Benchmark Estimates of Release Accident Rates in Hazardous Materials Transportation by Rail and Truck

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Consistent, reliable estimates of release accident rates are essential when using risk assessment to compare the safety of rail and truck for a given shipment of hazardous materials. The estimates that appear in the literature have shortcomings or inconsistencies that make it difficult, if not impossible, to perform such a comparison. Yet claims are made that one transport mode is safer than the other, and risk assessors are using estimated accident rates that are out of date or inaccurate. This paper derives benchmark estimates of release accident rates for the two modes using Department of Transportation (DOT) incident reports to count the number of release accidents in 1982, and official statistics of the Interstate Commerce Commission (ICC) and the Census Bureau to evaluate the level of exposure to release accidents in that year. In addition to providing useful reference data for future risk assessments, the results show that there can be no general answer to the question of which mode is safer, since it depends on the release accident rate (which varies with release severity, carrier type, vehicle type, and track or road type) and such other factors as the size and design of the containers used.

One of the findings in the recent report of the congressional Office of Technology Assessment (OTA) on the transportation of hazardous materials (*1*) is that trucking is the least safe mode of transportation for hazardous materials. To be exact, the report says that "hazardous materials flow and accident data, poor as they are, show clearly that truck transport has the greatest risk of accidents." A recent advertisement placed by a railroad in a trade magazine (*2*, p. 9) echoed this conclusion in terms of hazardous waste, stating that "DOT statistics show that shipping hazardous waste by rail is actually safer than by over-the-road motor carriers." Neither the report's nor the advertisement's authors supported their statements with numerical accident rates for rail and truck transportation.

Risk assessment is the process of generating these frequencies and consequences, and it is essential to have consistent estimates of release accident rates for rail and truck when the purpose of the risk assessment is to compare the safety of these two modes of transportation. By "consistent," it is meant that in calculating the rates, the number of accidents is counted in the same way for both modes, the level of exposure to accidents is measured in the same way, and the same period of time is used to count accidents and measure exposure in each mode. The research in this paper was stimulated by the dearth of consistent, reliable estimates of rail and truck accident rates in the literature. As a result of this research, it was found that no simple answer exists to the question of which mode has a higher rate, since it depends (among other factors, such as the containers) on the size of the releases that are of concern, the carriers performing the transportation, the vehicles being used, and the types of track or roadway involved.

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ACCIDENT RATES

Accident rates are estimated from historical data by calculating the ratio of the number of accidents that occurred during a given period to the level of exposure to accidents during the same period. Typically, accident rates are used to forecast the number of accidents in a given situation into the future, which is done by multiplying the accident rate by the anticipated level of exposure. Therefore, it is important that any such accident rate is deemed to be representative of the future situation. This usually means that the most recently available data were used to estimate the accident rate and that a sufficient amount of data was used. The choice of a time period may be limited by the fact that the accident data and the exposure data must both be available for the same period.

Exposure needs to be measured in terms that correspond to the kind of accidents in question, so that any increase in the level of exposure would result in a proportional increase in the number of accidents. For accidents arising from the mechanical failure of a vehicle or its fittings or appliances, exposure might be measured by the number of hours of operation. For accidents involving package or container failures, exposure might be measured by the number or volume of shipments. For accidents due to hazards encountered while in transit, exposure might be measured by the number of ton-miles or vehicle-miles.

RELEASE ACCIDENT DATA

The DOT's Office of Hazardous Materials Transportation maintains a database of all the reports it receives on transportation-related releases of hazardous materials. With the exception of battery spills and spills of paint and other consumer products in retail packages of five gallons or less, any unintentional release occurring during loading, unloading, transportation, or temporary storage associated with any mode of transportation (except pipelines) is supposed to be reported and reflected in this database. Concerns have been expressed in the literature about underreporting or misreporting of incidents (*1, 3*), and one report performed for OTA attempted to estimate the magnitude of the shortfall (*4*), but there is no simple resolution to these problems.

