A Synthesis of Safety Implications of Oversize/Overweight Commercial Vehicles

By

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Prepared by

UTCA
University Transportation Center for Alabama
The University of Alabama, The University of Alabama at Birmingham,
and The University of Alabama in Huntsville
UTCA Report Number 07115
June 2009

UTCA Theme: Management and Safety of Transportation Systems
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This synthesis supports a 2006 International Technology Scanning Tour of several European countries that investigated commercial motor vehicle size and weight enforcement programs. The synthesis objective was to identify the relationship between vehicle safety and crash causation factors for oversize/overweight (OS/OW) commercial vehicles. It was prepared through a review of over 100 research reports and journal articles, and over 50 interviews with domestic and international heavy truck agency, industry and enforcement officials.

Case studies provided insight into the impact of truck size and weight regulations. The Kentucky and West Virginia legislatures gave weight exclusions to coal trucks to keep that industry economically viable. Minnesota agriculture and industry faced lower shipping costs in adjacent states and Canada. A Minnesota DOT project found that four new heavy trucks would be cost beneficial without causing undue infrastructure or safety concerns.

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

- In general, as commercial vehicles become larger and heavier, crash rates decrease but crash severity increases. A lack of consistency and lack of methodological rigor supporting previous findings precludes definitive conclusions regarding either a positive or negative relationship between larger/heavier vehicles and safety; suggesting only that additional research is needed to understand the complex relationship.
- No existing truck crash data set contains sufficient information for a scientific analysis of the contributions of size and weight (especially OS/OW) to crash causation or severity.
- Studies in Canada indicate that the largest vehicles, LCVs, have lower crash rates (all severities) than other trucks and all-vehicles as a group.
- Another study in Canada found that large truck performance measures (static roll stability, off tracking, etc.) are highly correlated to large truck crash rates.

As part of the study, UTCA made recommendations on topics like collecting additional high quality data to create comprehensive databases, incorporating weight databases (weigh-in-motion, virtual WIM, etc.) to expand existing truck safety databases like the Truck Involvement in Fatal Accidents and Large Truck Crash Causation files. If needed, provide specialized training to selected troopers, police officers and other involved personnel to help them determine the cause or contributing causes of heavy truck crashes during site investigation.
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Executive Summary

This synthesis was prepared to support an International Technology Scanning Tour conducted by the US 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 was 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 semitrailer trucks to haul up to 120,000 pounds 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 semitrailers 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 (Woodroofe, 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, as commercial vehicles become larger and heavier, crash rates decrease but crash severity increases. A lack of consistency and lack of methodological rigor supporting previous findings precludes definitive conclusions regarding either a positive or negative relationship between larger/heavier vehicles and safety; suggesting only that additional research is needed to understand the complex relationship.

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 largest 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 US 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:

The following 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 to 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 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 FARS data collection system.

- Where needed, provide specialized training to troopers, police officers and other involved 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 FHSCA 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.

The UTCA researchers express their appreciation to the Advisory Panel for their assistance and encouragement. They also thank Mr. Tom Kearney of FHWA, Mr. Ken Agent of the Kentucky Transportation Center and Mr. Tom Petrolino of the National Transportation research Center, Inc. for providing much useful information for the synthesis. The authors are also grateful to the students and staff of UTCA for providing assistance during the preparation of the synthesis.
1.0 Introduction

Objective

The specific objective of this research project was to prepare a synthesis of safety implications of oversize/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 US 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 US 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, US 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 US (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 US. After review, seven of these practices were classified as high priority projects for implementation research. One of the seven was to develop this
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 Transportation 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 Two of this report covers the rapid growth of heavy commercial vehicles. Section Three outlines truck types, weights, sizes and regulations. Section Four covers heavy truck characteristics that effect crashes, and Section Five provides an overview of general trends for heavy truck crashes. Section Six compares OS/OW trucks crashes to those of “normal” heavy vehicles, and Section Seven provides case studies of OS/OW commercial vehicle experiences in two states. Section Eight presents findings and recommendations resulting from the project. Section Nine lists the reference materials reviewed in the project, and Section Ten lists the members of the project advisory panel.
2.0 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. It 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. US Freight Shipments by Mode (FHWA, 2007a)

<table>
<thead>
<tr>
<th>Mode</th>
<th>2002 (19.3 billion tons)</th>
<th>2035 (37.3 billion tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>59.7%</td>
<td>61.4%</td>
</tr>
<tr>
<td>Rail</td>
<td>9.7%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Water</td>
<td>3.6%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Air, air &amp; truck</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Intermodal¹</td>
<td>6.7%</td>
<td>7.0%</td>
</tr>
<tr>
<td>Pipeline &amp; unknown</td>
<td>20.2%</td>
<td>19.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

¹US Postal Service and 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 US 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 US registered trucks increased 42% and the vehicle miles traveled (VMT) almost doubled (Truck Safety Coalition, 2007). This amounts to annual growth rates of about 1.8% for truck registrations and 3.5% 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 ten 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 Five of this report.
Table 2-2. Large Truck Registrations, Mileage, Crashes, and Crash Rates (NHTSA, 2005a)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number Registered</th>
<th>VMT (millions)</th>
<th>Number Involved in Crashes</th>
<th>Vehicle Population Rate*</th>
<th>VMT Involvement Rate**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>6,719,421</td>
<td>178,156</td>
<td>4,472</td>
<td>66.55</td>
<td>2.51</td>
</tr>
<tr>
<td>1996</td>
<td>7,012,615</td>
<td>182,971</td>
<td>4,755</td>
<td>67.81</td>
<td>2.60</td>
</tr>
<tr>
<td>1997</td>
<td>7,083,326</td>
<td>191,477</td>
<td>4,917</td>
<td>69.42</td>
<td>2.57</td>
</tr>
<tr>
<td>1998</td>
<td>7,732,270</td>
<td>196,380</td>
<td>4,955</td>
<td>64.08</td>
<td>2.52</td>
</tr>
<tr>
<td>1999</td>
<td>7,791,426</td>
<td>202,688</td>
<td>4,920</td>
<td>63.15</td>
<td>2.43</td>
</tr>
<tr>
<td>2000</td>
<td>8,022,649</td>
<td>205,520</td>
<td>4,995</td>
<td>62.62</td>
<td>2.43</td>
</tr>
<tr>
<td>2001</td>
<td>7,857,675</td>
<td>209,032</td>
<td>4,823</td>
<td>61.38</td>
<td>2.31</td>
</tr>
<tr>
<td>2002</td>
<td>7,927,280</td>
<td>214,603</td>
<td>4,587</td>
<td>57.86</td>
<td>2.14</td>
</tr>
<tr>
<td>2003</td>
<td>7,756,888</td>
<td>217,917</td>
<td>4,721</td>
<td>60.86</td>
<td>2.17</td>
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<tr>
<td>2004</td>
<td>8,171,363</td>
<td>226,505</td>
<td>4,902</td>
<td>59.99</td>
<td>2.16</td>
</tr>
<tr>
<td>10-yr growth</td>
<td>+ 21.6%</td>
<td>+27.1%</td>
<td>+9.6%</td>
<td>-9.9%</td>
<td>-14.0%</td>
</tr>
<tr>
<td>Annual growth</td>
<td>+2.0%</td>
<td>+2.4%</td>
<td>+0.9%</td>
<td>-1.0%</td>
<td>-1.3%</td>
</tr>
</tbody>
</table>

* Rate per 100,000 vehicles. **Rate per 100 million vehicle miles traveled.

Twenty years of data from 1982-2002 (Truck Safety Coalition, 2007) and ten 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%, respectively. During the same time periods, annual VMT growth rates were 3.7%, 2.4% and 2.0%. 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 become dominant, and it will be even more difficult to provide sufficient enforcement for truck freight shipments.
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 to Canada and North and South Dakota.

Over the past several years, the State of Minnesota Legislature has annually considered proposals to change TSW laws. A good example is the 2005 legislative session, in which twelve 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 pounds max), special paper products (108,000 pounds 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 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 finding 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. The State of 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 costs) 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.
3.0 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 the National Highway Traffic Safety Administration (NHTSA) of a gross vehicle weight (GVW) greater than 10,000 pounds. These and other definitions are applicable in certain situations. For example, when a 10,000 pound load is carried by a small, two-axle truck with dual rear tires, it is a significant load. But when the same 10,000 pound load is spread across the trailer of an eighteen wheeler it is a light load. So 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.

Trucks 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 pounds.” 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>
<thead>
<tr>
<th>Type LCV</th>
<th>GVW, pounds</th>
<th>Total Length</th>
<th>First Trailer</th>
<th>Second Trailer</th>
<th>Third Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky Mountain Double</td>
<td>105,000</td>
<td>95 ft</td>
<td>48 ft</td>
<td>28 or 28.5 ft</td>
<td></td>
</tr>
<tr>
<td>Turnpike Double</td>
<td>135,000</td>
<td>120 ft</td>
<td>48 ft</td>
<td>48 ft</td>
<td></td>
</tr>
<tr>
<td>Triple Trailer</td>
<td>110,000</td>
<td>110 ft</td>
<td>28.5 ft</td>
<td>28.5 ft</td>
<td>28.5 ft</td>
</tr>
</tbody>
</table>

Only 21 states allow doubles with trailers longer than 28.5 feet. The 16 states west of the Mississippi River that allow them are predominantly agriculturally based, and the remaining five...
states are in the eastern US. 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).

Figure 3-1. Examples of FHWA truck classifications (FHWA, Vol. 2, 2000).
Size and Weight Regulations

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 pounds, tandem weights from 32,000 pounds to 34,000 pounds, and GVW from 73,280 to 80,000 pounds. But when the STAA was adopted, many over-the-road drivers continued to limit their vehicles to 73,280 pounds 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):

\[
W = 500 \left[ \ln(N-1) + 12N + 36 \right]
\]

Equation 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
- \(N\) = 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 to other heavy vehicles, the tri-axle 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.

The 1974 weight limits and the bridge formula were well conceived and are still in effect today. When Congress adopted the 1982 STAA, it increased the allowable federal truck width to 102 inches, 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 foot tractor-semi-trailer vehicle included twin trailers, often called “twin pups” of 20 or 28.5 feet. 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 pounds per single axle
- Up to 34,000 pounds for a tandem axle
- Up to 48 feet of length for trailers of combination trucks operating on the NN
- Up to 28.5 feet per trailer for combination trucks with two trailers while operating on the NN
- Up to 8.5 feet 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.
Legal OS/OW Trucks

Just because a vehicle exceeds established 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 state roads where the weight or dimension limits exceed 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 Two of this report outlined how the State of 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 that were operating illegally. Unfortunately, there was insufficient data to make such a determination.
Section Summary

This section of the report has documented that trucks 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 US shipping fleet.

Federal regulations have caused sizes and weights of commercial vehicles in the US 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.
4.0 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 Five 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 pound truck takes 25% longer to stop than an 80,000 pound truck and a 120,000 pound truck can travel as much as 50% further before stopping than an 80,000 pound 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. It combines scales, remote cameras, license plate readers, transponders and communications equipment to capture information 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 that made significant contributions to understanding the overall role of truck size, weight and speed in the crash.

**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, additional axles, and additional 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% 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 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 overweigh loads on braking is 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% 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 a crash 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 that potential effects of that error must be taken into consideration.

As an alternative to investigating officers’ estimates of speed, researchers sometimes use the posted speed limit in seeking the relationship between speed and truck safety. Again, this introduces an error of unknown magnitude which must be accounted for in a controlled scientific study.
Speed estimates of investigating officers and reliance on posted speed limits are certainly useful for general findings and general comparisons of crash groups. But at this point, there is little scientific data to support the exact degree of involvement of speed in causing a truck crash or the degree of damage done to the vehicles. Accurate scientific research to quantify the relationship between OS/OW truck weight and speed during a crash sequence is badly needed and highly desired as a way to help understand truck collisions and improve truck safety. One way to improve speed estimates could be obtained through widespread training of more crash investigation officers in understanding the intricacies of truck braking while controlling the units of an articulated vehicle.

Vehicle Roadway Interaction

Many sections of the Interstate System were designed 50 years ago and some of the NN roads were designed as much as 70 years ago. They were designed to handle the characteristics of the “design vehicle” (turning radii, lane width, slope of hills, sight distance, etc.). That was typically the largest vehicle using the roadway in question at the time the road was designed (NHTSA, 2005b). But since then, commercial motor vehicles have drastically increased in size, weight, and speed. Consequently, today’s OS-OW vehicles are often traveling on highways designed for smaller, lighter, and slower commercial trucks.

Roadway characteristics, especially for older roads, can contribute to crashes. The following sample of truck-highway interactions demonstrates how they contribute to truck accidents:

- Highway type has a primary effect on the number, type and severity of truck crashes.

- Safety-deficient characteristics of larger trucks include operation on horizontal curves, superelevation, skid resistance and passing sight distance (Eicher, et al. 1986).

- Off-tracking is a major concern especially in areas where multi-trailer combinations are prevalent (FHWA Vol. 1, 2000).

- Because of their irregular size, oversize vehicles can sometimes disrupt a perfectly working roadway. One example is when larger vehicles block the view of highway signs that would normally be accessible by all motorists (FMSCA, 2007).

- Kentucky researchers related that truck acceleration is a problem in the hilly portion of the state. Heavy trucks drop to crawl speed (about 15 mph) on long upgrades, which leads to an increase in rear end crashes when approaching vehicles do not recognize that the trucks are at low speed until it is too late to stop safely.

- Heavy truck rollovers tend to occur more often on freeway ramps, especially when they have tight radii. Off ramps have more crashes than on ramps, typically because the driver underestimated the sharpness of the ramp curve and did not reduce speed sufficiently.
• More serious large-truck single-vehicle crashes occur on curved sections than on straight sections (Eicher, et al. 2002).

• For LCV operations there appear to be several critical road issues: lane and shoulder width on horizontal curves, intersections and access points, shoulder and pavement integrity, stopping and intersection sight distances, and vertical grades (Montufar and Associates, 2007).

Drivers

Driver skill, age, training and other factors play prominent roles in driver safety and crash avoidance. For example, prior to the introduction of antilock truck brakes, the skill of the driver was the key ingredient in the stopping distance for trucks with conventional braking.

Kentucky researchers noted that truck drivers compensated for reduced operating capabilities of larger and heavier trucks (Pigman and Agent, 1999). But they also indicated that drivers of other vehicles exhibited behavior that contributed to truck crash rates. For example, when approaching curves, slowed down and shifted the lateral placement of their vehicles, both of which are undesirable.

Truck drivers also contribute to crashes though poor driving habits, impairment from fatigue or drugs/alcohol, weak training and other factors. The discussion of the role of truck drivers is minimized in this section of the report, but it will be discussed in greater detail in the review of truck crash statistics and trends.

Prominent Crash Types

The way a driver applies conventional truck brakes in a crucial situation is important. Locked wheel braking causes the wheel to skid. Once skidding begins, momentum takes over and the wheel continues traveling in a straight line unless acted upon by some additional force. The steering wheel is of no use once the front tires of a tractor start skidding. If the rear axle of either the tractor or the trailer start to skid first, it can be impossible for the driver to hold the tractor and trailer in alignment. Or on a horizontal curve, a truck with locked front wheels will continue to travel in a straight line and run off the road.

The most lightly loaded wheel begins to skid first. This makes loading the trailer very important. If the load is not balanced on the trailer, the tires on the lighter loaded side begin to skid before the tires on the heavier loaded side, causing the vehicle to pull to one side and potentially leading to loss of control.

In an emergency braking situation, the front of the tractor goes nose down as the tires skid. This is because the stopping force, tire friction, is at the pavement level and pushes backward, while the center of gravity of the truck is well above that and pushes the tractor forward. The same
thing happens to the trailer in an emergency braking situation; the front becomes lower and the rear becomes higher. There is an important consequence of this – the rear tires become more lightly loaded and will start skidding before the other tires. This can cause loss of control of the vehicle.

The simplest way to prevent skidding and provide control of the vehicle is to prevent the brakes from locking. This is called controlled braking, and it is achieved by applying the brakes in a pulsating manner. Antilock brakes are an example of how controlled braking is achieved (TRB Synthesis 3, 2003). But this is not the case for air brakes because pulsation “will result in the rapid depletion of the compressed air supply, which in turn results in a total loss of braking ability” (Harwood, et al. 2003a). Instead, a practice called “modulating” is used when a vehicle has air brakes. This is a very difficult task to perform without causing a wheel to lock, and only the most experienced drivers achieve the best results (Harwood, et al. 2003a).

At last three different types of crashes occur when wheels lock on a large truck, depending upon which wheels lock. They are commonly called plow out, jackknife, and trailer swing crashes. In the plow out, the front wheels of the tractor lock so that the driver cannot steer, but the tractor and trailer stay aligned. In the jackknife crash, the rear wheels of the tractor lock; then if the tractor and trailer get out of alignment the rear wheels begin to skid outward. The trailer swing crash is initiated when the rear wheels of the trailer lock and begin to skid sideways. These types of collisions are illustrated in Figure 4-1.

