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Longitudinal Review of State-Level Accident Statistics for Carriers of Interstate Freight

by C. Saricks and T. Kvitek

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March 1994

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Work sponsored by United States Department of Energy,
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LONGITUDINAL REVIEW OF STATE-LEVEL ACCIDENT STATISTICS FOR CARRIERS OF INTERSTATE FREIGHT

by

C. Saricks and T. Kvitek

ABSTRACT

State-level accident rates by mode of freight transport have been developed and refined for application to the U.S. Department of Energy's (DOE's) environmental mitigation program, which may involve large-quantity shipments of hazardous and mixed wastes from DOE facilities. These rates reflect multiyear data for interstate-registered highway carriers, American Association of Railroads member carriers, and coastal and internal waterway barge traffic. Adjustments have been made to account for the share of highway combination-truck traffic actually attributable to interstate-registered carriers and for duplicate or otherwise inaccurate entries in the public-use accident data files used. State-to-state variation in rates is discussed, as is the stability of rates over time. Computed highway rates have been verified with actual carriers of high- and low-level nuclear materials, and the most recent truck accident data have been used, to ensure that the results are of the correct order of magnitude. Study conclusions suggest that DOE use the computed rates for the three modes until (1) improved estimation techniques for highway combination-truck miles by state become available, (2) continued evolution of the railroad industry significantly increases the consolidation of interstate rail traffic onto fewer high-capacity trunk lines, or (3) a large-scale off-site waste shipment campaign is imminent.

1 BACKGROUND AND OBJECTIVES

Carriers of freight, regardless of commodity or mode of carriage, are subject to the risk of accidents in which cargo may be damaged and people may be killed or injured. The Center for Transportation Research of Argonne National Laboratory (ANL) has developed a set of state- and waterway-specific "risk factors" aimed at increasing the understanding of accident risk involved in the transport of hazardous waste by authorized interstate carriers. The risk factors, which include accident involvements and accident-related fatalities and injuries, have been expressed as rates per unit-shipment distance.

This effort builds on work originally performed in support of the U.S. Department of Energy's (DOE's) development of a risk-analysis program for the shipment of spent

commercial nuclear-reactor fuel under the Nuclear Waste Policy Act of 1986. That effort was broadened to include shipments of mixed and hazardous wastes that could be anticipated under DOE's site environmental mitigation program.

The calculated accident rates have been charted by transportation mode, within states or waterways; for highway transport by heavy combination trucks, rates have been charted by highway administrative class as well. An earlier set of risk-factor rates was included as risk-measurement units in the 1989 publication, *Data Base of Accident and Agricultural Statistics for Transportation Risk Assessment* (Saricks et al. 1989). That report cited several shortcomings in the method selected to compute the risk factors for transportation; chief among these shortcomings was the fact that the method's use of a single year's data (in this case, for 1985 or 1986) would fail to depict ongoing or newly emerging trends at the state level that use of consecutive, multiyear data could reveal; therefore, the method would also fail to indicate whether or not the individual risk factors were changing over time.

The authors of this report have five objectives:

1. To update the accident-risk-factor database with 1987 and 1988 data.
2. To increase the relevance and, ideally, the precision of the accident statistics applied as risk factors, by applying the best currently available information concerning only those carrier types of interest to the spent-fuel-shipping campaign, namely highway contract carriers that are interstate-registered, railroads that are members of the Association of American Railroads, and interstate barge lines.
3. To examine a through-time (longitudinal) series of accident data (minimum of three years) for each carrier type, in order to identify any indication of favorable or adverse responses to recent developments, such as the return to a 65-mph speed limit on rural freeways, the compromise of some safety practices (as shown by the failure of combination trucks to pass state-administered, roadside safety checks), and the continuing consolidation of railroad traffic on more densely used lines.
4. To conduct statistical tests of annual values of rates for each transportation mode, by state.
5. To attempt to verify or empirically confirm the risk estimates for highway transport (which, of the three modes considered, relies on the most questionable public-use databases), through contact with individual carriers and examination of subsequent-year (i.e., 1991) accident and flow data for heavy combination trucks, to see if 1986-88 trends are continuing.

The following section describes how the authors went about preparing revised rates and discusses the follow-up effort for preparing highway risk estimates. Section 3 presents and interprets findings by transportation mode, with respect to trends observed and statistical analyses performed. Section 4 discusses conclusions in light of those findings and identifies areas of further productive research.

2 PROCEDURES

The procedures used to develop individual-year and through-time series of accident, fatality, and injury rates, by transportation mode and by state, were fundamentally identical to the procedures documented by Saricks et al. (1989); however, some modifications were made in order to provide more precise estimates. The approach for each transportation mode is described below.

2.1 HIGHWAY TRANSPORT BY HEAVY COMBINATION TRUCKS

Combination trucks are rigs composed of a separable tractor unit containing the engine/propulsion plant and one to three freight trailers connected to each other and to the tractor. These rigs generally weigh at least 26,000 pounds empty and up to 80,000 pounds fully laden, and each tractor-trailer combination generally has five or more axles. Just as the railroad freight car is the standard unit of haulage by rail, the heavy combination truck is the standard unit of haulage by highway. For this reason, we selected the full range of reported accidents of interstate-registered carriers as the appropriate basis of estimation for risk involved in transportation of spent fuel by highway.

We hypothesize that it is appropriate to use the universe of all interstate-registered heavy-truck movements as the basis of accident-involvement-rate computation because "trucks don't know their cargo." This is certainly valid to a point, and it implies a generally conservative approach. However, the argument is also tenable that, in the case of route-controlled hazardous materials shipments, both shipper and carrier have a higher-than-average awareness of transport risk and prepare the cargoes and drivers for such shipments accordingly. This preparation should have a twofold effect of dramatically reducing component/equipment failure and mitigating the "human error" contribution to accident causation, leaving most remaining accident-precipitating events in the category of random occurrences largely unavoidable by the truck driver (such events collectively represent between 10 and 20% of total accident causation, on the basis of reported causative factors in the database). Thus, while risk for the backhaul or "deadhead" components of these shipments *may* assume the industry average, risk should be lower than average for the loaded miles.

Although it may be assumed that trucks carrying spent fuel will be subject to greater-than-average safety precautions, our analysis is conservative in that neither the type of cargo nor the lading status of the truck (i.e., loaded or empty) is a factor, and additional safety precautions are disregarded in the study. Risk involved in highway transportation is defined as the number of accident involvements¹ of heavy combination trucks in a given year per unit of travel by these trucks in that same year. (If travel units were reported or

¹ An accident is a truck-unit multiplier; for example, the collision of two trucks in a single accident represents two accident involvements.

estimated in miles, they were converted to kilometers for consistency with the risk factors already embedded in hazardous waste calculations.) Therefore, the rate is a fractional value, with accident-involvement count as the numerator of the fraction and vehicular activity (total travel distance) as its denominator. For example, if there were 36,000 accident involvements among heavy combination trucks in 1986, and these trucks traveled 120 billion kilometers in that year, the risk would be

$$\frac{3 \text{ road accident involvements}}{10^7 \text{ shipment kilometers}} .$$

Both loaded- and unloaded-truck travel is included in the denominator.

It was further determined that this unit should be broken down within a given state by road type according to the Federal-Aid Administration Classification System, which is the basis of federal formulas for funding road maintenance and improvement under the Federal-Aid Highway Act. This classification system is as follows:²

- Federal-Aid Interstate (FAI) highway system (urban and rural combined),
- Federal-Aid Primary (FAP) highway system, and
- Federal-Aid Secondary (FAS) (rural) highway systems.

The FAI is further divided into urbanized areas (FAI-U) and rural areas (FAI-R). Such a breakdown not only enhances estimation of within-state (between-classes) variance, to complement the depiction of between-states (nonstratified) variance, but also introduces into the database implicit qualities that can lead to higher or lower risk, such as differences among the systems with respect to average roadway standards and permitted extremes in road geometries.

State-level data for interstate-registered trucks (which consist of total counts of accident involvements by road type, sorted by state code) were processed to generate the numerators of the risk rates. The procedure for generating the denominator was less straightforward but aimed for equal reliability. This procedure is described in Section 2.1.2.

2.1.1 Accident Data

The primary source of combination-truck-accident data, with associated fatalities and injuries, is the *50-T Master File of Accidents of Motor Carriers of Property*, compiled annually from carrier-submitted reports by the Office of Motor Carriers (OMC), formerly the Bureau of Motor Carrier Statistics (BMCS), of the U.S. Department of Transportation (DOT). The

² Under the Intermodal Surface Transportation Efficiency Act of 1991, the "primary" and "secondary" classifications will be eliminated and combined into a single "National Highway System."

50-T file is the only comprehensive, central source of accessed data for public use: it covers accident involvements of heavy combination trucks owned and operated by interstate-regulated carriers, by year and for all states. All but a few of the accidents recorded in this file each year involve some configuration ("bobtail" to "turnpike triple") of heavy combination truck, and only records involving such configurations were selected. Reporting requirements in the past have stipulated that carriers must report any accident in which damage to property of \$2,000 or more was recorded, or in which a fatality or injury occurred (reporting of other accidents was at the carriers' discretion). Subsequently, the reporting threshold was raised to \$4,200 in 1986, \$4,400 in 1987, and \$4,900 in 1988, with the fatality and injury criteria being retained.

Using the Statistical Analysis System[®] (SAS), we generated a state-by-state listing of the salient components of each of the accident-involvement records for heavy combination trucks in the OMC 50-T master files for 1986, 1987, and 1988. From this information, we manually assigned the accident location provided on each record to the relevant administrative category (FAI-U, FAI-R, FAP, FAS, or none of the above). This in turn necessitated state-by-state transcription of the FAP system overlay from a national map of that system provided by the regional office of the Federal Highway Administration (FHWA). Because carrier reporting occasionally results in duplication of entries for fatalities and/or injuries in a given accident, we scrupulously checked SAS records to eliminate such double-counting.