The rail and truck incidents that were reported to DOT in 1982 are the ones used as the basis for the release accident rate calculations in this paper, because 1982 was the most recent year for which exposure data could be found for both of these modes. First the number of rail incidents was counted; then two separate counts were made of the number of truck incidents, depending on whether a for-hire truck or a private truck was involved.

Several different subsets of these incidents were also examined to see how accident rates vary as a function of these differences. In the rail mode the number of incidents in the subset involving tank cars only was counted separately, and in the truck mode the number of incidents in the subset involving only tank trucks was counted separately. Then for the entire set of incidents in each mode, and for both subsets, first the number of incidents in the subset referred to as "significant spills" (incidents in which the reported release quantities exceeded 5 gallons or 40 pounds) was counted separately; then the number of incidents in the subset referred to as "casualty related" (incidents in which the release resulted in a fatality or a reportable injury) was counted separately.

A summary of the release accident data extracted by counting the number of incidents in 1982 appears in Table 1.

EXPOSURE DATA

To obtain an estimate of the total number of car-miles of hazardous materials transported by rail in 1982, first for all types of cars and then for tank cars only, two data sources were used: (1) the ICC's File of Carload Waybill

TABLE 1 RELEASE ACCIDENT DATA SUMMARY

	Total	Significant Spills	Casualty-Related
All Types of Rail Cars and Trucks			
Rail	838	256	27
Truck (for-hire)	5314	1434	65
Truck (private)	357	233	11
Tank Cars and Tank Trucks Only			
Rail	736	197	25
Truck (for-hire)	936	692	31
Truck (private)	248	178	8

NOTE: Number of incidents reported to DOT in 1982.

TABLE 2 TRUCK-MILE STATISTICS FROM THE TRUCK INVENTORY AND USE SURVEY (*4*)

	Truck-Miles[a]
All types of trucks	
For-hire	9804
Private	6416
Tank trucks only	4428

[a] Millions of truck miles of hazardous materials in 1982.

Statistics for 1982 and (2) output from the Princeton national rail network model. The Waybill File provides information about the locations of origination and termination of rail shipments, as well as the locations of the interlining junctions. By extracting the records for hazardous materials shipments from the file and then inspecting the car type field in each record to see whether or not the shipment was made in a tank car, a full description of the hazardous material carloads transported in all car types and in tank cars only in 1982 was obtained. Then the model's software was used to assign these carloads to routes through the network based on the origination/termination and junction information, and to compute the total number of car-miles in all car types and in tank cars only. The car-mile calculation is performed by multiplying the number of carloads on each link of the network by the respective length of the link in miles and summing the results of these multiplications to get the total number of car-miles transported by rail in all car types and in tank cars only.

The Census Bureau's most recent collection of truck transportation statistics in the United States is contained in the 1982 Truck Inventory and Use Survey (*4*). Table 2 shows the survey's statistics for the number of truck-miles of hazardous materials transported in for-hire and private trucks in 1982 (p. 78 of the summary volume) and for the number of truck-miles of hazardous materials in tank trucks in 1982 (p. 114), rounded to the nearest million.

To estimate the breakdown of the number of hazardous material truck-miles in tank trucks by for-hire trucks versus private trucks, the survey statistics relating to the truck-miles of all tank truck shipments of liquids and gases, whether hazardous or not (summary volume, p. 74) were used. These show that the fraction shipped in for-hire trucks was only 459.0 divided by 6609.5, or 6.94 percent. Applying this factor to the total of 4428 million truck-miles of hazardous materials in tank cars shown in Table 2 yields 307 million as the number of truck-miles transported in for-hire tank trucks and 4121 million as the number of truck-miles in private tank trucks.

The results of the exposure level calculations for both the rail mode and the truck mode are summarized in Table 3.

RELEASE ACCIDENT RATES

Dividing the accident data in Table 1 by the respective exposure data in Table 3 yielded the estimated release accident rates in Table 4. These estimates are shown to

TABLE 3 EXPOSURE DATA SUMMARY

	All Types of Rail Cars and Trucks	Tank Cars and Tank Trucks Only
Rail	549	402
Truck (for-hire)	9804	307
Truck (private)	6416	4121

NOTE: Millions of vehicle-miles of hazardous materials in 1982.

three or four significant digits and are expressed as the number of incidents per billion vehicle-miles (BVM), where the term *vehicles* is used to mean rail cars or trucks.