Drivers fear jackknifing because they have no control of the truck and the cab ends up sliding sideways. An impact in this mode can have severe results on the cab. Fortunately, relatively few truck crashes are the jackknife type. The University of Michigan Transportation Research Institute (UMTRI) annually conducts detailed investigations to gather supplementary data to merge with truck crash data. This creates a “truck involvement in fatal accidents” (TIFA) file that is the basis for the annual Factbook (Jarossi, et al. 2003; also 2004, 2005 and 2006). This reference document indicated that in fatal accidents involving large trucks, 96% of the time the crash did not involve jackknife. Only 1% of all truck accidents were caused by jackknife and 3% had it as a subsequent event during the crash sequence (Jarossi, et al. 2003).

![Figure 4-1. Three types of locked wheel crashes (Harwood, et al. 2003a).](image-url)
Two other prominent types of truck accidents are rollover (loss of roll stability) and rearward amplification behavior of multiple-unit vehicles (Ervin, et al. 1986). OS/OW vehicles are more prone to rollover than all other large trucks because their center of gravity is higher than other trucks (FHWA Vol. 1, 2000), and longer vehicles are more unstable than shorter vehicles. These are two types of crashes are also called steady-state turn induced rollover and evasive maneuver induced rollover.

The steady-state turn induced rollover typically occurs when a truck takes a curve so fast that the vehicle is not able to offset the lateral acceleration force acting on it. This type of truck rollover is often seen at entrance and exit ramps of interchanges. The height of the center of gravity (cg) of the load, the track width of the trailer, and the stiffness properties of the springs and tires are the primary factors that resist truck rollover (see Figure 4-2). In part “b” of the figure, the truck is moving along a sharp horizontal curve to the left. Centrifugal force is acting through the cg of the load and pushing it to the right. As the trailers begin to tilt, the cg of the load moves to the right and makes it easier for the left tires to lift from the pavement to initiate the rollover.

![Figure 4-2. Truck rollover factors (Harwood, et al. 2003a).](image)

A measure of the resistance to rollover is called the static roll stability (SRS). The SRS value for a trailer is the amount of lateral acceleration that causes a wheel to begin lifting off the pavement (i.e., the beginning of rollover). Typical values for a fully loaded semi-trailer are in the range of 0.30-0.33 g (9.6-10.7 ft/sec²). A typical automobile has an SRS about three times larger than this, so it takes about three times as much lateral acceleration to induce rollover of an auto as a truck.

The second situation that can easily induce rollover in LCVs is a sudden lateral maneuver by the driver that causes the movement to reverberate down the length of the vehicle. It is associated with higher speed vehicles (mostly above 50 mph) and is typically a sudden shift from one lane to another. It is called “rearward amplification” as successive trailers experience more rapid shifts than the previous ones. A “crack-the-whip” phenomenon occurs as the lateral movement is exacerbated by the time it reaches the rearmost trailer (FHWA Vol. 2, 2000), resulting in a rollover of the rear trailer, which may drag the other trailer(s) and the tractor over also.
Research has shown that lateral acceleration is increased by the following situations (Harwood, et al. 2003a):

- A larger number of trailing units,
- Shorter trailers experience more amplification than longer ones,
- Loose dolly connections,
- Greater loads in the rearmost trailers, and
- Increased vehicle speeds.

Although rollover crashes can be spectacular and gruesome, the data do not support that rollover crashes are a dominant cause of fatalities. In 2005 only 4% of truck crashes involved rollovers, but they led to 13.6% of all fatal truck accidents. In other words, this type of crash is three to four times more likely to produce fatalities than other types of truck crashes (4% of crashes cause 13.6% of fatal crashes).

Section Summary

This chapter has discussed some of the truck characteristics related to crash causation and crash severity. This included braking, type of truck, loads, speed, enforcement, driver, vehicle-road interaction, and specific types of crashes. The discussion identified ways in which these and other characteristics contribute to crashes. However, for most of these factors there have been too few scientifically controlled studies for a complete understanding of their interactions with each other and their contributions to crashes. Additional high-quality data must be obtained, and additional scientific studies are needed to provide that information.
5.0 Heavy Truck Crashes in General

Early Large Truck Safety Research

When the Surface Transportation Assistance Act of 1982 was enacted, it allowed longer, wider and heavier tractor-trailer trucks to operate on the nation’s roadway system. Truck operations and truck safety in the US came under close examination, and intensive research was directed toward these topics. This was important because both industries and agencies conducted research to develop safer and more efficient heavy commercial vehicles. Samples of the research findings and important issues are contained in the following paragraphs.

In the 1980s, excess speed was cited in 20% of all heavy truck accidents, more than any other factor. Beilock, et al noted, “Two factors most commonly associated with heavy vehicle accidents are speed too fast for conditions and the level of driver training” (Beilock, et al. 1989).

Eicher (19820 noted that, “More truck rollovers occur in large-truck accidents at freeway on- and off-ramps than in accidents at other locations. More occur on off-ramps than at on-ramps.” Eicher later found (2002) that many more serious large-truck single-vehicle crashes occurred on curved sections that straight sections.

In 1984, Olsen (1984) investigated braking by trucks and found that unloaded heavy trucks had much lower braking efficiencies than those achieved by cars. Experimental data showed that friction of truck tires was about 0.7 as much as passenger car tires. He also noted, “For locked wheel stops on a poor wet road, trucks require stopping distances that are approximately 1.2 times those attained by passenger cars. For controlled stops… trucks require stopping distances that are approximately 1.4 times those required for passenger cars.” Fancher also studied braking and pointed out that unlocked-wheel braking performance of empty trucks was a problem that needed improvement (Fancher and Mathew, 1990).

In 1985, Eicher wrote, “The lack of accident data collection on large trucks, the need for better on-site investigation of large-truck accident causation, and the necessity of more research on the behavior of large trucks on each functional class of roadway are discussed” (Eicher, et al. 1986). Interestingly, Eicher’s three needs (better accident data, site investigation, and truck behavior) have not been adequately addressed in the 23 years since he identified them.

Eicher also identified four safety-deficient design characteristics of larger trucks – operation on horizontal curves, superelevation, skid resistance and passing sight distance (Eicher, et al. 1986). He also identified two performance characteristics that were highly related to truck accidents – roll stability and rearward amplification of multiple-unit vehicle combinations (Ervin, et al. 1986). McGee published a list of high priority truck safety issues in 1986. This included safety
1986 research indicated that truck drivers were commonly thought to compensate for reduced operating capabilities of larger and heavier trucks. However, research showed that drivers of opposing vehicles altered the lateral placement of their vehicles when approaching larger or heavier trucks. “At sharp curves, opposing vehicles slowed down significantly and made other undesirable changes to pass large trucks” (Firestine, et al. 1989)

AASHTO formed an “Ad Hoc Group on Truck Size and Weight Research and Policy” to develop proposals for a set of national truck size and weight criteria and associated polices (AASHTO, 1990). The group recommended that criteria be developed for an 88,000-pound vehicle and for two new types of trucks under 80,000 pounds. Various safety enhancements to vehicles were considered, including antilock brakes, vehicle activity recorders, under-ride protection, air suspension systems, better tires, vehicle proximity alerts, and on-board weight scales.

Interestingly, many of the issues identified over 20 years ago continue to be problematic today. During preparation of this synthesis, UA researchers found that they are still important and that desired safety relationships, such as safety as a function and weight, length, size, etc., are not yet clearly defined.

More Recent Large Truck Safety Research

In the past decade traffic safety research has undergone a metamorphosis due to enhancements in data bases and computational tools, data mining, better control of variables in a study, and the development of advanced statistical methodologies to improve the confidence that can be placed in safety research findings. This is important because it was not uncommon to find that prior studies were limited or drew conflicting conclusions on a topic.

Two landmark recent studies illustrate that the highest level of safety study criteria and methodologies can be applied to groups of prior studies to draw stronger conclusions. In a 2002 study for the Montana DOT and the Western Transportation Institute to characterize commercial vehicle safety, Carson (2002) gathered large truck data for more than 6,500 commercial vehicle crashes that occurred in a seven year period. These crashes were matched to carrier profile information to examine crash trends. In addition the study critically reviewed almost 70 prior truck studies or publications. For example, 14 studies between 1969 and 1985 were evaluated on
the topic of single trailers versus doubles trailers. Samples of Carson’s findings pertinent to this study include the following:

- Driver fatigue was a noted contributor to large truck crash frequency.
- Older, more experienced drivers were found to be safer.
- Use of alcohol and drugs was a contributing factor to crash rates; however, this was confined to a low portion of drivers.
- The safety findings for various vehicle configurations were somewhat conflicting.
- There was good agreement among prior studies about gross vehicle weight (GVW); higher weights were associated with lower crash rates, but higher crash severities.
- Studies consistently showed that smaller carriers had higher fatal crash rates.
- Commercial vehicle crash rates and severities varied by roadway type, with rural roadways having less frequent but more severe crashes.

Later Carson, et al. (2007) performed a similar study on Texas large truck crashes. Three years of Texas data yielded over 44,000 truck crashes which were matched with carrier profile information. This data was buttressed by a thorough review of 160 research reports. Although there were few studies that directly addressed vehicle weight, but Carson did extract several useful pieces of information.

Vallette et al. (1981) concluded that truck crash rates varied inversely with truck weight for both double and single trailer combinations. Similarly, Polus and Mahalel (1983) observed a decreasing trend in crash rate and truck driver injury with increasing gross vehicle weight.

Conversely, Campbell et al. (1988) noted a moderate increase in single-unit and combination truck crash rates for higher gross weight, although the relatively small number of data points and the high degree of scatter make drawing conclusions from these data difficult.

Proponents of increased allowable size and weight vehicle limits purport little overall effect on highway safety; small possible increases in crash rates per truck-VMT would be approximately offset by the reduction in truck-VMT resulting from the new trucks’ higher productivity. Crash rates per ton-mile of highway freight are predicted to decline (Stowers et al. 1983). Considering crashes involving heavy truck between 1978 and 1987 - a time when truck sizes and weights dramatically increased in response to relaxed regulations in Manitoba, Canada – Clayton et al. (1989) reported essentially constant heavy truck crashes in terms of numbers and severity.
As for the relationship between vehicle weight and safety outcomes, the five studies noted by Carson had the following outcomes for increasing vehicle weight:

- 1981, Vallette et al. decreasing crash rate trend
- 1983, Polus and Mahalel decreasing crash rate trend
- 1983, Stowers et al. decreasing crash rate trend
- 1988, Campbell et al. moderate increasing trend
- 1989, Clayton et al. constant trend

Interestingly, the three earlier studies all found a decreasing trend, while the two later studies found otherwise. Given the data limitations of the 1988 study, this suggests that there might have been a decreasing or constant trend in the 1980s between heavy truck weight and safety outcomes. However, it is not a clear trend, and the implications for this synthesis project are unclear because none of the studies indicated whether the crash-involved vehicles were overweight.

Of particular interest to this synthesis was a statement identified by Carson in TRB Special Report 267 (2002) on the regulation of commercial vehicle weights, sizes and lengths “… there is a dearth of literature linking vehicle size and weight to large truck safety levels… studies conducted over the last 60 years have not yielded definitive conclusions.” One of the primary conclusions stated in the same document was, “It is essential to examine the safety consequences of size and weight regulation. Research and monitoring needed to understand the relationship of truck characteristics and truck regulations to safety and other highway costs are not being conducted today.”

In general, the Texas study findings reinforced the Montana study and expanded them. Sample findings from the Texas study that are appropriate to this synthesis include the following:

- Driver fatigue contributed to increased large truck crash frequencies and severities, though this was difficult to measure and was often defined differently from study to study.
- Both increased hours (industrial fatigue) and days (cumulative fatigue) of driving were associated with higher crash risk.
- Age and experience were noted contributors to large truck safety levels.
- Younger drivers consistently had higher crash involvement rates. Older, more experienced drivers were safer drivers but had increased fatality risk in a crash if the driver was age 51 or older.
- The findings were consistent about the effects of GVW; higher GVW resulted in lower crash rates but a higher crash severities. However, there were few historical studies to confirm this relationship.
- Smaller carriers generally had higher fatal crash rates than larger carriers, but the definition of a “small” carrier varied from study to study.
- Owner-operators had higher crash rates than drivers employed by a company.
- Local operation carriers had higher injury/fatality and overall crash rates than intercity operation carriers. Conversely, carriers with longer average hauls were observed to have lower safety levels.
- Crash severity decreased as the number of intrastate drivers increased; but increased as the number of trip-leased drivers increased.
- Higher gross revenues for the carrier and higher wages for the driver were both associated with higher levels of large truck safety.
- Higher degrees of either horizontal or vertical roadway curvature resulted in a higher crash frequencies.
- The effect of speed limits on safety levels was unconfirmed, whether the speed limit was uniform or differentiated by vehicle type.

Enforcement

Enforcement is a primary safety tool, because it is a deterrent to drivers and vehicles that exhibit actions or situations that decrease safety. Examples include violation of regulations or state code for size, weight, speed, load, truck condition, brake condition, driving under the influence, failure to maintain the driver’s log or similar issues. Either drivers or trucks can be placed out of service for serious violations.

As part of the preparation of this synthesis, interviews were conducted with managers of state police agencies or CMV enforcement units in the southeastern US. Interestingly, many indicated they did not consider that speed played the major role in crashes, nor did they think it was the primary cause of truck crashes. They thought that improper lane changes, aggressive driving and similar driver actions were more likely to cause crashes.

Regardless of the type of violation enforced, issuing a citation to a truck in moving traffic is not an easy task. Stopping an offending commercial motor vehicle for enforcement purposes and later returning it into the traffic flow without creating a traffic hazard is one of the most challenging situations an officer can confront (FMSCA, 2002). Interviews with enforcement officials in both the US and Europe confirmed this. The director of a state police organization indicated that agency officers rarely stop a commercial motor vehicle on an Interstate highway. Instead, they usually escort the truck to a ramp where it is safer than stopping in moving traffic. And if it is difficult to stop a truck on an Interstate highway, it is virtually impossible to find a location to stop one on a two-lane rural arterial highway.
One CMV enforcement commander indicated that he thought that law enforcement officers are hesitant to pull over offending trucks because: (1) they know the driver needs to make a living, (2) there is often no place to pull the vehicle over, (3) they often don’t know what to do once the truck is pulled over because they may not have current specialized training and knowledge to conduct a vehicle inspection, evaluate log books, etc.

Placing more enforcement vehicles on the road helps. It is widely accepted that enforcement visibility and vehicle violations have an inverse relationship. This is especially true for overweight vehicles. As enforcement visibility goes up, the number of overloaded vehicles goes down (Taylor, et al. 2007).

The level of local and state funding, state code and regulations, and priorities are different from jurisdiction to jurisdiction. It is no wonder that enforcement practices vary from state to state. This means that heavy truck crashes are reported differently, compounding the issue of identifying safety trends and designing countermeasure programs.

Truck regulations are technical and complex, and enforcement officers need continuing specialized training to do the job efficiently. Often they depend upon grants from the FMSCA, the state DOT or the Governor’s Highway Safety Office to stay up to date in training and equipment. All states now have declining revenues and budget shortfalls. In many cases these shortfalls have resulted in reduced CMV enforcement activities. A survey of CMV enforcement directors showed that 57% now view lack of enforcement resources as a major concern (TRB Synthesis 10, 2006), because it is causing a decline in the completeness and accuracy of enforcement records.

A common theme among those interviewed in this project was the difficulty of staying up to date on truck regulations. One state motor carrier enforcement officer recalled confusion when some FHWA programs were transferred to NHTSA, then later transferred back. He lost his local contact person twice, and as a very busy man felt pushed to learn how to deal with different people in different agencies with different operating practices.

It is easy to see how this could happen. FMSCA focuses on safety of vehicles (tires, brakes, loads, etc.) and drivers (fatigue, falsifying records, risk taking, etc.). FHWA deals mainly with the road as infrastructure, the role of the road in crashes, and truck dimensions and weights as they affect infrastructure. Truck issues have different priorities and different perspectives in the two agencies. Upon the creation of FMSCA it absorbed some FHWA programs; some trucking issues fell between the cracks and local truck enforcement officials experienced trouble in maintaining their programs. Even though the issue has improved considerably since then, enhanced cooperation between the two agencies could lead to crossover uses of data for trucks, drivers, companies, enforcement, and other factors that could improve heavy vehicle safety.

Roadside Inspections

In spite of the difficulty in mastering heavy vehicle regulations and inspection procedures, about 180 million commercial vehicles are currently weighed across the nation each year and 3.3
million roadside inspections are performed (Harrison, 2008). As a result, over a recent three year period the Motor Carrier Management Information System maintained by NHTSA received 892,724 commercial vehicle size and weight violations.

Table 5-1 summarizes safety inspection actions over three years. It shows that approximately three million annual roadside inspections were performed. Amazingly, from 2000 through 2005, the percent violations issued was virtually constant at around 73% (TRB Synthesis 10, 2006).

Even with three million nationwide inspections annually, enforcement actions against drivers of heavy trucks and buses appear minimal when compared to actions against drivers of other types of motor vehicles (FMSCA, 2002).

**Weigh Stations**

One tool used by enforcement officers is the static weigh station. Truck weights can be captured quickly and there is space to perform inspections if needed. Due to today’s high volumes of large trucks, most stations have difficulty in accommodating even a significant percentage of heavy vehicles on the road (Bergan, et al. 1998). Recognizing the certainty of receiving a citation for an overweight load, some truck drivers find ways to dodge weigh stations and other enforcement actions.

