or axle group. For a semitrailer, this distance is its effective wheelbase. In the case of a multitrailer combination, the effective wheelbases of all the trailers in the combination, along with the tracking characteristics of the converter dollies, affect offtracking. In general, longer wheelbases worsen low-speed offtracking. Chapter 6 provides data on the extent of offtracking for a variety of truck configurations and trailer lengths.

Standard STAA double (two 28-foot trailers) and triple (three 28-foot trailers) combinations offtrack less than the standard tractor and 53-foot semitrailer combination, as they have more articulation points in the vehicle combination and use trailers with shorter wheelbases. Low-speed offtracking is a readily measured and/or calculated metric.

VEHICLE ACCELERATION AND SPEED MAINTENANCE

As a vehicle's weight increases, its ability to accelerate quickly and to climb hills at prevailing traffic speeds is degraded, unless larger engines or different gearing arrangements are used. Poor acceleration is a concern when it results in large speed differentials between vehicles in traffic as crash risks increase significantly with increasing speed differential. Table V-4 indicates that crash involvement may be from 15 to 16 times more likely at a speed differential of 20 miles per hour.

Table V-4
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.

ON STEEP GRADES

On routes with steep grades frequently traveled by trucks, special truck climbing lanes have been built. Otherwise, trucks should be able to maintain reasonable grade climbing performance. In the past, hill climbing performance has been addressed by requiring larger trucks to be equipped with higher horsepower engines. However, this can be counterproductive, since larger engines tend to consume more fuel and emit air pollutants. While in some cases larger engines may be necessary to maintain grade climbing performance, a more easily enforced approach is to specify minimum acceptable speeds on grades and minimum acceptable lengths of time to accelerate from a stop to 50 miles per hour or to accelerate from 30 to 50 miles per hour.

If single drive axle tractors are used in multitrailer combinations the tractor might not be able to generate enough tractive effort to pull the vehicle up the hill under slippery road conditions. In these cases, either tandem-axle tractors or tractors equipped with automatic traction control could be used.

NON-SIGNALIZED INTERSECTIONS

Heavier vehicles entering traffic on two-lane roads from non-signalized intersections could require more time to reach operating speed. Also, longer vehicles crossing non-signalized intersections from a stopped position on a minor road could increase by up to 10 percent the sight distance required by traffic on the major road. If sight distances at the intersection are obstructed, approaching vehicles might have to decelerate abruptly, which could cause a crash or disrupt traffic flow.

The degree to which larger or heavier trucks perform worse than others, which is of particular concern in cases where frequent truck-car conflicts can be anticipated, depends on their comparative acceleration performance characteristics. If equipped with appropriate powertrains that ensure adequate acceleration performance, or if routes were screened for suitability, these concerns would be minimized, regardless of the vehicle size or configuration.

AERODYNAMIC EFFECTS

Truck-generated splash and spray is sensitive to vehicle aerodynamics. Another aerodynamic effect is the buffeting of adjacent vehicles from air turbulence. Air turbulence around trucks is not increased with truck length or weight. Rather, the front of the truck and gaps between the tractor and the semitrailer(s) it tows can be the source of a transient disturbance to adjacent vehicles, especially if they are operating in substantial crosswinds. Double-trailer combinations have two of these gaps, while triple-trailer combinations have three.

Efforts to improve truck aerodynamics are continual, since the fuel economy benefits that result are substantial. Both buffeting and splash and spray effects will be reduced as market-driven product development proceeds.

SUMMARY

Notwithstanding driver, roadway, and weather effects, only in cases of component failure does vehicle performance directly cause a crash to occur. Importantly however, 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. Multitrailer combinations without compensating design features have inferior performance capabilities compared to single-trailer combinations and these differences, especially if frequently challenged in traffic conflict situations, result in incrementally higher crash likelihoods.

PERFORMANCE-BASED APPROACH TO TS&W REGULATION

Some countries allow more productive trucks under a performance-based approach to ensure that these trucks would, under certain restrictions, enhance highway safety, that is, decrease the likelihood of a crash. The ultimate approach to TS&W regulation would be based on how a vehicle performs, that is, its roll stability when turning or making an evasive maneuver, the amount of wear it imposes on pavements and bridges, and how it fits on the highway system relative to intersections and sharp curves. This is in contrast to regulation of the physical characteristics (such as weight and dimension specifications -- TS&W limits) with which a vehicle must comply before it may be operated. For example, TS&W regulations could require that a vehicle: (1) deflect a pavement no more than a certain accumulated amount, (2) cause a bridge to be stressed no more than a certain level, (3) offtrack no more than a certain distance, or (4) have a tendency to roll over no greater than a given level.

For ease of regulatory compliance and enforcement, traditionally, TS&W limits have been set so that a vehicle complying with these limits is determined to perform within acceptable limits. Historically, in the United States, vehicle performance has been of concern relative to pavement and bridge consumption and low-speed offtracking. However, other concerns have arisen regarding: (1) acceleration ability for climbing steep grades, entering freeway traffic, and clearing intersections; (2) the time required to pass or be passed by other vehicles, which is a function of vehicle speeds and overall lengths; and (3) vehicle stability when making tight turns such as on freeway interchange ramps or when making high-speed evasive maneuvers. Current Federal TS&W limits have not been based on these latter performance concerns, although they have been considered in the evaluation of potential changes to the current limits such as for this Study.

Experience under the current regime of Federal TS&W law and regulation has shown that trucks, though being in compliance with regulatory limits, perform outside intended standards, especially for bridge stress levels. This results from the simple specification of the current regulations, which nevertheless, provide for easier compliance and enforcement. Several countries employ various forms of a performance-based approach to TS&W regulation, and among these countries a broad range of limits are specified. A recent study[5] examined TS&W regulations in approximately 30 industrialized countries and found that the greatest disparity among countries was in the gross weights allowed, which ranged from 61,700 pounds in Switzerland to 110,200 pounds in Norway for a 5-axle semitrailer combination. Further, authorities use different performance criteria to regulate vehicles, such as, dynamic stability, turning abilities, and ability to maintain speed. Table V-5 describes various performance measures, most of which are in effect in various countries.

ALTERNATIVE APPROACHES

There are two basic methods for implementing performance based regulations: (1) vehicle type certification with the certification shown for enforcement purposes by a placard on the vehicle or vehicle unit or by a permit in the power unit, and (2) the “envelope vehicle” approach with weight and dimension specifications depending on the type of truck configuration: single-unit truck, single-trailer combination, and multitrailer combination (see Exhibit V-20). The remaining performance-based approach discussion primarily focuses on performance criteria that measure a vehicle’s tendency to avoid rolling over, that is, its stability when turning (especially in tight turns at low speeds) and making evasive maneuvers at high speeds.

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[5] "Applicability of Performance-Based Standards to Truck Size and Weight Regulation in the United States,” James York and Tom Maze, in *Road Transport Technology -- 4: Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions, June 25-29, 1995*. Ed. Christopher B. Winkler. pp. 37-142.

Table V-5
Example Safety Performance Measures

Performance Measure	Country	Description
Rollover Threshold	**Canada New Zealand**	**The lateral acceleration at which a vehicle rolls over when it is driven in a steady circular turn. It is customarily measured in "g", the lateral acceleration relative to gravitational acceleration (32.2 ft/sec^2).**
High-Speed Offtracking	**Canada New Zealand**	**The distance between the path of the last axle in a configuration and the steering axle (the "lateral offset" to the outside) in a steady turn at high speed.**
Rearward Amplification	**None**	**The ratio of the peak lateral acceleration of the rear trailer of a multiple trailer combination vehicle to the peak lateral acceleration of the power unit in a rapid steering maneuver that results in a lateral offset movement of the vehicle, such as might be required to avoid an obstacle in its path.**
Dynamic Rollover Stability	**Canada New Zealand**	**An objective safety outcome of rearward amplification, describing how close a truck or unit of a combination, usually the last trailer, comes to rolling over in a rapid steering maneuver.**
Transient High-Speed Offtracking	**Canada New Zealand**	**A second objective safety outcome of rearward amplification, describing the extent by which the rear axle of a combination tracks outside the path of the steering axle of the tractor in a rapid steering maneuver.**
Low-Speed Offtracking	**Canada New Zealand**	**The distance between the path of the last axle in a configuration and the steering axle in a low-speed turn. The last axle typically tracks inboard of the steering axle.**
Turning Circle	**European Union**	**Performance is measured by tracing the path of the furthest outward projection (that is, tractor front bumper) of a vehicle and the path of the furthest inward projection (that is, trailer rear corner).**
Friction Demand (In Tight Turn)	**Canada**	**The minimum level of pavement friction on which a vehicle can negotiate an intersection turn without under-steering excessively.**
Braking Efficiency	**Canada**	**A measure of the amount of tire/pavement friction used, compared to the amount available, before the wheels lock up. Another measure is the ability to stop in a controlled manner within a certain distance (stopping performance).**
Gradeability Startability and Acceleration	**Finland British Columbia**	**The ability of a truck to accelerate through an intersection or a rail crossing and the ability of a truck to maintain speed on a grade are related to the power of the engine, and the characteristics, particularly the weight, of the truck.**

Regarding the implementation of the vehicle type certification approach in particular, the general consensus of opinion expressed in interviews of State officials during this Study is that any assessment of the institutional feasibility of a performance-based approach has to be tentative unless or until it is decided what aspects of performance are included, how these attributes can be measured, and how truck performance can be tested by those responsible for TS&W regulation. Canadian and New Zealand experiences with these approaches follow.

CANADA

The Canadian experience with performance-based standards for trucks and truck combinations evolved out of a study conducted by the Road Transport Association of Canada (RTAC) in the early 1980's. The RTAC process studied many of the performance measures outlined in Table V-6 and based on those analyses established truck configurations that were known to meet the following criteria: (1) interact acceptably with the highway infrastructure; (2) have higher safety performance properties than existing configurations; and (3) increase productivity for industry.

However, Canada did not specify its regulations in performance terms. After evaluating the vehicle stability and control (VS&C) performance, it determined the vehicle weights and dimensions required to ensure that performance standards would be met for each of several truck configurations. This is the “envelope vehicle” approach. It differs from the U.S. Federal approach in two ways: (1) VS&C performance was explicitly considered along with pavement and bridge wear considerations, and (2) weights and dimensions are specified by truck configuration type.

A list of the acceptable configurations was developed to achieve a degree of uniformity in size and weight limits among the Provinces. Benefits evolving from the application of the RTAC approach included expansion in the use of the tridem-axle group in Canada, and improvements in stability and control of larger combinations through the use of B-train doubles with additional weight. In 1989 the Provinces and Territories agreed to implement recommendations from the RTAC Study through a Memorandum of Understanding on Vehicle Weights and Dimensions.

Table V-6
Pros and Cons of Two Performance Based (PB) Approaches to TS&W Regulation

Vehicle Type Certification	**Pros**	**Gives truck manufacturers and motor carriers greater flexibility to create more productive trucks. This is particularly useful for freeway/turnpike operations or special hauling arrangements of natural resources in remote areas.**
		Insures that vehicle performance requirements are met irrespective of changing truck technology, which otherwise can have unanticipated negative impacts in the future.
		A permit provides a means for collecting fees for any additional highway cost responsibility occasioned by larger, heavier trucks.
		Can screen out undesirable truck configurations.
	Cons	**Initial certification of type compliance is an involved process, but once done, it is valid for all trucks of that type for the jurisdiction(s) accepting the certification.**
		Compliance with and enforcement of the performance-based approach are more cumbersome and potentially more costly depending on the operating and equipment specifications of the certification/permit.
		Capability to certify vehicle type compliance is presently minimal and time will be required for the needed licensed professional capability to become available.
		Being a new approach, it would require putting new organizational structure and procedures in place.
Envelope Vehicle	**Pros**	**Simple compliance, administrative, and enforcement procedures.**
		Easily implemented as compliance and enforcement mechanisms are largely in place.
	Cons	**The accommodation of innovative truck designs would often require legislative action.**
		Future truck designs meeting envelope vehicle parameters could perform worse than the standards that resulted in the "envelope" specifications.
		Current TS&W regulations are largely independent of truck configuration type, which adds a significant dimension to TS&W regulation.
		Requires performance assessments by public agencies.

Sources: Interviews of State Officials conducted during the study.
FHWA sponsored "1995 Truck Size and Weight Performance-Based Workshop," Ann Arbor, Michigan.
"Truck Weight Limits: Issues and Options," Special Report 225, TRB, National Research Council, Washington, D.C., 1990.

NEW ZEALAND[6]

The New Zealand performance-based approach (vehicle type certification) requires evidence of a productivity improvement and no reduction in safety levels from the existing condition. The regulations are guided by performance and service principles established by the Land Transport Safety Authority (LTSA), a Crown entity that is controlled by a Board of Directors selected from industry. The LTSA serves as advisor to the government on land transport safety issues. Proof of no reduction in safety levels is the demonstration of vehicle dynamic performance using computer simulation models.