The upper half of Table 4 shows that, if all types of rail cars and trucks are taken into account, then the estimated release accident rate for rail is *higher* than the truck rate, for both for-hire and private trucking, regardless of whether all the incidents are considered or only a subset consisting of the more serious ones. If all incidents are considered, then the first column shows that the estimated railroad rate (1525 incidents per BVM) is almost three times as high as the estimated for-hire truck rate (542 incidents per BVM) and more than twenty-seven times as high as the estimated private truck rate (55.6 incidents per BVM).

If attention is limited instead to significant spill incidents only (i.e., those with reported release quantities above 5 gallons or 40 pounds), then the second column shows that the estimated railroad rate (466 incidents per BVM) is more than three times as high as the estimated for-hire truck rate (146 incidents per BVM) and almost thirteen times as high as the private truck rate (36.3 incidents per BVM).

Taking only casualty-related incidents into account (i.e., those in which a fatality or a reportable injury was attributed to the release), the third column shows that the estimated railroad rate (65.5 incidents per BVM) is almost ten times as high as the estimated for-hire truck rate (6.63 incidents per BVM), and more than thirty-eight times as high as the private truck rate (1.71 incidents per BVM).

Looking only at tank cars and tank trucks, the three columns in the lower half of the table show that the estimated railroad rate is *lower* than the respective, estimated for-hire truck rates for each of the three incident categories. The estimated for-hire tank truck rate exceeds the estimated rail tank car rate by a factor of 1.7 for all incidents, by a factor of 46 for significant spill incidents only, and by a factor of 1.6 for casualty-related incidents only.

It is evident throughout Table 4 that the estimated for-hire truck rate is much greater than the estimated private truck rate, for all types of trucks as well as for tank trucks only, regardless of whether all incidents are considered, or significant spill incidents only, or casualty-related incidents only.

Table 4 also reveals some interesting facts about tank-type vehicles in rail and for-hire truck transportation. In the rail mode, the rate for significant spills from tank cars is 49.0 incidents per BVM. This is much lower than the estimated rate for significant spills from *all* types of rail cars (466 incidents per BVM) and much lower than the estimated rate for spills from tank cars (1830 incidents per BVM). Therefore, rail tank cars appear to be designed well enough to avoid all but the smallest spills.

Compared to rail tank cars, the estimated rate for significant spills from for-hire tank trucks is much higher, with a value of 2,254 incidents per BVM. This is also much higher than the estimated rate for significant spills from *all* types of for-hire trucks (146 incidents per BVM), and somewhat lower than the rate for all spills from for-hire tank trucks (3,049 incidents per BVM). Thus, while tank trucks operated for-hire compare poorly to railroad tank cars and to all for-hire trucks in avoiding large spills, they are more successful in avoiding large spills than small spills.

A similar comparison in the case of private trucking of hazardous materials shows that tank trucks are less likely to be involved than all trucks in any accident involving a spill, and that the same is true when attention is limited to accidents with larger spills.

Note that the estimated release accident rates for the total incidents, involving all types of rail cars and trucks, do not agree well with the results of the incident rate analysis in (*4*), which are based on nine years of data (1976–1984) and which are expressed in ton-miles. (Conversion factors of 20,000 gal/carload and 8,000 gal/truckload may be assumed.) There are two principal reasons for the discrepancies: (1) the authors of (*4*) "compensated" for nonreporting by tripling the number of rail incidents and doubling the number of truck incidents, and (2) they used a slightly lower estimate of rail exposure based on the 1977 Waybill File and a substantially lower estimate of truck exposure based on the 1977 Commodity Transportation Survey.