### Table 5-1. Roadside Safety Inspection Activity Summary by Inspection Type (FHWA, 2006)

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
</tr>
<tr>
<td>All Inspections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number Inspections</td>
<td>(R) 3,019,872 100.0</td>
<td>(R) 3,019,262 100.0</td>
<td>2,867,124 100.0</td>
</tr>
<tr>
<td>w/ No Violations</td>
<td>(R) 812,783 27.0</td>
<td>(R) 810,814 26.9</td>
<td>772,850 27.0</td>
</tr>
<tr>
<td>w/ Violations</td>
<td>(R) 2,201,089 73.0</td>
<td>(R) 2,208,448 73.1</td>
<td>2,094,274 73.0</td>
</tr>
<tr>
<td>Driver Inspections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Inspections</td>
<td>(R) 2,957,646 100.0</td>
<td>(R) 2,962,085 100.0</td>
<td>2,808,360 100.0</td>
</tr>
<tr>
<td>w/ No Violations</td>
<td>(R) 1,883,071 63.7</td>
<td>(R) 1,893,106 63.9</td>
<td>1,782,300 63.5</td>
</tr>
<tr>
<td>w/ Violations</td>
<td>(R) 1,074,575 36.3</td>
<td>(R) 1,068,979 36.1</td>
<td>1,026,060 36.5</td>
</tr>
<tr>
<td>w/ OOS Violations</td>
<td>(R) 200,256 6.8</td>
<td>(R) 197,338 6.7</td>
<td>184,609 6.6</td>
</tr>
<tr>
<td>Vehicle Inspections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Inspections</td>
<td>(R) 2,164,847 100.0</td>
<td>(R) 2,252,986 100.0</td>
<td>2,093,394 100.0</td>
</tr>
<tr>
<td>w/ No Violations</td>
<td>(R) 675,167 31.2</td>
<td>(R) 698,396 31.0</td>
<td>649,658 31.0</td>
</tr>
<tr>
<td>w/ Violations</td>
<td>(R) 1,489,680 68.8</td>
<td>(R) 1,554,590 69.0</td>
<td>1,443,736 69.0</td>
</tr>
<tr>
<td>w/ OOS Violations</td>
<td>(R) 495,621 22.9</td>
<td>(R) 531,927 23.6</td>
<td>489,754 23.4</td>
</tr>
<tr>
<td>Hazardous Materials Inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Inspections</td>
<td>(R) 181,592 100.0</td>
<td>(R) 179,213 100.0</td>
<td>170,962 100.0</td>
</tr>
<tr>
<td>w/ No Violations</td>
<td>(R) 148,409 81.7</td>
<td>(R) 145,763 81.3</td>
<td>139,191 81.4</td>
</tr>
<tr>
<td>w/ Violations</td>
<td>(R) 33,183 18.3</td>
<td>(R) 33,450 18.7</td>
<td>31,771 18.6</td>
</tr>
<tr>
<td>w/ OOS Violations</td>
<td>(R) 9,575 5.3</td>
<td>9,957 5.6</td>
<td>9,496 5.6</td>
</tr>
</tbody>
</table>

Key: OOS = out of service; R = revisited.
When drivers of oversize or overweight vehicles notice that a weigh station is open, some purposely lag to the rear of a large group of trucks. As the station becomes saturated with the initial trucks in a platoon, it has to close temporarily to process the vehicles already in line. This allows the OS/OW driver to bypass the station. This technique is called “plugging” (Taylor, et al. 2007). To combat the plugging practice, some states use weigh-in-motion (WIM) devices to pre-weigh CMVs as they approach the station. That way they detain only those which are already known to be OS/OW. This practice is cost effective for weigh stations and reduces delays to trucks (Bergan, et al. 1997).

Another enforcement avoidance practice used by truck drivers is to avoid weigh stations all together. According to the article “Heavyweight Safety,” if a weigh station is open, up to 14% of truck drivers will try to dodge it, and some are willing to travel as far as 160 miles to avoid a weigh station (Taylor, et al. 2007This usually involves a shift to secondary roads, although enforcement officers can combat the traffic shift by utilizing portable WIMs on the secondary routes (Taylor, et al. 2007). Interviews conducted during preparation of this synthesis confirmed the problem of OS/OW trucks dodging weigh stations. One state CMV enforcement director said, “About 90% of overweight truckers go around the fixed scales. Even if the trucks are not in violation of weight, they feel that their trip will be slowed too much if they go through the weigh station.” Another CMV state enforcement director said, “Our problem is with intrastate truckers hauling seasonal loads. They dodge scales and drive at night to dodge enforcement.”

Overview of Fatal Large Truck Crashes

Trend in Fatalities

In the US large trucks are involved annually in crashes that cause over 5,000 fatalities and more than 125,000 injuries. In 2005, 5,212 people were killed in large truck crashes, approximately 12-13% of all traffic fatalities that occurred that year (NHTSA, 2005a). Fatal truck crashes for a 30-year period are shown in Figure 5-1.

![Figure 5-1. Fatalities in crashes involving large trucks, 1975-2005 (NHTSA, 2005a).](image-url)
Even though the number of annual large truck crash fatalities is now rising slowly, they are still 23% lower than the distinct all-time-high in 1979. The decrease is comprised of a 45% drop in truck occupant fatalities and a 16% drop in fatalities of passenger car occupants involved in heavy truck accidents (IIHS, 2007). This dispels a common myth – that the number of fatalities caused by large trucks is increasing rapidly.

The fatality rates for both passenger vehicles and large truck occupants declined over the past 25 years. There has been a 10% drop in the rate of fatal truck crashes per 100,000 trucks and a 14% drop in the VMT death rate. But the severity of truck crashes is high considering that large trucks account for only 3% of all registered vehicles, but 12-13% of fatal crashes. In other words, large truck crashes are about four times more severe than crashes where large trucks are not involved.

**Distribution of Fatalities**

Another concern regarding truck crash fatalities is the distribution among the crash victims. Passenger vehicle occupants are the most vulnerable in large truck crashes. This is largely due to the energy associated with large truck weights, which are 3 to 20 times heavier than passenger vehicles. In 2005, 68% of the fatalities (3,561) were the occupants of passenger vehicles involved in truck crashes (NHTSA, 2005a). This is illustrated by Figure 5-1, which shows that over a 20-year period there were many fewer fatalities among truck drivers than fatalities in the other vehicle involved in a truck accident.

**Crash Most Harmful Event**

Table 5-2 tabulates truck crash severity as a function of the most harmful event in the crash sequence. Of the 442,000 truck crashes in 2005, the dominant type (69.9%) involved a large truck impacting another motor vehicle in motion. In about one-third of these crashes, the impact area was the front of the truck. Of fatal crashes involving large trucks, frontal impact occurred in over 60% of vehicle-to-vehicle crashes and almost half (46.8%) of all impact scenarios (NHTSA, 2005a). The second most prevalent impact point for fatal crashes was the rear of the truck (15.0%), often in the form of under-ride accidents. A relatively small portion of fatal truck crashes (3.5%) involved collisions with fixed objects, while a more significant type of crash involved collisions with non-fixed objects (10.5%). This latter category is particularly troublesome, since these crashes commonly resulted in the death of someone outside of a vehicle (8.6%).
Speed

The TIFA Factbook 2005 (Jarossi, et al. 2005) noted that speed was a factor in fatal crashes. Over 73% of all fatal truck accidents involved speeds greater than or equal to 55 mph. This makes sense since most of these vehicles are involved in over-the-road delivery of freight and operate on high speed, high quality arterial roadways and Interstate highways.

In addition to enforcement, there are other ways to control truck speeds. Ontario, Canada has an aggressive program to track heavy trucks through GPS units, and they analyze the data for planning purposes. Some of this data will be very useful in future safety studies. As part of its overall heavy truck safety program, the provincial government recently passed a bill mandating use of “speed limiters” on most large trucks to cap speeds at 105 kilometers per hour (65.2 mph). This will improve both safety and environmental emissions (Trucking Info, 2008).

Prevalent Characteristics

In fatal crashes involving large trucks, 73% involved combination trucks (NHTSA, 2005a, Jarossi, et al. 2005). In 72% of the crashes, the roadway had two travel lanes, followed by four lanes (13%) and three lanes (10%). Some other key characteristics include that most fatalities occurred in rural areas (≈ 65%), during the daytime (≈ 67%), and on weekdays (≈ 81%) (Jarossi, et al. 2005; NHTSA, 2005b). During the work week, around 70% of the crashes occurred during the daytime, with the highest proportion occurring from noon until about 4:00 p.m. On weekends, fatalities were distributed throughout the day (Jarossi, et al. 2005).
**Driver Factors in Fatal Crashes**

The previous discussion of Carson’s studies illuminated many driver factors (age, experience, trip length, etc.) that affect crash rates. The 2005 TIFA Factbook (Jarossi, et al. 2005) contains additional information about driver involvement. One interesting pattern involved prior incidents of truck drivers in fatal crashes. Incidences were categorized as prior accidents, license suspensions, speeding citations, and other moving violations. For all categories, 69% of truck drivers in fatal crashes had zero previous incidences, 13% had one previous incidence, and 14% had two previous incidents. Less than 4% had previously been involved in more than two crashes or received two citations or license suspensions. Only one-fourth of the involved drivers had ever been in a previous crash. Overall, prior incidences among truck drivers are much better than among automobile drivers.

The Factbook also examined driver fatigue as a factor in fatal truck crashes (Jarossi, et al. 2005). About 37% of the time, the duration of a trip prior to the collision could not be determined. But where the time was known, in 29% of the crashes the truck driver had been on the road for one to two hours, and in 14% of the crashes the driver had been on the road for two to four hours. In only 3% of fatal truck crashes had the driver been behind the wheel for more than eight hours.

**Truck Configurations**

Annual data for truck configurations involved in fatal crashes can be found in the TIFA Factbook (Jarossi, et al. 2005). The 2005 values are reproduced as Table 5-3 of this synthesis. In general, fatal crashes appear to resemble the distribution of individual truck configurations in operation on the nation’s highways. For example, individual straight trucks (SUs) and tractor semi-trailers are the dominant vehicles in use in the US. Table 5-3 indicates that these two classifications accounted for 89.9% of fatal crashes. SUs accumulated 30.8% and tractor semi-trailers 59.1%. The remaining fatal crashes are scattered throughout the classifications in the table.

It is worth noting that trucks with triple trailers were involved in only four fatal crashes in 2005 (0.1% of national total). The probable reasons for the low number of fatalities are that triples are allowed in only 13 western states so there are fewer of them, and their routes are mostly on Interstate and other high quality highways. Another factor is that freight firms assign their best drivers to them, because the extra trailer adds additional value to the cargo.
Table 5-3. 2005 Fatal Involvements by Truck Configuration (Jarossi, et al. 2005)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Straight trucks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight truck only</td>
<td>1647</td>
<td>30.8%</td>
</tr>
<tr>
<td>Straight truck, 1 trailer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight + full trailer</td>
<td>38</td>
<td>0.7%</td>
</tr>
<tr>
<td>Straight + other</td>
<td>129</td>
<td>2.4%</td>
</tr>
<tr>
<td>Straight + other (gooseneck hitch)</td>
<td>48</td>
<td>0.9%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>215</td>
<td>4.0%</td>
</tr>
<tr>
<td>Other straight combinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrecker + two</td>
<td>11</td>
<td>0.2%</td>
</tr>
<tr>
<td>Straight, unknown if pulling trailer</td>
<td>5</td>
<td>0.1%</td>
</tr>
<tr>
<td>Straight + 2 full trailers</td>
<td>1</td>
<td>0.0%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>17</td>
<td>0.3%</td>
</tr>
<tr>
<td>Total straight trucks</td>
<td>1879</td>
<td>35.2%</td>
</tr>
<tr>
<td><strong>Tractor combinations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor, no trailers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bobtail tractor</td>
<td>90</td>
<td>1.7%</td>
</tr>
<tr>
<td>Tractor carrying cargo</td>
<td>3</td>
<td>0.1%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>93</td>
<td>1.7%</td>
</tr>
<tr>
<td>Tractor, 1 trailer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor and semi-trailer</td>
<td>3159</td>
<td>59.1%</td>
</tr>
<tr>
<td>Tractor + other (non semi-trailer)</td>
<td>11</td>
<td>0.2%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>3170</td>
<td>59.3%</td>
</tr>
<tr>
<td>Tractor, 2 trailers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double, A dolly</td>
<td>124</td>
<td>2.3%</td>
</tr>
<tr>
<td>Double, B train</td>
<td>1</td>
<td>0.0%</td>
</tr>
<tr>
<td>Double with unknown dolly</td>
<td>6</td>
<td>0.1%</td>
</tr>
<tr>
<td>Tractor + semi-trailer + full trailer</td>
<td>53</td>
<td>1.0%</td>
</tr>
<tr>
<td>Tractor + semi-trailer + unknown</td>
<td>1</td>
<td>0.0%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>185</td>
<td>3.5%</td>
</tr>
<tr>
<td>Tractor, 3 trailers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triple, A dollies</td>
<td>3</td>
<td>0.1%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>3</td>
<td>0.1%</td>
</tr>
<tr>
<td>Other tractor combinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor + 3 saddle-mount trailers</td>
<td>1</td>
<td>0.0%</td>
</tr>
<tr>
<td>Subtotal</td>
<td>1</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total tractors</td>
<td>3452</td>
<td>64.6%</td>
</tr>
<tr>
<td>Unknown</td>
<td>12</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>5343</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

**Weights and Sizes of Trucks in Fatal Crashes**

Data for crash involvement of standard lengths and weights of trucks are given in Table 5-4. The weight and dimensional data were gathered from crash reports, inspection records, owner’s records, and similar sources.
For length involvement in fatal crashes, the three categories from 56 to 75 feet had higher levels of involvement than other categories, about 45% of all fatal crashes. As for weight, there seemed to be two clusters. Almost 20% of fatal crashes were in the range of 25,001-35,000 pounds (SU vehicles), and 11% were in the category of 70,001-75,000 pounds (tractor semitrailers).

<table>
<thead>
<tr>
<th>Length in feet</th>
<th>%</th>
<th>Weight in pounds</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;16</td>
<td>0.1</td>
<td>≤ 5000</td>
<td>0.0</td>
</tr>
<tr>
<td>16-20</td>
<td>4.8</td>
<td>5,001-10,000</td>
<td>5.3</td>
</tr>
<tr>
<td>21-25</td>
<td>10</td>
<td>10,001-15,000</td>
<td>6.4</td>
</tr>
<tr>
<td>26-30</td>
<td>8.5</td>
<td>15,001-20,000</td>
<td>4.8</td>
</tr>
<tr>
<td>31-35</td>
<td>2.4</td>
<td>20,001-25,000</td>
<td>4.0</td>
</tr>
<tr>
<td>36-40</td>
<td>1.8</td>
<td>25,001-30,000</td>
<td>11.0</td>
</tr>
<tr>
<td>41-45</td>
<td>1.8</td>
<td>30,001-35,000</td>
<td>8.8</td>
</tr>
<tr>
<td>46-50</td>
<td>3.5</td>
<td>35,001-40,000</td>
<td>3.8</td>
</tr>
<tr>
<td>51-55</td>
<td>8.1</td>
<td>40,001-45,000</td>
<td>2.9</td>
</tr>
<tr>
<td>56-60</td>
<td>15.6</td>
<td>45,001-50,000</td>
<td>2.7</td>
</tr>
<tr>
<td>61-70</td>
<td>18.5</td>
<td>45,001-50,000</td>
<td>3.0</td>
</tr>
<tr>
<td>71-75</td>
<td>10.7</td>
<td>55,001-60,000</td>
<td>3.0</td>
</tr>
<tr>
<td>76-80</td>
<td>0.9</td>
<td>60,001-65,000</td>
<td>3.1</td>
</tr>
<tr>
<td>81-85</td>
<td>0.2</td>
<td>65,001-70,000</td>
<td>4.4</td>
</tr>
<tr>
<td>86-90</td>
<td>0.2</td>
<td>70,001-75,000</td>
<td>10.7</td>
</tr>
<tr>
<td>91-95</td>
<td>0.1</td>
<td>75,001-80,000</td>
<td>1.2</td>
</tr>
<tr>
<td>96-100</td>
<td>0.1</td>
<td>80,001-85,000</td>
<td>1.2</td>
</tr>
<tr>
<td>101+</td>
<td>0.2</td>
<td>85,001-90,000</td>
<td>0.5</td>
</tr>
<tr>
<td>unknown</td>
<td>7.6</td>
<td>≥ 90,001</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 90,001-100,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100,001-110,000</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110,001-120,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120,001-130,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>130,001-140,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>140,001-150,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150,001-160,000</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160,001-170,000</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 170,001</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unknown</td>
<td>16.8</td>
</tr>
</tbody>
</table>

Bold italic font designates overrepresented lengths or weights (i.e., a greater than average proportion of crashes in the designated categories)

More data is needed to interpret the table. For example, there is a spike for crashes in the 70,001 to 75,000 pound category. But the number of crashes in that category might simply reflect the
number of vehicles on the road in that category. Data is also needed for the number of miles driven in each category. Crash rates cannot be calculated for any category of length or weight unless the total number of miles driven annually is known for that category. But of those miles, how many were driven on (very safe) Interstate highways as opposed to older (much less safe for large trucks) county roads? What was the average speed in a given category compared to another category? What was the prevalent load carried? These questions illustrate the types of data needed to conduct a scientifically grounded analysis of truck crashes as a function of weight and speed. There are many other contributing factors that must also be considered.

