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Report to the Chairman, Subcommittee on Surface Transportation, Committee on Public Works and Transportation, House of Representatives

March 1992

TRUCK SAFETY

The Safety of Longer Combination Vehicles Is Unknown

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GAO

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Resources, Community, and
Economic Development Division

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March 11, 1992

The Honorable Norman Y. Mineta
Chairman, Subcommittee on Surface
Transportation
Committee on Public Works and
Transportation
House of Representatives

Dear Mr. Chairman:

Because of concerns over the safety of longer combination vehicles (LCV), the Congress, in the Intermodal Surface Transportation Efficiency Act of 1991, Public Law 102-240, prevented the expansion of LCV use into states that did not allow them before June 1, 1991.[1] In response to your October 17, 1990, request, this report presents the results of our initial study on the safety of LCVs. As agreed with your office, we (1) reviewed the current extent of LCV use, (2) summarized results of numerous studies on LCV safety, and (3) identified major operational characteristics that affect LCV safety. As required by the act, a second study will address the history and effectiveness of the procedures and controls used by the states to ensure safer LCV operation.

Results in Brief

Twenty states—most of them in the West—allow LCVs to operate but have very different restrictions on the types of LCVs allowed, the routes on which they can operate, their length, and their weight. Nine states limit the routes open to LCVs to interstate highways and turnpikes, two states allow limited additional travel beyond interstate highways, and the remaining nine states allow LCVs on most routes open to other trucks—including over 110,000 miles of generally smaller two-lane roads.

Existing studies that examine the accident rates of multiple-trailer trucks have reached widely different conclusions concerning the safety of LCVs. For example, some studies have found that multiple-trailer trucks are less likely to be involved in accidents than single-trailer trucks, while other studies have shown that multiple-trailer trucks are more likely to be involved in accidents. Weaknesses in the data used and different study approaches contributed to the different results. Most studies contained

[1]For purpose of this report, an LCV is any truck combination with (1) two trailers that have a combined trailer length longer than twin 28-foot trailers, which are allowed nationwide, or (2) three trailers. Also, some straight trucks (single-unit) with a trailer(s) may also qualify as LCVs, as noted in fig. 1. Most LCVs weigh more than the 80,000 pounds generally allowed on the interstate system.

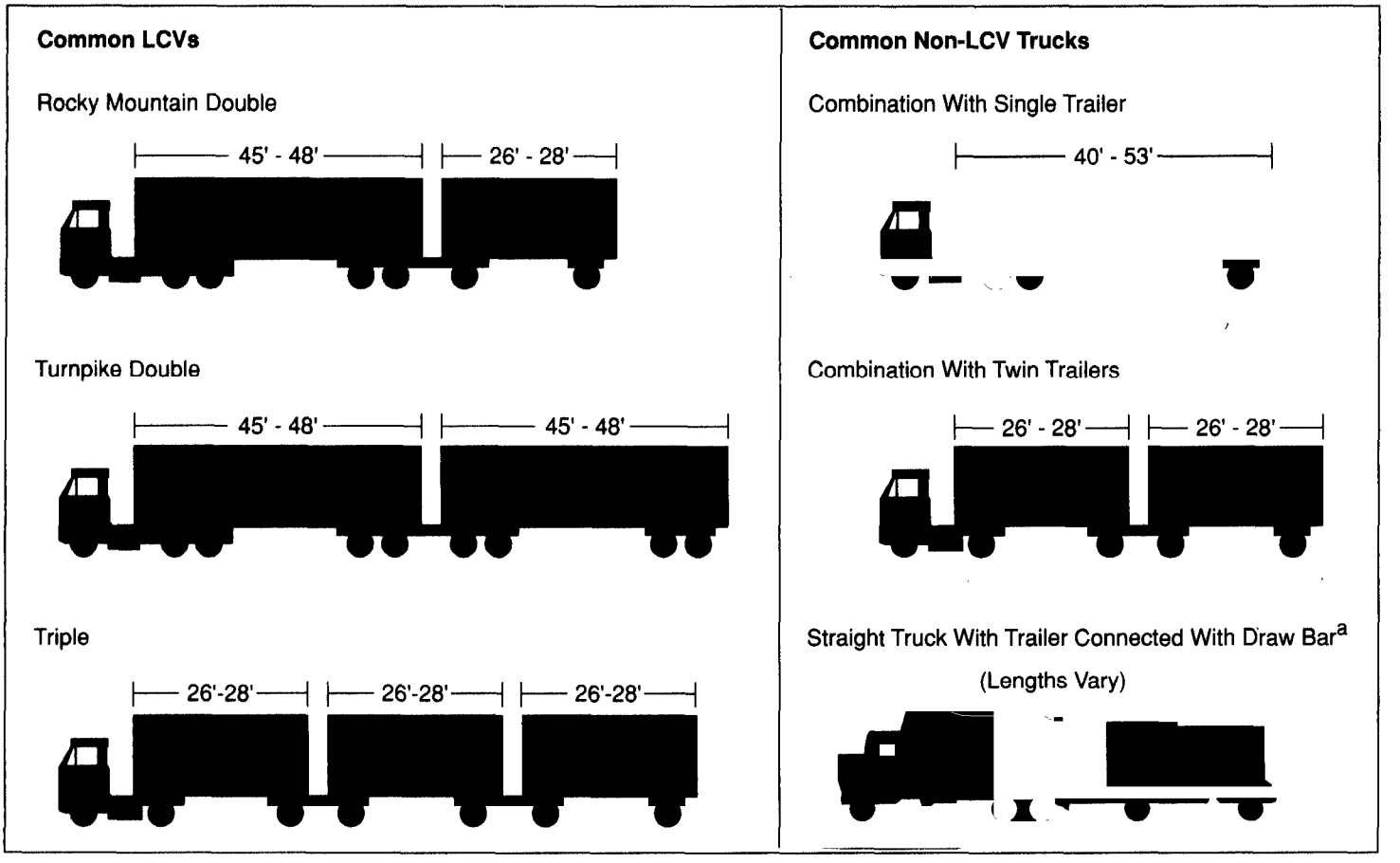
little specific information on LCVs and therefore reported primarily on non-LCV trucks with twin 28-foot trailers, which are allowed nationwide and have some of the same operational characteristics as LCVs. Thus, the safety of LCVs is still largely unknown.

LCVs may be less stable and maneuverable than single-trailer trucks, which can influence LCV safety. Studies testing the operational characteristics of LCVs indicate that their trailers are more apt to sway than the trailer of a single-trailer truck and that sudden steering movements can be amplified toward the rear of LCVs. In addition, some LCVs need a wider turn path than do single-trailer trucks. These operational characteristics can cause LCVs to move outside their lane of travel or, in the extreme, can cause the rear trailer(s) to roll over. Further, LCVs can require longer distances to stop and often lack the acceleration needed to move smoothly with traffic. It is important to note, however, that LCVs' operational characteristics are affected by a complex array of factors, including the type of LCV, the driver, the distribution of the load, the equipment used, and road conditions.

Background

Figure 1 illustrates the three most common types of LCVs—Rocky Mountain doubles, turnpike doubles, and triples—and distinguishes them from other trucks allowed to operate nationwide. Carriers utilize LCV configurations with all types of trailers in response to specialized transportation needs and states' different length and weight restrictions.

Figure 1: Distinguishing LCVs From Other Trucks



[a]Under our definition of an LCV, this configuration can also be classified as an LCV if the length of the cargo portion of the single-unit (straight) truck, the draw bar, and the trailer exceeds the length of the twin 28-foot trailers or if a second trailer is added.

Source: American Trucking Association and Transportation Research Board.

Determining allowable vehicle weights and sizes is primarily the responsibility of state governments, although the federal government has set limits for interstates and certain other federally assisted highway systems. The Federal-Aid Highway Act of 1956 was amended in 1958 to set vehicle width at 96 inches for certain highways and to limit vehicle gross weight to 73,280 pounds for the interstate system. The weight limit was raised to 80,000 pounds in 1974. Subsequent highway bills have repeatedly granted states exceptions to the weight limit through "grandfather" provisions. The Surface Transportation Assistance Act of 1982 increased vehicle width to 102 inches, retained vehicle weight at 80,000 pounds, and

continued the grandfather provisions. The 1982 act also required states to allow trucks with single trailers of up to 48 feet and with twin trailers of up to 28 feet each to operate nationwide on federally assisted highways.[2]

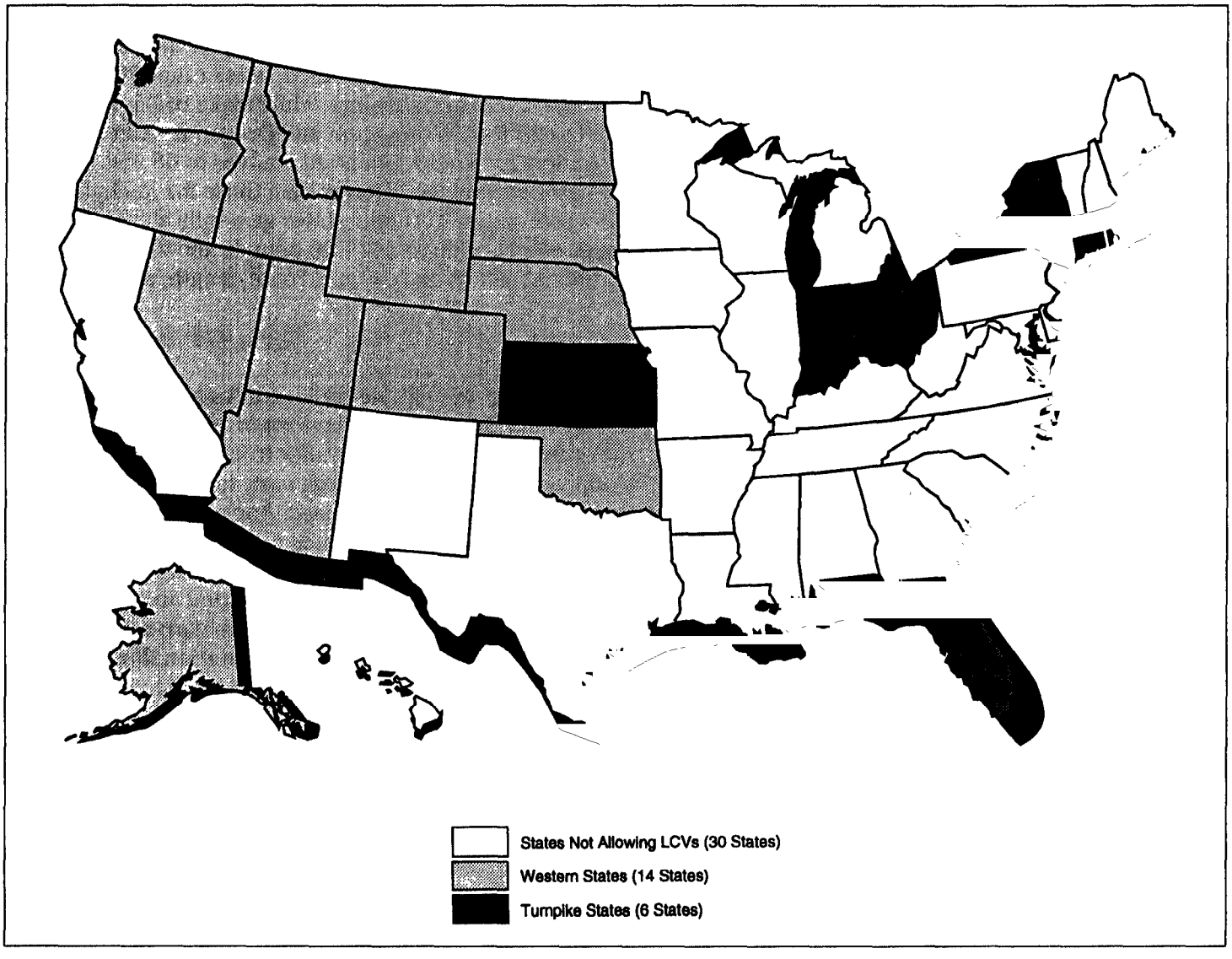
In December 1991, the President signed the Intermodal Surface Transportation Efficiency Act of 1991, preventing the expansion of LCV use. The act limits operation to the 20 states that permitted it as of June 1, 1991. The act permits states to further restrict LCV use within their borders, but otherwise it maintains existing state restrictions. These include restrictions on the types of LCVs allowed, the routes on which they can operate, their length, and their weight and other state restrictions in effect as of that date. In addition, to improve transportation data, the act (1) establishes a Department of Transportation (DOT) Bureau of Transportation Statistics, (2) requires a National Academy of Sciences study of DOT's capabilities and needs in collecting data, and (3) provides grants to states to improve accident data for trucks and buses.