TABLE 4 1982 RELEASE ACCIDENT RATES

	Total	Significant Spills	Casualty-Related
All Types of Rail Cars and Trucks			
Rail	1525	466	65.6
Truck (for-hire)	542	146	6.63
Truck (private)	55.6	36.3	1.71
Tank Cars and Tank Trucks Only			
Rail	1830	49.0	62.2
Truck (for-hire)	3049	2254	101
Truck (private)	60.2	43.2	1.94

NOTE: Incidents per billion vehicle-miles of hazardous materials.

QUALIFICATIONS ABOUT THE ESTIMATED RATES

Ideally, separate release accident rates should be estimated for each of the three major activities that are addressed by the hazardous material incident reports: (1) loading and unloading, (2) transportation, and (3) temporary storage. The reason is that the appropriate way to measure exposure level differs from one activity to the next. The number of tons or vehicles is an appropriate measure for loading and unloading, while the number of ton-miles or vehicle-miles is an appropriate measure for transportation, and the number of ton-hours or vehicle-hours is an appropriate measure for storage. The principal obstacle to producing separate rates is that DOT does not require the incident report to specify the activity being conducted when the release occurred, although in some cases this can be inferred from remarks written on the reports.

Because the total number of incidents was simply divided by the total number of vehicle-miles to obtain the estimated release accident rates in each category in Table 4, the following qualifications should be stated about the use of these estimates in risk assessment calculations. If the actual average length of haul for the situation in question is less than the average length of haul for the comparable shipments made in 1982, then there will be more loadings and unloadings per vehicle-mile; hence, the figure of interest in Table 4 will *under*estimate the actual release accident rate. Similarly, if the actual average length of haul is *greater* than the 1982 average, then the figure in Table 4 will *over*estimate the actual rate. Furthermore, if the situation in question involves temporary storage and the actual average storage time is *less* than the average storage time for comparable shipments made in 1982, then there will be less storage per vehicle-mile; hence, the figure of interest in Table 4 will *over*estimate the actual rate. Similarly, if the actual storage time is *greater* than the 1982 total, then the figure in Table 4 will *under*estimate the actual rate.

ADJUSTMENT OF THE ESTIMATED RATES BY TYPE OF TRACK AND ROADWAY

The estimation of release accident rates reflected in Table 4 was based on aggregate national statistics, with no distinction made about the type of track used in rail shipments and the type of roadway in truck shipments. In practice, however, most risk assessments deal with relatively localized situations, where the characteristics of the rail and truck routes involved can readily be identified and should be taken into account. The following approach provides a way to make adjustments in the estimates in Table 4 according to track type and roadway type.

A convenient way to distinguish among different types of railroad track is to use the six classes of track that are defined by the Federal Railroad Administration. The mandated speed limit is lowest on Class 1 track, which has the worst quality, and highest on Class 6 track, which has the best quality. In a report containing various kinds of hazardous material risk assessment statistics for rail transportation, Arthur D. Little, Inc., published estimates by track class of the accident rates for derailments on mainlines (*5*, Table 3-11). The results are shown in Table 5.

These rates can be used to develop factors for crudely adjusting the estimated rates in Table 4 in order to reflect differences in track type. (The adjustments are crude because the word *accident* is defined somewhat differently in Table 4 than in Table 5.) The factors shown in Table 5 are simply the ratios of the accident rate for each track class to the accident rate for all classes combined. Since the figures in

TABLE 5 MAINLINE DERAILMENT ACCIDENT RATES (*5*)

Track Class	Accident Rate	Adjustment Factor
1	53.20	21.37
2	17.30	6.95
3	5.59	2.24
4	0.59	0.24
5/6	0.84	0.34
All	2.49	1.00

NOTE: Accidents per billion gross ton-miles.

Table 4 also relate to all classes combined, they can be adjusted for track class simply by multiplying them by the appropriate factor from Table 5.

For example, adjusted estimates by tracking class of the rate of release accidents for tank cars are shown in Table 6. A vast difference in the estimated rates from one track class to another is obvious.

