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TRENDS IN STATE-LEVEL FREIGHT ACCIDENT RATES: AN ENHANCEMENT OF RISK FACTOR DEVELOPMENT FOR *RADTRAN*

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ABSTRACT

Under the Nuclear Waste Policy Act, the Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM) is concerned with understanding and managing risk as it applies to the shipment of spent commercial nuclear reactor fuel. Understanding risk in relation to mode and geography may provide opportunities to minimize radiological and non-radiological risks of transportation. To enhance such an understanding, a set of state-or waterway-specific accident, fatality, and injury rates (expressed as rates per shipment kilometer) by transportation mode and highway administrative class was developed, using publicly-available data bases. Adjustments made to accommodate miscoded or incomplete information in accident data are described, as well as the procedures for estimating state-level flow data. Results indicate that the shipping conditions under which spent fuel is likely to be transported should be less subject to accidents than the "average" shipment within mode.

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The transportation of freight is subject, without regard to commodity or mode of carriage, to risk of an accident in which the cargo may or may not be damaged or in which fatality or injury may be sustained. Among the concerns of the Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM) in carrying out its responsibilities under the Nuclear Waste Policy Act is to understand and manage risk as it applies to shipment of spent commercial nuclear reactor fuel to a) a final geologic repository and b) to and from a monitored retrievable storage facility. With several years' lead time now available to plan for these shipments, opportunities to minimize both radiological and non-radiological risks of transportation may be realized by understanding risk in relation to mode and geography. In support of increasing this understanding, the Center for Transportation Research of Argonne National Laboratory developed a set of state- (or waterway-) specific "risk factors" (accident involvements, accident-related fatalities, and injuries expressed as rates per unit shipment distance) by transportation mode and highway administrative class. The rates were subsequently included as risk-measurement units in the latest revision to the RADTRAN nuclear materials shipment model documented in *Data Base of Accident and Agricultural Statistics for Transportation Risk Assessment* (Argonne National Laboratory Report No. ANL/EAIS/TM-2). That report cited several shortcomings in the method selected to compute the so-called risk factors for transportation, chief among them that the method's use of a single year's data (in this case, for 1985 or 1986) would a) fail to depict ongoing or newly-emerging trends at the state level that use of consecutive multiple-year data could reveal, and b) therefore also fail to indicate if the individual risk factors are changing over time.

There were five objectives of the effort documented in this paper.

1) Update the accident risk factor data base with 1986 through 1988 data.

2) 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, interstate-registered highway contract carriers, member railroads of the Association of American Railroads, and interstate barge lines.

3) Examine a time series of accident data (minimum of three years) for each carrier type 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, compromise of some safety practices as shown by the failure of combination trucks to pass state-administered roadside safety checks, and continuing consolidation of railroad traffic on more densely-used lines.

4) Conduct statistical tests of annual values of rates for each mode by state to assess and discover any significant year-to-year differences or trends.

5) Update affected RADTRAN data blocks as necessary.

PROCEDURES

The procedures used to develop individual year and time-series accident, fatality, and injury rates by mode by state are described for each mode below.

Highway Interstate Carrier Combination Trucks

Combination trucks are rigs composed of a) a separable tractor unit containing the engine/propulsion plant, and b) one or more (but fewer than four) trailers, connected to each other and to the tractor, in which or upon which freight is hauled. These rigs generally weigh at least 33,000 pounds empty up to 80,000 pounds fully laden, and there are generally five or more axles in each tractor-trailer combination. Total weight in excess of 80,000 pounds (generally up to 132,000 pounds) is permitted in most states if the number of trailer axles is increased. Just as the railroad freight car is the standard unit of haulage by rail, the heavy combination truck is the standard freight hauling unit of interstate highway commerce. This is why the full range of reported accidents involving such units was selected as the appropriate basis of estimation for risk of spent fuel transportation by highway.

Although it may be assumed that trucks carrying spent fuel will be subject to safety precautions greater than the average, 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. Risk of highway transportation is therefore defined as the number of accident involvements[1] of heavy combination trucks in year i per unit of travel by heavy combination trucks in year i (if travel units are reported or estimated in miles, they were converted to kilometers for consistency with the risk factors already embedded in RADTRAN). The rate is therefore a fractional value, with accident count as the numerator of the fraction and vehicular activity (total travel distance) as its denominator. Both loaded and unloaded truck travel is included in the denominator. Further, it was determined that this unit should be disaggregated within state by road type according to the

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

Federal-Aid Administration Classification System (i.e., FAI, FAP, and FAS road types), which is the basis of the road maintenance and improvement funding formulas under the Federal-Aid Highway Act. Such disaggregation not only enhances estimation of within-state (between class) variance, to complement the depiction of between-state (non-stratified) variance, but also introduces into the data base a surrogate for objective risk itself (i.e., differences among the systems with respect to average roadway standards and permitted extremes in road geometrics).