The table contains data for the number of vehicles in fatal crashes weighing more than 80,000 pounds or over 80 feet in length. This is the first crash data in this synthesis that indicates vehicles that might exceed weight or dimensional limits. But there are not many of them. For this synthesis, the most important data in Table 5-4 show that a large majority of fatal truck crashes occurred below the maximum allowable weight and maximum length set by the 1982 STAA. Of fatal crashes, 81.3% involved trucks weighing 80,000 pounds GVW or less. Less than 3% of trucks in fatal crashes exceeded the weight limit, and less than 1% exceeded 80 feet. However, the STAA prescribes weight limits for SU trucks and other classifications based on their axle patterns. So many trucks in Table 5-4 could be in violation of the weight regulations for their vehicle types and axle loads. This illustrates the limitations of many of the existing large truck data sets. Additional supporting data are needed to understand them and to use them in scientific studies.

On the other hand, vehicles in Table 5-4 that appear to exceed the federal regulations for size or weight could have been operating under a permit approved by a state highway agency, or could have been operating on a road grandfathered by the STAA, or could have been operating under state approved exclusion legislation. This fact and the brief discussion in the past few paragraphs illustrate why many data sets currently available are not sufficient to isolate and analyze OS/OW vehicle crashes.

Section Summary

The literature now includes research on a good number of heavy truck crash trends and factors. This section of the synthesis overviewed many of them, including early and more recent research results, the trend in fatalities, the distribution of fatalities among the involved vehicles, the most harmful event in the crash sequence, speed, enforcement, driver, truck weight and size, and other pertinent factors.

But, the literature yielded very little crash data on OS/OW commercial vehicles. Where data is available, it does not include sufficient information for a controlled scientific study. There remains a need for crash exposure (number of crash opportunities, for example miles driven) to be determined for individual classes of trucks, and for sufficient supporting data (i.e., road system used, driver characteristics, type of load) for these categories. Until that information is known, it will be difficult or impossible to conduct higher level scientific analyses of large truck crashes to help identify causation, severity and critical issues in these crashes.
6.0 Data Associated with OS/OW Heavy Vehicles

This section of the synthesis presents some of the challenges in gathering and interpreting data for OS/OW crashes, reviews examples of that data and the results of prior studies, and indicates what is now known about the relationship between size/weight and safety.

Two Meanings for OS/OW Vehicles

The objective of this synthesis was to identify the safety implications of OS/OW commercial vehicles. But during project interviews CV enforcement officers seemed to have two meanings of the term OS/OW:

- There is the legal definition – vehicles that have been weighed or measured and found to exceed the applicable TSWs.

- There is a subjective and less obvious meaning – vehicles with the size, weight, condition or a combination that make them look or operate differently (larger, heavier) than other large commercial vehicles.

For the first definition, data pertinent to this synthesis may be found from the records of investigating officers who measured or weighed vehicles after crashes. Lacking that data, it may sometimes be established by starting with the crash record for a specific truck, and assembling supporting data from files of entities involved with the truck (i.e., WIM or virtual WIM files, records of the shipper or receiver, freight firm, driver, law enforcement and others). The latter method is a long and arduous process that may or may not establish the weight or dimensions of an OS/OW vehicle involved in a crash. But that time could be shortened considerably if provisions are made to automatically truck weigh station, WIM and virtual WIM data with federal and state DOT safety offices.

The second definition is informal and varies from person to person. For some people, trucks that are operating legally beyond normal limits (for example LCVs) sometimes seem too large or awkward to law enforcement officers, and are called as OS/OW. Data for the second meaning of OS/OW may be found in safety studies involving larger or heavier vehicles, especially LCVs. Numerous reports provide general information about this type of truck crash, but few contain robust findings regarding size, weight and accident causation.
Comprehensive Data is Necessary

When interpreted correctly, raw data for OS/OW trucks involved in collisions can provide general trends and comparative numbers, but they are not sufficient to determine why or how these collisions happen. This is underscored by the following statements from a national study:

The Comprehensive Truck Size and Weight Study, Volume 1 (FHWA Vol. 1, 2000) conducted an extensive review of prior studies that failed to identify the relationship of size and weight of large CVs to crash rates or crash severities. The investigators identified three factors that made it difficult to isolate this relationship:

- After a crash, investigating officers rarely knew the weights or dimensions of involved large CVs, so this information was seldom included on written crash reports.

- Data is available for the number of crashes within individual classifications of trucks, but the same data detail is not available for the number of miles driven by vehicles in individual classifications. This is especially true for the largest classifications, which makes it difficult to estimate crash rates.

- Even when crash rates can be estimated for the largest commercial vehicles, the rates may not translate to other types of roads or other geographic locations. These vehicles travel almost entirely on the Interstate System or similar high quality highways, which have lower crash rates than other road types. So it is not rational to compare their crash rates to those of trucks that operate exclusively on lower quality roads that have much higher crash rates.

Volume III of the same study (FHWA Vol. 2, 2000) indicated that isolating the effects of size and weight on crash rates is difficult, as illustrated by the following statements of both limitations and study findings:

- One reason is that LCVs and other larger and heavier trucks constitute such a small portion of all truck travel. Even in situations where general truck data are sufficient to draw conclusions about the causes and severities for truck crashes, the data are less capable of differentiating trends for smaller subsets like the largest and heaviest trucks.

- “Available data sets are capable of differentiating between the crash experiences of single-unit trucks and combination vehicles… truck crash data are available which distinguish between single-trailer and multitrailer combinations… Differentiation among the number or lengths of trailers in these combinations, or their operating weights, is typically not possible from reported data.”

- “Few of these past studies controlled for the confounding factors that can significantly influence overall crash rate results, principal among those being differences in operating environments.” In other words, there are many variables that can contribute to a single crash (multiple factors each for the driver, the vehicle, and the roadway environment).
An ideal data set would contain accurate data values for all factors that influence a crash, for each vehicle in the crash. But most data sets do not include sufficient factors or complete data for each factor. If data values cannot be identified for these factors, or if the factors cannot be controlled, it is very difficult to find truth in the data.

- In spite of the limitations of available data, it is possible to draw conclusions about key trends. For example, multiple studies have demonstrated that truck crash rates are higher for undivided, higher speed roads than for Interstate and similar highways. Another example is that roads with higher traffic density and increased conflicts (intersections, side friction, etc.) increase the opportunities for truck crashes.

- The policies and regulations for TSWs contribute to truck crashes because they directly affect weight, track width, wheelbase, axle spacing, overall length, number of units, and similar factors. Collectively, the interaction between these factors plays a key role in truck control and stability. Trucks of different type, size and configuration behave differently, with most larger and heavier commercial vehicles being more susceptible to crash types like rollover. They are also more difficult to control during an emergency or an accident sequence.

**Data Sets with Promise**

Currently there exist few data sets capable of supporting such a thorough analysis. Several with potential are identified here. At the moment none of them contain sufficient data items or enough truck crashes to provide the desired relationship between OS/OW trucks and safety. But these data files have potential if they are expanded and continued on a large scale.

The literature indicates that some comprehensive data bases have been assembled, containing many parameters involved in heavy truck crashes. So far these efforts have been by individual researchers for individual projects, and by a few agencies and organizations on a continuing basis.

**WIM**

One way to expand truck safety data is through truck weight databases like weigh station data, WIM data and virtual WIM data. These systems collect CMV weight data continuously on many main roads. Where a common vehicle identifier is available, measured weight records can be pulled directly from upstream WIM systems and integrated into truck safety databases for downstream routes. This offers opportunities to combine WIM data with existing truck safety data sets to produce more robust information regarding crashes of individual heavy trucks. This could significantly advance the state of safety knowledge on this topic and prove to be a cost effective data collection method over time.

Even though there are many advantages of using WIM weight data for truck safety studies, it is not a universal solution. There are too few WIM sites to capture data on all trucks. Also, some
existing WIM sites may not be able to obtain or communicate vehicle identification information. For individual crashes, trucks might offload between the WIM site and the traffic crash, or might take other actions that make it difficult to relate the particular vehicle and particular load to the WIM station data. But overall, WIM data appears to be a logical addition to truck safety data sets. Over time it should improve the scientific accuracy of truck safety studies.

Expansion of WIM and virtual WIM stations appears to be desirable for infrastructure protection, enforcement planning and operations, and truck safety reasons. As additional sites are developed, it would be very helpful to ensure that the collected data can be communicated to agencies desiring truck weights for safety purposes.

**LTCCS**

The Large Truck Crash Causation Study (LTCCS) assembled a comprehensive truck database (FMSCA, Jan 2006). Crash records were merged with information about the firm owning the truck and the specific load involved in the crash, along with other pieces of information. This required time consuming human effort to gather, validate, and merge the data items. Currently this database contains less than 1,000 crashes. It supports research in specific topics, but it is not all inclusive and requires additional data items and many more records of individual crashes to unlock the relationships involved in a complex truck accident sequence.

The nature of the data set is to promote collision avoidance and crash prevention. In other words, data is gathered to provide knowledge about a specific crash type that might prevent or minimize the future occurrence of this type of collision. For an individual crash, data collection starts by defining one critical event. This is the “starting point for the LTCCS data collection, as it is for the analysis. All the other data essentially builds out from the critical event.”

**TIFA**

UMTRI annually conducts detailed investigations to gather supplementary data to merge with truck fatal crash data. This creates a large data file for fatal accidents (TIFA) that is the basis for the annual *Truck Involvement in Fatal Accidents Factbook* (Jarossi, et al. 2003; also 2004, 2005 and 2006). The *TIFA Factbooks* were used throughout the research for this synthesis project, and provided data for many of the tables in Section Five.

As with the LTCCS data, the TIFA file does not contain all desired data items to determine crash rates or fatal crash rates for subgroups of vehicles, or to determine the interactions between contributing factors for an OS/OW crash.

**Individual Research Studies**

Another method to study OS/OW crashes is for an individual researcher to assemble a large data set within a specific state with the cooperation of multiple agencies within that state. Such a study could be regional if sponsored by a federal agency.
Two such studies were reviewed in Section Five of this synthesis. In 2002 Carson conducted a major investigation in Montana (Carson, et al. 2002). She gathered large truck data for more than 6,500 commercial vehicle crashes that occurred in a seven year period, and matched them to carrier profile information. To supplement this data, she critically reviewed almost 70 prior truck studies or publications. In 2007, Carson, et al., (2007) performed a similar study on Texas large truck crashes. Three years of Texas data yielded over 44,000 truck crashes which were matched with carrier profile information. This data was supported by a critical review of 160 research reports. Carson used modern approaches to evaluate data and control confounding variables, and advanced statistical procedures. This type of research, if conducted regionally or nationally offers promise of finding answers.

The previous paragraphs established that there are multiple definitions for OS/OW, that large comprehensive data sets are needed for definitive answers, and that current data collection methods do not provide that data. The synthesis will next discuss what is known about trucks that are oversize or overweight and have been involved in crashes.

**Data for Which OS/OW was Established or Probable**

During the literature review a few examples of OS/OW data were identified. The first of these was data on the lengths and weights of trucks involved in fatal crashes, shown in Table 5-4 earlier in this synthesis. That information has been extracted and reproduced as Table 6-1 for additional discussion in this section.

<table>
<thead>
<tr>
<th>Length in feet</th>
<th>Weight in pounds</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>80 ft or less</td>
<td>Less than 80,000</td>
<td>80.3</td>
</tr>
<tr>
<td>Unknown</td>
<td>Unknown</td>
<td>16.8</td>
</tr>
<tr>
<td>81-85</td>
<td>80,001-85,000</td>
<td>1.2</td>
</tr>
<tr>
<td>86-90</td>
<td>85,001-90,000</td>
<td>0.5</td>
</tr>
<tr>
<td>91-95</td>
<td>90,001-95,000</td>
<td>0.2</td>
</tr>
<tr>
<td>96-100</td>
<td>95,001-100,000</td>
<td>0.1</td>
</tr>
<tr>
<td>101+</td>
<td>100,001-110,000</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>110,001-120,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>120,001-130,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>130,001-140,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>140,001-150,000</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>150,001-160,000</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>160,001-170,000</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>≥ 170,001</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The information in Table 6-1 constitutes a relatively small portion of total fatal truck involvements. In addition, there is no way to confirm that they are OS/OW vehicles. The crashes could have occurred in states where their size and weight were grandfathered, or they
could have been given exclusion from state TSWs, or they could have been issued OS/OW permits by a state highway agency. It is possible that the vehicles in the left (length) column are LCVs, but this cannot be determined from the data. If they are LCVs, it is impossible to determine which types of LCVs are involved. In addition, exposure data is missing so fatal crash rates cannot be estimated. A good summary of the table is that the information is interesting, but not helpful for the primary purpose of this synthesis.

For several years through 2004, the TIFA Factbook included a limited amount of information about LCVs known to be oversize or overweight and involved in fatal accidents. Examples of this information are shown in Tables 6-2, 6-3 and 6-4. Table 6-2 contains two types of data. First it displays 39 LCV crashes with fatal involvement, by LCV subcategory with percent involvement for that subcategory. Second it shows each subcategory as a percent of all truck fatal crashes in 2004 (added by UTCA researchers).

<table>
<thead>
<tr>
<th>Combination Type</th>
<th>LCV Fatal Crashes</th>
<th>*LCV % All Fatal Truck Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Rocky Mountain Double</td>
<td>9</td>
<td>23.1</td>
</tr>
<tr>
<td>Turnpike double</td>
<td>6</td>
<td>15.4</td>
</tr>
<tr>
<td>Other LCVs</td>
<td>15</td>
<td>38.5</td>
</tr>
<tr>
<td>Overweight</td>
<td>9</td>
<td>23.1</td>
</tr>
<tr>
<td>Triple</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*There were 4,902 fatal truck crashes in 2004, from Table 3-1

Table 6-3. Fatal Truck Involvement and Fatalities for Selected Combination Types (Jarossi, et al. 2004)

<table>
<thead>
<tr>
<th>Combination Type</th>
<th>Involvements</th>
<th>Total Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longer combination vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over length</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Over weight</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Both</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Triple</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>39</td>
<td>41</td>
</tr>
<tr>
<td>Non-LCV tractor and two trailers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STAA double</td>
<td>91</td>
<td>118</td>
</tr>
<tr>
<td>Unknown double</td>
<td>26</td>
<td>38</td>
</tr>
<tr>
<td>Subtotal</td>
<td>117</td>
<td>156</td>
</tr>
<tr>
<td>Other tractor combinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor Semi-trailer</td>
<td>3,160</td>
<td>3,369</td>
</tr>
</tbody>
</table>

This is an improvement over the data presented previously, because it pertains to only LCV vehicles, but it still does little to enhance the overall understanding of the relationship between OS/OW and safety. Exposure data is not given, so it is not possible to estimate crash rates to compare within subcategories or to other large truck types. Nor is there sufficient detail to
identify the factors that contributed to causation or severity of these crashes. With such a limited number of crashes (only 39, or 0.8% of all truck fatal crashes), it is not possible to draw sweeping conclusions about any of these topics.

Table 6-3 is similar to Table 6-2, but with additional details. It compares the 39 fatal LCV crashes to crashes of double trailers that did not exceed 80 feet in length, and to crashes of tractor semi-trailers. This additional information is helpful in seeing the big picture of fatal truck crashes, but does not provide the level of detail desired for this synthesis. There are no supplemental data that relate safety to truck size. Nor are there exposure data for any of the truck categories or subcategories, so rates cannot be calculated. The number of crashes on any line of the table may simply reflect the number of trucks in that category, or it may reflect that they drive on different types of highways. Definitive answers to these questions cannot be determined solely from the table.

Table 6-4: Fatal Truck Involvement by GVW and LCV Type (Jarossi, et al. 2004)

<table>
<thead>
<tr>
<th>Combination GVW, pounds</th>
<th>Over length No.</th>
<th>Overweight %</th>
<th>Total</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>25,001-30,000</td>
<td>0</td>
<td>0.0</td>
<td>9</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>30,001-35,000</td>
<td>2</td>
<td>10.5</td>
<td>11.1</td>
<td>1</td>
<td>13.2</td>
</tr>
<tr>
<td>35,001-40,000</td>
<td>4</td>
<td>21.1</td>
<td>5.1</td>
<td>1</td>
<td>6.2</td>
</tr>
<tr>
<td>40,001-45,000</td>
<td>1</td>
<td>5.3</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>45,001-50,000</td>
<td>3</td>
<td>15.8</td>
<td>5.1</td>
<td>0</td>
<td>5.1</td>
</tr>
<tr>
<td>45,001-50,000</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>55,001-60,000</td>
<td>3</td>
<td>15.5</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>60,001-65,000</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>65,001-70,000</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>70,001-75,000</td>
<td>1</td>
<td>5.3</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>75,001-80,000</td>
<td>2</td>
<td>10.5</td>
<td>5.1</td>
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<td>5.1</td>
</tr>
<tr>
<td>80,001-85,000</td>
<td>0</td>
<td>0.0</td>
<td>6.7</td>
<td>0</td>
<td>6.7</td>
</tr>
<tr>
<td>85,001-90,000</td>
<td>0</td>
<td>0.0</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>90,001-95,000</td>
<td>0</td>
<td>0.0</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>95,001-100,000</td>
<td>0</td>
<td>0.0</td>
<td>5.1</td>
<td>0</td>
<td>5.1</td>
</tr>
<tr>
<td>100,001-110,000</td>
<td>0</td>
<td>0.0</td>
<td>1.1</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>110,001-120,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>120,001-130,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>130,001-140,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>140,001-150,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>150,001-160,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>160,001-170,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>170,001-180,000</td>
<td>0</td>
<td>0.0</td>
<td>2.1</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
<td>15.8</td>
<td>0.0</td>
<td>0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 6-4 identifies yet another level of information. For each of the 39 LCVs in the previous two tables, it shows the specific weight category for which a vehicle exceeded the length or weight criteria or both. (The TIFA Factbook for 2004 also lists the same data by truck length categories, if the reader is interested.) It is interesting that no truck under 80,000 pounds.
exceeded its allowable weight, while 16 exceeded the appropriate length criteria. One other conclusion can be drawn; the data is widely scattered across the weight categories. This is illustrated in the table by bold italics for each weight category for which at least one vehicle was OS or OW. Such data scatter further complicates the task of drawing sweeping conclusions about LCV crashes.