As a basis for distinguishing among different types of roadways used by trucks, one can use the statistics published in the Federal Highway Administration's 1981 report on accident experience with large trucks (*6*). That report provides figures for the accident rates for all trucks by roadway type and for all roadway types combined, for California and Michigan, as well as for several other states (Table 33, p. 74). It also presents a figure for the accident rate for all trucks in California and Michigan combined (Table 6, p. 36). These figures are presented in Table 7 along with the results of calculations from these figures of the accident rate by roadway type for the two states combined. Adjustment factors calculated in the same way as the rail factors are also shown (with a similar caveat about their crudeness).

Using these factors, the adjusted estimates of for-hire tank truck release accident rates shown in Table 8 were obtained. Comparing Tables 6 and 8 to illustrate the effect that track type and roadway adjustments have on the relative safety of rail and for-hire truck transportation in tank-type vehicles, the following is evident. Although rail has a lower overall rate of release accidents for tank-type vehicles than for-hire trucking (1930 vs. 3049 incidents per BVM), if the rail transportation of hazardous materials in tank cars were confined to Class 3 track in some region,

TABLE 6 TANK CAR RELEASE ACCIDENT RATES BY TRACK CLASS

Track Class	Release Accident Rate
1	39,107
2	12,719
3	4,099
4	439
5/6	622
All	1,830

NOTE: Incidents per billion vehicle-miles of hazardous materials.

TABLE 7 TRUCK ACCIDENT RATES BY ROADWAY TYPE (7)

Roadway Type	Accident Rate			Adjustment Factor
	California	Michigan	Combined	
Rural freeway	169	81	141	0.60
Rural nonfreeway	289	146	244	1.04
Urban freeway	198	395	261	1.11
Urban nonfreeway	161	571	292	1.24
Overall	211	285	235	1.00

NOTE: Accidents per hundred million vehicle-miles.

while the distribution pattern of tank truck transportation among the different types of roadways in that region followed the national pattern, the railroad accident rate would be higher than the overall rate for the tank trucks that are operated for hire (4099 vs. 3049 incidents per BVM). By contrast, if the for-hire truck transportation of hazardous materials in tank trucks were confined to rural freeways in some region, then its accident rate would be higher than the overall rate for rail transportation in that region (3171 vs. 1830 incidents per BVM).

TABLE 9 COMPARISON OF RELEASE ACCIDENT RATES

	Ours	BPNL Propane
Tank trucks	685[a]	284[b]
Tank cars	1830	3258[b]

NOTE: Incidents per billion vehicle-miles of hazardous materials.
[a]Based on the rates in Table 4, weighted by the for-hire truck-miles and private truck-miles of petroleum products in the Census survey (5, pp. 76, 77).
[b]Obtained by dividing the release probabilities in Table 10.3 of (8) by the average shipment distances in Table 10.1.

CONCLUSIONS

There is no shortage of estimates of release accident rates in the literature for both truck and rail transportation of hazardous materials. These estimates are measured in different ways, however, and they vary in terms of how accurate and current they are. In some cases it is hard to determine how good the estimates are because the references do not explain adequately how the numbers were obtained. These complications make it difficult, if not impossible, to compare the truck and rail rates that have been published in different sources.

In their study of the truck and rail transportation of propane (8), Battelle Pacific Northwest Laboratory (BPNL) estimated the release accident rates for the two modes in a consistent manner, and Table 9 shows a comparison of their results with those from this study. The comparison is a rough one, because their results are based on 1971–1976 data and are limited to propane shipments of hazardous materials. During that period, too, DOT was just beginning to collect reports, and the massive retrofitting of tank cars with protective features such as headshields and shelf couplers had not yet been done. The results in this paper, on the other hand, are for 1982 and are based on all shipments of hazardous materials. Both sets of results are for tank cars and tank trucks only. The authors' estimate for the truck mode is 2.4 times higher than theirs, while their rail estimate is 1.8 times higher than the authors.' Hence, in terms of release accident rates, the truck mode was found to be less safe than they found it and the rail mode, to be safer.

TABLE 8 FOR-HIRE TANK TRUCK RELEASE ACCIDENT RATES BY ROADWAY TYPE

Roadway Type	Release Accident Rate
Rural freeway	1829
Rural nonfreeway	3171
Urban freeway	3385
Urban nonfreeway	3781
Overall	3049

NOTE: Incidents per billion vehicle-miles of hazardous materials.

