Hazardous Materials Serious Crash Analysis: Phase 2

Final Report

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Abbreviations and Acronyms

CFR	Code of Federal Regulations
DOT	U.S. Department of Transportation
FIPS	Federal Information Processing Standard
FMCSA	Federal Motor Carrier Safety Administration
HM	Hazardous Material(s)
Hazmat	Hazardous Material(s)
HMIS	Hazardous Materials Information System
MC	Motor Carrier
MCMIS	Motor Carrier Management Information System
PAR	Police Accident Report
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIH	Poisonous by Inhalation
RQ	Reportable Quantity
RSPA	Research and Special Programs Administration
UN	United Nations
UMTRI	University of Michigan Transportation Research Institute
VRT	Visual Risk Technologies, Inc.

Final Report
Hazardous Materials Serious Crash Analysis: Phase 2

Executive Summary

This report presents the results of the second phase of the Hazardous Materials Serious Crash Analysis, a project sponsored by the Federal Motor Carrier Safety Administration (FMCSA). A crash is defined as serious if it results in one of the following: a fatality, an injury requiring transport to a facility for immediate medical attention, or at least one vehicle towed from the scene as a result of disabling crash damages. This project has three basic purposes:

- Enhance the current methodology for identifying and characterizing serious hazardous material (HM) truck crashes in the United States.
- Improve the capability to analyze causes and effects of selected serious hazardous materials crashes.
- Support the implementation of hazardous materials truck transportation safety and risk reduction strategies for packages, vehicles, and drivers.

The first phase of this project consisted of a pilot test to evaluate the feasibility of enhancing the current approach for serious HM truck crash identification, data collection, and analysis. In the second phase, the phase one tools and techniques were applied to roughly half the crashes reported in MCMIS for the calendar year 2002, with the goal of showing how the enhanced data (i.e., the HAZMAT Accidents Database) might be used to improve truck transport safety.

Findings

Crash analyses utilizing the HAZMAT Accidents Database focused on developing associations between impact measures and explanatory variables. Impact measures consisted of:

- Number of serious crashes,
- Crashes resulting in spills, fatalities, and injuries

Explanatory variables are crash characteristics that help explain cause and effect. Table ES-1 shows the five types of explanatory variables. The crash analysis process involved associating explanatory variables with impacts to determine how vehicle, driver, packaging, infrastructure, and situational characteristics influence crash occurrences in general, as well as those that result in spills.

Table ES-2 shows the number of serious HM crashes and spills from crashes by HM Group that were analyzed in the second and third columns and provides an estimate of the number HM crashes and spills by HM Group that might be obtainable if all the HM crashes for 2002 were analyzed. Note that the estimates are actually based on vehicle-involvements and not crashes and spills directly. For example, if a crash involved two separate vehicles carrying hazardous materials, then that crash would have two vehicle involvements. As the number of such cases (four) is very small, treating the estimated totals as if they represented crashes and spills does not affect any results.

Table ES-1. Explanatory Variables Used in the HAZMAT Database

Vehicle	Driver	Packaging	Infrastructure	Situational
Configuration	Age	Package Type	Road Surface	Pre-Crash Condition
Cargo Body	Experience	Quantity Shipped	Road Condition	Dangerous Event
GVW	Condition	Quantity Lost	Road Type	Vehicle Speed
		Age (Cargo Tank)	Trafficway	Impact Location
		Rollover Protection	Access Control	Primary Reason
		Inspection History	Speed Limit	Accident Type
		Design Specification	# of Lanes	Weather Condition

In addition to the aggregate dataset that uses data from all the HM Groups, several HM groups, specifically 2.1, 2.2, 3, 5, 8, and 9, contained sufficient data to perform crash-level analyses. However, only Class 3 contained a sufficiently large enough sample to perform a HM class-specific spill analysis based on motor carrier HM crash data for a single year. It was therefore concluded that obtaining crash data for more than one year would be necessary to enhance the ability to perform HM class-specific spill analyses.

Table ES-2. Sampled Crashes by HM Group

HM Group	Description	Analyzed Crashes		Estimated 2002 Totals	
		Crashes	Spills	Crashes	Spills
1.1 - 1.6	Explosives	19	2	21	2
2.1	Flammable Gases	148	14	256	21
2.2	Non-flammable Gases	60	8	102	12
2.3	Gaseous Poisons	11	1	18	2
3.0	Flammable Liquids	544	125	914	182
4.1 - 4.3	Flammable and Reactive Solids	7	2	8	2
5.1 - 5.2	Oxidizing Materials	31	9	36	10
6.1 - 6.2	Poisonous and Infectious Substances	14	2	16	2
7.0	Radioactive Materials	4	2	4	2
8.0	Corrosive Liquids	75	16	139	23
9.0	Miscellaneous Hazardous Materials	57	23	86	27
Unknown	HM Group could not be determined	17	5	28	9

Selected analysis results are organized into the following categories: Vehicle, Driver, Packaging, Infrastructure, and Situational.

Vehicle

- Across all vehicle configurations, the spill percentage increases as trailers are added to the configuration. Straight trucks with trailers have a spill-to-crash ratio of 22.9 percent, versus 15.4 percent for straight trucks alone. Tractors with two or more trailers have a spill-to-crash ratio of 21.3 percent, versus 18.6 percent for tractors with a single trailer.

- The most common vehicle configuration used in transporting hazardous materials involved in crashes is the tractor/semi-trailer. This configuration is involved in 60 percent of all crashes. The next most common configuration involved in hazardous material crashes is the straight truck, being involved in 30 percent of all crashes. The tractor/semi-trailer configuration is the dominant vehicle configuration for all classes of hazardous material except for Division 2.1, where 69 percent of the crashes involve the straight truck configuration.

- The straight truck vehicle configuration has a somewhat lower spill to crash ratio than the tractor/semi-trailer configuration, 13 percent versus 18 percent, respectively. This lower ratio is not because of the vehicle configuration but because the straight truck configuration is dominated by Division 2.1 shipments, which have a significantly lower spill-to-crash ratio, 8 percent versus 18 percent, respectively.

Driver

- The average age of a hazmat driver involved in a crash was 44. Examining spill percentage (the weighted number of spills divided by the weighted number of crashes) as a function of driver age shows that the highest category was the *18 to 24* year-old group at 32 percent, the next was the *greater than 65* year-old group at 27 percent. Even though they represented the largest segment of the driver population, middle-aged drivers all had a below-average spill percentage with the lowest being the *45 to 54* year-old group at 14 percent. Essentially, the spill-to-crash ratio by driver age follows an upside-down bell shaped curve, with drivers 45 to 54 years old having the lowest rate of spills.

- A serious HM crash is likely to be more severe if it involves a driver with less experience (see Figure ES-1). Inexperience often leads to problems with recognition and decision-making. Using the spill percentage (the weighted number of spills divided by the weighted number of crashes) as an indicator of severity for the crashes in which driver experience was obtained, spills occurred in about 20 percent of the crashes. However this percentage is close to 30 percent for drivers with less than three years experience and about 10 percent for drivers with more than six years experience. While the data were limited, there is a clear trend toward a lower percentage of crashes that result in a spill as driver experience increases.

- Spills occur in approximately 18 percent of all HM crashes. In over 94 percent of all HM crashes, the driver *appeared normal* and the spill percentage was about 15 percent. Based on the limited data available for drivers whose driving ability is physically or mentally impaired, the percentage of crashes with spills when the driver was *ill, fatigued,* or *asleep* increased to about 30 percent and increased to above 50 percent when the driver was *under the influence of drugs or alcohol.* There was also an *unknown* category with an even higher spill percentage. In reviewing several of these HM crashes, the driver condition at the time of the crash was *unknown* because the driver was fatally injured in the crash.

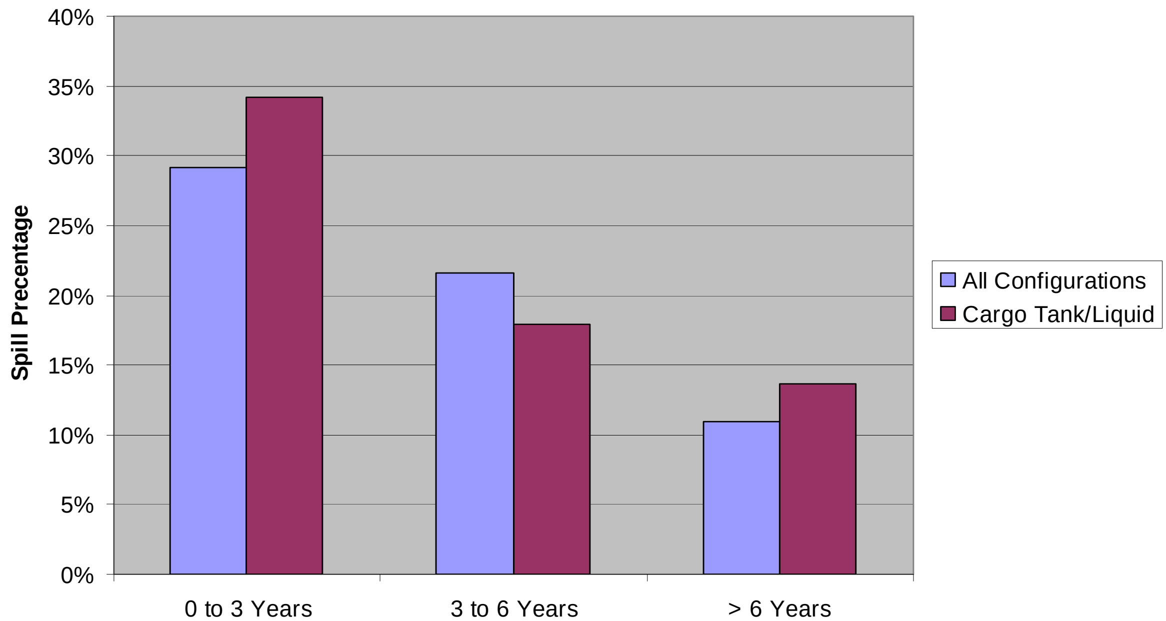

Figure ES-1. Cargo Tank Spill-to-Crash Ratio versus Driver Experience

- There is an extremely low spill-to-crash ratio for crashes where the primary reason is "other vehicle induced," in contrast to a relatively high spill-to-crash ratio when driver error is involved. Although crashes occur frequently where the other vehicle is at fault, spills are far more likely to occur in crashes where the truck driver is at fault.

- Of all serious crashes, 26 percent are single-vehicle crashes that involve only the hazmat vehicle. Of those single-vehicle crashes, *driver recognition, decision,* and *performance* errors were judged to be the primary cause of 66 percent of crashes. If *driver non-performance* (about 9 percent of the total) is added, then almost 75 percent of the single-vehicle crashes are the result of driver error. In multi-vehicle crashes, the other vehicle was responsible for over 60 percent of the crashes. However when the hazmat vehicle is responsible for the crash, the primary cause is listed as *driver decision error* in over 85 percent of the crashes.

Packaging

- When the DOT406 specification tank was involved in a serious crash, hazardous material was spilled 13 percent of the time as compared to MC306 tanks, which experienced spills 20 percent of the time. The difference is even larger when comparing the DOT407 and MC307 specification designs. With these two designs, spills occurred in 26 percent of the crashes involving the DOT407 and 37 percent of the crashes involving the MC307. The introduction of the DOT406 and DOT407 designs have clearly enhanced container integrity. This relationship is shown in Figure ES-2.

- The annual estimate for the number of crashes for MC306 cargo tanks is 2.2 times that of DOT406 cargo tanks (283 and 130, respectively). With the assumption that the crash rates for these cargo configurations are relatively equal, this implies that the DOT406 containers have not fully penetrated the market.

- The spill-to-crash ratio is higher for crashes where the impact occurred in the HM cargo region. Impacts in the cargo region resulted in spills in 23 percent of crashes; whereas, impacts elsewhere resulted in spills in 12 percent of crashes. As expected, a direct impact on the HM cargo region would subject the cargo body and/or packaging to a more severe impact, increasing the likelihood of a breach of the packaging and resulting in a release of the hazardous material to the environment.

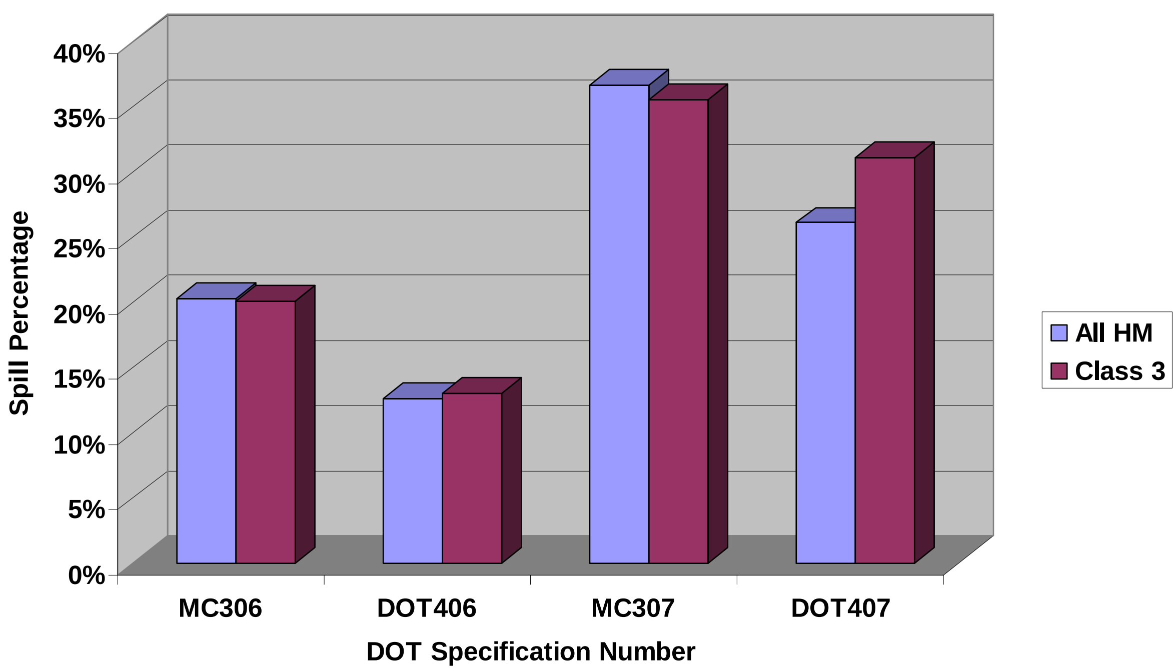

Figure ES-2. Spill Performance versus Cargo Tank Specification

- Seventy-eight percent of all spills involved cargo tanks, which is slightly lower than the percentage of all crashes they comprise (85 percent).

- Of serious cargo tank crashes, 25 percent are single-vehicle crashes. The single-vehicle crashes account for 66 percent of the spills, 76 percent of the rollovers, and 77 percent of the crashes that result in both rollover and spill. This cargo configuration is commonly used for Class 2, 3, 8, and 9 shipments. Driver recognition and driver performance errors were frequently listed as the primary cause for these single-vehicle crashes.

- Rollovers occur in approximately 22 percent of all HM serious crashes involving cargo tanks. An analysis of rollover percentage as a function of the loading (empty, part full, and full), showed a linear increase in the tendency to rollover based on the quantity of cargo. Empty tanks were least likely and full tanks most likely to rollover. Although partial loads rolled over at a higher rate than trucks carrying empty tanks, they appear to be more stable than the full tanker loads. The data indicate that rollover stability is most closely correlated with the vehicle's center of gravity. That is, the higher the center of gravity (as in a full tanker truck) the more likely the vehicle is to rollover. HM tanker truck rollovers are especially important for safety and risk analyses because there is a very strong correlation between rollovers and spills. One of the most likely locations for a rollover is on entrance and exit ramps, in which more than 87 percent of all rollovers result in a spill.

<u>Infrastructure</u>

- Spills occur in about 14 percent of the serious crashes on Interstates. On average, however, spills occur in 18 percent of all crashes. This slight difference may be attributable to design elements associated with Interstate construction such as medians, shoulders, and guardrails that reduce the likelihood that a truck will be involved in a rollover. The results show that rollover events occur in 19 percent of all crashes on Interstates, compared to an average of 23 percent when considering all road types.

