Characteristics of Accidents and Incidents in Highway Transportation of Hazardous Materials

DOUGLAS W. HARWOOD, EUGENE R. RUSSELL, AND JOHN G. VINER

Existing accident and incident data bases provide insight into the nature of the safety risks involved in hazardous materials transportation by highway. This paper presents analyses of data from the U.S. Department of Transportation Research and Special Programs Administration (RSPA) Hazardous Materials Incident Reporting System, the FHWA Motor Carrier Accident Reports, and the Missouri Statewide Accident Reporting System. These analyses document the types of accidents and incidents that occur when transporting hazardous materials by truck on public highways. This paper focuses on the predominant role of traffic accidents as a cause of severe hazardous materials incidents. Existing traffic accident data are used to determine the probability of a hazardous materials release, given an accident involving a hazardous materials-carrying vehicle. The types of accidents in which this probability is higher or lower than average are identified. The purpose of this paper is to present analyses of use to highway agencies in managing hazardous materials transportation on their road networks. Thus, incidents associated with loading and unloading operations that are included in the RSPA data base have been excluded from these analyses.

Hazardous materials (hazmat) transportation is a large and growing segment of the transportation industry. Special concern is addressed to safety in the transportation of hazardous materials because of the potential for fires, explosions, ground water contamination, and toxic effects on human health if hazardous materials are inadvertently released. Effective management of hazardous materials transportation safety requires a thorough understanding of the risks of accidents and incidents and the characteristics of accidents and incidents that may occur.

Most previous evaluations of hazardous materials transportation safety have been broad in scope, covering all modes of transportation. This paper focuses solely on highway (i.e., truck) hazmat transportation. However, highway transportation is a predominant part of the hazmat transportation safety problem, accounting for more than 85 percent of the hazmat releases reported to federal agencies. This paper focuses on those releases that occur during actual transportation on public highways and omits incidents that occur during loading and unloading in terminal or yard areas. While loading and unloading incidents are part of the overall risk of hazmat transportation, such incidents are not part of the safety problem faced by highway agencies in managing the highway system. In addition, loading and unloading incidents are not relevant to the analysis of alternative routes for hazmat shipments.

This paper presents estimates of the probability of a hazmat release, given an accident involving a truck carrying hazardous materials. This probability, which was found in this study to be from 13 percent to 15 percent overall, has only been quantified indirectly in past research. In this study, it is quantified directly from existing data bases. The analyses show that the probability of a hazmat release, given an accident, is strongly dependent on the accident type and other accident-related variables.

The analyses also show the preponderant role of traffic accidents as a cause of severe hazmat incidents. Between 35 and 68 percent of severe hazmat incidents are caused by traffic accidents, depending on the definition chosen for a severe incident.

ACCIDENTS, INCIDENTS, AND EXPOSURE

The analysis of existing data bases related to hazardous materials transportation requires an understanding and careful distinction between accident, incident, and exposure data bases.

Accident data bases contain reports of traffic accidents obtained either from police reports, motorist or motor carrier reports, or independent follow up investigations. Each record in an accident data base documents the characteristics of a particular accident or a particular accident-involved vehicle. The accident data bases of interest in hazmat safety analyses are those that contain data on truck accidents where a determination can be made as to whether the truck (or trucks) involved in an accident was carrying hazardous materials. It is also desirable to be able to determine whether a hazardous materials release occurred in a particular accident.

Incident data bases contain reports of occurrences where a hazardous material was unintentionally released. The incidents of primary interest are releases of hazardous materials during their transportation by highway. Several types of incidents must be considered including releases resulting from (a) traffic accidents, (b) valve or container leaks, and (c) fires or explosions.

Figure 1 presents a classification scheme based on recent work by the Organization for Economic Cooperation and Development that clearly distinguishes between hazmat accidents and incidents (*1*). The figure shows that some accidents are not incidents, some incidents are not accidents, and some

D. W. Harwood, Midwest Research Institute, Kansas City, Mo. 64110. E. R. Russell, Kansas State University, Manhattan, Kan. 66502. J. G. Viner, Traffic Safety Research Division, FHWA, 6300 Georgetown Pike, McLean, Va. 22101.

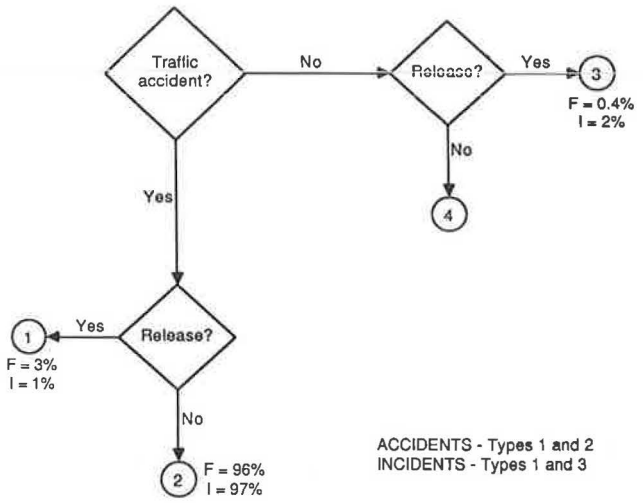

FIGURE 1 Classification scheme for on-highway events and causes of resulting fatalities and injuries for trucks carrying hazardous materials.

occurrences are both incidents and accidents. Figure 1 also presents estimates of the distribution of fatalities and injuries associated with highway transportation of hazardous materials. The development of these estimates is addressed later in this paper.

Accident and incident data are useful because they indicate the frequency with which particular events occur. However, the assessment of accident or incident risk requires *corresponding* exposure data. Exposure is a measure of opportunities for accidents or incidents to occur, such as number of hazardous materials shipments, tons of hazardous materials shipped, or, best of all, vehicle-miles of hazmat shipments.