Although the method detailed above is rather cumbersome, we determined that it was at least 50% more accurate (assuming that the 50-T records are complete and authentic) than the method used in a pilot study for this task, in which accident records were tabulated according to the road-identifier preface of the coded location. Moreover, our method enabled efficient "cleanup" of misassigned or miscoded records, a step that proved to be especially important when dealing with years for which a very large number of reportable accidents appeared in the data. With the annual miscoding rate being about constant, the total number of incorrect records was higher in such years, and propagation of error would have been greater.

2.1.2 Flow Data

To construct a denominator for the estimate of road accident/fatality risk per shipment-kilometer, it was necessary to develop estimates of total kilometers (converted from miles) of combination-truck travel, by state, per unit of time. The following factors also needed to be considered: (1) a proportion of truck travel is deadhead mileage, in which no actual shipment is involved; and (2) a truck's accident risk is largely independent of its cargo. Therefore, for both highway and rail activity, all relevant movements, loaded or empty, are included in the denominator.

In its annual publication *Highway Statistics*, the FHWA reproduces a series of tables that present the results of data analyses performed by using fuel sales data reported by states, vehicle counts by type at official 24-hour counting stations across the country, and data from such studies as the *Truck Inventory and Use Survey* (U.S. Bureau of the Census

1982) regarding vehicular usage patterns and fuel economy. More detailed versions of these tables, in spreadsheet format, are released to the public on floppy disks by the FHWA's Office of Highway Information Management. The detailed tables permit estimation of vehicle-miles of travel (VMT) by state, by vehicle type, and by urban and rural roadway classification. However, the numerators (accident counts) for each rate include only data from accidents reported by interstate-registered carriers; therefore, it was necessary to adjust the denominator (travel distance) in each case to approximate the state-level travel accounted for *only* by heavy combination trucks involved in interstate movements. This adjustment was made possible by estimating shares of heavy-truck travel accounted for by operators who traveled exclusively to predominantly *intrastate* and those who traveled primarily *interstate*, as reported in the 1987 *Truck Inventory and Use Survey* (TIUS).

According to TIUS, over-the-road, diesel-powered trucks with gross weight in excess of 33,000 pounds (virtually all of which are heavy combination rigs) nationally account for about 13% of all truck-miles. Of these trucks, some 35% (accounting for over 28 billion VMT annually) accumulate more than 25% of total miles on roads outside their "home" state of registry. We selected the travel share of this subset, approximately 53% of total travel by heavy combination trucks, as representing the accrual attributable to interstate-registered carriers. Thus, we applied an initial multiplier (deflator) of 0.53 to FHWA's estimate of total combination-truck miles for each state. An additional adjustment was then made to reflect the differences in VMT participation of interstate carriers by administrative class. For example, we deflated rural interstate VMT by combination-trucks by only 30% (that is, interstate carriers account for 70% of the combination-truck VMT on rural interstate highways), but we deflated urban interstate VMT by at least 40% and federal-aid secondary VMT by 70%, to echo the relatively greater use of these facilities by locally oriented, noninterstate trucks. Deflators are based on the nationwide share of reported accidents accounted for by each administrative class. Following adjustment, we renormalized the sum of each state's combination-truck VMT over all classes, including those classes not used in the spent-fuel transportation study (i.e., federal-aid urban and all nonfederal systems), to 53% of the original FHWA total. The resulting final shares for FAI-R, FAI-U, FAP, and FAS became the rate denominators.

Rates were computed for 1986, 1987, and 1988 individually and for the three years collectively. (See Tables A.1 through A.4 in the Appendix.) Data for the numerators (accident, fatality, and injury counts) were derived exclusively from the 50-T file of the OMC.

Remaining problems with the use of the FHWA flow data include missing information and possible bias in counting station-related data. In the current floppy-disk files, the combination-truck share of VMT for Oklahoma is given only for 1986, necessitating the use of the 1986 split for Oklahoma for all three years. Also, apparently there were some misplaced decimal points in New Mexico's truck-VMT shares for 1988. In some cases, combination-truck shares based on counts at permanent counting stations of the Highway Performance Monitoring System (HPMS) reflect the expectation that a large number of trucks will be counted at that site, rather than a desire to establish a truly random surveillance location. However, until significantly better methods for estimating heavy-truck flows by

state are generally available, the application of HPMS counts and state fuel-tax data used by the FHWA to prepare VMT estimates is probably the best available alternative. Nonetheless, the reliability of this approach should be checked and questioned periodically, especially as better data and techniques become available (Hu et al. 1990).

An enhancement to the process of preparing the rates for combination trucks is that all components of the annual 50-T accident records except counting, checking, and quality assurance are now fully automated for each year. This permits faster updating and investigation of data already collected and creates the opportunity for more efficient computation of rates for additional years.

2.1.3 Empirical Verification and Subsequent Examination of Highway Rates

Because the application of available statistics for combination-truck travel is not as straightforward as that for freight-train railcars and barges, and because some of the information itself is not as reliable, we felt we needed additional verification of highway rates. In an effort to verify or at least increase the credibility of the revised accident risk/probability rates for highway transport by heavy combination vehicles, we consulted two sources.

The first source was information obtained directly from the transportation-services divisions of four over-the-road carriers of high- and low-level nuclear materials; these carriers were:

1. Nuclear Assurance Corp., Georgia;
2. Tri-State Transportation (a subsidiary of TRISM, Inc.), Missouri;
3. McGil Special Services, Georgia; and
4. Hittman Transport, Pennsylvania.

Representatives of the transport service divisions listed above were all contacted by telephone; in each case, one of the authors spoke with either the director of transportation services (often a corporate vice-president in charge of specialized operations) or an officer of the division within the company that had been given responsibility for carrier operations. Each was asked the following question: is a range of one to five reportable accidents per 10 million (10^7) total truck-miles consistent with, higher than, or lower than your firm's experience? Two of the four provided actual computed rates in this range, on the basis of experience in 1992 and 1993, while the other two indicated that their long-term experience fell precisely within this range, even when unladen miles were included (Anderson 1993; Cooney 1993; Shelton 1993; Kirby 1994). A conclusion reached from these discussions is that rate estimates reported in Table A.4 of this document, as applied to haulers of high- and low-level nuclear materials by tractor-trailer combination trucks, are in the correct order of magnitude. Perhaps, if consideration is limited to truck-miles involved with actual manifest movements, the estimates might even be slightly high.

The second source was 1991 data from the DOT Office of Motor Carriers (a filtered, cleaned version of the 50-T file for calendar 1991), combined with data derived from the 1991 edition of the FHWA's *Highway Statistics* giving estimates of miles traveled by interstate-registered carriers driving heavy combination trucks. Six typical states in 1991 were examined (see Table 1) as the basis of a second assessment of whether the accident/fatality/injury rates given in Table A.4 were sufficiently conservative or would require upward revision. Again, the universe of cases was restricted to reportable accidents and (estimated) kilometers of travel, by state, of heavy combination trucks operated by motor carriers of property registered with the Interstate Commerce Commission (ICC). DOE is likely to require both interstate registry and specialty-transport certification for any highway carrier with whom it contracts for transport of large-volume wastes, but our data do not permit specific identification of such carriers in both the accident and travel-activity database; thus, we examined the larger subset of all ICC-registered carriers. The selected states are "typical" for the purpose at hand in that a high proportion of heavy-combination-truck shipments passing through them has both origin and destination beyond the state borders (i.e., they are important corridor states), yet a broad spectrum of truck shipments also originates or terminates within the state.

As the figures in Table 1 indicate, there has been little change, except primarily downward, from the Table A.4 rates for these states, even though reported accidents off of the interstate system in urban areas (but still occurring on the Federal-Aid system) are now included. These results also appear to reconfirm the Table A.4 rates as reasonable and in the correct order of magnitude.

2.2 RAILWAY TRANSPORT BY FREIGHT-TRAIN RAILCARS

As for highway transport, it was deemed appropriate for rail transport that we examine the types of railroad shipments involved in relocation of spent fuel. Spent-fuel casks will move over railroad routes in sections of one, two, three, or more railcars, up to and including unit (dedicated) trains. Therefore, although the propulsion medium for rail shipments is the locomotive, the conveyance (haulage) medium is the railcar, which has no independent power source and may bear the consequences of forces originating from elsewhere in the train.

2.2.1 Accident Data

The rail numerator, parallel to the numerator for the truck-accident unit-risk factor, is total, reportable railcar-accident involvements, by state, per unit of time. In this case, distinctions may be drawn from available data about the type of track on which an accident occurred (main, yard, siding, or industrial); however, similar partitioning according to track-speed class (an index of track physical condition) is very difficult, because this parameter is incomplete in accident records and does not appear at all in flow data.

TABLE 1 Filtered Accident Statistics for Interstate-Registered Heavy Combination Trucks, for Six Representative States, 1991^a

State	Total	Inter-State	Other F-A ^b	Fatalities	Injuries	I/R HCTVM ^c	Acc. Rate ^d	Fat. Rate ^d	Inj. Rate ^d
Alabama	533	224	309	I ^e = 6 OFA ^e = 51	I = 234 OFA = 286	I = 1364 OFA = 734	I = 1.64 OFA = 4.21	I = 0.44 ^f OFA = 6.95	I = 1.72 OFA = 3.90 ^f
Arizona	298	239	59	I = 25 OFA = 10	I = 238 OFA = 65	I = 1148 OFA = 492	I = 2.08 OFA = 1.20 ^f	I = 2.18 OFA = 2.03 ^f	I = 2.07 OFA = 1.32 ^f
Indiana	963	514	449	I = 35 OFA = 44	I = 409 OFA = 424	I = 2722 OFA = 1281	I = 1.89 ^f OFA = 3.51	I = 1.29 ^f OFA = 3.43 ^f	I = 1.50 ^f OFA = 3.31
Kansas	327	117	210	I = 4 OFA = 23	I = 107 OFA = 189	I = 446 OFA = 403	I = 2.62 OFA = 5.21	I = 0.90 ^f OFA = 5.71 ^f	I = 2.40 OFA = 4.69 ^g
Virginia	534	311	223	I = 23 OFA = 23	I = 299 OFA = 232	I = 1284 OFA = 604	I = 2.42 OFA = 3.69 ^f	I = 1.79 ^f OFA = 3.81 ^f	I = 2.34 OFA = 3.84 ^f
Washington	255	162	93	I = 12 OFA = 10	I = 132 OFA = 74	I = 755 OFA = 618	I = 2.15 OFA = 1.51 ^f	I = 1.59 ^g OFA = 1.62	I = 1.75 OFA = 1.20 ^f

^a Counts in columns 2-4 include duplicate entries in the 50-T file that are obviously multivehicle involvements reported by two or more carriers, but injuries or fatalities arising from these accidents are *not* double-counted. Entries for off-road locations (e.g., parking lot, truck stop, PU/D site) are excluded, as are local street locations that would not be traveled by a DOE hazardous materials shipment. *All locations on the designated Federal-Aid system identified as of 1991 are included*, whether or not the route would permit avoidance of densely populated areas.