- On divided highways there are about 15 hazmat spills for every 100 crashes. This low spill rate is counterbalanced by the high spill rate on entrance and exit ramps, almost 50 hazmat spills per 100 crashes. On undivided highways, there are about 20 hazmat spills per 100 crashes, just slightly above the average of 18 hazmat spills per 100 crashes. The lower spill rate for divided highways is to be expected given the high correlation between Interstates and divided highways.

<u>Situational</u>

- Two pre-crash conditions dominate, *in traffic lane* and *maneuvering*. Maneuvering is defined as any driver activity involving changing lanes such as passing or turning as well as going around a curve. *In traffic lane* is the pre-crash condition for over 70 percent of all crashes and leads to about 65 percent of all spills. While *maneuvering* is the primary cause for fewer crashes (about 25 percent), it results in a larger percentage of the spills (about 35 percent). One plausible explanation is that a crash that begins with a driver performing a maneuvering action is more likely to lead to the driver losing control of the vehicle, resulting in a *rollover*. While *rollovers* occur in only 24 percent of all hazmat crashes, they account for over 75 percent of all spills.

- Only 25 percent of all serious crashes are single-vehicle crashes. However, over 60 percent of all spills result from single-vehicle crashes. As shown in Figure ES-3, 60 percent of all crashes are multiple-vehicle crashes that occur while the hazmat vehicle is within the traffic lane. These dominate the crash total. The multiple-vehicle maneuvering crashes, and the single-vehicle crashes that occur while maneuvering and when within traffic lanes are more equally distributed, each contributing about equally to the crash total. Spills occur in approximately 18 percent of all crashes and the contributions are about equal (about one-third each) from single-vehicle crashes that occur while the vehicle is in its traffic lane, single-vehicle crashes that occur when maneuvering, and multiple-vehicle crashes that occur while the vehicle is in its traffic lane.

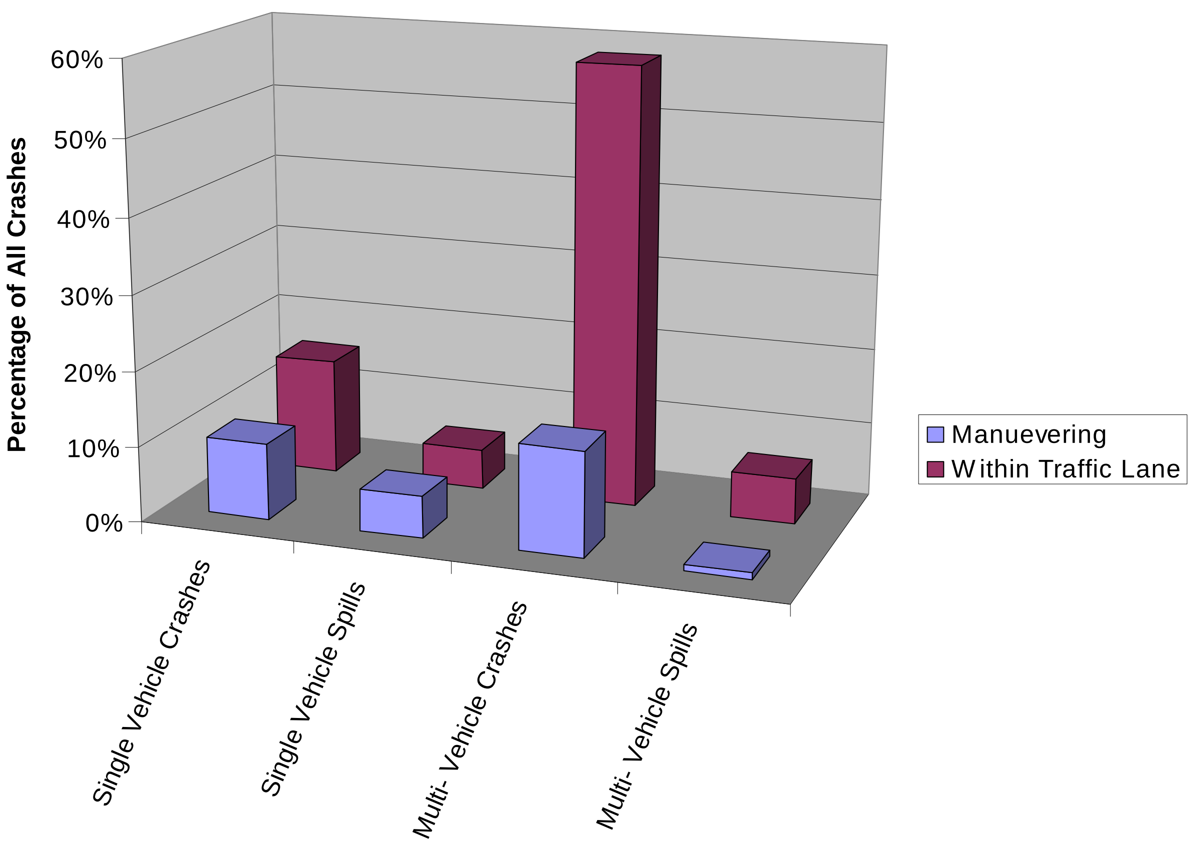

Figure ES-3. Statistics for Selected Pre-crash Conditions

- Data analysis confirms the widely held belief that the spill-to-crash ratio is significantly higher for rollover events than for other crash types. Figure ES-4 quantifies the probability of spills in all crashes and in crashes with rollovers for all hazard classes and for Class 3 crashes. The lower spill probability for all tanks is probably attributable to the differences in tank designs, Class 2 tanks typically being more robust because they must contain either a low temperature liquid or a gas under pressure. With more data, it might eventually be possible to examine the effect of the tank specification on the spill probability in rollover and non-rollover crashes. Keeping the HM truck upright appears to be an important mitigation strategy for preventing serious consequences in a hazardous materials crash.

- The data also show that the spill-to-crash ratio increases for cargo tanks as their loading increases, with fully loaded tanks resulting in spills 34 percent of the time.

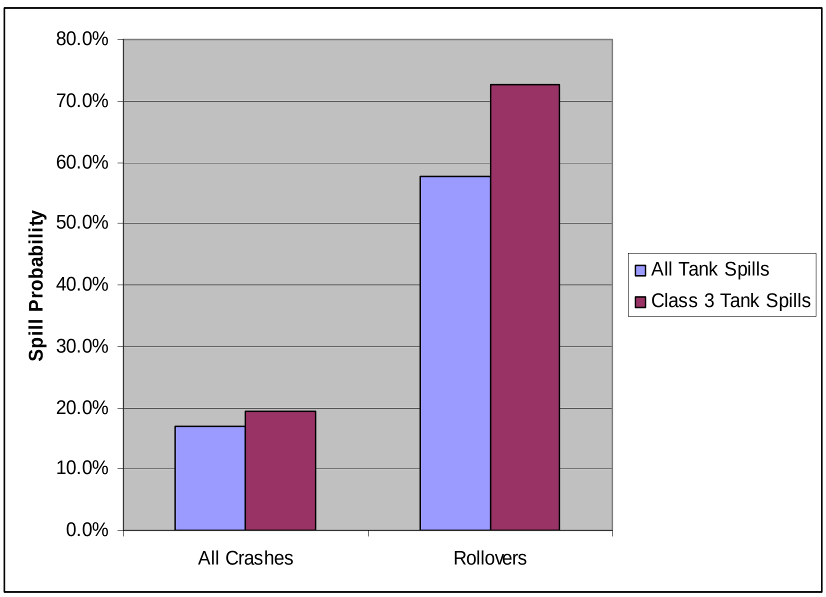

Figure ES-4. Comparison of Class 3 Tank Crashes and Those Involved in Rollovers

Data Collection Challenges

Beginning with the Motor Carrier Management Information System (MCMIS) Crash file for records entered in calendar year 2002, the project team performed the following data collection procedures:

- Of the approximately 105,000 serious crashes reported in MCMIS for 2002, identified approximately 2,100 MCMIS crash records involving hazardous materials, electronically transferred these MCMIS crash records into the HAZMAT Accidents Database, and requested Police Accident Reports (PARs) from the respective states where the crashes occurred.

- Identified approximately 100 crashes that were also reported to the Hazardous Materials Information System (HMIS) database maintained by the Research and Special Programs Administration and electronically transferred the data into the HAZMAT Accidents Database.

- Initially selected 1,000 crashes reported to MCMIS and using the PAR for each, validated the information electronically transferred from MCMIS and filled in blank records. Partway through the process, it was realized that there were many non-HM crashes in the 1,000 that were selected and an additional 260 were selected to bring the number of HM vehicles to be analyzed back up to nearly 1,000 cases. For the 1,260 selected crashes, the fields unique to the HAZMAT Accidents Database were populated for all the vehicles that were carrying hazmat. Data were entered for 966 hazmat crashes that involved 970 hazmat vehicles. Since some of these vehicles carried multiple types of hazardous material, over 1,000 hazardous material records were associated with these 970 vehicles.

- Validated and supplemented the data by corresponding with the involved carriers using telephone calls, faxes, and e-mails.

In implementing these procedures, PARs were requested from every state. Five states were not able to provide copies of their PARs. Of the states that did provide PARs, twenty-six had commercial vehicle supplements to the PARs; however, four states did not provide the supplements with the PARs. The supplements typically provided more detailed cargo and vehicle information than was obtainable from the PARs of states without supplements. However, these supplements were not consistent from state to state.

A significant project finding is the amount of revision required for MCMIS Crash file data to obtain an accurate portrayal of the number and types of hazardous materials involved in serious truck crashes. For example, as shown in Table ES-3, the initial assignment of hazard class to vehicle crashes based on MCMIS Crash file data differed significantly from the final assignment of hazard class to vehicle crashes once the HAZMAT Accidents Database was finalized. Overall, about 20 percent of the crash records were re-assigned to a different hazard class as a result of a PAR review and another 20 percent were found to involve no hazardous material.

The data collected in this project significantly enhances MCMIS HM crash information. In addition to filling in blank fields and correcting erroneous entries, populating fields such as Pre-crash Events, Primary Reasons, and Impact Location provided a much more detailed description of HM vehicle crashes. These additions created a substantially broader and more accurate information base for the analysis of HM motor carrier safety.

Many useful analyses can be performed using the larger data set collected during phase two. While limitations remain because, even with 1,000 records, many conditions rarely occurred, the increased accuracy gained using the consistent dataset means that fewer crashes will have to be recorded before conditions affecting safety can be identified and shown to be significant.

Table ES-3. Comparison of Initial HM Classification using MCMIS and the Final Classification for HM Vehicles

HM Class	MCMIS	HAZMAT Database
1	50	19
2	139	235
3	569	553
4	16	7
5	27	31
6	14	14
7	8	5
8	67	78
9	78	58
Unknown	289	15
Non-HM	None	242
Total Vehicles	1,257	1,257

Conclusion

The HAZMAT Accidents Database design and data entry system provides a methodology by which HM crash data can be collected, validated, and utilized in support of motor carrier safety policy analysis. The data collection process utilizes MCMIS as the originating source, and then enhances the accuracy, completeness, and breadth of crash records, by incorporating information collected from other sources. As a result, it is possible to identify significant findings with fewer crashes as well as enabling more comprehensive safety analysis to be performed.

By populating the HAZMAT Accidents Database with a crash sample of nearly 1,000 records, enhanced capability already exists from which the cause and effect of HM crashes can be evaluated. The results of the data analyses confirm that the enhancement of the data in the MCMIS Crash file leads to insights into the safety and risk aspects of HM transportation that could not be made by analyzing the MCMIS Crash file alone. Simultaneously, because the data being analyzed are more complete and extensive, it is possible to place greater confidence in analysis results because they no longer rely exclusively on the original MCMIS crash records. In some cases, the results simply confirm widely held beliefs, while in other cases, completely new findings have been realized.

Selected analyses compared the results for Class 3 crashes with overall results and others compared cargo tank crashes with overall results. Such analyses clearly show the types of studies that could be performed for other package types and for other HM classes/divisions had more data been available. Because fewer crashes occur in these other packagings and hazardous material groups, such findings and insights will only be realized by collecting HM motor carrier crash data for more than one year. An added benefit of this approach would be the ability for FMCSA to monitor HM crash trends over time.

1.0 Introduction

Battelle and its subcontractors[1] are conducting the Hazardous Materials Serious Crash Analysis project for the Federal Motor Carrier Safety Administration (FMCSA). This project has three basic purposes:

- Enhance the current methodology for identifying and characterizing serious hazardous material (HM) truck crashes in the United States.
- Improve the capability to analyze causes and effects of selected serious hazardous materials crashes.
- Support the implementation of hazardous materials truck transportation risk reduction strategies for packagings, vehicles, and drivers.

The project has been conducted in two phases. Phase I was a pilot test to evaluate the feasibility of enhancing the current approach for serious HM truck crash identification, data collection and analysis. In Phase II, more comprehensive data collection and analysis were performed based on the results of Phase I, leading to a more formal assessment of HM truck crash cause and effect.

This report presents the results of Phase II. In this phase, the major purpose was to take the Motor Carrier Management Information System (MCMIS) Crash file for serious crashes occurring in 2002, extract the crashes that involve hazardous materials and, for a sample of 1,000 HM crashes, supplement the data in MCMIS with information from other sources. These sources included the Hazardous Materials Information System (HMIS) database maintained by the Research and Special Programs Administration (RSPA), Police Accident Reports (PARs) filed by individual states, and direct correspondence with the involved carriers.

Sample crash information was input and stored in the HAZMAT Accidents Database, a specially designed database that enabled the aforementioned information sources concerning a particular crash to be assembled into as complete a record as possible, both in terms of characteristics describing the crash event, as well as the accuracy of the information itself. Extensive database protocols and quality control checks were employed to accomplish this objective. Once the database development task was complete, analyses were performed on the database for the purpose of providing useful information that might support the development of more rigorous HM truck safety policy.

This report summarizes the process of designing the database, selecting the crash sample, collecting and compiling crash information from multiple sources, validating the data and performing crash analyses. In some cases, sufficient data could not be obtained using a one-year sample of HM truck crashes to explore the full potential of this tool in performing safety analyses. However, several analyses considered to be statistically credible were performed on the selected sample to demonstrate the current analysis capabilities and to outline the tool's future analysis potential.

[1] The Battelle team consisted of Battelle Memorial Institute (Battelle), University of Michigan Transportation Research Institute (UMTRI) and Visual Risk Technologies, Inc. (VRT).

2.0 Database Development

2.1 Database Design

The HAZMAT Accidents Database was designed to capture and augment information about crashes involving hazardous materials contained in MCMIS and HMIS records. Organized as a relational database, it also stores supplemental data obtained from the PARs and from phone calls to the carrier or other key persons involved in the crash. What follows is a brief summary of the database design. A more detailed description appears in Appendix A. It should be noted that the terms *crash*, *accident*, and *incident* are used interchangeably in this report.

The starting screen presents the user with several options (see Figure 2-1). The “Incident Notification” button initiates data entry for a crash. “UN Numbers” stores the four-digit UN Number that is used internationally to uniquely identify a specific material. UN Numbers are comprised of a two-digit HM Code and a two-digit division code. “Commodities” holds the definition of a particular commodity, the two-digit HM code, UN number, short and long name, the reportable quantity (RQ) limit[2], and if the material is “poisonous by inhalation[3].” The basis for this information is the Hazardous Materials Table presented in 49 CFR 172.101. “Accident Record Status” summarizes the completeness of the records and enables access to a Status Summary of all crashes entered into the database. “Agencies” contains the name of the agency providing the crash information. “DOT Numbers” supports entry of a carrier’s DOT number[4], address, phone number and fax number. “Packages” consists of the name and description of the packaging that was used for the HM shipment (e.g., MC 307 cargo tank).