Risk measures, such as accident or incident rates per million vehicle-miles, can be expressed as the ratio of frequency of accidents or incidents to exposure:

$$R = A/E$$

where

R = a measure of risk (e.g., accident rate),
A = a frequency measure (e.g., number of accidents), and
E = an exposure measure (e.g., vehicle-miles of travel).

To be useful in establishing hazmat transportation policies, risk measures must be quite specific. For example, an accident rate for a specific type of truck traveling on a particular type of road can be obtained only if both the accident and exposure populations are stratified accordingly.

A major weakness of hazmat safety research and truck safety research, in general, is that valid exposure data corresponding to a particular accident data set are seldom available. For this reason, this paper concentrates on what can be learned from existing incident and accident data bases in the absence of exposure data.

HAZMAT INCIDENT ANALYSES

The characteristics of hazmat incidents were determined through analysis of the U.S. Department of Transportation Research and Special Programs Administration (RSPA) Hazardous Materials Incident Reporting System (HMIR) data base. A highway-related hazardous materials incident is an unintentional release of a hazardous material during, or in connection with, its transportation by highway. Hazmat incidents in all modes, including highway transportation, are required by law to be reported to the RSPA HMIR by all carriers engaged in interstate transportation (*2*). RSPA receives nearly 5,000 reports of highway-related hazmat incidents each year. Carriers engaged solely in intrastate transportation are not required to report hazmat incidents to RSPA; therefore, it is not clear how many incidents are not reported to RSPA.

No minimum quantity released or minimum property damage threshold requirement exists for reporting hazmat incidents to RSPA. Any incident, no matter how small, is technically reportable if the hazardous material escapes from its container. It is not necessary for the hazardous material to escape from the vehicle. The only exceptions to this general rule are small-quantity releases of electric battery acid and certain paint products that were excluded from the reporting requirements in 1981.

The RSPA reporting requirements are currently being expanded to include incidents in which a highway is closed for an hour or more or when persons are evacuated from the vicinity of a potential incident site, even if no hazmat release occurs (*3*). There have been instances in which an overturned truck carrying hazardous materials caused a major highway to be closed for many hours and the surrounding population to be evacuated because of the possibility of a release. In the proposed revision, such incidents will now be reportable to RSPA even if no release occurs. The proposed revision to the HMIR report form will also distinguish explicitly between incidents that occur en route and incidents that occur in terminal and loading areas.

The RSPA HMIR data are based entirely on self-reporting by carriers. This self-reporting system undoubtedly leads to underreporting of incidents, but the level of underreporting is uncertain. Further analysis of underreporting problems in the RSPA HMIR is provided by Harwood and Russell (*4*).

Annual Incident Frequencies

The RSPA HMIR data include both on-highway and off-highway incidents, and it is not always possible to distinguish clearly between such locations. For this analysis, the following types of incidents were presumed to occur on the highway:

- Incidents caused by a traffic accident.
- Incidents caused by cargo shifting or damage by other freight.
- Incidents that occurred in a different city or state from either the origin or the destination of the shipment.
- Incidents in which the city or state where the incident occurred is unknown.

The following types of incidents were presumed to occur off the highway:

- Incidents involving loading or unloading.
- Incidents involving material dropped in handling.
- Incidents involving external puncture not caused by a traffic accident.

The location of incidents that do not fit any of the above definitions was treated as unknown.

Given these definitions, 39 percent of the 28,433 hazmat incidents in the RSPA data for 1981–85 (inclusive) occurred at locations off of public highways, such as in terminals or shipping yards. Approximately 48 percent (13,547) of hazmat incidents occurred on the highway, and the locations of the remaining 13 percent of incidents could not be determined.

Hazmat incidents that do not occur on public highways are not of direct concern to highway agencies, because these incidents could not involve a release onto a highway right-of-way. Therefore, the subsequent analyses in this paper address the 13,547 incidents that one can be reasonably sure occurred on public highways.

Causes of Hazmat Incidents

Table 1 presents the distribution of hazmat incidents by the type of failure that occurred. For all reported incidents, the major failure types are body or tank failures (20 percent), valve or fitting failures (24 percent), and cargo shifting (37 percent).

Traffic accidents were found to constitute approximately 11 percent of all hazmat incidents. This is a higher proportion of traffic accidents than reported in previous studies (*4–6*), because off-highway incidents have been excluded from the data.

Severe incidents are of greatest concern in the management of hazardous materials transportation safety. However, no commonly accepted definition exists as to what constitutes a severe incident. Table 1 illustrates the distribution of failure types in on-highway hazmat incidents for progressively less-restrictive definitions of incident severity ranging from "death only" to "all reported incidents." The severe nature of unintentional releases of hazardous materials in traffic accidents can be clearly seen in Table 1. Note that, although traffic accidents constitute just 11 percent of all reported incidents, they account for 35 to 68 percent of the severe incidents, depending on the definition selected for severe incidents. In the 35 incidents in which a fatality occurred as a result of a release, more than 90 percent (32 incidents) were caused by traffic accidents.

Valve or fitting failure is the second leading failure type in these various definitions of severe incidents. Valve or fitting failures, which constituted 24 percent of all incidents, were attributed to 29 percent of the incidents that resulted in deaths or injuries and lesser percentages of the other severity level definitions. No other failure type accounted for more than 14 percent of the severe incidents for any of the severity levels examined. Thus, regardless of the definition selected for a severe incident, traffic accidents account for a more important part of the hazardous materials highway safety problem than is suggested by overall release statistics.

In the analyses that follow, severe incidents have been defined as those that involve either (a) a fatality or injury caused by the hazmat release, (b) property damage of $50,000 or more caused by the hazmat release, or (c) a fire or explosion. Table 1 shows that by this definition, traffic accidents constitute 56 percent of severe incidents. In fact, nearly a quarter of traffic accidents that cause a hazmat release result in a severe incident.