Among the restrictive conditions to ensure that safety is not compromised are: (1) the design of the vehicles must be such that the simulated loading conditions cannot be exceeded, assuming the highest density product for which the approval is valid (has the effect of being limited to enclosed trailers, such as van and tank trailers); (2) no tolerances shall be applied to the vehicle weights prescribed (design capacity must not exceed the approved weight for the approved commodity); (3) maximum speed capability shall be controlled to 90 kilometers per hour; (4) an approved tachograph or electronic speed-time recording device shall be fitted and used at all times and the output made available to any enforcement officer on request; and (5) the stability levels specified shall be achieved by every unit of the combination.

An 88,000-pound, A-train double-trailer combination policy for milk trucks was the first regulation developed under the process, and any A-train combination that meets the performance standards under all loading conditions can be considered for approval. This approval required compliance with three stability performance measures: (1) static roll threshold of 0.45 g's or greater; (2) dynamic load transfer ratio of 0.6 or less; and (3) high speed transient offtracking of 0.5 meters or less.

This process has resulted in significant costs and related difficulties for industry. It was found that only one organization existed in New Zealand with the capability of conducting the simulation testing. Additional difficulty arose from the lack of data needed for testing vehicles and components. Consequently, the performance standards were revised through negotiations between the LTSA and industry. Since only twenty vehicles have been qualified and are operating under the A-train double-trailer policy, the policy is considered a limited success.

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[6] "Regulating Heavy Vehicle Safety in New Zealand Using Performance Standards," John Edgar, LTSA, New Zealand. In *Road Transport Technology -- 4: Proceedings of the Fourth International Symposium on Heavy Vehicle Weights and Dimensions*, June 25-29, 1995. Ed. Christopher B. Winkler. pp. 115-119.

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Winkler, C.B.; Fancher, P.S.; Bareket, Z.; Bogard, S.; Johnson, G.; Karamihas, S.; and Mink, C. 1992. *Heavy Vehicle Size and Weight -- Test Procedures for Minimum Safety Performance Standards,* Report Number DOT HS 807 855. U.S. DOT, NHTSA, Washington, D.C.

APPENDIX A

SUMMARY OF TRUCK CRASH RATE ESTIMATES FROM SELECTED STUDIES

Table V-7 lists crash rate estimates compiled through the review of seven sources (listed in Table V-8). As can be seen in the Table, a variety of quantities are presented depending on the specific source. One might compare the crash rates of different truck configurations within a single study, however, there is no assurance that a different study with a different population would agree with the findings of another study. No data set presently available contains both crash and exposure information on all of these aspects of LCVs or non-LCVs in sufficient detail to fully address questions as to the differences in their comparative crash involvement histories.

Table V-7
Crash Rates from Past Studies
(Per MVMT)

Truck Configuration	**Source**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Single-Unit			**0.369**		**Fatal 0.009 All 0.86**		
Semitrailer	**Local 1.51 Intercity 0.812**	**All 6.79 Casualty 1.51**	**0.486**	**Interstate 3.83 Other Hwys 28.45 Locals 15.65**	**Fatal 0.035 All 1.38**	**Fatal 0.0244**	**Fatal 0.0298**
Truck-Trailer	**Local 0.981 Intercity 0.833**	**All 5.69 Casualty 1.61**	**0.584**	**Interstate 3.52 Other Hwys 18.8 Locals 9.96**			
STAA Double			**0.458**		**Fatal 0.043 All 1.39**	**Fatal 0.0208**	**Fatal 0.0346**
RMD							
Turnpike Double							

Table V-8
Sources For Information in Table V-7

A	**“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.**
B	**“Differential Truck Accident Rates for Michigan,” Richard W. Lyles; Kenneth L. Campbell; Daniel F. Blower, and Polichronis Stamatiadis, Transportation Research Record 1322.**
C	**“Analysis of Accident Rates of Heavy-Duty Vehicles,” Kenneth L. Campbell, Daniel F. Blower; R. Guy Gattis, and Arthur C. Wolfe, UMTRI Report, April 1988.**
D	**“Comparison of Accident Rates for Two Truck Configurations,” Paul P. Jovanis; Hsin-Li Chang; and Ibrahim Zabaneh, Transportation Research Record 1249.**
E	**“Truck Accidents by Classification,” V.D. Graf and K. Arculeta, CALTRANS, FHWA/CA/TE-85.**
F	**“Larger Dimensioned Vehicle Study, Final Report” FHWA, September 1993.**
G	**“Comparison of California Accident Rates for Single and Double Tractor-Trailer Combination Trucks,” C.S. Yoo; Martin L. Reiss; and Hugh W McGee; BioTechnology Incorporated, March 1978.**

CHAPTER 6

HIGHWAY INFRASTRUCTURE

INTRODUCTION

Highway infrastructure protection historically has been the primary consideration in determining TS&W limits as the weights and dimensions of trucks in particular determine the costs that highway agencies must bear to construct and maintain a highway system to serve present traffic and that anticipated in the near future. This Chapter is intended to acquaint the reader with the technical and practical side of TS&W interaction with the infrastructure elements. Pavement deterioration increases with axle weight, the number of axle loadings, and the spacing within axle groups. The axle loads and spacing on trucks also affects the design and fatigue life of bridges. Truck dimensions influence roadway design -- truck width affects lane widths, trailer or load height affects bridge and other overhead clearances, and length affects intersection and curve design. And conversely, truck designs are determined by existing pavement and bridge strength and roadway geometry.

Pavement types analyzed in this Study include flexible, asphaltic concrete; and rigid, portland cement concrete. Bridge features included in the analysis are span length and type of member support -- simple or continuous. The list of roadway geometry features analyzed includes interchange ramps, intersections, and mainline curves. Alternative truck configurations analyzed, in terms of their interaction with highway infrastructure features, include single-unit or straight trucks and single- and multitrailer truck combinations.

OVERVIEW OF INFRASTRUCTURE IMPACTS

The TS&W characteristics -- axle weights, GVW, truck length, width, and height -- affect 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**	**GVW**	**Axle Spacing**	**Truck Length**	**Truck Width**	**Truck Height**
Pavement	Flexible	E		E			
	Rigid	E		e			
Bridge Features	Short-Span	E		E	E		
	Long-Span		E	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

There are two aspects of truck weight that are interdependent and that 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 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, is distributed among the axles and determines axle loads. Over time, the accumulated strains (the pavement deformation from all the axle loads) deteriorate pavement condition, eventually resulting in cracking of both rigid and flexible pavements and permanent deformation or rutting in flexible pavements. If the pavement is not routinely maintained, the axle loads, in combination with environmental effects, will accelerate the cracking and deformation. Proper pavement design relative to loading is a significant factor in pavement life, and varies by highway system and the number of trucks in the traffic stream.

Axle groups, such as tandems or tridems, distribute the load along the pavement, allowing greater weights to be carried and 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 9 to 10 feet results in no apparent interaction of 1-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 deterioration beyond that occasioned by a single axle, dependent on the number of axles in the group. This benefit to pavements of adding axles to a group decreases rapidly beyond 4-axles.

Axle loads also have a beneficial effect on short-span bridges -- that is, bridge spans that are shorter than the truck, thereby resulting in only 1-axle group, front or rear, being on the span at any time. While spreading the axles in an axle group is beneficial to short-span bridges, it is detrimental to pavement. It is not GVW but the distribution of the GVW over axles that impacts pavements.

However, GVW *is* a factor for the life of long-span bridges -- that is, bridge spans longer than the wheelbase of the truck. Bridge bending stress is more sensitive to the spread of axles than to the number of axles. The FBF takes into account both the number of axles and axle spreads in determining allowable GVW.

In the context of roadway geometrics, increasing 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 requires the construction of truck climbing lanes. Some of these effects can be ameliorated by changes in truck design, primarily to engine and drive train components. The GVW also has a second order effect on offtracking -- that is, on how the rear axle of a trailer tracks relative to the steering axle of the truck. Other truck characteristics affected by roadway geometrics are discussed in more detail later in this Chapter.

IMPACT OF DIMENSIONS

The dimensions of trucks and truck combinations have various 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 offtracking and vehicle width. Swept path affects highway geometrics in terms of interchange ramp or roadway 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 that 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 stress for long-span bridges. 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. A truck at mid-span is the loading condition for the maximum 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 stress in the span at the pier.

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

BRIDGES

Bridges are critical to the safe and efficient movement of people and freight on the Nation's highways. This section discusses the important considerations that have influenced the decision making and investments of Federal and State transportation officials for bridges.

BRIDGE DESIGN[1]

Most highway bridges in the United States were designed according to the design guidelines of the AASHTO. These guidelines 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.

Dynamic effects (vibration resulting in bridge loads that vary above and below that load resulting trucks operating at higher speeds. In bridge design, design loadings (in the static condition) 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 its GVW.

A key task in bridge design is to select bridge members that are sufficiently sized to support the various loading combinations 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); and 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

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[1] 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.*

of the load-bearing capacity of the main structural members may be required to support the weight of the bridge.

In most instances, the loading event that governs bridge capacity 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 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.

The methods used to calculate stresses in bridges caused by a given loading are necessarily conservative; therefore, the actual measured stresses are generally much less than calculated stresses. Providing for a margin of safety is necessary to bridge design 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 may increase during the design life of a structure; and
- Overweight loading is occasionally allowed by permit.

The 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 load capacity will be reached within the bridge’s design life.

The margins of safety used by bridge designers in the past have been reduced in recent bridge design procedures. Use of new design procedures and computer-aided engineering and design has enabled more precise analysis of load effects and the selection of smaller bridge members. Also, the competition between the steel and concrete industries has led each group to foster lower costs for their own material. For example, many designs now proposed for steel bridges reduce the safety factor by reducing the number of girders, which increases their spacing.

Design and construction of highway bridges in the United States has been governed by the AASHTO's *Standard Specifications for Highway Bridges* since 1931, with subsequent revisions. In the early 1990s AASHTO decided to develop an entirely new bridge code to incorporate state-of-the-art bridge engineering that is based on the load and resistance factor design (LRFD) approach.[2] In 1993, AASHTO adopted LRFD bridge design specifications on a trial basis, as an

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[2] FHWA http://www.ota.fhwa.dot.gov/tech/struct/dp99lr.html, February 19, 1998.

alternative to standard bridge design specifications. In 1996, interim LRFD specifications were made available by AASHTO and conversion to this method was encouraged wherever practical.[3]

The LRFD method applies statistically determined factors to bridge design parameters, using a series of load and resistance factors to account for variabilities in loads and material resistance. The specifications use statistical methods and probability theory to define the variations in loading and material properties and the likelihood that various load combinations will occur simultaneously.[4]

BRIDGE IMPACT

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, such as 55 percent or 75 percent. 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 -- 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.

BRIDGE INVENTORY AND OPERATING RATINGS

States rate bridges, at their discretion, at either an inventory rating (55 percent of the yield stress) or operating rating (75 percent of the yield stress).[5] Bridges are never intentionally loaded to yield stress in order to provide an adequate margin of safety. The design stress level for bridges is the same as the inventory rating, 55 percent of the yield stress. These two ratings are also used for posting bridges; either may be used under AASHTO guidelines, at the option of the State. A sign specifying weight limits is posted on bridges 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 either the 55 percent or 75 percent level of the yield stress.

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[3] AASHTO http://www2.epix.net/~lrfd/develop.html, February 19, 1998.

[4] Ibid.

[5] 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 level for posting purposes, both ratings have been used in past studies to assess the bridge impacts for evaluating TS&W policy scenarios. Significant cost differences result from choice of rating. Use of the lower stress level (inventory rating) results in more bridges being identified as needing to be upgraded to accommodate increased weights or decreased lengths.[6]

Following the reviews of the TRB Special Reports 225 and 227 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. The FHWA used this 68.8 percent of yield to estimate the bridge cost impacts of LCVs. The resulting cost estimate reported by the FHWA in May 1991 was much closer to that based on the 75 percent rating, the TRB findings.

BRIDGE STRESS

Bridge stresses caused by vehicles depend on both GVW and the distances between the axles that 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 (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 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.

TS&W REGULATION RELATED TO BRIDGE PROTECTION

The TS&W regulation to protect bridges generally takes the form of a bridge formula or table. Federal bridge protection regulation, which became effective in 1975, uses a formula. Some States still use bridge tables, which were grandfathered by the 1975 Federal law. Other States use bridge tables for issuing overweight permits. The FBF is based on overstress criteria, the amount of bridge stress above the design stress to be allowed.

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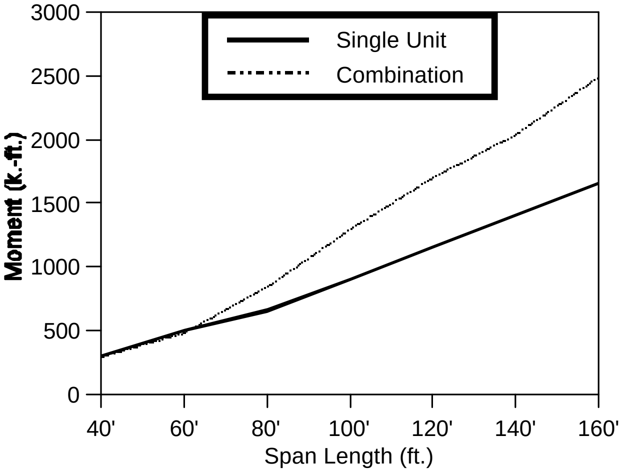
[6] The TRB *Special Reports 225, Truck Weight Limits: Issues and Options* and *227, New Trucks for Greater Productivity and Less Road Wear: an Evaluation of the Turner Proposal* estimated the bridge costs of the TS&W changes under study based on the operating rating of 75 percent of yield stress, whereas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

Figure VI-1
Maximum Bending Moments on a Simple Span Bridge:
50,000-pound Single Unit 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, one that did not preserve the underlying FBF 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 similarly susceptible. 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.[7]

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[7] Fisher, 1977.