^b F-A = All other designated Federal-Aid system routes; candidates for inclusion in National Highway System are defined pursuant to Intermodal Surface Transportation Efficiency Act of 1991.

^c I/R HCTVM = Millions of estimated travel-kilometers (laden and unladen) in the state by interstate-registered, heavy combination trucks.

^d Acc. Rate, Fat. Rate, Inj. Rate = Calculated accident-involvement rate per 10⁷ truck-kilometers, fatality rate per 10⁸ truck-kilometers, and injury rate per 10⁷ truck kilometers, respectively, by interstate-registered, heavy combination carriers over Interstate and other Federal-Aid highways.

^e I signifies Interstate system (urban + rural); OFA signifies other Federal-Aid system highways.

^f Decreased 20% or more under three-year average rates reported in Table A.4.

^g Increased 20% or more over three-year average rates reported in Table A.4.

For railroads, reliable sources of empirical information and inference exist for both accidents and fatalities (numerator) and railcar-kilometers (denominator). The source for the numerator is the annual *Accident/Incident Bulletin* compiled from carrier reports by the U.S. Department of Transportation's (DOT's) Federal Railroad Administration (FRA) Office of Safety. This file (available on tape in a public-use version and supplemented by a published, annual summary of statistics) contains comprehensive, internally consistent descriptors for each accident, including the state of occurrence. The file is checked by the FRA for duplicate entries (more than one railroad involved in an accident), which are eliminated. By definition, an accident is a collision, derailment, or other event involving the operation of railroad on-track equipment and resulting in damages that exceed the reporting threshold. The 1985 through 1988 files are recent, complete annual records available for this study; therefore, we used these files for compiling a set of one four-year and four one-year estimates of rates (Table A.5).

2.2.2 Flow Data

The denominator of the unit-risk factor is total railcar-kilometers moved per unit of time. This figure is based on flow data for rail shipments and is calculated by state. The numerator and denominator yield the desired ratio of accident involvements per shipment kilometer.

Rail shipments, which move on dedicated, privately owned networks, are closely monitored by the carriers themselves through the manifests or waybills required for each shipment. The commodity, number of cars, and actual routing of the shipment are entered into a computer file, along with other data. The ICC requires that all railroads annually report on these shipments by submitting a representative, quality-checked sample of waybills (nominally 1%, but actually higher). The ICC then processes these records into both proprietary data (carriers, origin, and destination points identified) and public-use data (only origin, interchange, and designation states identified). The public-use file for an average year contains well over 300,000 records; each record is drawn from a specific waybill and includes origin and destination regions, rail miles of the shipment, and (expanded) number of railcars loaded for that shipment.

We applied expansion factors to obtain a reliable estimate of the total (loaded) shipments in a given year. In its annual handbook, *Railroad Facts*, the Association of American Railroads (1986, 1987) reported the proportion of railcar-miles in the preceding year that were actually involved in shipments; by converting the waybill sample's railcar-miles to railcar-kilometers and dividing by this proportion (usually 50 to 60%), we obtained total railcar-kilometers by origin and destination state.

Finally, these values (cars $\times$ kilometers) were assigned to the appropriate origin, destination, and intervening states. Shipments with origin and destination in the same state required only summation of the (factored) car-kilometers. We used a procedure developed for an earlier project on freight-network-flow forecasting for interstate shipments. During the time this study was conducted, a fully coded version of the FRA national rail network was

kept on file at Argonne National Laboratory; this code included link-specific movement/impedance costs by commodity type. The impedances appropriate for a typical commodity shipment of high value (but not premium service) were applied to develop a set of most probable flow factors for all interchanges among each of the 48 contiguous states (plus the District of Columbia). These vectors provide length information as well as actual fractions of each state-to-state vector on the rail network in origination, intervening, and destination states. Thus, an algorithm already constructed to manipulate such vectors was used to allocate each cell total of the state-to-state origin/destination matrix for year 1985 car-kilometers across all appropriate states. This total was multiplied by the corresponding set of fractions and all state fractional allocations were summed into a car-kilometer total by state. These final 49 totals (48 states plus D.C.) became the denominators for the 1985 risk estimates.

Beginning with the 1986 waybill sample, the ICC no longer provided data about state origin and destination in the public-use file but included such information only at the more aggregated district level of the Bureau of Economic Analysis. This is apparently due to a confidentiality requirement on public-use data; with the recent increase in railroad mergers and consolidations, some states are effectively served by only one rail carrier, and state-level data therefore become carrier-specific data, which remain proprietary. In order to develop 1986 unit-risk denominators consistent with the 1985 assignment procedure, it was necessary to use a secondary source of waybill information, namely *Railroad Traffic in the United States*, a compendium of statistics developed from the waybill sample and published annually by ALK Associates (1986, 1987, 1988). Schematics of interstate railcar movements presented in the compendium, in conjunction with car-movement data from the edition of *Railroad Facts* covering 1986, served as the basis for expanding the 1985 state-level railcar-kilometer totals to 1986 estimated values. Comparison of 1985 and 1986 flow graphs in these publications enabled a reasonable determination of which states showed increased rail traffic, decreased traffic, or no net change; expansion factors were applied consistent with both these inferences and with the national control total presented in the 1986 compendium (ALK Associates 1988, p. 43).

2.3 WATERWAY TRANSPORT BY BARGES AND OTHER MARINE VESSELS

In the context of freight transport by domestic waterways, state borders have no significance. The characteristics of each waterway are independent of the political jurisdictions through which that waterway passes, because a single national entity, the U.S. Army Corps of Engineers (the Corps), is responsible for maintenance over the entire navigable length of the waterway. Therefore, we made an administrative decision to use each geographic waterway system, rather than each state, as the basis for estimating unit-risk factors for water transport. The Corps manages five waterway systems: Atlantic Coast, Gulf (of Mexico) Coast, Pacific Coast, Mississippi River (including the Arkansas, Ohio, Tennessee-Tombigbee, and Missouri navigable tributaries), and Great Lakes.

2.3.1 Accident Data

The commercial vessel casualty file (CVCF) of the U.S. Coast Guard is the source of data for barge and other (revenue) marine-vessel accidents and damage on the domestic waterway system. Records are continuously compiled from reports of waterway situations in which:

1. Actual physical damage to property exceeds \$25,000;
2. Material damage affects the seaworthiness, maneuverability, or efficiency of a vessel;
3. A vessel is stranded or grounded (with or without damage);
4. Loss of life occurs; and/or
5. Injury occurs that causes any person to remain incapacitated for more than 72 hours, except injury to harbor workers not resulting in death and not resulting from vessel casualty or vessel equipment casualty.

The records include vessel characteristics, event, cause, total vessels/crafts involved in the incident, fatalities/injuries, and monetary damage; specific vessel codes indicate whether the vessel was carrying hazardous cargo (U.S. Coast Guard 1984).

We used the 1985 through 1988 CVCF in developing the numerators for waterborne unit-risk factors. (See Tables A.6 through A.11 in the Appendix.) All casualty records for the following vessel activities were included: break-in-bulk hauls, barge tow, bulk solid cargoes, oil tankers, container hauls, roll-on roll-off cargoes, unclassified freight hauls, combination (mixed) freight hauls, gas carriers, ore or bulk-oil hauls, offshore transfers, bulk-liquid-chemical hauls, and other unclassified or unknown freight.

All casualties, fatalities and injuries were tabulated by waterway system, from the output records. The Tennessee-Tombigbee Waterway was included in the Lower Mississippi system, rather than among Gulf Coastal waterways, because traffic on the "Tenn-Tom" in general represents an alternative to use of the Mississippi River and its tributaries. The total vessel involvement in each situation (greater than the casualty count) was obtained from each record in order to estimate the likelihood of a craft's involvement in accident-related delays (with no reportable damage sustained). For example, if only two barges in a tow of 22 sustain damage in an accident, the involvement count for that accident is 22, but the casualty count is two and the accident count is one. Vessel counts include the total of dumb (non-self-propelled) barges.

2.3.2 Flow Data

Waterway movement statistics were obtained from the Corps' most recent annual reports on domestic waterborne commerce, which cover calendar years 1985 through 1988

(U.S. Army Corps of Engineers 1987, 1988, 1989, 1990). Movement statistics are reported in tons and ton-miles by waterway; in order to convert these values to units consistent with those used in the highway and rail transport analysis, ton-miles were first converted to ton-kilometers by multiplication, then divided by a barge shipment weight that would be representative of future spent-fuel movements in large casks. Tobin, Meshkov, and Jones (1985) have estimated this value to be about 500 short tons. Thus, dividing each waterway's ton-kilometer total by 500 yields the shipment-kilometer denominator needed for computing the unit-risk factor. These rates are shown at the bottom of Table A.10.

3 RESULTS

Computed rates and statistical findings are discussed by mode in the sections below.

3.1 HIGHWAY TRANSPORT

Tables A.1 through A.3 present the accident-involvement (see Section 2.1) and fatality counts and estimated kilometers of travel for interstate-carrier, combination trucks, by states, for the three years investigated. Fatalities are deaths that are attributable to the accident and that occurred at any time within 30 days thereafter. Vehicle-kilometers of travel (VKT) can be converted to vehicle-miles of travel (VMT) by dividing by 1.609.

Table A.4 shows the corresponding three-year-average rates for accident involvements, fatalities, and injuries sustained in the accidents. As described above, these rates are simply the counts of involvements, fatalities, and injuries within each state and road category, divided by the estimated kilometers of travel for interstate-registered, heavy combination trucks within that category. Especially high values (i.e, greater than twice the standard deviation of the distribution of rates for a given highway classification, given the total U.S. rate as the mean) are noted.