State-level data for interstate-registered trucks (i.e., total counts of accident involvements by road type sorted by state code in the 50-T file) were processed to generate the numerators of the risk rates. The procedure for generating the denominator was less straightforward but almost aimed for equal reliability.

Accident Data

The primary source of heavy 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 Safety (BMCS), of the U.S. Department of Transportation (DOT). The 50-T file is the only comprehensive central source of public-use, easily accessed data covering heavy combination truck accident involvements of trucks owned and operated by interstate regulated carriers by year 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 we selected only records involving such configurations. Straight trucks were not considered to directly influence an understanding of risk as it applies to spent nuclear fuel shipments and were therefore excluded from the data. 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 retained.

The OMC 50-T file consists of carrier-submitted reports, resulting in the potential for inaccuracy due to both a) inadequate or incorrect accident *location* information and b) underreporting.

In order to accurately assign the records in the OMC 50-T file to the correct Federal-Aid administrative category (FAI-Urban, FAI-Rural, FAP, FAS, or none of the above), each record had to be manually quality-checked to eliminate any inaccuracies due to incorrect or inadequate city, state, or route information. In some cases this information was completely missing from a record; in other cases, some portion of the location information was not correct. Incorrect city information included the use of mountain and county names rather than city names. In addition, city names were often misspelled, such as "Greenville" instead of "Greenfield." Incorrect state abbreviations were found in approximately 1% of the records (i.e., "MN" instead of "NM," "NJ" instead of "NY," or for Nebraska - "NB" instead of "NE"). Incorrect route information was also found. For example, the record may read "Hwy 23" instead of "Hwy 25" or "Route 15" instead of "Route 51."

Regarding inaccuracies due to underreporting, there is no reason to believe that underreporting would be biased toward any particular state(s) and therefore only the magnitude of the rates would be affected.

A state-by-state listing of the salient components of each of the heavy truck accident involvement records in the OMC 50-T master files for 1986, 1987, and 1988 was generated through the Statistical Analysis System (SAS®) in order to manually assign the accident location provided on each record (as described above) to the relevant administrative category (FAI-Urban, FAI-Rural, 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 Chicago regional office of the Federal Highway Administration (FHWA). Because carrier reporting occasionally results in duplication of entry for fatality(s) and/or injury(s) in a given accident, SAS records were scrupulously checked to eliminate such double-counting. Although the detailed method is rather cumbersome, it was determined to be at least 50% more accurate than tabulating accident records according to the road identifier preface of the coded location (assuming that the 50-T records are complete and authentic). Moreover, it enabled efficient "cleanup" of mis-assigned or miscoded records, a step which proved to be especially important in 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 therefore have been greater).

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 heavy combination truck travel by state per unit time. The following factors also had to be considered: (1) a proportion of truck travel is dead-head 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, on the systems of interest 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 using fuel sales data reported by states, vehicles counts by type at official 24-hour counting stations across the country, and data from studies such 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 FHWA's Office of Highway Information Management. The detailed tables permit estimation of vehicle-miles of travel (VMT) by state by vehicle type 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 became 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 enabled by estimating shares of heavy truck travel accounted for by operators of a) predominantly to exclusively in<u>tra</u>state and b) primarily interstate highway carriage as reported in the 1982 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 percent of all truck-miles. Of these trucks, some 35 percent (accounting for over 28 billion VMT annually) accumulate more than 25 percent of total miles on roads outside their "home" state of registry. We selected the travel share of this subset, approximately 53 percent of total travel by heavy combination trucks, as representing the accrual attributable to interstate registered carriers. Thus, an initial multiplier (deflator) of 0.53 was applied to FHWA's estimate of total combination truck miles for each state. An additional adjustment was made to reflect the differences in VMT participation of interstate carriers by administrative class. For example, rural Interstate VMT by combination trucks was deflated by only 30 percent (that is, interstate carriers account for 70 percent of the combination truck VMT on rural Interstate highways), but urban Interstate VMT was deflated by at least 40 percent and federal-aid secondary VMT by 70 percent to echo the relatively greater use of these facilities by locally-oriented non-interstate trucks. Deflators are based on the nationwide share of reported accidents accounted for by each administrative class. Following adjustment, the sum of each state's combination truck VMT over all classes, including those classes not used in this study (i.e., federal-aid urban and all non-federal systems), was re-normalized to 53 percent 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. Data for the numerators (accidents, fatality and injury counts) were derived exclusively from the 50-T file of the Office of Motor Carriers, U.S. Department of Transportation.

