Accident Rates of Multiunit Combination Vehicles Derived from Large-Scale Data Bases

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The operating characteristics of multitrailer vehicles could be expected to make them more dangerous than other vehicles, but previous accident involvement studies have produced mixed results, with no consistently strong indications of greater hazard. A review of these studies, however, indicates sufficiently severe limitations in their sample sizes and data reliability to readily explain the great degree of scatter in their findings. The size and reliability issues of previous studies are overcome by using large national data sources to calculate overall involvement rates of various vehicle configurations. No suitable sources of nonfatal accidents or disaggregate travel information were located. Use of national data rather than state and highway-type-specific data obscures the safety effects of differences in vehicle operations but at least allows an overall comparison of fatal accident involvement rates. Because current multitrailers are concentrated more than single trailers on the safest highways, rural Interstates, multitrailers appear in this study to be safer than they would if differences in operations were considered. The most reliable sources of fatal accident and travel data indicate that multitrailers, single trailers, and single-unit trucks have fatal accident involvement rates of 9.96, 6.01, and 3.00 per 100 million mi traveled, respectively. The ratio of fatal accident involvement rates for multitrailers to single trailers is 1.66. The multitrailer to single-unit truck ratio is 3.32. Most previous studies have indicated doubles or multitrailer fatal accident rates to be higher than singles, but with less difference. The higher ratios here can be attributed in part to larger and more reliable data sources than have been used in the past.

As trucks have grown in size and prevalence in recent years, the safety of heavy trucks has become an increasingly important public policy issue. The driving public overwhelmingly considers large trucks, especially doubles and triples, to be unsafe. Public fears of such vehicles have been widely expressed through opinion surveys as well as letters to the press and elected representatives. Because large multiunit trucks are less stable, more subject to environmental forces, more difficult to stop safely, and more difficult to keep on a desired path than other vehicles, such fears appear to be intuitively justified.

Despite the commonsense expectation of the greater danger of large multiunit trucks, studies of accident and fatality involvement rates of large multiunit vehicles have produced mixed results. Most such studies have been hampered by data availability and reliability. Most have been based on small sample sizes. Many have compared accident rates of vehicles in general use with accident rates of a small number of vehicles operating in special environments or under special conditions. Together, the unreliable data, small samples, and great differences in how various vehicles are used could be expected to produce a great deal of scatter in estimates of accident involvement rates, as appears to be the case.

The objective of this study was to identify and analyze the most valid large-scale sets of national accident and travel data available and to use these data sets to derive the best possible estimates of accident or fatality involvement rates of multiunit and other truck configurations. A lack of sufficient data prevented the desirable disaggregate comparison of relative accident rates on different highway facility types in different regions of the country. Although the aggregate comparison presented obscures the differences in operations of multiunit and other vehicles, the approach used overcomes previously prevalent sample size deficiencies.

REVIEW OF PREVIOUS STUDIES

Operating Characteristic Studies

Two recent reports to Congress by FHWA discussed safety issues associated with large multiunit combination vehicles. *The Feasibility of a Nationwide Network for Longer Combination Vehicles* (*1*) in June 1985 reported large multitrailer vehicles to be much worse than current large one-trailer vehicles at accelerating to and maintaining highway speeds. Triples and Rocky Mountain doubles were also reported to be much less stable—more likely to jackknife, overturn, and wander from a straight path while traveling on a straight highway. All of these larger combinations were found to be more prone to unsafe braking as a result of poor brake adjustment. The study concluded that despite the safe records of such vehicles in their specially permitted operations, there was not enough evidence to indicate that these difficulties could be overcome sufficiently to allow them to be safely operated in general use.

The other FHWA study, *Longer Combination Vehicle Operations in Western States* (*2*), reaffirmed the findings of the earlier study. In addition, a high percentage of drivers who operated triples during tests in Utah and Colorado were reported to have pointed to the triples' sway and other characteristics as factors making them less safe than more conventional trucks. Several drivers who wrote to the docket for

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public comment set up as part of the study said that triples are unsafe vehicles with poor handling characteristics, particularly in poor weather.

According to a recent study by the University of Michigan's Transportation Research Institute (*3*), length, weight, and number of trailers all have significant influences on such vehicle characteristics as low- and high-speed offtracking, ability to brake in a straight line, rollover, handling during turns, and rearward amplification (the tendency of following trailers to deviate from a straight line when very small steering adjustments are made). The study found that the higher gross weight of larger multitrailer trucks causes a loss in turning ability at higher speeds, increasing the likelihood of sideswipe accidents. Higher weight also increases the tendency for a vehicle to roll over during turning maneuvers. Although higher gross weight decreases the tendency of an individual axle to lock up during braking, as long as there is relatively uniform trailer loading, a much more reliable way to lessen wheel lockup would be to install antilock brakes.

Increasing the number of trailers even without increasing the gross weight of a vehicle was found to greatly magnify rearward amplification and decrease the braking efficiency of a vehicle (*3*).

Accident Rate Studies

Numerous studies of multiunit combination vehicle accident rates have been performed in the past 10 years. All suffer from some degree of data reliability problems. In 1986, TRB published a special report (*4*) that in large part confirmed our assessment of the degree of data unreliability in such studies. The report contains a discussion of accident involvement and severity rates and reviews 14 studies reporting relative accident rates for twins and tractor-semitrailers. Five of the 14 studies were found by TRB to be most nearly free from obvious methodological flaws, although they still had limitations concerning the accuracy or representativeness of the data.

In a 1981 study, Chira-Chavala and O'Day (*5*) found accident involvement rates for twin-trailer and single-trailer combinations to be nearly identical. The accident data for this study were taken from accidents reported to FHWA for 1977 (the MCS-50T data base described in the next section), and the exposure estimates were based on the 1977 Truck Inventory and Use Survey (TIUS). This is one of the few previous studies to have used sufficient quantities of accident data to overcome the small-sample-size criticism. However, MCS-50T data are severely limited in their ability to provide reliably representative accident information. The 50T reports cover only interstate motor carriers who report their accidents. Studies completed since 1981 have indicated that only 30 to 60 percent of accidents that should be reported are reported. There is evidence of widely varying bias depending on geographic region, size of motor carrier, and other factors. The potential wide variations in reporting rates between singles and multis negate the accuracy of the findings. Even if there were identical reporting rates between singles and multis, however, the differences between the configurations in ratios of interstate to intrastate carriers would introduce another level of uncertainty (*5*).

Glennon in 1981 (*6*) found twin-trailer vehicles to be involved in accidents only 6 percent more frequently per mile traveled than single-trailer vehicles. The study has been faulted in legal proceedings concerning twin-trailer trucks because the procedure used to select matched pairs unnecessarily excluded some of the available semitrailer travel and accident data. The study apparently failed to attain the minimum possible statistical uncertainty in its estimates because of the small amount of data available, but the procedure did not necessarily bias the comparisons either for or against twins. The use of entirely self-reported data raises many questions as to potential bias, as does the use of a single motor carrier.