Although some of these higher values are affected by the fact that smaller states have fewer reported accidents, the highest accident rates in recent years for rural truck travel on the Federal-Aid Interstate system — meeting the $2 \times$ standard deviation criterion — have occurred in Connecticut, Massachusetts, and New Jersey. Interstate-truck travel in general shows the highest accident rates in New Jersey and New York, with the highest fatality rates in North Carolina. Shipments on urban portions of the Interstate system have had higher accident rates in Illinois, Maine, Montana, New Mexico, and South Dakota (the last four states having admittedly small and generally avoidable urban components).

Truck-shipment routing over the Federal-Aid Primary highways has been subject to the relatively highest accident and fatality exposures in Delaware and West Virginia. Interstate shipments using the Federal-Aid Secondary system are most likely to be near the pick-up or delivery end of their hauls, because these lower-echelon roads are generally not designed to meet heavy-duty line haul standards. Massachusetts and (for fatalities) Rhode Island are the two states that have experienced accident and fatality rates on this system more than two standard deviations higher than the national average.

With respect to accident counts on the Interstate system, no state had a year with a value greater than 140% of its three-year mean; the 12 highest excursions (in percentage difference) from the mean are shown in Table 2. All but two of these highest excursions occurred in 1988. Of the handful of states for which the highest yearly Interstate-system accident count over the period did not occur in 1988, most were located off the national

TABLE 2 Highest One-Year Excursions from Three-Year Mean in Truck Accident Statistics, by State

State	1986-87-88 Mean I-State Count of Accidents	Highest One-Year Accident Total	Year
California	487	611	1988
North Carolina	298	354	1988
Arizona	209	248	1988
South Carolina	170	205	1988
New Mexico	155	186	1987
Massachusetts	138	164	1988
Nevada	70	83	1988
Idaho	58	74	1988
Maine	41	50	1988
North Dakota	17	21	1986
Rhode Island	16	19	1988
New Hampshire	10	14	1988

highway corridors that carry the highest truck flows. Because nationwide total combination-truck travel steadily increased year-to-year through the period, it may be inferred (but not conclusively demonstrated) that accident increases tracked truck-volume increases during the three years.

3.2 RAILWAY TRANSPORT

Table A.5a shows total and mainline-only accidents involving railcars, with estimated car-kilometers. Table A.5b shows total and mainline-only rail-freight accident rates, by state, for 1986, 1987, and 1988, as well as a four-year-average rate for each state and for the United States, incorporating 1985 data (not shown). Nationwide average rates for fatalities and injuries were 6.50×10^{-10} fatalities and 7.83×10^{-8} injuries per railcar-kilometer. Both rates were generally declining over the four-year period studied; fatality rate decreased by over 20% and injury rate by over 36%. This reduction could not be attributed to the change in reporting threshold, because all fatality- and injury-causing events must be reported to FRA.

Because of the observed reduction in nationwide fatality and injury rates, we analyzed the variance in accident-involvement rates to assess whether a corresponding trend could be established. The result of this analysis was that a weighted accident rate (assigning greater significance to the most recent years' data) is not statistically different from the simple average rate over all four years, implying that there was no identifiable, net downward trend in rail-freight accident rates that would correspond to the decline in fatality and injury rates. Some states did experience an apparent accident-rate reduction during this

time, but we could not exclude the possibility that this was due primarily to annual changes in the accident-cost-reporting threshold.

Several of the values in the columns headed "Main Only" in Table A.5b emphasize a key feature of rail operations at the state level: in most cases, bypassing rail-freight yards (for car classification and sorting) significantly reduces accident likelihood. Although rail-yard accidents are generally low-speed, low-impact events with limited damage to cargo, the relatively high total rail-accident rates for such major freight-interchange states as California, Illinois, and Texas, when compared to the corresponding "main only" rates, suggests that the extra delays in shipment time such incidents produce can be avoided by through hauls. Such hauls should in any case be more the rule than the exception for DOE waste shipments by rail.

Our analysis indicates that the four-year-average rates shown in Table A.5b will be reasonable approximations of state-level risk factors in hazardous waste for the next several years, except where low flows indicate that either national average rates or rates for contiguous states should be used.

3.3 WATERWAY TRANSPORT

Tables A.6 through A.10 report annual and four-year-average accident statistics for U.S. domestic waterways and coastal movements. Rates are computed for both accident involvements (total number of dumb and self-propelled vessels actually present in an accident, as described in Section 2.1) and casualties (dumb and self-propelled vessels sustaining damage) in order to be consistent with truck and rail rates, which include both damaged and undamaged shipments, and to acknowledge the importance of shipment delay due to an accident, even if no actual damage is sustained by the vessel.

Among inland waterways throughout the period analyzed, the Great Lakes experienced the lowest casualty rates, while Gulf Coast waterways experienced the highest. In terms of accident involvements, the Great Lakes again have the lowest rates, while the rates for Gulf Coast and Atlantic Coast waterways are approximately tied for highest. The accident-involvement and casualty rates for the Mississippi-Missouri system are low, relative to Gulf Coast rates.

By far the lowest accident-involvement and casualty rates are registered by coastwise shipping. Such shipments avoid congested waterways and are therefore subject to fewer delays (e.g., at locks and dams) and less restrictive clearances than their inland counterparts. The landborne equivalent to shipping along the coasts, with respect to relative freedom both from delay and from interaction with other freight movements, is probably through-rail hauling done by unit trains. However, we do not have separate data for unit-train accidents and flows; therefore, we cannot make a direct comparison.

For each waterway type, Table 3 (corresponding to Table 2, which shows highway accident counts) shows the year experiencing the highest excursion from the four-year mean

for accident-involvement and casualty counts. The distribution of accident-involvement and casualty counts fails to establish any conclusive trend.

TABLE 1. Highest Excursions from the Four-Year Mean in Waterway Accident and Casualty Statistics

Waterway	Accident Involvements		Casualties	
	Year of Maximum Count	Percent by which Year's Count Exceeded 4-yr Mean for Waterway	Year of Maximum Count	Percent by which Year's Count Exceeded 4-yr Mean for Waterway
Atlantic Coast	1988	125	1988	111
Gulf Coast	1988	121	1988	116
Pacific Coast	1986	136	1986	132
Mississippi System	1985	107	1985	115
Great Lakes	1987	109	1985	108
Coastwise	1988	137	1988	148

4 CONCLUSIONS AND SUGGESTIONS

We have endeavored to improve the procedure by which disaggregate risk factors for transportation accidents, fatalities, and injuries are computed, for application to hazardous-waste shipments that may cross state lines. Our efforts have resulted in refinement and revision of the rates (risk factors) documented in the publication *Data Base of Accident and Agricultural Statistics for Transportation Risk Assessment* (1989). Specifically, we have constructed a multiyear average covering recent-year data for relevant route categories on each of the three modes of interest (highway combination truck, rail freight, and waterway freight). We also have modified highway rates so that activity (flow) estimations are fully consistent with accident, fatality, and injury counts. Most updating procedures have also been automated in spreadsheet programs.

Although disaggregate (i.e., subnational) flow data of reasonably good quality are available for the rail and waterway modes, the same cannot be said for the highway-freight mode, which is still subject to substantial estimation error at the state level, leading to highly erratic year-to-year shifts in truck-flow volumes in several states. Thus, despite the high degree of quality control exercised in preparing highway-rate numerators, equivalent control is not possible for the denominators. This knowledge led to the verification activities described in Section 2.1.3.

Our suggested actions are presented below, by transportation mode.

4.1 HIGHWAY TRANSPORT

- Continue to utilize, on an interim basis, highway risk factors that are based on the 1986-88 three-year-average rates shown in Table A.4 of this document.
- Continue to investigate and evaluate procedures to improve estimation of annual combination-truck highway mileage by state.
- If and when better estimation procedures become available, compute new state rates for those years using the 50-T compatibility adjustment described in this document.

4.2 RAILWAY TRANSPORT

- Four-year-average rail-accident rates computed for this report show reasonable stability; therefore, these rates could continue to be applied for an indefinite period (see Table A.5b). However, noteworthy changes in railroad operations, such as the formation of multimodal carriers and continuing consolidations among long-haul carriers, may progress to the point at which reexamination of annual data and reestimation of rates

are warranted. In any case, reexamine the rates before final implementation of any major shipment program involving hazardous waste from DOE site-remediation cleanups.

- Apply national average or contiguous-state rates in those few states (and the District of Columbia) where low rail-traffic volumes produce extreme annual values for state-level rates; the latter rates are clearly unrepresentative and should not be included in any routing-decision process.

4.3 WATERWAY TRANSPORT

- Use the rates presented in Table A.10 of this document. These should prove adequate for the next several years.
- Monitor accident-involvement and casualty rates in Gulf Coastal waters. A significant increase in risk in these waterways could jeopardize any planning for extensive use of Gulf ports for waterborne hazardous-waste shipments.