States Have Widely Different Restrictions on LCV Use

The extent of LCV use varies in the 20 states that allow the vehicles, as shown in figure 2. Some of the turnpike states, so called because they allow LCVs only on designated turnpikes, have allowed LCV use for about 30 years; other Western states have allowed use for fewer than 10 years. To ensure safer operation, states have instituted different restrictions, including those on the types of LCVs allowed, the routes on which they can operate, their length, and their weight.

[2]Using grandfather provisions, many states have allowed slightly longer trailers than those allowed by the act, generally increasing the limits from 48 feet to 53 feet and from 28 feet to 28-1/2 or 29 feet.

Figure 2: States Allowing LCVs



Rocky Mountain doubles are allowed in all 20 states, turnpike doubles in 17, and triples in 14. Nine states restrict LCVs to interstates or designated turnpikes. In contrast, nine Western states allow at least one type of LCV to travel on nearly all interstate highways on which trucks with twin 28-foot trailers operate, including at least 28,000 miles of the smaller two-lane roads. Nine of the Western states also allow LCVs on at least 85,000 miles of additional, mostly two-lane, roads. In total, LCVs are allowed on over 110,000 miles of two-lane roads.

States' restrictions on the length of LCVs may apply to individual trailers, combined trailers, the overall vehicle, or some combination of these limits. Such limits result in very different-size LCVs. For example, the maximum length of individual trailers for Rocky Mountain doubles ranges from 40 feet in Oregon to 59-1/2 feet in Oklahoma, while triple trailer maximum lengths are usually 28 to 29 feet. Washington and Oregon restrict the length of combined trailers for Rocky Mountain doubles to 68 feet, resulting in trailer lengths several feet shorter than those for Rocky Mountain doubles in other states. Turnpike states generally allow heavier LCVs, with a maximum weight of up to 147,000 pounds allowed by Florida. (App. I provides additional details on LCV type, route, length, and weight restrictions.)

Safety of LCVs Is Still Largely Unknown

Studies to determine the safety of multiple-trailer trucks have reached widely different conclusions. Some studies have reported that multiple-trailer trucks are safer than single-trailer trucks, and other studies have reported the opposite. This is due, in large part, to the different approaches and data bases the studies have used. Approaches include comparing multiple-trailer trucks' accident rates per million miles traveled and accident involvement to single-trailer trucks', comparing the severity of accidents involving both types of vehicles, investigating accidents in detail, surveying drivers, and collecting comments from carriers that use LCVs and the states that allow them. Both the Transportation Research Board (TRB) and the Office of Technology Assessment (OTA) have pointed out weaknesses in the accident and travel data on which studies of multiple-trailer trucks' accident rates are often based.

Different Approaches and Data Contributed to Varied Conclusions

Nine studies—conducted by organizations such as TRB, the University of Michigan Transportation Research Institute, and the California Department of Transportation—that compared the accident rates and accident involvement of multiple-trailer trucks and single-trailer trucks arrived at widely different conclusions over the trucks' relative safety. (See app. II.) Studies comparing rates ranged from finding multiple-trailer trucks to be 20 percent less likely to be involved in accidents than single-trailer trucks to 58 percent more likely. One study that compared the relative accident involvement of single- and multiple-trailer trucks found multiple-trailer trucks to be 200 to 300 percent more likely to be involved in accidents. Such differences stem from the approaches and different data bases used. For example, five of these studies depended on various national and state data bases for accident and travel data, two relied on records from large

carriers with better safety records than those of the general truck population, and the remaining two used different data sources and approaches to compare accident rates and involvement. TRB's review of most of these studies warned of weak data and pointed out that generalizing from these studies was not possible.

In addition to the above nine studies, other studies by the Federal Highway Administration (FHWA), OTA, TRB, and the University of Michigan Transportation Research Institute and studies sponsored by rail and trucking interests used different approaches to provide additional safety information. Studies comparing the severity of accidents (incidence of fatalities and injuries) involving multiple-trailer and single-trailer trucks reported little difference in severity, but noted that multiple-trailer trucks more often operate on safer divided highways, which lowered the number of accidents. Both in-depth analyses of accidents involving large trucks and driver surveys indicate that multiple-trailer trucks have operational characteristics that require the driver to have additional training and skill.

Another reason why the studies have reached different conclusions is that some studies compiled comments from carriers using LCVs and from individual states allowing LCVs to operate. These data generally show an excellent safety record—particularly for triples. It should be noted, however, that (1) much of the information on triples is from large carriers with strong safety programs that used only experienced, well-trained drivers; (2) state accident data have weaknesses similar to those in national data, which may affect accident rates reported for LCVs by some states; and (3) some states' special controls on routes, equipment, and operating environment make the conditions under which LCVs operate safer.

Inadequate Data Undermine Analysis of LCV Safety

TRB and OTA have recently reported that both truck travel and accident data provided by national and state data bases generally are inadequate. A 1990 TRB study stated that existing truck data are not adequate for determining trends in truck safety or for guiding actions that could reduce accident loss. This study summarized major weaknesses in national and state truck travel and accident data bases, concluding, "There are no truck data that are consistent over a period of years and provide details by type of truck, road class, and geographical area." OTA reached a similar conclusion in a 1991 study. Regarding LCVs, OTA stated, "LCV use and accident data are simply inadequate to accurately determine the consequences of LCV use on a wider network."

Knowing the number of miles trucks travel is critical to accurately determining accident rates, usually discussed in terms of accidents per million miles traveled. Determining the miles traveled by all types of combination trucks—let alone the miles traveled by LCVs specifically—has proven quite difficult, as evidenced by the large variations in the national estimates commonly used by safety studies. For example, estimates based on periodic surveys of carriers or operators were from 22 to 37 percent lower than estimates based on states' traffic counts reported to DOT, although both types of estimates have been criticized by researchers.

Reliable data on nonfatal accidents involving trucks are also not available. A major source for these data is the accident reports that carriers are required to report to DOT, but these reports are neither complete nor consistent. Only interstate carriers must submit accident reports, and DOT has reported that up to 40 percent of these reports are not filed. Also, certain reporting criteria have changed over time, lessening consistency. State data bases that include information on truck accidents within the state have also been criticized because there are inconsistent reporting criteria among and within states, a lack of detail on the type of trucks involved, and inadequate quality controls. (See apps. II and III for details on various safety studies and limitations in the data.)

LCVs' Operational Characteristics Can Influence Safety

Federal, state, trucking organization, and carrier officials have recognized that LCVs have characteristics that can reduce their stability and maneuverability and influence safety. As a result, most states have instituted various levels of special controls for these vehicles. Perhaps the most discussed operational characteristic of LCVs is their potential instability. Major concerns about their operation at highway speeds are caused by the tendency of trailers to sway and of rapid steering movements to be amplified toward the rear of the vehicle (rearward amplification). Trailer sway, the side-to-side movement of multiple trailers, can be caused by poor maintenance of critical connecting mechanisms (points of articulation), uneven distribution of the load, incompatible or inadequate equipment, rutted highways, or wind gusts. Rearward amplification—often called the "crack the whip" effect—is usually initiated when drivers make sudden steering maneuvers to avoid obstacles. Both trailer sway and rearward amplification are worse for triples because their trailers are shorter and because they have more points of articulation. According to studies, these operational characteristics can increase the chances that the driver could lose control of the vehicle and possibly have a trailer or trailers roll over. (See app. IV for more explanation.)

LCVs' stability during braking and the distance the vehicles require to stop are also operational characteristics that have been heavily debated. Braking tests are usually conducted with experienced drivers, recommended equipment, properly adjusted brakes, and properly distributed loads. Part of the recommended equipment is a device that allows brakes on the rear trailer to be applied first, "stretching" the vehicles to facilitate a straight stop. Some tests have shown that LCVs can stop in a fairly short distance, comparable to that for single-trailer trucks, given LCVs' additional wheels and related braking capacity. Studies also indicate, however, a number of potential problems with LCVs' braking under other conditions. During roadside inspections, the most frequent violation concerning equipment is brakes that are out of adjustment. Brakes' being out of adjustment is even more critical for LCVs because of the greater number of brakes that must be adjusted and must work in the proper sequence. In addition, if an LCV's last trailer is empty or lightly loaded, the chance is increased that the trailer's brakes will lock and cause the trailer to swing to the side. These factors could make the braking of LCVs in actual operation less effective than that of LCVs in controlled test conditions.

Operational testing and computer simulation show that certain LCVs are less maneuverable than single-trailer trucks. LCVs with longer trailers require a wider path to turn than single-trailer vehicles. This "off-tracking" occurs when the rearmost trailer's wheels do not follow the path of the tractor's front wheels. At slower speeds, the rear trailer's wheels require additional space toward the inside of the curve, but as speed increases, these wheels require more space toward the outside of the curve. Inward and outward off-tracking can cause the last trailer to move outside its lane of travel. The same increased points of articulation and shorter trailer lengths that decrease triples' stability at higher speeds decrease triples' inward off-tracking at lower speeds and allow them to negotiate curves in about the same space needed by single-trailer trucks. Turnpike doubles, on the other hand, exhibit more inward off-tracking because they have fewer points of articulation and longer trailers. Inward off-tracking can cause trailers to hit roadside objects, overrun curbs, or encroach into other lanes at intersections.

At high speeds, however, triples exhibit the worst outward off-tracking as they go around curves. According to an FHWA study, at 55 miles per hour (mph) on the same curve, triples off-tracked about 2 feet—compared to 1 foot for turnpike doubles. Increased outward off-tracking can create

particular problems on two-lane roads if the last trailer encroaches into the lane for oncoming traffic.

Safety studies also cite potential problems if the additional weight of LCVs decreases their ability to accelerate and move with the traffic flow. The authors of one study note that a speed difference of 15 mph between vehicles can increase accident rates 8.9 times; a difference of 20 mph, 15.5 times. Unless LCVs' power is increased, the vehicles may be less able to climb hills, pass, and merge—creating such differences in speed between them and surrounding traffic. Because they may be slower and are longer than other vehicles, LCVs can also require additional time and space to maneuver in traffic. Before making left turns across intersections, for example, drivers of LCVs must ensure that an adequate gap exists in the oncoming traffic for the last trailer to clear the intersection.

Because of these operational characteristics, drivers of LCVs must be well trained. To compensate for LCVs' operational differences and reduce the number of accidents involving LCVs, states allowing them have historically imposed additional controls on their drivers, the equipment, carriers using LCVs, and the vehicles' operating environment—although these controls, such as the route restrictions previously discussed, vary among states. (See app. IV for more details on LCVs' operational characteristics.)