In a 1978 study in California, Yoo, Reiss, and McGee (*7*) found twin-trailer vehicles to have close to the same injury and fatal accident rates as single-trailer vehicles. The accident data were derived from 1974 State Highway Patrol reports. Exposure estimates were based on the relative proportions of singles and twins in limited observations at 15 counting stations. The traffic counts were far too few to properly account for the high degree of temporal and locational variation in travel, rendering the accident rate estimates highly uncertain. The possible differences in the predominant operational environments for the two truck configurations were also not investigated, although the extensive use of twins in California may make such differences insignificant.

In 1983 FHWA found fatal accident involvement rates of double-trailer vehicles to be 20 percent higher than involvement rates of single-trailer vehicles (*8*). Injury accident involvement rates were only 9 percent higher for twins. The data were collected from 12 motor carriers that reported miles of travel and accident data for a 12-year period. Because none of the data were closely scrutinized, there could have been bias in the self-reported data. In addition, because both double usage and overall accident rates changed during the 12-year period, bias is likely to be inherent in such a long time period. Finally, there are likely to be regional and operating-characteristics biases because of the areas and highway systems on which twins operate.

Graf and Archuleta in 1985 found doubles to be involved in accidents 12 percent more often than singles on rural highways and 21 percent less often on urban highways (*9*). Doubles were found to have a 23 percent greater chance of being involved in fatal accidents than are singles. Both travel and accident data were for 18 highway segments. In this sense, the sample design was good, because it limited comparison between twins and singles to similar operating environments. Unfortunately, the sample sizes were far too small to make significant conclusions. In addition, travel data were collected at only one location and during one time period for each highway segment, even though some of the segments had multiple entries and exits. All segments could have had differential growth in doubles and singles traffic, making the actual involvement rates uncertain.

It can be seen, then, that none of the five studies given qualified endorsements by TRB provides conclusive accident rates. Each has serious flaws. Since the 1986 TRB study, there have been three other safety studies worth reviewing here.

Jovanis et al. (*10*) used travel and accident data supplied by several large LTL motor carriers to conclude that doubles were safer than singles. Using paired comparisons, doubles were shown to have significantly lower accident rates in 1983 and 1985 and significantly higher rates in 1984. Because data from only a few motor carriers and from highways having both doubles and singles operations were considered, the authors claimed to have controlled for roadway, traffic, and environmental variables.

The authors used data supplied by trucking companies with well-established safety programs that were known to make a good-faith effort to comply with federal safety laws. This raises many issues concerning the degree to which the results can be generalized to other companies. Also, the atypical operations among some of the participating companies (using fixed-location team drivers, for example) would cause bias if these atypical companies used doubles more or less frequently than other participating companies. Finally, the small sample sizes by themselves render any conclusions questionable and explain the major differences from year to year in relative safety of the configurations.

An FHWA study (*11*) consists of a voluntary reporting program in which several states collect travel data for selected portions of their highway systems and report corresponding accident involvements. During 1988, four states reported some data on the rural Interstate system, although during the period from 1983 to 1988 a total of 13 states reported data for between 6 months and 6 years. An unweighted average for all reporting states over the entire time period indicates that doubles have a 10 percent lower fatal accident involvement rate than singles on the rural Interstate system, a 20 percent higher rate on other rural principal arterials, and more or less random variation on the other systems, all of which have few reported data.

Although state-reported data covering all motor carriers are inherently less biased than data reported by only a few motor carriers, there are three problems with this study. First, sample sizes are far too small, are not designed to represent the national highway system, and vary greatly from year to year depending on the whim of each participating state. Second, severe limitations on state-reported accident and travel data, discussed in the following section, create substantial uncertainty in results derived from these sources. Finally, FHWA makes no attempt to analyze, adjust, evaluate, or make consistent the data submitted by each volunteer state.

In 1988 Campbell et al. (*12*) used data from the 1980 to 1984 Trucks Involved in Fatal Accidents (TIFA) data base and the 1985 National Truck Trip Information Survey from the University of Michigan. They found double-trailer fatal accident involvements to be 7 percent less than single-trailer fatal involvement rates. When adjustment for travel patterns is made by accounting for road type and time of day, however, doubles have 10 percent higher fatal involvement rates. This adjustment provides an interesting finding, but the small sample size used to estimate travel data (only 5,000 trucks of all types) makes validity of the results questionable. The biggest problem with the study, however, is that the use of accident data from one time period and travel data from another negates the validity of the results if there is differential growth among vehicle classes—a prospect that appears highly likely, because doubles were rapidly expanding during this time period. If doubles usage did grow faster than singles, a relative downward adjustment in prior-year travel estimates for doubles should be made, resulting in a relative increase in their accident rate.

In 1988 Jones and Stein (*13*) used case-control data gathered from Interstate highways in Washington State from 1984 to 1986. They found doubles to have 2.5 to 3 times the accident involvement rate of singles. The study has subsequently been criticized because sample traffic counts taken by the state produced estimates of the proportion of singles and doubles travel that did not agree with the implicit proportional estimates derived from the case-control study. Our assessment is that neither travel study used sufficient quantities of data to prove or refute the other travel estimate and that widely varying estimates of accident rates are to be expected when such small samples are used.

STUDY METHOD

Calculation of an accident or fatality involvement rate requires accurate counts of the number of accidents or fatalities as well as the miles traveled for each category of vehicle for which rates are desired. The available sources of each type of information were considered in this study, and the best ones were used. As most previous studies have found, there are severe limitations in current data related to both accidents and miles traveled by vehicle category. The most recent study to reaffirm this lack of adequate data was TRB's *Special Report 228: Data Requirements for Monitoring Truck Safety* (*14*). Thus, an important first step in the study was to consider and select the best available accident and travel data.

Choice of Accident Data Sources

Most states have established uniform accident reporting forms for use throughout their state, but wide variations exist among states. Only 22 states have any vehicle classification scheme on their accident reporting form, and only 10 of these states distinguish between doubles and other combination vehicles. Nine states have a blank space in which to enter vehicle type, with no guidance as to what classification scheme to use. The other 20 do not mention vehicle type on the form but rely on the narrative description of the accident to supply a vehicle description. The inconsistencies and gaps resulting from these varying reporting methods and classification schemes make it difficult to aggregate accident data on the national or multistate level.

One alternative to using state accident data is to use accident data reported by motor carriers. This alternative was discarded for three reasons: (*a*) even several years of data reporting by dozens of volunteer motor carriers could not produce sufficient data to produce statistically reliable results; (*b*) comparisons would not be valid because of wide variations in types of operations by various carriers, who would presumably use doubles in varying proportions; and (*c*) self-reported data are prone to inadvertent or intentional bias.

