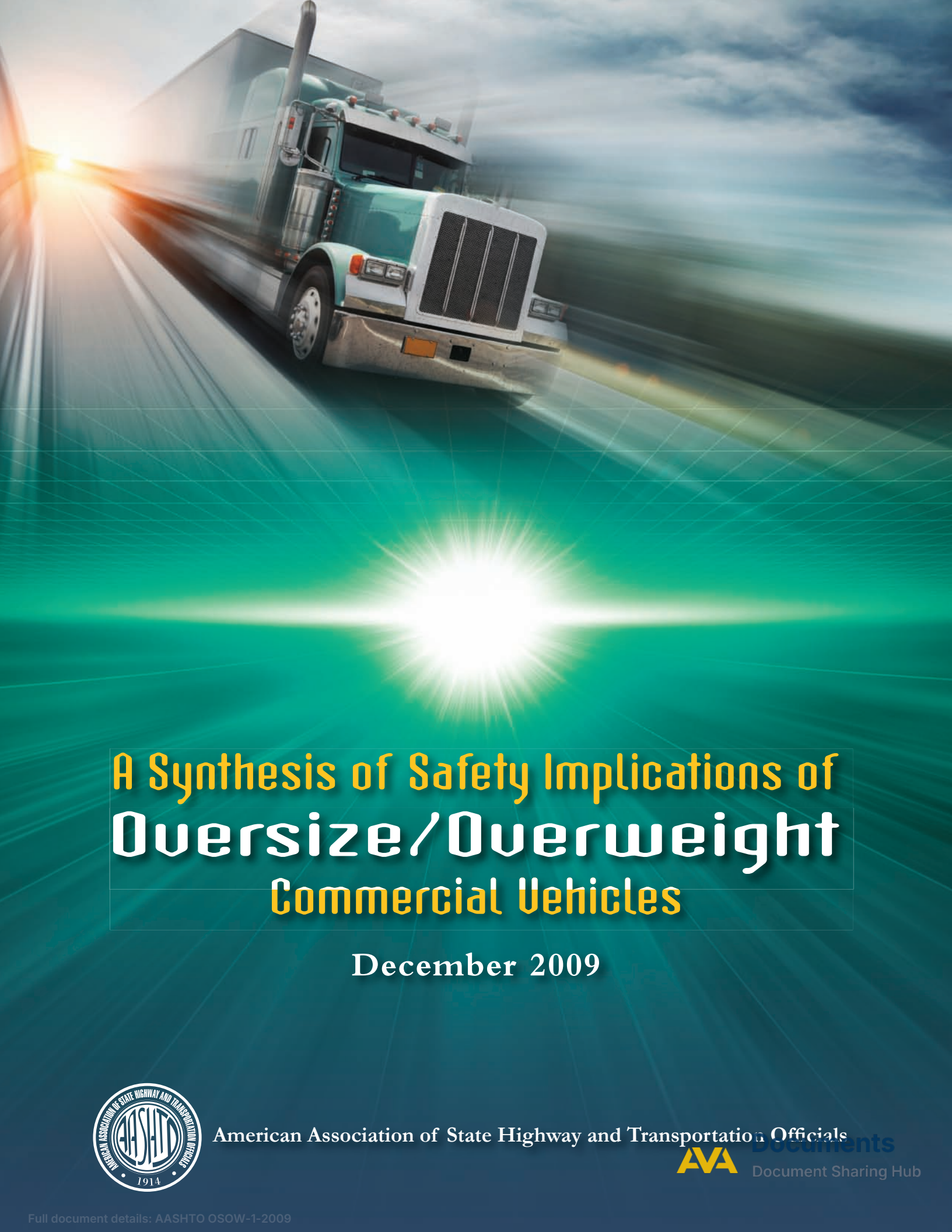




A Synthesis of Safety Implications of Oversize/Overweight Commercial Vehicles

December 2009

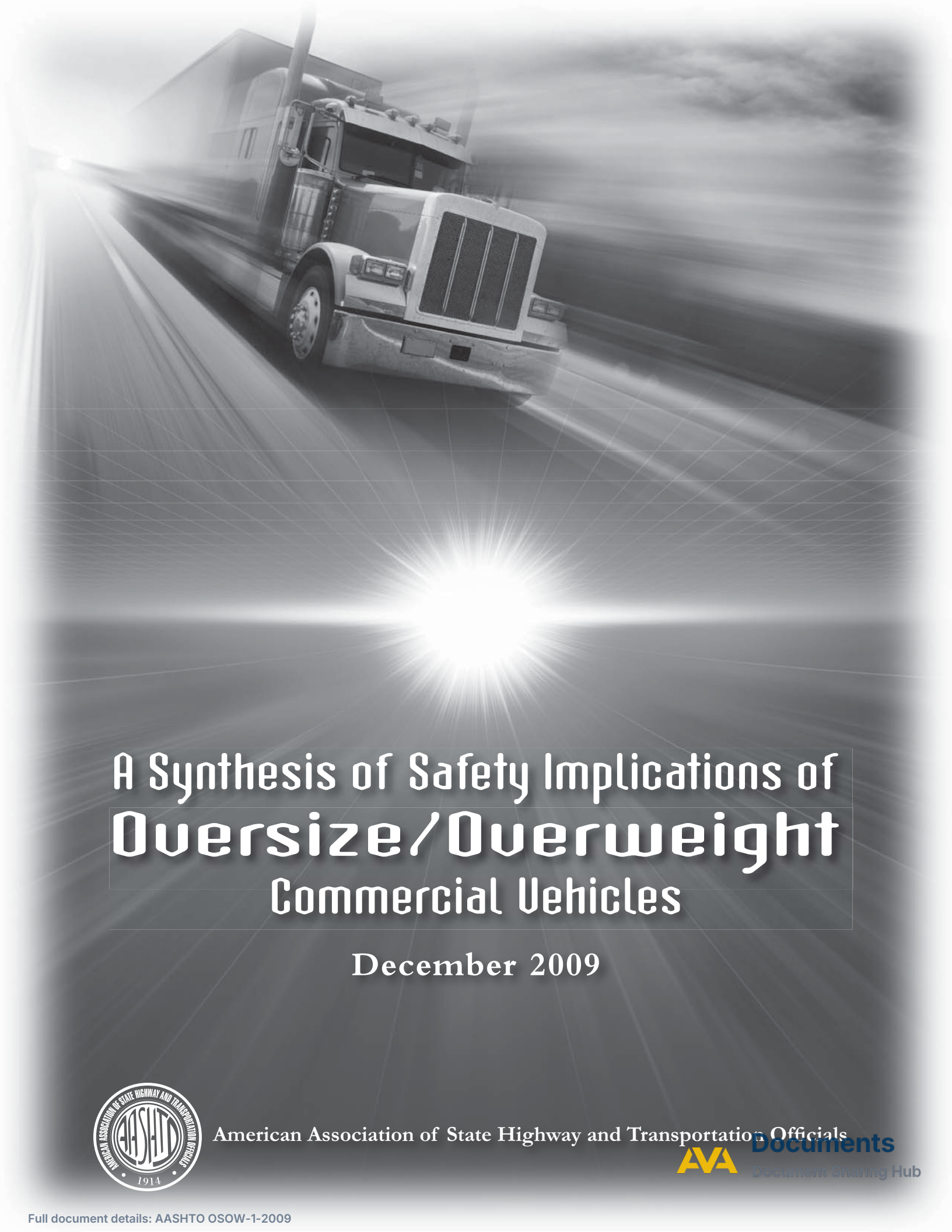


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Acknowledgements

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The students and staff of the University Transportation Center for Alabama provided wonderful support to the authors during the preparation of the synthesis by assisting with the literature review, analyzing data, preparing tables and figures, and otherwise supporting the authors.