The general causes of hazmat releases are summarized in Table 2. Approximately 50 percent of incidents are attributable to human error and 35 percent are attributable to package failure. Previous analyses of the RSPA data base have indicated that, overall, human error is responsible for more than 60 percent of hazmat releases. The lower proportion of hazmat releases attributable to human error and the higher proportion of incidents attributable to package failure in Table 2 occur because human error predominates in off-highway loading and unloading incidents, which have been excluded from the analysis. It should be noted that the literature suggests driver error is a significant cause of traffic accidents; thus, in this sense, human error is ultimately responsible for a large portion of the traffic accidents shown in Table 2. When the analysis shown in Table 2 is limited to severe incidents, traffic accidents dominate, of course, as they did in Table 1. However, in severe incidents not caused by traffic accidents, package failure is actually a more common cause than human error.

Type of Hazardous Material Involved

The distribution of the type of hazardous material released in hazmat incidents was analyzed in the RSPA data. Where

TABLE 1 DISTRIBUTION OF ON-HIGHWAY HAZMAT INCIDENTS BY FAILURE TYPE AND INCIDENT SEVERITY, 1981–1985

	Death Only		Death or Injury		Death or Injury or Explosion		Death or Injury or Explosion or Fire		Death or Injury or Explosion or Fire or Property Damage Over $100K		Death or Injury or Explosion or Fire or Property Damage Over $50K		Death or Injury or Explosion or Fire or Property Damage over $10K		All Reported Incidents	
Failure Type	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Traffic accident	32	(91.4)	107	(35.5)	112	(34.7)	188	(41.7)	233	(46.4)	355	(56.1)	723	(68.1)	1,427	(10.8)
Body or tank failure	0	(0.0)	37	(12.3)	38	(11.8)	40	(8.9)	42	(8.4)	42	(6.6)	63	(5.9)	2,741	(20.2)
Valve or fitting failure	0	(0.0)	86	(28.6)	88	(27.2)	101	(22.4)	101	(20.1)	104	(16.4)	112	(10.5)	3,289	(24.3)
Cargo shifting	0	(0.0)	39	(13.0)	44	(13.6)	52	(11.5)	52	(10.4)	54	(8.5)	70	(6.6)	4,945	(36.5)
Fumes or venting	0	(0.0)	2	(0.7)	2	(0.6)	2	(0.4)	2	(0.4)	2	(0.3)	2	(0.2)	15	(0.1)
Other	3	(8.6)	30	(10.0)	39	(12.1)	68	(15.1)	72	(14.3)	76	(12.0)	92	(8.7)	1,100	(8.1)
TOTAL	35		301		323		451		502		633		1,062		13,547	

more than one hazardous material was released in a single incident, the incident was classified on the basis of the primary material released (listed first in the RSPA data file).

The predominant hazardous materials released were found to be flammable and combustible liquids (46 percent of all releases) such as gasoline and corrosive materials (40 percent). Poisonous gases and liquids constituted 5 percent of all releases. No other single hazard class constituted more than 3 percent of releases. These RSPA data also indicated that flammable and combustible liquids constituted 71 percent of the releases resulting from traffic accidents, as opposed to 46 percent of all releases. By contrast, corrosive materials accounted for only 13 percent of the releases in traffic accidents, but 43 percent of the releases from other causes. Thus, it appears that corrosive materials, by their nature, are much more likely to produce a valve, fitting, or container failure than other placarded materials.

The distribution of severe hazmat incidents by type of material released was also studied. About 55 percent of severe incidents involved flammable and combustible liquids, as compared with 46 percent of all incidents. Thus, flammable and combustible liquids were overrepresented in severe incidents as compared with total incidents. The opposite appeared to be true for corrosive materials. Corrosive materials were involved in 24 percent of severe incidents, as compared with 40 percent of all incidents.

Consequences of Incidents

The RSPA data base contains the consequences of each reported incident, including the number of deaths and injuries and the dollar amount of property damage. In the case of incidents related to traffic accidents, the RSPA data includes only deaths and injuries that are a direct result of the hazmat release. Other deaths and injuries resulting from the accident are not reported. The same interpretation probably holds for property damage from hazmat incidents, but this point is not clear from the instructions for completing the hazmat incident report (*2*).

The RSPA data show that 0.3 percent of hazmat incidents result in one or more deaths and 2.2 percent of hazmat incidents result in one or more personal injuries. Thus, it is apparent that the deaths and injuries from hazmat releases result from a relatively small proportion of the total number of incidents.

Table 3 summarizes the consequences of hazmat incidents from 1981 to 1985, inclusive. During this period, there were 54 deaths and 473 injuries from on-highway hazmat releases, or an average of approximately 11 deaths and 95 injuries per year in the United States. Approximately 90 percent of the deaths and 25 percent of the injuries were attributed to releases resulting from traffic accidents. On average, 10 deaths and 23 injuries per year were attributed to releases from traffic accidents. Releases resulting from traffic accidents were about 100 times more likely to cause deaths and three times more likely to cause injuries than releases from other causes.

On-highway releases resulted in about $10 million in reported property damage per year at an average reported cost of about $3,600 per incident. Releases resulting from traffic accidents resulted in about 80 percent of the total reported property damage costs. Releases from traffic accidents resulted in about 30 times more reported property damage costs per incident than releases from other causes.