**Summary of Data for Which OS/OW was Established or Probable**

After conducting a comprehensive literature review and interviewing over 50 trucking agency, industry and enforcement officials, the UTCA research staff concluded that, unfortunately, the contributions of overloads to truck crashes are not adequately documented in the literature. Additional research must be conducted and additional, very specific data must be gathered at a large number of crash sites for OS/OW commercial vehicles.

**Data for LCVs and Other Large, Heavy Commercial Vehicles**

Several studies are discussed in this part of the synthesis as examples of research on the safety of large, heavy commercial vehicles. They include an important TRB Special Report, multiple Canadian studies focused on the safety of different categories of trucks as compared to other vehicles, and a Minnesota study that examined the safety impacts of proposed new heavy commercial vehicles.

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

Sometimes a crucial decision must be made, but sufficient data are not available or multiple studies of available data fail to yield conclusive results. In this case, engineers and scientists sometimes use a consensus of expert opinion to guide the decision. Such was the case in 1990 when the Transportation Research Board of the National Academies assembled panels of experts to look at the effects of truck weight limits, especially as related to single trailers versus double trailers. The result of the separate panels’ deliberations became TRB Special Report 225 “Truck Weight Limits: Issues and Options” (1990) and TRB Special Report 227 “New Trucks for Greater Productivity and Less Road Wear: An Evaluation of the Turner Proposal” (1990).

The Report 225 panel is emphasized in this synthesis. A portion of its work involved evaluating prior studies using “appropriate methodologies to isolate the effects of vehicle configuration on accident involvement rates.” Of four recent studies examined, research by Campbell (1988) became the basis by which the panel estimated the differences in crash rates between single-trailer and double-trailer trucks. The panel decided to use a ratio of 1.1 for double-trailer truck fatal and non-fatal crashes when compared to single-trailer trucks to estimate the impact of changes to truck size and weight regulations.

The Report 227 panel later concurred with this recommendation, but decided to use a ratio of 1.09 for doubles equipped with standard A-frame dollies. In addition, the 227 panel concluded that doubles using a B-Train configuration would have a rate nearly equal to singles (Morris,
The B-Train dolly is more stable than the A-frame, because it has one less articulation point and is more stable.

Overall, the Report 225 panel concluded that the state of knowledge was incomplete regarding the difference in single-trailer and double trailer safety, and that the difference in the two was probably small. They identified a list of unanswered research questions that limited the ability to draw stronger conclusions about the role of truck weight in crashes. They recognized that the Campbell study (1988) was the only research that directly measured the relationship between weight and crash involvement of tractor semitrailers. But at the same time they noted that the identified relationship was not strong and there were “substantial uncertainties” in the study data. However, the panel accepted the Campbell study as the best available estimate of the weight/safety relationship.

For this synthesis, the important points about TRB Special Report 225 are that it used expert opinion to establish the credibility of the Campbell, et al., report, and that it accepted the estimate that double-trailer crash rates were 1.1 times higher than single-trailer crash rates. These decisions were reinforced by the 227 Panel, except that it established separate rates for double trailers depending upon the type of connection between them.

**LCVs on the Alberta, Canada Sub-network, 1995-1998**

At the request of the Alberta Infrastructure Transportation and Economic Branch, Woodrooffe (Woodrooffe, 2001) conducted a review of crash rates on a designated 1800 mile LCV “sub-network” of roads suitable for LCV travel. This represented about 20% of all roads in Alberta and included both four-lane divided and two-lane undivided highways. The primary goals of the project were to determine the road safety performance of commercial trucks, including LCVs, and to determine the factors that contributed to LCV crashes.

To interpret the results of this study, the reader must understand two important points. First, the project involved a considerable effort to acquire appropriate data, especially exposure data. The absence of sufficient high quality data led the authors to conclude that their estimates of vehicle travel contained ± 10% error. This error carried over to the crash rates established in the project. Second, the researchers used very specific definitions in describing vehicle involvement in crash rates. There were 13,810 collisions on the sub-network during the study period, but there were 21,294 vehicles involved in these collisions.

Where the collision was the important issue:

Collision rate (for a given vehicle type) = \[
\frac{\text{Number of collisions involving given vehicle type}}{\text{Total miles traveled by that type vehicle}}
\]

If the type of vehicle was the important issue:

Vehicle collision rate = \[
\frac{\text{Number of vehicles of a given type involved in collisions}}{\text{Total miles traveled by that type vehicle}}
\]

The latter definition was of importance to this project. In this portion of the synthesis, the vehicle involvement type is explained at the bottom of individual tables.
The sub-network study is important because it negated or minimized the effects of several confounding factors. First, all study vehicles traveled on a common network, so all were subjected to the same road types and the same environmental issues. Woodruffe conducted separate investigations of urban and the rural roadways. This meant that the effects of urban/rural location, highway type, and crash environment were identical for all vehicles.

An example of the findings of this study is shown in Figure 6-5. The first seven rows in the table examine the seven types of vehicles, and the final three rows examine three general groups of vehicles. (All metric tables in the synthesis were converted to ft-lb units by UTCA researchers.)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Vehicles In Collisions</th>
<th>Travel, 100MVM</th>
<th>Collisions/100M MVM</th>
<th>*Safety Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>19,206</td>
<td>135.38</td>
<td>142</td>
<td>5</td>
</tr>
<tr>
<td>Single unit truck</td>
<td>715</td>
<td>2.37</td>
<td>301</td>
<td>6</td>
</tr>
<tr>
<td>Tractor semi-trailer</td>
<td>918</td>
<td>7.17</td>
<td>128</td>
<td>4</td>
</tr>
<tr>
<td>Multi-trailer</td>
<td>418</td>
<td>2.50</td>
<td>629</td>
<td>7</td>
</tr>
<tr>
<td>Rocky Mountain double</td>
<td>11</td>
<td>0.66</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Turnpike double</td>
<td>22</td>
<td>0.74</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Triple</td>
<td>3</td>
<td>0.06</td>
<td>54</td>
<td>3</td>
</tr>
<tr>
<td>All vehicles</td>
<td>21,294</td>
<td>148.89</td>
<td>143</td>
<td>2</td>
</tr>
<tr>
<td>All trucks</td>
<td>2,088</td>
<td>13.51</td>
<td>155</td>
<td>3</td>
</tr>
<tr>
<td>All LCVs</td>
<td>37</td>
<td>1.45</td>
<td>25</td>
<td>1</td>
</tr>
</tbody>
</table>

Collisions of two or more vehicles of the same type were counted as one incident, i.e., a collision of two personal vehicles was counted as one event. But a collision involving two types of vehicles was counted as two events

*Inserted by UTCA researchers, rank of 1 = lowest collision rate/100 MVM

The table gives a quick overview of the crash rates for all seven vehicle types in the study. It indicates that all three LCVs (Rocky Mountain Double, Turnpike Double and triple) had lower crash rates than the other types of vehicles traveling on the LCV system. This finding is tempered by the fact that the three LCV types experienced only 37 crashes (0.18% of the total) in four years. The small sample of 37 crashes was further subdivided into three LCV classes of very small sample sizes, which limits the reliability of the calculated rates. For example, triples experienced only six crashes in seven years. Of further interest is that total triple travel in the study period amounted to only 60,000 miles, or 0.04% of total travel by all classes of vehicles during the study period. With such a small exposure, even one or two crashes will cause a significant jump in the collision rate.

To help interpret the data in the table, the UTCA researcher added a column called “safety rank.” This simply ranks the various types of vehicles by the rate, collisions per 100 million vehicle miles traveled. It shows that as a group, LCVs have lower crash rates than other trucks or personal vehicles. Within that group, Rocky Mountain doubles, Turnpike Doubles and triples had the lowest crash rates in that order. Again, the sample size limits the ability to generalize this finding.
Collision rates were also calculated by crash severity using the 1995-1998 data. This information is shown in Table 6-6. For fatal, injury and PDO crashes, LCVs had lower crash rates. This echoes the findings noted for Table 6-5.

Table 6-6. Fatal, Injury and PDO Rates by Vehicle Type for the Alberta Sub-network, 1995-1998 (Woodruffe, 2001)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Collision rate 100 MVM</th>
<th>Fatal Rate 100 MVM</th>
<th>Injury Rate 100 MVM</th>
<th>PDO rate 100 MVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>142</td>
<td>1.9</td>
<td>26.3</td>
<td>113.7</td>
</tr>
<tr>
<td>Unit truck</td>
<td>301</td>
<td>5.9</td>
<td>55.2</td>
<td>240.1</td>
</tr>
<tr>
<td>Tractor semitrailer</td>
<td>128</td>
<td>5.3</td>
<td>35.0</td>
<td>87.7</td>
</tr>
<tr>
<td>Multi-trailer</td>
<td>629</td>
<td>28.6</td>
<td>185.0</td>
<td>415.1</td>
</tr>
<tr>
<td>Rocky Mountain double</td>
<td>17</td>
<td>0.0</td>
<td>3.0</td>
<td>13.5</td>
</tr>
<tr>
<td>Turnpike double</td>
<td>30</td>
<td>2.7</td>
<td>6.8</td>
<td>17.6</td>
</tr>
<tr>
<td>Triple</td>
<td>54</td>
<td>0.0</td>
<td>35.8</td>
<td>71.5</td>
</tr>
<tr>
<td>All vehicles</td>
<td>143</td>
<td>2.2</td>
<td>27.4</td>
<td>113.4</td>
</tr>
<tr>
<td>All truck</td>
<td>154</td>
<td>5.4</td>
<td>38.0</td>
<td>111.1</td>
</tr>
<tr>
<td>All LCVs</td>
<td>25</td>
<td>1.4</td>
<td>6.2</td>
<td>17.8</td>
</tr>
</tbody>
</table>

Note: Collisions of two or more vehicles of the same type were counted as two or more incidents, i.e., a collision of two triples is counted as two events. A collision of two types of vehicles is counted as two events

Subsequent LCV Study in Alberta, 1999-2005

The Alberta Infrastructure and Transportation Policy and Corporate Services Division initiated a second study of the safety of LCVs on a designated trucking network of highways and in urban areas. The study was conducted by Montufar & Associates using data for 1999-2005. It was similar to the Woodroffe study (Montufar and Associates, 2007), but there were two differences that led Montufar not to make a direct comparison to Woodroffe results: (1) expansion of the network and (2) improved traffic monitoring and traffic data sources.

The Alberta sub-network had been expanded and renamed the LCV network. In 1999-2003, it consisted of about 2,800 centerline miles, not including urban areas, of which 1,100 permitted turnpike doubles and triples. In 2004-2005 it consisted of 2,300 centerline miles, of which 12,500 permitted turnpike doubles and triples.

The 1999-2004 safety results of the LCV network analysis are presented in Tables 6-7 and 6-8. The first table overviews of the crash rate for different vehicle types. Compared to the earlier study by Woodroffe, the overall collision rates had dropped for the “all vehicles” and LCV categories, while the collision rate for the “all trucks” category had become larger.

As with the previous study, LCVs had lower crash rates than the other two general categories of vehicles. In fact, Rocky Mountain doubles had the lowest collision rate, followed closely by Turnpike doubles (see the Safety Rank column in the table). Triples jumped to the fifth highest collision rate among the seven categories, even though there were only eight collisions that
involved triples. The reason for the jump is the very low exposure rate. Over four years these vehicles travelled only about 80,000 miles on the LCV network. This underscores the difficulty in obtaining reliable rates with such small sample sizes. Even one additional crash causes a dramatic change in rate when the miles traveled are converted to the basis of 100 million miles per year.

Table 6.7. Collision Rates by Vehicle Type for the Alberta LCV-network, 1999-2005 (Montufar and Associates, 2007)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Vehicles In Collisions</th>
<th>Travel, 100 MVM</th>
<th>Collisions/100 MVM</th>
<th>*Safety Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>59,905</td>
<td>347.2</td>
<td>173</td>
<td>6</td>
</tr>
<tr>
<td>Single unit truck</td>
<td>3,825</td>
<td>18.5</td>
<td>206</td>
<td>7</td>
</tr>
<tr>
<td>Tractor semi-trailer</td>
<td>2,491</td>
<td>35.1</td>
<td>71</td>
<td>3</td>
</tr>
<tr>
<td>Multi-trailer</td>
<td>983</td>
<td>13.4</td>
<td>73</td>
<td>4</td>
</tr>
<tr>
<td>Rocky Mountain double</td>
<td>36</td>
<td>0.70</td>
<td>52</td>
<td>2</td>
</tr>
<tr>
<td>Turnpike double</td>
<td>21</td>
<td>0.81</td>
<td>26</td>
<td>1</td>
</tr>
<tr>
<td>Triple</td>
<td>8</td>
<td>0.08</td>
<td>99</td>
<td>5</td>
</tr>
<tr>
<td>All vehicles</td>
<td>67,269</td>
<td>415.8</td>
<td>162</td>
<td>3</td>
</tr>
<tr>
<td>All Trucks</td>
<td>7364</td>
<td>68.6</td>
<td>107</td>
<td>2</td>
</tr>
<tr>
<td>All LCVs</td>
<td>65</td>
<td>1.59</td>
<td>41</td>
<td>1</td>
</tr>
</tbody>
</table>

Collisions of two or more vehicles of the same type were counted as two incidents, i.e., a collision of two personal vehicles was counted as one event. A collision involving two types of vehicles was counted as two events.

*Inserted by UTCA researchers, rank of 1 = lowest collision rate/100 MVM

Table 6-8 compares the severity rates for collisions, fatal crashes, injury crashes and property-damage-only crashes. As with prior tabulations, LCVs had the lowest rates when compared to other trucks and to all vehicles.


<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Collision rate 100 MVM</th>
<th>Fatal Rate 100 MVM</th>
<th>Injury Rate 100 MVM</th>
<th>PDO rate 100 MVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>173</td>
<td>2.3</td>
<td>40.8</td>
<td>129.5</td>
</tr>
<tr>
<td>Unit truck</td>
<td>206</td>
<td>4.0</td>
<td>42.2</td>
<td>160.2</td>
</tr>
<tr>
<td>Tractor semi-trailer</td>
<td>71</td>
<td>2.5</td>
<td>20.4</td>
<td>48.1</td>
</tr>
<tr>
<td>Multi-trailer</td>
<td>73</td>
<td>3.7</td>
<td>24.2</td>
<td>45.4</td>
</tr>
<tr>
<td>Rocky Mountain double</td>
<td>52</td>
<td>1.4</td>
<td>10.1</td>
<td>40.2</td>
</tr>
<tr>
<td>Turnpike double</td>
<td>26</td>
<td>2.5</td>
<td>6.1</td>
<td>17.2</td>
</tr>
<tr>
<td>Triple</td>
<td>99</td>
<td>0.0</td>
<td>49.5</td>
<td>49.5</td>
</tr>
<tr>
<td>All vehicles</td>
<td>162</td>
<td>2.4</td>
<td>38.5</td>
<td>120.9</td>
</tr>
<tr>
<td>All truck</td>
<td>107</td>
<td>3.1</td>
<td>26.8</td>
<td>77.4</td>
</tr>
<tr>
<td>All LCVs</td>
<td>41</td>
<td>1.9</td>
<td>10.1</td>
<td>28.9</td>
</tr>
</tbody>
</table>

Collisions of two or more vehicles of the same type were counted as two incidents, i.e., a collision of two personal vehicles was counted as one event. A collision involving two types of vehicles was counted as two events.

In summarizing their study, the Canadian researchers stated that the severity outcome of LCV collisions on the LCV network was lower than that of other vehicle types. About three-quarters
of LCV collisions were property damage only. About half of the LCV collisions were of the single vehicle type, mostly at night and often involving wildlife. LCV collisions were also over-represented during winter months.

The synthesis researchers elected to combine the two Alberta studies, since they represented over a decade of the same vehicle classifications on the same network. Table 6-9 was prepared as a composite of the Woodrooffe and Montufar studies. The synthesis authors recognize that merging the two studies diminishes the reliability of the results. In addition to the two reasons given by Montufar, there were changes in network mileage, traffic control, congestion, data collection techniques, and other factors. For a specific example of the change, Woodrooffe estimated that there was a ± 10% error in the estimate of vehicle exposure (travel) in his study. In the subsequent study by Montufar, available data allowed a more accurate estimate of vehicle travel.