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Preface

This synthesis report was prepared as a follow-up to the *Commercial Motor Vehicle Size and Weight Enforcement in Europe* international scan which was conducted from June 17, 2006 through July 2, 2006. It is timely given the pressures of the increasing need to move loads that exceed the established vehicle size and weight limits. While studies have addressed the impact these larger than normal loads have on pavement and bridges, much less information is available on their safety implications. As a supplement to the scan, this report describes what is known and what more needs to be known about the safety implications of overdimensional and overweight loads.

The American Association of State Highway and Transportation Officials (AASHTO) is grateful to the Federal Highway Administration International Technology Scanning Program and the National Cooperative Highway Research Program for their co-operation and partnership in the International Scanning Program.

AASHTO also very much appreciates the willingness of the Alabama Department of Transportation to sponsor this report through the University Transportation Center for Alabama. AASHTO thankfully acknowledges the hard work of Dr. Daniel S. Turner and Ms. Leslie Anne Nicholson and their support staff at the University of Alabama in Tuscaloosa in preparing this report.

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Table of Contents

List of Tables	x
List of Figures	xi
Executive Summary.....	1
Section 1. Introduction	5
Objective.....	5
Background	5
The Project.....	6
Content of This Report	6
Section 2. The Concern—Heavy Commercial Truck Growth.....	7
Reason for Concern.....	7
Explosion in Growth of Large Commercial Vehicles	7
Summary of Commercial Vehicle Growth.....	10
Case Study—Minnesota Investigation of Larger Commercial Vehicles	10
Summary of Case Study	12
Section Summary	12
Section 3. Heavy Vehicle Types, Weights, and Sizes	13
Types of Vehicles	13
Size and Weight Regulations.....	14
Legal OS/OW Trucks	17
Section Summary	18
Section 4. Truck Characteristics Affecting Crashes	19
Introduction	19
Truck Weights and Loads	19
Truck Types and Sizes	21
Truck Brake Systems	21
Antilock Brakes	22
Speed	22
Vehicle Roadway Interaction.....	23
Drivers	24
Prominent Crash Types	24
Section Summary	27

TABLE OF CONTENTS

Section 5. Heavy Truck Crashes in General	29
Early Large Truck Safety Research	29
More Recent Large Truck Safety Research	30
Enforcement	33
Roadside Inspections	35
Weigh Stations	35
Overview of Fatal Large Truck Crashes	37
Trend in Fatalities	37
Distribution of Fatalities	37
Crash Most Harmful Event	38
Speed	39
Prevalent Characteristics	39
Driver Factors in Fatal Crashes	39
Truck Configurations	40
Weight and Size of Trucks in Fatal Crashes	41
Section Summary	42
Section 6. Data Associated with OS/OW Heavy Vehicles	45
Two Meanings for OS/OW Vehicles	45
Comprehensive Data Is Necessary	46
Data Sets with Promise	47
WIM	47
LTCCS	48
TIFA	48
Individual Research Studies	49
Data for Which OS/OW was Established or Probable	49
Summary of Data for Which OS/OW Was Established or Probable	53
Data for LCVs and Other Large, Heavy Commercial Vehicles	53
<i>TRB Special Report 225: Truck Weight Limits: Issues and Options</i>	53
LCVs on the Alberta, Canada Sub-Network, 1995–1998	54
Subsequent LCV Study in Alberta, 1999–2005	56
Ontario B-Train Safety Study	59
Proposed New Vehicles in Minnesota	61
Section Summary	62
Section 7. Illustrative Case Studies	65
Case Study: States with Special Overweight Exemptions	65
Kentucky	65
Special Highway Designation	65
Truck Crash Study	66
Overweight Trucks	66

Truck Violations.....	67
Truck Braking Field Test.....	68
Other Kentucky Findings.....	70
West Virginia.....	70
Special System Designation.....	70
Decrease in Citations and Crashes.....	71
Section Summary.....	71
Section 8. Summary, Findings, and Recommendations.....	73
Summary by Topic.....	73
Growth of Commercial Vehicles.....	73
Truck Size and Weight Laws (TSWs).....	73
Heavy Truck Crashes in General.....	73
OS/OW Compared with Normal Heavy Vehicles.....	74
Minnesota, Kentucky, and West Virginia Case Studies.....	75
Project Findings.....	77
Primary Findings Regarding OS/OW Commercial Vehicles and Safety.....	77
More Specific Findings.....	78
Additional, More-Specific Data Needed.....	78
Effect of Weight on Crash Cause and Severity.....	79
Speed.....	80
Size–Speed–Weight.....	80
Enforcement.....	80
Enhanced Research Needed.....	81
Build an Ideal Data Set.....	81
Recommendations.....	82
Bibliography.....	85
Glossary of Terms Related to Heavy Trucks.....	95
Acronyms.....	99

List of Tables

2-1	U.S. Freight Shipments by Mode	8
2-2	Large Truck Registrations, Mileage, Crashes, and Crash Rate	9
3-1	Approximate Lengths/Weights of Prominent Types of LCVs.....	14
5-1	Roadside Safety Inspection Activity Summary by Inspection Type.....	36
5-2	2005 Large Truck Crashes, Most Harmful Event and Crash Severity	38
5-3	2005 Fatal Involvements by Truck Configuration	40
5-4	2005 Fatal Involvement by Truck Length and Weight.....	41
6-1	Fatal Truck Involvements That Might Be Oversize or Overweight	50
6-2	Common LCV Fatal Involvements	51
6-3	Fatal Truck Involvement and Fatalities, Selected Combination Types.....	51
6-4	Fatal Truck Involvement by GVW and LCV Type	52
6-5	Collision Rates by Vehicle Type for Alberta Sub-Network, 1995–1998	55
6-6	Fatal, Injury, and PDO Rates by Vehicle Type for Alberta Sub-Network, 1995–1998	56
6-7	Collision Rates by Vehicle Type for the Alberta LCV Network, 1999–2004.....	57
6-8	Fatal, Injury, and PDO Rates by Vehicle Type for Alberta LCV Network, 1999–2005.....	58
6-9	Eleven-Year Composite Crash Rates by Crash Severity, Vehicles in Collisions on the Sub- and LCV Networks, 1995–2005	59
6-10	Ontario Analysis of Collision Rates by Truck Classification	60
6-11	Effect of Truck Configuration and Vehicle Miles of Travel on Fatal Involvement Rates	61
7-1	Allowable Weights on Kentucky Coal Haul Roads	66
7-2	Kentucky Truck Inspection for 1997 and 1998	68
7-3	KTC Truck-Braking Field Test	69

List of Figures

2-1	Truck and Infrastructure Growth Trends	10
3-1	Examples of FHWA Truck Classifications	14
3-2	Illustration of the Effects of Axle Weights and Spacings	17
4-1	Three Types of Locked-Wheel Crashes	26
4-2	Truck Rollover Factors	26
5-1	Fatalities in Crashes Involving Large Trucks, 1975–2005.	37
6-1	Fatal Crash Rates from <i>TRB Special Report 225</i> , Adjusted to Minnesota Truck-Crash Rates	62
7-1	Six-Axle Trucks Weighing Over 80,000 Lbs.	67

Executive Summary

This synthesis was prepared to support an International Technology Scanning Tour conducted by the U.S. Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP). This implementation project was associated with a scanning tour of several European countries to investigate commercial motor vehicle size and weight enforcement programs (Honefanger, et al., 2007).