Remaining problems with the use of the FHWA flow data include missing information and possible bias in counting station-related data. In the current FHWA files, 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. There were also apparently some misplaced decimal points in New Mexico 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 FHWA to prepare VMT estimates is probably the best available alternative. Notwithstanding, its reliability should periodically be checked and questioned, 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 except counting, checking, and quality assurance of the annual 50-T accident records are now fully automated for each year. This permits faster updating and investigation of already-collected data and creates the opportunity for more efficient computation of rates for additional years.

Rail Transport by Freight Train Railcars

Accident Data

As for highway transport, it was deemed appropriate for rail transport to examine the types of railroad shipments that will be 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. The rail parallel to the numerator for the truck accident unit-risk factor is total reportable railcar accident involvements by state per unit 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.

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 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 and 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 resulting in damages that exceed the reporting threshold. The 1985 through 1988 files are recent complete annual records available for this study, and they have therefore been used for compiling a set of four one-year and one four-year estimates of rates.

Flow Data

The unit-risk factor denominator based on flow data for rail shipments is total railcar-kilometers moved per unit time by state, yielding the desired ratio of accident involvements per shipment-kilometer. Because rail shipments move on dedicated, privately owned networks, they are much more closely monitored by the carriers themselves through the manifests or waybills required for each shipment. That is, the commodity, number of cars, and actual routing of the shipment are entered into a computer file along with other data. The Interstate Commerce Commission (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 (origin, interchange, and designation states only 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.

Expansion factors are applied 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) reports 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%), total railcar-kilometers by origin and destination state are obtained.

Finally, these values (cars x kilometers) are assigned to the appropriate origin, destination, and intervening states. Shipments with origin and destination in the same state require only summation of the (factored) car-kilometers. For interstate shipments, a procedure developed for an earlier project on freight network flow forecasting was utilized. A fully coded version of the FRA national rail network is on file at Argonne National Laboratory; this code includes 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 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 that are accounted for by the 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. This final set of 48-state (plus the District of Columbia) totals became the denominators for the 1985 risk estimates.

Beginning with the 1986 waybill sample, the ICC no longer provides state origin and destination data in the public-use file but includes 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 had increased rail traffic, decreased traffic, or had 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).

Water Transport on Inland Waterways and Along the Coasts

Accident Data

In the context of freight transport by domestic waterways, state borders have no significance. That is, the characteristics of each waterway are independent of the political jurisdictions through which it 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, an administrative decision was made 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 such domestic (48 state) waterway systems and the coastwise routes (waterborne within a 32-km limit) of the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, Mississippi River (including the Ohio, Tennessee, Missouri, and Arkansas navigable tributaries), and Great Lakes.

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

1. Actual physical damage to property exceeds $25,000,
2. Material damage affects 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 causing 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).

The 1985 through 1988 CVCF was used in developing the numerators for waterborne unit-risk factors. All casualty records for the following vessel activities were included: break-in-bulk hauls, barge tow, bulk solid cargoes, oil tankerages, 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 the Gulf Coastal waterways, because traffic on the "Tenn-Tom" represents in general an alternative option to use of the Mississippi River (and its tributaries) itself. 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). Vessel counts include the total of dumb (non-self-propelled) barges. For example, if only two barges in a tow of 22 total sustain damage in an accident, the involvement count for that accident is 22 but the casualty count is 2 and the accident count *1*.

Flow Data

Waterway movement statistics were obtained from the Corps' most recent annual reports on domestic waterborne commerce, which covers calendar year 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.