The “Incident Notification” selection has several additional screens used to fully describe the crash sequence and associated details. The initial Incident Summary screen contains basic information on the accident record number, date, time and a description of the accident, commonly entered from the PAR. There are also buttons on the bottom of the Incident Summary screen that provide various editing functions such as printing a summary of the incident and deleting an unwanted record. Subsequent screens, shown as tabs on the Incident Summary screen, provide information on the Location, Incident Details, Agency Response, Vehicles Involved, Fatalities/Injuries and Notifications. Under the Vehicles Involved tab, there are additional tables for entering Carrier, Driver, Hazmat, and Event Detail information.

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[2] Reportable quantity is the amount of a *hazardous substance* under section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. 9601(14) (CERCLA; 42 U.S.C. 9601 et seq) that triggers additional requirements during transportation (49 CFR 172.101, Appendix A).

[3] Poisonous (or toxic) by inhalation refers to a material which is a gas at 20°C (68°F) or less and a pressure of 101.3 kPa (14.7 psia) (a material which has a boiling point of 20°C (68°F) or less at 101.3 kPa (14.7 psia)) and which is either known to be or is presumed to be so toxic to humans as to pose a hazard to health during transportation (49 CFR 173.115).

[4] DOT numbers are assigned by FMCSA to registered motor carriers. [Intrastate carriers can have DOT numbers; all carriers shipping placarded quantities of hazmat are required to register with the Pipeline and Hazardous Materials Safety Administration (PHMSA).]

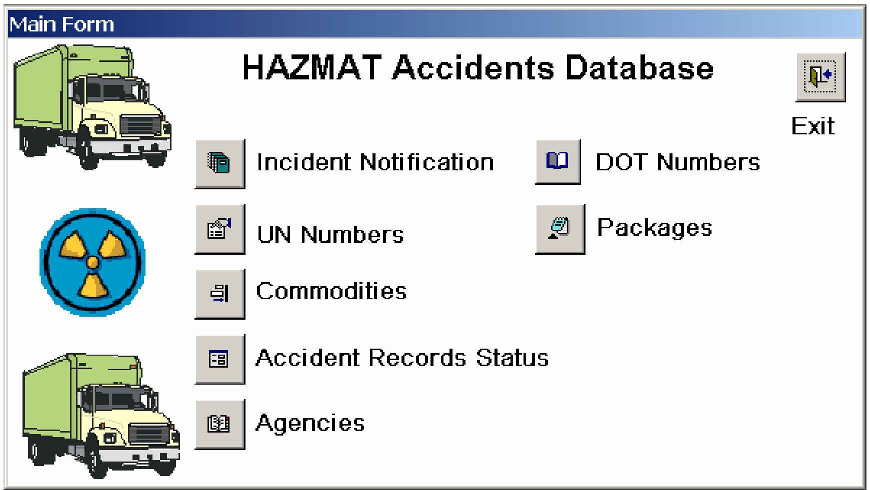

Figure 2-1. Main Database Entry Screen

The most common way to enter a crash record into the database was by importing information from the MCMIS Crash file or HMIS database, and then modifying/augmenting the record with content from the PAR and through carrier correspondence as the information became available. This process was aided by the availability of pick lists containing eligible entries for particular fields.

2.2 Selection of Crash Records

The process of selecting records to include in the HAZMAT Accidents Database is explained in detail in Appendix B. What follows is a summary description of this activity.

The process began with the roughly 105,000 MCMIS records for vehicles involved in crashes for calendar year 2002 obtained from FMCSA. Each MCMIS crash record contains five fields that could be used to indicate whether the crash involved a truck carrying hazardous materials. These are described in Table 2-1.

Table 2-1. Hazardous Material MCMIS Parameters

Parameter Name	Description	# Entries
HAZ_PLAC	"Y" if shipment is placarded	1,293
HAZ_1DIG	Single-digit HM class	13,451
HAZ_4DIG	Four-digit UN number	1,521
HAZ_NAME	Commodity name or hazard	830
HAZ_CARGO	"Y" if cargo was lost in accident	422

Table 2-2 presents the current hazardous materials classification system used in the U.S. There are nine primary hazard classes and, with their divisions, comprise 19 distinct categories. The four-digit UN numbers are used internationally to uniquely identify specific materials. UN numbers are assigned by the United Nations' Economic and Social Council Committee of Experts on the Transport of Dangerous Goods. It is possible for two shipments of materials with the same UN number to be shipped as different classes. One example is molten sulfur, UN2448, which is shipped domestically as a Class 9 material and internationally as a Division 4.1 material.

Table 2-2. Hazardous Material Classifications

Class 1 – Explosives
Division 1.1 Explosives with a mass explosion hazard
Division 1.2 Explosives with a projection hazard
Division 1.3 Explosives with predominantly a fire hazard
Division 1.4 Explosives with no significant blast hazard
Division 1.5 Very insensitive explosives with a mass explosion hazard
Division 1.6 Extremely insensitive articles
Class 2 – Gases
Division 2.1 Flammable gases
Division 2.2 Non-flammable, non-toxic (non-poisonous) gases
Division 2.3 Toxic (poisonous) gases
Class 3 – Flammable liquids and Combustible liquids
Class 4 – Flammable solids; Spontaneously combustible materials; and Dangerous when wet materials/Water-reactive substances
Division 4.1 Flammable solids
Division 4.2 Spontaneously combustible materials
Division 4.3 Water-reactive substances/Dangerous when wet materials
Class 5 – Oxidizing substances and Organic peroxides
Division 5.1 Oxidizing substances
Division 5.2 Organic peroxides
Class 6 – Toxic (poisonous) substances and Infectious substances
Division 6.1 Toxic (poisonous) substances
Division 6.2 Infectious substances
Class 7 – Radioactive materials
Class 8 – Corrosive substances
Class 9 – Miscellaneous hazardous materials/Products, Substances or Organisms

For calendar year 2002, there were approximately 200 MCMIS records where all five parameters listed in Table 2-1 were filled out. In general, if the shipment was placarded, one of the other entries was filled out, making it slightly easier to identify possible hazmat crash records. The single-digit HM class parameter had over 13,000 entries. Of those entries, over 12,400 contained a value of "9", which could be interpreted to mean that a Class 9 Miscellaneous Hazardous Material was being shipped or that the commodity being shipped was *unknown*. The number of "9" entries so far exceeded any previous estimates of the number of annual Class 9 shipments that a "9" entry in this field could not be considered as a basis for identifying a hazmat crash. There were also over one hundred "0" entries in the HAZ-1DIG field. These were normally accompanied with entries in other fields, enabling the "0" to be reassigned to the correct hazard class. Ultimately, the list of potential hazardous material vehicles involved in crashes was estimated to be about 2,059 based on the values entered in these five fields. These considerations are fully discussed in Appendix B.

The next step was to cross-correlate the MCMIS records with HMIS records using the crash date and carrier name. An additional 29 new vehicles were identified in this manner. In examining the MCMIS records for these crashes, none had an entry in any of the descriptive fields, commodity name, one-digit hazard class number, or four-digit UN Number. At best, they had a value of “N” in the placard field. The lack of any triggers to indicate that the shipment was hazardous explained why the records were not initially selected using the MCMIS entries. Thus, out of roughly 105,000 MCMIS crash records reported in 2002, 2,088 were identified as truck crashes involving hazardous materials. For all 2,088 cases, Police Accident Reports (PARs) were requested from the states.

Unfortunately, it became readily apparent that this selection process did not identify all of the hazardous material truck crashes that occurred in calendar year 2002. While the 2002 MCMIS database contained over 100,000 truck records, there were wide variations in the number of records provided by individual states. For example, there were nearly 5,000 crash records reported for Ohio and only 20 for Pennsylvania. There is also evidence that the number of HM crashes was grossly underreported by some states. Texas, for example, reported nearly 11,000 truck crashes into MCMIS, yet none were identified as involving hazardous materials. It was subsequently discovered that Texas has a truck supplement page in its accident report that addresses whether hazardous cargo was involved, but this information was never entered into MCMIS. This MCMIS reporting oversight was apparently true for several states. Given such wide reporting variability among the states, it is clear that well over 2,000 hazardous materials truck crashes occurred in the country during the one-year period of observation.

The final step was to select 1,000 crashes for more detailed analysis. For the purpose of trying to achieve statistical confidence in analyzing crashes across all HM groups, it was decided to select all vehicles involved in Class 1, 4, 5, 6, and 7 crashes. This represented 155 vehicles. Crashes reported in the HMIS database were all selected as well. In the end, 781 hazmat vehicles were randomly sampled from among the remaining 1,869 hazmat vehicles.

This breakdown of crashes into HM groups was considered to be preliminary because it was developed using the aforementioned hazmat fields in the MCMIS Crash file which were often left blank. The inaccuracy of the selection was soon realized when not all states supplied the requested PARs and the sample size was 77 short. Then, a first reading of the remaining sampled PARs revealed that an additional 183 did not involve any HM cargo. As a result, an additional 260 crashes were randomly selected from among the remaining PARs to bring the total analysis sample back to 1,000 hazardous material crashes. When all of the PARs for the second sample of 260 were analyzed, many more were found not to involve hazardous materials. Ultimately, the final analysis sample consisted of 970 hazmat vehicles. Since several of these vehicles were found to be carrying multiple hazardous materials, the total number of hazmat records included in the analysis was 1,012.

2.3 Populating Crash Records

Once the sample of crash records considered likely to involve hazardous materials had been selected, the first step was to import the relevant fields from the MCMIS Crash file into the Incident table of the HAZMAT Accidents Database (see Appendix C). In addition to distributing the parameters across the Incident table, information from the MCMIS Crash file was also placed in the Vehicle, Hazmat, Driver, and Hazmat Packaging tables.

A similar process was used for any crashes with an HMIS record. Because the HMIS fields are more fully populated, any fields in the database that were common to HMIS and MCMIS were overwritten by the HMIS information. The remaining HMIS information was also incorporated into the database.

The next step was to input PAR data. As the information was being filled in from the PAR, the data entry form showed the default values for any parameters that were previously entered based on information supplied by MCMIS and HMIS. Any inconsistencies were changed to reflect the information contained in the PAR. Frequently the changes were not inconsistencies but expansions of the data. For example, many PARs list the actual Gross Vehicle Weight of the vehicle and, in those cases, that number was input in place of a broad weight category.

The final step in populating the HAZMAT Accidents Database involved entering information obtained through direct correspondence with the involved carrier. The most valuable benefit from these calls was in verifying the accuracy of the entered information. Then, the conversation was directed at information that only the carrier could supply, such as the amount of material being shipped; whether there was a spill and, if so, how much; the manufacturer and specification number of the packaging; and the year the packaging was fabricated. In the case of shipments with multiple packages, packaging details were difficult to obtain. However, for cargo tanks, the situation was much different. Carriers were frequently able to provide the DOT specification number for the tank, the year it was manufactured, the manufacturer, type of rollover protection on the cargo tank, and the inspection history. Many could estimate the amount of material being shipped and if any was spilled. The type of damage to the cargo tank could sometimes be recalled, usually only if there was a spill. Most carriers were also willing to provide information on the driver's experience.

Overall, responses were received from about two-thirds of the carriers. Some carriers did not consent to providing the information, typically for legal reasons. In other cases, consent was given, but the information was never provided despite several inquiries. While the process was time consuming, much useful information was obtained.

2.4 Quality Control Checks

Several quality control checks were built into the data collection process. Additional details on the type and extent of the quality checks are provided in Appendix B.3. Accuracy checks were performed at three critical junctures: (1) after the data from the PAR was entered for the crash, (2) after the carrier calls were completed and (3) whenever a reviewer changed a pre-existing database entry. Special efforts were also made to identify and reconcile blank fields. In addition, error-trapping queries were run to identify reporting inconsistencies (e.g., Interstate highways that were not flagged as limited/controlled access). Finally, summary reports were generated of each recorded crash to use in reviewing the entered information or to use as a reference during carrier correspondence.

2.5 Projected Distribution of Crashes by HM Group

The sampling plan selected all Class 1, 4, 5, 6, and 7 vehicles and randomly sampled vehicles from the remaining HM groups. As a result, weighting factors are necessary to extrapolate any analysis findings to the entire population of HM vehicles. The process of developing the weighting factors was difficult because of the number of crashes where the class of hazardous material was initially unknown, in addition to cases where the MCMIS-reported HM group was inaccurate. The hazardous material class was changed as more accurate information became available. Note that the annual crash and spill estimates are actually based on vehicle-involvements and not crashes and spills directly. For example, if a crash involved two separate vehicles carrying hazardous materials, then that crash would have two vehicle involvements. In the cases analyzed, the number of such cases (four) is very small and treating the estimated totals as if they represented crashes and spills does not affect any results. Slightly more cases (38 vehicles) involved more than one hazardous material being carried on the same vehicle, which could lead to some double-counting when conducting an analysis across multiple HM groups. In performing the spill analyses, another potential reporting inaccuracy was noted. There is no way to distinguish between loss of a package from a vehicle and loss of hazardous material from the package. Both are coded as spills in MCMIS and in the PARs. This was most evident with the two Class 7 crashes that resulted in spills. In both cases, the crash released packages from the semi-trailer but no radioactive material was released from the packages. In this report, the release of the Class 7 packages during the crash was classified as a spill.

Table 2-3 shows how the vehicles in each crash were initially assigned to HM groups and how they were reassigned following PAR and carrier input.

Table 2-3. Initial and Final Allocation of Vehicles to HM Groups

MCMIS one-digit HM Code	Initial HM Cases from MCMIS	Cases Found to be non-HM	Final HM Group Based on PAR Information and Carrier Correspondence												
			1.1 - 1.6	2.1	2.2	2.3	3.0	4.1 - 4.3	5.1 - 5.2	6.1 - 6.2	7.0	8.0	9.0	Unknown	Total
1	50	9	15	3	2	1	11		1	2		4		2	41
2	232	33		126	51	5	10		2			2		3	199
3	569	69	1	4	7	1	465	1			2	2	17		500
4	16	1		1			3	5	1	2		1	2		15
5	27	3					3		21						24
6	14	4				1			1	8					10
7	8	4									3		1		4
8	67	6		2	1	1	3					51	3		61
9	78	0	1	4	4		24		1	1		6	33	4	78
Unknown	196	120	2	8	5	3	34		5			12		7	76
Total	1,257	249	19	148	70	12	553	6	32	13	5	78	56	16	1,008

In Table 2-3, the first column shows the one-digit HM codes that are assigned in MCMIS. The second column shows how the 1,257 HM vehicles that are being analyzed were initially coded. The columns to the right of the second column show the reassignment of HM classes after entering the PAR information and correspondence with the carrier. If no reassignments were necessary, then there would be only entries on the diagonal where the MCMIS code and the HM group match (3 and 3.0, for example) and all vehicles assigned a code of 2 in MCMIS would be distributed between the 2.1, 2.2, and 2.3 HM groups used in the analysis. Reallocations are shown by additional entries in that row. For example, of 50 crashes initially characterized as involving Class 1 materials, only 15 remained designated as Class 1 crashes after this process was completed, with the others being reassigned to different HM categories. Note also that the final number of Class 1 crashes (shown in the fourth column) was 19 because there was one Class 3 crash, one Class 9 crash, and 2 unknowns that were reassigned to Class 1. Overall, more than 20 percent of the crash sample required a change in the initial MCMIS hazmat class assignment based on the PAR information and carrier correspondence. There were only a handful of cases where the HM group was reassigned based on carrier correspondence, usually to non-hazmat. Most of the reassignments were the result of inputting information available in the PAR.

There are some instances of double-counting in Table 2-3. There were 10 crashes involving multiple heavy trucks where all the trucks were labeled as carrying hazardous materials. In 38 vehicles, multiple hazmat commodities were being carried and only one of the commodities was listed in the MCMIS crash file.

The MCMIS Crash file continues to be the basis for many transportation risk assessments. Consequently, it is useful to compare such analyses performed using the MCMIS data with the results obtained using the HAZMAT Accidents Database. It can be seen in Table 2-3 that many more crashes were reassigned from *Unknown* to an HM class in the HAZMAT Accidents Database, thereby expanding the sample size upon which analyses can be performed. Moreover, many crashes in MCMIS were assigned to the wrong HM class, introducing the potential for error in any analysis or safety study that would be relying on the accuracy of this information.