Accident rates are fundamental to risk assessment, and the importance of having accurate estimates cannot be overstated. Along with data on the volumes of hazardous materials transportation on the routes of interest and information about the hazards of conducting transportation on those routes, accident rate estimates are one of the basic building blocks needed to calculate a risk profile. In a risk profile an evaluation is made of the frequency of hazardous materials transportation accidents as a function of the level of the consequence of the accidents for all routes collectively in the region of interest (or for any individual route segment of particular concern). Development of a risk profile requires that the release accident rates be combined with the flow data to calculate the release accident frequencies, and that the estimated spill quantities be combined with knowledge of the chemical, physical, or biological properties of the materials (depending on the impacts of interest) in order to calculate the accident consequences.

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DISCUSSION

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In the introduction to his work, the author is quite explicit about previous research efforts failing to develop consistent, reliable estimates of release accident rates due to methodological shortcomings, indicating that this paper represents a significant contribution by providing benchmark estimates in which we can have some statistical faith. On the contrary, it appears that the author has adopted a methodology that provides a classic illustration of many of the pitfalls identified by previous researchers and that, alas, we remain a long way from being able to develop the quality estimates that are so desperately needed. In fact, systemic problems in accident and exposure (volume) databases available for this type of application will deter development of reliable empirical estimates for years to come.

It is interesting to note the author's claim that by using only 1982 rail and truck accident and exposure data, some sort of consistency has been established. This is far from the case. First, as noted by the author, the accident/incident database used for truck and rail suffers from underreporting and misreporting. What the author does not state is that the underreporting may be as large as 30 to 50 percent, and it is not uniform across both modes, with truck underreporting being a more significant problem. The implications of this are twofold: (1) the reported accident/incident frequencies are biased toward making trucks look relatively safer, and (2) the accident rates reported in the paper should not be taken out of context by other analysts looking for accident rate estimates. In fact, given the known uncertainties in these numbers, carrying the rates out to two significant digits is clearly inappropriate.

The exposure (volume) data similarly suffer from consistency problems. The Waybill file (rail) and TIUS (truck) are collected using two completely different sampling designs with varying levels of precision. Whereas the Waybill file represents a sample of individual rail shipments, TIUS is based on a survey of truck owners who provide an annual estimate of their mileage and a percentage range of how often they are carrying hazardous materials. When aggregating from these data, one simply cannot claim that the "level of exposure to accidents is measured in the same way," as the author does.

There are also some troubling aspects to the accident rates reported in the paper. First, the author does not clarify what is meant by "vehicle-miles." In the case of rail, there would be major differences in the magnitude of the accident rates depending on whether this is defined as train-miles or car-miles. If it is train-miles, and the train is carrying ten cars loaded with hazardous materials, then the resulting accident rate would vary by an order of magnitude depending on the exposure definition. Second, knowing the methodological problems with the derived accident rates, it is inappropriate for the author to disaggregate by truck class and roadway type, particularly since (1) the reported classification data are for accident rates, and not release accident rates, and (2) the data come from 1981 and 1983 for truck and rail, respectively, and not from 1982, which is the author's prior analytic focus. While the latter point may seem trivial, it is important to recognize the downturn in the economy in 1982 that had a major impact on freight transport and safety statistics for that year alone.

In summary, it is apparent that some serious methodological flaws exist that render any widespread use of the reported rates dangerous to the extent that many people are looking for such numbers to plug into their risk assessments without knowledge of the derivation of these estimates. If it is any consolation, however, the author is not alone in his approach to this problem. He merely joins the rest of us who are struggling to perform risk estimation under conditions of limited data availability.

AUTHOR'S CLOSURE

The OTA report on hazardous materials transportation is a highly informative study, but some of the sweeping conclusions related to incident reporting and commodity flows were not justified by the analysis that was shown. One such conclusion, identified in the opening paragraph of my paper, is that "truck transport has the greatest risk of accidents." Another one, restated by the discussant in percentage terms in the second paragraph of his comments, is that "for rail and Interstate highway transport, the number of releases is underrepresented by factors of 3 and at least 2, respectively."