RESULTS

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

Heavy Combination Trucks

Table 1 shows the computed three-year average rates for interstate carrier combination truck accident involvements, fatalities, and injuries sustained in the accidents. Fatalities are deaths attributable to the accident that occurred at any time within thirty days thereafter. As described above, these rates are simply the counts of involvements, fatalities, and injuries within each state and road category divided by the estimated interstate-registered heavy combination truck kilometers of travel within that category. Magnitudes of these values are in a range approximately one-tenth of what is frequently cited as an average accident rate for all trucks over all road types. 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 highlighted. 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 interstate system--meeting the 2 x standard deviation criterion--have been experienced by **Connecticut, Massachusetts,** and **New Jersey**, and 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 a higher accident rate exposure 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 highway has been subject to the highest (relative) 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 haul because these lower-echelon roads are generally not designed to meet heavy-duty line haul standards. However, because they do provide direct access to many nuclear power plants, their use under NWPA, although limited, may be unavoidable. **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.

Examination of the computed rates indicates that they increased for all relevant federal administrative classes in 1988 (over 1987), returning to levels at or above those for 1986. How much of the increase on the interstate system may be attributable to the return to the 65 mph speed limit cannot be directly determined, but work now in progress at the University of Michigan Transportation Research Institute may provide insight on this issue. With respect to accident counts on the interstate system, no state had a year with a value greater than 140 percent of its three-year mean: the twelve highest excursions (in percentage difference) from the mean are shown below. 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 highway corridors carrying the highest truck flows. Because nationwide total combination truck travel steadily increased year to year through the period, it may therefore be inferred (but not conclusively demonstrated) that accident increases tracked truck volume increases during the three years.

HIGHEST ONE-YEAR DIVERGENCES FROM THREE-YEAR INTERSTATE MEAN

STATE	86-87-88 MEAN I-STATE COUNT OF ACCIDENTS	HIGHEST 1-YR 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

Railroads

Table 2 shows total and mainline railroad accident counts, estimated car-kilometers, and total and mainline-only accident rates by state for 1986, 1987, and 1988, plus a four-year average rate for each state and the U.S. which incorporates (not shown) 1985 data. Nationwide average fatality and injury rates 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; fatality rate decreased by over 20 percent and injury rate by over 36 percent. This reduction cannot be attributed to change in reporting threshold because all fatality- and injury-causing events must be reported to FRA.

Given the observed reduction in nationwide fatality and injury rates due to rail accidents and incidents over the period, analysis of variance was conducted on the four years of state accident involvement rates to assess whether a corresponding trend could be established for accidents. 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 years, implying that there was no identifiable net downward trend in rail freight accident rates for the nation as a whole over the period 1985-88 that would correspond to the decline in fatality and injury rates. While some states did experience an apparent rate reduction during this time, we could not exclude the possibility that th· · was due primarily to annual changes in the accident cost reporting threshold.

Italicized rates in Table 2 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 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 spent fuel transportation by rail.

Our analysis indicates that the four-year average rates shown in the last columns of Table 5 will be reasonable approximations of state-level risk factors in RADTRAN for the next several years, except for those states whose relatively low railcar-kilometer totals result in inflated rates even for very low accident counts (i.e., CT, DE, DC, NH, RI, VT).

Domestic Waterways

Table 3 reports four-year average accident statistics for U.S. domestic waterways and coastwise movements. Rates are computed for both accident involvements (total number of dumb and self-propelled vessels actually present in an accident) and casualties (dumb and self-propelled vessels sustaining damage) in order a) to be consistent with truck and rail rates, which include both damaged and undamaged shipments, and b) to acknowledge the importance of shipment delay due to an accident even if no actual damage is sustained by the vessel containing the shipment.

Among inland waters throughout the period analyzed, the Great Lakes experience the lowest and Gulf Coast waterways the highest casualty rates. For 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. No statistically discernible trend is apparent for any of these waterways, although the Gulf Coast involvement rate appears to be increasing somewhat. Causal factors are unclear: the Gulf waterways experience a wide mixture of shipping activity including shrimpers, petroleum tankers, oil platform service, bulk grain hauls, container traffic, and personal pleasure craft. The opportunities for conflict in space and time among the various components of this activity are numerous, but conditions are not such to guarantee that such interaction will occur. By contrast, the intermediate involvement and casualty rates for the Mississippi-Missouri system are surprisingly low given the relatively congested nature of river shipping.

Lowest involvement and casualty rates by far are registered by coastwise shipping. Such shipments avoid congested waterways and are therefore subject to fewer delays, such as at lock and dams, and less restrictive clearances than their inland counterparts. The landborne equivalent of shipping along the coasts, with respect to relative freedom from both delay and interaction with other freight movements, is probably through-rail hauls such as unit trains.