2.6 Removal of Sampling Bias using Weighting Factors

The most frequent hazardous material crashes involved Classes 2, 3, 8, and 9. While the goal was to develop more detail for 1,000 crashes, there was also a desire to obtain as much information as possible for crashes involving shipments for the less-commonly shipped materials in Class 1, 4, 5, 6, and 7 crashes. Thus, it was decided to include all the crashes associated with these rarer classes. The decision was also made to include all crashes for which complementary records could be identified in the HMIS database. Because of this over-sampling, any tables which show the distribution of crashes by hazard class will over-represent the rare classes and under-represent the more-commonly shipped classes. To remove this analysis bias, weighting factors were developed for each class of hazardous material based on the initial assignment of classes from the MCMIS crash file. The weighting factors that were developed are shown in Table 2-4. For the Class 1, 4, 5, 6, and 7 crashes, and the crashes identified from the HMIS, the vehicle weighting factor should be one since all these crashes have been analyzed. For Division 2.2, the sampled crashes represented half the Division 2.2 crashes that were identified using

MCMIS. Thus a weighting factor of 2 was applied to all the vehicle crashes which were initially assigned to Division 2.2 in MCMIS. This represents the assumption that among all the 2002 hazmat crash records identified using MCMIS, there was a second, identical crash record for the one that was sampled and analyzed.

The HM Classes shown in Table 2-4 are based on the initial hazmat class assignments using the MCMIS crash file. The entry “Unknown” represents the crashes where the MCMIS crash file indicated the vehicle was placarded or hazardous material was spilled but the HM class number, UN Number, or HM description fields were blank. Similarly, since both the MCMIS and PARs require only the single-digit HM Class number and not a two-digit HM Division number, if the UN Number fields or the descriptive fields were left blank it was only possible to specify the HM Class as “20” not “21”, “22” or “23.” Thus, all the entries have an entry with a “0” as a second digit in the HM Class column in Table 2-4. There is also a separate entry for crashes identified in HMIS, which were treated similarly to the rarer HM classes that were sampled at 100 percent.

Table 2-4. Weighting Factors Used to Remove the Sampling Bias from the Analysis

HM Class	Vehicle Weighting Factors
10	1.021
20	1.773
21	1.813
22	2.000
23	1.000
30	1.771
40	1.000
50	1.000
60	1.000
70	1.000
80	2.175
90	1.738
Unknown	1.776
HMIS	1.039

Once a weighting factor has been assigned to the vehicle crash record, it is not changed, even if after entering the PAR information. Thus, if a record was initially given a weighting of “1.773” because it was initially assigned to HM Class “20,” that weighting would be retained even after it was found to be a “23” or a “30” after entering the PAR information. While the weighting factors for the Class 1, 4, 5, 6, 7 crashes and those crashes identified from the HMIS should be one because all crashes were selected, it turns out that it was not possible to obtain the PAR for one Class 1 vehicle crash so the weighting factor for Class 1 was slightly greater than one to account for this unanalyzed crash record. Similarly, there were four HMIS records out of 106 for which the PAR was not obtained and the HMIS record gave a very incomplete description.

Thus, for the HMIS records, the weighting factor of “106/102” or “1.039” was used for all crashes that were reported to HMIS by the carrier.

2.7 Database Enhancements and Limitations

The fields in the HAZMAT Accidents Database reflect a list of parameters that are considered pertinent for safety analysis. While every effort was made to obtain relevant information, it was not expected that it would be possible to populate all of the fields. Nevertheless, significant improvements were made in the breadth and accuracy of HM crash information from which safety assessments can be performed.

These improvements are evident by comparing initial MCMIS tables with the completed HAZMAT Accidents Database. In addition to broadening the selection of eligible entries to many of the descriptive tables, new tables were also created that are not present in ether MCMIS or HMIS, such as Pre-crash Events, Primary Reasons, and Impact Location. Moreover, data collected from PARs and from carrier correspondence for nearly 1,000 MCMIS crash records enabled many MCMIS data fields that were initially blank to be populated. Appendix D shows a field-by-field analysis of these improvements for the Incident and Vehicle tables in the crash sample.

Despite the improvements, there remain fields that are largely blank. No PAR captured information on evacuations. Only one state, Kentucky, captured information on road closures. The vehicle speed was captured in roughly 50 percent of the PARs, and the trailer dimensions, length, and width could be obtained in only one-quarter of the cases. The other fields were filled out for more than 80 percent of the selected crashes and in some states that figure was 100 percent. Some states, such as California, have extensive PARs that provide information on all the key parameters as well as other parameters that might be of future interest. Roughly 60 percent of the states use a commercial vehicle supplement, designed to capture data required for the MCMIS Crash file. These supplements tend to have a uniform HM section that provides all the information needed to fill out the five hazardous material entries in MCMIS. Unfortunately, about 25 percent of the states that are known to have commercial vehicle supplements did not provide the supplemental form. When a state has a commercial vehicle supplement, almost all the useful information on the vehicle and cargo are removed from the standard sections of the PAR so failure to obtain these supplements resulted in many of the blank fields in the HAZMAT Accidents Database.

3.0 Crash Analyses

Crash analyses utilizing the HAZMAT Accidents Database focused on developing associations between impact measures and explanatory variables. Impact measures consisted of:

- Number of serious crashes
- Crashes resulting in spills, fatalities and injuries

For purposes of this analysis, the impacts associated with fatalities and injuries are not shown, except in limited cases to illustrate that relationships shown for spills do not necessary apply to fatalities and injuries. This crash and spill segmentation enabled the ability to examine the frequency with which certain types of crashes occurred as well as the subset that resulted in more serious consequences.

Several explanatory variables were identified to explore their effect on crash risk and outcome. Five types of explanatory variables were defined by the database:

Vehicle
- Configuration
- Cargo body
- GVW

Driver
- Age
- Experience
- Condition

Packaging
- Package type
- Quantity Shipped
- Quantity Lost
- Age (Cargo Tank)
- Rollover Protection
- Inspection History
- Design Specification

Infrastructure
- Road surface
- Road condition
- Road type
- Trafficway
- Access control
- Speed Limit
- # of Lanes

Situational
- Pre-crash condition
- Dangerous event
- Vehicle speed
- Primary reason
- Accident type
- Weather condition

The crash analysis process involved associating explanatory variables with impacts to determine how vehicle, driver, packaging, infrastructure, and situational characteristics influence crash occurrences in general, as well as those that result in serious outcomes (e.g., spills).

The distribution of crashes and those resulting in spills across HM groups using the HAZMAT Accidents Database is displayed in Table 3-1. Note that the annual crash and spill estimates are actually based on vehicle-involvements and not crashes and spills directly. For example, if a crash involved two separate vehicles carrying hazardous materials, then that crash would have two vehicle involvements. The number of such cases (four) is very small and treating the estimated totals as if they represented crashes and spills does not affect any results. Slightly more cases (38 vehicles) involved more than one hazardous material being carried on the same vehicle, which could lead to some double-counting when conducting an analysis across multiple HM groups.

As shown in Table 3-1, Class 3 crashes are prevalent, while some HM categories are sparsely populated. This is consistent with truck flow data; for example, the 2002 Commodity Flow Survey data show that Class 3 materials accounted for 61.5 percent of all hazardous materials truck ton-miles.[5] As a rule of thumb, if an HM group contained fewer than 25 records, it was felt that any additional analyses of these records would produce inconclusive information, because the sample size would be considered too small to yield a statistically significant finding. The exception to this rule would be when the impact differences are so large that significance can be demonstrated with fewer than 25 observations.

Using this criterion, the total number of crashes for HM groups 1, 2.3, 4, 6, and 7 were considered too small to warrant HM group-specific analysis. Although the contribution from these groups is shown in the tables in Appendix E, they have not been analyzed separately in any of the tables presented in this section. It should be noted that during database development, the selection process attempted to include every known crash in calendar year 2002 that fell into each of these HM groups. The absence of a large enough sample to support analysis purposes implies that crashes involving these types of shipments appear to happen infrequently enough that a multi-year sample is required to support meaningful study of these individual hazmat classes.

In addition to the crash- and spill-level analyses that were conducted using the entire sample, additional analyses were conducted on certain components, such as cargo type, or on crashes involving HM group 3 materials. As Table 3-1 indicates, HM group 3 is the only one with sufficient data to always support spill-related analyses. Additionally, in many cases there was no appreciable difference when analyzing all crashes or only those involving Class 3 materials. The data presented in this chapter only highlight Class 3 results where they differ from the overall trends.

It is also important to note that because some HM groups were sampled at 100 percent, comparative analyses among the HM groups would require the use of weighting factors such as those shown in Table 2-4. Because so few of the HM groups are sufficiently populated for any parameter using one year of data, only limited HM group comparisons using the weighting factors were performed in this analysis.

The discussion below presents the most significant of the analysis findings. Unless otherwise stated, the results are based on an analysis of all the crashes that have been analyzed, irrespective of their hazmat group. The weighting factors discussed in Table 2-4 have been used to remove any sampling bias from these overall analyses. The results presented in Appendix E represent a

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[5] 2002 Commodity Flow Survey, Hazardous Materials Extract, U.S. Bureau of the Census and U.S. Bureau of Transportation Statistics, Report No. EC02TCF-US(HM), December 2004.

complete set of analyses tables by HM Group, thereby presenting an estimate for all serious hazardous material truck crashes in 2002. The sampling bias has also been removed from these tables. In general, the reported analyses measure impacts across all sampled crashes and for HM groups. In selected cases where the parameter groups are well populated, results for individual HM Groups are also presented. Usually these group-specific analyses include just the Class 3 HM group.

Table 3-1. Sampled Crashes by HM Group

HM Group	# Crashes	# Spills
1.1 - 1.6	21	2
2.1	256	21
2.2	102	12
2.3	18	2
3.0	914	182
4.1 - 4.3	8	2
5.1 - 5.2	36	10
6.1 - 6.2	16	2
7.0	4	2
8.0	139	23
9.0	86	27
Unknown	28	9

3.1 Crash Severity

Figure 3-1 shows the percentage of crashes resulting in spills for single- and multi-vehicle crashes. Twenty-six percent of all crashes analyzed involved only a single vehicle and, of these, 43 percent resulted in a spill. Multiple vehicles were involved in 74 percent of the crashes analyzed and, of these, 9.7 percent resulted in a spill. Presented another way, 60 percent of all spills were in single-vehicle crashes and only 18 percent of the non-spill crashes involved only a single vehicle.

Figure 3-2 displays the percentage of crashes resulting in spills, respectively, by HM group. This is considered a good indicator of the distribution of crash severity because spills are generally associated with crashes deemed to have serious outcomes. Although, as mentioned above, spill-level analyses by HM groups other than group 3 would only be statistically significant if there was a large difference among them. The information presented in Figure 3-2 is illustrative of the distribution of the underlying data used in subsequent analyses. As noted, the percentage of crashes resulting in spills range from 10 to 30 percent depending on the HM group. Of particular interest is that HM group 9 is disproportionately represented in terms of spill involvement (5.3 percent of crashes and 9.4 percent of spills), implying that on a relative basis, crashes involving these hazardous materials are more likely to result in spills. On the other hand, materials in HM groups 2.1 and 2.2 have fewer spills than would be expected from the number of crashes involving these materials. The discussion below will delve into reasons that contribute to these findings.

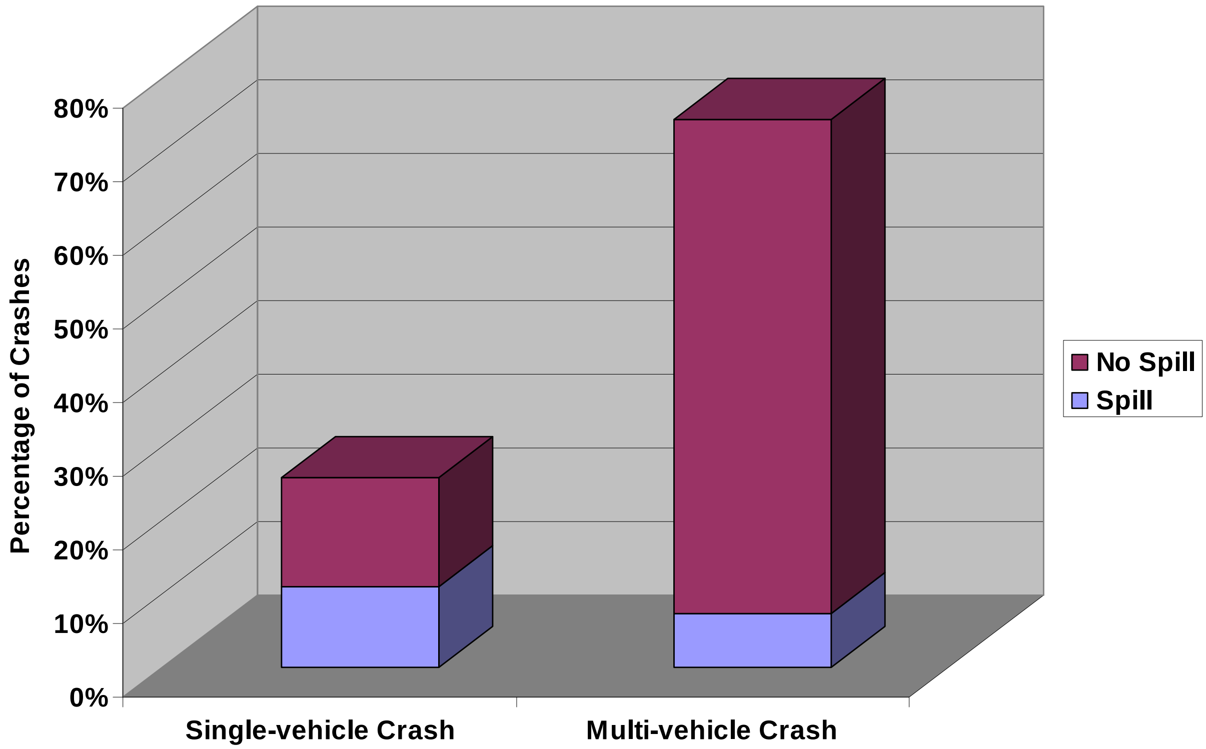

Figure 3-1. Single- and Multi-vehicles Crashes Resulting in Spills

3.2 Vehicle Characteristics

Analyses involving vehicle characteristics focused on two variables: (1) vehicle configuration and (2) cargo body type. Analyses of vehicle characteristics associated with HM crashes were performed across the HM groups by removing the sampling bias. Isolated analyses of just cargo tanks were also performed across HM groups and for Class 3 shipments.

3.2.1 Vehicle Configuration

Table 3-2 displays the distribution of crashes by vehicle configuration within each HM group. As expected, tractor/trailers dominate across most HM shipment categories, with straight trucks as the next most prevalent vehicle configuration. Straight trucks were more frequently involved in crashes involving Class 2.1 shipments than tractor/trailers, presumably because of their more common use in moving Class 2.1 materials. There were no remarkable findings associated with the relationship between vehicle configuration and spills across all vehicle configurations. As shown in Figure 3-3, the spill percentage increases as trailers are added to the configuration but since adding a trailer (to either a tractor/trailer or straight truck) does not double the spill percentage, spills are less likely on a per unit basis. The higher spill percentages for the *light truck/van* and *other/unknown* vehicle configurations shown in Figure 3-3 are not considered significant because there are only a few crashes for these vehicle configurations, as shown in Table 3-2.