TRAFFIC ACCIDENT ANALYSES

The only nationwide source of truck accident data containing information on hazmat transportation is the Motor Carrier Accident Report data (*7*) maintained by the FHWA Bureau of Motor Carrier Safety (BMCS) (recently renamed the Office of Motor Carriers). This data base is valuable because it iden-

TABLE 2 DISTRIBUTION OF ON-HIGHWAY HAZMAT INCIDENTS BY CAUSE OF RELEASE, 1981–1985

	All Reported Incidents		Severe Incidents Only	
Cause of Release	No.	%	No.	%
Traffic accident	1,457	(10.8)	355	(56.1)
Human error	6,845	(50.5)	101	(16.0)
Package failure	4,691	(34.6)	128	(20.2)
Other	550	(4.1)	49	(7.7)
Total	13,543		633	

TABLE 3 SUMMARY OF CONSEQUENCES OF ON-HIGHWAY HAZMAT INCIDENTS, 1981–1985

	All Reported Incidents	Incidents Caused by Traffic Accidents	Incidents Resulting from Other Causes
Number of incidents	13,547	1,457	12,090
Number of deaths	54	50	4
Deaths per incident	0.0040	0.0340	0.0003
Number of injuries	473	115	358
Injuries per incident	0.035	0.079	0.030
Total property damage ($)	48,297,000	38,412,000	9,885,000
Property damage per incident ($)	3,565	26,364	818

tifies whether each accident-involved truck was transporting hazardous materials and whether those hazardous materials were released. Thus, the BMCS data can be used to compare the frequency and distribution of truck accidents that resulted in a hazmat release, with all accidents involving hazmat-carrying trucks and truck accidents in general.

Two important disadvantages of this data base should be noted. First, while nationwide in scope, the data base does not include all truck accidents, but only those of regulated interstate motor carriers. Second, as do the RSPA hazmat incident data, the BMCS accident data are dependent on self-reporting by carriers. This self-reporting system is known to result in underreporting of accidents to BMCS. One previous study noted that the percentage of property-damage-only accidents is substantially smaller in the BMCS data than in data on police-reported accidents from the National Accident Sampling System (NASS), indicating that minor accidents are probably underreported to BMCS (*8*). The property damage threshold for reporting truck accidents to BMCS was $2,000 for the entire period covered in this paper. On January 1, 1986, however, the reporting threshold was raised to $4,200.

The following section presents tables of the characteristics of truck accidents in general and accidents involving hazmat-carrying trucks. Selected tables also indicate the breakdown of accidents involving hazmat-carrying trucks into accidents where the hazardous materials being carried were and were not released. All tables are based on less than 1 percent missing data unless otherwise noted.

Annual Accident Frequencies

The BMCS data for 1981 through 1985 show that hazmat-carrying trucks were involved in approximately 5 percent of all truck accidents. Approximately 15 percent of accidents involving trucks carrying hazardous materials resulted in a hazmat release, as compared with the 20 percent estimate developed by Abkowitz (*9,10*) in research for the Environmental Protection Agency. The Abkowitz estimate was developed indirectly, while the 15 percent estimate presented here for the probability of a release is based on actual data. Underreporting of accidents to BMCS may produce a bias in the estimate of the probability of a release presented here. However, past research has shown that accident reporting levels increase as accident severity increases (*11–13*). Therefore, accidents resulting in a release are more likely to be reported than other accidents, and 15 percent should be a conservative (upper bound) estimate of the overall proportion of hazmat accidents resulting in a release. The effect of selected factors on the probability of a release, given an accident, is examined in the remaining tables.

The BMCS data base is incomplete for some factors for the years 1982 and 1983. In those years, selected accident factors were not entered into the computer data base as an economy move. Entry of all available data was resumed in 1984. For consistency, the remaining tables that use the BMCS data are based on data for 1984 and 1985 only, so that each table is using the same set of accidents. Approximately 14 percent of accidents involving hazmat-carrying trucks in 1984 and 1985 resulted in a release.

Relationship to Intersecting Facilities

Table 4, which shows the distribution of BMCS-reported truck accidents by their relationship to intersections, freeway ramps, and railroad-highway grade crossings, presents some important findings concerning the likelihood of hazmat releases in different types of accidents. Intersection accidents are less likely to result in a hazmat release than accidents in general; in fact, only 10 (4 percent) of 283 accidents at intersections involving hazmat-carrying trucks resulted in a release. Accidents involving hazmat-carrying trucks on freeway ramps are more likely to result in a release, with 22 percent releases for hazmat accidents on on-ramps and 26 percent releases for hazmat accidents on off-ramps. Railroad grade crossings have the highest likelihood of a release when an accident occurs, with 10 (45 percent) of the 22 reported accidents resulting in a release.

Accident Type

Table 5 presents the distribution of accident types for hazmat accidents and truck accidents in general. Multiple-vehicle collisions are the leading type of accident, both for vehicles carrying (47 percent) and not carrying (52 percent) hazardous materials. However, the leading accident types that result in hazmat releases are single-vehicle overturning accidents, which constitute 41 percent of releases, and single-vehicle run-off-road accidents, which constitute 23 percent of releases. While multiple-vehicle collisions represent 47 percent of the accidents for trucks carrying hazardous materials, these accidents result in only 16 percent of all hazmat releases. Single-vehicle collisions represent 53 percent of the accidents for trucks

TABLE 4 DISTRIBUTION OF BMCS-REPORTED TRUCK ACCIDENTS BY RELATIONSHIP TO INTERSECTING FACILITIES, 1981–1985

Intersecting Facilities	Accidents Involving Trucks Not Carrying Hazmat		Accidents Involving Trucks Carrying Hazmat						Probability of a Hazmat Release Given an Accident (%)
			Combined		No Release		Hazmat Release		
	No.	%	No.	%	No.	%	No.	%	
None	60,828	(85.5)	3,172	(85.7)	2,726	(85.6)	446	(85.8)	14.2
At-grade intersection	5,762	(8.1)	283	(7.6)	273	(8.6)	10	(1.9)	3.5
Off-ramp	2,376	(3.3)	116	(3.1)	86	(2.7)	30	(5.8)	25.9
On-ramp	1,884	(2.6)	110	(3.0)	86	(2.7)	24	(4.6)	21.8
Railroad grade crossing	314	(0.4)	22	(0.6)	12	(0.4)	10	(1.9)	45.5
TOTAL	71,164		3,703		3,183		520		14.0

carrying hazardous materials, but result in 84 percent of all releases.