Safety of LCVs Could Diminish in the Future

Two key factors that could impact the future safety of LCVs are projections for an increase in traffic density and a shortage of experienced truck drivers. DOT projects tremendous growth in traffic over the next 30 years, indicating that the number of vehicle miles traveled will nearly double by 2020. Intercity trucking has grown rapidly during the 1980s, and truck travel is projected to account for a larger share of the total miles traveled by all vehicles in the future. Although traffic density in the Western states is and will probably be lower than in the rest of the country, LCVs in the West are likely to encounter heavier traffic than they do today.

A chief concern of the trucking industry is a shortage of well-trained and experienced drivers, which is projected to worsen. The Department of Labor's estimates indicate that trucking will have one of the greatest demands for workers in the future. One estimate is that up to 500,000 truck driving jobs will go unfilled in the 1990s. Industry sources note that the shortage is caused by the reduced numbers of new drivers entering the labor force, carriers' inability to retain drivers, reduced student loans for truck driving schools, stricter federal licensing requirements for drivers,

poor working conditions (particularly long periods away from home), and low wages. Regarding low wages, the Department of Commerce reports that transportation employees' salaries increased by only 34 percent in the 10 years from 1980 through 1989, compared to 58 percent for all U.S. workers. This overall shortage of drivers and the increased numbers of LCVs could result in carriers' using less-experienced drivers.

Conclusions

Although LCVs have operated for over 30 years, little definitive information on their safety is available. Studies comparing accident rates and involvement of trucks with multiple trailers and trucks with single trailers have yielded widely varied results—partly because of weaknesses in truck accident and travel data. Until shortcomings in the data are overcome, the actual impact all types of LCVs have on highway safety will not be known. In the face of widely different results of safety studies and weaknesses in truck accident and travel data, the Congress enacted Public Law 102-240, which prohibits the expansion of LCV use. Although the act also requires several actions to improve transportation data, it does not specify the type of truck data required.

Recommendation

To improve transportation data and to help determine the safety of LCVs, we recommend that the Secretary of Transportation improve truck accident and travel data, especially as they relate to the reporting of nonfatal accidents, the estimates of truck travel, and the identification of truck configurations.

Scope and Methodology

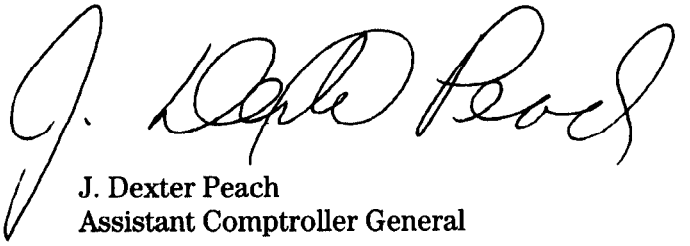
Our work was conducted from December 1990 to September 1991, in accordance with generally accepted government auditing standards. We did not independently research state laws, regulations, and policies restricting LCV operation, but summarized available information and updated it with state officials. We reviewed existing studies of LCV safety to determine those considered by experts to be most reliable, but we did not independently assess the reliability of the studies, the methodologies used, or reliability of the data on which the studies were based. We interviewed truck, railroad, and DOT officials concerning LCV safety and attended numerous meetings and seminars concerning this topic.

We discussed this report with FHWA officials, who generally agreed with the facts presented, and incorporated their comments as appropriate.

However, as you requested, we did not obtain written agency comments on this report.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days from the date of this letter. At that time, we will send copies of the report to interested congressional committees, the Secretary of Transportation, and the Administrator of FHWA. We will also make copies available upon request. The work was performed under the direction of Kenneth M. Mead, Director, Transportation Issues, who can be reached on (202) 275-1000. Other major contributors are listed in appendix VI.

Sincerely yours,



J. Dexter Peach
Assistant Comptroller General

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Abbreviations

DOT	Department of Transportation
FARS	Fatal Accident Reporting System
FHWA	Federal Highway Administration
GAO	General Accounting Office
HPMS	Highway Performance Monitoring System
LCV	longer combination vehicle
mph	miles per hour
NTN	National Truck Network
NTTIS	National Truck Trip Information Survey
OTA	Office of Technology Assessment
TIFA	Trucks Involved in Fatal Accidents
TIUS	Truck Inventory and Use Survey
TRB	Transportation Research Board

Operations of and Restrictions on Longer Combination Vehicles

Currently 20 states allow longer combination vehicles (LCV), but the extent of LCV operation varies dramatically. For example, 2 states allow only one type of LCV, 5 allow two types, and 13 allow all three types. Route restrictions are particularly diverse, with about half of the states allowing fairly unrestricted operation and the other half severely limiting routes open to LCVs. Also, states' different length and weight restrictions result in different-size LCVs, even of the same type. It should be noted that the length of trailers, including those used by LCVs, has increased from 40 feet, common in 1960, to 48 and 53 feet in 1990.

States Allowing LCVs

All 20 states allow Rocky Mountain doubles, although they are used infrequently in the 6 turnpike states; 17 allow turnpike doubles; and 14 allow triples. Five turnpike states have allowed LCV use for over 30 years. In contrast, seven Western states have allowed the vehicles for 10 years or less. Oklahoma did not allow LCVs until 1986. Further, not all LCV types were approved at the same time by each state. While Ohio, for example, first allowed turnpike doubles in 1960, the state did not approve triples' use until 1990. Conversely, Oregon allowed triples in 1967, but did not approve Rocky Mountain doubles' use until 1982. Table I.1 notes when the various types of LCVs were approved by the individual states.

Table I.1: First Year That Permanent Operation Was Allowed for Each Type of LCV, by State

State	Year operation was allowed, by type of LCV		
	Rocky Mountain doubles	Turnpike doubles	Triples
Western			
Alaska	1984	1984	[a]
Arizona	1976	1976	1976
Colorado	1983	1983	1983
Idaho	1968	1968	1968
Montana	1968	1972	1987
Nebraska[b]	1984	1984	1984
Nevada	1969	1969	1969
North Dakota	1983	1983	1983
Oklahoma	1986	1986	1987
Oregon	1982	[c]	1967
South Dakota	1981	1984	1988
Utah	1974	1974	1975
Washington	1983	[c]	[c]
Wyoming	1983	[c]	[c]
Turnpike[d]			
Florida	1968	1968	[c]
Indiana	1956	1956	1986
Kansas	1960	1960	1960
Massachusetts	1959	1959	[c]
New York	1959	1959	[c]
Ohio	1960	1960	1990
Total number of states	**20**	**17**	**14**

[a]Triples were allowed to operate in Alaska during the summer months of 1990 and 1991 so their operation could be evaluated. As of September 1991, no decision had been made on whether or not permanent operation would be allowed.

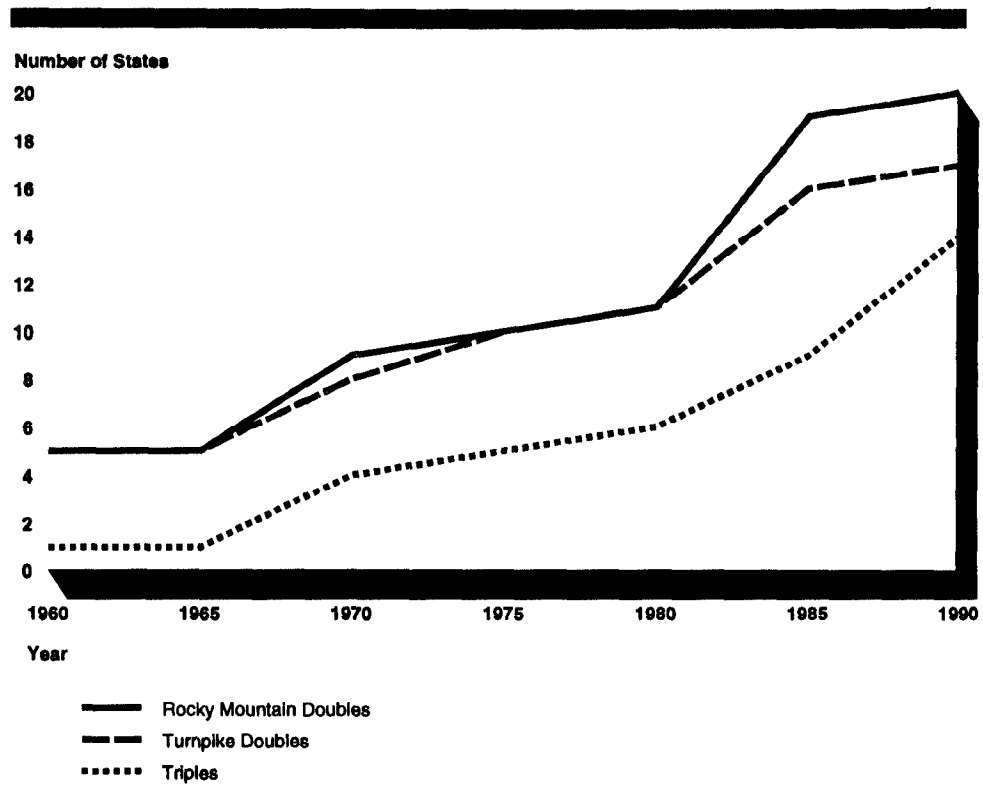
[b]Nebraska allows only LCVs with empty trailers to travel on the interstate highways. Because the last permit for this use expired in 1989, no LCV operation existed in the state as of September 1991.

[c]This type of LCV is not allowed to operate in the state.

[d]Although these states' regulations do not prohibit the use of Rocky Mountain doubles, Indiana officials stated that these LCVs have never been used in their state, and officials of the other turnpike states said that very few operate in their states.

Figure I.1 illustrates the growth in the number of states allowing each type of LCV from 1960 to 1990. The number of states allowing LCVs increased substantially during the 1980s, particularly between 1980 and 1985 for those allowing Rocky Mountain doubles and during the late 1980s for those allowing triples.

Figure I.1: Growth in the Number of States Allowing Each Type of LCV, 1960-90



Route Restrictions

Among the 20 states that allow LCVs, 9 severely limit the routes open to these vehicles. Three states (Arizona, Colorado, and Nebraska) limit operations to interstate highways, and the six turnpike states limit them to designated turnpikes and toll roads.[1] The remaining 11 states allow LCVs to use noninterstate roads, and 9 of these states allow LCVs on the majority of their National Truck Network (NTN) mileage.[2] In addition, nine states allow LCVs on additional routes beyond the network. Most of these noninterstate roads on the NTN and the additional routes are two-lane roads. Route restrictions often depend on the type of LCV—shorter LCVs are generally less restricted.

[1]Indiana refers to its LCV route as a toll road, while the other states call their LCV routes turnpikes. In this report, we will refer to all six states as turnpike states and their LCV routes as turnpike mileage.

[2]The NTN, mandated by the Surface Transportation Act of 1982 to increase the efficiency of freight transportation, includes nearly all of the 44,849-mile interstate highway system and about 152,000 miles of noninterstate roads. The percentage of major noninterstate mileage placed on the truck network varies dramatically among the 50 states, from less than 10 percent in 11 states to over 95 percent in 18 states. Of these 18, 13 are states allowing LCVs.

Interstate Mileage Open to LCVs

As shown in table I.2, 10 of the 14 Western states allow Rocky Mountain doubles on the states' entire interstate highway system, 7 allow turnpike doubles, and 8 allow triples. Of the 14 states, Alaska has no interstate roads. Arizona is the most restrictive in terms of interstate mileage open to LCVs. The state allows LCVs on only 29 miles of interstate. The approved interstate route allows LCVs traveling between Utah and Nevada to cross the northwest corner of Arizona.