In spite of these limitations, the synthesis authors felt merging the two studies would offer additional insight into the relationship between truck sizes/configurations and safety. It is rare that 11 years of data are available for any safety topic, especially for LCVs on the same network where travel values are available. The merger had the desired effect of increasing the sample size for both LCV crashes and LCV exposure. The aggregate data for travel increased the reliability of estimated crash rates, moving both Rocky Mountain doubles and Turnpike doubles above a million miles of travel, and moving triples to 140,000 miles.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>100 million VMT</th>
<th>Collision rate 100 MVM</th>
<th>Fatal Rate 100 MVM</th>
<th>Injury Rate 100 MVM</th>
<th>PDO rate 100 MVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>482.5</td>
<td>163.9</td>
<td>2.2</td>
<td>36.7</td>
<td>125.1</td>
</tr>
<tr>
<td>Straight truck and bobtail</td>
<td>20.9</td>
<td>217.2</td>
<td>4.3</td>
<td>43.7</td>
<td>169.3</td>
</tr>
<tr>
<td>Tractor semi-trailer</td>
<td>42.3</td>
<td>80.6</td>
<td>3.0</td>
<td>22.8</td>
<td>54.8</td>
</tr>
<tr>
<td>Legal-length tractor double trailer</td>
<td>15.9</td>
<td>88.0</td>
<td>4.3</td>
<td>28.1</td>
<td>55.6</td>
</tr>
<tr>
<td>Rocky Mountain double</td>
<td>1.4</td>
<td>34.5</td>
<td>0.7</td>
<td>6.6</td>
<td>27.2</td>
</tr>
<tr>
<td>Turnpike double</td>
<td>1.6</td>
<td>27.7</td>
<td>2.6</td>
<td>6.4</td>
<td>17.4</td>
</tr>
<tr>
<td>Triple trailer</td>
<td>0.14</td>
<td>80.5</td>
<td>0.0</td>
<td>43.9</td>
<td>58.5</td>
</tr>
<tr>
<td>All vehicles</td>
<td>564.7</td>
<td>119.1</td>
<td>1.8</td>
<td>28.3</td>
<td>89.0</td>
</tr>
<tr>
<td>All trucks</td>
<td>82.2</td>
<td>115.0</td>
<td>3.5</td>
<td>28.6</td>
<td>82.9</td>
</tr>
<tr>
<td>All LCVs</td>
<td>3.1</td>
<td>33.10</td>
<td>1.6</td>
<td>8.2</td>
<td>23.6</td>
</tr>
</tbody>
</table>

*Table 6-9 is a composite of information in Tables 6-6 ad 6-8, covering a 10-year period. It is subject to the same table notes and restrictions as those tables.

Note: Care should be used in interpreting this table. There were distinct differences in the Woodrooffe and Montufar studies, including improvement in commercial vehicles, roadways, data and other issues over the 10 years covered by this table.

The primary finding from this table is a familiar one, the average crash rate for LCVs was about one-half to one-third of the crash rate for the “all trucks” category, for all severities. Another key point, discussed previously, can be seen in the table. Trucks drove about 15% of the total travel on this network, but LCV travel constituted only 0.05% of all miles driven. It is difficult to isolate causation or to identify any of the confounding factors (weight, load type, day versus night travel, weather, etc.) with such a small data sample.
**Ontario B-Train Safety Study**

Ontario allows some of the heaviest axle and GVW loads in North America (Corredor, et al. 2005). Safety is handled by establishing threshold values for truck performance measures like SRS, low speed offtracking, high speed offtracking, etc. (CCMTA, 1987). This concept was based on a study conducted at UMTRI in the late 1980s (Francher, 1989). Although there were some limitations to the study, in many locations the concept was generally accepted and used as the basic for policy and design. A good example is when New Zealand (De Pont, et al. 2002) adopted a minimum static rollover threshold requirement in 2002. “Supportive research showed that vehicles with low static rollover threshold, high load transfer ratio and low yaw damping ratio have a higher likelihood of being involved in a rollover crash. (CCMTA, 1987)”

The Ontario Ministry of Transportation decided to investigate the relationship between performance measures and truck safety in 2005. This study became known as the Ontario B-Train Safety Study. Corredor, et al., used eight years of truck crash data (1995-2002) for the study, and matched crashes to tractor trailer classifications by tracing license plates. Performance measures were assembled for typical tractor-trailer configurations, including 1- and 2-axle semi-trailers, 3-axle semi-trailers, 4-axle semi-trailers, 5-axle semi-trailers, A and C-train doubles, and B-train doubles. The data included empty and loaded vehicles, vehicles with adjusted axles and misadjusted axles, and other typical parameters. After extensive simulation studies, the researchers found “a high correlation between performance characteristics and collision rates per class…”

As part of the research, collision rates were developed from the Ministry’s accident and commercial vehicle survey databases. This information is shown in Table 6-10. This information is of interest to this synthesis because they (indirectly) describe semitrailer safety as a function of size and weight. Semitrailers with 1- and 2-axes are obviously smaller and carry lighter loads than 5-axle semitrailers. (UTCA researchers note that semitrailers with more than two axes are rare in the US.) The table shows the expected collision pattern. The crash rate increased as the number of axles on the semitrailer increased, since additional axles were only needed to larger trailers and heavier loads.

<table>
<thead>
<tr>
<th>Tractor-trailer classification</th>
<th>Collisions/100 MVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- and 2-axle semitrailers</td>
<td>0.72</td>
</tr>
<tr>
<td>3-axle semitrailer</td>
<td>0.97</td>
</tr>
<tr>
<td>4-axle semitrailer</td>
<td>1.06</td>
</tr>
<tr>
<td>5+ axle semitrailer</td>
<td>1.66</td>
</tr>
<tr>
<td>A-train and C-train double</td>
<td>2.14</td>
</tr>
<tr>
<td>B-train double</td>
<td>0.58</td>
</tr>
<tr>
<td>Average</td>
<td>0.82</td>
</tr>
</tbody>
</table>

The semitrailer axles listed in the table do not include tractor axles.

UTCA researchers converted rates from millions of Km to millions of miles.
The table contains another important finding that reinforces the expected trend in the relationship between vehicle performance measures and truck safety. For double trailers, the collision rate appears to be highly related to the type of connection between the two trailers. B-train doubles have collision rates almost four times lower than A- and C-train doubles. This is most likely because B-train dollies provide a more stable connection between the two trailers and provide better performance.

Proposed New Vehicles in Minnesota

The Minnesota case study (Cambridge Systematics, 2006) introduced in section two of this document, provided another good example of the study of crashes for large, heavy trucks. The University of Michigan Transportation Research Institute was engaged to evaluate the safety and performance characteristics of a number of proposed larger trucks for the Minnesota roadway system.

In their evaluation, UMTRI researchers leaned heavily on a Campbell study (1988) and TRB Special Report 225 (1990), both of which were discussed earlier in this section. Campbell’s study examined large trucks in fatal crashes for various configurations, road classes and operating environments. With respect to road systems, Campbell established that doubles traveled a much higher proportion of their mileage on very safe controlled-access highways as compared to the roads traveled by the other truck classes in his study. He developed an adjustment to account for the difference in road systems to estimate the crash rate that doubles would probably have experienced if they had traveled on the same roads as the other two truck classes. This is reflected in Table 6-1, and indicates that after adjustment, doubles had a crash rate about 1.1 times greater than tractor semitrailers.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>1985 M VMT</th>
<th>1980-1984 Fatal Involvements</th>
<th>1985 Fatal Rate 100 M VMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single unit trucks</td>
<td>14,680</td>
<td>5,420</td>
<td>7.7</td>
</tr>
<tr>
<td>Tractor-semitrailers</td>
<td>33,450</td>
<td>16,260</td>
<td>10.2</td>
</tr>
<tr>
<td>Doubles</td>
<td>2,007</td>
<td>829</td>
<td>8.6</td>
</tr>
<tr>
<td>Doubles adjusted</td>
<td></td>
<td></td>
<td>11.2</td>
</tr>
</tbody>
</table>

Campbell’s study also indicated a relationship between crash rates and weight, which was used to plot fatal crash rates versus vehicle GVW for the three truck types in his study. His fatal rates (Table 6-11) and his plot were accepted by the TRB Special Report 225 panel as the best available study on the relationship between truck size and weight and fatality rates.

For the Minnesota project, UMTRI researchers used Campbell’s plot of truck weights vs. fatal crash rate, but normalized it to reflect current Minnesota truck crash rates. This was necessary because fatal crash rates for large trucks had diminished substantially since the Campbell study. The resulting plot is reflected in Figure 6-1. This established a basic tool to predict crash rates for the new truck designs investigated by the Minnesota DOT.
The safety relationships in Table 6-11 and Figure 6-1 covered SU, semi-trailer and double-trailer classifications, but did not cover the larger, heavier LCVs. So to assess the safety of the proposed four new Minnesota trucks, UMTRI researchers incorporated the Woodrooffe findings (2001) from the Alberta sub-network study, along with similar safety findings from the “Ontario B-Train Safety Analysis” (Corredor, et al. 2005) shown in Table 6-10. The combination of these studies provided a factual basis for assessing the safety of the proposed new truck configurations.

![Figure 6-1. Fatal crash rates from TRB Special Report 225, adjusted to Minnesota truck crash rates (Cambridge Systematics, 2006).](image)

The study of proposed new truck configurations in Minnesota contributed useful information to this synthesis, through a review of important prior studies of multi-trailer trucks, supplemented by recent studies that concentrated on the safety of various LCV and multiaxle semitrailers.

**Section Summary**

This section began by defining two meanings of the term OS/OW – vehicles that had been weighed and found to exceed established regulations, and vehicles with size, weight or condition that made them look or operate differently (larger or heavier) than other commercial vehicles. Next it briefly reviewed prior studies that found data were not available to identify the relationship between truck size/weight and crashes, and that such data was badly needed.

Concentrating on the first definition of OS/OW, three examples of data sets with promise, LTCCS, TIFA, and comprehensive data sets assembled by individual studies were discussed. In addition, data for which OS/OW was established or probable was introduced and reviewed. But these data sets were found to be insufficient to determine the desired relationship between vehicle size/weight and safety.

The section then shifted to an examination of studies of large commercial vehicles, especially LCVs and unique multi-axle semitrailers. It started by reviewing the important role of TRB
Special Report 225, which identified a study that established a relationship between truck weight and safety; however, the Report panel noted that there were substantial uncertainties in the data.

Two studies in Alberta, Canada and one in Ontario, Canada provided crash estimates for large commercial vehicles including semitrailers with up to five axles, doubles (including A-train, B-train, and C-train) and LCVs (Rocky Mountain doubles, Turnpike doubles and triples). Exposure data was acquired for each of these classifications so that crash rates, and sometimes fatal and injury rates, could be calculated. This established that LCVs and doubles using B-train dollies had lower crash rates than other truck types. This portion of the synthesis also established that performance measures of various truck configurations were highly correlated to collision experience.
7.0 Illustrative Case Studies

Case Study: States with Special Overweight Exemptions

Kentucky and West Virginia were examined as case studies because both allow certain commercial vehicles hauling coal to exceed normal weight limits. In both instances, the state legislatures adopted exclusion legislation allowing overweight shipments of coal on designated highways. The purpose of allowing the overweight shipments was to reduce shipping costs and thereby keep the price of coal competitive with coal produced in other states.

Kentucky

Kentucky legislation has allowed coal haulers to exceed normal weight limits for over 20 years. Researchers at the Kentucky Transportation Center (KTC) at the University of Kentucky have conducted heavy commercial vehicle crash research, investigated heavy vehicle crashes, and reconstructed a number of these crashes. They have generated a number of research reports dealing specifically with legally overweight commercial vehicles on the highways of their state, providing a wealth of information for preparation of this synthesis.

Special Highway System Designation

The coal production industry is dominant in the Eastern Kentucky economy (Pigman, et al. 1995). In 1986 the Kentucky Legislature created the Extended-Weight Coal Haul Road System to allow trucks to haul larger loads to decrease coal transport costs. The increases in allowable loads were appreciable, as shown in Table 7-1. Additionally, vehicles that loaded away from scales were allowed a five percent tolerance. So a five-axle tractor and semi-trailer could legally weigh 126,000 pounds. The legislation did not require upgrades to either tractors or trailers, such as brakes, engines, or structural modifications, to accommodate the increase in load.

<p>| Table 7-1. Allowable Weights on Kentucky Coal Haul Roads (Pigman, et al. 1995) |
|---------------------------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Truck Type</th>
<th>Max Allowable Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU, 3-axle</td>
<td>100,000</td>
</tr>
<tr>
<td>SU, 4-axle</td>
<td>100,000</td>
</tr>
<tr>
<td>Tractor semi-trailer, 5 or more axles</td>
<td>120,000</td>
</tr>
<tr>
<td>Trucks that load away from scales</td>
<td>+ 5%</td>
</tr>
</tbody>
</table>

To qualify, a coal shipping company had to register its vehicles and pay a small fee. Additionally, the trucks were restricted to the Coal Haul Road System.
In 1992 KTC initiated a thorough evaluation of the impacts of the Coal Haul Road System. The system seemed to be successful in enhancing competitiveness and economic viability of the Kentucky coal industry. But the heavier weights of coal trucks added approximately $9 million annually to pavement overlay costs for the Extended Weight road system. The evaluation also found that the overall crash rate for the extended-weight system was basically the same as the statewide rate. Injury rates were also similar. The greatest difference was a higher fatal crash rate on the extended weight system compared to both the statewide rate and the rate for a base system selected for comparison.

**Truck Crash Study**

In 1998 KTC initiated another truck accident study (Pigman and Agent, 1999) using a database of crashes from 1994-1997. This information was supplemented by police crash reports for 383 fatal crashes in which trucks were involved. For about two-thirds of the crashes, the primary contributing factor in truck wrecks was the action of the other driver – not the truck driver. The other driver crossed the centerline or median, or turned into the truck’s path 47% of the time. In 13% of the crashes the other driver ran into the rear of a slow or stopped truck. KTC observed that in the hilly portions of Kentucky, heavy trucks dropped to crawl speed (about 15 mph) on long upgrades. There was a pattern of rear end crashes when vehicles approaching from the rear did not recognize that the trucks were at low speed until it was too late to stop safely.

After analysis of the truck crashes, KTC researchers identified four types of situations with higher potential for truck accidents: interchange ramps, steep grades, sharp curves on two-lane roads, and intersections with restricted sight distance or high speed.

**Overweight Trucks**

During this study KTC collected truck weight data from weigh-in-motion stations to evaluate the distribution of coal truck weights. Data was gathered from US 23 (an Extended-Weight Coal Haul road) in the southeastern portion of the state for 19,000 six-axle trucks that weighed more than 80,000 pounds. The highest recorded weight was 220,600 pounds, and the average weight (158,000 pounds) was 25% above the legal limit. Eighty-eight percent of the vehicles exceeded the 126,000 pound weight limit for coal trucks. As a comparison, KTC obtained weights of five-axle trucks at a nearby weigh station on I-24. An extremely small number were over 80,000 pounds, so KTC used a limited sample of 304 six-axle trucks weighing over only 22% were over 100,000 pounds and 5% over 120,000 pounds. Both data sets are displayed in Figure 7-1.

Several conclusions can be drawn for this discussion and the figure. First, at both sites the distribution of overweight vehicles was linear. Second, the coal truck weights far exceeded the I-24 trucks, since 88% of coal trucks and “only” 42% of I-24 trucks exceeded the weight limit. Finally, the ratio of maximum weight to legal weight was about the same (188% to 173%).
Figure 7-1. Six-axle trucks weighing over 80,000 pounds (Pigman and Agent, 1999).

**Truck Violations**

During the 1996-97 year 2,313 citations were issued to overweight trucks; 6.1% of these cases were later dismissed (Pigman and Agent, 1999). The most citations were given in three counties with weight-enforcement stations. In 1997-98, 118,792 inspections were performed on trucks or driver records (see Table 7-2). Over 17% of the trucks were taken out of service, and about 4% of the drivers were taken out of service. The four largest truck violations constituted 72% of the total. The major violations included (in order) lighting, brakes—all other, brakes out of adjustment, and tires. These four, in the same order, constituted 77% of the out-of-service violations. For drivers, the four largest violations—log book, traffic enforcement, medical certificate, and hours of service—amounted to 78% of the total. Two types of driver out-of-service violations were dominant—log book (49%) and hours of service (27%).

<table>
<thead>
<tr>
<th>Type Inspection</th>
<th>Level I inspection std, vehicle and driver</th>
<th>Level II walk around inspections: veh. &amp; driver</th>
<th>Level III inspection: driver-only</th>
<th>Levels IV and V inspections</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>25,513</td>
<td>8,310</td>
<td>21,667</td>
<td>144</td>
<td>55,634</td>
</tr>
<tr>
<td>1999</td>
<td>30,813</td>
<td>8,990</td>
<td>22,980</td>
<td>375</td>
<td>63,158</td>
</tr>
<tr>
<td>Vehicle out of service</td>
<td>20%</td>
<td>23%</td>
<td>12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver out of service</td>
<td>5.3%</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Multiple recommendations were made to minimize truck crashes. There were nine recommendations for the vehicle, most centering on making the truck more visible, improving the brakes, and providing better under-ride protection for the rear and sides of the trailer. Fourteen recommendations were made for roadways. These included items like installing rumble strips to alert drivers they were crossing over the centerline, widening the pavement and providing more warning signs at sharp curves, and providing more warning signs at steep grades.
Four recommendations were made to improve truck driver safety. These recommendations supported more driver training on standard operating procedures (using flashers when going very slowly, etc.) and recognizing the signs of driver fatigue. Increased enforcement of truck violations was the final recommendation concerning the drivers.