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.[8] 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.

FEDERAL BRIDGE FORMULA

In 1975 along with axle and maximum GVW limits for Interstate highways, Federal law adopted a bridge formula 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. The 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.[9] That Study 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, FBF:

$$W = 500 [L N / (N - 1) + 12 N + 36]$$

where:

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

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

N = number of axles in the axle group

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

The FBF is based on assumptions about the amount by which the design loading can be 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 these bridges by Federal, State, and local governments, and because these bridges carry high volumes of truck traffic.

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[8] AASHTO specifications give different allowable fatigue stresses for different categories of detail. These fatigue rules were initiated in the mid-1970s, 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).

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

Although a level of up to 30 percent is considered 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.

The FBF 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 3-axle single-unit truck with a wheelbase of 20 feet to operate at 51,000 pounds. If the wheelbase of this truck is increased to 24 feet, the maximum weight allowed under FBF would increase to 54,000 pounds as shown in Table VI-2.

Table VI-2
FBF 3-axle, 4-axle, And 5-axle Single-unit Truck Limit

Distance[10] (Feet)	GVW (Pounds)		
	3-Axles	4-Axles	5-Axles
20	51,000	55,500	60,500
24	54,000	58,000	63,000
28	57,000	60,500	65,500
32	60,000	63,500	68,000
36		66,000	70,500
40		68,500	73,000

As noted, there is a greater gain in allowable load by adding an axle than by increasing the distance between axles. For instance, at 30 feet a 3-axle vehicle is allowed a maximum GVW of 58,500 pounds and by adding 2 feet can gain only 1,500 pounds. If the same 3-axle vehicle at 30 feet adds an axle there is a gain of 3,500 pounds -- or 2,000 pounds more than by increasing distance by 2 feet. Increasing the number of axles in an axle group without increasing the overall length of the group has very little effect in reducing bridge stress. However, more axles do provide substantial benefits to pavements.

POTENTIAL ALTERNATIVES TO FBF

Actually, the FBF is not just one formula but 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 by the number of axles. Thus the FBF is not effective in modeling the actual physical phenomenon, and it results in loads, especially for long combinations, that overstress bridges more than intended. More importantly, it encourages the addition of axles to obtain more payload even though one or both bridge stress criteria are exceeded. At other times, the equation restricts allowable loads for some short trucks below that

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[10] Between the outside axles of any group of 2 or more axles.

allowed by the stress criteria themselves. In summary, the FBF actually results in overstressing some of the bridges it is intended to protect.

Since 1975, there have been a number of proposals to revise the FBF and reduce its shortcomings. However, significant areas of concern have been identified with respect to the alternatives as well. Three alternative formulas proposed in recent years are discussed here: a TRB (a combination of the Texas Transportation Institute (TTI) and FBFs) alternative, an AASHTO alternative, and a Goshen alternative.

TRB ALTERNATIVE

In 1990, the TRB recommended adoption of the formula developed by the TTI which 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.[11] The TRB Report further recommended the FBF 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:

$$W = 1{,}000\ (L/2 + 62)$$

where:

W = allowable weight

L = wheelbase for truck configuration

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[11] TRB Special Report 225.

AASHTO 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 FBF; (2) consider a limit on maximum extreme axle spacing of 73 feet in the short term; (3) retain existing single- and tandem-axle limits; (4) control tridem-axle weights -- and the special permitting of vehicles with GVWs more than 80,000 pounds -- using the original TTI bridge formula which protects both H-15 and HS-20 bridges, as opposed to the TTI formula mentioned above, which protects only HS-20 bridges. 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.

GHOSN ALTERNATIVE

In 1995 a research study by Ghosn and others for FHWA, proposed a new formula based on structural reliability theory as a replacement for the FBF.[12] 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 the FBF when applied to long vehicles. It results in bridge stresses well above the criteria selected for this Study. Therefore, it was not considered.

ALLOWABLE WEIGHTS BASED ON FBF STRESS CRITERIA

Original research conducted for this Study suggests that a series of look-up tables may be developed based on the underlying the FBF stress criteria -- 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 truck configurations. The following discussion illustrates how this approach might be applied to three vehicles: (1) a tractor-semitrailer combination vehicle with a 3-axle tractor and 2-axle semitrailer, (2) a tractor-semitrailer combination vehicle with a 3-axle tractor and a semitrailer with a tridem-axle group, and (3) a RMD. The GVWs for each configuration with varying semitrailer lengths were calculated based on axle spacing.

Table VI-3 presents the weight values for the first vehicle combination under the FBF, TTI, and FBF stress criteria; and Figure VI-2 graphically displays maximum GVW from the Table, for semitrailers of varying lengths.

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[12] *Bridge Overstress Criteria*, Michael Ghosn, Charles G. Schilling, Fred Moses, and Gary Runco, Report by the City College of the City University of New York for the FHWA (Washington, D.C., FHWA, 1995).

Table VI-3
Maximum GVW For 5-axle Semitrailer Combination Applying Federal And TTI Bridge Formulas And FBF Stress Criteria

Semitrailer Length (Feet)	Maximum GVW (1,000 Pounds)			Semitrailer Length (Feet)	Maximum GVW (1,000 Pounds)		
	FBF	**TTI**	**FBF Stress Criteria**		**FBF**	**TTI**	**FBF Stress Criteria**
28.0	70.0	70.1	78.4	**45.0**	80.0	80.0	80.0
35.0	74.5	77.1	80.0	**48.0**	80.0	80.0	80.0
40.0	78.0	80.0	80.0	**53.0**	80.0	80.0	80.0

NOTE: GVWs specific to 22.5-foot tractor wheelbase, 52-inch tractor tandem spread, and trailer 48-inch tandem spread. The distance from the first drive axle (on the tractor to the last trailer axle is the trailer length minus 6 feet.

Figure VI-2
Maximum GVW For 5-axle Semitrailer Combination Applying Federal and TTI Bridge Formulas And FBF Stress Criteria

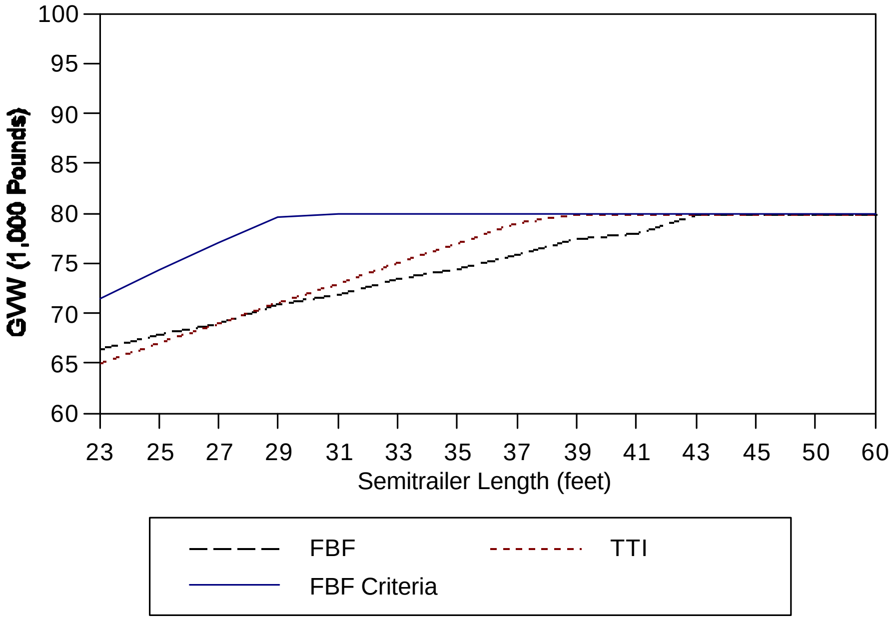

Table VI-4 presents weight values and maximum GVWs for the 6-axle semitrailer combination with the semitrailer supported at the rear by a tridem-axle group. In this case, both the tractor wheelbase and semitrailer length are varied (common descriptive dimensions). The allowable GVW for varying semitrailer lengths is shown in Figure VI-3.

Table VI-4
Maximum GVW For 6-axle Semitrailer Combination Applying Federal And TTI Bridge Formulas And FBF Stress Criteria
Tractor Wheelbase = 22.5 Feet

Semitrailer Length (Feet)	Maximum GVW (1,000 Pounds)			Semitrailer Length (Feet)	Maximum GVW (1,000 Pounds)		
	FBF	TTI	FBF Stress Criteria		FBF	TTI	FBF Stress Criteria
28.0	75.0	70.1	73.4	**45.0**	85.5	87.1	88.6
35.0	79.5	77.1	84.5	**48.0**	87.5	90.1	90.0
40.0	82.5	82.1	88.7	**53.0**	90.5	92.0	94.2

Figure VI-3
Maximum GVW For 6-axle Semitrailer Combination Applying Federal And TTI Bridge Formulas And FBF Stress Criteria
Tractor Wheelbase = 22.5 Feet

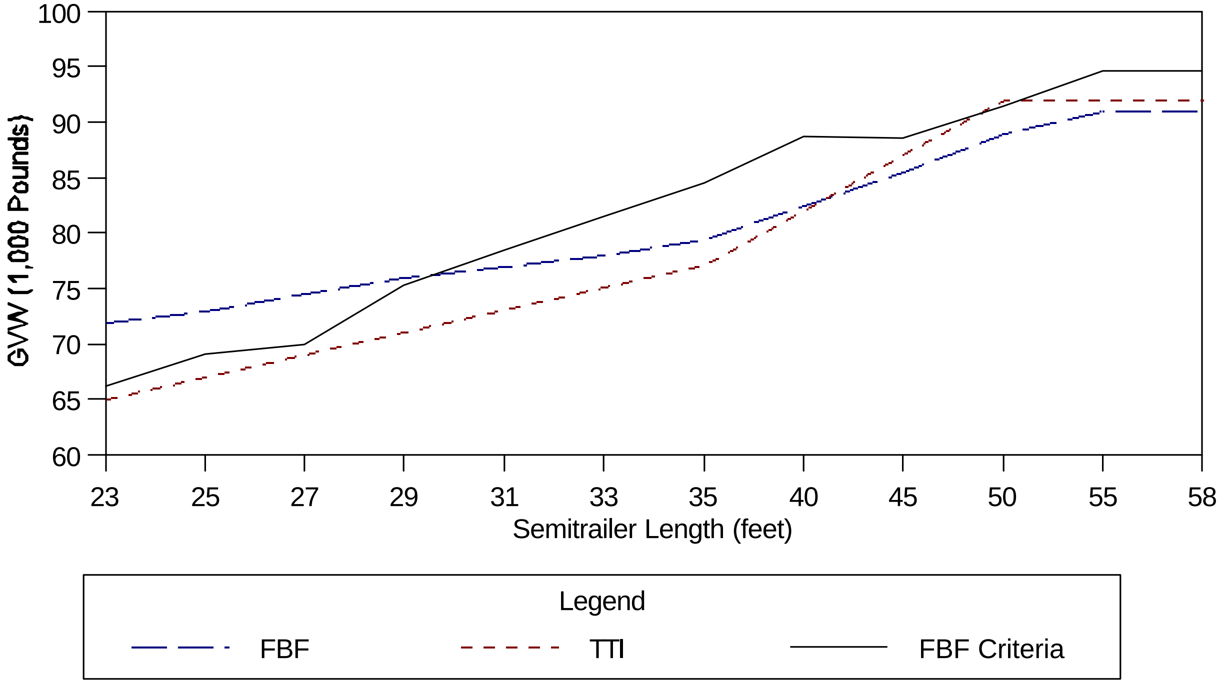

Table VI-5 presents the values and maximum GVWs for the RMD combination, a tractor-semitrailer combination with a 3-axle tractor pulling a 2-axle semitrailer and a 2-axle full trailer. The tractor and semitrailer length of this double are varied, with the trailer remaining constant at 28 feet. The limiting 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 9-axle vehicle). The GVW for varying semitrailer lengths is shown in Table VI-5.