The objective of this project is to identify known relationships between commercial vehicle safety and crash causation factors and to prepare a synthesis of safety implications of oversize/overweight (OS/OW) commercial vehicles. This information can be used to support commercial vehicle enforcement and permitting practices. Another purpose for this information is to justify expenditures and investments on size and weight enforcement to enhance safety.

University Transportation Center for Alabama (UTCA) researchers examined over 100 research reports and journal articles to prepare this synthesis. More than 50 interviews were conducted with domestic and international agency, industry, and enforcement officials.

Insight was gained into the impacts of truck size and weight (TSW) regulations through three case studies. This included the Kentucky Coal Haul Road System and a similar system in West Virginia where legislative exemptions allowed semi-trailer trucks to haul up to 120,000 lbs of coal to keep the states' economies competitive. The third case study involved Minnesota, where agriculture and industries were at an economic disadvantage due to larger TSW limits in adjacent states and Canada. The Minnesota DOT conducted a thorough study of increasing TSWs and found that four new truck configurations would be cost beneficial.

The state of practice in estimating large truck crash rates is complicated because of the many configurations and the wide range of possible weights for any particular configuration. It appears that for single-unit trucks, tractor semi-trailers, and doubles, the findings of *TRB Special Report 225* (1990) can be used in the absence of agency specific rates. For longer combination vehicles (Rocky Mountain doubles, Turnpike doubles, A-, B-, and C-train doubles, triples, and unique international heavy vehicles with multiple axles), three Canadian studies between 1995 and 2004 appear to have developed acceptable estimates of crash rates and crash severity rates (Woodrooffe, 2001; Corredor, et al., 2005; Montufar and Associates, 2007).

During this project, UTCA researchers identified four primary findings regarding the contributions of OS/OW to commercial vehicle crashes:

- In general, crash rates decrease but crash severity increases as commercial vehicles become larger and heavier. This synthesis project did not identify scientific measures of reliability for this trend. The lack of a confirmed relationship suggests *neither* a positive (larger, heavier vehicles are safe) nor a negative (larger, heavier vehicles are unsafe) relationship between CMV size and weight and safety. It suggests *only* that additional research is needed to understand the complex relationships.
- No existing truck crash data set was found to have sufficient information for a scientific analysis of the contributions of size and weight (especially OS/OW) to crash causation or severity. The complex, confounding relationships between the contributing factors and the small sample sizes for different configurations of the largest commercial vehicles are two examples of why existing data is not sufficient.
- Studies in Canada have indicated that the longest combination vehicles, (LCVs), have lower crash rates (all severities) than other trucks and all vehicles as a group. Additional research is required to isolate and identify the reasons for this, but it could be because operation of these vehicles is restricted to higher level roadways, involved shipping firms assign better drivers, or similar reasons.
- Another study in Canada found that large truck performance measures (static roll stability, off tracking, etc.) are highly correlated to large truck crash rates. Controlling truck safety through performance thresholds might offer a better way to enhance U.S. large truck safety than some current programs.

Based upon these findings and many more-detailed findings within the synthesis, UTCA researchers made several recommendations to increase the collection of pertinent data and to otherwise enhance the opportunity to understand the relationship of large commercial vehicle size and weight to crash causation and severity. These recommendations are intended to address the need for additional data and for enhanced awareness of the complexity of heavy truck crashes:

- Make data available, if possible online, from weigh stations, weigh-in-motion (WIM), and virtual WIMs, especially when weight and dimensional data can be attributed to specific vehicles that are later involved in traffic crashes. This data can add significant scientific merit to truck safety studies. The weight data can also be used for state and federal planning and enforcement activities.
- Expand the number of WIM and virtual WIM stations to provide more data at relatively small incremental costs compared with alternative labor intensive methods to collect the same data.
- Expand the “Truck Involvement in Fatal Accidents” and “Large Truck Crash Causation” databases. They are prepared by supplementing crash data with specific information about the configuration of each involved truck, driver information, citation information, load information, and much more. It seems realistic to use weight databases to expand these files for individual truck crashes.
- Conduct a regional study of OS/OW vehicles. Since triples are restricted to the northwest, that might be a good location for such a study. One desirable outcome of such a study is to distinguish between legal and illegal OS/OW vehicles in crashes.

- Inventory states with categorical exclusions to TSWs that allow very heavy commercial vehicles, to see if any of them have comprehensive records of crashes of OS/OW vehicles. If a significant number of states contribute data, it might provide a suitable national database.
- Examine load and weight distribution of commercial vehicles involved in collisions to find the relationship between weight and factors like braking capacity and handling characteristics. That could provide a breakthrough in CV safety knowledge.
- Conduct an intensive project to gather significant, high-quality data to analyze OS/OW commercial vehicle crashes, including follow-up crash-site investigations to collect truck-specific data using a crack team of experts. This can be patterned after the Fatality Analysis Reporting System (FARS), a data collection system.
- Where needed, provide specialized training to troopers, police officers, and other personnel to help them determine the cause or contributing causes of heavy-truck crashes. This can affect the type and amount of data that they collect.
- Encourage FHWA and FMSCA to continue to work together to develop and administer policies and programs that address the big picture of roadway safety, of which heavy truck safety an important element. This would include sharing of agency specific data and research programs to optimize the results.

SECTION 1

Introduction



Objective

The specific objective of this research project was to prepare a synthesis of safety implications of over-size/overweight (OS/OW) commercial vehicles. The purpose was to identify and document known relationships between commercial vehicle safety and causal factors like vehicle type, weight, length, speed, load, driver, etc. This information can be used to modify commercial vehicle enforcement and permitting practices, and it can justify investments and expenditures on size and weight enforcement in the interests of safety. A secondary purpose of this project was to identify research needed to guide future safety and enforcement enhancements.

Background

This project was conducted as part of implementation efforts associated with an International Technology Scanning Tour conducted by the U.S. Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP). Scanning tours seek innovative solutions for U.S. transportation challenges. This implementation project was associated with a scanning tour of several European countries to investigate commercial motor vehicle size and weight enforcement programs (VSW Scan Tour).