Because neither state nor self-reported data bases were deemed adequate, the use of federal data bases was thoroughly explored. The alternatives are (*a*) the MCS-50T data base of accident reports filed by interstate motor carriers for accidents involving an injury, fatality, or more than $4,400 worth of property damage (26,000 such reports were received in 1987); (*b*) the Fatal Accident Reporting System (FARS) data base consisting of all fatal highway accidents (42,000 in 1988); (*c*) the National Accident Sampling System (NASS) consisting of accidents occurring at 50 sites nationwide (about 12,000 accidents per year); and (*d*) the TIFA program, which is not strictly a federal system but attempts to combine data from the 50T and FARS systems, supplemented by additional information.

The 50T data base covers only 30 to 60 percent of interstate truck accidents and a smaller portion of overall truck accidents. Because there is demonstrable reporting bias by carrier size, carrier type, and accident severity, the data base cannot be used to develop estimates of relative accident rates, the primary objective of this study, even though it could be used for numerous other related investigations. The NASS system has far too few heavy truck accidents to provide a statistically meaningful comparison of accident characteristics by configuration. It was not found to be useful for this study.

Both FARS and TIFA were chosen for use in this study. FARS includes a reasonably complete set of fatal highway accidents and much better configuration information than is available from the police accident reports, but still includes uncertainty as to whether some of the involved vehicles are multitrailer or single-trailer combinations. TIFA successfully matches only about one-third of the reported heavy truck fatal accidents with 50T accidents and is several years behind, but the matching process and follow-up interviews give it the best available configuration information.

Choice of Travel Data

Limitations in the current knowledge of vehicle miles of travel (VMT) are comparable with the severe limitations of accident data compilations, in which only fatal accidents are comprehensively compiled at the national level. Direct collection of VMT by the federal government is limited to the Bureau of the Census's TIUS, which surveys more than 100,000 owners of heavy vehicles at 5-year intervals. The 1987 national survey results were published and the data tape was made available in September 1990.

TIUS provides an excellent source of national travel data, with the best available vehicle configuration information and the largest, best-designed sample. One problem, however, is that travel is not reported by state or highway type. Another is that the survey covers only power units. Although tractors may operate at different times with varying numbers and types of trailers, most operate consistently with the same number of trailers. It is estimated that approximately as many miles are traveled by normally doubles tractors with single trailers as are traveled by normally singles tractors with two or more trailers.

The major source of national travel data besides TIUS is FHWA's collection of state-compiled travel data, reported under the Highway Performance Monitoring System (HPMS). One of the HPMS forms required by FHWA asks each state for estimates of VMT for each class of highway, as well as the percentage breakdowns of this travel into each of 13 vehicle classes. Although the classes are not sufficient to distinguish triples or larger doubles from other multitrailer combinations, it is possible to derive overall estimates of multitrailer miles traveled. All states but Oklahoma submit these estimates regularly, most of them annually, but a few biannually.

This set of data represents the best source of information from which to estimate travel in each state. Some limitations of the data are discussed later, but these limitations can be reasonably overcome by following FHWA's adjustment procedures and by carefully considering what types of configurations are included in each travel category.

Derivation of Vehicle Travel Estimates

As discussed, FARS collects information for each fatal highway accident from police accident reports supplemented by additional investigation by NHTSA-funded state employees. TIFA matches 50T and FARS data and contacts operators of involved vehicles. These are by a large margin the most usable and accurate large-scale accident data sets for use in determining the overall safety rates of various vehicle configurations. The FHWA-adjusted state-reported travel data and TIUS travel data are the best available sources of exposure information. This section of the report describes the use of these four sources to develop comparative fatality involvement rates. The latest available FARS data (1988) and the latest available TIFA data (1986) were used in this comparison, along with the 1986 HPMS and the 1987 TIUS travel data.

The first step in the analysis was to assess the validity of the HPMS state-reported travel data. Each state and the District of Columbia were asked more detailed information about how the estimates were derived, and 31 states responded. In addition, FHWA staff were asked numerous questions about how they assessed and adjusted the data. On the basis of the responses received, we concluded that the travel data collected by the states cannot be used in raw form, but must be adjusted to compensate for the sampling methodology used.

To begin with, states appear to substantially overreport combination truck travel. Thirty of the 31 states responding to the survey classify trucks only on weekdays and make no attempt to correct for the substantially lower truck percentages on weekends. FHWA attempts to adjust for this effect in some of these states by using the results of a week-long 1982 classification study in five states. The resulting adjustment results in only a slight reduction in combination truck travel rates. FHWA also adjusts overall VMT up or down for each highway type in each state to match its careful evaluation and calibration of statewide travel, while leaving truck percentages the same. This has a further effect on aggregate truck VMT, because percentage travel by trucks varies by highway system and state.

No attempt is made by FHWA to adjust for multitrailer travel estimates independently of single-trailer travel estimates because neither the 1982 classification study nor any other study provides any data with which to make this separate adjustment.

Besides the day-of-week errors, another potential source of error is in the classification methodology itself. Most states use a combination of manual and automatic vehicle counting and classification. Manual counting is subject to human error, in which "odd" vehicle classes (such as multitrailer vehicles) are subject to greater percentages of misclassification than the more common classes, but there is not necessarily systematic bias. Automatic classification, however, is subject to substantial systematic bias. Closely spaced vehicles are commonly counted as multitrailer vehicles. There is little calibration between manual and automatic methods of classification, and what there is usually looks at overall error rates, rather than error rates for individual classes. Thus an overall error rate of, say, 1 percent appears good. However, if much of this error is concentrated in doubles classes, which in all states make up less than 1 percent of total travel, the error rate could be substantial. Several states have suggested that the classification procedures commonly used result in systematic overestimation of doubles VMT.

There are no specific data on how much to adjust multitrailer counts to overcome the probable bias resulting from current classification procedures. Because we could not adjust the state-reported proportions, it is likely that our estimates of doubles travel are too high in many states. This results in a lower estimated accident rate for doubles than actually occurs. As described later, this hypothesized systematic overcounting of doubles is borne out by the TIUS travel figures. Future improved vehicle classification counts are thus likely to raise estimates of multiunit combination vehicle accident rates derived from count data.

Instead of attempting to derive independent estimates of large truck overcounting, we adjusted state-reported data to match FHWA-published figures. FHWA figures are based on what we believe to be partial compensation for some of the systematic sources of bias mentioned earlier. The state-reported proportions of travel for each vehicle configuration were applied to the travel in each functional class in each state as published in Table VM-1 of the 1986 and 1988 *Highway Statistics* reports (*15*). This process revealed an obvious problem for New Mexico's 1988 data, which was related to the implementation of new equipment and procedures. The problem was sidestepped by obtaining advance estimates of New Mexico's 1989 data and replacing its 1988 estimates with an average of 1987 and 1989 estimates (*16*).