Table VI-5
Maximum GVW for RMD with Semitrailer of Variable Length And 28' Trailer Applying Federal and TTI Bridge Formulas And FBF Stress Criteria
Tractor a = 18.2 Feet, Tractor B = 22.5 Feet

Semitrailer Length (Feet)	**GVW (1,000 Pounds)**					
	FBF		**TTI**		**FBF Stress Criteria**	
	Tractor A	Tractor B	Tractor A	Tractor B	Tractor A	Tractor B
45	109.5	109.5	105.16	107.3	111.4	112
48	111	111	106.6	108.8	112.8	113.4
53	111	111	109.1	111.3	115.2	116

In summary, there is significant variation in the results derived from the three formulaic approaches by vehicle configuration. In general, the TTI formula is better matched than the FBF for bridges, and there is a significant amount of load capacity available before limits are exceeded for the 5- and 6-axle semitrailer and 7-axle RMD configurations. This is not the case, however, for larger vehicles such as the 9-axle turnpike doubles -- FBF allows too much weight for these in terms of the stress criteria. The TTI curve for that vehicle is on the low side of the FBF stress criteria curve. Also, FBF is conservative for multiaxle short straight trucks.

There are benefits to adhering to the criteria on which the FBF is based and incorporating the consideration of continuous beams into the control. Tools such as user-friendly computer software programs can be designed to assess allowable loading configurations for any vehicle, and standard (bridge formula) tables for the more common vehicles can be generated. The use of the FBF stress criteria described in this section addresses the documented drawbacks of FBF and provides a basis for truck weight control that conforms to the criteria upon which both FBF and TTI are based -- but to which they do not always adhere.

It should be noted that the FBF, by design, incorporates a degree of control for pavement damage by explicitly including the number of axles in the formula. The TTI formula and FBF stress criteria 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.

PAVEMENTS

The condition and performance of highway pavements depend on many factors, including the 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.[13]

WEIGHT

While pavement engineers traditionally have used ESAL factors estimated from the AASHO Road Test (started in 1956 and completed in 1962) as the basis for designing pavements, there is increasing recognition that better relationships between axle load and pavement deterioration are needed. Pavement distress models used in both the 1982 and 1997 Federal HCA Studies (HCAS) abandoned the use of ESALs to relate axle loading to pavement deterioration, 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 were not used as the basis for estimating pavement costs for this Study, they are widely understood by highway administrators, pavement engineers, and others concerned with the pavement impacts of TS&W scenarios. Therefore, they are used here as a benchmark for comparing relative pavement impacts of various truck configurations with different numbers and types of axles.

Pavement deterioration 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, as a vehicle with more axles has less effect on pavements. For example, a 9-axle combination vehicle carrying 80,000 pounds has less effect on pavements than a 5-axle combination vehicle carrying 80,000 pounds. A significant amount of additional weight can be carried by the 9-axle vehicle without causing greater pavement consumption relative to the 5-axle vehicle. Comparing vehicles in terms of ESALs provides information on load-related pavement impact, but it does not include an offsetting benefit gained by a reduction in the number of trips required to transport

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

the same amount of freight. Vehicles are often compared in terms of ESALs per unit of freight carried as a means of including the reduction in pavement deterioration 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.[14] Additionally, pavements are much more vulnerable to traffic loadings during spring thaw in areas 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 an unknown degree by an increase in the time or duration of loading. The net effect of changes in axle spacing on pavement deterioration is complex and highly dependent on the nature of the pavement structure.[15]

TIRE CHARACTERISTICS

In recent years, several studies on the impact of tire characteristics on pavement have raised concern over the possibility of accelerated pavement deterioration, 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, result in a smaller size tire “footprint” on the pavement and, consequently, a concentration of weight over a smaller area.[16] These changes hasten the wear of flexible pavements, increasing both the rate of rutting and the rate of cracking.

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[14] 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 million ESALs per year. 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 million 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.

[15] TRB *Special Report 225*.

[16] 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.

The AASHTO load equivalency factors 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 deterioration of substituting single for dual tires. Both standard and wide-based tires have been considered. Past investigations of the pavement deterioration effects of single versus dual tires have found that single tires induce more pavement deterioration than dual, but that the differential wear effect diminishes with increases in pavement stiffness, in the width of the single tire, and in tire load.[17]

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 flexible pavements (the most common type of pavement) as they do not have good rut resistance. Another finding is that one of the wheels in a dual tire assembly is frequently overloaded due to variability in the roadway cross-section and that the average overload causes an increase in rutting similar to that caused by wide-based single and dual tire assemblies.

Based upon past studies, single tires have more adverse effects on pavements than dual tires,[18] it appears likely, however, that past investigations have overstated the adverse effects of single tires 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 multiaxle group, pavement deterioration 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 than perfect tracking is beneficial to pavement deterioration, as the fatiguing effect is diminished because the repetitive traffic loads are distributed over wider areas of the pavement surface. The greater overall width of dual tires naturally subjects a greater width of pavement to destructive stresses, therefore, wander is expected to have a smaller beneficial effect for dual than for single tires. Once rutting

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[17] 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 5-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.

[18] 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 Tabataee (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.”

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.[19]

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.[20] 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.[21] 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. This means the tire absorbs more of the dynamic bouncing of the truck, and less of the dynamic load is transmitted to the pavement.

SUSPENSION SYSTEMS

The subject of road-friendly suspensions -- within the context of the broader subject of vehicle-pavement interaction -- was researched as an Organization for Economic Cooperation and Development (OECD) Project -- the Dynamic Interaction between Vehicles and Infrastructure Experiment (DIVINE) Project -- involving the United States and 16 other countries.[22] The work focused on (1) how well different suspension systems distribute load among axles in a group (the more evenly, the better); (2) how well different suspension systems dampen vertical dynamic

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[19] The TRB *Special Report 225* examined the importance of loading imbalance and wander. The TRB Study examined two types of pavement deterioration: 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 deterioration were reduced when wander was taken into account, although the effects were still significant.

[20] 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.

[21] 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.

[22] 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 deterioration 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 deterioration.

loads (the more, the better); and (3) spatial repeatability of dynamic loads. The research also examines how road and bridge characteristics act to excite a truck, and in turn influence the loads received by the road and bridge.

The findings of the DIVINE research primarily relate to the physical interaction between heavy vehicles and the highway infrastructure -- pavements and bridges. The research breaks new ground, providing scientific evidence of the effects of heavy vehicles. Conclusions that relate to vehicle and pavement interaction are summarized from the final report.

Pavement wear -- the gradual loss of functional condition -- is expressed in permanent deformations to the longitudinal profile of the pavement surface. Whereas, pavement damage results from an accumulation of rutting and cracking distress from repeated applications of vehicle loads. "Road research . . . has historically tended to over-emphasize pavement damage, and the true importance and nature of pavement wear has not yet been recognized."[23] The DIVINE research focused primarily on examining pavement wear rather than damage.

Two scientific breakthroughs resulted from the DIVINE accelerated pavement tests: "the effects of dynamic loading were measured for the first time, and a detailed statistical analysis of both the pavement and vehicle variables was undertaken."[24] Conclusions reached are:

- Changes in pavement profile under dynamically-active steel suspensions relate to: local structural compliance (the opposite of strength), and local dynamic wheel load.

- Changes in pavement profile under dynamically-quiet air suspensions are mainly related to the local structural compliance of the pavement.

- The relationship between tensile strain at the bottom of the pavement surfacing layer and dynamic wheel loading appears to depend on the pavement thickness. For thick pavement, strain is directly related to dynamic wheel loading. For thin pavement, strain directly related to dynamic wheel loading is weaker. This difference in pavement behavior is believed to be related to changes in tire contact conditions occurring from variances in the dynamic wheel load.

- Air suspension would increase pavement life by 60 percent for thick pavement and 15 percent for thin pavement (based on two types of implied assumptions: selected pavement response parameter measured and analyzed, and the "damage law" applied).

- Spatial repeatability on a relatively smooth road would increase total wheel loading at certain locations by approximately 10 percent, reducing pavement life at those locations by approximately 35 percent to 50 percent.

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[23] OECD DIVINE Programme, Final Report "Dynamic Interaction of Heavy Vehicles with Roads and Bridges," May 1997, p. 145.

[24] Ibid.

The findings indicate that "pavement wear is the key concept to be used in the scientific consideration of the effect of heavy vehicles on highway pavements."[25]

Additionally, recent research outside the DIVINE Program evaluated the role of suspension damping in enhancing the road friendliness of a heavy vehicle. The findings indicated an increase in linear suspension damping tends to reduce the dynamic load coefficient and the dynamic tire forces -- factors related to road wear. The research concluded 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.[26] 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.[27]

The research has yet to produce any compelling argument to incorporate a suspension system determinant into U.S. 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 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 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 Canada and the United States raises concern for resulting pavement deterioration when a driver, attempting to improve fuel consumption, fails to lower the axle when loaded. A 1988 and 1989 survey conducted in Ontario and Quebec found that approximately 17 percent and 21 percent, respectively, of trucks on highways in those Provinces had lift axles.[28] Lift axles have been adopted in response to GVW limits governed by the number

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[25] Ibid, p. 147.

[26] 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.

[27] 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 RTAC: 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.

[28] Billing, et. al.

of axles (such as the FBF), 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. Improperly adjusted lift axles can damage 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 4-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 carrying little or no weight, this vehicle would produce approximately 4.0 ESALs.

PAVEMENT COST

Unit pavement costs and pavement costs per unit of payload-mile by configuration are shown in Tables VI-6 and VI-7. They illustrate how the addition of axles allows for increased payloads and at the same time reduces pavement deterioration. Particularly striking, are comparisons between the 3- and 4-axle single unit trucks, the 5- and 6-axle semitrailer combinations, and the 5- and 8-axle doubles. As shown in Table VI-7, the 4-axle truck has costs per payload ton-mile about 75 percent of that for the 3-axle truck even though its gross weight is 10,000 pounds more than the 3-axle truck. The comparison of the 6-axle semitrailer with the 5-axle is very similar on non-Interstate highways. The costs for the 8-axle double-trailer are less than half those for the 5-axle double-trailer. Triples do not compare well with doubles. Generally, truck owners would be opposed to adding axles because this increases the tare weight of the vehicle and reduces payload capacity.

TS&W REGULATION RELATED TO PAVEMENT PRESERVATION

TIRE REGULATIONS

Federal law and most State 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. Recent research gives conflicting views as to whether or not pressures should be regulated.[29]

Federal, and most State, laws do not discourage or prohibit the use of wide-base tires. The consensus of United States and international research is that these tires have substantially more

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[29] 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.

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 -- which are widely used in Europe -- are being increasingly adopted by U.S. trucking operations. The benefits of wide-base tires are reduced energy use, emissions, tire 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.

Table VI-6
Unit Pavement Cost For Various Truck Types
$/1,000 MILES

		Truck Type								
		Single-Unit		**Semitrailer**		**Double-Trailer**			**Triple**	
		3-Axles	**4-Axles**	**5-Axles**	**6-Axles**	**5-Axles**	**7-Axles**	**8-Axles**	**7-Axles**	
	GVW (Pounds)	54,000	64,000	80,000	90,000	80,000	100,000	105,000	100,000	115,000
Area Type	**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
	Freeway & Expressway	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

Historically, many States specified some form of tire load regulation for safety. In recent years, additional States have adopted tire load regulations 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.

Table VI-7
Unit Cost per Payload-mile for Various Truck Types
$/1,000 Ton-miles

		Truck Type								
		Single-Unit		**Semitrailer**		**Double-Trailer**			**Triple**	
	Weights (Pounds)	**3-Axles**	**4-Axles**	**5-Axles**	**6-Axles**	**5-Axles**	**7-Axles**	**8-Axles**	**7-Axles**	
	GVW	54,000	64,000	80,000	90,000	80,000	100,000	105,000	100,000	115,000
	Tare	22,600	26,400	30.490	31,530	29,320	38,600	33,470	41,700	41,700
	Payload	31,400	37,600	49,510	58,470	50,680	61,400	71,530	58,300	73,300
Area Type	**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
	Freeway & Expressway	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

SPLIT-TANDEM VERSUS TRIDEM-AXLE LOAD LIMITS

There is increasing use of split tandem axle groups with spreads up to 10 feet, particularly in flatbed heavy haul operations. These axles are allowed to be loaded at single axle limits -- 20,000 limits -- 20,000 pounds on each of the 2 axles -- as opposed to 34,000 pounds on a closed tandem when they are split more than 8 feet. They offer two key benefits to 5-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 at a significant cost to pavement life.

In the United States, the allowable load on a group of three axles connected by a common suspension system (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 specific load limit in the same way the United States specifies single and tandem axle limits without direct reference to a bridge formula. This is not to say that these tridem limits are not bridge-related. For example, the tridem limits prescribed by the RTAC, which vary as a function of spacing, are based on bridge loading limitations -- not pavement limitations.

THE GVW LIMIT

The existing legal Federal maximum GVW (cap) limit for the Interstate System is 80,000 pounds, although some States allow truck combination weights above this cap under Federal grandfathering provisions. Axle weight limits and the FBF 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 loads 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.