When granting permits to OS/OW vehicles, U.S. officials make their decisions based primarily on minimizing infrastructure damage (bridges and pavements). However, European officials include safety when making similar permit decisions. Members of the VSW Scan Tour were impressed with the European approach and made safety a priority research recommendation upon returning to the United States (Honefanger, et al. 2007).

One of the pivotal observations by the scan team occurred in Belgium, where officials had observed a safety relationship involving excessive weight and excessive speed of OS/OW vehicles. As a result, regional administrative regulations had been directed toward commercial vehicles to diminish crashes.

The scanning team felt that this topic could be explored in the United States so appropriate consideration could be given to safety when issuing permits.

At the conclusion of the VSW Scan Tour, members had identified a large number of effective European practices for enforcing vehicle size and weight criteria. Many of the practices were marked as appropriate for use in the United States. After review, seven of these practices were classified as high-priority projects for implementation research. One of the seven was to develop a safety synthesis of overweight/oversize commercial vehicles, which became the genesis of this project.

The Project

The University Transportation Center for Alabama (UTCA) learned about the need for conducting a project to compile the safety synthesis through one of the members of the VSW Scan Tour. Since one of UTCA's theme topics is safety, the project was well within the Center's capabilities. The UTCA Executive Committee committed to the project, called for proposals, and awarded the project in 2007.

The research involved a traditional review of over 100 domestic and international reports and journal articles to define the state of knowledge, to identify voids in the knowledge, to draw conclusions about safety, and to identify needed research. More than 50 interviews were conducted with domestic and international agency, industry, and enforcement officials. Contacts and interviews were conducted with scan team members and managers of FHWA, the National Highway Traffic Safety Administration (NHTSA), the Federal Motor Carrier Safety Administration (FMCSA), state agencies, and organizations. Additional telephone interviews were conducted with European officials, and personal interviews were conducted at the Heavy Truck 2008 Conference in Paris (Turner, et al., 2008).

Content of This Report

Section 2 of this report covers the rapid growth of heavy commercial vehicles. Section 3 outlines truck types, weights, sizes, and regulations. Section 4 covers heavy truck characteristics that effect crashes, and Section 5 provides an overview of general trends for heavy truck crashes. Section 6 compares OS/OW trucks crashes to those of "normal" heavy vehicles, and Section 7 provides case studies of OS/OW commercial vehicle experiences in two states. Section 8 presents findings and recommendations resulting from the project. The Bibliography Section lists the reference materials reviewed in the project, and the members of the project advisory panel are listed on pg. v at the front of the book.

SECTION 2

The Concern—Heavy Commercial Vehicle Growth



Reason for Concern

There are at least two reasons for concern about the safety of OS/OW vehicles. First, the number of large trucks has climbed rapidly for over two decades, and it is projected to continue to climb. As more American roads approach their absolute capacities, inserting additional large trucks into the vehicle mix compounds the situation. This is problematic because it restricts mobility and quality of life, and it threatens to curtail economic competitiveness.

The second major reason for concern involves the world-wide movement to new types of heavy vehicles with more axle and wheel types and groupings. These vehicles are capable of carrying larger loads, decreasing the number of trips required to deliver goods to market. Using these vehicles in America would appear to reduce congestion and underwrite economic viability. But they cannot be used on federal routes and other major roadways due to federal and state size and weight restrictions. Additionally, there is not a consensus on the safety of these vehicles.

Explosion in Growth of Large Commercial Vehicles

The number of large commercial vehicles (18-wheelers) on American highways has grown rapidly. This is due to several factors. “Just in time” delivery decreases costs associated with owning and operating large warehouses. The time value of merchandise can be considerable. For example, an inventory of \$2 million that sits on store shelves for a month represents interest costs of over \$10,000. In today’s tight markets, manufacturers and wholesalers can maintain their profit margin by doing away with warehouses and moving goods quickly from the manufacturer to the consumer. Since delivery by truck is normally more rapid than delivery by either train or water, trucking firms have absorbed more and more of freight delivery. Table 2-1 indicates the current truck volume and share of freight shipments, along with a projection of the future values.

Table 2-1. U.S. Freight Shipments by Mode (FHWA, 2007a)

	2002	2035
	19.3 Billion Tons	37.3 Billion Tons
Truck	59.7%	61.4%
Rail	9.7%	9.5%
Water	3.6%	2.8%
Air and Truck	0.1%	0.1%
Intermodal*	6.7%	7.0%
Pipeline and Unknown	20.2%	19.3%
Total	100.0%	100.0%

* U.S. Postal Service, courier shipments, and all intermodal combinations, except air and truck.

Emerging international manufacturing capability is also expanding the role of truck freight. International goods saturate American ports and airports with shipments that must be delivered to retailers. Americans have changed their purchasing patterns and now prefer low-cost mega stores as their primary retailing outlet. These mega centers purchase their goods, largely overseas, at low costs and depend upon well-coordinated freight shipments from key distribution locations to move them to regional stores. It is clear that U.S. manufacturers and retailers rely on large truck freight for economic competitiveness in their specialty areas, especially in the global marketplace.

Between 1982 and 2002, the number of U.S. registered trucks increased 42 percent and the vehicle miles traveled (VMT) almost doubled (Truck Safety Coalition, 2007). This amounts to annual growth rates of about 1.8 percent for truck registrations and 3.5 percent for VMT. This was extreme growth on a roadway system that was already saturated in many places.

More recent numbers are shown in Table 2-2, which displays 10 years of data, from 1995 through 2004. At the end of that period, there were 8.2 million large commercial trucks on the nation's highways, traveling some 227 billion miles annually. The table relates the number of trucks involved in crashes, and the crash rates on both a vehicle population basis and a VMT basis. Truck crashes are discussed in more detail in Section 5 of this report.

Table 2-2. Large Truck Registrations, Mileage, Crashes, and Crash Rates (NHTSA, 2005a)

Year	Number Registered	VMT (millions)	Number Involved In Crashes	Vehicle Population Rate*	VMT Involvement Rate**
1995	6,719,421	178,156	4,472	66.55	2.51
1996	7,012,615	182,971	4,755	67.81	2.60
1997	7,083,326	191,477	4,917	69.42	2.57
1998	7,732,270	196,380	4,955	64.08	2.52
1999	7,791,426	202,688	4,920	63.15	2.43
2000	8,022,649	205,520	4,995	62.26	2.43
2001	7,857,675	209,032	4,823	61.38	2.31
2002	7,927,280	214,603	4,587	57.86	2.14
2003	7,756,888	217,917	4,721	60.86	2.17
2004	8,171,363	226,505	4,902	59.99	2.16
10-yr growth	+ 21.6%	+27.1%	+9.6%	−9.9%	−14.0%
Annual growth	+2.0%	+2.4%	+0.9%	−1.0%	−1.3%

* Rate per 100,000 vehicles.