The next step involved matching national control totals for vehicle group travel. Although FHWA does not publish breakdowns of travel by state and vehicle group, Table VM-2 in *Highway Statistics* contains estimates of travel by highway type and vehicle group that are derived by adjusting the state-reported figures to compensate for their sampling procedures (as discussed earlier). Each group of vehicles was proportionally adjusted to simultaneously match both the state highway class and the national vehicle type totals. This process maintained the same overall proportion of multitrailer to single-trailer combination travel as reported by each state for each functional highway class (this breakdown is not published by FHWA but can be purchased in spreadsheet form).

Table 1 gives the adjusted 1988 VMT by state for four categories of vehicles: passenger vehicles (including automobiles, motorcycles, buses, and light trucks and vans), single-unit trucks (six tires and larger), single-trailer combination vehicles, and multitrailer combination vehicles. The national travel by multitrailers is less than 0.3 percent of all highway travel. Only New Mexico and Wyoming show estimates of multitrailer travel above 1 percent of total highway traffic.

Considering the assumptions necessary for use of FHWA data, use of TIUS data is easier. In addition, the better configuration information allows a better match with accident data, as will be seen later. Several adjustments or refinements, however, are necessary and desirable.

The first adjustment concerns year of travel. The 1987 TIUS was actually conducted in early 1988 and asked each of 104,606 truck operators how many miles they traveled during calendar year 1987. To match the resulting 1987 travel estimates with the 1986 TIFA and the 1988 FARS, we adjusted the survey mileage up or down to match the average annual growth rates by vehicle configuration shown between 1982 and 1987. Table 2 gives the published estimates of miles traveled from the 1982 and 1987 TIUS reports for several vehicle configurations, the average growth rates, and the resulting projections of 1987 traffic to 1986 and 1988 (*17*). The 1982 TIUS did not distinguish between full and partial trailers on trucks, so a single growth rate was derived for and applied to the 1987 truck-trailer miles.

These unadjusted TIUS estimates are used for one set of accident and fatality rate calculations described later. It is also desirable, however, to adjust for three other phenomena: the overrepresentation of low-mileage vehicles in TIUS, the inclusion of off-road mileage, and the absence of government-owned vehicles. Using the Census-supplied computer data tapes, it is possible to compensate for the first two factors.

A number of TIUS respondents reported very low annual mileage. One common hypothesis is that many of these respondents answered in hundreds or thousands of miles rather than actual miles traveled. This would result in underestimates of travel for each truck type. One could compensate for these possible poor responses by replacing all mileage estimates below a certain level with the average miles traveled for each particular truck type. The upward adjustments in travel resulting from applying a lower threshold of 2,200 mi per year would be 16.06 percent for single-unit trucks, 10.47 percent for truck-trailers, 5.74 percent for single-trailer combinations, and 0.89 percent for multitrailer combinations.

Each TIUS respondent also reports the percentage of off-road miles traveled. Removal of off-road miles reduces travel of single units by 6.19 percent, truck-trailers by 4.24 percent, single trailers by 1.26 percent, and multitrailers by 0.89 percent. The net combined adjustments leave multitrailer mileage unchanged but increase single-unit mileage by 9.87 percent, truck-trailer mileage by 6.23 percent, and single-trailer mileage by 4.48 percent. These adjustments are reflected in the "adjusted TIUS mileage estimates" in the accident and fatality rate tables below.

It was not possible to estimate government truck travel, but it appears that governments have many more single-unit than combination trucks. The error of excluding them is estimated to be negligible, but on the side of underestimating the accident and fatality rates of single-trailer and multitrailer combinations.

Compilation of Accident and Fatality Data

The fatality involvement data for 1988 were taken directly from FARS using the body type and number of trailing units fields. Using the number of trailing units field alone overestimates fatality rates for combination vehicles, because it includes light vehicles with trailers. Using body type allowed us to distinguish between truck-trailers and tractor-trailer combination vehicles. Unfortunately, FHWA travel data do not separate truck-trailer travel, and it is mixed among all three

TABLE 1 STATE-REPORTED VMT FOR 1988 ADJUSTED TO MATCH VM-1 AND VM-2

	Psgr Veh	Sngl Unit	1 Trlr Comb	2 Trlr Comb	All Veh
ALABAMA	36484.	1103.	2051.	47.	39684.
ALASKA	3700.	97.	40.	5.	3841.
ARIZONA	30783.	1394.	1868.	203.	34247.
ARKANSAS	17314.	430.	1405.	71.	19219.
CALIFORNIA	229254.	3979.	6759.	1582.	241575.
COLORADO	25809.	911.	876.	68.	27665.
CONNECTICUT	24380.	607.	1045.	30.	26062.
DELAWARE	5929.	205.	261.	9.	6404.
DIST. OF COLUMBIA	3338.	59.	8.	0.	3405.
FLORIDA	99515.	2362.	3403.	39.	105319.
GEORGIA	58441.	1403.	2304.	114.	62262.
HAWAII	7196.	181.	36.	6.	7419.
IDAHO	7302.	351.	406.	69.	8127.
ILLINOIS	73770.	1525.	3075.	114.	78483.
INDIANA	45859.	1330.	3829.	106.	51124.
IOWA	19768.	641.	1443.	55.	21907.
KANSAS	19452.	586.	1067.	56.	21161.
KENTUCKY	29087.	1005.	1476.	47.	31614.
LOUISIANA	31489.	1328.	1865.	0.	34682.
MAINE	10640.	433.	328.	0.	11401.
MARYLAND	35180.	1102.	1192.	23.	37498.
MASSACHUSETTS	41620.	667.	1019.	28.	43334.
MICHIGAN	73819.	1500.	2317.	263.	77899.
MINNESOTA	34301.	887.	1196.	62.	36447.
MISSISSIPPI	19885.	420.	1677.	62.	22043.
MISSOURI	41464.	1073.	2886.	148.	45570.
MONTANA	7263.	495.	328.	53.	8138.
NEBRASKA	12163.	382.	815.	47.	13407.
NEVADA	8262.	264.	388.	76.	8989.
NEW HAMPSHIRE	8991.	294.	221.	0.	9507.
NEW JERSEY	55226.	1575.	1867.	3.	58671.
NEW MEXICO	12431.	929.	1724.	200.	15283.
NEW YORK	98809.	1735.	3029.	119.	103692.
NORTH CAROLINA	53230.	2103.	2531.	79.	57943.
NORTH DAKOTA	5207.	238.	312.	9.	5765.
OHIO	75852.	2240.	3742.	157.	81990.
OKLAHOMA	29920.	816.	1560.	92.	32388.
OREGON	23254.	691.	1058.	202.	25204.
PENNSYLVANIA	74809.	2786.	3532.	111.	81238.
RHODE ISLAND	5419.	165.	266.	3.	5853.
SOUTH CAROLINA	29665.	597.	1439.	59.	31759.
SOUTH DAKOTA	6204.	184.	237.	9.	6634.
TENNESSEE	40869.	932.	2263.	130.	44193.
TEXAS	144258.	4093.	7884.	223.	156458.
UTAH	12356.	260.	527.	120.	13263.
VERMONT	5188.	223.	142.	0.	5553.
VIRGINIA	53613.	1630.	2165.	46.	57453.
WASHINGTON	38975.	1031.	1493.	313.	41813.
WEST VIRGINIA	12650.	511.	696.	27.	13884.
WISCONSIN	39155.	1253.	1996.	54.	42458.
WYOMING	4658.	233.	686.	80.	5658.
All States	1884206.	51231.	84730.	5418.	2025586.