The tables below show, for each waterway type, the year experiencing the highest excursion of the four-year mean accident involvement and casualty count respectively. It corresponds to the table of highway accident counts, and flags a) the existence of any trend for all waterways through the four-year period and/or b) concern about developments in any single waterway system. The distribution indicates that there was no generally "bad" year in the four.

WATERWAY	YEAR OF MAXIMUM COUNT IN ACCIDENT INVOLVEMENTS	PERCENT BY WHICH COUNT IN THAT YEAR EXCEEDED 4-YR. MEAN FOR THAT WATERWAY
ATLANTIC COASTAL	1988	125
GULF COASTAL	1988	121
PACIFIC COASTAL	1986	136
MISSISSIPPI SYSTEM	1985	107
GREAT LAKES	1987	109
COASTWISE	1988	137

WATERWAY	YEAR OF MAXIMUM COUNT IN CASUALTIES	PERCENT BY WHICH COUNT IN THAT YEAR EXCEEDED 4-YR. MEAN FOR THAT WATERWAY
ATLANTIC COASTAL	1988	111
GULF COASTAL	1988	116
PACIFIC COASTAL	1986	132
MISSISSIPPI SYSTEM	1985	115
GREAT LAKES	1985	108
COASTWISE	1988	148

CONCLUSIONS AND SUGGESTIONS

Ongoing efforts to improve the procedure by which disaggregate non-radiological risk factors for transportation accidents, fatalities, and injuries are computed for use in the spent-fuel version of RADTRAN 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.* Specifically, a multi-year average covering recent year data has now been constructed for relevant route categories on each of the three modes of interest (highway combination truck, rail freight, and waterway freight), and highway rates have been modified such that activity (flow) estimation techniques are fully consistent with accident, fatality and injury counts. Most updating procedures have also been automated in spreadsheet programs. Although disaggregate (i.e., sub-national) flow data of reasonably good quality is available for 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. Our conclusions on recommended actions are presented below by mode.

Highway Combination Truck

- Replace, *on an interim basis*, current highway risk factors in RADTRAN with the 1986-88 three-year average rates shown in Table 1.
- Continue to investigate and evaluate procedures to improve estimation of annual highway combination truck 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 and replace the (then-) current RADTRAN highway risk factors.

Rail Freight

- Four-year average rail accident rates show reasonable stability; they could therefore replace the rates now used in RADTRAN and be used *for an indefinite period.* However, noteworthy changes in railroad operations such as the formation of multi-modal carriers and continuing consolidations among long-haul carriers may progress to the point that re-examination of annual data and re-estimation of rates are warranted. In any case this should occur before final implementation of the spent fuel shipment program.
- *National* average rates should be applied in those few states where low rail traffic volumes produce extreme annual values of state-level rates; the latter rates are clearly unrepresentative and should not be included in any routing decision process.

Waterborne Freight

- Replace rates currently used in RADTRAN with four-year average rates presented in Table 3. Use of these more stable values will correct errors that may now be present in the RADTRAN risk factor data block for waterways. The rates of Table 3 should prove adequate for the next several years.
- Investigate the possible increase in Gulf Coastal involvement and casualty rates through calendar 1991 (as data become available) to verify or refute the emergence of a trend. A significant increase in risk in these waterways could jeopardize any planning for extensive use of Gulf ports during the spent fuel shipping program.

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Table 1

HIGHWAY COMBINATION TRUCK ACCIDENT, FATALITY, AND INJURY RATES BASED ON REPORTABLE INTERSTATE CARRIER ACCIDENTS, REPORTED FATALITIES & INJURIES, AND ESTIMATED FLOWS, 1986-88

(10^{-7} ACCIDENTS AND INJURIES PER SHIPMENT-KILOMETER, 10^{-8} FATALITIES PER SHIPMENT-KILOMETER)[a]

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
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**	3.23	2.56	9.09	1.01	**5.11**	2.20	1.17	9.09	1.71	**4.61**	2.55	1.89	7.09
DE	2.56	--	2.56	7.35	4.81	1.66	--	1.66	**19.50**	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**	1.76	3.53	6.40	1.78	5.33	1.39	2.38	7.84	2.30	**8.23**	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**	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**	4.32	13.40
MA	1.42	**6.47**	2.68	3.43	**46.10**	1.30	**6.23**	2.53	3.93	**52.20**	1.13	**4.99**	2.09	3.02	**43.90**
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