** Rate per 100 million vehicle miles traveled.

Twenty years of data from 1982–2002 (Truck Safety Coalition, 2007) and 10 years of data from 1995–2004 (NHTSA, 2005a) were compared to examine rates of growth. In addition, the final five years of data were examined. The annual growth for 20-years, 10-years, and the final 5-years for registered trucks was 1.8, 2.0, and 0.5% percent, respectively. During the same time periods, annual VMT growth rates were 3.7, 2.4, and 2.0 percent. In other words, the rate of growth is slowing for both indicators. This might be from infrastructure limitations (congestion) or from market saturation (no additional goods left to ship by truck), or other reasons. This bit of encouraging news is tempered by the saturated condition of the nation's highways and the enormous workload created for enforcement agencies.

FHWA projections for the coming 25 years are shown on Figure 2-1. Viewed in this manner, it is easy to see why historical truck growth has been so noticeable on the nation's highways and why it has been such a challenge for the nation's enforcement officers. The dashed lines indicate the authors' anticipated range of potential growth over the next 30 years. The clear implication is that growth will continue at a strong rate. Without additional understanding of the growth components, congestion can worsen and it will be even more difficult to provide sufficient enforcement for truck freight shipments.

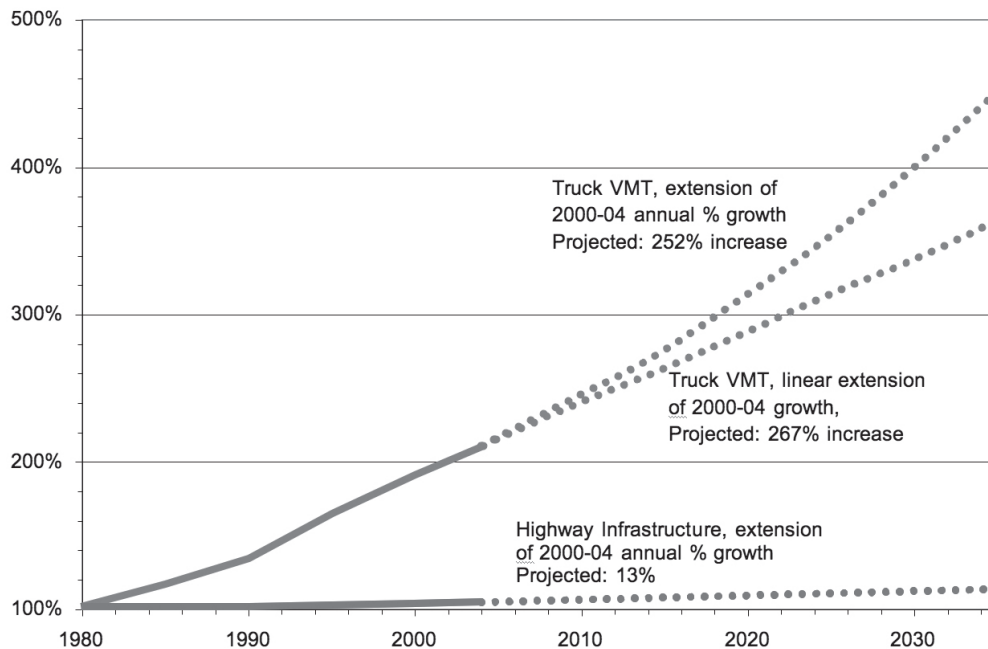


Figure 2-1. Truck and Infrastructure Growth Trends (NHTSA, 2005a)

Summary of Commercial Vehicle Growth

In summary, a review of historical trends of truck freight movements has documented a rapid and sustained growth, principally to support the American economy during a period of change from small retail outlets to large mega-centers, and from domestic suppliers to global suppliers. This growth is projected to continue into the future, and will cause continuing strains on infrastructure and enforcement capabilities.

Case Study—Minnesota Investigation of Large Commercial Vehicles

Developments in Minnesota illustrate the impact that truck size and weight (TSW) laws have on a state's economy (Cambridge Systematics, 2006). The state competes with agricultural and timber products from adjacent states and Canada, which allow larger loads on trucks. TSW makes a difference in economic viability, because it controls the amount of payload that can be carried in a truck. In other words, Minnesota's smaller payloads require more truck loads and greater transportation costs when compared with Canada and North and South Dakota.

Over the past several years, Minnesota's legislature has annually considered proposals to change TSW laws. A good example is the 2005 legislative session, in which 12 bills were introduced that affected state TSW laws. Typically the proposals were tailored to fit the economic, infrastructure, or other needs of a specific industry (ores, sand and gravel, timber, agriculture, etc.). The sheer number of bills introduced

in the legislature and the number of years that this has occurred are good measures of the economic pressure on industry and agriculture for larger vehicles that can carry heavier loads.

In 2005, Minnesota already had weight exceptions and exclusions for timber haulers (90,000 lbs max), special paper products (108,000 lbs max), vehicles transporting first haul of unprocessed or raw farm products or forest products, farm trucks, waste haulers, implements of husbandry, and livestock hauling. In addition, weight increases are allowed for winter, harvest season, interstate routes in winter, and timber haulers in winter.

Minnesota trucking advocates and other stakeholders raised numerous issues that appeared to limit productivity of freight shipments. There were strong feelings that several of these issues placed specific local industries at an economic disadvantage, including the following (Cambridge Systematics, 2006):

- The proliferation of exemptions, exceptions, and tolerances in Minnesota TSW laws created inequities and adversely impacted enforcement and infrastructure.
- Variations in TSW laws for different state road classifications limited productivity.
- Complexity of TSW laws added costs and complicated compliance.
- TSW laws in adjacent states were not consistent, creating cross-border barriers to freight movement.
- Permitting of OS/OW trucks and the enforcement of TSW laws were inconsistent across Minnesota jurisdictions and a centralized system was needed.
- Flexibility of weight limits and vehicle configurations could allow greater payloads.
- Changes to size and weight laws would raise concerns about infrastructure impacts on local roads and bridges.
- TSW changes to allow larger and heavier trucks would cause safety concerns.

To address these and other issues, the Minnesota Department of Transportation partnered with public and private contractors, and engaged a consultant to assess whether changes to the state's TSW laws would benefit the state's economy while protecting roadway infrastructure and safety.

The contractor and stakeholders created guiding principles like complying with federal laws, protecting highway infrastructure and safety, benefiting Minnesota's industries and economy, improving uniformity of TSW applications, and covering the costs imposed on the system. The study was extensive and considered items like industry challenges, pavement considerations, bridge considerations, and impacts on safety. The following are the key findings of the technical analyses (Cambridge Systematics, 2006):

- Four heavier truck configurations were found to be feasible and to generate net statewide benefits,
- Changes to spring-load restrictions and other related TSW regulations were developed and found to offer net benefits,
- Each of the proposed changes was justified through rigorous cost-benefit analyses that considered transport savings, pavement costs, bridge inspection costs, rating and posting impacts, bridge fatigue and deck wear effects, increased bridge design load requirements, safety, and congestion, and
- Detailed analyses were conducted for each of these topics, and tables of results were published in a final report.

Summary of Case Study

This case study clearly indicated the economic pressures that bear on segments of American industries and agriculture. It illustrated that these segments are interested in changes to truck sizes and weights to decrease transportation expenses so that they are economically viable. Minnesota responded to these concerns with a rigorous study of the effects of TSW, and found that use of larger and heavier vehicle on its highways would be cost beneficial and justified.