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APPENDIX:
ACCIDENT STATISTICS AND RATE TABLES

TABLE A.1 Reportable Highway Combination-Truck Accidents, Fatalities, and Estimated Flows, by State and by Road Type, 1986^a

State ^b	Combination-Truck Accidents Reported by Interstate Carriers					Heavy-Truck Accident Fatalities Reported by Interstate Carriers					Est. Interstate-Registered Motor-Carrier, Combination Truck km (10 ⁶)				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
AL	78	98	176	228	49	2	19	21	20	10	158	809	967	413	83
AZ	39	142	181	49	10	5	18	23	13	0	162	822	984	139	22
AR	57	108	165	195	34	5	19	24	40	3	114	519	633	397	27
CA	223	170	393	307	16	12	34	46	54	4	1239	1383	2622	2144	89
CO	56	62	118	83	17	3	7	10	12	3	115	295	410	221	34
CT	165	44	209	39	11	7	12	19	2	2	516	214	730	52	15
DE	21	-	21	37	4	1	-	1	5	1	94	0	94	47	7
FL	118	102	220	301	43	5	27	32	40	6	562	1273	1835	656	56
GA	192	184	376	273	44	8	18	26	30	6	355	1393	1748	591	62
ID	9	43	52	40	7	0	5	5	8	3	34	223	257	77	41
IL	472	191	663	312	13	21	17	38	41	0	430	1360	1790	506	114
IN	273	172	445	378	35	27	11	38	73	3	346	1332	1678	739	154
IA	40	124	164	139	16	3	2	5	17	1	103	682	785	349	43
KS	57	63	120	177	1	3	10	13	35	0	91	314	405	336	35
KY	87	110	197	107	55	8	11	19	14	4	139	884	1023	194	59
LA	75	78	153	146	30	6	14	20	25	6	273	591	864	437	180
ME	14	22	36	32	4	0	2	2	5	0	10	109	119	78	27
MD	154	76	230	141	19	12	7	19	18	2	433	364	797	403	30
MA	53	53	106	43	28	7	10	17	5	7	157	135	292	135	9
MI	179	98	277	175	3	11	3	14	25	2	547	1027	1574	582	50
MN	45	54	99	130	17	3	5	8	35	3	91	254	345	346	93
MS	33	55	88	187	11	2	7	9	49	4	96	533	629	366	143
MO	173	148	321	236	34	14	11	25	42	2	226	913	1139	432	70
MT	18	48	66	53	3	0	5	5	9	1	10	191	201	107	11
NE	21	56	77	69	2	4	4	8	7	0	24	368	392	208	34
NV	19	42	61	24	5	4	6	10	6	2	42	279	321	59	26
NH	0	6	6	26	7	0	1	1	5	0	15	62	77	30	43
NJ	140	149	289	214	29	7	18	25	16	5	705	216	921	244	21
NM	24	97	121	57	7	6	7	13	10	0	61	534	595	90	7
NY	212	211	423	217	74	3	11	14	35	5	340	589	929	646	52
NC	111	133	244	287	97	13	14	27	55	17	161	688	849	591	179
ND	3	18	21	24	0	0	0	0	1	0	7	144	151	106	8
OH	199	397	596	368	101	6	27	33	29	4	605	1994	2599	1097	210
OK	60	74	134	136	25	3	14	17	13	2	158	676	844	333	111
OR	36	128	164	130	9	2	8	10	25	1	88	470	558	266	23
PA	151	565	716	496	53	6	39	45	66	5	462	1769	2231	720	74
RI	13	5	18	5	2	0	0	0	0	1	36	17	53	14	1

TABLE A.1 (Cont.)

State ^b	Combination-Truck Accidents Reported by Interstate Carriers					Heavy-Truck Accident Fatalities Reported by Interstate Carriers					Est. Interstate-Registered Motor-Carrier, Combination Truck km (10 ⁶)				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
SC	22	108	130	177	19	4	16	20	25	2	87	668	755	384	128
SD	0	32	32	41	1	0	1	1	8	0	3	213	216	136	25
TN	154	185	339	199	8	7	16	23	26	0	288	1488	1776	311	38
TX	291	272	563	461	54	13	24	37	79	5	1300	2172	3472	1496	419
UT	23	79	102	45	4	0	8	8	12	0	98	309	407	95	15
VT	0	12	12	26	4	0	0	0	1	2	3	72	75	47	7
VA	75	224	299	230	30	3	11	14	44	5	285	777	1062	545	35
WA	38	106	144	80	11	2	2	4	8	0	270	369	639	256	133
WV	25	100	125	130	21	0	9	9	13	7	58	290	348	90	57
WI	50	111	161	192	12	0	5	5	20	1	85	526	611	661	27
WY	14	145	159	41	5	0	5	5	3	1	12	389	401	121	25
USA	4312	5500	9812	7483	1084	248	520	768	1124	138	10837	31955	42792	18294	3150

- ^a Accidents = Accident involvements of heavy combination trucks,
 Fatalities = Accident-related deaths occurring up to 30 days after date of accident,
 FAI-U = Federal-Aid Interstate highway system in urbanized areas,
 FAI-R = Federal-Aid Interstate highway system in rural areas,
 FAI = Federal-Aid Interstate highway system (urban and rural combined),
 FAP = Federal-Aid primary highway system, and
 FAS = Federal-Aid secondary (rural) highway system.

- ^b Includes only the 48 contiguous states, plus the totals for the nation as a whole (USA).

TABLE A.2 Reportable Highway Combination-Truck Accidents, Fatalities, and Estimated Flows, by State and by Road Type, 1987^a

State ^b	Combination-Truck Accidents Reported by Interstate Carriers					Heavy-Truck Accident Fatalities Reported by Interstate Carriers					Est. Interstate-Registered Motor-Carrier, Combination Truck km (10 ⁶)				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
AL	79	113	192	243	26	7	8	15	37	8	168	894	1062	453	87
AZ	46	152	198	51	10	8	23	31	6	2	194	1227	1421	210	55
AR	35	92	127	217	38	0	7	7	41	3	80	724	804	453	62
CA	212	245	457	303	26	22	27	49	55	3	1239	1684	2923	2346	108
CO	71	92	163	82	21	1	10	11	16	2	67	273	340	143	35
CT	120	103	223	36	19	4	9	13	1	0	539	228	767	189	17
DE	29	-	29	41	9	1	-	1	9	3	97	0	97	65	24
FL	99	154	253	310	44	13	33	46	49	4	297	1189	1486	950	92
GA	151	234	385	316	32	8	24	32	39	7	511	1296	1807	454	72
ID	5	44	49	42	10	0	3	3	5	0	39	202	241	78	45
IL	418	304	722	294	21	26	15	41	35	3	533	1577	2110	473	92
IN	117	328	445	438	53	8	13	21	76	9	388	1759	2147	1187	153
IA	36	119	155	136	1	3	4	7	20	0	109	709	818	358	45
KS	41	71	112	178	6	8	6	14	44	0	105	375	480	347	38
KY	66	134	200	122	60	2	13	15	11	4	152	886	1038	223	64
LA	77	84	161	147	44	17	14	31	20	5	217	698	915	376	167
ME	6	30	36	40	7	0	1	1	2	0	11	133	144	72	29
MD	101	176	277	117	46	6	19	25	11	2	359	397	756	413	32
MA	52	91	143	57	39	5	3	8	6	2	569	61	630	165	2
MI	126	167	293	157	8	2	14	16	26	0	421	916	1337	561	94
MN	38	51	89	118	15	4	4	8	20	2	196	268	464	294	55
MS	28	79	107	169	20	1	16	17	29	5	234	745	979	502	111
MO	160	159	319	274	38	21	10	31	51	10	263	941	1204	419	77
MT	7	46	53	52	0	1	2	3	10	0	10	225	235	92	13
NE	17	76	93	89	5	0	4	4	17	0	26	384	410	210	34
NV	17	48	65	30	9	1	5	6	5	3	24	338	362	63	19
NH	0	9	9	30	7	0	1	1	4	0	17	67	84	56	18
NJ	149	213	362	216	30	11	17	28	9	1	369	215	584	257	32
NM	40	146	186	54	5	1	18	19	9	0	19	602	621	101	6
NY	279	193	472	195	59	13	11	24	32	10	452	783	1235	581	67
NC	112	183	295	286	106	10	17	27	28	18	187	744	931	436	129
ND	0	12	12	17	1	0	1	1	0	0	10	141	151	108	34
OH	218	432	650	456	138	16	20	36	68	11	900	1940	2840	972	44
OK	60	123	183	137	26	5	14	19	27	1	156	662	818	380	142
OR	38	82	120	124	4	3	3	6	15	0	95	461	556	331	48

TABLE A.2 (Cont.)

State ^b	Combination-Truck Accidents Reported by Interstate Carriers					Heavy-Truck Accident Fatalities Reported by Interstate Carriers					Est. Interstate-Registered Motor-Carrier, Combination Truck km (10 ⁶)				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
PA	170	649	819	530	60	10	60	70	76	6	487	1801	2288	744	74
RI	6	5	11	4	1	0	2	2	1	1	39	18	57	21	1
TN	235	234	469	173	26	14	30	44	19	7	286	1315	1601	347	26
TX	337	311	648	444	55	36	40	76	81	14	1133	2037	3170	1615	486
UT	26	71	97	38	8	1	5	6	7	0	114	326	440	97	15
VT	0	9	9	27	6	0	0	0	2	1	3	78	81	35	10
VA	82	241	323	217	25	3	17	20	35	1	229	1058	1287	487	50
WA	47	73	120	76	8	3	10	13	8	0	290	351	641	245	127
WV	21	107	128	126	32	1	3	4	22	2	83	280	363	116	11
WI	34	100	134	204	19	0	2	2	29	3	82	539	621	732	30
WY	0	143	143	33	14	0	10	10	3	1	18	406	424	119	26
USA	4046	6699	10745	7674	1261	299	589	888	1148	162	11927	32806	44733	19236	3082

- ^a Accidents = Accident involvements of heavy combination trucks,
 Fatalities = Accident-related deaths occurring up to 30 days after date of accident,
 FAI-U = Federal-Aid Interstate highway system in urbanized areas,
 FAI-R = Federal-Aid Interstate highway system in rural areas,
 FAI = Federal-Aid Interstate highway system (urban and rural combined),
 FAP = Federal-Aid primary highway system, and
 FAS = Federal-Aid secondary (rural) highway system.

- ^b Includes only the 48 contiguous states, plus the totals for the nation as a whole (USA).