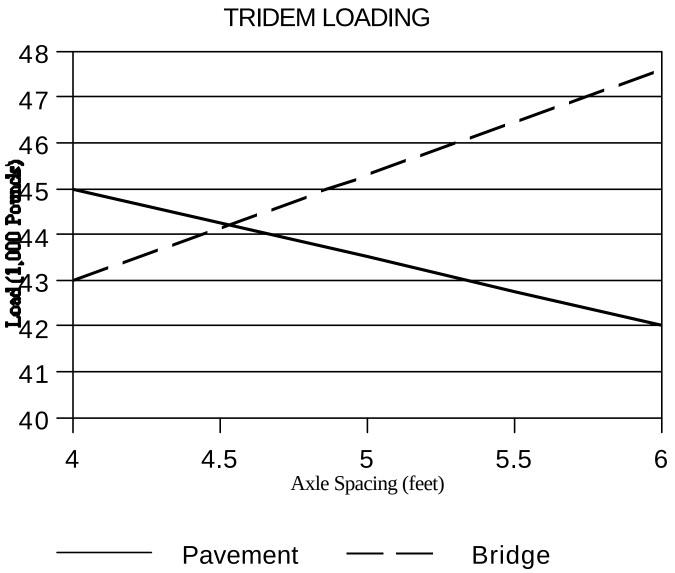
The tridem-axle weight limit of 44,000 pounds was determined by observing where the curve of the increasing bridge allowable load function crosses the curve of the decreasing pavement load equivalency function (see Figure VI-4). The two curves cross at a spread of 9 feet between the two outer axles which gives 44,000 pounds for both functions. To stop short of 9 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 6-axle semitrailer combination is more effective in reducing pavement damage than a 5-axle semitrailer combination with a split tandem (two trailer axles spread apart), which is allowed under the current FBF. Table VI-8 provides the weight limits for a tridem axle between 8 and 16 feet and Figure VI-4 illustrates the impact on pavement and bridges.

Table VI-8
Tridem-axle Weight Limits

Axle Spreads (Feet)	Distance Between Adjacent Axles (Feet)	Load at LEF=1	Allowable Bridge Load (1,000 Pounds)
8	4	45	43
12	6	42	48.6
16	8	40	------

Figure VI-4
Pavement and Bridge Impact of Tridem-axle



USE OF TRIDEMS

The use of tridem axles could increase truck load capacity while reducing pavement damage.[30] Many heavy bulk haulers have already switched from 3-axle to 4-axle single unit trucks, and as noted above, significant pavement cost savings may be possible. The 80,000-pound GVW limit poses a constraint on adding axles to 5-axle combinations because 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 5-axle combinations. To illustrate this, as shown in Figur VI-5, a 6-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 5-axle tractor-semitrailer carrying 80,000 pounds are 2.37 (flexible) and 3.94 (rigid).

Assuming tare weights of 28,000 and 29,500 pounds for the 5- and 6-axle combinations, respectively, and using the AASHTO load equivalence factors, the ESALs per million pounds of payload for the trucks shown in Figure VI-5 are shown in Table VI-9.

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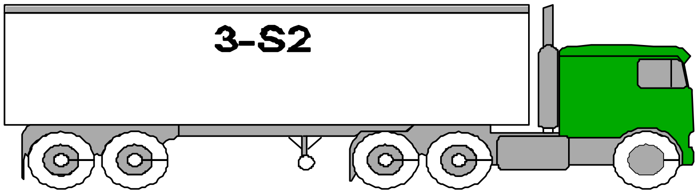
[30] Both the TRB *Special Report 225* and the AASHTO TS&W Subcommittee suggest consideration of the TTI bridge formula which could allow about 90,000 pounds for a 6-axle tractor-semitrailer combination.

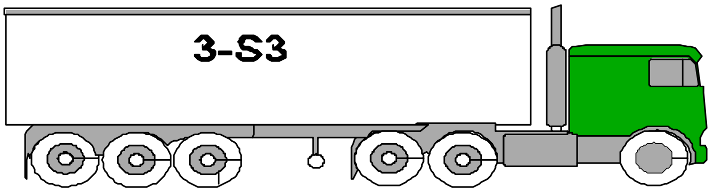
Figure VI-5
ESAL Comparison of 5-axle and 6-axle Combinations on Pavement

5-Axle Tractor-Semitrailer



				TOTAL
Weight (pounds)	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

6-Axle Tractor-Semitrailer



				TOTAL
Weight (pounds)	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

Table VI-9
ESALS per Million Pounds Payload for 5- and 6-axle Combinations

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

ROADWAY GEOMETRY

ELEMENTS OF ROADWAY GEOMETRY AFFECTING TRUCK OPERATIONS

INTERCHANGE RAMPS

Access and exit ramps for controlled access highways are intended to accommodate design vehicles at certain design speeds. Otherwise, trucks heavier than the design vehicle have an increased probability of rolling over, and trucks longer than the design vehicle will have trailer wheels that travel off the pavement to the inside of a curve. The TS&W, configuration, and speed influence the potential for rollover on short loop ramps. The AASHTO policy recommends widening ramps to accommodate combination vehicles. For example, the width of a 1-lane ramp, with no provision for passing a stalled vehicle, would be 15 feet on a tangent section.

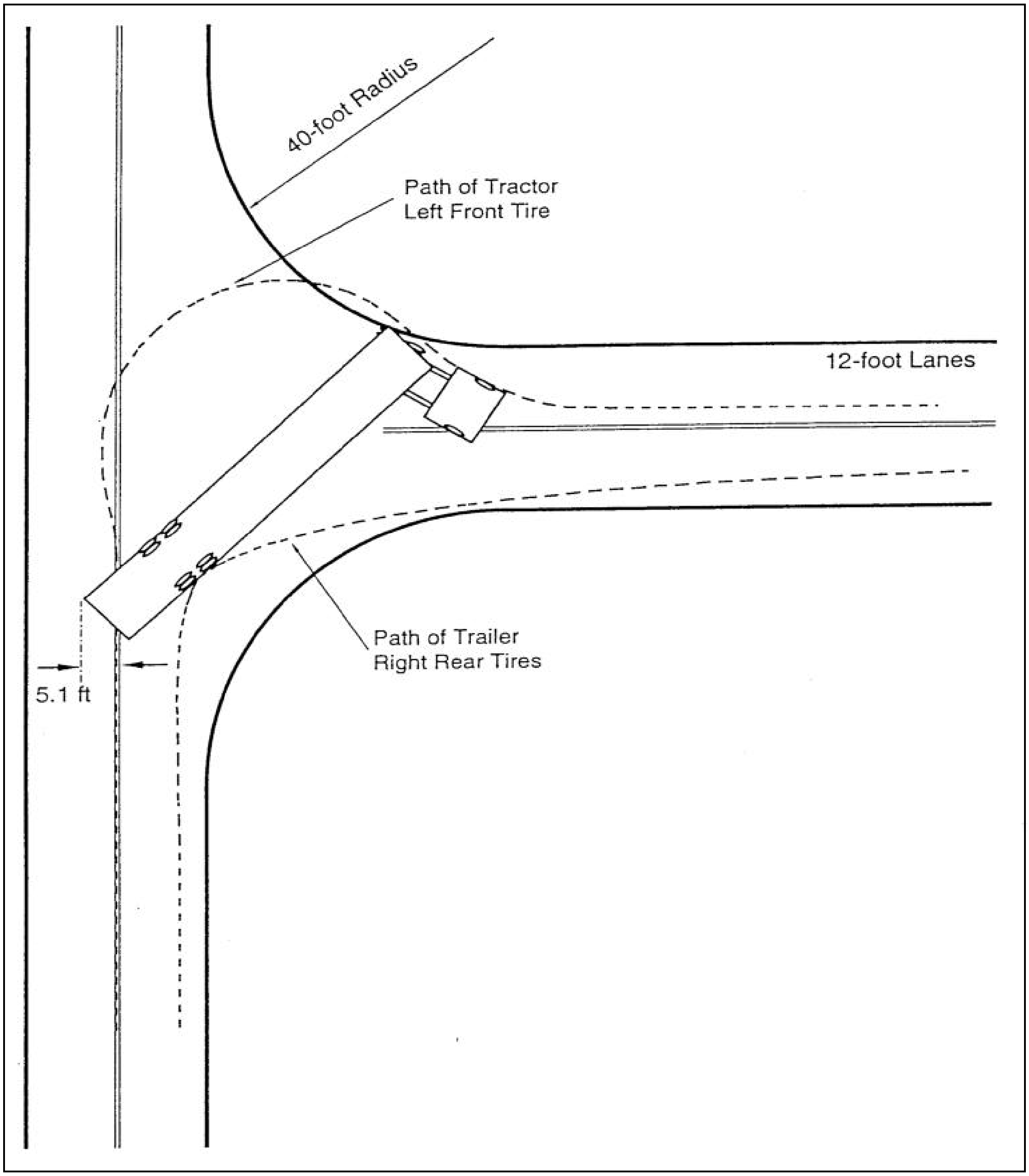
The extreme case for design consideration occurs when traffic is congested and stop-and-go conditions exist. The speed component to the offtracking equation is negligible and maximum offtracking to the inside of the curve occurs. Under this condition, the turnpike doubles analyzed in this study offtrack 20 percent more than a 5-axle 53-foot semitrailer combination and as a result, encroach on adjacent lanes or shoulders and necessitate widening beyond AASHTO standards.

INTERSECTIONS

Most 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 determining needed intersection improvements to accommodate offtracking requirements. Additionally, the increased time required for a large truck to complete its turn requires longer traffic signals and affects pedestrian safety and intersection efficiency. Figure VI-6 illustrates the intersection maneuver.

Proper design and operation requires that no incursion into the path of vehicles traveling in opposing directions 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 5-axle tractor-semitrailer combination with a 48-foot semitrailer. Even more intersections would be inadequate to accommodate vehicles that offtrack more than the standard 48-foot semitrailer combination.

Figure VI-6
Path of Tractor Semitrailer Keeping Tires Within Lanes



NOTE: Distance from kingping to rear axle is 40 feet; distance from rear axle to rear of trailer is 14.5 feet

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 where controls on vehicles, routing, or travel times are needed. 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. Another option for States might be the provision of staging areas where routes and intersections have prohibitive constraints off Interstate-type highways.

CLIMBING LANES

The ability of a truck to maintain speed on a grade is described by the term "gradeability;" the truck's ability to start on a grade from a standstill is termed "startability." The ability of various trucks to start and to maintain speeds on grades is a complex subject that primarily depends on net engine horsepower, torque, gearing, drive train efficiency, friction, GVW, and minimum allowable speed. Gradeability and startability are discussed in Chapter 5, Safety and Traffic Operations. The AASHTO recommends that separate climbing lanes be provided on grades that have substantial truck traffic or that cause typical trucks to slow by more than 10 miles per hour.[31]

CROSS-SECTION

Cross-section refers to the shape of the surface of the roadway perpendicular to the direction of traffic.[32] 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 with greater offtracking. The presence of cross-slope discontinuities can also be a problem for vehicles more prone to rollover because of the dynamic forces that they tend to introduce.

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. Truck combinations with longer trailers are often prone to producing relatively large amounts of offtracking beyond that provided for in AASHTO

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[31] Substantial is not defined by AASHTO. There is no universally acceptable standard and it is left to the States to define.

[32] 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 grade or elevation is generally highest at the centerline.

standards. For 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 that are designed to maximize stopping sight distance. Vertical curves are generally designed for passenger cars, as a passenger car driver's eye is lower than is a truck driver’s. 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.

PASSING SIGHT DISTANCES

Distances required for passing trucks can be significantly longer than for automobiles and pickups. 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 multilane highways, passing is not as critical as passing on a 2-lane highway with traffic in opposing directions. Sight distance criteria for marking passing and no-passing zones on 2-lane highways are more appropriate for a passenger car passing another passenger car: they do not consider trucks, even the standard truck-and 48-foot semitrailer combination vehicle at 80,000 pounds.

The additional lengths of LCVs could require as much as 8 percent more passing sight distance for cars passing LCVs on 2-lane roads; longer and/or heavier trucks would require incrementally longer passing sight distances to pass cars safely on 2-lane roads.

DIMENSIONAL LIMITS IMPACTING TRUCK MANEUVERS

LENGTH LIMITS FOR SEMITRAILERS

The STAA of 1982 requires States to allow the operation of a semitrailer of at least 48 feet long on the NN. 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, Florida, Kansas, Louisiana, New Mexico, Oklahoma, Texas, and Wyoming.[33] Most of these States allow trailers in the 57- to 60-foot range to operate.

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[33] *Federal Size Regulations for Commercial Motor Vehicles,* U.S. DOT, Publication Number FHWA-MC-96-03.

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 passage of the ISTEA, Federal law allowed States to permit longer trailers in combination (commonly referred to as doubles) but did not require States to do so.

OVERALL LENGTH LIMITS

The STAA of 1982 established a prohibition against State laws specifying a maximum length for semitrailer and STAA 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 are important from the standpoint of safety and traffic operations. The effect on roadway geometric design relates to lane and shoulder width and vertical clearances. A 1-lane ramp with a narrow shoulder would result in a blockage if a truck were disabled. Many older structures (overpasses) were constructed with minimal vertical clearances. The addition of pavement overlays over the years may have further reduced these clearances. Increases in vehicle height increases the potential for striking these overhead structures as well as vehicle rollover.

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. The maximum extent of offtracking for a turn of a given radius and length occurs at the rearmost axle or the center of the rearmost axle group.