Accidents involving hazmat-carrying trucks are twice as likely as other truck accidents to result in an overturn. Furthermore, releases occur in 38 percent of hazmat overturns as compared with 14 percent of all accidents involving hazmat-carrying trucks. Hazmat accidents are 1.5 times as likely as other truck accidents to involve a single-vehicle running off the road and such accidents result in a hazmat release 33 percent of the time. These accident types are characteristic of tank trucks and represent the relatively larger use of tankers in hazmat trucking as compared with trucking in general.

By contrast, single-vehicle collisions with parked cars or nonmotorists (i.e., pedestrians, bicycles, and animals) and multiple-vehicle collisions (including both car-truck and truck-truck collisions) are less likely than average to result in a release. This confirms the finding in Table 8 that intersection accidents are less likely to result in a hazmat release, because accidents at intersections typically involve multiple-vehicle collisions.

The principal special concerns in accidents involving trucks carrying hazardous materials are the actual and potential consequences of hazmat releases. From this perspective, the analysis findings indicate that data on accidents involving hazmat-carrying trucks can be misleading without data on whether a hazmat release occurred in these accidents, because the probability of a release, given an accident, varies widely among accident types.

Truck Configuration

Table 6 presents the distribution of BMCS-reported accidents by truck configuration. The table reflects the overwhelming predominance of single-trailer combination trucks in both hazmat transportation and trucking in general. The table indicates that both single-unit and double-trailer combination trucks are slightly less likely than average to release their cargo when involved in an accident, and single-trailer combination trucks are slightly more likely than average to release their cargos, but the differences are not large. Truck trailers (single-unit trucks towing a full trailer) appear to have the highest likelihood of a hazmat release when involved in an accident.

Table 7 presents the distribution of accidents by cargo area configuration (van, flatbed, tanker, and other) for single-trailer combination trucks in the BMCS data. Table 7 shows that the majority of accidents for trucks not carrying hazardous materials involve van semitrailers, while the majority of accidents for hazmat-carrying trucks involve tankers. Table 7 also indicates that the probability of a hazmat release, given an accident, is above average for tankers and below average for vans.

TABLE 5 DISTRIBUTION OF BMCS-REPORTED TRUCK ACCIDENTS BY ACCIDENT TYPE

Accident Type	Accidents Involving Trucks Not Carrying Hazmat		Accidents Involving Trucks Carrying Hazmat						Probability of a Hazmat Release Given an Accident (%)
			Combined		No Release		Hazmat Release		
	No.	%	No.	%	No.	%	No.	%	
SINGLE-VEHICLE ACCIDENTS									
Noncollision Accidents									
Ran-off-road	4,483	(6.3)	357	(9.6)	239	(7.5)	118	(22.7)	33.1
Jackknife	4,864	(6.8)	158	(4.3)	146	(4.6)	12	(2.3)	7.6
Overturn	5,263	(7.4)	574	(15.5)	359	(11.3)	215	(41.3)	37.5
Separation of units	278	(0.4)	36	(1.0)	28	(0.9)	8	(1.5)	22.2
Fire	425	(0.6)	33	(0.9)	32	(1.0)	1	(0.2)	3.0
Cargo spillage	268	(0.4)	21	(0.6)	0	(0.0)	21	(4.0)	100.0
Cargo shifting	206	(0.3)	6	(0.2)	5	(0.2)	1	(0.2)	16.7
Other noncollision	157	(0.2)	7	(0.2)	6	(0.2)	1	(0.2)	14.3
Collision Accidents									
Collision with fixed object	7,774	(10.9)	241	(6.5)	210	(6.6)	31	(6.0)	12.9
Collision with parked vehicle	6,591	(9.3)	254	(6.9)	246	(7.7)	8	(1.5)	3.1
Collision with train	314	(0.4)	22	(0.6)	12	(0.4)	10	(1.9)	45.5
Collision with nonmotorist	1,241	(1.7)	66	(1.8)	65	(2.0)	1	(0.2)	1.5
Other collision	2,508	(3.5)	169	(4.6)	159	(5.0)	10	(1.9)	5.9
MULTIPLE-VEHICLE ACCIDENTS									
Collision with passenger car	28,316	(39.8)	1,360	(36.7)	1,313	(41.3)	47	(9.0)	3.5
Collision with truck	7,758	(10.9)	372	(10.0)	337	(10.6)	35	(6.7)	9.4
Collision with other vehicle type	703	(1.0)	27	(0.7)	26	(0.8)	1	(0.2)	3.7
TOTAL	71,149		3,703		3,183		520		14.0

TABLE 6 DISTRIBUTION OF BMCS-REPORTED TRUCK ACCIDENTS BY TRUCK CONFIGURATION, 1984–1985

Truck Configuration	Accidents Involving Trucks Not Carrying Hazmat		Accidents Involving Trucks Carrying Hazmat						Probability of a Hazmat Release Given an Accident (%)
			Combined		No Release		Hazmat Release		
	No.	%	No.	%	No.	%	No.	%	
Single-unit	6,861	(9.6)	350	(9.5)	311	(9.8)	39	(7.5)	11.1
Single-trailer combination	57,603	(80.9)	2,886	(77.9)	2,460	(77.3)	426	(81.9)	14.8
Double-trailer combination	3,079	(4.3)	278	(7.5)	253	(7.9)	25	(4.8)	9.0
Triple-trailer combination	53	(0.1)	10	(0.3)	10	(0.3)	0	(0.0)	0.0
Truck trailer	423	(0.6)	118	(3.2)	93	(2.9)	25	(4.8)	21.2
Bobtail	2,796	(3.9)	42	(1.1)	40	(1.3)	2	(0.4)	4.8
Other	349	(0.5)	19	(0.5)	16	(0.5)	3	(0.6)	15.8
TOTAL	71,164		3,703		3,183		520		14.0