Table I.2: Interstate Mileage Open to LCVs in the Western States

State	Total miles of interstate highways	Interstate mileage open to: Rocky Mountain doubles	Turnpike doubles	Triples
Alaska[a]	0	0	0	0
Arizona[b]	1,166	29	29	29
Colorado	939	791	791	791
Idaho	611	611	611	611
Montana	1,191	1,191	1,191	1,191
Nebraska	481	443	443	443
Nevada	545	545	545	545
North Dakota	571	571	571	571
Oklahoma	929	929	929	929
Oregon	727	727	[c]	727
South Dakota	677	677	677	677
Utah	938	938	938	938
Washington	762	762	[c]	[c]
Wyoming	914	914	[c]	[c]
Total	**10,451**	**9,128**	**6,725**	**7,452**

[a]Alaska does not have interstate roads, although certain roads (nearly all are two-lane) are termed "interstate designated."

[b]The only other mileage (noninterstate) in Arizona open to LCVs is access (up to 20 miles) on highways south its border with Utah.

[c]This type of LCV is not allowed to operate in the state.

While many of the Western states allow LCVs on all of their interstate highways, the six turnpike states limit LCVs to designated turnpikes that constitute about 24 percent of these states' interstate mileage. Table I.3 shows the turnpike mileage open to LCVs in the turnpike states and compares this mileage with the total interstate mileage in these states. Except for in Florida, turnpike mileage open to LCVs is part of the federal interstate highway system.

Table I.3: Turnpike Mileage Open to LCVs in the Turnpike States

State	Total miles of interstate highways	Turnpike mileage open to: Rocky Mountain doubles	Turnpike doubles	Triples
Florida	1,395	346[a]	346[a]	[b]
Indiana	1,118	157	157	157
Kansas[c]	870	236	236	236
Massachusetts	564	131	131	[b]
New York	1,501	544	544	[b]
Ohio	1,565	241	241	241
Total	**7,013**	**1,655[a]**	**1,655[a]**	**634**

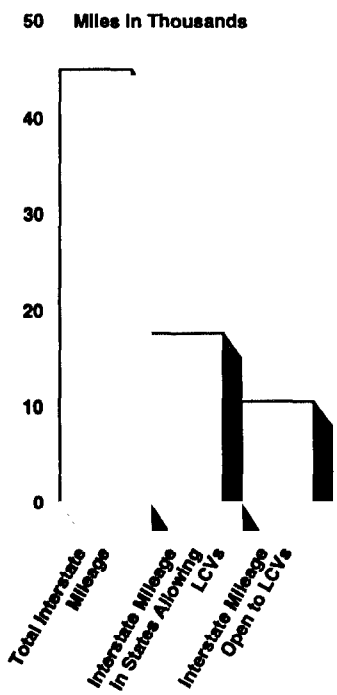
[a]Unlike the other turnpike states, Florida's turnpike mileage is not a part of the state's interstate highway system.

[b]This type of LCV is not allowed to operate in the state.

[c]Kansas also allows LCVs on about 14 miles of other roads to allow access from the neighboring states of Colorado and Oklahoma.

Combining the interstate mileage from tables I.2 and I.3 reveals that almost 17,500 miles of the nation's 45,000 miles of interstate highways are in the 20 states allowing LCVs. These states, however, open less than 10,500 miles of interstate highways to LCVs—as depicted in figure I.2.

Figure I.2: Interstate Mileage Open to LCVs in the 20 States Allowing Them



National Truck Network Mileage and Other Routes Open to LCVs

While 3 Western states (Arizona, Colorado, and Nebraska) restrict LCVs to interstates, 9 of the other 11 states allow nearly unlimited travel on the NTN for the smaller Rocky Mountain doubles. Two states (Idaho and Oklahoma) limit travel on the network. Other types of LCVs are generally more restricted on the network. (See table I.4.)

Table I.4: Noninterstate Mileage on the National Truck Network Open to LCVs in the Western States

		Noninterstate NTN mileage open to					
		Rocky Mountain doubles		Turnpike doubles		Tripes	
States	Total miles of noninterstate NTN highways	Miles	Percent	Miles	Percent	Miles	Percent
Alaska	493	493	100	493	100	380	77
Idaho	1,875	893	48	0		893	48
Montana	5,453	5,453	100	5,453[a]	100	0	
Nevada	1,876	1,857	99	1,857	99	1,857	99
North Dakota	1,671	1,671	100	1,671	100	1,671	100
Oklahoma	5,308	927	17	927	17	927	17
Oregon	4,031	4,031	100	[b]		1,536[c]	38
South Dakota	5,996	5,996[d]	100	311	5	311	5
Utah	2,620	2,620[e]	100	0		0	
Washington	5,028	5,028	100	[b]		[b]	
Wyoming	2,931	2,931	100	[b]		[b]	
Total	**37,282**	**31,900**	**86**	**10,712**	**29**	**7,575**	**20**

[a]Montana restricts turnpike doubles longer than 95 feet to interstates.

[b]This type of LCV is not allowed to operate in the state.

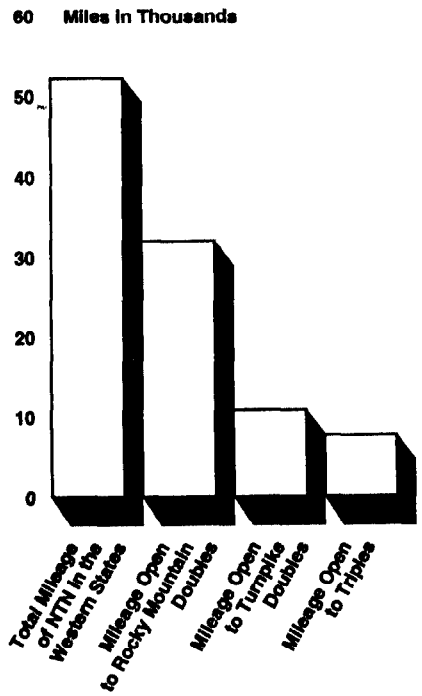
[c]Oregon officials could not readily identify how much of the NTN is open to triples because individual routes, both on and off the network, are approved. Officials estimated, however, that at least 1,536 miles of these routes are on the network.

[d]South Dakota restricts Rocky Mountain doubles with a combined trailer length longer than 81-1/2 feet to the same routes as its turnpike doubles and triples.

[e]Utah allows LCVs up to 92 feet long, generally Rocky Mountain doubles, on this mileage. Longer LCVs are allowed only on interstates.

The 14 Western states allowing LCVs include approximately 52,000 miles of the 152,000 miles of noninterstate roads on the NTN, but the mileage open to each type of LCV varies, as illustrated in figure I.3. Rocky Mountain doubles are by far the least restricted—allowed on nearly 32,000 miles, while triples are the most restricted—allowed on approximately 7,600 miles of the NTN.

Figure I.3: Noninterstate Mileage on the National Truck Network Open to Each Type of LCV in the Western States



Over 110,000 miles of the routes open to LCVs are two-lane roads—about 28,000 miles on the NTN and at least another 85,000 miles in addition to the NTN. Although nine states allow LCVs to travel on routes in addition to the NTN, 80 percent of the 85,000 miles are in Montana. The remaining portion is in Alaska, Idaho, Nevada, North Dakota, Oregon, South Dakota, Utah, and Wyoming.

Length and Weight Restrictions

As shown in table I.5, states also have different limits on the length and weight of LCVs. In restricting the length of LCVs, states limit the length of individual trailers, combined trailers, or overall vehicles or impose some combination of these restrictions.

The turnpike states generally allow heavier LCVs. In these states, the maximum gross weight allowed ranges from 120,000 pounds in Kansas to 147,000 pounds in Florida. Half of the 14 Western states allow maximum gross weights for LCVs of 110,000 pounds or less; 6 allow weights of up to 129,000 pounds; and 1 allows 135,000 pounds. Because the maximum weight allowed is often based upon factors such as the number and spacing

of axles, we have listed in table I.5 only the maximum weights for LCVs in general, as provided by state officials.

Table I.5: States' Restrictions on the Length and Weight of LCVs

	Maximum allowable length for										
	Rocky Mountain doubles				Turnpike doubles						
	Individual trailers				Individual trailers				Triples		
State	First	Last	Combined trailers	Overall vehicle	First	Last	Combined trailers	Overall vehicle	Each trailer	Overall vehicle	Maximum gross weight for all LCVs (pounds)
Western											
Ala.	48'		90'				95'		28'6"	120'	135,000
Ariz.	48'	29'		90'	45'	45'		105'	28'6"	105'	121,000
Colo.	48'	28'6"			48'	48'			28'6"		110,000
Ida.				105'	45'	45'		105'		105'	115,000
Mont.			81'	95'				100'	28'6"	110'	124,000
Neb.	48'	28'		95'				105'		105'	[a]
Nev.	48'	42'		105'	45'	45'		105'	28'6"	105'	129,000
N.D.	53'	28'6"		110'	45'	45'		110'	28'6"	110'	105,500
Okla.	59'6"	29'			59'6"	59'6"[b]			29'		90,000
Ore.	40'		68'					[c]	35'[d]	105'	105,500
S.D.	48'	48'		110'	48'	48'		110'	28'6"	110'	129,000
Utah	48'	28'6"		98'	45'	45'		105'	28'6"	105'	129,000
Wash.			68'					[c]		[c]	105,500
Wyo.	48'	40'	81'					[c]		[c]	117,000
Turnpike[e]											
Fla.	48'	48'		116'	48'	48'		116'		[c]	147,000
Ind.	48'6"	48'6"			48'6"	48'6"			28'6"		127,400
Kans.				119'				119'		119'	120,000
Mass.	48'	48'		114'	48'	48'		114'		[c]	127,400
N.Y.	48'	48'		114'	48'	48'		114'		[c]	143,400
Ohio				90'	48'	48'		112'	28'6"	105'	127,400

[a] In Nebraska trailers must be empty.

[b] Because Oklahoma has a gross vehicle weight limit of 90,000 pounds, state officials told us that turnpike doubles with 59-1/2 foot trailers are not actually used in Oklahoma.

[c] This type of LCV is not allowed to operate in the state.

[d] Oregon requires that the three trailers be of similar length; they may differ by no more than 6 feet.

[e] Length restrictions by the turnpike states (except for Ohio) are set for turnpike doubles, and these states' regulations do not mention Rocky Mountain doubles. Indiana officials said Rocky Mountain doubles have never operated in their state, while officials from the other turnpike states said that very few Rocky Mountain doubles operate in their states.

Accident Rates of Multiple-Trailer Trucks and Related Limitations in the Data

Because combinations with two 28-foot trailers are allowed nationwide, they constitute a far greater percentage of multiple-trailer truck travel than do LCVs. Consequently, much of what is known about the safety of LCVs is drawn from studies using data primarily on these smaller combinations, which do have some of the same operational characteristics as LCVs. Thus, LCV-specific accident and travel data are not readily available. Both the Transportation Research Board (TRB) and the Office of Technology Assessment (OTA) have noted inadequacies in truck accident and travel data. Nine studies, discussed by the TRB and others, used varied data bases and different approaches to reach widely different conclusions concerning multiple-trailer truck safety. Eight of these studies, which examined accident rates, ranged from finding multiple-trailer trucks from 20 percent less likely to be involved in accidents than single-trailer trucks to 58 percent more likely to be involved in accidents. The other study, which compared the relative accident involvement of single- and multiple-trailer trucks without looking at accident rates, found multiple-trailer trucks 200 to 300 percent more likely to be involved in accidents.

To develop accident rates, the number of accidents involving each type of vehicle is divided by the number of miles each type vehicle is driven. The resulting rates are discussed in terms of accidents per million miles traveled. Study results are also sometimes compared by developing ratios, using 1.0 as the base accident rate for single-trailer trucks. While some studies include all types of reported accidents, others consider only those accidents causing fatalities because the reporting of the latter type is thought to be more reliable.