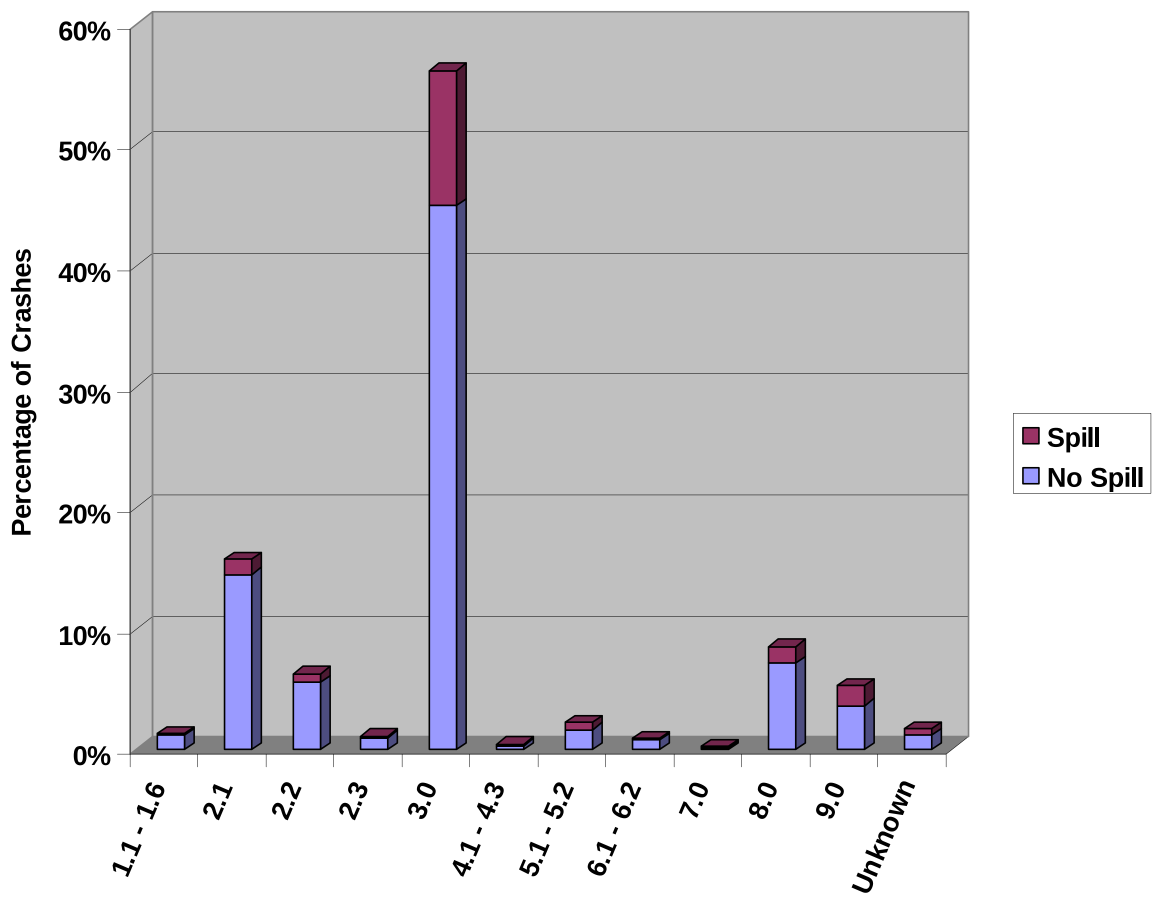

Figure 3-2. Crashes Resulting in Spills by HM Group

Table 3-2. Crashes by Vehicle Configuration

HM Group	Straight Truck	Straight Truck with Trailer	Tractor/ Trailer	Tractor/ Trailer (2 or more)	Light Truck/ Van	Other Truck Configuration	Unknown	Total
2.1	177	7	68	2	2		1	256
2.2	50	5	55	2	4		1	117
3.0	221	33	633	33	2	4	1	926
5.1 - 5.2	8	1	21	7				36
8.0	15	2	106	18		2	2	145
9.0	5	2	68	11		2	1	88
Other/Unknown	63	12	21	1	2	0	0	98
Total	537	62	972	73	9	7	6	1,667

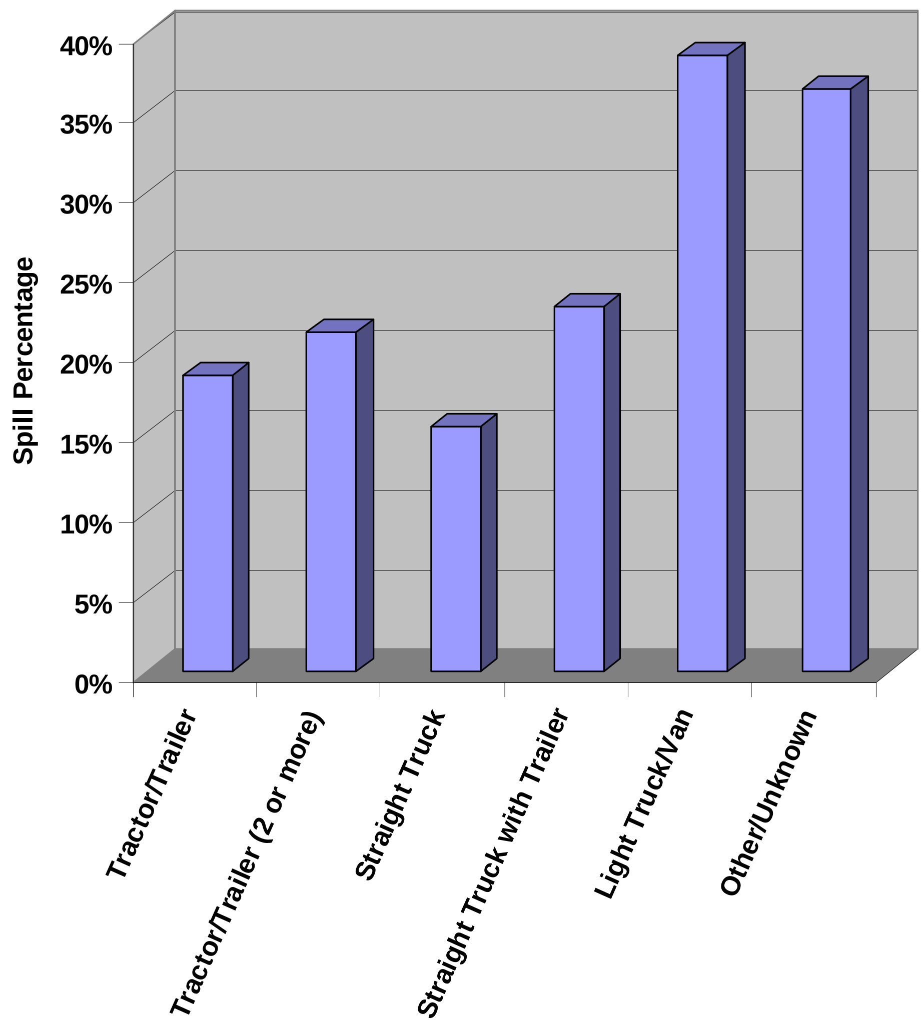

Figure 3-3. Spill Percentage by Vehicle Configuration

It will be noted by comparing the total at the lower right hand corner of Table 3-2 with other tables that this number varies. The reason for this variability is the extent to which the various data fields are populated. In the case of Table 3-2, if the vehicle configuration field is blank for some crashes, then that crash is not included in the table and the total is reduced accordingly. In addition, the total for many tables is typically above the total number of crashes analyzed (970), because crashes can involve multiple hazmat vehicles and hazmat vehicles can carry packagings from more than one HM group. This small amount of double counting does not affect any analysis results. The use of weighting factors to remove the sampling bias in the crashes that were analyzed further increases the crash total. The data shown in Table 3-2 actually represent an unbiased estimate of the total number of hazmat crashes reported in MCMIS in 2002.

3.2.2 Cargo Body

Table 3-3 displays the distribution of crashes by cargo body type within each HM group. Tanks are the most prevalent cargo body reported in the crash database, dominating all other cargo body types across every HM group shown, with 77 percent of the total. Vans, which include semi-trailers, are the next most involved cargo body type, with a relatively large representation in HM classes 2.3, 6.1, 5, and 8.

Table 3-3. Crashes by Cargo Body

HM Group	Flatbed	Tank	Van	Dump	Other	Unknown	Total
2.1	35	199	10	0	9	4	256
2.2	9	67	18	0	6	3	103
3.0	8	813	74	0	4	17	916
5.1 - 5.2	4	11	15	5	2	0	36
8.0	6	72	51	0	2	8	139
9.0	1	66	11	6	0	3	86
Other/Unknown	13	25	49	4	2	3	96
Total	76	1,252	228	15	25	37	1,633

In Table 3-3, the less populated HM groups have been summed and placed into the Other/Unknown category. More data would be needed to make a separate line for these inadequately populated HM groups meaningful.[6] Within the tank cargo body category are several tank specifications. The only four specifications sufficiently populated using the 970 sampled crashes are the MC306, MC307, DOT406, and DOT407 cargo tanks. For these four specification cargo tanks, the Class 3 sample size was sufficiently large enough to support a comparative analysis as well. These results are presented in Figure 3-4.

Cargo tanks were involved in 74 percent of all spills, not much different than their overall representation among all crashes. What is particularly interesting about these results, however, is the comparison of the relative contribution of each tank specification to overall crashes and to

[6] This same approach has been used in the other tables in this Chapter.

crash-induced spills. Figure 3-4 shows the overall spill percentage and the Class 3 spill percentage for the four cargo tank specifications. If the purpose of introducing the 400 series designs was to enhance container integrity, the lower spill percentages appear to provide clear evidence that this objective is being met.

Not shown in the figure is the total number of crashes involving MC306 and DOT406 cargo tanks. The annual estimate for the number of crashes for MC306s is 2.2 times that of DOT406s (283 and 130, respectively), showing that the DOT406 containers have not fully penetrated the market. Although there are fewer data points, the same statement is valid when comparing the MC307 and DOT407 results. In fact, FMCSA estimates that there are twice as many MC306 cargo tanks as DOT406 cargo tanks.[7]

[7] Available at http://www.fmcsa.dot.gov/safetyprogs/hm/Tank_check02_External.htm as of 2/15/2005.

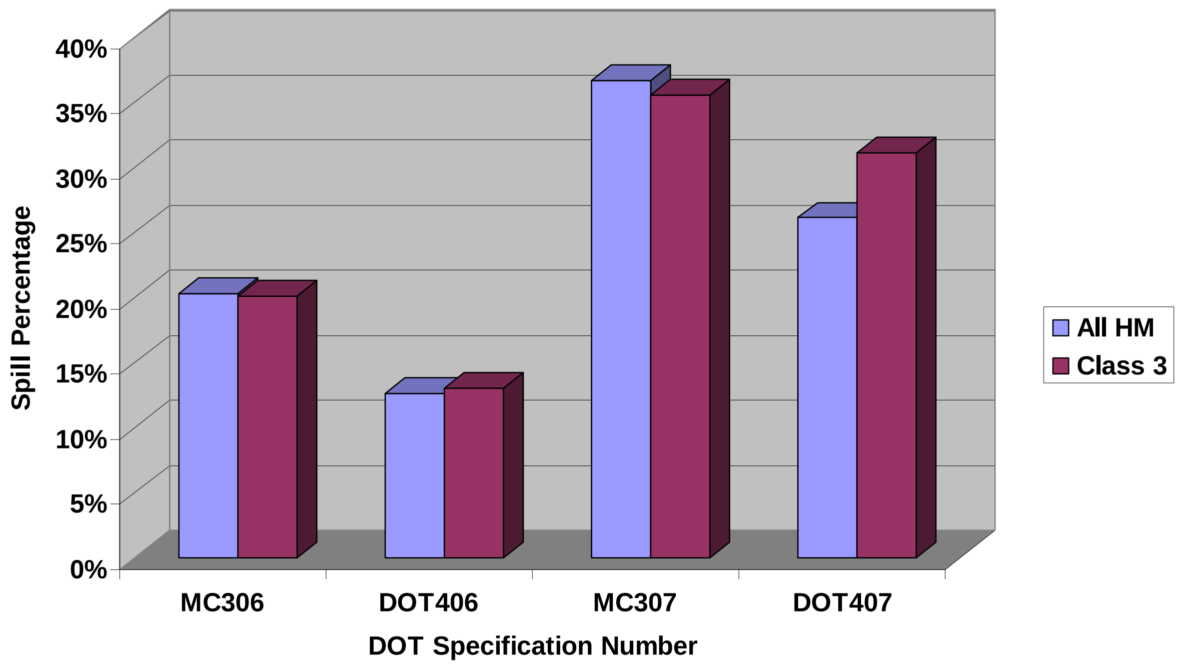

Figure 3-4. DOT Tank Specification for All HM and Class 3 Crashes

3.3 Driver Characteristics

Analyses involving driver characteristics focused on three variables: (1) driver age, (2) driver experience and (3) driver condition. While analyses of driver characteristics associated with HM crashes were performed across several HM groups, analyses of driver characteristics relative to crash-induced spills were limited to all crashes.

3.3.1 Driver Age

Table 3-4 displays the distribution of crashes by driver age within each HM group. Irrespective of the HM group, most drivers in the crash sample are distributed in age in a bell-shaped curve, with the peak in the 35-44 age range. The decline is sharper in the 55-64 year-old age category and there are very few in the 65 and older driver population. There were only 48 drivers 18 to 24 years old, representing 1.5 percent of the total. Of all the drivers, there were only 4 that were under 21. These results appear to be intuitive. There was a noticeable relationship between driver age and spill probability. Younger and older drivers were more likely to be involved in crashes in which there was a spill than middle-aged drivers. This relationship followed an "upside down" bell curve, with drivers 45 to 54 years old having the lowest rate of spills, as shown in Figure 3-5. This effect does not carry over to injuries and fatalities where there is little discernible relationship between age and the percentage of crashes resulting in casualties.

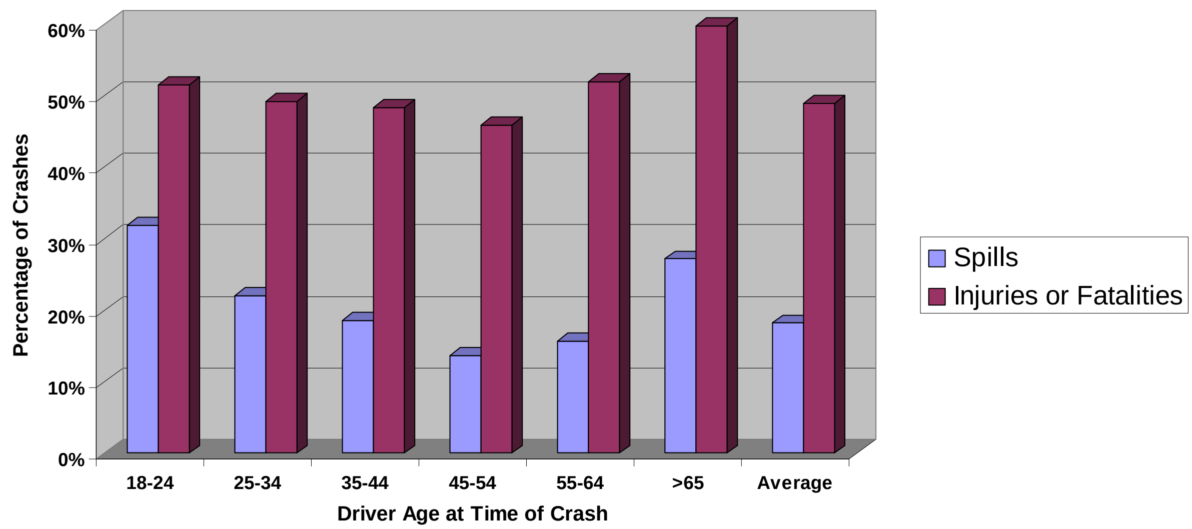

Figure 3-5. Spills and Casualties by Driver Age at Time of Crash

Table 3-4. Crashes by Driver Age

HM Group	18-24	25-34	35-44	45-54	55-64	65-78	Total
2.1	5	64	81	62	37	5	255
2.2	5	17	29	29	15	5	101
3.0	21	194	284	228	150	21	898
5.1 - 5.2	1	12	12	9	3	0	36
8.0	10	22	49	34	18	3	137
9.0	4	17	24	24	10	4	83
Other/Unknown	1	16	17	35	20	6	94
Total	48	343	495	421	253	44	1,604

3.3.2 Driver Experience

Table 3-5 presents the distribution of crashes, spills, and casualties (fatalities and injuries) by driver experience. It should be noted that information on driver experience was not in the PAR and had to be obtained through carrier contact. Many carriers could provide the date of hire for the driver but many did not know the total driving experience of the driver involved in the crash. Hence, this field was only sparsely populated. Based on the information shown in Figure 3-6, it appears that there is a trend toward lower spill-to-crash percentages as the driver's experience increases. A similar trend is not observed for crashes that result in injuries or fatalities. Assuming the parameter is distributed according to the binomial distribution, it can be stated with greater than 95 percent confidence that drivers with more than six years experience have a lower spill-to-crash ratio and drivers with less than three years experience have a higher spill-to-crash ratio. Assuming the trend shown continued, it would take about 10 times more data to obtain the 95 percent confidence level for drivers with three to six years experience, because their spill-to-crash ratio is closer to the average. This analysis shows that when the difference among groups is large enough, only a few data points are needed to demonstrate significance at the 95 percent confidence level. In this case, in the raw data, there were 58 drivers with more than 6 years experience and they only had 8 crashes that resulted in a spill.