Type of Cargo Involved

Table 8 presents the frequency distribution of BMCS-reported accidents by type of cargo involved (hazardous or otherwise). The table indicates quite a distinct difference in the distribution of cargo types for hazmat-carrying trucks and trucks in general. Trucks carrying liquids in bulk constitute 50 percent of accidents involving hazmat-carrying trucks, but only 2 percent of all other truck accidents. The predominance of tank trucks carrying bulk liquids represents a major difference in exposure between hazmat trucking and other forms of trucking.

The data in Table 8 show that liquid tankers (19 percent of releases) are slightly more likely than average to release their cargo in a traffic accident; and releases in the 40 accidents involving trucks transporting bulk solids occurred two times more often than average (30 percent of releases). On the other hand, trucks transporting gases in bulk, explosives, and hazardous materials in general freight are less likely than average to release their cargo in a traffic accident.

Consequences of Accidents

Table 9 summarizes the consequences of the BMCS-reported accidents, and refers to all deaths, injuries, and property damage resulting from the accident. Unlike the consequences reported for hazmat incidents, these consequences are not necessarily the result of a hazmat release. It should be noted in Table 9 that accidents involving hazmat-carrying vehicles tend to involve slightly greater consequences than truck accidents in general. Accidents in which a hazmat release occurs clearly involve more deaths, more injuries, and more property damage than accidents in which there is no release. The greater consequences when a release occurs may be due in part to the consequences of the release, but also indicate that the accident involved higher speeds or greater collision forces than other accidents, which in turn may cause both the hazmat release and the higher damages.

Table 10 summarizes the distribution of the BMCS truck accident data by accident severity levels. The table shows that a hazmat release is more likely in fatal and injury accidents than in property-damage-only accidents, undoubtedly because of the greater forces involved. It is important to note that 83 percent of the fatalities and 85 percent of the injuries in accidents involving hazmat-carrying trucks occur in accidents in which there is no hazmat release. A comparison of all cases common to both the BMCS and RSPA files provides insight into the cause of injuries and fatalities in accidents in which a release occurs.

The 130 cases common to both files in 1983 (i.e., accidents with releases) involved 10 fatalities and 109 injuries. How-

TABLE 7 DISTRIBUTION OF BMCS-REPORTED TRUCK ACCIDENTS BY CARGO AREA CONFIGURATION FOR SINGLE-TRAILER COMBINATION TRUCKS, 1984–1985

Configuration	Accidents Involving Trucks Not Carrying Hazmat		Accidents Involving Trucks Carrying Hazmat						Probability of a Hazmat Release Given an Accident (%)
			Combined		No Release		Hazmat Release		
	No.	%	No.	%	No.	%	No.	%	
Van	30,349	(64.3)	621	(24.5)	557	(26.0)	64	(16.6)	10.3
Flatbed	7,890	(16.7)	70	(2.8)	60	(2.8)	10	(2.6)	14.3
Tank	3,389	(7.2)	1,764	(69.7)	1,470	(68.5)	294	(76.4)	16.6
Other	5,597	(11.8)	76	(3.0)	59	(2.7)	17	(4.4)	22.4
TOTAL	47,225		2,531		2,146		385		15.2

Note: Cargo area configuration missing for 17.8% of accidents.

TABLE 8 DISTRIBUTION OF BMCS-REPORTED TRUCK ACCIDENTS BY CARGO TYPE, 1984–1985

Cargo Type	Accidents Involving Trucks Not Carrying Hazmat		Accidents Involving Trucks Carrying Hazmat						Probability of a Hazmat Release Given an Accident (%)
			Combined		No Release		Hazmat Release		
	No.	%	No.	%	No.	%	No.	%	
General freight	23,651	(33.7)	741	(20.1)	680	(21.4)	61	(11.8)	8.2
Gases in bulk	42	(0.1)	259	(7.0)	238	(7.5)	21	(4.1)	8.1
Solids in bulk	1,310	(1.9)	40	(1.1)	28	(0.9)	12	(2.3)	30.0
Liquids in bulk	1,618	(2.3)	1,831	(49.6)	1,486	(46.8)	345	(66.6)	18.8
Explosives	12	(0.1)	70	(1.9)	63	(2.0)	7	(1.4)	10.0
Empty	15,989	(22.8)	220	(6.0)	210	(6.6)	10	(1.9)	4.5
Other	27,478	(39.2)	529	(14.3)	467	(14.7)	62	(12.0)	11.7
TOTAL	70,100		3,690		3,172		518		14.0

TABLE 9 SUMMARY OF CONSEQUENCES OF BMCS-REPORTED TRUCK ACCIDENTS, 1984–1985

	Trucks Not Carrying Hazmat	Trucks Carrying Hazmat		
		Total	No Release	Hazmat Release
No. of accidents	71,164	3,703	3,183	520
No. of deaths	4,994	326	273	53
Deaths per accident	0.070	0.088	0.086	0.102
No. of injuries	54,522	2,955	2,514	441
Injuries per accident	0.77	0.80	0.79	0.85
Total property damage ($)	743,643,000	56,927,000	39,609,000	17,318,000
Property damage per accident ($)	10,450	15,373	12,444	33,304