Nationwide truck accident and travel data bases were used by three studies, state data bases by two, and various other data sources by the remaining four studies. A TRB study of national and state truck accident and travel data bases revealed numerous concerns about these data, as noted below.

National and State Accident Data Bases

National accident data bases for trucks include two systems that contain information only on fatal accidents and one that also includes information on certain nonfatal accidents: the Fatal Accident Reporting System (FARS), the Trucks Involved in Fatal Accidents (TIFA), and the Computerized Motor Carrier Accident Reports. TRB noted that state data have some of the same weaknesses that are present in the national systems, particularly inconsistent reporting of accidents and the inability to identify different truck configurations.

Fatal Accident Reporting System: This national data base, maintained by the Department of Transportation's (DOT) National Highway Traffic Safety Administration, consists of police reports of accidents that result in at least one fatality within 30 days of the accident. The quality of the data is thought to be good because the police reports are supplemented by information from other state sources. Computerized since 1975, this data base does not include information on nonfatal accidents, motor carriers, or truck cargos. Information on the number of trailers in a combination has been included since 1983.

Trucks Involved in Fatal Accidents: Sponsored by the motor carrier industry, this data base was developed by the University of Michigan Transportation Research Institute to provide details not available in FARS. TIFA has been available since 1980. The main strengths of TIFA are quality control exceeding that of FARS, increased detail on drivers, the ability to identify vehicle configurations, and increased information on motor carriers. The main limitations are a lack of data on nonfatal crashes and a time lag of 1-1/2 to 2 years between the time of the accident and the availability of data on it.

Computerized Motor Carrier Accident Reports: This data base derives its information from Form 50T reports which motor carriers are required to submit to the Federal Highway Administration's (FHWA) Office of Motor Carriers. Unlike FARS and TIFA, this system includes data on both fatal and nonfatal accidents and detailed information on drivers, vehicles, and carriers. Although data from this system have been available since 1973, they are neither consistent or complete. One source of inconsistency is the changing threshold for reporting accidents. The dollar amount of property damage—which is used to define the threshold—has changed over time. Currently, consideration is being given to replacing the dollar amount with a requirement to report all accidents in which a vehicle is towed away. The data base does not include accidents involving intrastate carriers (only interstate carriers must report), and it relies on the industry's self-reporting (underreporting was estimated by FHWA officials to be as much as 40 percent). In addition, this data base lacks quality control because the information carriers report is not verified.

State Accident Data Systems: TRB noted that most states do not consistently report accidents causing fatalities and injuries. Although state information includes descriptions of accident locations not available from national data, reporting criteria vary among the states and even within the same state. In addition, details on the truck configuration are generally

limited. For example, some states do not distinguish between single-unit trucks and combination vehicles or between single-trailer and multiple-trailer configurations.

National Estimates of Truck Travel

In developing accident rates, studies used three different estimates of the miles trucks travel nationwide. Two estimates are based on surveys that sampled operators and carriers, while one is based upon individual states' ongoing traffic counts, which are compiled, adjusted, and reported by FHWA. FHWA's estimates are higher than those relying on the survey method. TRB and others have cited limitations on both methods, as discussed below.

Truck Inventory and Use Survey (TIUS): This data base, prepared by the U.S. Census Bureau once every 5 years, is compiled from a survey of a nationwide sample of about 100,000 trucks belonging to carriers. The sample is randomly selected from vehicle registration files. According to TRB, TIUS' strengths include its relatively large sample size and the detail it provides on the vehicle and carrier. Although it provides information on "typical" operations and tractor use, it does not detail the use of specific configurations of tractor-trailer combinations. Other limitations include a lack of information on the types of roads traveled and on the drivers. In addition, TIUS relies on self-reporting, with no built-in quality control.

National Truck Trip Information Survey (NTTIS): Sponsored by the motor carrier industry, this estimate was drawn from telephone interviews conducted by the University of Michigan Transportation Research Institute of a sample of about 4,000 operators of medium-sized and large trucks with a gross vehicle weight of over 10,000 pounds. On four different days during the 12-month survey period, trained interviewers asked each operator for details on the last 24 hours of operation and, on the basis of these interviews, calculated the number of miles traveled. According to TRB, NTTIS is more accurate and complete than TIUS and allows estimates of the miles traveled (1) by specific configurations of vehicles, (2) on different types of roads, and (3) at different times. NTTIS also includes information on the driver, vehicle dimensions and weight, cargo type, and carrier. The survey may not reflect current operations because it was conducted in 1985, while its sample was drawn from 1983 registration files. Also, data are not available by state or region, and NTTIS relies on self-reported information.

Highway Performance Monitoring System (HPMS): HPMS' data are derived from the travel estimates that states submit to FHWA on an ongoing basis. States count vehicles traveling selected sections of road and multiply the number times the lengths of the road sections. Estimates are available by FHWA's vehicle classes and road types. The information on vehicle classes includes the number of axles combination vehicles have, but does not identify individual types of LCVs. According to TRB, the strengths of HPMS include that it reflects current truck populations and includes data on road types and regions. TRB questions the consistency and quality of the system's data, however, because states have not employed uniform methods of selecting road sections and counting vehicles. FHWA has prescribed uniform methods, which some states began using in 1986, but, according to the agency, all states did not adopt until 1990. Furthermore, FHWA does not have a mechanism to control or access the quality of data submitted by individual states.

As shown in table II.1, FHWA's estimates are consistently higher than those derived from carrier surveys in the 3 years for which these surveys are available. FHWA has criticized these surveys, asserting that they underestimate truck travel.

Table II.1: Estimates of Miles Traveled by Combination Trucks

Miles in billions

	Miles traveled, by year of estimate		
Source of Estimate	**1982**	**1985**	**1987**
Traffic counts reported to FHWA[a]	60	79	86
Surveys of carriers[b]	47	50	64
Percentage survey estimate is of FHWA's	78%	63%	74%

[a]Estimates are from HPMS.

[b]The 1982 and 1987 estimates are from TIUS, and the 1985 estimate is from NTTIS.

Given the limitations in the previously discussed accident data, major differences in estimates of miles traveled, and a lack of reliable data on nonfatal accidents, it is not surprising that results widely differed in the studies examined.

Comparative Accident Rates of Major Studies

Eight of the nine most frequently discussed studies compared the accident rates of multiple- and single-trailer trucks. These eight studies showed multiple-trailer trucks to be from 20 percent less likely to be involved in accidents than single-trailer trucks to 58 percent more likely to be involved in accidents. The remaining study, which compared accident involvement of the two types without regard to accident rates, found multiple-trailer trucks to be 200 to 300 percent more likely to be involved in accidents. Four approaches were used to conduct these studies. TRB reviewed eight of the studies, and its comments are noted below. The ninth and most recent study was presented at the organization's annual meeting in January 1991.

Approach One: Use of National and State Data Bases

Five of the nine studies compared accident rates of multiple- and single-trailer trucks by using aggregated national or state accident and travel data. Because of the predominance of combinations with twin 28-foot trailers over LCVs nationwide, most vehicles considered by the studies were the former type. Three studies used the nationwide accident and travel data to broadly compare accident rates, while the other two used California's accident and travel data. These five studies had results that ranged from finding multiple-trailer trucks 21 percent less likely to be involved in accidents than single-trailer trucks to 58 percent more likely (66 percent if the authors' adjustments to the data base are considered).

1. Mingo, Roger D., Joy R. Esterlitz, and Bret L. Mingo. "Accident Rates of Multi-unit Combination Vehicles Derived From Large-scale Databases." Annual Meeting of TRB, Washington, D.C.: Jan. 13-17, 1991.

Sponsored by the American Association of Railroads, this study used most of the national data bases previously discussed and demonstrates the differences that can result. Using FARS' accident data and HPMS' travel data, this study found multiple-trailer trucks to be 22 percent more likely to be involved in accidents than single-trailer trucks. When the authors used TIFA's accident data and TIUS' lower truck travel estimates (as adjusted by the authors), multiple-trailer trucks were found to be 66 percent more likely to be involved in accidents than single-trailer trucks (without the authors' adjustments to the data base, the figure is 58 percent).

Data from both FARS and TIFA were used because the authors felt they were more reliable than available data on nonfatal accidents. For travel data, the authors preferred TIUS, but showed the results using both TIUS and HPMS. While authors of this study criticized previous studies, citing limitations of sample size and concerns about the reliability of these studies' data, the

American Trucking Association criticized this study, noting the wide differences between its findings and those of other studies and the numerous adjustments the authors made to the data.

2. Campbell, K., et al. Analysis of Accident Rates of Heavy Duty Vehicles. University of Michigan Transportation Research Center. DTNH22-83-C-07188. Ann Arbor, Mich.: Apr. 1988.

Using 1980-84 data from TIFA and 1985 data from NTTIS, this study found that multiple-trailer trucks (primarily combinations with twin 28-foot trailers) had a 10 percent higher accident rate than single-trailer trucks. The study adjusted for differences in the classes of roads the trucks traveled, the time of day travel occurred, and the area (rural or urban). Without these adjustments, however, multiple-trailer trucks were shown to be involved in fewer fatal accidents.

TRB noted that this study had two potentially important limitations. First, 5 years of accident data (1980-84) were compared with only 1 year of travel data (1985). Because the use of combinations with twin 28-foot trailers was growing rapidly during the period, using 1985 travel data would overestimate the number of miles these vehicles traveled in earlier years. This overestimation would yield lower accident rates for the combinations with twin 28-foot trailers. Second, TRB noted that it was not possible, on the basis of the data provided, to determine the statistical significance of the difference in the accident rates for the two types of vehicles.

3. Chira-chavala, T., and J. O'Day. A Comparison of Accident Characteristics and Rates for Combination Vehicles With One or Two Trailers. Highway Safety Research Institute. UM-HSRI-81-41. Ann Arbor, Mich.: Aug. 1981.

This study used 1977 data on fatal and nonfatal accidents reported to FHWA's data base (Form 50T) and 1977 travel data from TIUS. Accident data were limited to those reported by carriers registered with the Interstate Commerce Commission because of the underreporting suspected of other carriers. The study found no overall difference in the accident rates of twin- and single-trailer trucks.

Limitations of this study cited by TRB include its reliance on carrier-reported data and the relatively small number of twin-trailer vehicles (300) in the sample.

4. Graf, V. D., and K. Archuleta. Truck Accidents by Classification. California Department of Transportation. FHWA/CA/TE-85. Sacramento: Jan. 1985.

California's data on fatal and nonfatal accidents and truck travel for this study were taken from 18 road segments in the state for a 5-year period, from 1979 through 1983. Accident records were from highway patrol reports, while travel estimates were from a single traffic count done on each segment. Limiting the study to specific road segments was an attempt to circumvent the uncertainties of statewide travel estimates and to ensure that the differences in road type were not the reason for any difference in accident rates. Overall, the study found no statistically significant difference in the accident rates of combinations with twin 28-foot trailers and combinations with a single trailer. California does not allow any type of LCV to operate within the state. When results were segregated by road type, however, the study found that twin-trailer trucks were 21 percent less likely to be involved in accidents on urban roads and 12 percent more likely on rural roads than were single-trailer trucks.

TRB cautioned that this study's results should not be considered to represent conditions outside of California, because of the state's unique widespread and long-standing use of twin-trailer trucks. At the time of the study, twin-trailer trucks with all types of trailers had been hauling a variety of freight for years in California. In many other states, twin-trailer trucks generally with van-style trailers had been hauling general freight, and some states had just begun to allow these trucks to operate. In addition, TRB considered the study's travel estimates uncertain, particularly for the urban areas.