[a]Rates shown in raised characters are two or more standard deviations greater than the national average rate for that highway category

Table 1 (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
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	1.27	1.99	9.68	3.25	5.53	1.63	2.59	5.06	2.23
MT	**10.00**	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**	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**	**4.24**	6.80	9.69	1.56	**6.56**	3.06	4.57	11.50	2.69	**8.00**	**4.28**	6.86	11.30
NM	**9.64**	1.92	2.35	4.77	12.20	**9.01**	1.93	2.32	6.99	5.56	**8.92**	1.86	2.25	4.62	10.60
NY	5.69	2.93	**3.93**	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**	6.71	11.00	6.37	2.19	2.99	5.53	6.22
ND	4.40	0.99	1.18	1.99	0.40	4.00	0.48	0.68	0.98	0	4.80	0.84	1.07	1.63	0
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	10.70
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**	3.12	2.35	2.84	0.86	**23.30**
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**	2.09	2.18	3.94	1.49	**14.30**	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**	1.44	2.41	5.85	4.67
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
UT	2.52	2.41	2.44	3.70	5.00	0.59	2.21	1.80	8.25	2.17	2.08	2.22	2.18	3.73	4.35
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**	7.87	1.28	1.67	1.60	**17.80**	1.70	2.78	2.80	2.79	**9.91**	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 =	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

Table 2

TOTAL AND MAINLINE ONLY REPORTABLE RAILROAD FREIGHT CAR ACCIDENTS ON CARRIER-OWNED TRACK, AND ESTIMATED CAR-KILOMETERS FOR 1986, 1987, AND 1988, WITH ACCIDENT RATES BY STATE FOR 1986, 1987, 1988 AND 1985/8 COMBINED (RATE UNIT IS 10^{-8} ACCIDENTS PER RAILCAR-KILOMETER)

STATE	ACCIDENTS INVOLVING RAILCARS 1986 TOT.	1986 MAIN ONLY	1987 TOT.	1987 MAIN ONLY	1988 TOT.	1988 MAIN ONLY	ESTIMATED CAR-KILOMETERS 1986	1987	1988	RAIL FREIGHT ACCIDENT RATES 1986 TOT.	1986 MAIN ONLY	1987 TOT.	1987 MAIN ONLY	1988 TOT.	1988 MAIN ONLY	1985-8[a] TOT.	1985-8[a] MAIN ONLY
AL	33	17	47	33	41	25	851,331,810	979,823,840	992,034,050	3.88	2.00	4.80	3.37	4.13	2.52	**4.80**	**2.75**
AZ	24	18	24	20	27	22	1,715,650,560	1,847,785,910	1,870,812,350	1.40	1.05	1.30	1.08	1.44	1.18	**1.75**	**1.30**