TABLE 2 TRAVEL DATA AND GROWTH RATES FOR SELECTED TRUCK TYPES FROM 1982 AND 1987 TIUS (MILLIONS OF MILES TRAVELED)

	Single Unit	1-Trlr Comb	2+ Trlr Comb	Truck w/ Full Trl	Truck w/ Partial	All Trk Trlr
1987 Travel	38770	57056	2692	1476	2325	3801
1982 Travel	36276	46075	1939			3294
Annual Growth	1.3%	4.4%	6.8%			2.9%
1986 Travel	38258	54668	2521	1434	2259	3694
1988 Travel	39289	59548	2875	1519	2393	3911

other truck types (single unit, single-trailer combination, and multitrailer combination). This difficulty can be sidestepped by using TIUS data, which distinguish and describe truck-trailers.

Table 3 gives the number of fatalities in each state in which each type of vehicle was involved. The "unknown and miscellaneous" category includes farm vehicles, combination vehicles with an unspecified number of trailing units, and vehicles for which the FARS investigator could not obtain information. About half of these unknown vehicles are known to be heavy trucks but were not classifiable among the three potential heavy truck classes.

Truck-trailers presented a special difficulty when using FHWA travel data, because some are widely considered to be doubles, whereas others would be more properly classified as single-trailer combinations or as single-unit trucks, depending on the nature of the power unit and the trailer. Unfortunately, no information is available from FARS on the nature of the trailing unit, so additional data sources must be used to attempt to place the vehicle in the class in which it would have been counted by the state in which the accident occurred. If the trailing unit were a full trailer, most states either intentionally or unintentionally would have classified the vehicle as a multitrailer combination in their travel esti-

TABLE 3 FATALITIES INVOLVING VEHICLES OF EACH TYPE, BY STATE (FATALITIES COUNTED ONCE FOR EACH INVOLVED VEHICLE)

	Psgr Veh	SU Truck	1-Trlr	Trk-trl	Doub+	Unknown	Total
ALABAMA	1366	39	126	0	0	16	1023
ALASKA	125	1	2	0	0	4	97
ARIZONA	1273	28	68	5	10	45	944
ARKANSAS	824	21	121	0	2	9	610
CALIFORNIA	7570	167	306	21	124	118	5390
COLORADO	670	10	44	1	0	6	497
CONNECTICUT	672	14	21	0	1	13	484
DELAWARE	235	8	18	0	0	4	160
DIST. OF COLUMBIA	74	0	1	0	0	8	60
FLORIDA	4354	168	209	18	2	92	3078
GEORGIA	2148	46	190	1	0	126	1653
HAWAII	208	5	3	3	0	3	148
IDAHO	309	6	23	1	5	8	257
ILLINOIS	2652	82	197	3	3	25	1837
INDIANA	1518	40	132	9	4	31	1101
IOWA	750	27	63	0	3	16	557
KANSAS	679	13	49	1	2	9	483
KENTUCKY	1153	54	61	3	0	14	838
LOUISIANA	1279	29	100	3	0	15	925
MAINE	316	19	29	0	0	4	255
MARYLAND	1114	56	49	0	0	21	782
MASSACHUSETTS	944	24	13	0	0	49	725
MICHIGAN	2463	57	119	4	15	48	1704
MINNESOTA	852	18	52	4	1	15	612
MISSISSIPPI	968	122	2	0	0	15	722
MISSOURI	1490	53	81	2	3	24	1103
MONTANA	250	1	12	1	2	1	198
NEBRASKA	330	15	34	2	0	6	261
NEVADA	367	11	14	0	5	5	286
NEW HAMPSHIRE	235	21	3	0	0	3	166
NEW JERSEY	1456	49	88	0	0	0	1051
NEW MEXICO	623	4	28	0	6	16	487
NEW YORK	2963	144	110	9	3	58	2255
NORTH CAROLINA	2199	50	183	7	2	32	1573
NORTH DAKOTA	130	4	8	0	0	1	104
OHIO	2358	87	210	1	8	49	1763
OKLAHOMA	875	10	68	4	5	11	634
OREGON	969	26	62	2	9	10	677
PENNSYLVANIA	2656	94	268	4	3	22	1931
RHODE ISLAND	175	5	3	0	0	0	125
SOUTH CAROLINA	1418	44	95	8	6	31	1034
SOUTH DAKOTA	177	8	6	1	0	6	147
TENNESSEE	1783	49	105	4	5	22	1266
TEXAS	4474	84	361	4	6	110	3393
UTAH	403	6	33	0	1	8	297
VERMONT	159	10	6	1	0	10	129
VIRGINIA	1413	87	67	0	0	14	1071
WASHINGTON	1085	24	46	3	7	8	778
WEST VIRGINIA	606	20	44	0	2	3	460
WISCONSIN	1092	51	74	1	1	12	807
WYOMING	181	4	31	0	7	0	155
All States	64383	2015	4038	131	253	1176	71996

mates. Partial trailers would have been variously classed as single-unit trucks, single-trailer combinations, or multitrailer combinations, depending on the state.

On the basis of a review of each state's practice and TIUS-based estimates of the relative prevalence of truck-trailer configurations of each type, estimates were made of how truck-trailers would have been classified in each state. Truck-trailer fatalities were apportioned among the three truck classes according to these estimates. Unclassifiable vehicles were not included in the estimates.

A better, but not as up-to-date, source of fatal accident data is the TIFA program. The 1986 fatal accident involvements given in Table 4 were taken directly from this source, which does not publish results by state (*18*). The configurations were derived by matching 50T and FARS data, as reported earlier, supplemented by telephone interviews when necessary to clarify information. There is a possible bias toward undercounting doubles accidents, because each report showing multitrailer involvement initiated telephoned verification that the vehicle was actually a double. No similar screening was done for single trailers, so it is reasonable to expect some multitrailers to have been mistakenly considered single-trailer vehicles and not corrected. Thus it is likely that the actual number of fatal accidents involving doubles and triples is higher than given in Table 4, although no adjustments were made in this study.

RESULTS

Six different estimates of fatality or fatal accident rates could be developed using the three travel estimates (FHWA, TIUS, and adjusted TIUS) and two accident data sources (FARS and TIFA). Four of the six are presented here.