TABLE A.3 Reportable Highway Combination-Truck Accidents, Fatalities, and Estimated Flows, by State and by Road Type, 1988^a

State ^b	Combination-Truck Accidents Reported by Interstate Carriers					Heavy-Truck Accident Fatalities Reported by Interstate Carriers					Est. Interstate-Registered, Motor-Carrier, Combination-Truck km (10 ⁶)				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
AL	99	117	216	253	31	9	21	30	32	3	221	904	1125	538	98
AZ	52	196	248	49	4	5	24	29	16	0	150	1004	1154	355	89
AR	32	135	167	190	34	12	18	30	33	5	63	691	754	434	66
CA	243	368	611	299	28	15	61	76	47	5	1058	1706	2764	3405	118
CO	59	105	164	85	15	6	6	12	12	2	114	372	486	244	51
CT	111	132	243	35	20	4	10	14	2	3	429	165	594	188	23
DE	27	-	27	47	12	3	-	3	9	0	110	0	110	58	21
FL	94	184	278	323	68	6	35	41	59	5	523	1163	1686	895	97
GA	150	265	415	330	32	8	35	43	55	5	146	1450	1596	449	133
ID	5	69	74	50	10	0	6	6	7	0	37	253	290	113	32
IL	456	306	762	349	20	35	31	66	41	4	405	1415	1820	506	98
IN	133	412	545	454	65	5	34	39	57	10	407	1670	2077	764	240
IA	43	149	192	165	0	3	17	20	30	0	124	807	931	385	49
KS	32	83	115	192	9	5	4	9	21	2	94	375	469	387	43
KY	86	155	241	145	54	5	17	22	18	4	175	969	1144	235	69
LA	94	94	188	138	50	11	7	18	25	6	204	684	888	409	172
ME	8	42	50	52	10	0	6	6	8	2	10	143	153	78	36
MD	126	140	266	122	45	2	14	16	10	4	446	232	678	250	27
MA	59	105	164	66	39	3	11	14	8	3	431	192	623	184	12
MI	132	176	308	181	9	8	17	25	25	1	416	1069	823	774	102
MN	49	63	112	155	12	3	5	8	19	11	209	292	501	322	56
MS	29	89	118	201	5	8	11	19	37	0	118	601	719	374	303
MO	173	225	398	277	43	7	16	23	49	3	488	1143	1631	616	315
MT	7	64	71	57	2	0	2	2	5	0	12	210	222	102	25
NE	15	78	93	81	4	1	5	6	14	0	26	432	458	243	43
NV	21	62	83	29	6	3	0	3	9	0	24	352	376	69	18
NH	1	13	14	12	10	0	1	1	0	4	13	72	85	70	11
NJ	155	163	318	209	34	7	10	17	18	5	528	255	783	439	43
NM	43	116	159	46	10	3	11	14	4	1	31	732	763	138	5
NY	236	211	447	240	51	10	7	17	28	5	485	725	1210	834	75
NC	115	239	354	289	132	6	40	46	29	23	223	1001	1224	641	218
ND	8	11	19	20	2	1	1	2	2	0	8	130	138	92	34
OH	254	443	697	518	129	8	27	35	87	18	621	1662	2283	964	80
OK	61	102	163	141	22	5	14	19	16	0	168	699	867	434	169
OR	39	125	164	152	7	2	6	8	17	4	100	589	689	377	52

TABLE A.3 (Cont.)

State ^b	Combination-Truck Accidents Reported by Interstate Carriers					Heavy-Truck Accident Fatalities Reported by Interstate Carriers					Est. Interstate-Registered, Motor-Carrier, Combination-Truck km (10 ⁶)				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
PA	121	734	855	600	66	15	62	77	87	10	515	1842	2357	790	78
RI	13	6	19	7	2	1	1	2	1	0	66	46	112	82	1
TN	267	244	511	210	33	25	27	52	28	6	249	1683	1932	389	43
TX	381	383	764	539	62	22	58	80	88	10	1250	1998	3248	2092	668
UT	36	90	126	29	11	1	9	10	6	1	125	362	487	111	16
VT	0	11	11	22	7	0	1	1	1	3	3	82	85	37	8
VA	77	227	304	253	36	11	20	31	30	8	375	893	1268	466	96
WA	56	93	149	81	11	2	4	6	7	0	317	368	685	404	150
WV	23	108	131	131	21	2	5	7	24	7	93	446	539	126	26
WI	54	105	159	208	13	2	5	7	29	1	94	754	848	764	79
WY	0	188	188	52	11	0	14	14	17	1	17	598	615	130	30
USA	4319	7628	11947	8324	1329	293	758	1051	1196	188	12011	34174	46185	22082	4332

^a Accidents = Accident involvements of heavy combination trucks,

Fatalities = Accident-related deaths occurring up to 30 days after date of accident,

FAI-U = Federal-Aid Interstate highway system in urbanized areas,

FAI-R = Federal-Aid Interstate highway system in rural areas,

FAI = Federal-Aid Interstate highway system (urban and rural combined),

FAP = Federal-Aid primary highway system, and

FAS = Federal-Aid secondary (rural) highway system.

^b Includes only the 48 contiguous states, plus the totals for the nation as a whole (USA).

TABLE A.4 Highway Combination-Truck Accident, Fatality, and Injury Rates Based on Reportable Interstate-Carrier Accidents, Reported Fatalities and Injuries, and Estimated Flows, 1986-1988 (10^{-7} accidents and injuries per shipment-kilometer, 10^{-8} fatalities per shipment-kilometer)

State ^a	Accident-Involvement Rates					Accident-Fatality Rates					Accident-Injury Rates				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
AL	4.68	1.26	1.85	5.16	3.96	3.29	1.84	2.09	6.34	7.84	4.66	1.24	1.83	5.62	4.22
AZ	2.71	1.60	1.76	2.12	1.45	3.56	2.13	2.33	4.97	1.20	2.89	1.65	1.82	2.20	2.77
AR	4.82	1.73	2.09	4.69	6.84	6.61	2.28	2.78	8.88	7.10	4.09	1.95	2.20	4.38	5.94
CA	1.92	1.64	1.76	1.15	2.22	1.39	2.56	2.06	1.98	3.81	1.82	1.68	1.74	1.12	2.67
CO	6.28	2.76	3.60	4.11	4.42	3.38	2.45	2.67	6.58	5.83	5.47	2.82	3.45	3.95	3.67
CT	2.67	4.60 ^b	3.23	2.56	9.09	1.01	5.11 ^b	2.20	1.17	9.09	1.71	4.61 ^b	2.55	1.89	7.09
DE	2.56	-	2.56	7.35	4.81	1.66	-	1.66	13.50 ^b	7.69	3.46	-	3.46	7.18	3.08
FL	2.25	1.21	1.50	3.73	6.33	1.74	2.62	2.38	5.92	6.12	2.36	1.28	1.58	4.12	7.92
GA	4.87	1.65	2.28	6.15	4.04	2.37	1.86	1.96	8.30	6.74	4.37	1.75	2.26	6.43	3.71
ID	1.73	2.30	2.22	4.93	2.29	0	2.06	1.78	7.46	2.54	1.18	2.12	1.99	3.54	1.69
IL	8.75 ^b	1.76	3.53	6.40	1.78	5.33	1.39	2.38	7.84	2.30	8.23 ^b	1.49	3.20	6.12	1.55
IN	4.58	1.92	2.43	4.72	2.80	3.51	1.22	1.66	7.66	4.02	4.36	1.81	2.30	4.42	2.32
IA	3.54	1.78	2.02	4.03	1.24	2.68	1.05	1.26	6.14	0.73	3.78	1.46	1.76	3.48	0.88
KS	4.48	2.04	2.56	5.11	1.38	5.52	1.88	2.66	9.35	1.72	3.66	1.91	2.28	4.09	1.12
KY	5.13	1.46	1.99	5.74	8.80	3.22	1.50	1.75	6.60	6.25	5.52	1.33	1.94	5.28	8.12
LA	3.54	1.30	1.88	3.53	2.39	4.90	1.77	2.59	5.73	3.28	4.57	1.32	2.16	4.46	2.85
ME	9.03 ^b	2.44	2.93	5.44	2.28	0	2.34	2.16	6.58	2.17	4.52	1.53	1.75	5.00	1.63
MD	3.08	3.95	3.46	3.56	12.40	1.62	4.03	2.69	3.66	8.99	3.41	3.98	3.66 ^b	4.32	13.40
MA	1.42	6.47 ^b	2.68	3.43	46.10 ^b	1.30	6.23 ^b	2.53	3.93	52.20 ^b	1.13	4.99 ^b	2.09	3.02	43.90 ^b
MI	3.16	1.59	2.12	2.68	0.81	1.52	1.23	1.33	3.96	1.22	3.04	1.29	1.87	2.61	1.38
MN	2.66	2.06	2.29	4.19	2.16	2.02	1.72	1.83	7.69	7.84	2.08	1.46	1.69	3.28	1.86
MS	2.01	1.19	1.35	4.48	0.65	2.46	1.81	1.93	9.26	1.62	1.85	1.10	1.25	4.55	0.50
MO	5.18	1.78	2.61	5.36	2.49	4.30	1.23	1.99	9.68	3.25	5.53	1.63	2.59	5.06	2.23
MT	10.00 ^b	2.52	2.89	5.38	1.02	3.12	1.44	1.52	7.97	2.04	4.69	1.79	1.93	3.95	0.20
NE	6.97	1.77	2.09	3.62	0.99	6.58	1.10	1.43	5.75	0	6.58	1.17	1.50	3.54	0.54
NV	6.33	1.57	1.97	4.35	3.17	8.89 ^b	1.14	1.79	10.50	7.94	5.67	1.58	1.93	3.72	2.54
NH	0.22	1.39	1.18	4.36	3.33	0	1.49	1.22	5.77	5.56	0	1.14	0.94	4.17	2.22
NJ	2.77	7.65 ^b	4.24 ^b	6.80	9.69	1.56	6.56 ^b	3.06	4.57	11.50	2.69	8.00 ^b	4.28 ^b	6.86	11.30
NM	9.64 ^b	1.92	2.35	4.77	12.20	9.01 ^b	1.93	2.32	6.99	5.56	8.92 ^b	1.86	2.25	4.62	10.60
NY	5.69	2.93	3.98 ^b	3.16	9.48	2.04	1.38	1.63	4.61	10.30	4.49	2.56	3.28	2.71	10.00
NC	5.92	2.28	2.97	5.17	6.37	5.08	2.92	3.33 ^b	6.71	11.00	6.37	2.19	2.99	5.53	6.22
OH	3.16	2.27	2.52	4.42	11.00	1.41	1.32	1.35	6.07	9.88	2.85	2.02	2.25	4.40	1070
OK	3.76	1.47	1.91	3.61	1.73	2.70	2.06	2.18	4.88	0.71	3.34	1.36	1.74	3.05	1.59
OR	3.99	2.20	2.48	4.17	1.63	2.47	1.12	1.33	5.85	4.07	3.82	1.69	2.02	2.94	0.57
PA	3.02	3.60	3.48	7.21	7.92	2.12	2.97	2.79	10.20	9.29	2.68	3.28	3.15	7.28	6.42
RI	2.27	1.98	2.16	1.37	16.70	0.71	3.70	1.80	1.71	66.70 ^b	3.12	2.35	2.84	0.86	23.30 ^b
SC	3.13	1.83	1.99	6.27	2.27	2.88	2.57	2.61	8.61	3.95	2.65	2.20	2.26	6.96	2.27
SD	8.57 ^b	2.09	2.18	3.94	1.49	14.30 ^b	0.42	0.62	5.38	2.13	5.71	1.38	1.95	2.94	0
TN	7.97	1.48	2.48	5.56	6.26	5.59	1.63	2.24	6.97	12.10	7.70 ^b	1.44	2.41	5.85	4.67

TABLE A.4 (Cont.)