Table 3-5. Crashes by Driver Experience

	0-3 Years	3-6 Years	> 6 Years	Total
Crashes	85	39	96	220
Spills	25	8	10	44
Fatalities/Injuries	48	16	50	115

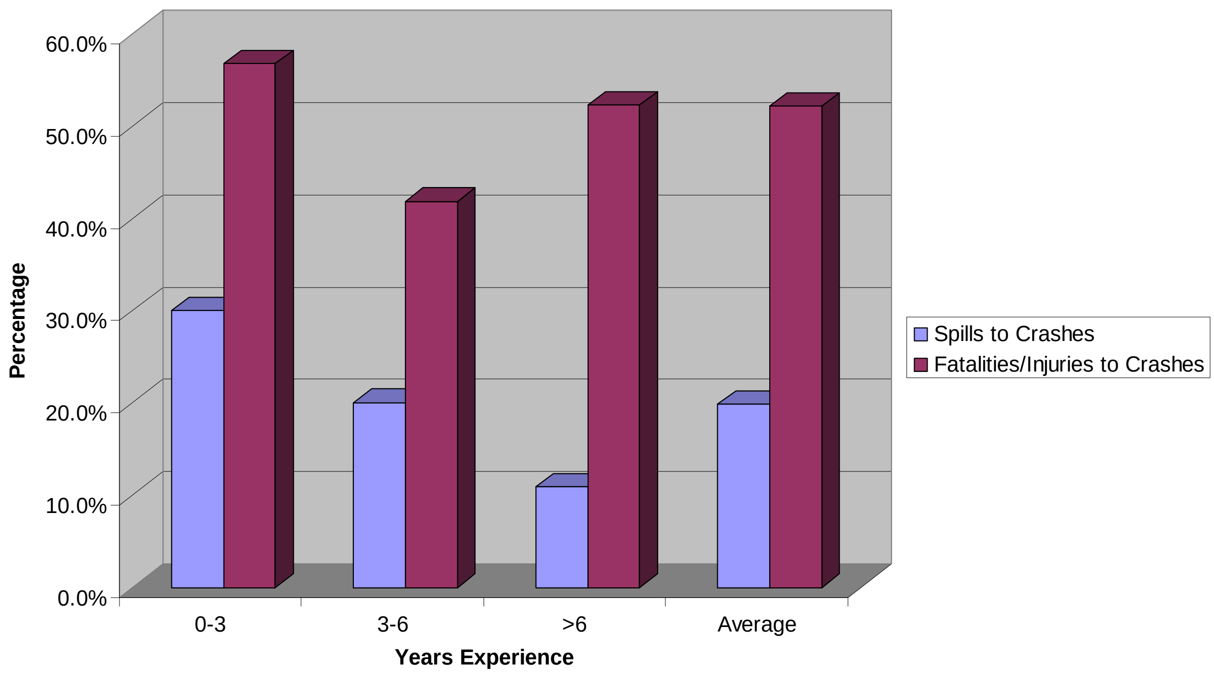

Figure 3-6. Spill and Casualty Probabilities per Crash versus Driver Experience

3.3.3 Driver Condition

Table 3-6 presents the distribution of crashes by driver condition. In 94 percent of the cases, the driver appeared normal according to the PARs associated with the crash sample. There are only a handful of instances where this was not the case and they were more associated with fatigue/asleep[8] problems than with drug use, alcohol use, or illness.

Table 3-6. Crashes by Driver Condition

	Appeared Normal	Asleep/ Fatigue	Illness	Under Influence of Drugs/Alcohol	Unknown or Blank	Total
Crashes	1,287	35	5	8	24	1,359
Spills	187	12	2	4	18	223
Fatalities/Injuries	598	26	2	6	21	652

When examining crashes and taking spill information into consideration, the analysis is more revealing. As shown in Figure 3-7, spills occur at a disproportionately lower rate in crashes where the driver appeared normal than for other driver conditions. In over 94 percent of all crashes, the driver *appeared normal* and the spill percentage was about 15 percent. Based on the limited data available for drivers whose driving ability is physically or mentally impaired, the percentage of crashes with spills when the driver was *ill*, *fatigued*, or *asleep* increased to about 30 percent and increased to above 50 percent when the driver was *under the influence of drugs or alcohol.* Using the binomial distribution to estimate significance, the greater spill rate when the driver is impaired is statistically significant at greater than the 95 percent confidence level. The higher ratio for drivers on drugs and alcohol is significant only at the 80 percent confidence level due to the lower representation of these drivers among the data collected. The generally believed corollary to this finding is that if drivers do not appear normal, they are more likely to experience a spill if they are involved in a crash. It is intuitive that there are a high percentage of spills and casualties where the driver condition is unknown, because if the driver is killed or severely injured their condition is less likely to be determined. In addition, some states do not report driver condition on their PARs.

[8] Fatigue generally refers to being drowsy, which is assumed to correspond to reduced attentiveness and responsiveness; whereas, asleep refers to drivers who were determined to have fallen asleep at the wheel.

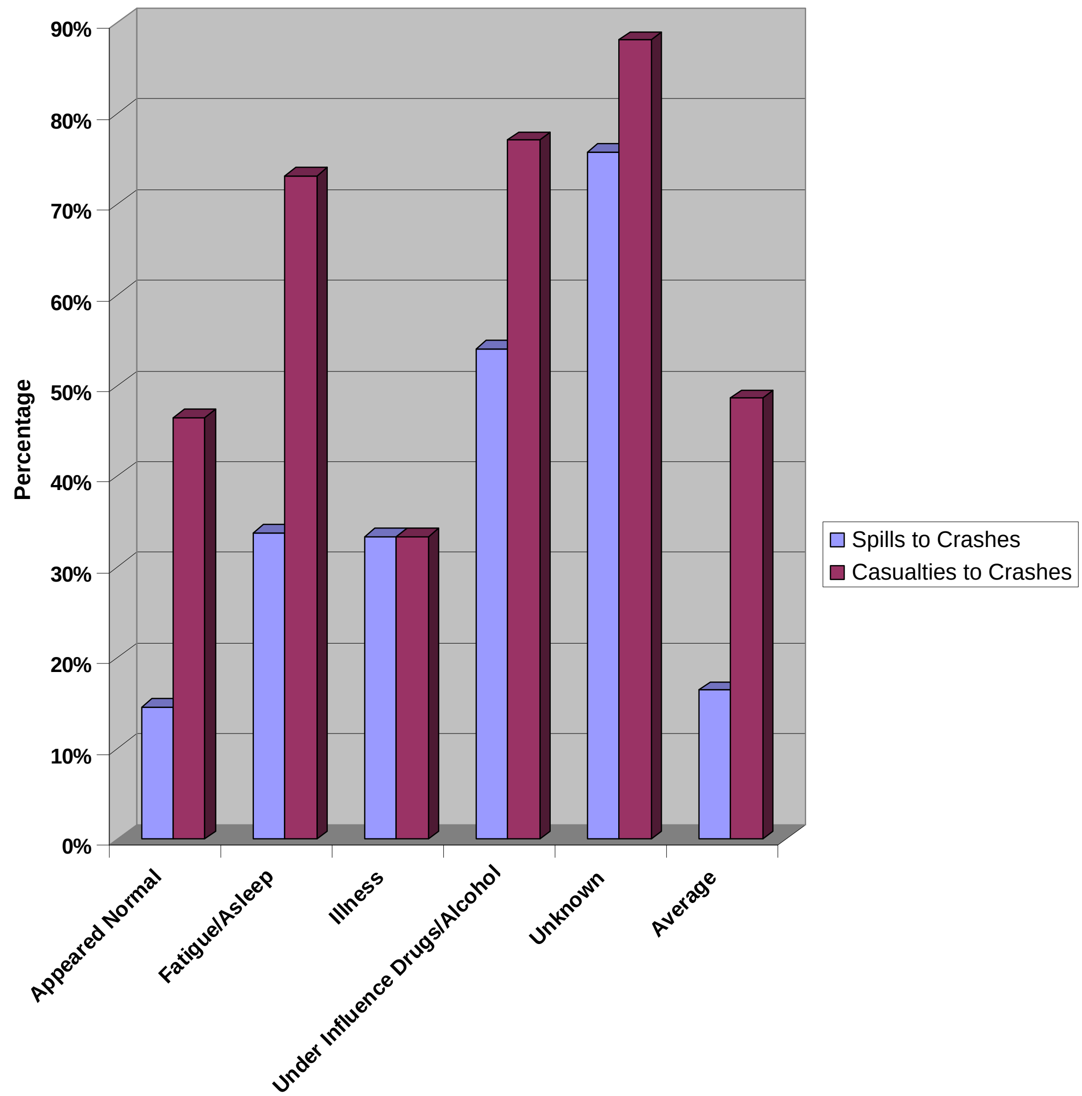

Figure 3-7. Driver Condition for Crashes

3.4 Packaging Characteristics

Analyses involving packaging characteristics were restricted to two variables, namely package type and impact location. While analysis of package type associated with HM crashes was performed across several HM groups, analysis of package type relative to crash induced spills was limited to those involving cargo tanks. Note that *packaging* generally means “a receptacle and any other components or materials necessary for the receptacle to perform its containment function in conformance with the minimum packing requirements” of the Hazardous Materials

Regulations; whereas, a *package* generally refers to the packaging and its contents.[9] In this report, packaging and package are used interchangeably.

3.4.1 Package Type

Table 3-7 presents the distribution of crashes and spills by package type. As expected, tanks are by far the most frequently used package, accounting for 85 percent of all crashes.

Table 3-7. Crashes and Spills by Package Type

	Can/Pail	Cylinder	Drum	Tank	Other	Unknown	Total
Crashes	15	50	46	917	47	4	1,080
Spills	10	6	13	168	14	4	215

In Figure 3-8, the spill-to-crash percentages for cargo tank crashes are presented. The figure shows that spills occur at a disproportionately lower rate in crashes involving Division 2.1 materials shipped in tanks. There are sufficient data on Division 2.1 crashes to determine that their spill rate is significantly different from the average at greater than 95 percent confidence. Figure 3-8 also shows a large percentage of Division 2.1 spills result from multiple-vehicle crashes. For all other classes, a large percentage of the spills are from single-vehicle crashes. In fact, for 2002, no spills of Class 8 hazmat were from a multiple-vehicle crash.

In Figure 3-8, no distinction is made between single- and multi-vehicle crashes. Of these cargo tank crashes, 24 percent are single-vehicle crashes. The single-vehicle crashes account for 66 percent of the spills, 76 percent of the rollovers, and 77 percent of the crashes that result in both rollover and spill. This cargo configuration is commonly used for Class 2, 3, 8, and 9 shipments. As discussed in Section 3.3, driver recognition and driver performance errors were frequently listed as the primary cause for these single-vehicle crashes.

Figure 3-9 shows the spill percentage (fraction of all crashes not percentage of all spills) for rollovers and run-off-road crashes for cargo tanks. Rollovers that occur with the vehicle running off the road have the highest spill percentage of the four combinations shown. When rollovers are not involved, running-off-the-road crashes experienced a lower spill percentage than other crashes.

3.4.2 Impact Location

Table 3-8 displays the distribution of crashes by impact location and HM group. This parameter is also not captured in MCMIS but is available from many PARs. The impact categories shown represent an aggregation of a larger set of impact locations that are shown as diagrams in many PARs and have been recorded in the database. In general, there are slightly more crashes where

[9] 49 CFR 171.8

the impact occurred in the HM cargo region (56 percent) versus crashes where the impact occurred in the non-HM cargo region (44 percent).

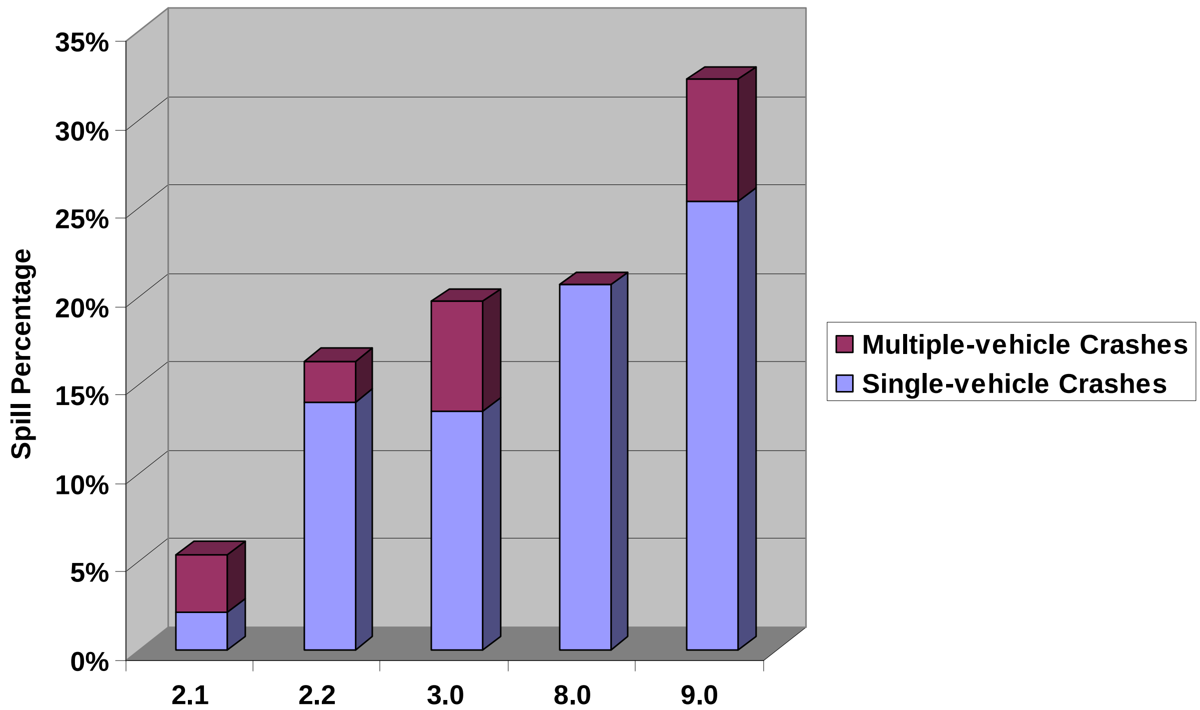

Figure 3-8. Package Type for Tank Crashes by HM Group

Table 3-8. Crashes by Impact Location

HM Group	HM Cargo Region	Non-HM Cargo Region	Total
2.1	144	102	246
2.2	60	41	100
3.0	493	389	883
5.1 - 5.2	19	17	35
8.0	63	67	130
9.0	52	28	80
Other/Unknown	47	44	91
Total	879	687	1,565

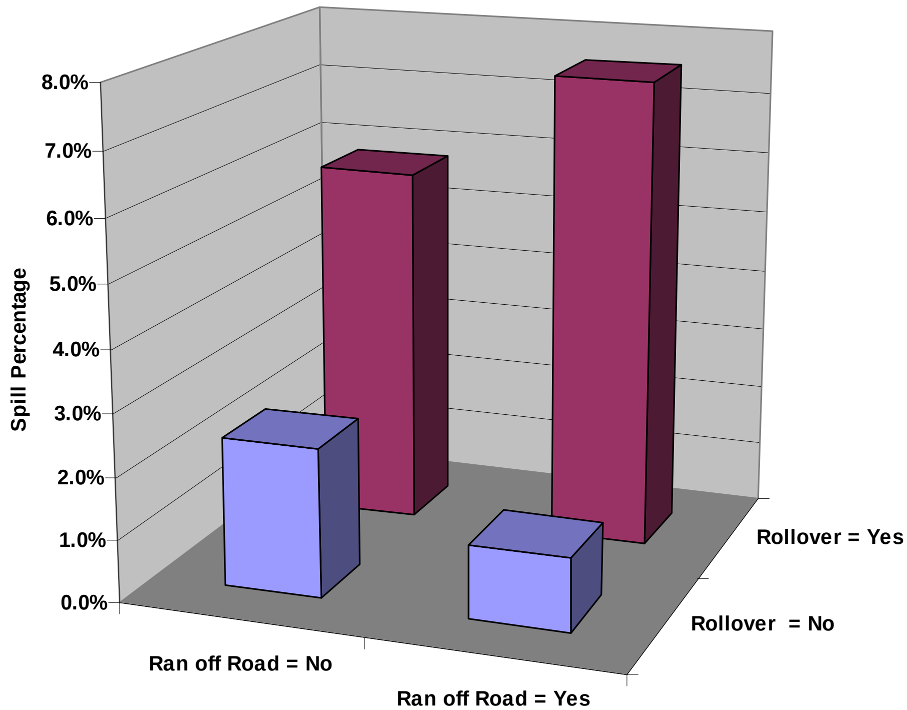

Figure 3-9. Rollovers and Run-off-Road Crashes involving Cargo Tanks

When examining the impact region for spill percentage, as presented in Figure 3-10, the results clearly indicate a higher spill-to-crash ratio for crashes where the impact occurs directly on the HM packaging (23 versus 12 percent). Again, this represents an intuitive finding, owing to the fact that the packaging is being subjected to greater stress as a result of the direct impact, increasing the likelihood of a breach of the packaging and subsequent spill.