AR	37	19	35	19	72	34	733,103,630	820,528,890	863,655,180	5.05	2.59	4.27	2.32	8.34	3.94	**6.78**	**3.54**
CA	116	60	80	48	105	56	2,273,667,000	2,424,771,810	2,430,681,630	5.10	*2.64*	3.30	*1.98*	4.32	*2.30*	**5.10**	***2.51***
CO	20	14	13	6	39	23	1,387,248,800	1,508,739,380	1,527,540,740	1.44	1.01	0.86	0.40	2.55	1.51	**1.73**	**1.02**
CT	3	2	2	1	3	0	11,332,830	11,996,330	12,025,570	26.47	17.65	16.67	8.34	24.95	0	25.27	**10.10**
DE	3	1	3	2	2	2	10,933,250	11,890,750	11,085,350	27.44	9.15	25.23	16.82	18.04	18.04	**17.71**	**11.07**
DC	0	0	2	2	0	0	600,000	633,540	692,240	0	0	316	316	0	0	117.09	73.05
FL	23	17	37	18	42	24	803,177,770	949,844,130	1,009,288,710	2.86	2.12	3.90	1.90	4.16	2.38	**4.02**	**2.21**
GA	71	34	82	34	78	34	1,102,592,500	1,210,796,110	1,262,297,020	6.44	3.08	6.77	2.81	6.18	2.69	**6.44**	**2.84**
ID	18	16	23	14	34	15	304,937,430	341,302,320	376,347,580	5.90	5.25	6.74	4.10	9.03	3.99	**7.01**	**4.14**
IL	294	78	270	84	271	73	2,513,780,400	2,707,385,820	2,985,382,880	11.70	*3.10*	9.97	*3.10*	9.08	*2.45*	**10.67**	***2.97***
IN	61	27	60	24	66	25	1,458,766,000	1,617,326,020	1,734,756,630	4.18	1.85	3.71	1.48	3.80	1.44	**4.64**	**1.93**
IA	111	45	88	46	87	51	629,783,060	691,587,220	727,936,440	17.63	7.15	12.72	6.65	11.95	7.01	**14.67**	**7.16**
KS	65	35	69	36	101	49	2,157,920,900	2,324,118,870	2,469,570,360	3.01	1.62	2.97	1.55	4.09	1.98	**3.61**	**1.75**
KY	50	25	40	21	39	20	1,046,253,600	1,060,549,250	1,084,396,770	4.78	2.39	3.77	1.98	3.60	1.84	**4.48**	**2.44**
LA	53	25	35	10	61	20	418,348,180	494,741,740	510,825,980	12.67	5.98	7.07	2.02	11.94	3.92	**12.37**	**4.28**
ME	10	6	11	5	14	7	35,434,970	37,415,770	26,629,940	28.22	16.93	29.40	13.36	52.57	26.29	37.80	18.59
MD	24	14	25	11	22	6	395,153,790	450,622,170	483,340,880	6.07	3.54	5.55	2.44	4.55	1.24	**5.62**	**2.58**
MA	21	10	19	7	13	5	170,282,690	188,791,500	177,896,540	12.33	5.87	10.06	3.71	7.31	2.81	**11.65**	**4.97**
MI	74	33	65	19	75	36	403,518,040	430,335,300	483,150,240	18.34	8.18	15.10	4.42	15.52	7.45	**16.47**	**7.19**
MN	111	34	89	47	119	55	1,285,943,200	1,425,718,310	1,514,944,760	8.63	2.64	6.24	3.30	7.86	3.63	**8.48**	**3.16**
MS	46	34	46	35	32	27	303,436,290	355,642,080	377,899,410	15.16	11.20	12.93	9.84	8.47	7.14	**11.52**	**8.51**