State	Accident-Involvement Rates					Accident-Fatality Rates					Accident-Injury Rates				
	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS	FAI-U	FAI-R	FAI	FAP	FAS
TX	2.74	1.56	2.00	2.78	1.09	1.93	1.97	1.95	4.77	1.84	2.53	1.42	1.83	2.53	0.92
VT	0	1.38	1.33	6.30	6.80	0	0.43	0.42	3.36	24.00	0	1.08	1.04	6.13	4.40
VA	2.63	2.54	2.56	4.67	5.03	1.91	1.76	1.80	7.28	7.73	2.49	2.46	2.47	5.39	4.81
WA	1.61	2.50	2.10	2.62	0.73	0.80	1.47	1.17	2.54	0	1.49	2.14	1.85	2.11	0.51
WV	2.95	3.10	3.07	11.70 ^b	7.87	1.28	1.67	1.60	17.80 ^b	1.70	2.78	2.80	2.79	9.91 ^b	7.13
WI	5.29	1.74	2.18	2.80	3.24	0.77	0.66	0.67	3.62	3.68	4.33	1.45	1.81	2.51	3.16
WY	2.98	3.42	3.40	3.41	3.70	0	2.08	2.01	6.22	3.70	0	2.84	2.74	1.86	2.35
USA	3.58	2.03	2.44	3.94	3.48	2.37	1.91	2.03	5.82	4.62	3.36	1.89	2.28	3.82	3.30
σ^c	2.36	1.25	0.69	1.77	6.98	2.70	1.27	0.63	3.01	11.74	1.99	1.22	0.69	1.79	7.10

^a Includes only the 48 contiguous states, plus the totals for the nation as a whole (USA).

^b Rates are two or more standard deviations greater than the national average rate for that highway category.

^c σ = standard deviation.

TABLE A.5a Total and Mainline-Only, Reportable Railroad-Freight-Car Accidents on Carrier-Owned Track and Estimated Car-Kilometers for 1986, 1987, and 1988 (10⁻⁸ accidents per railcar-kilometer)

State ^a	Accidents Involving Railcars						Estimated Car-Kilometers		
	1986		1987		1988		1986	1987	1988
	Total	Main Only	Total	Main Only	Total	Main Only			
AL	33	17	47	33	41	25	851,331,810	979,823,840	992,034,050
AZ	24	18	24	20	27	22	1,715,650,560	1,847,785,910	1,870,812,350
AR	37	19	35	19	72	34	733,103,630	820,528,890	863,655,180
CA	116	60	80	48	105	56	2,273,667,000	2,424,771,810	2,430,681,630
CO	20	14	13	6	39	23	1,387,248,800	1,508,739,380	1,527,540,740
CT	3	2	2	1	3	0	11,332,830	11,996,330	12,025,570
DE	3	1	3	2	2	2	10,933,250	11,890,750	11,085,350
DC	0	0	2	2	0	0	600,000	633,540	692,240
FL	23	17	37	18	42	24	803,177,770	949,844,130	1,009,288,710
GA	71	34	82	34	78	34	1,102,592,500	1,210,796,110	1,262,297,020
ID	18	16	23	14	34	15	304,937,430	341,302,320	376,347,580
IL	294	78	270	84	271	73	2,513,780,400	2,707,385,820	2,985,382,880
IN	61	27	60	24	66	25	1,458,766,000	1,617,326,020	1,734,756,630
IA	111	45	88	46	87	51	629,783,060	691,587,220	727,936,440
KS	65	35	69	36	101	49	2,157,920,900	2,324,118,870	2,469,570,360
KY	50	25	40	21	39	20	1,046,253,600	1,060,549,250	1,084,396,770
LA	53	25	35	10	61	20	418,348,180	494,741,740	510,825,980
ME	10	6	11	5	14	7	35,434,970	37,415,770	26,629,940
MD	24	14	25	11	22	6	395,153,790	450,622,170	483,340,880
MA	21	10	19	7	13	5	170,282,690	188,791,500	177,896,540
MI	74	33	65	19	75	36	403,518,040	430,335,300	483,150,240
MN	111	34	89	47	119	55	1,285,943,200	1,425,718,310	1,514,944,760
MS	46	34	46	35	32	27	303,436,290	355,642,080	377,899,410
MO	93	43	81	42	116	66	2,027,705,300	2,248,105,970	2,298,656,900
MT	28	21	29	19	52	29	2,075,546,200	2,344,978,290	2,468,228,300
NE	65	34	85	44	86	43	1,608,549,600	1,766,405,630	1,930,074,800
NV	7	4	3	2	9	6	214,382,250	233,157,130	226,713,630
NH	1	1	3	2	3	2	15,160,130	17,128,110	12,362,290
NJ	21	4	16	9	17	8	151,474,220	169,538,070	168,251,770
NM	19	11	21	17	20	15	2,101,734,500	2,263,605,120	2,314,504,570
NY	48	26	51	31	54	25	663,533,870	749,668,940	743,981,120

TABLE A.5a (Cont.)

State ^a	Accidents Involving Railcars						Estimated Car-Kilometers		
	1986		1987		1988		1986	1987	1988
	Total	Main Only	Total	Main Only	Total	Main Only			
NC	24	12	27	8	32	15	444,693,450	493,029,240	509,057,810
ND	25	17	30	23	20	15	1,148,575,200	1,237,035,750	1,339,254,790
OH	111	52	81	36	97	46	2,076,285,600	2,280,043,190	2,399,880,270
OK	47	27	37	20	46	23	895,916,570	1,050,057,770	1,221,035,760
OR	45	19	52	26	61	27	383,348,650	425,016,590	447,355,090
PA	82	63	82	46	71	39	1,687,160,600	1,941,804,780	2,004,933,600
RI	0	0	0	0	0	0	233,600	266,390	226,980
SC	15	7	17	13	19	14	323,618,890	358,794,520	377,652,450
SD	13	10	31	30	16	14	159,386,240	207,003,930	219,958,960
TN	49	17	52	21	86	23	1,003,857,150	1,112,971,030	1,137,997,310
TX	232	111	201	95	239	99	3,298,802,300	3,796,692,540	4,034,302,850
UT	11	4	6	3	36	13	298,087,350	324,192,840	321,733,150
VT	2	1	3	2	8	6	33,466,640	38,164,410	32,901,380
VA	51	17	57	30	64	30	1,194,261,760	1,298,851,180	1,393,158,010
WA	29	11	25	14	35	11	794,255,400	930,905,930	979,833,540
WV	66	53	58	45	39	30	574,169,340	582,014,590	641,776,430
WI	85	34	80	37	68	39	452,410,380	477,699,960	541,116,590
WY	28	15	32	18	39	19	1,097,080,200	1,227,910,990	1,353,994,100
USA	2465	1178	2325	1165	2675	1266	44,736,892,090	49,467,359,950	52,052,133,700

^a Includes the 48 contiguous states, the District of Columbia, and the totals for the United States (USA).

TABLE A.5b Railroad-Freight-Car Accident Rates, by State, for 1986, 1987, 1988, and 1985-1988 Combined (10⁻⁸ accidents per railcar-kilometer^a)

State ^b	1986		1987		1988		1985-88	
	Total	Main Only	Total	Main Only	Total	Main Only	Total	Main Only
AL	3.88	2.00	4.80	3.37	4.13	2.52	4.80	2.75
AZ	1.40	1.05	1.30	1.08	1.44	1.18	1.75	1.30
AR	5.05	2.59	4.27	2.32	8.34	3.94	6.78	3.54
CA	5.10	2.64	3.30	1.98	4.32	2.30	5.10	2.51
CO	1.44	1.01	0.86	0.40	2.55	1.51	1.73	1.02
CT	26.47	17.65	16.67	8.34	24.95	0	28.27 ^c	10.10
DE	27.44	9.15	25.23	16.82	18.04	18.04	17.71	11.07
DC	0	0	316	316	0	0	117.09 ^c	78.06 ^c
FL	2.86	2.12	3.90	1.90	4.16	2.38	4.02	2.21
GA	6.44	3.08	6.77	2.81	6.18	2.69	6.44	2.84
ID	5.90	5.25	6.74	4.10	9.03	3.99	7.01	4.14
IL	11.70	3.10	9.97	3.10	9.08	2.45	10.67	2.97
IN	4.18	1.85	3.71	1.48	3.80	1.44	4.64	1.93
IA	17.63	7.15	12.72	6.65	11.95	7.01	14.67	7.16
KS	3.01	1.62	2.97	1.55	4.09	1.98	3.61	1.75
KY	4.78	2.39	3.77	1.98	3.60	1.84	4.48	2.44
LA	12.67	5.98	7.07	2.02	11.94	3.92	12.37	4.28
ME	28.22	16.93	29.40	13.36	52.57	26.29	37.80 ^c	18.53 ^c
MD	6.07	3.54	5.55	2.44	4.55	1.24	5.62	2.58
MA	12.33	5.87	10.06	3.71	7.31	2.81	11.65	4.97
MI	18.34	8.18	15.10	4.42	15.52	7.45	16.47	7.19
MN	8.63	2.64	6.24	3.30	7.86	3.63	8.48	3.16
MS	15.16	11.20	12.93	9.84	8.47	7.14	11.52	8.51
MO	4.59	2.12	3.60	1.87	5.05	2.87	5.28	2.56
MT	1.35	1.01	1.24	0.81	2.11	1.17	1.73	1.10
NE	4.04	2.11	4.81	2.49	4.46	2.23	4.63	2.56
NV	3.27	1.87	1.29	0.86	3.97	2.65	3.23	2.19
NH	6.60	6.60	17.52	11.68	24.27	16.18	21.45	17.16 ^c
NJ	13.86	2.64	9.44	5.31	10.10	4.75	12.38	4.82
NM	0.90	0.52	0.93	0.75	0.86	0.65	0.94	0.66
NY	7.23	3.92	6.80	4.14	7.26	3.36	8.32	4.30
NC	5.40	2.70	5.48	1.62	6.29	2.95	5.70	2.27
ND	2.18	1.48	2.43	1.86	1.49	1.12	2.41	1.80
OH	5.35	2.50	3.55	1.58	4.04	1.92	4.73	2.12
OK	5.25	3.01	3.52	1.90	3.77	1.88	4.66	2.72
OR	11.74	4.96	12.23	6.12	13.64	6.04	12.48	5.77
PA	4.86	3.73	4.22	2.37	3.54	1.95	4.38	2.69
RI	0	0	0	0	0	0	105.33 ^c	0
SC	4.64	2.16	4.74	3.62	5.03	3.71	5.11	3.31
SD	8.16	6.27	14.98	14.49	7.27	6.36	10.19	9.09
TN	4.88	1.69	4.67	1.89	7.56	2.02	5.59	1.88
TX	7.03	3.36	5.29	2.50	5.92	2.45	7.12	3.16
UT	3.69	1.34	1.85	0.93	11.19	4.04	5.78	2.31
VT	5.98	2.99	7.86	5.24	24.32	18.24	15.22	11.59
VA	4.27	1.42	4.39	2.31	4.59	2.15	4.35	1.91