Section Summary

This section of the report has documented a prolonged rapid growth in the number of heavy commercial vehicles on the nation's highways, and the reason for that growth—changes in the nation's manufacturing and wholesale sectors (more rapid, just-in-time delivery), consumer purchasing patterns (mega stores that offer lower prices), and economic competitiveness (global market place). The forecast is for that growth to continue.

The Minnesota case study documented that transportation costs are crucial to some sectors of American industry and agriculture. Individual sectors or firms have increasingly sought exemptions from Minnesota truck size and weight laws to improve their ability to compete with neighboring states that allow larger and heavier transport vehicles. In this regard, the Minnesota research project recently made a major contribution to the state of knowledge for heavy commercial vehicles, finding that four new types of heavy trucks (with increased size and weight) would improve economic competitiveness without causing excess damage to road and bridge infrastructure or causing decreases in road safety.

SECTION 3

Heavy Vehicle Types, Weights, and Sizes



Types of Vehicles

Trucks may be classified by type of use, type of trailer, number of trailers, number of axles, weight, length, and other ways. A common definition is that a truck has three or more axles, or two axles with dual rear tires (Harwood, et al., 2003a). Another common definition is that used by NHTSA of a gross vehicle weight (GVW) greater than 10,000 lbs. These and other definitions are applicable in certain situations. For example, when a 10,000lb load is carried by a small, two-axle truck with dual rear tires, it is a significant load. But when the same 10,000-lb load is spread across the trailer of an 18-wheeler it is a light load. Items like the load, truck (and trailer) type, number of axles, and locations of those axles are important in classifying a truck. These and other factors are discussed in this chapter in terms of how they affect truck safety and operations.

Truck types are divided into two main categories: *single-unit* and *combination* vehicles (FHWA, Vol. 1, 2000). Single-unit trucks do not have trailers, and are characterized by short wheelbases. Examples of common single-unit trucks are soft drink and beer grocery trucks and overnight mail delivery service trucks. NCHRP Report 575 (Silvakumar, et al., 2007) indicates that for some purposes, a special category of single-unit trucks is used for heavy-duty work, the specialized hauling vehicle (SHV). Examples include ready-mix concrete trucks, dump trucks, and solid-waste disposal trucks.

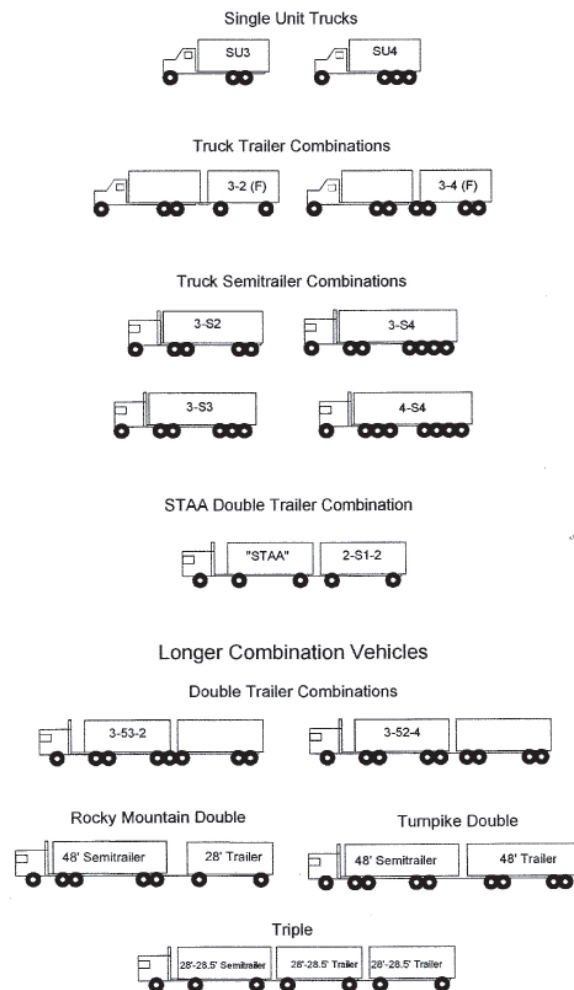
Combination vehicles are divided into two subcategories: *conventional combination* vehicles and *longer combination vehicles* (LCVs) (FHWA, Vol. 1, 2000). As part of the Surface Transportation Assistance Act of 1982 (STAA), Congress defined an LCV as “any combination of a truck tractor and two or more trailers or semi-trailers which operates on the Interstate System at a GVW greater than 80,000 lbs.” Table 3-1 provides approximate lengths and weights for the three most prominent types of LCVs. Figure 3-1 illustrates some of the most frequently seen types of large trucks that operate in the United States.

Table 3-1. Approximate Lengths/Weights of Prominent Types of LCVs
(FHWA, Vol. 1, 2000)

Type LCV	GVW	Total Length	First Trailer	Second Trailer	Third Trailer
Rocky Mountain Double	105,000 lbs	95 ft	48 ft	28 or 28.5 ft	
Turnpike Double	135,000 lbs	120 ft	48 ft	48 ft	
Triple Trailer	110,000 lbs	110 ft	28.5 ft	28.5 ft	28.5 ft

Only 21 states allow doubles with trailers longer than 28.5 ft. The 16 states west of the Mississippi River that allow them are predominantly agriculturally based, and the remaining five states are in the eastern United States. The 13 states that allow triples impose restrictions on them, and 11 of the 13 are located in the mid-western and northwestern states (FHWA, Vol. 1, 2000).

Size and Weight Regulations

**Figure 3-1.** Examples of FHWA Truck Classifications (FHWA, Vol. 2, 2000)

The federal regulations for TSW are contained in the Code of Federal Regulations, 23 CFR 657 and 23 CFR 658. The historical development of these regulations is traced in the remainder of this section of the report.

Until the mid-1950s, states controlled TSWs of vehicles operating on their roads. But the Interstate Highway System changed that. It was designed as a federal system with a uniform set of nationwide criteria. Given the extremely high cost of constructing and maintaining the new system, it was prudent to adopt federal TSWs to prevent such an investment from being prematurely damaged by oversize or overweight vehicles. The new federal limits were adopted by Congress in 1956. The basic provisions of the 1956 law set federal weight limits for trucks at 73,280 GVW and maximum truck width to 96 inches. A “grandfather” provision in the law allowed states to retain their existing laws for TSWs on these roads, even if they exceeded Congress’s limits. According to NCHRP Report 575, “at least 30 states exercise[d] their grandfather rights.”

The 1974 STAA increased federal limits for axle weights from 18,000 to 20,000 lbs, tandem weights from 32,000 to 34,000 lbs, and GVW from 73,280 to 80,000 lbs. But when the STAA was adopted, many over-the-road drivers continued to limit their vehicles to 73,280 lbs to make sure that they did not exceed any local or state weight laws regardless of where they were traveling (FHWA, Vol. 1, 2000).