3.5 Infrastructure Characteristics

Analyses involving infrastructure characteristics focused on five variables: (1) road surface, (2) road condition, (3) road type, (4) trafficway, and (5) access control. While analyses of infrastructure characteristics associated with HM crashes were performed across several HM groups, analysis of infrastructure characteristics relative to crash-induced spills was limited to Class 3 shipments.

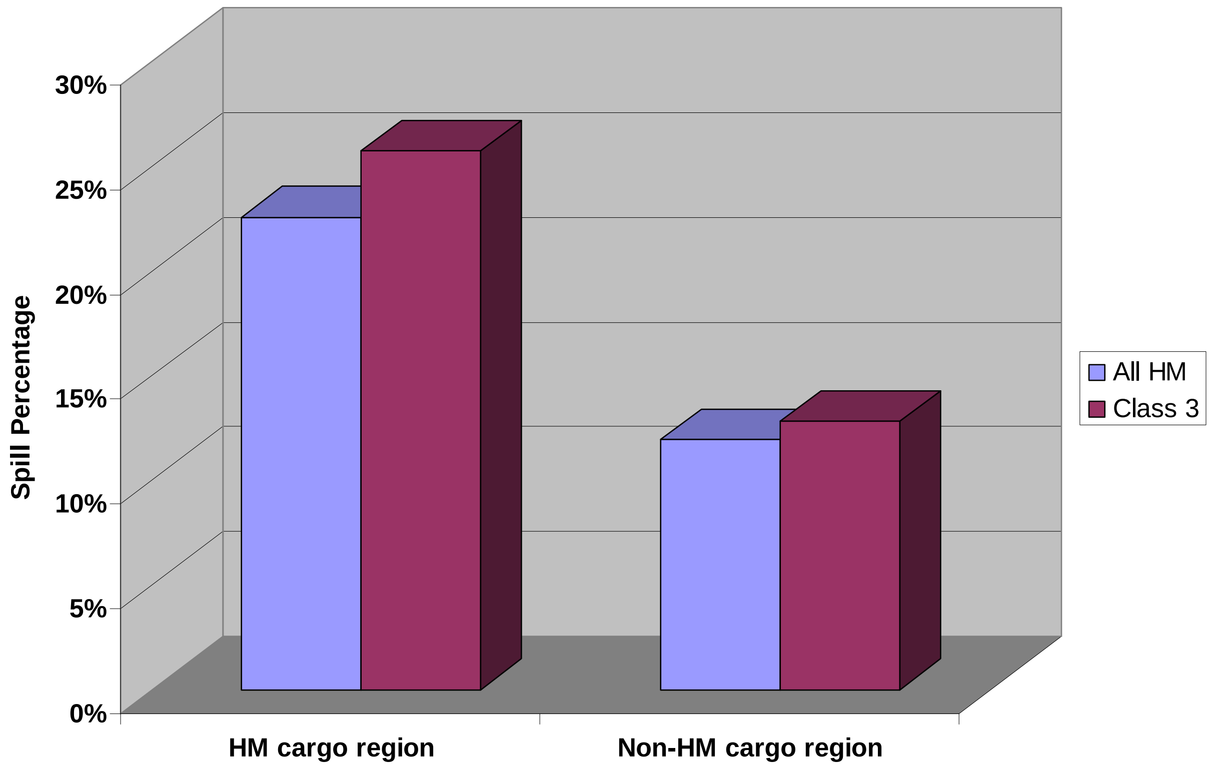

Figure 3-10. Crash and Spill Percentages by Impact Location

3.5.1 Road Surface

The distribution of crashes by road surface within each HM group appears in Table 3-9. With rare exception, crashes in the sample occurred on paved roads.[10] The only interesting observation comes from the relatively high frequency of crashes occurring on unpaved roads for Division 2.1 shipments. This presumably has to do with the distribution pattern of Division 2.1 deliveries. There were no remarkable findings associated with the relationship between road surface and spills for Class 3 crashes.

[10] It should be noted that one Division 2.1 crash and 13 Class 3 crashes with "unknown" road surface type were converted to "paved" as they occurred on an Interstate highway.

Table 3-9. Crashes by Road Surface

HM Group	Paved	Unpaved	Unknown	Total
2.1	142	20	11	173
2.2	73	0	5	77
3.0	570	16	20	605
8.0	30	0	0	30
9.0	76	0	2	79
Other	50	0	2	52
Unknown	66	0	3	69
Total	1,007	35	42	1,085

3.5.2 Road Condition

It can be seen from Table 3-10 that the dominant road condition is dry. However the number of crashes occurring under unfavorable road conditions is quite high, approaching 20 percent for wet conditions and 10 percent for snowy or icy conditions. Without knowledge of the annual amount of time that roads are typically wet or covered with snow or ice, it is impossible to know if these percentages are cause for concern. There were no remarkable findings associated with the relationship between road condition and spills, averaging 18 percent across all road conditions.

Table 3-10. Crashes by Road Condition

HM Group	Dry	Wet	Snow/Ice	Other/Unknown	Total
2.1	178	49	28	2	256
2.2	81	12	6	2	102
3.0	706	136	62	10	914
5.1 - 5.2	27	5	4	1	36
8.0	107	19	8	4	139
9.0	69	12	4	2	86
Other/Unknown	314	143	19	1	95
Total	1,482	375	131	22	1,629

3.5.3 Road Type

The road types have been aggregated into four categories, *Interstate, primary, secondary,* and *unknown.* As shown in Table 3-11, there are very few crashes where the road type was unknown after reading the PAR. It can be seen that overall and for most HM groups, more crashes occur on primary roads than on the other types. Primary roads are U.S. or State numbered highways. Notably, Division 2.1 shipments, which involve deliveries to many remote locations, are involved in a large number of reported crashes on secondary roads, nearly the amount occurring on primary roads.

Table 3-11. Crashes by Road Type

HM Group	Interstate	Primary	Secondary	Unknown	Total
2.1	38	115	102	2	256
2.2	34	58	10	0	102
3.0	262	434	212	7	915
5.1 – 5.2	19	16	2	0	37
8.0	64	48	26	1	139
9.0	30	41	15	0	86
Other/Unknown	45	31	17	2	95
Total	491	742	385	12	1,630

Based on all crashes, as shown in Figure 3-11, even though travel on Interstates is at a higher speed, by looking at the relative heights of the bars for each category, the ratio of spills to overall crashes is lower for Interstates than for primary and secondary roads. This is likely attributable to design elements associated with Interstate construction that increases the likelihood that a truck will remain upright in a crash and not roll over.

Figure 3-12 shows how the spills within each HM group are divided among the different road types, excluding the "Unknown" road type. The figure also shows the overall spill percentages within each HM group. Division 2.1 materials, for example, spill in approximately 8 percent of all crashes, with half on primary roads and half on secondary roads. They almost never spill on Interstates. Conversely, Division 2.2 materials spilled in about 12 percent of all crashes, but none of these occurred on secondary roads.

3.5.4 Trafficway

The distribution of crashes by trafficway within each HM group appears in Table 3-12. In general, this distribution is roughly evenly split between divided and undivided highways with a few occurrences on highway ramps and one-way roads. The exception is for Class 2.1 shipments, where crash occurrences on undivided highways prevail, as expected due to the distribution pattern of these shipments.

From the results in Figure 3-13, it can be seen that divided highways have a lower spill-to-crash ratio than their undivided highway counterparts. This is to be expected given the high correlation between Interstates and divided highways. Exit and on ramps show the highest spill-to-crash ratios of all trafficway types, possibly because of the propensity for these crashes to involve running of the road or a rollover. Cargo tanks show slightly lower spill-to-crash ratios than for all crashes on all trafficway types except for exit and on ramps, where their spill-to-crash ratio is higher. There is a very strong correlation between cargo tank rollovers and spills. One of the most likely locations for a rollover is on entrance and exit ramps, in which more than 87 percent of all rollovers result in a spill.

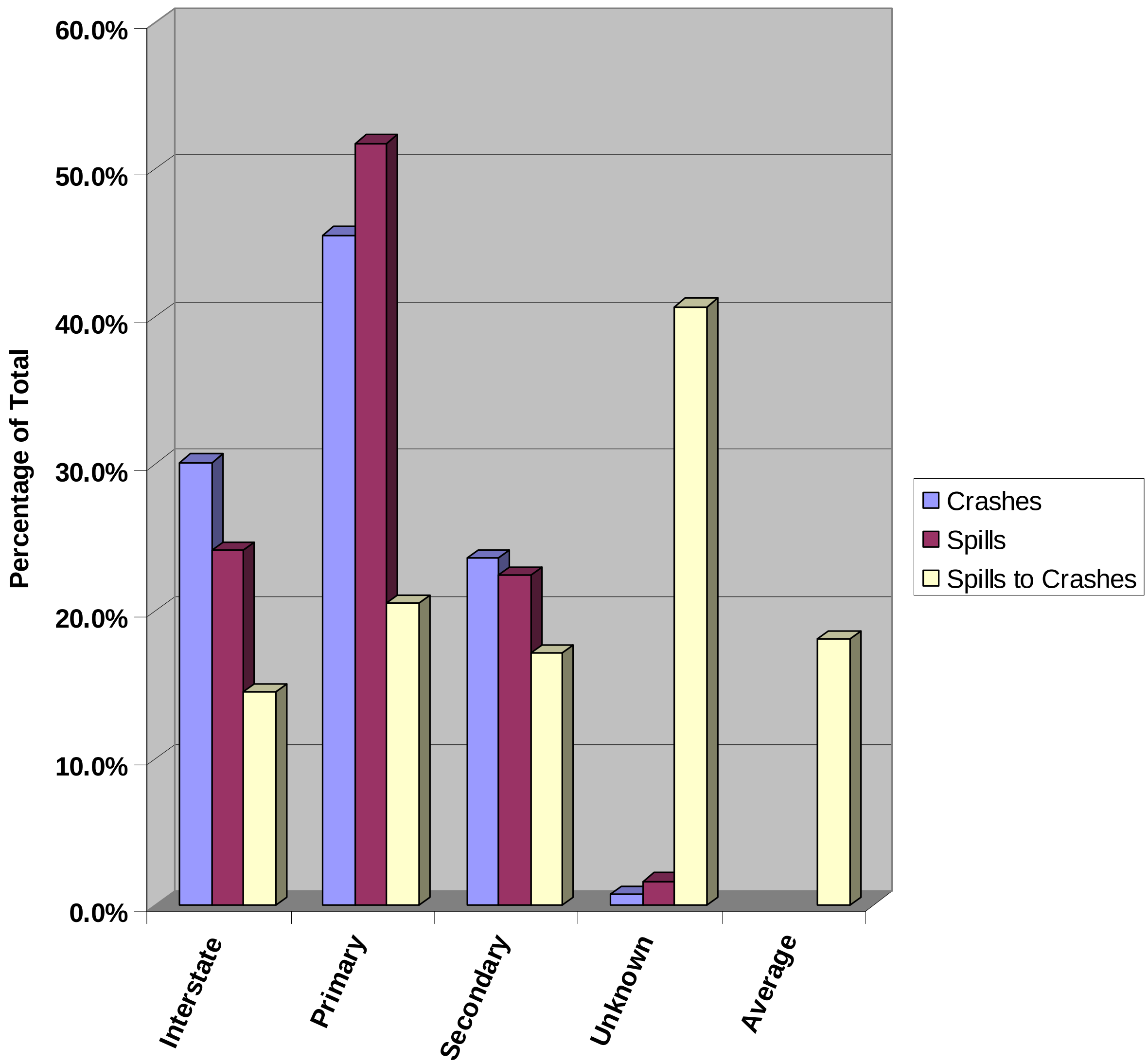

Figure 3-11. Road Type for Crashes and Spills

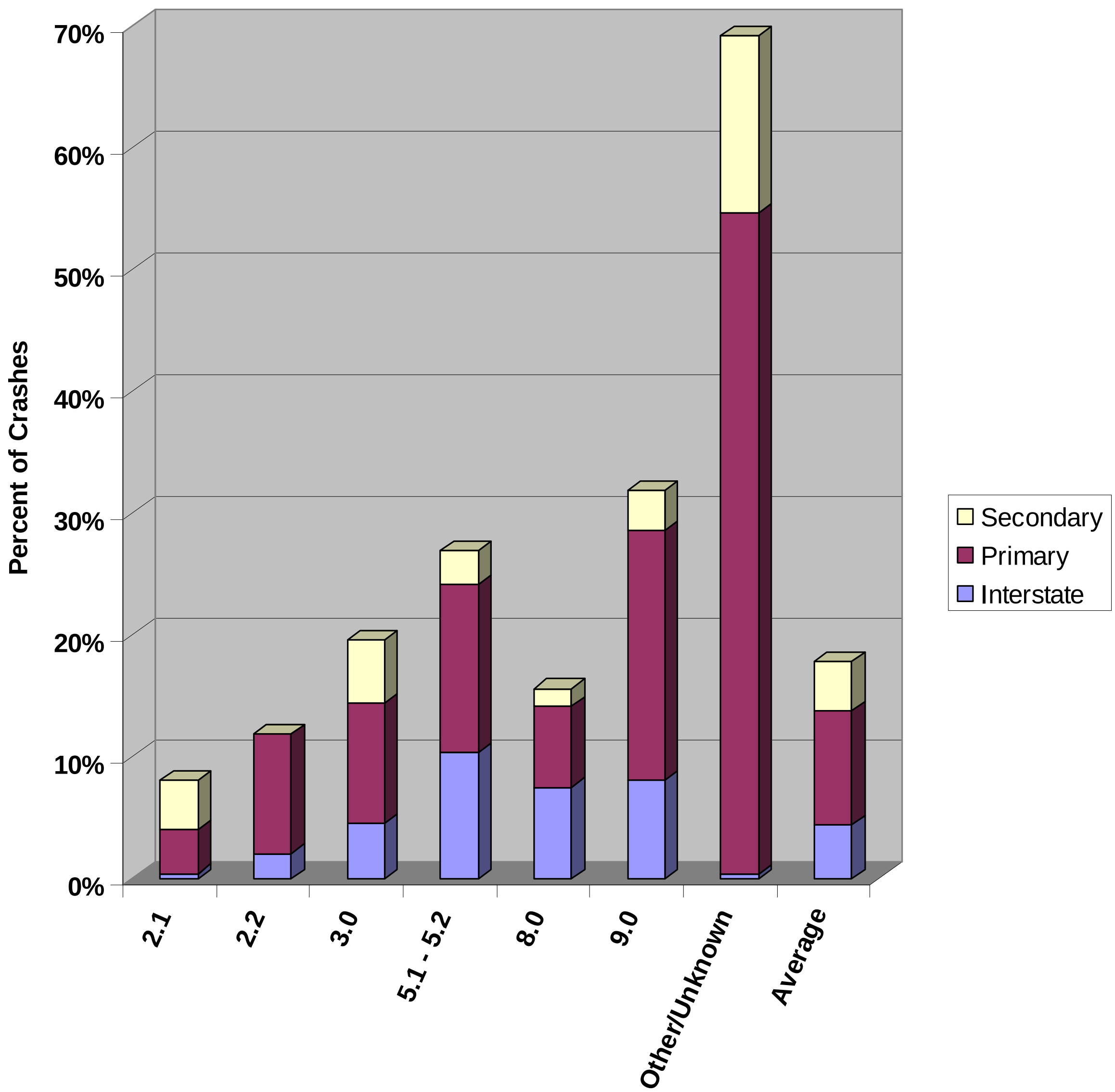

Figure 3-12. Contribution of Road Type to the Spill Percentage by HM Group

Table 3-12. Crashes by Trafficway

HM Group	Divided Highway	Exit/On Ramp	One-way Trafficway	Undivided	Unknown	Total
2.1	62	0	2	187	5	256
2.2	46	4	2	50	0	102
3.0	456	21	16	409	13	914
5.1 - 5.2	20	3	0	14	0	36
8.0	79	2	0	56	2	139
9.0	44	5	2	35	2	86
Other/Unknown	61	0	0	34	0	95
Total	768	34	21	784	22	1,629