[a]Rates shown in raised characters 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)

Table 2 (cont.)

STATE	ACCIDENTS INVOLVING RAILCARS 1986 TOT.	1986 MAIN ONLY	1987 TOT.	1987 MAIN ONLY	1988 TOT.	1988 MAIN ONLY	ESTIMATED CAR-KILOMETERS 1986	1987	1988	RAIL FREIGHT ACCIDENT RATES 1986 TOT.	1986 MAIN ONLY	1987 TOT.	1987 MAIN ONLY	1988 TOT.	1988 MAIN ONLY	1985-8[a] TOT.	1985-8[a] MAIN ONLY
MO	93	43	81	42	116	66	2,027,705,300	2,248,105,970	2,298,656,900	4.59	2.12	3.60	1.87	5.05	2.87	**5.28**	**2.56**
MT	28	21	29	19	52	29	2,075,546,200	2,344,978,290	2,468,228,300	1.35	1.01	1.24	0.81	2.11	1.17	**1.73**	**1.10**
NE	65	34	85	44	86	43	1,608,549,600	1,766,405,630	1,930,074,800	4.04	2.11	4.81	2.49	4.46	2.23	**4.63**	**2.56**
NV	7	4	3	2	9	6	214,382,250	233,157,130	226,713,630	3.27	1.87	1.29	0.86	3.97	2.65	**3.23**	**2.19**
NH	1	1	3	2	3	2	15,160,130	17,128,110	12,362,290	6.60	6.60	17.52	11.68	24.27	16.18	**21.45**	**17.16**
NJ	21	4	16	9	17	8	151,474,220	169,538,070	168,251,770	13.86	2.64	9.44	5.31	10.10	4.75	**12.38**	**4.82**
NM	19	11	21	17	20	15	2,101,734,500	2,263,605,120	2,314,504,570	0.90	0.52	0.93	0.75	0.86	0.65	**0.94**	**0.66**
NY	48	26	51	31	54	25	663,533,870	749,668,940	743,981,120	7.23	3.92	6.80	4.14	7.26	3.36	**8.32**	**4.30**
NC	24	12	27	8	32	15	444,693,450	493,029,240	509,057,810	5.40	2.70	5.48	1.62	6.29	2.95	**5.70**	**2.27**
ND	25	17	30	23	20	15	1,148,575,200	1,237,035,750	1,339,254,790	2.18	1.48	2.43	1.86	1.49	1.12	**2.41**	**1.80**
OH	111	52	81	36	97	46	2,076,285,600	2,280,043,190	2,399,880,270	5.35	2.50	3.55	1.58	4.04	1.92	**4.73**	**2.12**
OK	47	27	37	20	46	23	895,916,570	1,050,057,770	1,221,035,760	5.25	3.01	3.52	1.90	3.77	1.88	**4.66**	**2.72**
OR	45	19	52	26	61	27	383,348,650	425,016,590	447,355,090	11.74	4.96	12.23	6.12	13.64	6.04	**12.48**	**5.77**
PA	82	63	82	46	71	39	1,687,160,600	1,941,804,780	2,004,933,600	4.86	3.73	4.22	2.37	3.54	1.95	**4.38**	**2.69**
RI	0	0	0	0	0	0	233,600	266,390	226,980	0	0	0	0	0	0	**105.33**	**0**
SC	15	7	17	13	19	14	323,618,890	358,794,520	377,652,450	4.64	2.16	4.74	3.62	5.03	3.71	**5.11**	**3.31**
SD	13	10	31	30	16	14	159,386,240	207,003,930	219,958,960	8.16	6.27	14.98	14.49	7.27	6.36	**10.19**	**9.09**
TN	49	17	52	21	86	23	1,003,857,150	1,112,971,030	1,137,997,310	4.88	1.69	4.67	1.89	7.56	2.02	**5.59**	**1.88**
TX	232	111	201	95	239	99	3,298,802,300	3,796,692,540	4,034,302,850	7.03	*3.36*	5.29	*2.50*	5.92	*2.45*	**7.12**	**3.16**
UT	11	4	6	3	36	13	298,087,350	324,192,840	321,733,150	3.69	1.34	1.85	0.93	11.19	4.04	**5.78**	**2.31**
VT	2	1	3	2	8	6	33,466,640	38,164,410	32,901,380	5.98	2.99	7.86	5.24	24.32	18.24	**15.22**	**11.59**
VA	51	17	57	30	64	30	1,194,261,760	1,298,851,180	1,393,158,010	4.27	1.42	4.39	2.31	4.59	2.15	**4.35**	**1.91**
WA	29	11	25	14	35	11	794,255,400	930,905,930	979,833,540	3.65	1.38	2.69	1.50	3.57	1.12	**3.49**	**1.44**
WV	66	53	58	45	39	30	574,169,340	582,014,590	641,776,430	11.49	9.23	9.97	7.73	6.08	4.67	**9.61**	**7.42**
WI	85	34	80	37	68	39	452,410,380	477,699,960	541,116,590	18.79	7.52	16.75	7.75	12.57	7.21	**16.53**	**7.66**
WY	28	15	32	18	39	19	1,097,080,200	1,227,910,990	1,353,994,100	2.55	1.37	2.61	1.47	2.88	1.40	**3.10**	**1.97**
TOT. US	2465	1178	2325	1165	2676	1266	44,736,892,090	49,467,359,950	52,052,133,700	5.51	2.63	4.70	2.36	5.14	2.43	**5.57**	**2.66**
															σ =	21.48	11.12

Table 3

FREIGHT VESSEL ACCIDENT AND CASUALTY INVOLVEMENT RATES ON THE DOMESTIC WATERWAYS OF THE UNITED STATES, INCLUDING COASTWISE SHIPPING, FOR 1985-8 (RATE UNIT IS 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	913	1834	1481	5.455	**4.405**
Gulf Coast	988	2716	2360	5.341	**4.641**
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**, based on Tobin, Meshkov and Jones (ref. 1)

[b] Vessel involved in accident only; no damage reported

[c] Vessel was involved in accident and sustained casualty by either reportable damage, fatality, or injury

[d] Values in raised lettering are more than one standard deviation greater than the 1985-88 national inland waterway average

NOTE: 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}**
Composite injury rate for inland waterway movements is **2.05×10^{-8}** per shipment-kilometer
Injury rate for all domestic water traffic (incl. coastwise) is **0.90×10^{-8}**