TABLE 10 DISTRIBUTION OF BMCS-REPORTED TRUCK ACCIDENTS BY ACCIDENT SEVERITY, 1984–1985

Accident Severity	Accidents Involving Trucks Not Carrying Hazmat		Accidents Involving Trucks Carrying Hazmat						Probability of a Hazmat Release Given an Accident (%)
			Combined		No Release		Hazmat Release		
	No.	%	No.	%	No.	%	No.	%	
Fatal	4,034	(5.7)	265	(7.2)	221	(6.9)	44	(8.5)	16.6
Injury	33,569	(47.2)	1,777	(48.0)	1,493	(46.9)	284	(54.6)	16.0
Property-damage-only	33,561	(47.2)	1,661	(44.9)	1,469	(46.2)	192	(36.9)	11.6
TOTAL	71,164		3,703		3,183		520		14.0

ever, only two of these fatalities and four of these injuries had causes that were attributed to the release (by being reported on the RSPA form). Although the size of the accident sample, particularly that of the sample involving fatalities, is small, this result suggests that, in accidents in which a release occurs, about 80 percent of the fatalities and 95 percent of the injuries are not directly attributable to the release. Thus, traditional accident causes, and not the properties of the hazardous material transported, may be responsible for the vast majority of the fatalities and injuries in accidents involving hazmat-carrying trucks.

Combining the above estimate with the previously noted finding that, for release events, approximately 90 percent of deaths and 25 percent of injuries were attributable to traffic accidents, the estimates of the distribution of fatalities and injuries shown in Figure 1 can be derived. The dominant role of traffic accidents is clearly shown through the estimate that roughly 96 percent of all fatalities and 97 percent of all injuries involving trucks transporting hazardous materials resulted from traffic accidents in which no release occurred. It is important to note, however, that one major disaster involving numerous fatalities or injuries as a result of a release could greatly alter these estimates. The concern over such possibilities, along with the potential for major evacuations or route closures is, in fact, the key reason for interest in hazardous materials transportation as a separate highway safety issue.

STATE ACCIDENT DATA

The discussion of the BMCS accident data base indicates that the highway-related variables found there, including highway type (number of lanes, divided or undivided, access control) and area type (urban or rural), are generally inaccurate, incomplete, or unavailable. Therefore, alternative sources for these data elements in state accident data were investigated.

A review of the NHTSA publication *State Accident Report Forms Catalogue 1985* (*14*) indicates that the police accident report forms of 15 states indicate whether hazmat-carrying vehicles were involved in each reported accident. These states are Alabama, California, Florida, Illinois, Kansas, Louisiana, Maine, Minnesota, Missouri, New Hampshire, New York, Ohio, Pennsylvania, South Carolina, and Wyoming. In 13 of these states, the police report forms clearly distinguish which of the accident-involved vehicles was carrying hazardous materials. However, only three of these states (Louisiana, Missouri, and Wyoming) make it possible to determine whether a hazmat release had occurred. Supplementary analyses of hazmat accident characteristics were conducted with accident data from Missouri.

Missouri Accident Data

Since July 1, 1984, police-reported accidents in Missouri have included data identifying whether each vehicle involved in an accident was carrying hazardous materials, what type of hazardous materials was being carried, and whether a hazmat release had occurred. The Missouri data include all accidents investigated by police agencies in the state, not just those voluntarily reported by carriers—an advantage over the BMCS data. The Missouri data also include accidents for all types of trucks and all types of carriers, not just regulated interstate carriers. In addition, each accident was investigated by a police officer. While the experience and training of police officers vary widely, police officers generally are expected to have more training and experience in accident investigation and would use the accident reporting form with greater consistency than the individual motor carriers who report accidents to BMCS. However, it should be noted that accident data based on police reports are subject to the same types of underreporting biases as carrier-reported data, although perhaps not to the same extent.

The property-damage threshold for reporting accidents in Missouri is $500, which is substantially lower than the $2,000 threshold used by BMCS. Thus, the Missouri data may contain a greater proportion of property-damage-only accidents. On the other hand, Missouri, as do most states, classifies accidents involving Type C injuries (no visible injury) as injury accidents. BMCS classifies an accident as an injury accident only if a person receives medical treatment away from the scene. Therefore, the proportion of injury accidents in the Missouri data would also be expected to increase for this reason.

Approximately 200 accidents occurred in Missouri involving hazmat-carrying vehicles in both 1985 and 1986. About 13 percent of these Missouri accidents resulted in a hazmat release, which agrees with the percentage in the BMCS data for the entire United States (15 percent). Many of the analyses performed for the nationwide BMCS data were repeated for the Missouri data. The results of the Missouri analyses generally agree with the results obtained from BMCS analysis, given the smaller sample size of Missouri accidents.

Highway-Related Factors

No variable is available for the Missouri accident data that explicitly identifies the type of highway (number of lanes, divided or undivided, freeway or nonfreeway) on which each accident occurred. The highway class is a useful surrogate for

highway type. Table 11 presents the distribution of the Missouri hazmat accident data by highway class.

Table 11 indicates that all of the highway classes described previously experience a substantial proportion of hazmat accidents. The probability of a hazmat release, given an accident, is highest on the U.S. and state routes and county roads (primarily rural) and lowest on city streets.

Table 12 confirms the importance of area type (urban or rural) in predicting the probability of a hazmat release. These are nearly equal numbers of accidents in urban and rural areas in Missouri, but rural accidents are approximately three times as likely to result in a hazmat release. The greater likelihood of a hazmat release in rural accidents undoubtedly results from the higher speeds involved (and, thus, the higher forces generated in accident situations), but could also relate to the types of accidents that occur, the types of cargos transported, and the types of trucks used.

Similar findings are also evident in Table 13, which presents the distribution of hazmat accidents in Missouri by speed limit. The table demonstrates that the probability of a hazmat release given an accident is highest on highways with speed limits of 45 mph or more.