5. Yoo, C. S., et al. Comparison of California Accident Rates for Single and Double Tractor-Trailer Combination Trucks. BioTechnology, Inc. Falls Church, Va.: Mar. 1978.

This study used 1974 California data on fatal and nonfatal accidents and truck travel. Accident data for non-LCV twin-trailer and single-trailer combinations were drawn from highway patrol reports, while travel estimates were drawn from traffic counts at 15 locations around the state. The study attempted to account for several factors that can affect accident rates, such as differences in the two populations of drivers, trailer body styles, and the distribution of travel by time of day. This study concluded that there was no statistically significant difference between the accident rates of the two types of vehicles.

Limitations on this study extend beyond those listed for the previous California study. According to TRB, travel estimates were "highly uncertain" because the 15 locations were not chosen as a probability sample and the proportions of the two vehicle types varied greatly by location, time of day, and season of the year. As with the previously discussed California study, this study's results should not be generalized to represent conditions in other states.

Approach Two: Matched-pair Analysis

The matched-pair analysis method, used in two studies, attempted to account for some of the different conditions under which various truck types operate. It used major carriers' data on fatal and nonfatal accidents and truck travel to compare the carriers' accident rates for multiple- to single-trailer trucks, operating over the same routes. The results have generally shown accident rates for multiple-trailer trucks (predominantly combinations with twin 28-foot trailers) to be lower or similar to those for single-trailer trucks.

6. Jovanis, P. P., et al. "Comparison of Accident Rates for Two Truck Configurations." Transportation Research Record 1249. pp. 18-29.

This study, presented at the 68th Annual Meeting of TRB, Washington, D.C., used 1983 through 1985 data—on fatal and nonfatal accidents and truck travel—provided by two major carriers. These carriers used both twin- and single-trailer trucks that operated over the same randomly selected routes in the East, Midwest, and South. The study concluded that twin-trailer trucks have consistently lower total accident rates than single-trailer trucks and that the differences between the rates on all types of roads are statistically significant.

While using the same routes controlled for differences in travel patterns, the study, according to TRB did not control for the time of day or drivers' characteristics. Furthermore, the results apply only to the large national carriers that haul similar freight and have well-established safety programs. These carriers may not reflect the trucking population as a whole.

7. Glennon, J. C. Matched Pair Analysis. In Consolidated Freightways Corporation v. Larson et al. 647 F. Supp. 1479 (M.D. Pa. 1986).

This study used data provided by one large national carrier for operations in Pennsylvania from 1976 to 1980. The study compared about 300,000 pairs of similar trips by trucks with twin 28-foot trailers and single-trailer

trucks. Pennsylvania also does not allow any LCVs to operate within the state. The author randomly selected the paired trips from a pool of trips that occurred on the same date and over the same route. The trips were further analyzed to ensure that there were no large variations in the time of day they occurred or in drivers' characteristics (e.g., experience, accident records). This study concluded that there was no significant difference in the accident rates of the two types of vehicles.

According to TRB, this study's major strength was that it controlled many of the factors other than truck configuration that could affect accident rates. The major limitation cited was the study's applicability to only large national carriers similar in nature to the one in the study.

Approach Three: Case Control Method

Only one study used the case control method to compare the relative accident involvement, not the accident rates, of multiple- and single-trailer trucks. The study included both combinations with twin 28-foot trailers and the shorter Rocky Mountain doubles allowed by the state of Washington, but no other LCV types. The study found multiple-trailer vehicles to be 200 to 300 percent more likely to be involved in an accident than single-trailer trucks.

8. Stein, H. S., and I. S. Jones. "Crash Involvement of Large Trucks by Configuration: A Case Control Study." American Journal of Public Health, Vol. 78, No. 5 (May 1988), pp. 491-498.

This 2-year study, utilizing the case control approach, was conducted for the Insurance Institute for Highway Safety. The primary purpose of this approach was to minimize the effects of operating environment and time of day so that any effect of the vehicle configuration could be more easily detected. The study analyzed accidents on two of Washington's interstate highways. For each accident involving a large truck weighing over 10,000 pounds and resulting in more than $1,500 in property damage, three trucks were randomly selected for inspection from the traffic stream at approximately the same time and place as the accident, but 1 week later. By comparing findings for the three trucks selected and the one involved in the accident, the study assessed the effects of vehicle configuration and the driver's characteristics on accident involvement. This method allowed the two populations to be matched not only for roadway, but for time of day and day of week. As stated above, multiple-trailer trucks were found to be 200 to 300 percent more likely to be involved in accidents than single-trailer trucks.

TRB criticized the study, concluding that it had undercounted the number of twin-trailer trucks relative to single-trailer trucks, thereby inflating the accident involvement of the multiple-trailer trucks. The study's authors, however, have challenged TRB's conclusion—defending their count. TRB also noted that results of the study were only applicable to Washington. Because the study compared relative accident involvement, not accident rates, the authors cautioned against comparing their results directly to accident rates developed in other studies.

Approach Four: Synthesis of Prior Studies

TRB's 1986 study on combinations with twin 28-foot trailers looked at numerous past studies, selecting five on which to draw conclusions about the relative safety of these vehicles. It included analyses of not only comparative rates, but also of the severity of accidents, the integrity of the data used, the vehicles' operational features, and drivers' opinions. It found no net difference in accident rates of single-trailer and multiple-trailer trucks.

9. TRB, National Research Council. Twin Trailer Trucks. Special Report 211. Washington, D.C.: 1986.

For this study, TRB selected the five studies that it felt were the most nearly free of methodological flaws. Although these studies had shortcomings, the authors were able to compare the accident rates of twin- to single-trailer trucks under reasonably similar conditions. TRB compared the studies' results by developing ratios with the accident rate of single-trailer trucks considered to be 1.0. Studies using all types of accident data found for multiple-trailer trucks, accident rates that ranged from 0.79 to 1.12; if studies used data only on fatal accidents, the rates ranged from 0.93 to 2.29. In drawing its overall conclusion using these rates and other data, TRB determined that although twin-trailer trucks had slightly higher accident rates, their greater load capacity would reduce the number of these trucks, offsetting the difference in accident rates.

Summary of Additional Information on the Safety of Multiple-Trailer Trucks

The studies discussed in appendix II are not the only sources of information on the safety of LCVs. As with studies comparing accident rates, however, much of the additional safety information is drawn from studies that do not differentiate between combinations with twin 28-foot trailers and LCVs. Because the former vehicles raise some of the same operational concerns as LCVs, we have included information from these additional studies that (1) compared the severity of accidents involving multiple-trailer trucks to those involving single-trailer trucks, (2) investigated accidents involving large trucks to determine probable causes, (3) questioned drivers concerning multiple-trailer truck safety, and (4) collected and summarized information and comments from states, trucking organizations, and carriers familiar with these vehicles.

These studies noted that the type of highways over which vehicles travel is important in determining their accident involvement, that drivers of multiple-trailer trucks do not always have the special training needed to safely operate them, and that drivers of these trucks are concerned primarily with the tendency of trailers to sway and the difficulty of operating in bad weather. In addition, these studies pointed out that trucking organizations, carriers using LCVs, and states have been satisfied with the safety of the vehicles—especially triples—and that much of the credit for the excellent safety record belongs to the use of experienced drivers and special controls on these vehicles.

Studies Comparing the Severity of Accidents

TRB's 1986 study cited five studies that addressed the severity of truck accidents, comparing those involving trucks with twin 28-foot trailers to those involving trucks with single trailers. Three of these studies found no statistically significant difference in the severity of accidents, while the other two studies found slightly higher fatality rates for accidents involving multiple-trailer trucks. Two of these studies also stated that accidents involving multiple-trailer trucks had lower injury rates, however.

Perhaps more important than the mixed results concerning the severity of accidents is that four of these studies noted the importance of considering the types of roads involved when comparing accident rates. A separate study noted that the lowest accident rates were on divided highways, the highest on major rural and local undivided highways. The authors reasoned that a high rate on undivided highways was the result of the high speeds at which vehicles travel on these roads, combined with the poorer design of these roads.

Because multiple-trailer trucks spend more time on the safer, divided highways than single-trailer trucks do, comparing the accident rates of the two types of vehicles without considering road type is not entirely equitable. The fact that multiple-trailer trucks travel on safer roads should in and of itself result in somewhat lower accident rates for these trucks.

Investigations of Specific Accidents

Some studies carefully examine underlying factors that cause accidents involving large trucks. The most recent nationwide effort using this method, conducted by the National Transportation Safety Board, analyzed 189 such accidents, involving trucks with gross vehicle weights of over 10,000 pounds. This analysis included 41 accidents involving trucks with two trailers, of which only three could be identified as LCVs. The Board and FHWA cited this study in noting deficiencies in drivers' training and the importance of training for drivers of multiple-trailer vehicles. FHWA continued, stating that the stability and maneuverability of multiple-trailer trucks can be quite different from single-trailer trucks and even single-unit trucks with trailers. For example, small steering movements or slight applications of the brakes, particularly in a lane change, are magnified by a second trailer and can cause it to roll over. In the 41 investigations, these maneuvers often contributed to the accident.

Surveys of and Comments by Drivers

We examined two studies that included surveys of experienced drivers of multiple-trailer trucks and three other studies that included drivers' comments. Of the two driver surveys, one included 102 drivers of triples; the other, 178 drivers of trucks with twin 28-foot trailers. These drivers indicated that they are generally more comfortable driving single-trailer trucks than multiple-trailer trucks. Drivers' primary safety concerns were the tendency of trailer to sway and the difficulty of operating in bad weather. Drivers also commented that poor distribution of the load in multiple-trailers increase trailer sway. Drivers' comments from the other three studies generally concur with these opinions; one study noted that drivers reported they were more fatigued after driving multiple-trailer trucks than they were after driving single-trailer trucks.

Information From Trucking Organizations, Carriers, and States

Studies have also summarized information from (1) trucking organizations and individual carriers that use LCVs and (2) individual states that oversee LCV operation. Information from these sources is generally favorable to LCVs, pointing to excellent safety records—particularly for triples. Many of the statistics cited, however, are from large national carriers reporting excellent safety records for their overall fleet. Comments from states are often based on their own accident and travel data, thought to have some of the same problems (particularly, inconsistent reporting of accidents) that plague national data. It is important to note that these studies mentioned nothing about verifying reported information, nor did they discuss quality control measures or reporting criteria employed. They did, however, give much credit to the restrictions under which LCVs operate.

Trucking Organizations and Individual Carriers

The American Trucking Association has actively supported the position that all states should have the right to allow on their interstate systems trucks weighing more than 80,000 pounds—which in effect would give additional states the right to allow LCVs. The association's arguments include increased productivity for carriers and benefits to consumers in the form of lower freight costs; fewer accidents, as cited by several studies that show LCVs to have lower accident rates than single-trailer trucks; and a reduction in the number of trucks on the road because LCVs carry larger loads. Interest groups for railroads dispute these claims, citing studies indicating that the safety of LCVs has not been established by their limited operation and stating that freight diverted from the railroads would increase truck traffic—further decreasing highway safety and costing the railroads 52 percent of their net operating revenue. Citing safety reasons, truck driver organizations such as the Owner Operators Independent Drivers Association and the International Brotherhood of Teamsters have also opposed any increase in the use of LCVs.