In addition to specifying maximum weights for the vehicle, individual axles, and tandem axles, the 1974 Act also addressed allowable grouping and spacing of axles by introducing the federal bridge formula (Harwood, et al., 2003a):

$$W = 500 [LN(N-1) + 12N + 36] \quad (3-1)$$

where: W = maximum allowable weight for any group of two or more axles;

L = distance in feet between extremes of any group of two or more axles; and

N = number of axles under consideration.

The grouping is important due to the effect it has on bridges and pavements. Closely spaced axles concentrate the load and induce infrastructure damage. Axle groupings are illustrated in Figure 3-2. Compared with other heavy vehicles, the tri-axle, specialized hauling vehicle (SHV) truck has a very concentrated load, and this type of vehicle is known to have particular trouble staying under the limits of the federal bridge formula because of its short wheelbase (Silvakumar, et al., 2007). Indeed, this vehicle is often the critical load for short bridges, as illustrated by the 51,000 SHV in the figure.

When Congress adopted the 1982 STAA, it increased the allowable federal truck width to 102 in., which is the current limit. It also created a new category of truck, called the STAA double trailer combination (see Figure 3-1). This 48-ft, tractor-semi-trailer vehicle included twin trailers, often called “twin pups” of 20 or 28.5 ft. Longer limits were allowed if they were in legal operation prior to the adoption of the Act. These grandfathered lengths are listed in 23 CFR Part 658 Appendix B.

Another feature of the 1982 Act was creation of a National Network (NN) to support STAA vehicle mobility rights. The NN was defined (23 CFR, Part 658, Appendix A) as the Interstate System plus Primary System routes submitted by the states. The TSWs for this network including the following:

- Up to 80,000 GVW,
- Up to 20,000 lbs per single axle,
- Up to 34,000 lbs for a tandem axle,
- Up to 48 ft of length for trailers of combination trucks operating on the NN,
- Up to 28.5 ft per trailer for combination trucks with two trailers while operating on the NN, and
- Up to 8.5 ft of width for trucks within the above length limits on the NN.

The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) imposed a freeze on LCV weights, dimensions and routes. The “Comprehensive Truck Size and Weight Study” (FHWA Vol. 1, 2000) called this provision of ISTEA “the most significant legislative action related to federal TSW limits since 1982...” ISTEA grandfathered vehicles already legally operating, and they are identified in 23 CFR Part 658 Appendix C by state for the dimensions, weights, and networks allowed to remain in operation following the freeze. In effect, states which were not grandfathered when the STAA took effect were blocked from allowing LCVs.

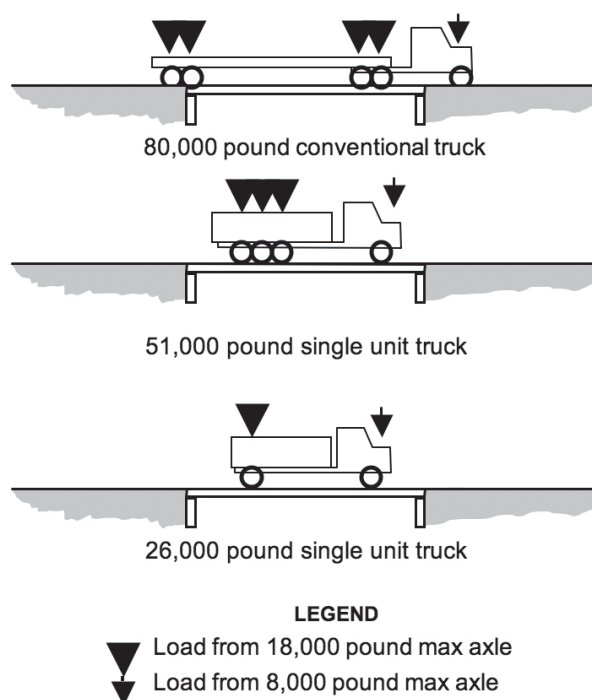


Figure 3-2. Illustration of the Effects of Axle Weights and Spacings

Legal OS/OW Trucks

Just because a vehicle exceeds established general federal or state maximum weight or dimension regulations does not necessarily mean that it is illegal. There are at least three situations in which the truck is allowed to exceed the federal limits.

1. There are roads where the weight or the dimension limits exceeds the general federal criteria, but the roads and their TSWs were “grandfathered” when the STAA was adopted by Congress.
2. There are instances when an OS/OW vehicle has received an overload or dimensional permit from the applicable state department of transportation.
3. Sometimes there are categorical exclusions from state laws. The case study in Section 2 of this report outlined how the Minnesota legislature created exclusions for many types of industries. Other examples will be introduced in case studies later in this report.

The research team for this project originally intended to gather separate data for OS/OW vehicles that were operating legally and those were operating illegally. Unfortunately, there was insufficient data to make such a determination.

Section Summary

This section of the report has documented that truck types are divided into two main subcategories: single-unit and combination vehicles. There are many variants of each category, based principally upon the number and location of axles and trailers.

Single-unit trucks do not have trailers, and within this category the specialized hauling vehicle (tri-axle dump truck, ready-mix concrete truck, etc.) is of particular interest due infrastructure damage caused by its closely spaced axles and concentrated load. The combination vehicle category is divided into two main subcategories: conventional combination vehicles and longer combination vehicles, which have two or more trailers.

This section of the report also documented the development of federal TSW regulations for the Interstate System and the National Network and the current limiting values of those regulations. These regulations are responsible for great uniformity in the U.S. shipping fleet.

Federal regulations have caused sizes and weights of commercial vehicles in the United States to remain relatively consistent for many years. This has provided stability in the freight industry and has protected infrastructure investments by federal, state, and local governments.

SECTION 4

Truck Characteristics Affecting Crashes



Introduction

This section of the report discusses some of the important truck characteristics related to crash causation and crash severity. They are introduced to illustrate that large truck crashes are complex events in which any of these characteristics might play the key role. For the crash of an individual OS/OW truck it might be possible to isolate and determine the contributions of some of the factors or characteristics. But the interaction between the factors makes it very difficult to understand all of them in a single crash, much less draw general conclusions about the causes of all of these crashes across the country.

In this section of the report, several of the prominent factors are introduced and discussed as they relate to causing truck crashes or contributing to the severity of truck crashes. Most of them will be discussed again in Section 5 when various crash statistics and trends are reviewed.

Truck Weights and Loads

The weight, size, and placement of the load can complicate control of the truck. For example, on a traditional tractor and trailer any of the following loading conditions changes vehicle handling characteristics (acceleration, deceleration, cornering, off tracking, etc.) and braking:

- A high load raises the center of gravity of the trailer and increases the chance of rollover.
- Placing the center of gravity of the load nearer one side of the trailer than the other causes more load to be shifted to the wheels on that side of the vehicle. This can contribute to rollover, loss of control, and unequal braking on the right and left side of the trailer.
- If the center of gravity of the load is placed nearer the front of the trailer than the rear, or vice versa, this causes some axles to carry more load than the others. This can cause early wheel lock of the lightly-loaded axle and loss of control of the vehicle geometry as the tractor rear axle or trailer rear axle swings sideways.