My objection to these conclusions, which I suppose are attributable to the discussant, is not that they are necessarily wrong but, rather, that they were not shown to be right. Given that the public deserves to have faith in congressional reports, it is unfortunate that the process by which these conclusions were reached was not subjected to an adequate peer review. It is unfortunate, too, that there are a number of mistakes in Abkowitz's comments on my paper, as the following point-by-point closure will demonstrate.

Note that in the cases where I have paraphrased the discussant's comment rather than quoted it verbatim, I have tried to preserve the essence of the actual statement.

1. "The underreporting [of incidents] may be as large as 30 to 50 percent and it is not uniform across both

modes, with truck underreporting being a more significant problem."

The credibility of these contentions is undermined by the careless use of apples and oranges in Chapter 2 of the OTA report, e.g., in the comparison of the HMIS and TAF databases on pp. 77 and 78. Moreover, if the EPA estimate cited on pp. 67 and 70 of the OTA report is true, that 90 percent of the releases over 100 gallons are reported, then underreporting does *not* appear to be a serious problem.

I suspect that a substantial number of smaller spills do go unreported, but I do not know how serious the problem is, nor do I know of any demonstrable reason why trucking companies would be worse at reporting than railroad companies. I also suspect that there was less underreporting in 1982, the year I used, than in the earlier years of OTA's 1976–1983 period, because of (a) the cumulative benefits of experience and (b) the 1981 reduction in reporting requirements.

2. Given the known uncertainties in the accident rate estimates, it is clearly inappropriate to carry them out to two significant digits.

The discussant is not using the term *significant digit* properly, as evidenced by the fact that the estimates in Table 4 were carried out not to two, but up to four, significant digits. This is a legitimate thing to do as long as the noninteger numbers that go into the calculation have at least four significant digits, which is true of the vehicle-mile numbers that I used.

3. One cannot claim that the level of exposure to accidents is measured in the same way when different sampling designs are used to collect the data.

This comment puzzles me for two reasons: (a) it has no basis in fact, and (b) Abkowitz himself did precisely the same thing when he compared ton-miles by truck, rail, and other modes in his paper in *Transportation Quarterly* (Vol. 40, No. 4, October 1986, pp. 483–502). An estimate is an estimate, regardless of how it is obtained. Some estimates may be more precise than others, but this does not preclude good estimates from being compared with not-so-good ones.

4. The author does not clarify what is meant by vehicle-miles. In the case of rail, it is not clear whether a vehicle is a train or a railcar.

The discussant's attention is drawn to the following statement in my first paragraph under the heading *Release Accident Rates*, which could not be clearer: "The term *vehicles* is used to mean rail cars or trucks." Even if Abkowitz had missed this statement, it strikes me as peculiar that anyone would think that the term *rail vehicle* means a train rather than a railcar.

5. "It is inappropriate for the author to disaggregate by track class and roadway type, particularly since (1) the reported classification data are for accident rates, and not release accident rates, and (2) the data come from 1981 and 1983 for truck and rail, respectively, and not from 1982."

With regard to the first part of this comment, I fully documented the method by which I obtained the estimates in Tables 6 and 8, with no attempt to pass them off as anything but "crude," stating that they were intended merely to illustrate "a way to make adjustments in the estimates in Table 4 according to track type or roadway type."

As for the second part, the discussant is wrong once again. The *1982 Truck Inventory and Use Survey* pertains to 1982 truck movements, not to 1981 (a fact that may be confirmed by calling Robert Crowther of the Bureau of the Census), and the 1982 File of Carload Waybill Statistics pertains to 1982 rail movements, not to 1983 (a fact that may be confirmed by calling Thomas Warfield of the Association of American Railroads).

6. "Some serious methodological flaws exist that render any widespread use of the reported rates dangerous to the extent that many people are looking for such numbers to plug into their risk assessments."

I encourage people to decide for themselves whether it would be "dangerous" to use the rates in my paper.

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