Major national carriers that use LCVs, particularly triples, have strongly supported their expanded use, pointing to accident rates far below those of the carriers' overall fleet. These carriers acknowledge, however, that the conditions under which LCVs operate are closely controlled. Drivers of triples are particularly well trained and experienced, the equipment used is well maintained, and the operating environment is more restricted than for other combinations. In addition, many of the firms operating triples cite safety records far superior to the general trucking population's, so the accident rates for LCVs operated by these firms are likely to be lower than would be expected for the total truck population. The following are typical of the accident rates quoted by large carriers:

- For 1983 through 1990, Roadway Express reported a rate of 1.39 accidents per million miles traveled for triples, 1.8 for doubles, and 2.51 for single-trailer trucks.
- From 1988 through 1991, Consolidated Freightways reported an accident rate for triples that ranged from 0.26 to 0.48 per million miles, a doubles rate from 0.39 to 0.50, and a single-trailer rate from 0.18 to 0.65. The associated mileage during this period was from 19 million to 22 million for triples, from 441 million to 480 million for doubles, and from 49 million to 55 million for singles.
- In 1990 United Parcel Service stated that its overall accident record was 15 times better than the national average for combination trucks. The company reported an accident rate for triples of 0.09 per million miles traveled; for doubles, a rate of 0.14; and for singles, a rate of 0.34.
- In May 1991, Yellow Freight reported that over the last 3 years its overall accident record was 3.5 times better than the record of the trucking industry as a whole. Over this period, the company operated triples for nearly 45 million miles with an accident rate that was 2 times better than the record of the company's overall fleet.

States

The states allowing LCVs provided generally favorable comments in several studies of the vehicles' safety, particularly concerning triples. Officials quoted in the studies gave much of the credit for the safe operation to the stricter state controls imposed upon LCVs and their drivers. Four states—Idaho, Nevada, Oregon, and Utah—provided much of the data and many of the comments for the studies we reviewed. As noted by table III.1, the number of accidents involving triples in these states showed no consistent increase from 1985 to 1990—despite growing use of LCVs during this period.

Table III.1: Accidents Involving Triples, Reported by Four States

Year	Idaho	Nevada	Oregon	Utah
1985	10	9	5	[a]
1986	6	8	12	[a]
1987	6	19	10	22
1988	19	9	13	26
1989	8	12	15	22
1990	6	[a]	10	17

[a]Data are not available for this year.

Source: Information obtained from state officials.

Idaho officials noted that LCVs are safer than single-trailer trucks in general, for two main reasons—only the best drivers operate LCVs, and the vehicles travel only on the best roads.

Nevada officials also reported accident rates per million vehicle miles traveled for different truck configurations, as shown in table III.2.

Table III.2: Nevada's Accident Rates, by Truck Configuration

	Number of accidents per million miles traveled, by truck configuration		
Year	Triples	Doubles	Singles
1986	0.34	0.90	2.12
1987	0.76	1.90	1.89

The study citing these rates noted that the increase in the accident rate for triples in 1987 is related to the fact that about 800 miles of two-lane roads were opened to them in that year, but the study did not discuss the changes in the rates for the other two truck configurations.

Oregon officials are convinced that strict operating requirements placed on triples are largely responsible for their lower accident rates. Using state truck accident statistics for 1979 to 1990, the Oregon Trucking Association cited an accident rate for triples of 0.24 per million miles traveled compared with a rate for all other combination trucks of 0.93.

Similarly, Utah DOT officials believe the state's strict enforcement of regulations and willingness to revoke permits, and the screening and training of drivers operating the LCVs are major reasons for their low involvement in accidents. Until 1987, triples had operated for over 19 years without a reported fatality. In 1987, 1988, and 1989, however, triples were involved in one fatality each year. From 1987 to 1990, LCVs in general were involved in an average of 9.0 percent of the state's truck accidents, but accounted for 16.1 percent of the fatalities resulting from these accidents.

Studies also noted comments from officials from four of the turnpike states, who noted favorable safety records for LCVs. Florida turnpike officials believe the record for turnpike doubles is very good for 25 years of operation compared with the record for single-trailer trucks. Indiana toll road officials indicated that triples (operated by United Parcel Service and one other firm) have had only one accident in about 5 years of operation.

These officials did not have accident statistics on other types of LCVs, however. Kansas turnpike officials noted that LCVs were involved in only 11 accidents in 5-1/2 years of operation. In Ohio, where 25 firms operate turnpike doubles and only United Parcel Service operates triples, turnpike officials reported that only seven accidents involving LCVs occurred in 1988, a rate of 1.2 accidents per million miles traveled on the Ohio turnpike.

Major Operational Characteristics and the Related Factors That Can Affect the Safety of LCVs

Numerous studies have provided insight into the safety of LCVs by examining operational characteristics that can affect their stability and maneuverability. Characteristics that can decrease the stability of LCVs include trailer sway, rearward amplification (the "crack the whip" effect), and trailer movement to the side in some circumstances when the brakes are applied. Characteristics that can decrease the maneuverability of the longer and heavier LCVs include low-speed off-tracking, high-speed off-tracking, a reduced ability to accelerate, and increased stopping distances. Research on these characteristics has been conducted by testing LCVs on tracks and highways under carefully controlled conditions, using computer simulation, and observing LCVs in actual operation.

Training and experience are critical factors affecting how well drivers deal with LCVs' operational characteristics. FHWA, the National Transportation Safety Board, Office of Technology Assessment (OTA), and the trucking industry have increasingly recognized the need for additional truck driver training—particularly for LCVs. Using an initial grant from FHWA, the Professional Truck Drivers Institute of America is developing a training curriculum to be used by truck driving schools for specialized vehicles—including trucks with twin 28-foot trailers; both Rocky Mountain and turnpike doubles; triples; and special cargo vehicles, such as those that haul bulk liquid or shifting loads. Studies indicate that drivers should be trained on how to handle LCVs' special operational characteristics, stay constantly alert, anticipate potential problems further in advance, and adjust their speed to conditions with greater diligence.

Different LCV configurations strongly affect the operational characteristics of the vehicles. For example, turnpike doubles' trailers with longer wheelbases and fewer points of articulation lessen trailer sway (increasing stability) but add to low-speed off-tracking (decreasing maneuverability). Triples' shorter wheelbases and additional points of articulation have the reverse effect, allowing more trailer sway (decreasing stability) but lessening low-speed off-tracking (increasing maneuverability).

Other factors affecting operational characteristics include the load distribution; the type, condition, and compatibility of the equipment used; and the weather and road conditions under which LCVs operate.

LCVs' Decreased Stability

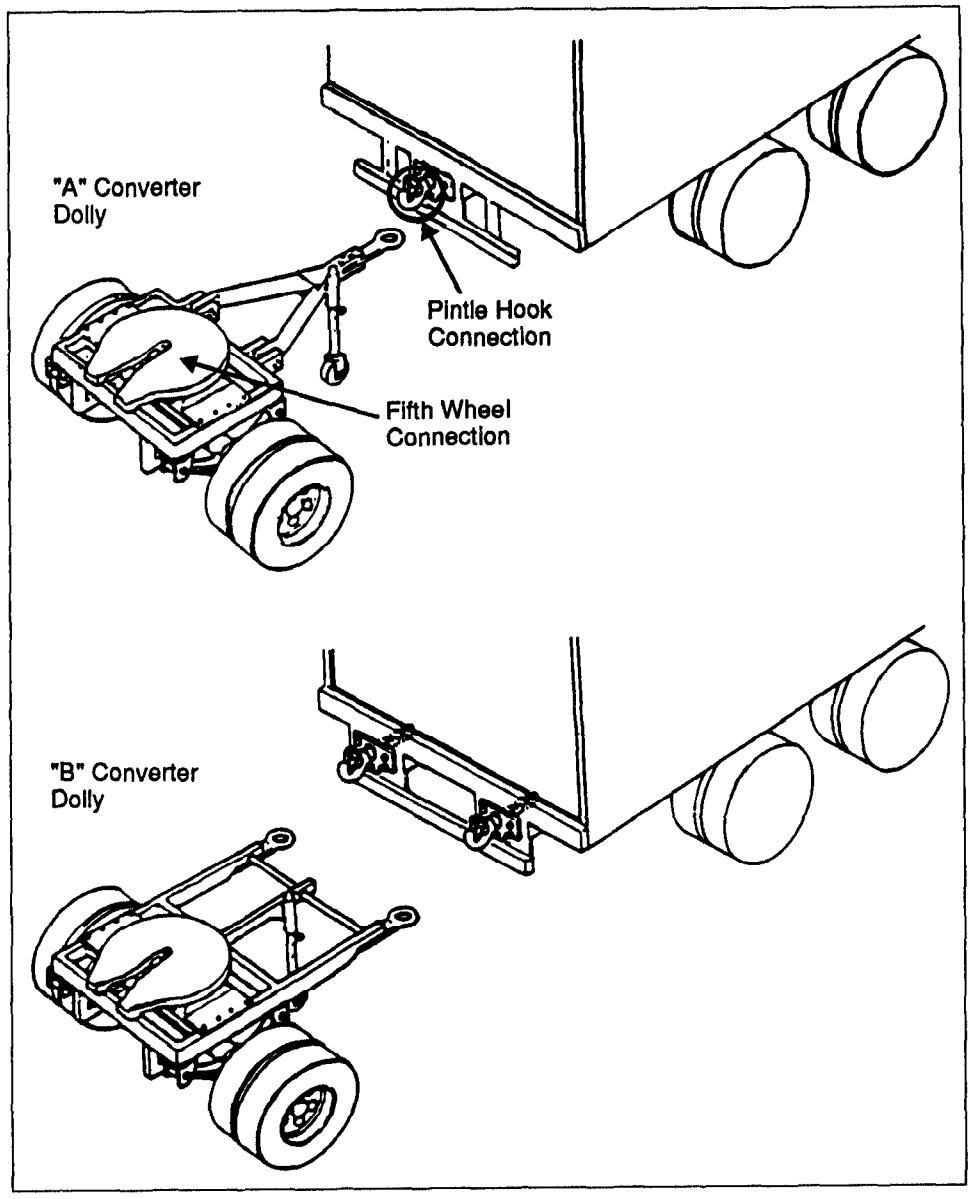
Perhaps the most often discussed feature of LCVs and other multiple-trailer trucks is their instability during operation—primarily due to trailer sway and rearward amplification. Also of concern is LCVs' ability to stop in a straight line. The extent of instability, which has been debated, depends on a vast array of variable factors, such as the vehicle configuration, load distribution, mechanical condition of the equipment, and drivers' skill.

Trailer Sway and Rearward Amplification

Trailer sway is the side-to-side movement of multiple trailers. Rearward amplification, the tendency of a rapid movement at the front of an LCV to be amplified as it travels toward the rear of the vehicle is most often attributed to the driver's sudden steering movements in unanticipated maneuvers. Both characteristics can result in excessive movement of trailers, which can be very dangerous if, for instance, they move into other lanes and interfere with other vehicles. In the extreme, LCVs' instability can cause rear trailers to roll over.

Certain configurations of LCVs are more prone to be unstable. Studies indicate, for example, that rearward amplification is 2.5 times greater for trucks with twin 28-foot trailers than for single-trailer trucks, but can be 1.5 times worse for triples with their five points of articulation than it is for trucks with twin 28-foot trailers. The type of converter dolly (the mechanism used to connect trailers) can affect both trailer sway and rearward amplification. A converter dolly with a single connection point with the lead trailer, the type generally used in the United States, is referred to as an "A" converter dolly. This type allows more trailer sway and rearward amplification than does the type of converter dolly with two connections points to the lead trailer, used more extensively in Canada and referred to as a "B" converter dolly. Figure IV.1 illustrates both types of converter dollies.

Figure IV.1: Two Major Types of Converter Dollies



Source: Road Transport Association of Canada.