Offtracking develops gradually as a vehicle enters a turn and, if the turn is long enough, eventually reaches what is termed as fully-developed offtracking. The offtracking does not continue to increase beyond this point for curves that are any longer. The extent of this fully-developed offtracking is used to determine if the nominal lane width can accommodate the offtracking or how much the lane should be widen through the curve to accommodate the offtracking characteristics of the trucks using the highway.

In contrast, for a short radius 90-degree turn such as a truck would make at an intersection, the turn is too short for fully-developed offtracking to occur. Nevertheless, the maximum extent of offtracking may be readily calculated for designing an intersection that can accommodate the trucks expected to make right turns at the intersection.

LOW-SPEED OFFTRACKING

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.

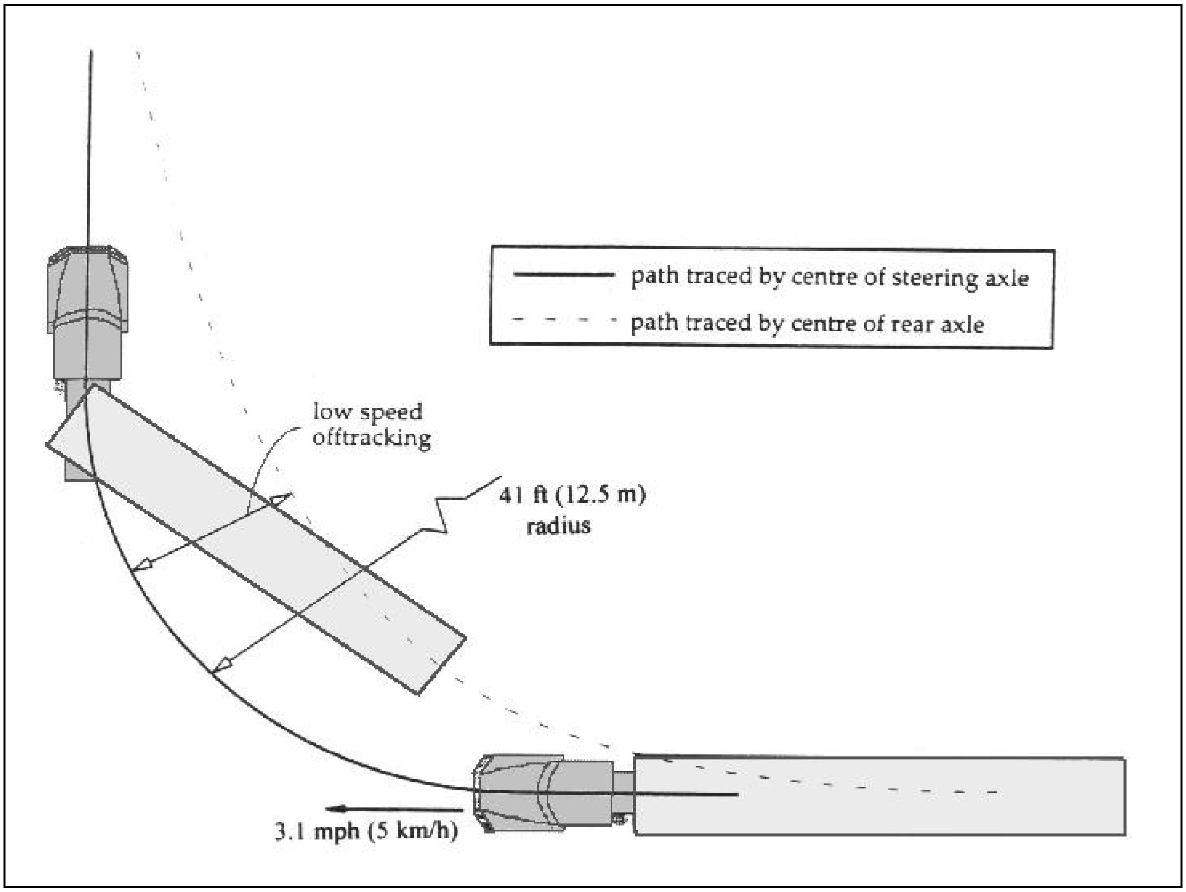
This performance attribute is affected primarily by the distance from the tractor kingpin to the center of the trailer rear axle, or the wheelbase of the semitrailer. In the case of multitrailer combinations, the effective wheelbase(s) of all the trailers in the combination, along with the tracking characteristics of the converter dollies, dictate this property. In general, longer wheelbases worsen low-speed offtracking. However, other factors including the use of tandem or tridem axles, the kingpin offset from the center of the supporting axle group, the cross slope of the roadway, the loads of the axles, and the truck suspension have small, generally negligible, effects on low-speed offtracking. Figure VI-7 illustrates low-speed offtracking in a 90-degree turn for a tractor-semitrailer combination.

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 OFFTRACKING

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-8 illustrates offtracking maneuver for a standard tractor-semitrailer.

Figure VI-7
Low-speed Offtracking



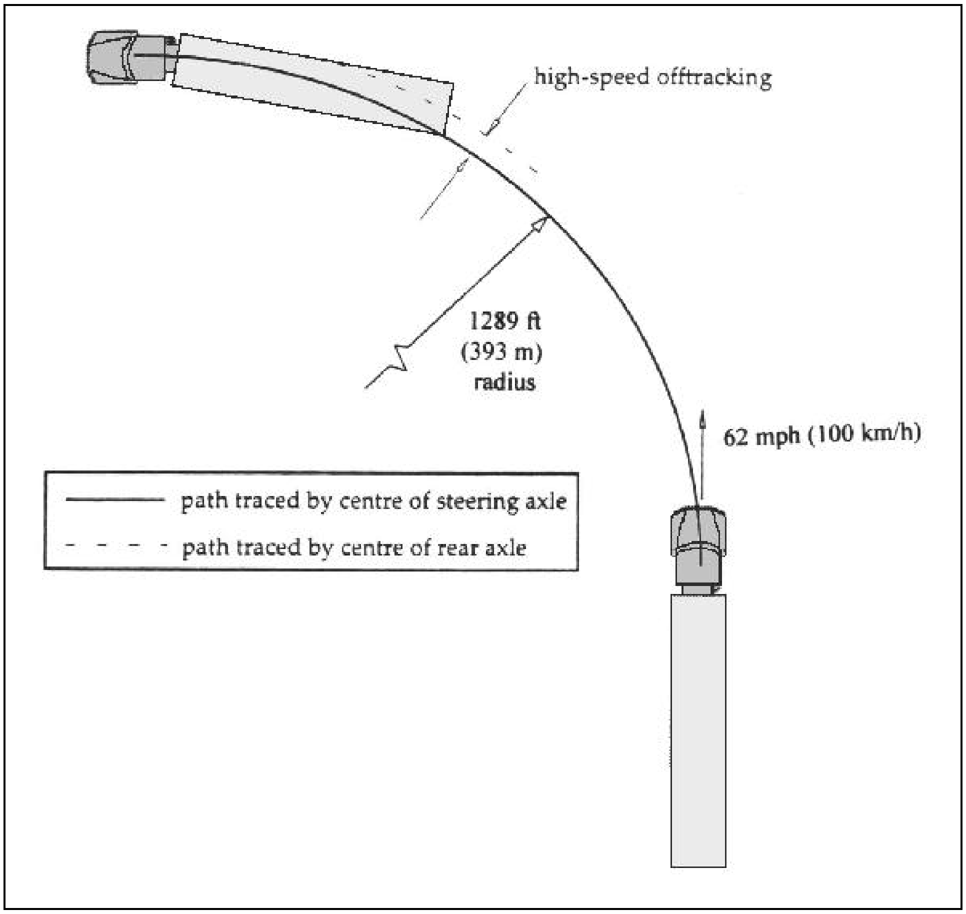
Source: Roaduser Research

OFFTRACKING ON MAINLINE HORIZONTAL CURVE 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 (1994), the minimum radius for a horizontal curve varies with the roadway design speed and the maximum superelevation rate. For horizontal curves with a

Figure VI-8
High-Speed Offtracking



Source: Roaduser Research

maximum superelevation rate of 0.06 feet/foot (the maximum superelevation 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
50	849
70	2,083

The 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. The 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.

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-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)**			
3-Axle Single Unit Truck	39.5	8.12	8.00	8.00
5-Axle Tractor Semitrailer	64.3	10.09	8.56	8.50
5-Axle Tractor Semitrailer	76.8	11.88	9.43	8.50
6-Axle Tractor Semitrailer	76.8	11.79	9.48	8.50
7-Axle Truck-Full Trailer	61.3	8.44	8.00	8.00
7-Axle Rocky Mtn Double	99.3	11.62	9.21	8.50
8-Axle B-Train Double	84.3	10.39	8.70	8.50
9-Axle Turnpike Double	124.3	14.29	10.54	8.50
7-Axle Triple	109.0	9.69	8.50	8.50

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; the turnpike double with 53-foot trailers would offtrack at low speeds into adjacent lanes or shoulders on 40-mile per hour design speed horizontal curves and on 30-mile per hour design speed ramps.

Table VI-12
Swept Path Width for Selected Trucks on Horizontal Curves At AASHTO Design Speed Criteria

		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)**			
3-Axle Single Unit Truck	39.5	8.80	8.26	8.00
5-Axle Tractor Semitrailer	64.3	11.54	9.95	8.80
5-Axle Tractor Semitrailer	76.8	13.65	11.12	9.30
6-Axle Tractor Semitrailer	76.8	13.22	10.85	9.14
7-Axle Truck-Full Trailer	61.3	8.98	8.34	8.00
7-Axle RMD	99.3	13.65	11.15	9.35
8-Axle B-Train Double	84.3	11.92	10.16	8.89
9-Axle Turnpike Double	124.3	16.69	12.83	10.05
7-Axle Triple	109.0	12.15	10.40	9.14

The analyses assume that the turn is made at the intersection of two 2-lane or two 4-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 4-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 2-lane road and 20 feet longer than the curb return radius on a 4-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 exhibits 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 4-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**
3-Axle Single Unit Truck	39.5	-9.97	-12.07	-13.37
5-Axle Tractor Semitrailer	64.3	-0.09	-4.47	-7.88
5-Axle Tractor Semitrailer	76.8	6.42	1.11	-3.49
6-Axle Tractor Semitrailer	76.8	5.34	0.16	-4.25
7-Axle Truck-Full Trailer	61.3	-8.10	-10.82	-12.54
7-Axle RMD	99.3	6.73	1.23	-3.48
8-Axle B-Train Double	84.3	1.58	-3.23	-7.02
9-Axle Turnpike Double	124.3	15.38	8.83	2.69
7-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 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 4-lane street to another 4-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 2-lane street to another without encroaching on either the curbline or an opposing lane, unless the curb return radius is very large (say, 100 feet), and then only by short trucks.

With a 30-foot curb return radius, 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 5-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, nearly all configurations examined can negotiate the turn without encroaching on the curb return. The exceptions that cannot successfully complete the turn are the tractors with 57.5-foot semitrailers, the longer RMD, and (especially) the turnpike doubles. At an even larger curb return radius of 100 feet, all but the turnpike double with 53-foot trailers can properly negotiate the turn.

TS&W REGULATION RELATED TO ROADWAY GEOMETRY

CURRENT REGULATIONS ON OFFTRACKING

Federal law does not address offtracking-related characteristics of trucks and combinations. In particular, it specifies no requirements for kingpin setting, kingpin setback, and rear overhang. In nearly 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 is 41 feet.

REGULATORY APPROACHES

Control of offtracking can be accomplished in either of two ways. The first requires specifying the length limit(s) of the combination units within the context of overall combination length, restrictions on the kingpin setback, wheelbase, and effective rear overhang, as in Canadian regulations. The second approach 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 European regulations. Such a regulation would require matching truck equipment with trailer equipment for operation based on knowledge of specific system characteristics, which would require extensive documentation and signage to implement and enforce.

CHAPTER 7

ENFORCEMENT OF TRUCK SIZE AND WEIGHT REGULATIONS

INTRODUCTION

Enforcement issues arising from changes to truck size and weight (TS&W) regulations can be identified more easily after reviewing the administration and enforcement of existing size and weight regulations. Consequently, this chapter provides: (1) a review of how the joint Federal/State program evolved, (2) a description of how the program is currently being administered, (3) a disclosure of enforcement activity, (4) a summary of information obtained from nine case studies of State practices, and (5) a discussion of ways to improve program administration and enforcement.

EVOLUTION OF FEDERAL/STATE PROGRAM

The Federal and State roles in the enforcement of TS&W provisions have evolved over time with Federal involvement being expanded by the Federal-Aid Highway Act of 1956 and more so after the STAA of 1978 and 1982. The 1956 Act formalized the Interstate highway program and established Federal vehicle weight and width limits for Interstate highways. The 1978 Act provided for stronger Federal oversight of State weight enforcement. The 1982 Act established Federal minimum length limits for truck combinations among other size and weight provisions.