The 1988 FARS and FHWA travel data indicate a fatality involvement rate for multiunit vehicles that is 22 percent higher than for single-trailer combination vehicles, 49 percent higher than for single-unit trucks, and 72 percent higher than for passenger vehicles (see Table 5). FARS and FHWA travel are the two sources that together allow estimates of individual state fatality rates, and they are presented here mostly for that reason, because the other data sources overcome the most important difficulties associated with each of them.

TABLE 4 FATAL ACCIDENT INVOLVEMENTS BY VEHICLE COMBINATION, 1986 (FROM TIFA REPORT)

Truck Type	No.	Pct.
01 Unknown	130	2.5
02 Straight Truck Only	1262	24.1
03 Bobtail Tractor	146	2.8
04 Straight Truck and Full Trailer	74	1.4
05 Straight Truck and Other Trailer	64	1.2
06 Tractor and Semitrailer	3273	62.4
07 Tractor and Other	23	0.4
08 Tractor and Semi and Full	235	4.5
09 Tractor and Semi and Other	6	0.1
10 Tractor and Three Trailers	3	0.1
11 Other	27	0.5
13 Straight and Two Trailers	1	0.0

The wide variation in fatality rates by state, especially among states with lower levels of doubles travel, illustrates the random variation in accidents and the inherent uncertainty associated with use of smaller data sets. Nearly all previous studies have used smaller samples than any single state presented here, so the range of results in previous studies should not be surprising.

California, which has by far the largest amount of travel by multitrailer units of any of the states, has an involvement rate for multitrailers of 9.0 fatalities per 100 million mi traveled, which is much higher than the national average. The rate for single-trailer combinations of 4.6 is slightly below the national average. Thus double-trailers in California (there are no triples) have a 98 percent higher fatality involvement rate than single-trailer combinations.

California has used doubles for many years, in contrast to many other states where they are a relatively recent addition to the traffic stream. Drivers of doubles have much experience with them. Police officers are familiar with them and know what to call them on accident forms. Their use in California is similar to the use of single-trailer combinations (although they are still used more on safer roads such as Interstate highways, and the rates would probably be even more disparate if correction were made for this phenomenon). This tends to confirm the validity of the hypothesis that, as multitrailer vehicles become used for more general as opposed to special purposes, their accident rates will increase even above their current levels.

The next comparison combines 1986 FHWA travel data with 1986 TIFA accident data. TIFA has greatly improved determination of vehicle configuration and shows an even more pronounced trend than does FARS with the same travel data. As indicated in Table 6, fatal accident rates for multitrailer vehicles are 47 percent higher than for single-trailer vehicles and 118 percent higher than for single-unit trucks. This phenomenon tends to confirm the hypothesis that many doubles involved in accidents are mistakenly reported as other types of vehicles or are classified as "unknown" types for lack of coherent classification methodology. Although TIFA did not verify that each vehicle reported as a single-trailer combination was not actually a double, at least it decreased the number of "unknown" vehicles, resulting in more doubles being identified. An even more thorough investigation than was performed by TIFA is likely to further increase the disparity between multitrailer and single-trailer fatal accident rates.

Although the bias in the TIFA verification process lowers multitrailer accident rates by an undetermined amount, the TIFA data base is more reliable than FARS because of its extra verification of vehicle configuration. It was first paired with FHWA data to isolate the effect of improving accident data from the effect of improving travel data. The final two comparisons, given in Table 7, use TIFA data in combination with the travel estimates derived from the 1987 TIUS as described earlier. The first fatal accident rate in the table is calculated on the basis of the year-interpolated published TIUS figures for 1987 and 1982. The second set of rates is based on additional tabulations of the TIUS data tape to account for low-reported-mileage vehicles and off-road travel.

TABLE 5 FATALITY INVOLVEMENT RATES BY STATE AND VEHICLE TYPE, 1988

	Psgr Veh	Sngl Unit	1 Trlr Comb	2 Trlr Comb	All Veh
ALABAMA	3.744	3.537	6.145	0.000	3.898
ALASKA	3.379	1.032	5.018	0.000	3.437
ARIZONA	4.135	2.045	3.641	7.140	4.173
ARKANSAS	4.759	4.888	8.614	2.835	5.084
CALIFORNIA	3.302	4.197	4.558	9.032	3.438
COLORADO	2.596	1.098	5.135	0.000	2.642
CONNECTICUT	2.756	2.308	2.009	3.327	2.766
DELAWARE	3.963	3.907	6.894	0.000	4.138
DIST. OF COLUMBIA	2.217	0.000	12.306	0.000	2.438
FLORIDA	4.375	7.111	6.354	32.856	4.598
GEORGIA	3.675	3.350	8.246	0.000	4.033
HAWAII	2.890	2.765	11.693	29.680	2.992
IDAHO	4.232	1.712	5.717	8.413	4.331
ILLINOIS	3.595	5.379	6.485	3.167	3.774
INDIANA	3.310	3.008	3.636	5.455	3.392
IOWA	3.794	4.215	4.365	5.493	3.921
KANSAS	3.491	2.218	4.685	3.562	3.558
KENTUCKY	3.964	5.375	4.296	1.278	4.065
LOUISIANA	4.062	2.184	5.522	0.000	4.112
MAINE	2.970	4.387	8.849	0.000	3.228
MARYLAND	3.167	5.081	4.110	0.000	3.307
MASSACHUSETTS	2.268	3.600	1.276	0.000	2.377
MICHIGAN	3.337	3.800	5.171	6.928	3.474
MINNESOTA	2.484	2.029	4.481	5.458	2.585
MISSISSIPPI	4.868	29.075	0.119	0.000	5.022
MISSOURI	3.593	4.940	2.835	2.844	3.627
MONTANA	3.442	0.202	3.784	4.938	3.281
NEBRASKA	2.713	3.930	4.270	2.531	2.887
NEVADA	4.442	4.172	3.612	6.563	4.472
NEW HAMPSHIRE	2.614	7.141	1.355	0.000	2.756
NEW JERSEY	2.636	3.112	4.714	0.000	2.715
NEW MEXICO	5.012	0.431	1.625	3.002	4.430
NEW YORK	2.999	8.298	3.751	7.067	3.170
NORTH CAROLINA	4.131	2.377	7.341	7.863	4.268
NORTH DAKOTA	2.497	1.682	2.566	0.000	2.480
OHIO	3.109	3.885	5.639	5.109	3.309
OKLAHOMA	2.924	1.226	4.461	8.032	3.004
OREGON	4.167	3.765	6.013	4.664	4.277
PENNSYLVANIA	3.550	3.374	7.634	4.848	3.751
RHODE ISLAND	3.229	3.035	1.127	0.000	3.127
SOUTH CAROLINA	4.780	7.371	7.048	12.937	5.044
SOUTH DAKOTA	2.853	4.347	2.701	6.356	2.985
TENNESSEE	4.363	5.688	4.640	3.856	4.453
TEXAS	3.101	2.053	4.630	2.686	3.221
UTAH	3.262	2.303	6.267	0.834	3.400
VERMONT	3.065	4.935	4.231	0.000	3.350
VIRGINIA	2.636	5.339	3.095	0.000	2.752
WASHINGTON	2.784	2.327	3.281	2.236	2.805
WEST VIRGINIA	4.790	3.917	6.323	7.303	4.862
WISCONSIN	2.789	4.070	3.758	1.860	2.899
WYOMING	3.886	1.717	4.516	8.709	3.941
All States	3.417	3.946	4.835	5.876	3.554

Whereas arguments could be made to favor either of these sets of estimates, both are more reliable than any other estimates of relative fatal accident involvement. Note the even more striking differences between single-trailer and multitrailer vehicles, and especially between both types of combinations and single-unit trucks. Multitrailers have a fatal accident rate 58 to 66 percent higher than that for single-trailer combinations and more than three times as high as that for single-unit trucks.