*Truck Braking Field Test*

To address concerns over the ability to safely stop heavily-loaded trucks, KTC conducted a carefully controlled braking test in October, 1997 (Pigman and Agent, April 1998). The tests were held on a tangent section of four-lane state highway, using a three-axle single unit dump truck and an eight-axle combination truck with three axles that could be lifted. The trucks were new, and the brakes were new and properly adjusted. However, the brakes were not yet seasoned, so they had not reached their optimum stopping ability.

The overall purpose of the test was to determine whether the two trucks could meet the requirement of the Federal Motor Carrier Safety Regulations, Part 392.53. This provision requires that SU trucks weighing over 10,000 pounds be able to stop within 35 feet from a speed of 20 mph with the maximum deceleration equaling 0.435. For combination vehicles the requirement is stopping within 40 feet from a speed of 20 mph with the maximum deceleration equaling 0.435.

The trucks were equipped with fifth wheel systems for measuring speed and stopping distance. Pressure instrumentation was applied to the brake control systems in order to monitor pressure and ensure that the brakes were fully applied. A dynamometer and braking test computer were used to determine average and maximum rates of deceleration. All instrumentation was calibrated. KTC, Testing Systems, Inc., and trucking experts were available at the site to observe and oversee the tests.

Tests were conducted at varying weights and at 20 and 40 mph. A few additional tests were run at 50 mph. Multiple repetitions were run for each weight at both 20 and 40 mph, and more than 70 trial runs yielded useful data. Speeds at onset of braking, stopping distances and deceleration rates were recorded. The stopping distance information is displayed in Table 7-3.

The field tests documented that the combination truck met FMCSR braking and deceleration tests for 20 mph for the full range of test weights including a maximum weight of approximately 150,000 pounds. The single-unit truck met the FMCSR regulation for weights up to 98,000 pounds, but it did not meet the deceleration portion of the test at its maximum weight of 120,000 pounds.
Three important findings emerged from this test. First, the braking distance increased with increasing weight. Second, the combination truck braking distance decreased as the number of axles on the pavement increased. These two findings conform to expectations. Third, braking distance was much more sensitive to the speed at which braking was initiated than to the gross weight of the vehicle. At higher speeds the impact is much more pronounced. In other words, doubling the weight of the vehicle had less effect on stopping distance than doubling the speed at initiation of braking. This third finding might not be known or suspected by truck drivers or shipping firms.

In summary, the two trucks performed well. There was no evidence that braking capability at the weights tested should be a safety concern. However, it should be noted that these were new vehicles, the brakes were properly adjusted, and the brakes were allowed to cool between test runs.

**Other Kentucky Findings**

During preparation of this synthesis, KTC researchers provided additional insights into the safety of overweight vehicles. Several interesting tidbits emerged from these conversations. For example, there has been more enforcement in recent years which has significantly reduced the number of extremely heavy loads. Also, some industries have decided not to pay for deliveries when the load is over the legal limit.
KTC researchers noted that investigation of truck crashes is difficult. Not many officers have advanced training to understand braking and stability issues. After a crash it is virtually impossible to weigh a truck and determine if it was overweight at the time of the crash, especially if it overturned and spilled the load. Few crashes have been reconstructed, due to the extensive cost for data collection and the time-consuming procedures associated with reconstruction.

The center of gravity of the load was the key factor in maneuvering and overturning. To get 120,000 pounds of coal onto a trailer, it was piled higher than the side boards of the trailer, a practice which raised the center of gravity. This lowered the threshold for rollovers. Reconstruction of truck crashes showed a high center of gravity to be the key factor in rollover crashes.

KTC researchers expressed that transportation researchers and practitioners need to know a lot more about safety relationships involving truck weight and truck speed. Even though there has been continuing and extensive discussion about the effect of extended weight loads on safety, KTC has not been able to find much evidence specifically linking truck crashes with truck weights. In other words, from looking at crash data, investigating crash sites, and reconstructing truck crashes, KTC researchers did not find much to support excess weight as a cause of truck crashes. They indicated that while it is possible, or even probable, that excess weight was a causal factor, sufficient data did not exist to support that conclusion.

**West Virginia**

**Special System Designation**

West Virginia shares a common boundary with Kentucky and a common dependence on coal as a major portion of the state’s economy. Following Kentucky’s example, in 2003 the state legislature established a Coal Resource Transportation System in 15 western counties. The coal truck weight limits were raised to match those of Kentucky including the same 5% margin for loading (see Table 7-1) and a requirement that a decal be purchased.

Insurance companies played a major role in passage of the legislation. Prior to the initiative they were considering refusal of coverage to coal trucks. Prior to implementation of the legislation, it was common to find 140,000 to 150,000 pound gross loads of coal being carried on trailers designed for 80,000 pounds, and safety was a major concern. To pass this difficult legislation, agencies and organizations worked with industries and truckers to collect input from around the state and develop a workable policy.

There were two other important aspects to the legislation. It transferred commercial vehicle weight enforcement responsibility to a special unit in the Public Service Commission, and it required that both coal shippers and receivers report overloaded trucks. This last provision was especially important, because it allowed the Transportation Enforcement Division of the Public
Service Commission to issue electronic citations upon receipt of notice of an overloaded truck by a shipper or receiver.

**Decrease in Citations and Crashes**

Dramatic results were seen following implementation of this legislation. The bottom dropped out of citations. In 2006 West Virginia had only 27 roadside citations plus 5 to 15 electronic citations per week. Career enforcement managers cannot recall seeing anything like these rates of compliance. And this carried over to safety. The number of truck fatalities has dropped each year and now is about 75% of its former value.

Part of the decrease in both citations and crashes has been aggressive enforcement. The Transportation Enforcement Division follows trends in crashes and citations and provides a toll-free telephone number to receive complaints about trucks. For every call that includes truck identification information, officers can identify the truck and driver and let the driver (and owner) know about the complaint. The thoughtful approach and multi-party coordination used in West Virginia resulted in strong legislation and good enforcement practices. The results are very positive.

**Section Summary**

This case study involved two Appalachian states that granted weight exclusions to coal trucks driving on designated highways to decrease transportation costs to maintain the viability of coal, the primary economic contributor in a major section of each state. The increases were significant, in the range of 150% of prior weight restrictions, including 120,000 pounds for semi-trailers plus a 5% tolerance if loaded away from a scale. Neither state required upgrades to the coal trucks to accommodate the increased load.

Kentucky found that crash and injury rates on coal haul roads stayed near the state average, but the fatality rate increased. Several typical types of crashes were identified, especially on long grades when coal trucks dropped to crawl speed. Motorists approaching from the rear often did not detect the slow speed and experienced crashes with the rear of the coal truck.

Data from Kentucky weigh stations indicated that after the legislation, trucks were severely overloaded. Almost 90% of coal trucks exceeded the increased weight limits, with an average tractor and semi-trailer weight of 158,000 pounds (25% over the coal truck limit). Of 19,000 vehicles observed, the heaviest weighed 220,600 pounds.

In brake testing, a new three-axle SU passed FMCSR low speed braking requirements at loads from 40,900 to 120,680 pounds. A new eight-axle combination truck (three axles could be lifted) passed the braking test at loads from 44,940 to 150,180 pounds. Three important findings emerged from this test. First, the braking distance increased with increasing weight. Second, the combination truck braking distance decreased as the number of axles on the pavement increased. These two findings conform to expectations. Third, braking distance was much more sensitive to...
the speed at which braking was initiated than to the gross weight of the vehicle. At higher speeds the impact is much more pronounced. In other words, doubling the weight of the vehicle had less effect on stopping distance than doubling the speed at initiation of braking. This third finding might not be known or suspected by truck drivers or shipping firms.

KTC researchers noted that investigating truck crashes is difficult, and that it is virtually impossible to establish the truck weight after a crash. Reconstruction is difficult and time consuming and rarely done. Researchers and crash investigators need to know a lot more about safety relationships involving truck weight and truck speed. KTC researchers noted that from gathering crash data, investigating crash sites and performing reconstruction, they did not find much to support excess weight as a cause of truck crashes. Although excess weight was a probable causal fact, sufficient data did not exist to support that conclusion.

West Virginia admired the success of Kentucky’s coal road system in increasing the economic viability of the state’s coal mining industry and passed exemption legislation for its own coal trucks. But they had the good fortune of including a requirement in their legislation that both shippers and receivers had to report each overweight truck. They also allowed the reporting of weights by email and allowed email to be the legal basis for issuing overweight citations. Consequently, overweight coal trucks have virtually disappeared from West Virginia.
8.0 Summary, Findings, and Recommendations

This project was conducted 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 could be used to modify commercial vehicle enforcement and permitting practices.

This section provides a short summary of key topics discussed previously in the body of the synthesis. In addition, the primary findings and recommendations from the research are documented in the following pages.

Summary by Topic

Growth of Commercial Vehicles

For over 25 years there has been a vigorous, continuous growth of heavy commercial vehicles on American highways. This reflects a shift in the American economy from small retail outlets to large mega-centers and from domestic suppliers to global suppliers. This growth of heavy commercial vehicles is projected to continue into the future to support the national economy.

Truck Size and Weight Laws (TSWs)

Federal code has placed TSW controls on large trucks for infrastructure protection and safety considerations. Over time the regulations have generated the desired effect and have provided a reasonable level of safety.

Heavy Truck Crashes in General

This section of the report was based on a traditional literature review, plus interviews with more than 50 domestic and international experts in heavy trucks, heavy truck enforcement, and heavy truck safety.

In general, it is clear that we know much less about heavy commercial vehicle crashes than car crashes. Overall there are now multiple dependable sources of such data, and the literature includes information on a good number of heavy truck crash trends and factors. This synthesis overviews many of them, including early and more recent research results, the trend in fatalities, the distribution of fatalities among the involved vehicles, the most harmful event in the crash sequence, speed, enforcement, drivers, truck weight and size, and other pertinent factors.
Although this information is good for developing a broad appreciation for truck safety topics and for determining general trends, care should be used in making detailed analyses with this type of data. Where applicable data is available, it rarely includes sufficient information for a controlled scientific study. There remains a need for crash exposure (i.e., the number of crash opportunities, for example annual miles driven) for individual classifications of trucks, for measures quantifying the degree of overweight by vehicles within each class, and for sufficient supporting data (i.e., type road system used, driver characteristics, type of load) for each classification. Until that information is known, it will be difficult or impossible to conduct higher level scientific analyses of large truck crashes to help identify crash causation, severity and other critical issues.

**Data Associated with OS/OW Heavy Vehicles**

CV enforcement officers think that there are two definitions of OS/OW: (1) vehicles involved in crashes that have been weighed and found to exceed TSWs and (2) vehicles for which size, weight or condition make them look or operate differently (larger, heavier, slower) than other large commercial vehicles.

Multiple prior studies have indicated that existing databases rarely include the weights of large commercial vehicles involved in crashes, nor do they contain other data items (in sufficient detail) to establish the relationship between weight/size and safety. Where weights are available as part of a data set, there are rarely a sufficient number of crashes to allow rigorous statistical evaluation. Section Five included statements made by recognized researchers over 40 years ago about the lack of data for large truck crashes and calling for collection of three specific types of data. Section Six indicated that such statements are still being made today. Findings of the Comprehensive Size and Weight Study were used to illustrate why current data is insufficient to pinpoint the effect of size and weight of large commercial vehicles on crash causation and severity.

There are a few national data sets that show promise of collecting data from multiple sources and merging it to build the comprehensive data necessary to unlock this issue. Three were discussed in this section of the synthesis: (1) truck weight data sets like state and WIM, virtual WIM, and weigh station information, (2) the Large Truck Crash Causation Study file and the (3) Trucks Involved in Fatal Accidents file. Neither of the last two files has sufficient data yet, but both files have promise if they are expanded by additional data items and if many more crashes are investigated and added to them.

Data from the TIFA file was used to illustrate what is now known about OS/OW crashes of LCVs. One portion of this file contained records of 39 LCVs known to be OS or OW. In general, this information was interesting but of little assistance in analyzing crashes of OS/OW vehicles. It did not contain sufficient detail to determine causes of crashes, or to control confounding factors.

TRB Special Report 225 was reviewed because it established national crash rates for large trucks. Expert opinion was used to evaluate prior research and to select the work of Campbell
(1988) for crash rate estimates for trucks, including double trailer configurations. The estimated rates increased from SU to tractor semitrailer to double trailer, with the double trailer rate about 1.1 times higher than the tractor semitrailer rate. But Report 225 indicated that even though it accepted the Campbell data, there were substantial uncertainties in the study data and the knowledge of crash rates was still incomplete.

Three Canadian studies of large commercial vehicles were examined. All three included LCVs. Two of the studies were in Alberta and one was in Ontario. The Alberta studies covered eleven consecutive years on the same network, which allowed control of the road type and crash environment during the studies. Both Alberta studies indicated that LCVs fatal, injury and PDO crash rates were less than those of other trucks and less than all vehicles as a group. LCV fatal crash rates were less than half of those of other trucks, and LCV injury and PDO crash rates were less than one-third of those of other trucks.

A study in Ontario examined the crash rates of four types of semitrailers and found that crash rates increased with increasing numbers of axles. For doubles, B-train vehicles had substantially lower crash rates than A- or C-train vehicles. The same study evaluated performance measures of the same types of heavy truck configurations and found that they were highly correlated to the safety records of the individual trucks configurations.

One final study was used as an example. UMTRI researchers evaluated proposed new large trucks as part of a project for the Minnesota DOT. For the evaluation of the safety of these vehicles, the researchers used the work of Campbell, one of the Alberta studies, and part of the Ontario study to develop crash rates for a range of truck types over a range of weights.

**Minnesota, Kentucky and West Virginia Case Studies**

The Minnesota case study documented that transportation costs are crucial to some sectors of American industry and agriculture. The state legislature receives a dozen requests per year for exemptions from TSW laws by various agricultural and industrial interests so they can compete with neighboring states that allow larger and heavier transport vehicles. A project for the Minnesota DOT found that four new types of heavy trucks (with increased sizes and weights) would improve economic competitiveness without causing excess damage to road and bridge infrastructure or decreasing road safety, while generating enough funding to pay for itself.

Kentucky and West Virginia were used as case studies because they have granted weight exclusions to coal trucks driving on designated highways to decrease transportation costs. This was done to maintain the viability of coal, the dominant economic contributor in major geographic portions of each state. The weight exclusions were in the range of 150% of prior weight restrictions, including 120,000 pounds for semi-trailers plus a 5% tolerance if loaded away from a scale. Neither state required upgrades to coal trucks, such as heavy duty brakes or improved handling characteristics or structural strength, to accommodate the increased load.

Research by the Kentucky Transportation Center found that crash and injury rates on coal haul roads stayed near the state average, but fatality rates increased. Several crash characteristics
were documented, including that most crashes were caused by drivers in other vehicles. They also identified common heavy truck crash types and common roadway situations related to these crashes.

Data from Kentucky weigh stations indicated that as a group, coal haul trucks were severely overloaded. Almost 90% of them exceeded the increased weight limits, with an average tractor and semi-trailer weight of 158,000 pounds (25% over the coal truck limit). Of 19,000 vehicles observed in a year, the heaviest weighed 220,600 pounds.

KTC evaluated two coal trucks against FMCSR low-speed braking standards. A new three-axle SU passed the test at loads from 40,900 to 120,680 pounds, and a new eight-axle combination truck (three axles could be lifted) passed at loads from 44,940 to 150,180 pounds. This outcome was somewhat surprising to enforcement officials and KTC researchers who conducted the test. For both trucks, the braking distances increased with increased weight. For the combination truck, the braking distances decreased with more axles on the pavement. Both trucks were more sensitive to increased speed at the initiation of braking than to increased weight. In other words, doubling the speed had a much larger effect than doubling the weight.

KTC researchers noted that investigating truck crashes was difficult, and that it was virtually impossible to establish truck weight after a crash. Reconstruction was arduous, time consuming, and rarely done. They felt that both researchers and crash investigators needed to know a lot more about safety relationships involving truck weight and truck speed. This would allow them to collect appropriate crash site data that related to weight, speed, and other factors that caused or contributed to the crash. KTC researchers noted that from gathering crash data, investigating crash sites and performing reconstruction, they did not find much to support excess weight as a cause of truck crashes. Although excess weight was a probable causal factor, sufficient data did not exist to support that conclusion.

West Virginia adopted legislation similar to the Kentucky, except that it required both shippers and receivers to file a report on each overweight truck. The act allowed email reporting, and made the email document the legal basis for issuing overweight citations. Consequently overweight coal trucks have virtually disappeared from West Virginia.

In summary, after more than 20 years of experience with coal haul trucks, Kentucky researchers have documented extreme loads, well above the exclusion limits for these trucks. A weigh station found that almost 90% were overweight, including one that was almost 100,000 pounds overweight. Accident studies showed that crash rates and injury rates on coal haul roads were near the state average, but the fatality rate was higher. Even with detailed crash investigation and reconstruction efforts, sufficient data could not be developed to associate excess weight with crash causation. West Virginia adopted similar legislation to allow overweight coal trucks but included an administrative clause that required shippers and receivers to notify the state of each overloaded truck; consequently their overweight citations and crashes dropped to all time low values.
Project Findings

This project drew several conclusions about current large or OS/OW commercial vehicle crashes. The findings regarding the extent of data available or needed were of special interest due to their effect upon analyzing OS/OW crash causation and severity. They are discussed in two general groups, primary findings and more specific findings on multiple topics.