PRE-STAA of 1982

Federal size and weight regulation has evolved in response to changing national responsibilities, interests, and needs, including interstate commerce. A national highway system consisting of a network of “interregional” highways was envisioned as early as the 1921 Highway Act, and subsequently led to the designation of the Interstate System in the 1956 Federal-Aid Highway Act. This Act provided funding to the States raised from “highway use” taxes placed in the newly created Highway Trust Fund. Even with the designation of the Interstate System, States still decided what roads were improved and what improvements were made. However, the provision of Federal-aid for highways carried with it a requirement that the States actively enforce both State and the newly imposed Federal weight and width limits.

Initially, each State sent a letter to FHWA stating that its laws were in compliance with Federal law, but starting in1974, this annual statement was required to be a certification by the State's governor or his or her representative. The FHWA evaluation of State enforcement and permit practices focused primarily on the use of an "apparent low level of activity" as the trigger for considering sanctions for some States in the late 1970s. Measures to determine this "low level of activity" were ratios of truck registrations to truck weighings, citations to weighings, and number of scales to miles of highways eligible for Federal-aid.

The STAA of 1978 intended to strengthen the State certifications by authorizing FHWA to impose stricter requirements. In response to the Act, FHWA required an annual State Enforcement Plan (SEP). The annual SEP has become the measure of performance against which the certification is evaluated and compliance determined. A State found to be in noncompliance could 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. As State highway agencies construct and maintain the infrastructure; and State law enforcement agencies enforce all laws, including those pertaining to TS&W; the level of enforcement is, to a great extent, dependent on cooperation between two or more State agencies. This includes a commitment of resources for facilities and equipment from the State highway agency and personnel from the State law enforcement agency(ies).

A 1979 U.S. GAO report on State enforcement of weight limits cited a need for improving the enforcement program administered by FHWA. The report criticized FHWA for failing to provide guidance and assistance to the States to improve TS&W enforcement programs. Other concerns included the States' expanded use of grandfather provisions 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.

POST-STAA of 1982

Prior to the STAA of 1982 the Federal interest in enforcement was primarily to ensure that maximum axle and GVW limits, including the FBF, applicable to Interstate highways were enforced. The 1982 Act required the designation of a NN for longer and wider (but not heavier) semitrailer and short double-trailer combinations.   Subsequently, the Federal preemption of State laws in ISTEA governing certain length limits and legal vehicle combinations expanded the Federal interest in size and weight regulation to include dimensions for LCVs. The States establish the size and weight limits for vehicles and loads on highways other than an Interstate (where weight, width, length, and configurations are largely governed by Federal law) or NN route (where size and configuration of vehicles are partly governed by Federal law). The NN has approximately 200,000 highway miles (44,000 miles of Interstate and approximately 155,000 of Non-Interstate).

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. Consequently, narrow, winding, mountainous routes with insufficient standards were included in the initial designation. FHWA subsequently revised the routes based on State review and submissions.

Further, State enforcement and administrative issues had not been addressed, creating confusion for both enforcement personnel and carriers. As access beyond the designated system was determined by the States, they developed procedures for a route review process. Enforcement of the restricted routes for the STAA vehicles required information such as maps or signs that showed which routes were restricted for which vehicle configurations. The enforcement of the limits on the nondesignated system was incorporated within State size and weight enforcement programs. FHWA regulations to standardize reasonable access for STAA vehicles became effective in 1990. Since then, virtually all access problems for these vehicles have been resolved.

The NN for large trucks provides a nationwide network for STAA combinations, however, because of problems associated with providing reasonable access for these larger combinations and because few of these trucks are actually loaded or unloaded at a site directly on an NN route, the actual miles open to these vehicles have increased substantially. As a result, the present NN may no longer be relevant. This raises the question whether any national system for larger or heavier trucks could be made to work successfully.

Further, assuming that all routes on the present NHS are suitable for larger and heavier trucks ignores the basic purposes for which the NHS was identified and the criteria used to identify its routes. Allowing such trucks on all NHS routes would probably have an adverse impact on some.

CURRENT ADMINISTRATION OF FEDERAL/STATE PROGRAM

The mission of FHWA's vehicle weight enforcement program is to administer its size and weight enforcement requirements and to monitor State compliance.[1] 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?" In this regard, FHWA noted in 1991 that, since the SEP requirement in 1979, State enforcement of truck weight limits had improved from a national perspective. FHWA cited the significant number of trucks that were weighed and

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[1] Stated in FHWA comments to the OIG's 1991 draft "Audit of the Vehicle Weight Program."

citations issued and the increasing use of technology, primarily weigh-in-motion (WIM) for screening trucks, as indicators of improvement although problems continued to exist.

The State role can be described as implementing Federal and State policy through enforcement of size and weight laws in a judicious manner for the purpose of preserving Federal and State infrastructure investments. The SEPs provide the baseline for evaluating the certifications, and provide FHWA with a means of evaluating trends and identifying potential issues associated with State enforcement. In addition, the FHWA annual review of certifications often leads to changes in State laws determined to be inconsistent with Federal law.

State administration was reviewed by looking at FY 1995 SEPs and State enforcement certifications submitted to FHWA. The information and data obtained from these documents pertained to enforcement strategy, State funding (budget) for the enforcement program, truck weighings and citations issued, and off loadings. Inconsistencies in State interpretations of 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 SEPs and certifications.

STATE ENFORCEMENT

The importance of enforcement in controlling vehicle weight has been underscored in past studies. 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. Further, it is difficult to obtain accurate information on the degree of noncompliance with weight limits. Quantifying the degree of noncompliance at the State and national levels continues to be difficult, as noted by Clayton and others in “Enforcement and Overweight Trucking.” This report discusses the difficulty of measuring the “real” picture of overweight trucking, but despite this, it emphasizes that without weight enforcement legal operators would be economically disadvantaged, road costs would be excessive, and there would be no incentive for operators to control loads.[2]

Nevertheless, actions are occurring at the State level to reduce incentives for overweight truck operation. 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. At the present time, fees and fines in the majority of States are too low to recover these costs.

While adequate fines and penalties are important elements in an effective program, judicial support is critical but beyond the direct control of State officials. Weight enforcement officers provide seminars or educational sessions for State legislators and judicial officers as part of their outreach. The problem of judicial support was evaluated in a 1985 FHWA report, which suggested alternative approaches to courts with administrative adjudication and expanded use of the Minnesota relevant evidence model.

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[2] Clayton, Nix, and Fepke in *Enforcement and Overweight Trucking*, presented at the Canadian Transportation Research Forum, June 1992.

FEDERAL INVOLVEMENT

Federal regulations detail the requirements for submission of annual SEPs and certifications of enforcement (Part 657 of Title 23 CFR). The certification must be by either the governor or his or her official designee. The requirements specify the data and supplemental information required, including a statement of enforcement of the ISTEA "LCV freeze."

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. As noted earlier, perhaps the most important and difficult question to be answered 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.

Failure to comply with the conditions or provide the information required may result in a withholding of Federal-aid highway funds. The FHWA uses 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 with the corresponding sanctions: (1) a State fails to submit the required certification--10 percent of highway funds, (2) FHWA determines there is 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 System--100 percent of Interstate funds. Since 1978, 23 States have received conditional approvals following the annual FHWA certification review. Table VII-1 details the reasons for the conditional approvals.

Table VII-1
FHWA Conditional Approvals of State Annual Size and Weight Certifications
1978 to 1994

Reason Cited for Conditional Rating	Frequency of Use	Number of States
Failure to Submit	0	0
Inadequate Enforcement	15	11
Conflict of Laws or Inconsistency with Federal Weight Limits	22	12

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 40 occasions where sanctions were threatened. Seven of these 40 cases resulted in letters being sent to the governor on the impending sanction. In all cases, conflicts were resolved and sanctions were not imposed. In two 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.

ENFORCEMENT ACTIVITY

State size and weight enforcement has increased in the last 10 years, even with the additional demands on the States for safety inspections under 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 in four states). 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 in some States, as well as weather factors and personnel constraints. 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.

During the same period, the total number of overweight citations issued (axle, gross, and bridge formula) 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-2 indicate, the percentage of trucks weighed that are cited for weight violations is very small and deviates little over time.

Table VII-2
State Weight Enforcement

Year	Weighed (including WIM)	Weighed (excluding WIM)	Weight citations	Violation rate	Offloaded	Load shift required
1985	105,234,000	97,330,000	664,033	0.007	106,618	371,104
1987	117,900,000	104,452,000	671,259	0.006	85,949	432,598
1989	146,950,000	124,687,000	692,673	0.006	79,309	438,584
1991	150,428,000	116,759,000	663,204	0.006	85,935	396,913
1993	162,615,000	111,889,000	653,492	0.006	76,611	451,643
1995	169,568,000	111,620,000	654,903	0.006	105,948	472,614

In addition to citations, the requirement for an overweight vehicle either to be offloaded or have the load shifted until the axle weights are within limits can be a strong incentive to comply. Off-loading and load-shifting requirements are effective immediately, and the inconvenience or added cost that the violator incurs may contribute to increased compliance. After decreasing from 1985 through 1991, off-loading and load shifting as enforcement tools appears 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, prosecutor guidelines, or officer discretion.

When the total number of trucks weighed is disaggregated by scale type, the distribution from 1985 through 1995, shown in Table VII-3, 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 did not use fixed scales as part of their enforcement strategy.

Table VII-3
Trucks Weighed by Scale Type

Year	Fixed	Semiportable	Portable	WIM	Total
1985	94,685,000	1,152,000	1,494,000	7,903,000	105,234,000
1987	101,801,000	1,444,000	1,206,000	13,449,000	117,900,000
1989	122,188,000	1,312,000	1,187,000	22,263,000	146,950,000
1991	114,271,000	1,233,000	1,255,000	33,669,000	150,428,000
1993	109,347,000	1,238,000	1,304,000	50,726,000	162,615,000
1995	109,275,000	1,107,000	1,237,000	57,948,000	169,568,000

A State’s choice of enforcement strategies depends 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 and disadvantages of each strategy, are noted in Table VII-4. 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 the use of technology such as WIM, automated vehicle identification (AVI), and cameras.

Table VII-4 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 bypass routes.

A relevant issue on TS&W enforcement is the number of truck axles–the more axles, the longer the time required to weigh the truck. For example, the average time required to weigh an 11-axle combination allowed in Michigan with portable scales is two hours.

A problem for weight enforcement at fixed facilities is "scale avoidance."[3] 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 49 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, needs to be a part of a comprehensive safety enforcement program.

Table VII-4
Selection Considerations for Weight Enforcement Strategies

Criteria	Fixed Facility	Mobile/Portable and WIM
Volumes of trucks weighed	700-800 per shift (2,500 per day)	3-5 per hour
Facility and technology used	Best for space and technology use	Adequate to limited
Cost to construct[1]	Ranges from $1.7 million to over $5 million[2]	Cost of land, equipment and signage ($300,000 or more)
Staffing requirements[1]	24 hours (2) days a week operation: minimum staffing of 17 persons	8 hours operation: minimum of 2 enforcement/inspectors[3]
Flexibility	Limited	Very flexible
Safety for officer, driver and vehicle	Excellent	Poor
Deterrence/visibility	High for 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

SAFETY AND WEIGHT ENFORCEMENT

The 1982 Motor Carrier Safety Act established MCSAP, a grant program to provide for State enforcement of Federal Motor Carrier Safety Regulations. Due to a significant increase in the number of commercial vehicles operating in interstate commerce, the resources available to FHWA were insufficient to meet the enforcement demands of carrier audits and field safety inspections. Prior to 1982, Federal motor carrier safety inspectors coordinated field inspections with State weight enforcement personnel, since the Federal inspectors had no legal authority to stop vehicles.

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[3] General Accounting Office, "Excessive Truck Weight: An Expensive Burden We Can No Longer Support," Washington, D.C., 1979.

In general, there are three commercial vehicle enforcement functions performed during roadside and scale house inspections. These are credentials verification, vehicle size and weight enforcement, and driver and vehicle safety inspections. Weight enforcement and MCSAP inspections are not mutually exclusive. Therefore, it is essential for determining the current level of enforcement that data from both motor carrier programs be included.

Currently, the States provide the bulk of the funding for weight enforcement, but since ISTEA, Federal funding is available for weighing vehicles 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. In Fiscal Year 1995, the Federal and State MCSAP and State TS&W enforcement expenditures totaled $342 million; 82 percent of this total came from State funds, as Table VII-5 shows. Table VII-6 shows the increase in MCSAP inspections relative to the increase in truck weighings.

As in the weight enforcement program, States determined by FHWA to have laws or regulations inconsistent or incompatible with Federal laws and regulations are subject to sanctions, in this

Table VII-5
Funding of State Motor Carrier Enforcement
Fiscal Year 1995

	Expenditures	**Personnel**
MCSAP Basic Grant	$61,267,000	1,069
Federal (80 percent)	$49,028,000	
State (20 percent)*	$12,239,000	
Weight Enforcement	$280,706,000	6,061
State (100 percent)		
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 handling 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.