TABLE 6 COMPARISON OF FATAL ACCIDENT RATES (FROM 1986 TIFA AND FHWA)

	Accidents	Million VMT	Rate/ 100 M
Single-Unit Trucks	1408	48413	2.91
Single-Trlr Coms	3360	77672	4.33
Multi-Trlr Combs	319	5024	6.35

These estimates should be considered to be better than the FARS-FHWA or TIFA-FHWA estimates for two main reasons: the better configuration information on TIUS and the superior sampling of TIUS. As described earlier, TIUS distinguishes between triples, doubles, tractor-trailer combinations, and truck-trailer combinations comparably with TIFA and much better than either FHWA or FARS. This eliminates the need to apportion truck-trailer accidents among the other truck classes to match likely traffic-counting categories. Also, the careful sample design and method of stratification elimi-

TABLE 7 COMPARISON OF 1986 FATAL ACCIDENT RATES FROM TIFA AND TIUS

Vehicle Type	Accidents	TIUS Miles (Millions) Deflated	Rate / 100 M	Adjusted TIUS Miles (Millions)	Rate / 100 M
Single-Units	1262	38258	3.299	42034	3.002
Truck/ Partial Trlr.	64	2259	2.833	2400	2.667
Truck/ Full Trlr.	74	1434	5.159	1523	4.859
Single-Trailers	3436	54668	6.285	57119	6.015
Multi-Trailers	251	2521	9.956	2521	9.956

nate the systematic errors of current state traffic classification practices. Together, these important advantages significantly increase the probable accuracy of TIUS-based travel estimates and the corresponding accuracy of fatal accident involvement rates.

Accidents involving tractors without trailers attached were apportioned to single-trailer and multitrailer combinations in proportion to travel, because TIUS data are derived from power unit travel estimates. In the FHWA data comparisons, which were classification-based travel, these accidents were placed in the single-unit category. In addition, the estimates for trucks with full and partial trailers are less reliable than the estimates for the other three categories because of sample sizes and operational uncertainties. They are included for completeness but have no direct bearing on this study's conclusions.

CONCLUSIONS

1. When the fatal accident rate of all current multitrailer operations is compared with the fatal accident rates of other trucks, multitrailers are shown to be much more dangerous than either single-unit trucks or single-trailer combinations.
2. As indicated in Table 8, which is arranged in order of increasing data quality, the apparent fatal accident overrepresentation of multitrailers increases as the data improve. Use of the best available sources indicates that multitrailers are more than 1.5 times as dangerous as single-trailer combinations and more than 3 times as dangerous as straight trucks.
3. The much higher rates for multitrailers would be expected in similar operations because of their inferior operating characteristics.
4. Most previous studies have also shown markedly higher fatality or fatal accident rates for doubles. The fact that this study found higher differences in fatal accident rates than most previous studies can be explained by small sample sizes and other errors in previous studies, as well as likely deterioration of doubles rates with their increasing usage.
5. TIFA is superior to FARS for assessing doubles accidents. The error rates in truck configuration reporting in FARS, though not great for most vehicle types, are unacceptably high for multitrailer vehicles.
6. The year-to-year variations, small samples, and systematic biases in travel data reported by states to FHWA require significant adjustments before the travel data can be considered adequate.
7. No reliable source of national accident data for nonfatal accidents is available, and the number of annual fatal accidents precludes the desirable disaggregation of accidents by region, state, and motor carrier type.
8. In assessing the safety implications of proposed changes in allowable truck configurations, one must consider not only the differences in existing accident rates but also the likely changes in rates that would result from more widespread use.

TABLE 8 COMPARISON OF INVOLVEMENT RATIOS DERIVED FROM VARIOUS DATA SOURCES

Data Sources	Multi-Trailer to Single-Unit Truck	Multi-Trailer to Single-Trailer
FARS/FHWA	1.49	1.22
TIFA/FHWA	2.18	1.47
TIFA/TIUS	3.02	1.58
TIFA/TIUS (Adj.)	3.32	1.66

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REFERENCES

1. *The Feasibility of a Nationwide Network for Longer Combination Vehicles.* FHWA, U.S. Department of Transportation, 1985.
2. *Longer Combination Vehicle Operations in Western States.* FHWA, U.S. Department of Transportation, 1986.
3. P. Fancher, A. Mathew, K. Campbell, D. Blower, and C. Winkler. *Turner Truck Handling and Stability Properties Affecting Safety.* University of Michigan Transportation Research Institute, Ann Arbor, 1989.
4. *Special Report 211: Twin Trailer Trucks.* TRB, National Research Council, Washington, D.C., 1986.
5. T. Chira-Chavala and J. O'Day. *A Comparison of Accident Characteristics and Rates for Combination Vehicles with One or Two Trailers.* Highway Safety Research Institute, University of Michigan, Ann Arbor, 1981.
6. J. C. Glennon. Matched Pair Analysis. *Consolidated Freightways Corporation vs. Larson et al.* U.S. District Court, Pennsylvania, Aug. 12, 1981.
7. C. S. Yoo, M. L. Reiss, and H. W. McGee. *Comparison of California Accident Rates for Single and Double Tractor-Trailer Combination Trucks.* BioTechnology, Inc., Falls Church, Va., 1978.
8. *Safety Comparison of Doubles vs. Tractor-Semitrailer Operation.* Bureau of Motor Carrier Safety, FHWA, U.S. Department of Transportation, 1983.