Primary Findings Regarding OS/OW Commercial Vehicles and Safety

The most pertinent overarching findings regarding the contributions of OS/OW commercial vehicles to crashes appear to be the following:

1. In general, as commercial vehicles become larger and heavier, crash rates decrease but crash severity increases. A lack of consistency and lack of methodological rigor supporting previous findings precludes definitive conclusions regarding either a positive or negative relationship between larger/heavier vehicles and safety; suggesting only that additional research is needed to understand the complex relationship.

2. No existing truck crash data sets contain sufficient information for a scientific analysis of the specific contributions of size and weight (especially OS/OW) to crash causation or severity. The complex, confounding relationships between the contributing factors, and the very small sample sizes for different configurations of the largest commercial vehicles are two of the primary reasons that existing data are not sufficient.

3. Studies in Canada have indicated that the largest 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.

4. Another study in Canada found that large truck performance measures (SRS, off tracking, etc.) are highly correlated to large truck crash rates. Controlling truck safety through performance thresholds might offer an alternative way to enhance US large truck safety programs.

To develop more effective large truck safety programs, much additional highly-targeted data must be collected to determine vehicle weights (perhaps from weight data sets collected continuously at upstream WIM or virtual WIM locations) and from the shipper and receiver, from the freight firm, from the law enforcement and judiciary systems, and from other sources. Analysis of such comprehensive data can begin to unravel the relationship between OS/OW trucks and crash causation and severity.
More Specific Findings

Additional, More-Specific Data Needed

The need for better, more complete data and for additional research has been known for some time. This is illustrated by quotations from several prior research publications.

In 1985 Eicher wrote, “The lack of accident data collection on large trucks, the need for better on-site investigation of large-truck accident causation, and the necessity of more research on the behavior of large trucks on each functional class of roadway are discussed” (Eicher, et al. 1986).

In 1986 McGee published a list of high priority truck safety issues, including “…safety record versus truck type, the relationship of gross weight to truck safety, the relationship of truck length to truck safety, and the type of accident versus type of truck…” (McGee, 1986).

A 2002 TRB Special Report provided a quote that still defines the OS/OW truck crash situation, “…there is a dearth of literature linking vehicle size and weight to large truck safety levels… studies conducted over the last 60 years have not yielded definitive conclusions” (Morris, 2002).

The same TRB report also commented on needed research, “It is essential to examine the safety consequences of size and weight regulation. Research and monitoring needed to understand the relationship of truck characteristics and truck regulations to safety and other highway costs are not being conducted today” (Morris, 2002).

UA researchers who compiled this synthesis concluded that there is little or no scientifically reliable data on crashes of longer and bigger combination vehicles. This is especially true for triples, which are allowed by only 11 western states and three eastern states (only on turnpikes for eastern states). All 14 states of that allow triples impose restrictions on their operation.

Law enforcement officers and national transportation agency researchers relate that crash data is reported differently from jurisdiction to jurisdiction. This limits its use, and makes it very difficult to construct a suitable national data set capable of supporting an intensive scientific analysis.

Existing data sets are limited, either in the type of data or breadth of data. To advance the state of knowledge, a comprehensive data set is needed, containing quantitative, digital data, not empirical data. Assembling such data could be an extensive, expensive effort.

Effect of Vehicle Weight on Crash Cause and Severity

Carson had similar findings in two comprehensive studies (Carson, et al. 2002 and 2007), noting that research findings about GVW were consistent; higher GVW resulted in lower crash rates but higher crash severities. However, she found few historical studies in either project to confirm this relationship.
After performing OS/OW truck research projects, investigating OS/OW crashes as part of a multidisciplinary team, and reconstructing OS/OW crashes, Kentucky Transportation Center researchers stated that they did not find much to support excess weight as a cause of truck crashes. Although excess weight was a probable causal fact, sufficient data did not exist to support such a conclusion.

Overloading trucks increases the time and distance it takes for them to stop. This was documented by the Truck Safety Coalition (2007). The same situation was encountered in Kentucky during a braking test on a SU and a tractor semi-trailer; loads were gradually increased until the vehicles were significantly OW. Braking distances increased with increasing weight. But a more significant trend was how much braking distance increased with increased speed. This topic was discussed more fully earlier in this synthesis.

There have been few studies on the role of freight loads in crashes. The total load and weight distribution of commercial vehicles involved in collisions are very influential in the cause, type, and severity of crashes. The relationship between weights and factors like braking capacity and handling characteristics are not yet clearly understood.

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, especially when the load spilled.

A vehicle may weigh more than the federal weight criteria applicable to the roadway upon which it is traveling and not be overweight. The load might be legal under a grandfather clause of federal legislation, be subject to a categorical exclusion under state law, or may have a valid state highway agency permit for a specific load and a specific trip. Additional data is needed to determine which OS/OW vehicles involved in collisions were operating illegally and which were legal due to grandfathering, state legislative exemptions or state DOT permits.

**Speed**

Carson noted that the effect of speed limits on safety levels was unconfirmed, whether the speed limit was uniform or differentiated by vehicle type (Carson, et al. 2007).

Speed is often mentioned in the literature, with various estimates of its involvement rate in causing crashes. Investigating officers feel that it contributes to truck crashes, and it was cited as a factor in 20% of Kentucky heavy truck accidents.

Speed reported on a crash report is an estimate by the investigating officer and contains an unknown amount of error. For this reason researchers sometimes use the posted speed limit as a surrogate for the actual speed of a heavy truck. It too contains an error of unknown size. The correlation between the speed estimates by investigating officers, posted speed limits and the actual speeds of trucks is unknown.
**Size-Speed-Weight**

There is a pressing need for studies linking size, weight, speed and safety.

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.

In a test conducted by KTC (Pigman and Agent, April 1998), a SU and a tractor semitrailer met current low speed FMSCR braking requirements. Braking distance was found to increase with increasing weight. Also, combination truck braking distances decreased as the number of axles on the pavement increased. Braking distance was much more sensitive to the speed at which braking was initiated than to GVW. In other words, doubling GVW had less effect on stopping distance than doubling the speed at initiation of braking. At higher speeds the impact was much more pronounced. Even though this test was conducted in limited circumstances, it does begin to reveal interesting findings.

Those who work in this field intuitively know that there has to be an increased safety risk from higher speed and weight, if for no other reason than speed and weight determine the energy that must be absorbed in the crash. But current data are insufficient for a complex analysis for different crash factors like rollover, exceeding braking system capacity, unusual wheel and axle configurations, etc. There is no data to support such a study.

**Enforcement**

Issuing a citation to a truck in moving traffic is a difficult task to perform without causing congestion or inadvertently creating a traffic hazard. Sometimes an officer directs a trucker to the next freeway exit where the citation is issued. But it is rarely possible to find such a convenient location on a two-lane arterial road.

One CMV enforcement commander indicated that law enforcement officers hesitate to pull over offending trucks because they know the driver has to make a living (sympathy), there may be no place to pull the vehicle over (congestion and safety), and they may not know how to conduct a vehicle inspection or how to evaluate a driver’s log book (lack of training).

OS/OW drivers are known to dodge enforcement and to use “plugging” and other techniques to avoid weigh stations (Taylor, et al. 2007). CV enforcement agency managers have reported that OS/OW drivers are likely to use secondary roads or to travel at night to avoid enforcement officials.

Small firms (less than five trucks) are most likely to exceed size and weight limits. Their vehicles are typically older and less maintained, and their drivers are more apt to run more loads in a day because these firms operate on such a low margin. As might be expected, they generally have higher crash rates. This situation is exemplified by the one-vehicle “ma and pa” trucking
firm. Enforcement officers find it emotionally difficult to issue citations to these drivers because it might make a difference in keeping their firms in business.

**Enhanced Research Needed**

A fictitious scenario will provide insight into the type data needed for a scientific, controlled study of truck crashes. Suppose that four identical types of heavy truck crashes occurred with four different crash maneuvers on four different roadway classifications, for four different truck configurations with four different load weights, and at four highly different speeds. In this case the accident sequence and outcome would likely be much different for each truck. It would be meaningless for a researcher to draw conclusions about truck crashes in general.

The state of practice in safety research is to identify and control the individual factors that affect crashes. In the preceding example, if the crash maneuvers, roadway classifications, truck configurations and truck weights were identical (i.e., control them so that their effect on the crash event is the same for every truck), then it might be possible to examine effects of the remaining factor – speed.

**Build an Ideal Data Set**

To fully understand why and how OS/OW crashes occur, researchers need much more information to interpret the role of size or weight. If truck classifications are used as the basis for the research, then additional data must be provided for each classification of truck, including miles driven (exposure), road type (local roads, city streets, Interstate highways, NN, etc.), load type and weights, type and condition of brakes, speed at onset of the accident sequence, extent of injuries to drivers, passengers and pedestrians, etc. The possible data combinations are almost endless. For the highest level of accuracy, the values of these data items are linked to a particular truck in the dataset – its type, size, weight, speed, maneuver, road type, etc., must be known. Rather than trying to understand every possible contributing factor at once, a better approach is usually to find a data set for which most of the individual data items can be controlled so that one or two factors can be studied at a time.

This idea data set does not yet exist for heavy vehicles. But it could be obtained in the future if the most important parameters (like actual weigh of the vehicle and load at impact) are identified and sources for that data are identified. For loaded weight, the obvious example is inclusion of existing weight data bases into safety data bases, and increasing the collection of such data for individual vehicles. WIM and virtual WIM systems are capable of providing such data.

**Recommendations**

The following 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 to 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 OW/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 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 FARS data collection system.

• Where needed, provide specialized training to troopers, police officers and other involved 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 FHSCA 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.
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12.0 Glossary of Terms Related to Heavy Trucks
(Source: ShipNorthAmerica, 2009)

'A' TRAIN – An 'A' train is a tractor pulling a semi trailer with a shorter trailer or pup by means of a reach or spindle hook.

AIR RIDE SUSPENSION – An air ride suspension is a suspension which supports the load on air-filled rubber bags rather than steel springs. Compressed air is supplied by the same engine-driven air compressor and reservoir tanks which provide air to the air brake system.

AXLE, SINGLE – A single axle is one axle mounted independently of any other axle.

AXLE, SPREAD TANDEM – A spread tandem axle is a two-axle assembly in which the axles are separated beyond the spacing of a normal tandem assembly in order to qualify for maximum axle loads allowed by regulations.

AXLE, TANDEM – A tandem axle is a two-axle assembly having a means of distributing or transferring weight between the two axles.

'B' TRAIN – A 'B' train is a tractor pulling two semi trailers. The lead unit has a fifth wheel at the back to attach the second semi trailer or pup.

BOBTAIL – A bobtail is a tractor operating without a trailer. Also refers to straight truck.

BOGIE – A bogie is an auxiliary axle assembly having a fifth wheel used for purpose of converting a semi trailer to a full trailer. Dollies can be used to haul multiple trailers behind a single power unit. (A bogie is also referred to as a dolly).

CAB – The control room on a truck where the driver sits.

CHASSIS WEIGHT – See tare weight.

COMBINATION VEHICLE – This is an equipment configuration that includes separate power unit (tractor) and at least one trailer.

COMMERCIAL TRAILER – A trailer used to handle freight in the transportation of goods for others; excludes house trailers, light farm trailers and car trailers.

CURB WEIGHT – See chassis weight.

DOLLY – An auxiliary axle assembly having a fifth wheel used for purpose of converting a semi trailer to a full trailer. Dollies can be used to haul multiple trailers behind a single power unit. (A Dolly also referred to as Bogie).

DOUBLE – A combination of two trailers pulled by a power unit. Usually refers to a power unit pulling two 28' trailers. See also Rocky Mountain Double and Turnpike Double.

EXTENDABLE FLATBED TRAILER – A flatbed trailer whose length may be readily increased or decreased within prescribed limits and with prescribed variations in load carrying capability. Used mainly for oversized loads.
FIFTH WHEEL – Coupling device attached to a tractor or dolly which supports the front of a semi trailer and locks it to the tractor or dolly. The fifth wheel's center is designed to accept a trailer's kingpin, around which the trailer and tractor or dolly pivot in turns.

FIXED TANDEM – Assembly of two axles and suspension that is attached to the chassis in one place, and cannot be moved fore and aft.

FLATBED / FLATDECK – A truck with a flat deck made of wood or metal for carrying cargo.

GOOSENECK – On a drop frame trailer, that portion of the trailer which extends upward and forward from the front of the loading deck to, and including, the upper coupler and front cross member.

GOOSENECK, REMOVABLE – This is a gooseneck that can be separated from the trailer and reconnected, usually through the use of large hooks or removable pins. Such goosenecks are usually removed by the tractor winch line or hydraulic cylinders.

HIGHBOY – A trailer with a flat deck.

HIGHWAY TRACTOR – A tractor is the power unit used for pulling trailers on the highway.

KINGPIN – A kingpin is an anchor pin at the center of a semi trailer's upper coupler which is captured by the locking jaws of a tractor's fifth wheel to attach the tractor to the semi trailer.

LCV – An LCV (Long Combination Vehicle), in general, is a vehicle longer than a standard doubles rig (tractor and two 28-foot semi trailers). Examples of LCVs which are permitted in some U.S. western states and eastern toll roads: Twin 48-foot trailers; triple 28-foot trailers.

LOGBOOK – Book carried by truck drivers in which they record their hours of service and duty status for each 24-hour period.

LOWBOY – Open flatbed trailer with a deck height very low to the ground, used to haul construction equipment or bulky or heavy loads.

PAYLOAD – Weight of freight being hauled.

PINTLE HOOK – Coupling device used in double trailer, triple trailer and truck-trailer combinations. It has a curved, fixed towing horn and an upper latch that opens to accept the drawbar eye of a trailer or dolly.

POWER UNITS – The power unit is the control and pulling vehicle for trailers or semi trailers.

PUP TRAILER – A short semi trailer with a single axle, usually between 26 and 32 feet long.

RED LINE – Term referring to the halfway point in a trailer. The line is usually painted across the inside ceiling of the trailer.

ROCKY MOUNTAIN DOUBLE – This is a combination vehicle consisting of a tractor, a 45 to 48 foot semi trailer and a shorter 28 foot semi trailer.

SEMI TRAILER – Truck trailer equipped with one or more axles and constructed so that the front end rests upon a truck tractor.

STAA Double – This is a combination vehicle consisting of a tractor, and two 28-foot van semi trailers connected by an A-train, with a maximum GVW of pounds. (It is sometimes called a Legal Double).

STEPDECK / SINGLE DROP – A trailer that has a main deck that is lower than the deck above the fifth wheel, but not as low as that of a double drop. The back of the deck is usually level with the top of the trailer tires.
STRAIGHT TRUCK – A vehicle with the cargo body and tractor mounted on the same chassis.
TARE WEIGHT – Weight of the empty truck, without occupants or load.
TRACTOR TRAILER – Tractor and semi trailer combination.
TRAILER – A vehicle designed without motive power, to be drawn by another vehicle.
TRI-AXLE – Truck, tractor or trailer with three axles grouped together at the rear (also referred to as a tridem).
TRUCK – A motor vehicle designed to carry an entire load. It may consist of a chassis and body; a chassis, cab and body; or it may be of integral construction so that the body and chassis form a single unit.
TURNPIKE DOUBLE – A combination vehicle consisting of a tractor and two trailers of 45 to 48 feet.
TWIN TRAILER – A short semi trailer (under 29 feet) designed to be operated as part of a combination vehicle with a tandem trailer of similar length.
VAN (DRY VAN) – Standard trailer or truck with all sides enclosed.
13. Acronyms

**AASHTO** – American Association of State Highway and Transportation Officials  
**ADT** – average daily traffic  
**CFR** – Code of Federal Regulations  
**CMV** – commercial motor vehicle  
**CV** – commercial vehicle  
**DOT** – Department of Transportation  
**FARS** – Fatality Analysis Reporting System  
**FHWA** – Federal Highway Administration  
**FMCSA** – Federal Motor Carrier Safety Administration  
**FMCSR** – Federal Motor Carrier Safety Regulations  
**GVW** – gross vehicle weight  
**ISTEA** – Intermodal Surface Transportation Efficiency Act  
**km** – kilometers  
**KTC** – Kentucky Transportation Center  
**LCV** – longer combination vehicles  
**LTCCS** – Large Truck Crash Causation Study  
**MVM** – million vehicle miles (traveled)  
**NCHRP** – National Cooperative Highway Research Program  
**NHTSA** – National Highway Transportation Safety Administration  
**NN** – National Network  
**OS/OW** – oversize/overweight  
**PDO** – property damage only  
**SHV** – specialized hauling vehicle  
**SRS** – static roll stability  
**STAA** – Surface Transportation Assistance Act  
**SU** – single unit truck  
**TIFA** – Truck Involvement in Fatal Accidents  
**TRB** – Transportation Research Board  
**TSW** – truck size and weight  
**UMTRI** – University of Michigan Transportation Research Institute  
**UTCA** – University Transportation Center for Alabama  
**VMT** – vehicle miles traveled  
**VSW** – vehicle size and weight