Table VII-6
Comparison of State Motor Carrier Enforcement Activity

	1985	1995
Trucks weighed (excluding WIM)	97,330,000	111,620,000
Trucks inspected (MCSAP)	372,000	1,799,000
TOTAL	97,702,000	113,419,000

case the withholding of up to 50 percent of their basic grant. Also, as in the weight enforcement program, the majority of States facing MCSAP sanctions implement the necessary changes and avoid loss of funding. Exceptions occurred in FY 1995 when sanctions were imposed on Maine and Pennsylvania and 50 percent of their basic grants was withheld.

CASE STUDIES

Interviews with size and weight enforcement officials were conducted in nine States to supplement available information on their operations. The criteria used to select the States included those allowing LCVs, not allowing LCVs, having marine ports, having high truck traffic corridors, using ITS-CVO in their program, being ranked in top 10 States for number of trucks weighed or weight citations issued, using fixed facilities, or having no fixed facilities for weighing. Table VII-7 provides descriptive information on the weight enforcement programs for each of the nine States. Key points from the case studies follow:

Weighing Facilities and Equipment

Problems of inoperable or obsolete equipment, repair or maintenance work not completed expeditiously, and inconsistencies between States and regions are common issues cited by FHWA in its annual review of the State certifications and confirmed in some of the case study States. For example, States subject to harsh winter weather conditions and with 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 weighing trucks safely.

Table VII-7
Overview of Case Study States

State	Enforcement Agency	Type of Scales Used	Grandfather Rights	LCVs Allowed	Relevant Evidence
Arizona	Dept. of Public Safety	Portable	No	Yes	Yes/1
California	Highway Patrol	Fixed, Portable	No	No	No
Georgia	DOT	Fixed, Portable	Yes	No	No/2
Maryland	State Police Transportation Authority	Fixed, Portable	Yes	No	No
Massachusetts	State Police	Portable, Mobile Units	Yes	Yes	No
Minnesota	State Patrol	Fixed POE, Portable	Yes	No	Yes
New Hampshire	Dept. of Safety	Portable	Yes	No	No
Oregon	DOT	Fixed POE, Portable	Yes	Yes	No
Pennsylvania	State Police, DOT	Fixed, Portable	Yes	No	No

1 Arizona enforcement may use weight slips as basis for tickets on GVW violations without weighing trucks on scales

2 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.

Also roadside inspection facilities are often insufficient to provide a safe environment for the officer and for the vehicle being weighed such that they limit the number of vehicles that can be safely stopped for weighing. The Minnesota State Patrol has written guidelines on selecting appropriate inspection areas for weight enforcement. Enforcement agencies in other States may consider implementing such guidelines, as in 1996 an Indiana State inspector and the driver of the truck being inspected were killed. This led to calls by some enforcement and industry representatives at the 1996 Commercial Vehicle Safety Alliance annual meeting to end roadside inspections

Grandfather Rights and Nonuniformity Between States

Nonuniformity in weight limits and permits resulting from grandfather rights in one or more States in a contiguous group is an issue raised by officials in many of the case study States. The impact of different limits or exceptions in neighboring States often results in permits or other exception in adjoining States without grandfather rights. The nonuniformity created by frequent changes in limits and exceptions suggests that a uniform standard, whether Federal or regional, may be desirable. Uniformity could level the playing field between States and the industries in those States. For instance, weight permits for hauling milk in New York and steel coils in Ohio were cited by Pennsylvania officials as one reason legislation was passed for new overweight blanket permits for hauling 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. This sequence is an example of the process of “ratcheting” weight limits upward, although only for specific commodities in these cases, over time because of competitive pressure from neighboring States.

Complex Regulations

State field enforcement personnel and officials interviewed during the case study process generally believed that complex regulations should be avoided, which confirms the TRB study findings presented in Special Report 225. 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 with them. Often, the education of industry occurs only when a ticket is written, and the State enforcement officer must explain the law to the driver. Consequently, regulations that require specialized equipment or facilities and technical expertise would be difficult to enforce.

IMPROVING ENFORCEMENT

Recent efforts that may improve State size and weight enforcement operations include pilot projects supporting relevant evidence legislation in four States, advances in ITS-CVO development and deployment, and revisions to the SEP and certification process published under an Advanced Notice of Proposed Rulemaking (ANPRM–Docket Number FHWA 93-28).

RELEVANT EVIDENCE

A 1985 FHWA report identified various administrative adjudication options that could be used to improve the effectiveness of State enforcement programs. One option was "relevant evidence," used in Minnesota since 1980. Minnesota allows bills of lading, weight tickets, and other documents that indicate the weight of a truck to be used as evidence in a civil proceeding to establish overweight violations. Enforcement is through an audit, generally of shipper or freight forwarder files; and civil action can be taken against the driver, the shipper, the owner, or the lessee for all or part of the fine, depending on the degree of responsibility for causing the overweight movement. The audit also provides a means to enforce multitrip permit use, determine how frequently they are used, and recover damage costs. Enforcement personnel interviewed 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 three-year pilot project to assist Iowa, Louisiana, Mississippi, and Montana in adopting relevant evidence laws. However, none of the States succeeded in passing legislation. Indications are that industry opposition contributed to defeat of the proposed bills. Several States have expressed a renewed interest in relevant evidence laws, which may be a viable option for the future.

Using a different approach, Georgia DOT adjudicates all weight citations through an administrative process rather than through a court system. In theory, this 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 the initiation of a collection process by the DOT investigative unit. This may include impoundment of the vehicle, suspension of its registration, or placement of a lien on the vehicle.

ITS–CVO DEPLOYMENT

CVISN DEVELOPMENT AND USE

The ITS elements that support CVO are collectively referred to as CVISN. CVISN includes activities 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 the operation of motor carrier programs to benefit government, carriers, and other stakeholders. Until recently, the use of technology for CVO had been more prevalent in the West and Northwest. In its oversight role of State weight enforcement programs, Federal involvement in CVO technology deployment has been most prominent in its advocacy of WIM and AVI systems.

Although CVISN technology holds some long-term promise in the identification of overweight vehicles, it also holds promise for permitting of vehicles and loads and 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 of doing so.   Minnesota's computerized permit system was one of the first implemented and has served as a model for other States. It has reduced the time involved for carriers and the State agency for issuing a “routine” permit to approximately 30 seconds.

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 may present themselves.

Weigh-In-Motion

The use of WIM for screening at fixed facilities provides enforcement with a tool to improve the efficiency and effectiveness of operations. Although WIM is excellent for screening purposes, it is not without its problems[4]. The 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 by Florida DOT to assess the feasibility of using WIM for weight enforcement exemplifies the benefits to be gained. The findings strongly support WIM use for identifying areas in need of enforcement targeting. They also support the conclusions of previous studies that lack of any enforcement results in high noncompliance and that high enforcement results in complete, or near complete, compliance for those trucks weighed. Periodic replication of this study approach in other States could provide useful information for evaluating the extent of the overweight problem nationwide.   One study recommendation was to require the States to report on weigh station bypass enforcement in the annual certifications. One limiting factor of the study is that the vehicles weighed were exclusively five-axle tractor trailers.

One possible use of WIM for enforcement would combine WIM with photo imaging for assessing civil penalties for violations. Another, 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 for weighing by portable scales.

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[4] “Weigh-In-Motion Technology Improves Highway Truck Weight Regulation” by Laurita, Sellner, and DuPlessis discusses WIM benefits and problems, citing New Jersey and Delaware's incorporation into planning of weigh stations and uses in by-pass route monitoring.

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 violations of stop signs and red lights based on a photograph or video reading of the vehicle plate. A combination of WIM and a camera license plate reader to match an overweight truck with the owner is being evaluated in Minnesota for the impact of weather and speed on the photo image. This combination of technologies could provide a means to enforce weight limits on overweight vehicles bypassing scales if problems associated with climate can be resolved.

AVI and Automatic Vehicle Classification (AVC) Systems

The AVI and AVC systems have been in use for many years, primarily by the private sector for 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 during the 1980s along the I-5 corridor from British Columbia through Washington, Oregon, and California to Arizona. The project evaluation team concluded that there were benefits to be derived if technical problems and barriers could be overcome and that the CVO services most ready for deployment are the automated roadside dimension and weight screening technologies.

More recent examples of the use of AVI and AVC technology for size and weight and other enforcement purposes are the Advantage I-75 project implemented in 1995 and the designation in 1996 of Maryland and Virginia as prototype States for technology deployment along the I-95 Corridor.

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. Customs brokers on the Canadian border use bar codes 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.

Geographic Information Systems

Geographic information systems (GIS) currently used by State transportation planners has potential use in strategic weight enforcement planning. State DOT GIS databases could include information on known “generators of truck traffic” such as asphalt plants, quarries, and landfills and access to the information could be provided for enforcement planning. Although individual enforcement officers may be familiar with the location of facilities in their patrol areas, a compilation of Statewide facilities is unlikely.

COSTS OF DEPLOYMENT AND MAINTENANCE

The use of ITS-CVO beyond Federal “prototype” and “pilot” State testing and evaluation is contingent on overcoming legal, institutional, and financial barriers and gaining industry acceptance. The cost of deployment and the required system maintenance are two issues that remain to be resolved. For example, the cost to implement and maintain the system proposed in Oregon’s 1993 ITS-CVO Strategic Plan is $23.3 million (1993 dollars) over a six-year period.[5] The technology included WIM and AVI (7 Interstate sites, 14 sites on the State primary system, and other sites on or off the State highway system) and dynamic warning systems. Federal funding for implementing 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 further 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 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.

POTENTIAL PROGRAM CHANGES

The current relationship between the Federal and State administrators of the TS&W enforcement program is best characterized as federally guided and State-administered.[6] However, the effectiveness of the relationship was reviewed in a 1991 audit by the DOT OIG, which found that improvements were needed in the vehicle weight enforcement and that FHWA should strengthen its administration of the program. The OIG review recommendations are shown by category in Table VII-8. The FHWA responded to the review by clarifying several legal and operational misunderstandings and started implementing other suggested improvements. The OIG also recommended that FHWA request congressional action to prohibit use of divisible load permits and multitrip nondivisible load permits on the Interstate system.

In further response, FHWA issued an ANPRM in December 1993 on State certification of size and weight enforcement. Comments were requested on nine problem areas identified by the OIG and FHWA in SEP and certification procedures. These were: (1) the magnitude and locations of the national overweight problem, (2) weight tolerances at scales are common despite Federal law, (3) preparation of SEPs and certifications is time consuming, (4) not all States are taking advantage of improved data collection to enhance program management and effectiveness,
(5) the amount of pavement deterioration attributable to vehicles with special permits is unknown,
(6) permit fees and overweight penalties do not always reflect true costs,
(7) enforcement plans lack specific, measurable goals, (8) there is inadequate vehicle size and

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[5] $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.

[6] Federal guidelines for annual certification and SEPs are specified in Part 657 of Title 23, CFR.

weight enforcement in some urban areas, and (9) sanction procedures do not clearly identify State settlement options.

Table VII-8
OIG Recommendations on Federal/ State
Weight Enforcement Program

1. Quantification of Nature and Extent of Overweight Vehicles	2. Plans and Strategies to Combat Overweight Vehicles	3. Application and Evaluation of Enforcement Techniques
Expand WIM use to collect data for use in quantifying the magnitude of the problem. Increase WIM use for planning enforcement details to be more effective. Improve WIM calibration. Purchase new equipment. Direct FHWA Divisions to work with the States to evaluate existing fine structures.	Develop comprehensive criteria to evaluate the adequacy and effectiveness of State programs needs to be developed by FHWA. Revise SEPs to contain information needed to measure effectiveness. Analyze SEPs more critically. Promote use of nontraditional enforcement technique.	Consider infrastructure damage factor in permit fee. Direct FHWA Divisions to promote, monitor, and evaluate WIM use more actively. Enforce prohibition of administrative weight tolerances. Use more off-loading. Use "relevant evidence" laws.

Comments to the docket were received from 21 State DOTs, and 9 State enforcement agencies. Twenty other interested parties also submitted comments. Generally, the States said by category:

1. Quantification of Nature and Extent of Overweight Vehicles

- The magnitude of the overweight truck problem could possibly be measured using WIM technology, but only with an infusion of significant Federal funding to the States.
- Use of ITS will be limited until its reliability and durability have been proven.

2. Plans and Strategies to Combat Overweight Vehicles

- The process for preparation and submittal of the SEPs and certifications is time consuming (one estimate is 4,160 hours) and could be improved.
- There is no one model for enforcement that fits all States.
- SEPs and certifications should take into account regional enforcement performance.
- The use of sanctions should be replaced with incentives such as a grant program for the States.

3. Application and Evaluation of Enforcement Techniques

- Enforcement discretion on tolerances should be accepted as a given with less emphasis by FHWA. If tolerances should be adopted by FHWA, they should not be percentage based.
- Permit fees do not recover damage costs
- Relevant evidence should not be mandated unless Federal funds are provided for implementation.

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 FHWA is also time consuming and complex. The increasing demand for more detailed information from the States is not only the result of a need to measure program effectiveness for FHWA and Congress but also of a need to be able to provide comparative data on potential conflicts and inconsistencies in policies. FHWA suspended the rulemaking pending the completion of this Study.