9. V. D. Graf and K. Archuleta. *Truck Accidents by Classification.* California Department of Transportation, Sacramento, 1985.
10. P. P. Jovanis, H. Chang, and I. Zabaneh. Comparison of Accident Rates for Two Truck Configurations. In *Transportation Research Record 1249,* TRB, National Research Council, Washington, D.C., 1989.
11. *Larger Dimension Vehicle Study.* Travel Monitoring Division, FHWA, U.S. Department of Transportation, 1990.
12. K. Campbell, D. Blower, R. Gattis, and A. Wolfe. *Analysis of Accident Rates of Heavy-Duty Vehicles.* University of Michigan Transportation Research Institute, Ann Arbor, 1988.
13. I. Jones and H. Stein. Crash Involvement of Large Trucks by Configuration: A Case Control Study. *American Journal of Public Health,* Vol. 78, No. 5, May 1988.
14. *Special Report 228: Data Requirements for Monitoring Truck Safety.* TRB, National Research Council, Washington, D.C., 1990.
15. *Highway Statistics* (1986 and 1988 editions). Office of Highway Information, FHWA, U.S. Department of Transportation, 1987 and 1989.
16. *New Mexico Traffic Survey, 1989.* Highway Planning and Research Division, New Mexico Highway and Transportation Department, Santa Fe.
17. *1982 Census of Transportation: Truck Inventory and Use Survey, United States* and *1987 Census of Transportation: Truck Inventory and Use Survey, United States.* Bureau of the Census, 1985 and 1990.
18. D. Blower, L. Pettis, and K. P. Sullivan. *Trucks Involved in Fatal Accidents, 1986.* University of Michigan Transportation Research Institute, Ann Arbor, 1990.

DISCUSSION

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The authors are to be commended for addressing an ongoing question by using available large-scale data bases. They faced the attendant difficulties of trying to achieve a consistency that is often not inherent in the data bases. The result was a laudable paper. However, the final conclusion, that double-trailer trucks were overinvolved in fatal crashes compared with single-trailer trucks by a ratio of 1.66, was a surprise to me. I have studied the same issue on several occasions.

It was possible to reexamine some of the analyses in the paper, which we did in an attempt to explain the authors' findings. The state-by-state data presented in Tables 1, 3, and 5 were the focus of the reanalysis. Table 3 contains FARS data, one of the two fatal accident data bases used by the authors. Unfortunately, TIFA data on a state-by-state basis were not included in the paper, so this discussion is limited to the FARS data analysis.

It is evident in Table 3 that the fatal doubles accidents are dominated by those in California. The data were reanalyzed to examine this domination. The reanalysis included reassigning "Trk-trl" accidents to the other truck categories on a state-by-state basis in the same way used by the authors. The resulting multitrailer to single-trailer fatal accident involvement ratios are as follows: all states, 1.215; California, 1.982; all but California, 0.939.

The apparent conclusion is that in California, doubles are twice as likely to be involved in fatal accidents as singles, but in the rest of the country doubles are slightly "safer." The authors suggest that the reason for this is that they have been in general use for many years in California, as opposed to special uses, and that therefore their accident rate will increase in the rest of the country as they become more common.

We believe that there is another explanation, which suggests both why the California rate is so high and that the doubles rate elsewhere is not likely to approach the California rate. Glauz and Harwood (*1*) analyzed accidents of doubles and singles in California on the basis of Caltrans data for an 18-month period, July 1976 through December 1977. One of the variables examined was the cargo area configuration. The findings in that study for all accident-involved doubles (not just fatal accidents) are given in the following table:

Configuration	*Number*	*Percent*
Fully enclosed (vans)	62	32
Platform (flatbed)	74	38
Tank	30	15
Bulk commodity or dump	24	12
Other	6	3
Total	196	100

It is evident that less than one-third of the accident-involved doubles were of the van type, which is the configuration used almost exclusively in the rest of the country. The remainder are intrastate haulers of special freight, such as fruits and vegetables from farms to packing plants, petroleum products from refineries to wholesalers and retailers, rock and earth from excavations to landfills, and so forth. These trucks tend to make short trips and probably use off-Interstate routes more often than interstate vehicles. (Nonfreeways generally have higher accident rates than freeways, so this factor alone tends to increase the accident rate of doubles in California. The authors voiced the opposite view.)

The suggested alternative hypothesis is that these specialized trucks are overinvolved in accidents and thus inflate the doubles accident rate in California. Furthermore, it is unlikely that these specialized trucks will be widely adopted elsewhere in the United States, because their use in California resulted from pre-1973 state legislation that allowed such configurations to operate at higher weights than singles. The use of these specialized doubles has an economic incentive in California because the freight they carry is heavy. The van-type doubles, which dominate doubles activity outside California, typically haul less-than-truckload freight that is less dense, so the extra space they provide is an incentive for their use.

In conclusion, the overinvolvement of double-trailer trucks in fatal accidents relative to single-trailer trucks that the authors found is likely to be primarily because of their high overinvolvement in California. Furthermore, the high doubles accident rate in California is associated with truck configurations unique to that state; they have not been adopted by industry in other states, nor are they likely to be under current state and federal laws.

REFERENCE

1. W. D. Glauz and D. W. Harwood. Large Truck Accident Rates: Another Viewpoint. In *Transportation Research Record 1038,* TRB, National Research Council, Washington, D.C., 1985, pp. 17–25.

AUTHORS' CLOSURE

Mr. Glauz raises some intriguing points in his analysis of fatal accident involvements of various trailer types in California. We must disagree, however, with both of his conclusions.

We used two sources of accident data and two sources of travel data in our calculation of fatal accident and fatality rates. In each case, the weaker source of data included state-by-state breakdowns, whereas the more reliable source did not. In each case, the more reliable source of the pair indicated that multitrailer combinations have a higher fatal involvement rate relative to single-trailer combinations than did the weaker source. One of the main findings of our study, in fact, is the increasing clarity of the trend as the quality of the data increases.

Mr. Glauz's first conclusion (that only in California are doubles more dangerous, whereas they are safer in the rest of the country) can only be supported by using the weakest of the four possible pairs of data sources. This pair of sources indicates an involvement rate ratio for multitrailers relative to single trailers of 1.22. Other pairs of sources presented in our paper yield corresponding ratios of 1.47, 1.58, and 1.66. Clearly, it takes more than California to explain differences of the last three magnitudes.

As for premises leading to his second conclusion (that California-type vehicles will not spread to other states), Mr. Glauz in our view correctly attributes the prevalence of tanker, dump, and flatbed doubles in California to the weight incentives created long ago by the California legislature. Let us suppose that Bridge Formula B were enacted nationally in place of the current 80,000-lb limit. The formula would allow doubles to operate at higher weights than existing singles and would create precisely the same sort of incentives to use these "unique" trailer types (the ones Mr. Glauz considers to be more dangerous than vans). We cannot agree, therefore, that such vehicles would be confined to California if size and weight laws were modified.

Our paper concluded that doubles are a special case, operating on the average under better conditions than single-trailer vehicles. Because of this, national comparisons of singles and doubles unfairly make doubles appear safer relative to singles than if similar operations of each were considered. We identified traffic conditions and types of operations as two factors across which controls are needed. Mr. Glauz's analysis suggests that body type is another desirable stratification variable, and with that we agree. If the data were available, we could certainly get better results by using all of these stratifications. It is equally certain, however, that the failure to be able to do so favors doubles (not singles), and that the comparable-condition disparity between doubles and singles is even greater than the condition-ignoring 1.66 ratio found in our paper.

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