Loading and mechanical and environmental factors can also affect trailer sway and overall stability. Uneven load distribution on individual axles or among trailers, particularly a last trailer that is empty or lightly loaded, can add to instability. Loads with higher centers of gravity can also decrease stability. Mechanical factors, including poorly lubricated fifth wheels,

which are connection mechanisms between the tractor and the first trailer and between the converter dolly and additional trailer(s), and loose-fitting pintle hooks (connections at the lead trailer) can increase instability. Environmental factors such as gusting winds or rutted highways can contribute to further problems. Rutted highways are of particular concern if axle widths of the converter dollies are narrower than those on the rear trailers. This arrangement can cause additional trailer sway because the narrower wheels of the converter dollies (96 inches) try to climb into the ruts, while the wider wheels on the rear trailers (102 inches) try to climb out.

Stability During Braking

Studies differ concerning the ability of LCVs to stop in a straight line. For example, one study indicated that additional trailers can have a stabilizing effect when the truck has the proper braking equipment, while another showed that multiple trailers move up to 5 feet to the side during braking tests. These conflicting results are not surprising, considering the myriad of factors that can affect braking tests. For example, the load distribution between trailers can be of critical importance. If the last trailer is empty or only partially loaded, the brakes, designed for a fully loaded condition, can overbrake this trailer. As a result, the wheels of an empty trailer can "lock up" and cause the trailer to swing into other lanes of traffic or off the road. Antilock brakes may lessen this problem, but as yet this technology is still being tested.

Another critical factor in braking stability is the mechanical condition of brakes and tires. Recommended equipment in some states includes a device that applies the brakes on the last trailer first—effectively pulling it to a straight stop. But not all LCVs have this device.

Concern About LCVs' Maneuverability

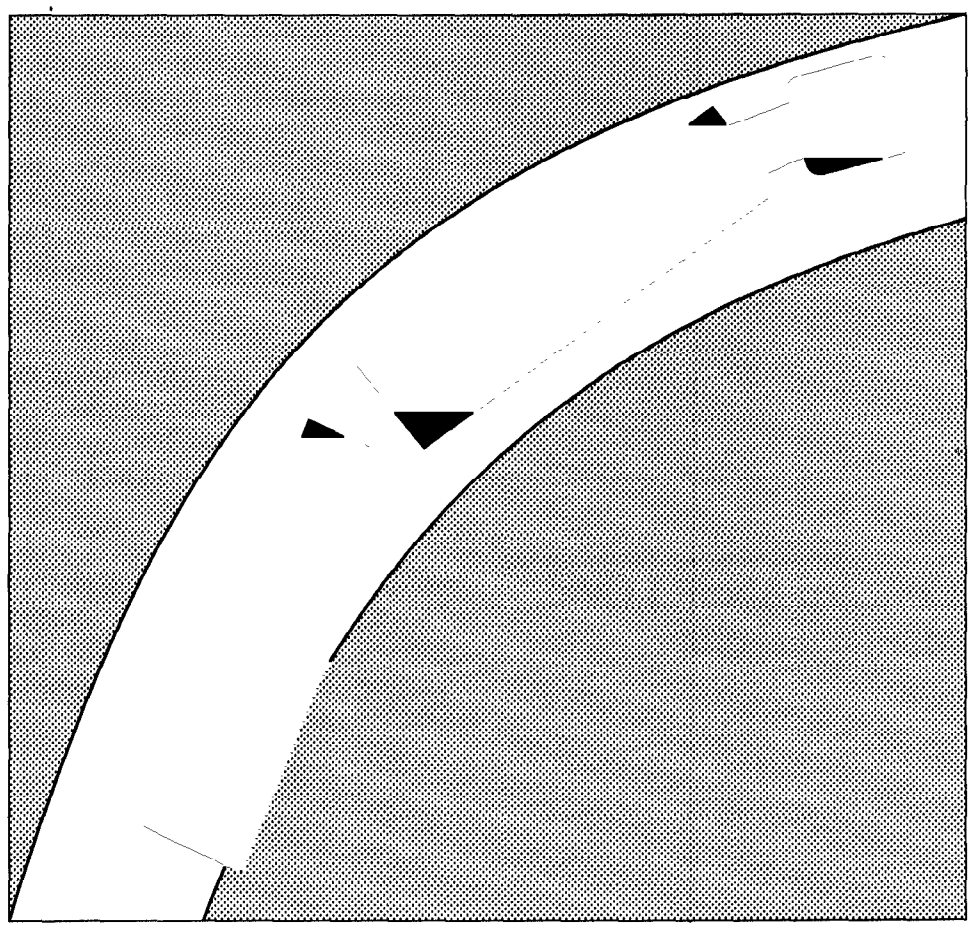
Studies also describe several characteristics affecting the maneuverability of LCVs. Among these characteristics are low-speed and high-speed off-tracking, a decreased ability to accelerate, and increased stopping distances. Studies reached different conclusions regarding the impact of these characteristics on safety.

Off-tracking at Low and High Speeds

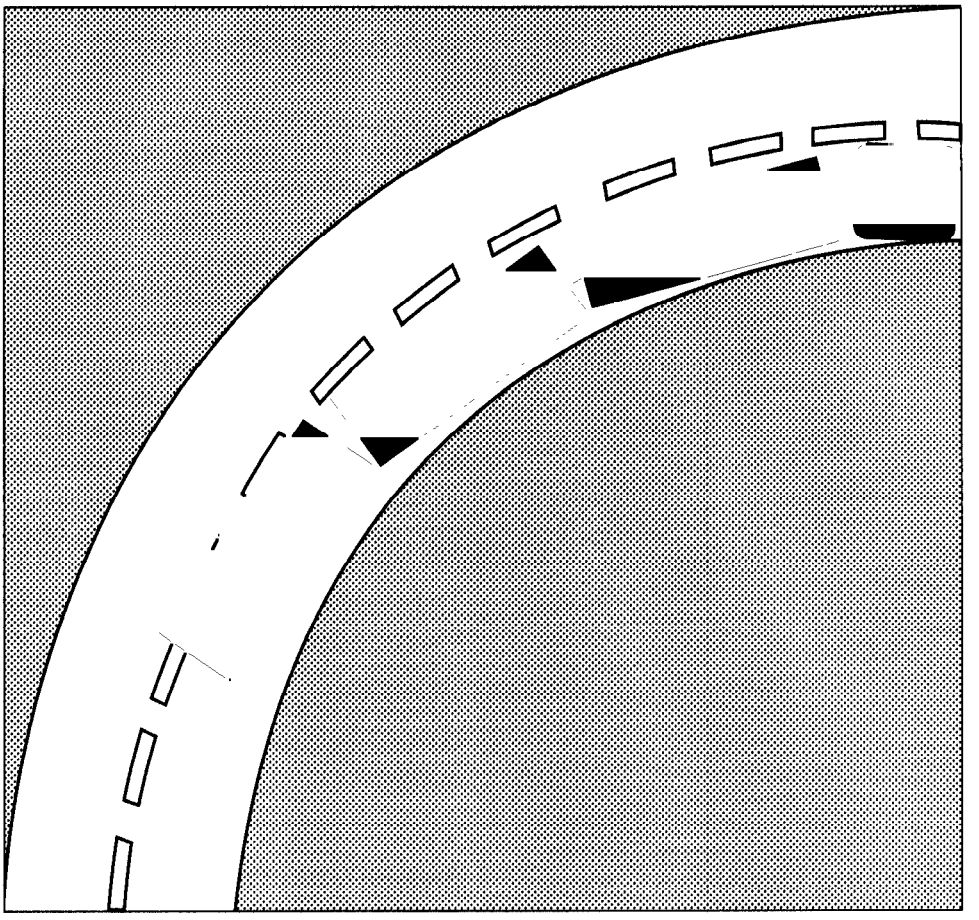
Off-tracking is defined as the additional width (over and above vehicle width) that is required to make a turn. When LCVs make turns, the tires of the rearmost trailer do not follow the path of the front tires of the tractor. The resulting "sweep path" may exceed the space available in the lane of travel. At lower speeds, additional space is required toward the inside of the curve, but as speeds increase, additional space is needed toward the outside of the curve. At slow speeds, the rear trailer's tires can strike roadside objects, overrun curbs, or encroach into adjacent lanes—particularly when multiple-trailer trucks turn at intersections. At higher speeds, the rear trailer's tires can cross center lines and encroach into adjacent traffic lanes or overrun a ramp's outside curb, which can cause trailer(s) to roll over. Figure IV.2 illustrates low- and high-speed off-tracking.

Figure IV.2: Low-speed and High-speed Off-tracking

Low-speed (Inward) **Off-tracking**



High-speed (Outward) Off-tracking



The configuration of an LCV greatly affects off-tracking. Triples, because of their trailers' shorter wheelbases and increased number of points of articulation, generally exhibit low-speed off-tracking similar to or even less than that of trucks with a single 45-foot trailer—depending on the severity of the curve. In contrast, turnpike doubles using trailers with longer wheelbases and having fewer points of articulation, exhibit increased low-speed off-tracking—nearly twice that of triples. Low-speed off-tracking by Rocky Mountain doubles is between these two extremes.

Factors such as shorter wheelbases on trailers and more points of articulation decrease low-speed off-tracking but increase high-speed off-tracking. Consequently, test results show that at 55 miles per hour (mph) on the same curve, trucks with single-trailers off-track about

6 inches, turnpike doubles slightly over 1 foot, Rocky Mountain doubles 1-1/3 foot, and triples slightly over 2 feet.

Decreased Ability to Accelerate

Because LCVs generally weigh more than 80,000 pounds and are longer than single-trailer trucks, the ability of these combinations to move compatibly with traffic has been a concern. In moving traffic, LCVs must have sufficient horsepower, engine torque, and drive train efficiency to climb hills, pass other vehicles, and merge with traffic without creating excessive speed differentials between themselves and other vehicles. Such speed differentials increase the likelihood of accidents, particularly on two-lane roads. One study pointed out that a speed differential of 15 mph between vehicles can increase the accident rate by 8.9 times; a differential of 20 mph, 15.5 times. LCVs must also be able to regain speed after stopping or when making a turn across an intersection—in order to clear it in the time available in gaps between oncoming traffic.

To the extent that power is not increased to compensate for LCVs' heavier weight, LCVs will generally move more slowly than non-LCV trucks. A loss of traction resulting from poor weather conditions (rain, snow, or ice), a failure to use chains when needed, and the greater aerodynamic resistance created by gaps between trailers can also further decrease LCVs' ability to accelerate.

Stopping Distances

Braking tests of LCVs have produced mixed results, and the ability of LCVs to stop effectively is heavily debated. Stopping distances in various tests have varied depending on a number of factors such as the drivers' skill, the equipment used, the load distribution, and the road conditions. Carriers that use triples to carry lighter cargo, for example, note that because the weight is spread over more axles, each axle has less demand on it—allowing shorter stopping distances. Studies also show, however, that braking is more complex for LCVs than for single-trailer trucks because of the greater number of brakes that must be properly adjusted and activated in the proper sequence (last trailer's first). Furthermore, roadside inspections disclose that the most commonly found problem is brakes that are out of adjustment, found in about half of these inspections. Mechanical devices called automatic slack adjusters can help maintain brakes' proper adjustment when these adjusters are properly installed and maintained.

LCVs' braking capability when these vehicles are going down long, steep hills has been a point of concern. This situation calls for the driver to shift

to the appropriate gear and properly apply the brakes. To perform well, the vehicle must have the proper brake equipment that is correctly adjusted. Naturally, the steeper and longer the grade, the more important using the proper braking technique and having the proper equipment become. One study noted that the test vehicle's brakes began to smoke on a long downhill highway, but a trucking organization's critique of this study attributed the problem to unmatched brake linings on the LCV.

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In addition to the studies discussed in appendix II, the following studies were used to prepare this report:

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