TABLE A.5b (Cont.)

State ^b	1986		1987		1988		1985-88	
	Total	Main Only	Total	Main Only	Total	Main Only	Total	Main Only
WA	3.65	1.38	2.69	1.50	3.57	1.12	3.49	1.44
WV	11.49	9.23	9.97	7.73	6.08	4.67	9.61	7.42
WI	18.79	7.52	16.75	7.75	12.57	7.21	16.53	7.66
WY	2.55	1.37	2.61	1.47	2.88	1.40	3.10	1.97
USA	5.51	2.63	4.70	2.36	5.14	2.43	5.57	2.66
σ^d	-	-	-	-	-	-	21.48	11.12

^a Nationwide average fatality rate, using count of fatalities consistent with combination-truck fatality counts, is 6.50×10^{-10} fatalities per railcar-kilometer. Nationwide average injury rate, using count of injuries consistent with combination-truck injury counts, is 7.83×10^{-8} injuries per railcar-kilometer.

^b Includes the 48 contiguous states, the District of Columbia, and the totals for the United States (USA).

^c Rates are one or more standard deviations greater than the national average rate for that category (i.e., all accidents on carrier-owned track or accidents on mainlines only).

^d σ = standard deviation.

TABLE A.6 Freight-Vessel Accident and Casualty-Involvement Rates on the Domestic Waterways of the United States, Including Coastwise Shipping, for 1985 (10⁻⁶ involvements per shipment-kilometer^a)

Waterway System	Total Accident Count	Total Accident Involvements ^b	Total Vessel ^c Casualty Count	Involvement Rate	Casualty Rate
Atlantic Coast	237	410	371	5.14	4.65
Gulf Coast	202	518	454	4.41	3.87
Pacific Coast	64	105	88	1.64	1.37
Mississippi (incl. Arkansas, Ohio, Tennessee-Tombigbee, and Missouri systems)	480	3833	2170	5.30	3.00
Great Lakes	77	151	129	0.62	0.53
All Inland Waterways	1060	5017	3212	4.08	2.62
Coastwise Movements	134	253	206	0.13	0.10

^a Shipment weight for spent fuel cask on barge estimated at 500 short tons, on the basis of Tobin, R.L., N.K. Meshkov, and R.H. Jones, *Preliminary Assessment of the Costs and Risks of Transporting Spent Fuel by Barges*, Argonne National Laboratory Report ANL/ER-TM-85-2 (Dec. 1985).

^b Vessel was involved in accident only; no damage reported.

^c Vessel was involved in accident and sustained casualty by reportable damage, fatality, or injury.

TABLE A.7 Freight-Vessel Accident and Casualty-Involvement Rates on the Domestic Waterways of the United States, Including Coastwise Shipping, for 1986 (10⁻⁶ involvements per shipment-kilometer^a)

Waterway System	Total Accident Count	Total Accident Involvements ^b	Total Vessel Casualty Count ^c	Involvement Rate	Casualty Rate
Atlantic Coast	237	488	384	5.91	4.65
Gulf Coast	236	701	618	5.59	4.93
Pacific Coast	90	164	135	2.45	2.02
Mississippi (incl. Arkansas, Ohio, Tennessee-Tombigbee, and Missouri systems)	347	2950	1520	3.83	1.97
Great Lakes	76	144	112	0.66	0.51
All Inland Waterways	986	4447	2769	3.52	2.19
Coastwise Movements	137	264	208	0.14	0.11

^a Shipment weight for spent fuel cask on barge estimated at 500 short tons, on the basis of Tobin, R.L., N.K. Meshkov, and R.H. Jones, *Preliminary Assessment of the Costs and Risks of Transporting Spent Fuel by Barges*, Argonne National Laboratory Report ANL/ER-TM-85-2 (Dec. 1985).

^b Vessel was involved in accident only; no damage reported.

^c Vessel was involved in accident and sustained casualty by reportable damage, fatality, or injury.

TABLE A.8 Freight-Vessel Accident and Casualty-Involvement Rates on the Domestic Waterways of the United States, Including Coastwise Shipping, for 1987 (10⁻⁶ involvements per shipment-kilometer^a)

Waterway System	Total Accident Count	Total Accident Involvements ^b	Total Vessel Casualty Count ^c	Involvement Rate	Casualty Rate
Atlantic Coast	181	363	316	4.36	3.80
Gulf Coast	265	674	604	5.53	4.95
Pacific Coast	69	104	88	1.41	1.20
Mississippi (incl. Arkansas, Ohio, Tennessee-Tombigbee, and Missouri systems)	411	3760	1898	4.64	2.34
Great Lakes	87	174	120	0.75	0.51
All Inland Waterways	1013	5075	3026	3.84	2.29
Coastwise Movements	100	185	152	0.10	0.08

^a Shipment weight for spent fuel cask on barge estimated at 500 short tons, on the basis of Tobin, R.L., N.K. Meshkov, and R.H. Jones, *Preliminary Assessment of the Costs and Risks of Transporting Spent Fuel by Barges*, Argonne National Laboratory Report ANL/ER-TM-85-2 (Dec. 1985).

^b Vessel was involved in accident only; no damage reported.

^c Vessel was involved in accident and sustained casualty by reportable damage, fatality, or injury.

TABLE A.9 Freight-Vessel Accident and Casualty-Involvement Rates on the Domestic Waterways of the United States, Including Coastwise Shipping, for 1988 (10⁻⁶ involvements per shipment-kilometer^a)

Waterway System	Total Accident Count	Total Accident Involvements ^b	Total Vessel Casualty Count ^c	Involvement Rate	Casualty Rate
Atlantic Coast	258	573	410	6.33	4.53
Gulf Coast	286	824	685	5.74	4.77
Pacific Coast	62	110	95	1.39	1.20
Mississippi (incl. Arkansas, Ohio, Tennessee-Tombigbee, and Missouri systems)	568	3750	1990	4.52	2.40
Great Lakes	82	172	116	0.64	0.43
All Inland Waterways	1256	5429	3296	3.85	2.34
Coastwise Movements	200	367	331	0.20	0.18

^a Shipment weight for spent fuel cask on barge estimated at 500 short tons, on the basis of Tobin, R.L., N.K. Meshkov, and R.H. Jones, *Preliminary Assessment of the Costs and Risks of Transporting Spent Fuel by Barges*, Argonne National Laboratory Report ANL/ER-TM-85-2 (Dec. 1985).

^b Vessel was involved in accident only; no damage reported.

^c Vessel was involved in accident and sustained casualty by reportable damage, fatality, or injury.

TABLE A.10 Freight-Vessel Accident and Casualty-Involvement Rates on the Domestic Waterways of the United States, Including Coastwise Shipping, for 1985-1988 (10^{-6} involvements per shipment-kilometer^a)^b

Waterway System	Total Accident Count	Total Accident Involvements ^c	Total Vessel Casualty Count ^d	Involvement Rate	Casualty Rate
Atlantic Coast	913	1834	1481	5.455	4.405 ^e
Gulf Coast	988	2716	2360	5.341	4.641 ^e
Pacific Coast	285	483	406	1.704	1.433
Mississippi (incl. Arkansas, Ohio, Tennessee-Tombigbee, and Missouri systems)	1806	14293	7878	4.563	2.419
Great Lakes	322	641	477	0.666	0.495
All Inland Waterways	4314	19967	12302	3.823	2.355
Coastwise Movements	571	1069	897	0.142	0.119

^a Shipment weight for spent fuel cask on barge estimated at 500 short tons, on the basis of Tobin, R.L., N.K. Meshkov, and R.H. Jones, *Preliminary Assessment of the Costs and Risks of Transporting Spent Fuel by Barges*, Argonne National Laboratory Report ANL/ER-TM-85-2 (Dec. 1985).

^b Composite fatality rate for inland waterway movements is 0.73×10^{-8} per shipment-kilometer; fatality rate for all domestic water traffic (incl. coastwise) is 0.32×10^{-8} per shipment-kilometer; composite injury rate for inland waterway movements is 2.05×10^{-8} per shipment-kilometer; and injury rate for all domestic water traffic (incl. coastwise) is 0.90×10^{-8} per shipment-kilometer.

^c Vessel was involved in accident only; no damage reported.

^d Vessel was involved in accident and sustained casualty by reportable damage, fatality, or injury.

^e Values are more than one standard deviation greater than the 1985-88 national inland waterway average.

DATE

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