- A loose or liquid load may shift during a maneuver or braking, placing a greater load on one side or the front of the trailer. This changes wheel loads and axle loads and affects braking.
- Overloading trucks increases the time and distance to stop. According to the Truck Safety Coalition (2007), “a 100,000-lb truck takes 25 percent longer to stop than an 80,000-lb truck and a 120,000-lb truck can travel as much as 50 percent further before stopping than an 80,000-lb truck.” The reader should note that these are not generalities, they are examples based on stopping from a specific speed. Stopping distance is highly dependent upon the speed at which braking is initiated, with higher speeds producing much longer distances than lower speeds.

Unfortunately, the contributions of the overloads to truck crashes are not adequately documented in the literature. One reason is that it has been virtually impossible to weigh a truck after it has crashed to see if it was overweight. In a severe crash, the truck often overturned and spilled the load, making it absolutely impossible to weigh. In some situations, records from weigh stations or weigh-in-motion (WIM) stations might provide data on the truck weight. This is especially true if the truck passes a virtual WIM prior to the collision. A virtual WIM combines scales, remote cameras, license plate readers, transponders, and communications equipment to capture weight, size, and other information, and to relate it to specific trucks using license plate and transponder information.

Where the load and load configuration are known for a particular truck crash sequence, it may be possible to estimate the effect of the overload through accident reconstruction or simulation. But this technique has been used rarely because it is very time consuming and might require shutting down a major highway or interstate to gather the needed data. Where simulation is used as part of the reconstruction, sophisticated software is necessary and high-level data are needed.

Multidisciplinary accident investigation teams in Kentucky found that reconstructing OS/OW crashes took an extended amount of time and resources. One reason is that law enforcement investigation of truck crashes is difficult. Few officers have the advanced training needed to understand braking and stability issues. Thus, important data might be inadvertently omitted or incorrectly gathered. Even though reconstruction is desirable, few truck crashes have been reconstructed due to the extensive time and cost for data collection and reconstruction procedures. WIM and virtual WIM data may provide the missing data and allow additional reconstruction efforts.

At this point, truck accident reconstruction has been done for individual crashes, but it has not been done on a large scale so that it could yield accurate information to make significant contributions to understanding the overall role of truck size, weight, and speed in OS/OW crashes.

Truck Types and Sizes

Factors like truck type, truck length, truck trailer type and length, and truck weight contribute to difficulty in controlling and braking a truck. For example, a rigid four-wheel automobile is relatively easy to brake. But adding articulation, more axles, and more wheels adds additional steering and handling characteristics that complicate braking. For an articulated vehicle like a tractor and trailer, braking becomes much more difficult. The driver must focus on keeping the tractor and trailer aligned during braking, which often limits deceleration to less than the full capability of the truck braking system.

As trucks grow longer and more axles are added, there are more wheels that need braking and the vehicle becomes harder to control. The additional axles can be in the form of additional trailers. The LCV with multiple trailers has proven to be the most difficult truck to bring to a halt (FHWA, Vol. 2, 2000). Or a tractor may pull a long trailer with extra axles to carry a specialized load. A fairly common vehicle in some international locations has as many as four closely spaced axles at the rear of the trailer. While in a sharp turn, the axles hold the tires in a straight line along the axis of the trailer, producing much friction and tire scrubbing. To alleviate this, a four-axle set can be equipped with steering, which can be automated to simplify vehicle operation. But in an emergency maneuver during an accident sequence, the stiff row of tires can contribute to steering difficulties. In Australia and New Zealand, this type of wheel arrangement with automated steering has been shown to contribute to accidents for trucks traveling small-radius curves at higher speeds (Prem, et al., 2008).

Researchers in Canada noted that prior studies showed disparate results about safety and vehicle size (Montufar and Associates, 2007). Some studies found that LCVs were safer than other truck configurations, some found that they were less safe, and one study found that LCVs were “no more or less safe” than other combination vehicles. Several studies related that direct comparison of crash rates between LCVs and other truck classifications was restricted due to lack of “reliable and relevant data” for LCV collisions and exposure.

Truck Brake Systems

Braking is an important part of a truck accident sequence. Conventional truck brakes are more complex and less effective than those of automobiles, and truck braking distances are longer than those of automobiles. In addition, drivers of trucks with conventional brakes typically fear skidding and losing control of their trucks, so they use less than the full stopping ability (friction) of a road.

Conventional truck brakes operate from air pressure, so they require frequent adjustment to maintain high braking efficiency. Since they are air activated, there are short delays between the time that the driver depresses the brake pedal and the operation of an individual brake. The brakes on individual wheels might not all provide the same stopping power, which complicates the driver’s job in controlling the vehicle in an extreme braking maneuver. All of these factors contribute to the difficulty in understanding the braking mechanism of trucks.

Antilock Brakes

Federal regulations now require that all new tractors, trailers, and single-unit trucks be manufactured with antilock braking systems. This has radically improved truck braking. Trucks (tractors and trailers) that are completely equipped with antilock brakes have braking capabilities approximately equal to that of passenger cars (FMSCA, 2007). The antilock requirement has been in effect since 1997 for tractors and 1998 for trailers and single-unit trucks. In large trucking fleets, the useful life of a tractor is about five to seven years, so the tractors on the road in 1997 have been largely replaced with new tractors with antilock brakes. However, individual firms may replace their tractors less frequently. Small shipping firms, especially one-vehicle “ma and pa” trucking firms, operate at a much tighter financial margin and cannot afford to replace their vehicles as often as larger companies. These firms are more likely to still be driving tractors with conventional brakes (Harwood, et al., 2003a).

The situation is different for trailers. Antilock brakes have been required since 1998, but trailers have a useful life of about 20–25 years. The fleet has not turned over since 1998, and there are still many on the road without antilock brakes (Harwood, et al., 2003a). A 2003 review of truck characteristics found that 43 percent of trailers were already equipped with antilock brakes five years after adoption of the federal regulation that required them (Harwood, et al., 2003a). That means the shift to antilock brakes on trailers is well underway and truck braking will continue to improve. This will alleviate prior concerns about conventional brakes, such as the lower friction properties of truck tires and excess stopping distances associated with trucks in general and unloaded trailers in particular.

Although truck brakes have improved considerably since 1998, the effects of overweight loads on braking are not well documented. This is a key piece of missing information that could improve heavy truck safety if known.

Speed

Truck speed is thought by investigating officers and safety officials to contribute to truck crashes. Kentucky researchers noted that, “Excess speed is cited in 20 percent of all heavy truck accidents, more than any other factor” (Beilock, et al., 1989).

But the speeds recorded on traffic accident reports by investigating officers are not exact. They are estimates based upon the officer’s examination of the vehicle, experience, and knowledge. A major contributor to this estimate is the amount of damage done to the vehicles or to fixed objects. Logic indicates that higher-speed trucks with greater weights have greater impact energy and cause more damage to themselves, to other vehicles, and to the occupants of those vehicles. However, reconstruction has shown that the crush damage from the accident is a poor predictor of energy and speed. For individual officers, there could be a sizable range of error associated with these estimates, and when used for scientific analyses the potential effects of that error must be taken into consideration.