TABLE 11 DISTRIBUTION OF POLICE-REPORTED HAZMAT ACCIDENTS IN MISSOURI BY HIGHWAY CLASS, 1985–1986

	Accidents Involving Trucks Carrying Hazmat						
	Combined		No Release		Hazmat Release		Probability of a Hazmat Release
Highway Class	No.	%	No.	%	No.	%	Given an Accident (%)
Interstate	96	(23.1)	82	(22.6)	14	(26.4)	14.6
U.S. or state route	145	(34.9)	121	(33.3)	24	(45.3)	16.6
Supplementary or county road	55	(13.2)	46	(12.7)	9	(17.0)	16.4
City street	118	(28.4)	113	(31.1)	5	(9.4)	4.2
Other	2	(0.5)	1	(0.3)	1	(1.9)	50.0
Total	416		363		53		12.7

TABLE 12 DISTRIBUTION OF POLICE-REPORTED HAZMAT ACCIDENTS IN MISSOURI BY AREA TYPE, 1985–1986

	Accidents Involving Trucks Carrying Hazmat						
	Combined		No Release		Hazmat Release		Probability of a Hazmat Release
Area Type	No.	%	No.	%	No.	%	Given an Accident (%)
Urban	210	(50.5)	197	(54.3)	13	(24.5)	6.2
Rural	206	(49.5)	166	(45.7)	40	(75.5)	19.4
Total	416		363		53		12.7

TABLE 13 DISTRIBUTION OF POLICE-REPORTED HAZMAT ACCIDENTS IN MISSOURI BY SPEED LIMIT, 1985–1986

	Accidents Involving Trucks Carrying Hazmat						
	Combined		No Release		Hazmat Release		Probability of a Hazmat Release
Speed Limit (mph)	No.	%	No.	%	No.	%	Given an Accident (%)
≤ 25	60	(14.7)	59	(16.5)	1	(1.9)	1.7
30	35	(8.6)	32	(9.0)	3	(5.8)	8.6
35	65	(15.9)	59	(16.5)	6	(11.5)	9.2
40	26	(6.4)	24	(6.7)	2	(3.8)	7.7
45	21	(5.1)	17	(4.8)	4	(7.7)	19.0
50	2	(0.5)	2	(0.6)	0	(0.0)	0.0
55	200	(48.9)	164	(45.9)	36	(69.2)	18.0
Total	409		357		52		12.7

NOTE: All data were collected before increase in Interstate highway speed limit to 65 mph for passenger cars and 60 mph for trucks in May 1987.

CONCLUSIONS

Existing accident and incident data bases provide insight into the nature of on-highway safety risks in hazmat transportation by highway. The following conclusions were drawn from analysis of these data bases:

Fatalities and Injuries

Approximately 99 percent of all fatalities and 96 percent of all injuries involving trucks carrying hazardous materials are not related to hazmat releases. Of the small remaining fraction of fatalities and injuries associated with releases, more fatalities occurred in releases caused by traffic accidents than in releases from other causes. For injuries, the reverse was found—more injuries were due to releases not caused by traffic accidents. It is important to note that one major disaster involving a release could greatly alter these distributions in any given year and, in fact, this concern is the reason that hazardous materials transportation is a separate highway safety issue.

Hazmat Incidents

Approximately 11 percent of hazmat incidents that occur on public highways is caused by traffic accidents. This estimate of the proportion of incidents caused by traffic accidents is higher than found in previous studies, because incidents that occur off the highway in terminals, yards, and loading areas have been eliminated.

About 90 percent of the deaths and 25 percent of the injuries resulting from hazmat releases were caused by traffic accidents. Between 35 and 68 percent of severe hazmat incidents are caused by traffic accidents, depending on the definition adopted for a severe incident. Thus, traffic accidents are far more likely to result in a severe incident than other causes.

Traffic Accidents Involving Hazmat-Carrying Trucks

Approximately 99 percent of the fatalities and injuries in accidents involving trucks carrying hazardous materials result from the physical collision itself, rather than the hazardous materials being transported. Approximately 13 to 15 percent of accidents involving hazmat-carrying trucks result in a hazmat release.

Higher than average probabilities of a hazmat release are found in traffic accidents involving the following:

- Truck-train accidents at railroad-highway grade crossings (45 percent release probability, based on 22 accidents).
- Freeway off-ramps (26 percent release probability).
- Freeway on-ramps (22 percent release probability).
- Overturning in a single-vehicle accident (38 percent release probability).
- Running off the road in a single-vehicle accident (33 percent release probability).
- Highways with speed limits of 45 mph or more (18 percent release probability).
- Trucks transporting solids in bulk (30 percent release probability, based on 40 accidents).

Lower than average probabilities of a hazmat release are found in traffic accidents involving:

- At-grade intersections (4 percent release probability).
- Truck collisions with parked vehicles (3 percent release probability).
- Truck collisions with pedestrians, bicyclists, and animals (2 percent release probability).
- Truck collisions with passenger cars (4 percent release probability).
- Truck collisions with other trucks (9 percent release probability).

Trucks carrying liquids in bulk constitute 50 percent of accident involvements for hazmat-carrying trucks and 2 percent of accidents for other trucks. This large difference is indicative of a major difference in tank truck exposure between hazmat and other trucking.

Data Sources

A number of states have added a data element indicating the presence or absence of hazardous materials to their police traffic accident report forms. At present, most of these state forms do not also note whether the hazardous material was released as a result of the reported accident. In truck accident analyses, it cannot be presumed that any fatalities and injuries that occur are related to the presence of hazardous materials because releases occur in only 15 percent of accidents and the probability of a release varies widely between accident types. Thus, accident report forms should also include a data element indicating whether a hazmat release occurred.

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