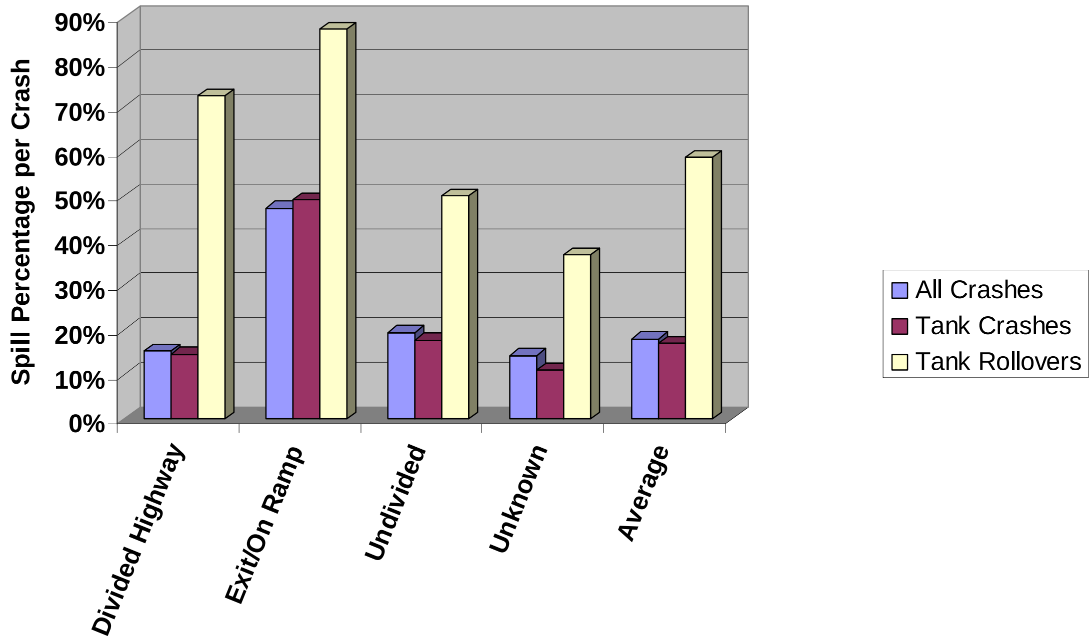

Figure 3-13. Spill Percentages by Trafficway

3.5.5 Access Control

The distribution of crashes by access control is presented in Table 3-13 by HM group. The surprising fact about access control is that such a large number of crashes occur on controlled/limited access highways where the opportunity for conflicting vehicle movements and running off the road are presumably reduced. A great deal of effort was put into identifying any state or U.S. highway segment that was controlled/limited access at the location of the crash. Thus the "Yes" column in Table 3-13 contains more than just Interstate designated routes.

Table 3-13. Crashes by Access Control

HM Group	Yes	No	Total
2.1	75	181	256
2.2	44	58	102
3.0	428	486	914
5.1 – 5.2	24	13	36
8.0	81	57	139
9.0	45	41	86
Other/Unknown	52	43	95
Total	749	880	1,629

It can be seen from Figure 3-14, there is a trend showing that the spill-to-crash ratio is lower for controlled/limited access highways than it is for highways with no access control.

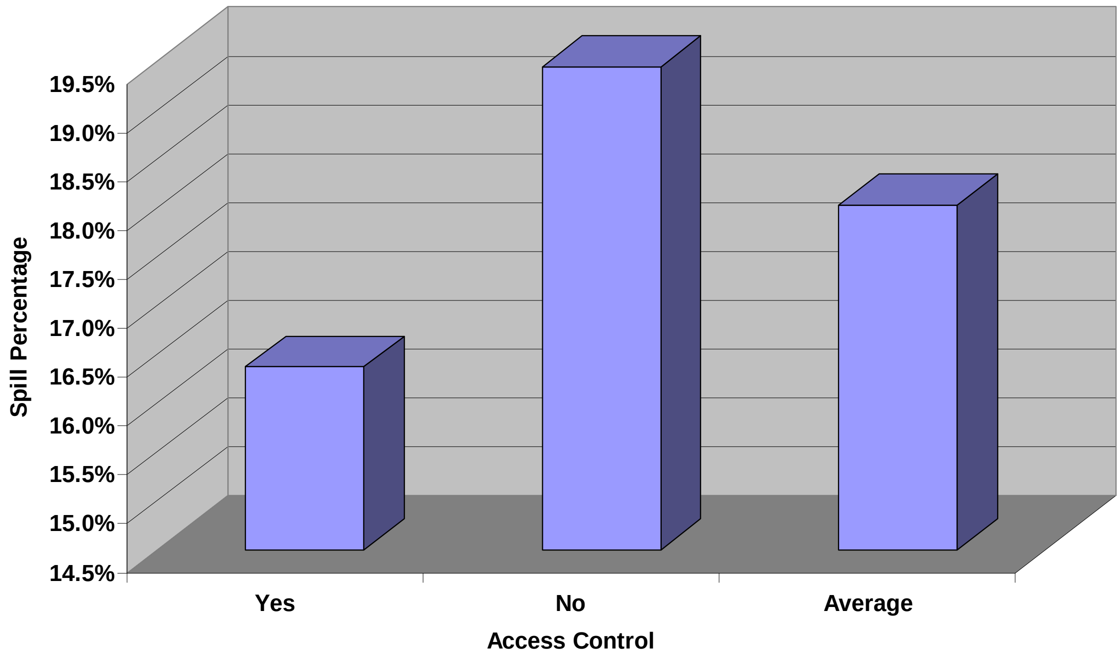

Figure 3-14. Spill Percentage by Access Control

3.6 Situational Characteristics

Analyses involving situational characteristics focused on seven parameters: (1) pre-crash condition, (2) dangerous events, (3) vehicle speed, (4) impact location, (5) primary reason, (6) accident type, and (7) weather condition. While analyses of situational characteristics associated with HM crashes were performed across all HM groups as a whole, analysis of situational characteristics relative to crash-induced spills was also included in some cases for cargo tanks and for single- and multiple-vehicle crashes. The latter is particularly important when examining primary reason and dangerous events.

3.6.1 Pre-crash Condition

The distribution of crashes by pre-crash condition is presented by HM group in Table 3-14. Perhaps surprisingly, these crashes are dominated by trucks occupying a specific traffic lane prior to the crash event, irrespective of HM group. The maneuvering category includes driver actions such as turning, going around a curve, and changing lanes.

Table 3-14. Crashes by Pre-crash Condition

HM Group	Maneuvering	Within Traffic Lane	Parked	Unknown	Total
2.1	73	180	4	76	180
2.2	26	74	2	31	71
3.0	223	663	23	212	704
5.1 - 5.2	5	31	0	12	25
8.0	24	96	0	31	93
9.0	6	53	4	5	57
Other/Unknown	201	349	6	476	75
Total	557	1,446	38	843	1,205

The percentages for crashes and spills for the primary pre-crash conditions are presented in Figure 3-15. The figure shows these percentages separately for single-vehicle and multiple-vehicle crashes. Only 3 percent of all crashes occurred while the HM vehicle was parked. Only 25 percent of all crashes are single-vehicle crashes. However, over 60 percent of all spills result from single-vehicle crashes. As shown in the figure, 60 percent of all crashes are multiple-vehicle crashes that occur while the hazmat vehicle is within the traffic lane. These dominate the crash total. The multiple-vehicle maneuvering crashes, and the single-vehicle crashes that occur while maneuvering and when within traffic lanes are more equally distributed, each contributing about equally to the crash total. Maneuvering is defined as any driver activity involving changing lanes such as passing or turning as well as going around a curve. Spills occur in approximately 18 percent of all crashes and the contributions are about equal (about one-third each) from single-vehicle crashes that occur while the vehicle is in its traffic lane, single-vehicle crashes that occur when maneuvering, and multiple-vehicle crashes that occur while the vehicle is in its traffic lane.

The results indicate that the spill-to-crash ratio is significantly higher for single-vehicle crashes than for multi-vehicle crashes, with a huge proportion of the crashes (71 percent) occurring with the vehicle initially within its traffic lane. Using spill totals (see Appendix E), 88 percent of spills involving multiple vehicles occur within the traffic lane, compared to only 49 percent of spills involving single-vehicle crashes. What these statistics show is that in most multiple vehicle accidents, the HM vehicle is within its traffic lane and is struck by the non-HM vehicle. This non-HM vehicle may be in its traffic lane (rear end collision), or may be maneuvering and therefore out of its traffic lane. Thus, even when the HM vehicle is within its traffic lane, it is still more likely to come into contact with other vehicles traveling at various speeds and directions resulting in collisions with significant consequences. A crash scenario that begins with a driver performing a maneuvering action (going around a curve, turning, or changing lanes) may lead to the driver losing control of the vehicle, running off the road and subsequently rolling. Such maneuvers subject the vehicle to increased lateral force that may result in rollover for a vehicle with a high center of gravity. The data shows that single-vehicle crashes involving a spill were just about as likely to involve maneuvering as not and multiple-vehicle crashes involving a spill were significantly more likely **not** to involve maneuvering.

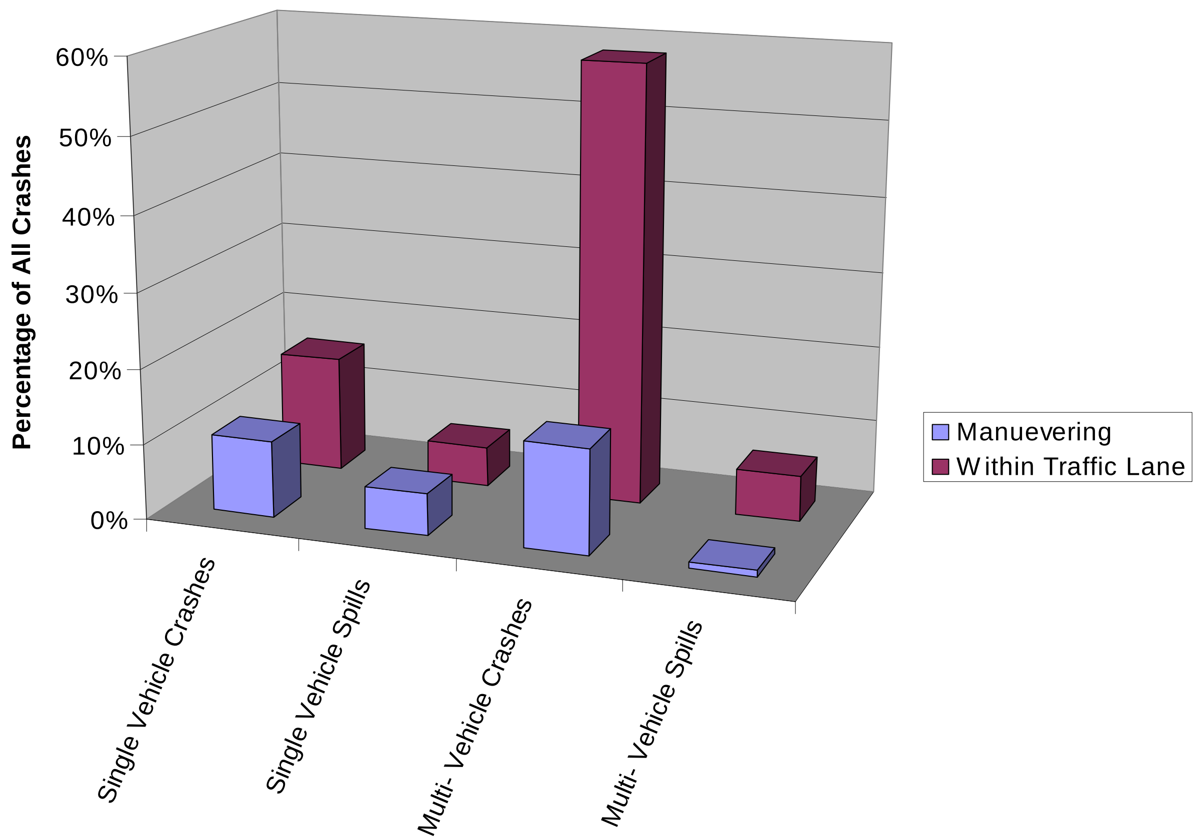

Figure 3-15. Statistics for Selected Pre-crash Conditions

3.6.2 Dangerous Event

Dangerous event is a difficult characteristic to analyze because the database allowed for a sequence of up to four dangerous events to be chronologically recorded. Thus, a rollover might not be an event involved in a particular crash, or it might have been a first, second, third, or fourth event in the crash sequence. Crash and spill tables for each event in the crash sequence are displayed in Appendix E.

Figure 3-16 provides the results of this assessment for crashes and spills for single- and multiple-vehicle crashes. For each of the dangerous events, the percentage that it is present in each of the crash and spill categories is shown. By looking at the relative heights of the bars, it can be seen that for multi-vehicle crashes, collision with a hard object, such as another vehicle or a bridge abutment, dominates for both crashes and spills. For single-vehicle crashes and spills, the dominant dangerous events are ran off road and rollover, with rollover showing the highest likelihood of being present in a crash or spill.

Rollovers occur in approximately 22 percent of all HM serious crashes involving cargo tanks. An analysis of rollover percentage as a function of the loading (empty, part full, and full), showed a linear increase in the tendency to rollover based on the quantity of cargo. Empty tanks were least likely and full tanks most likely to rollover. Although partial loads rolled over at a higher rate than trucks carrying empty tanks, they appear to be more stable than the full tanker loads. The data indicates that rollover stability is most closely correlated with the vehicle's center of gravity. That is, the higher the center of gravity (as in a full tanker truck) the more likely the vehicle is to rollover. HM tanker truck rollovers are especially important for safety and risk analyses because there is a very strong correlation between rollovers and spills. One of the most likely locations for a rollover is on entrance and exit ramps, in which more than 87 percent of all rollovers result in a spill.

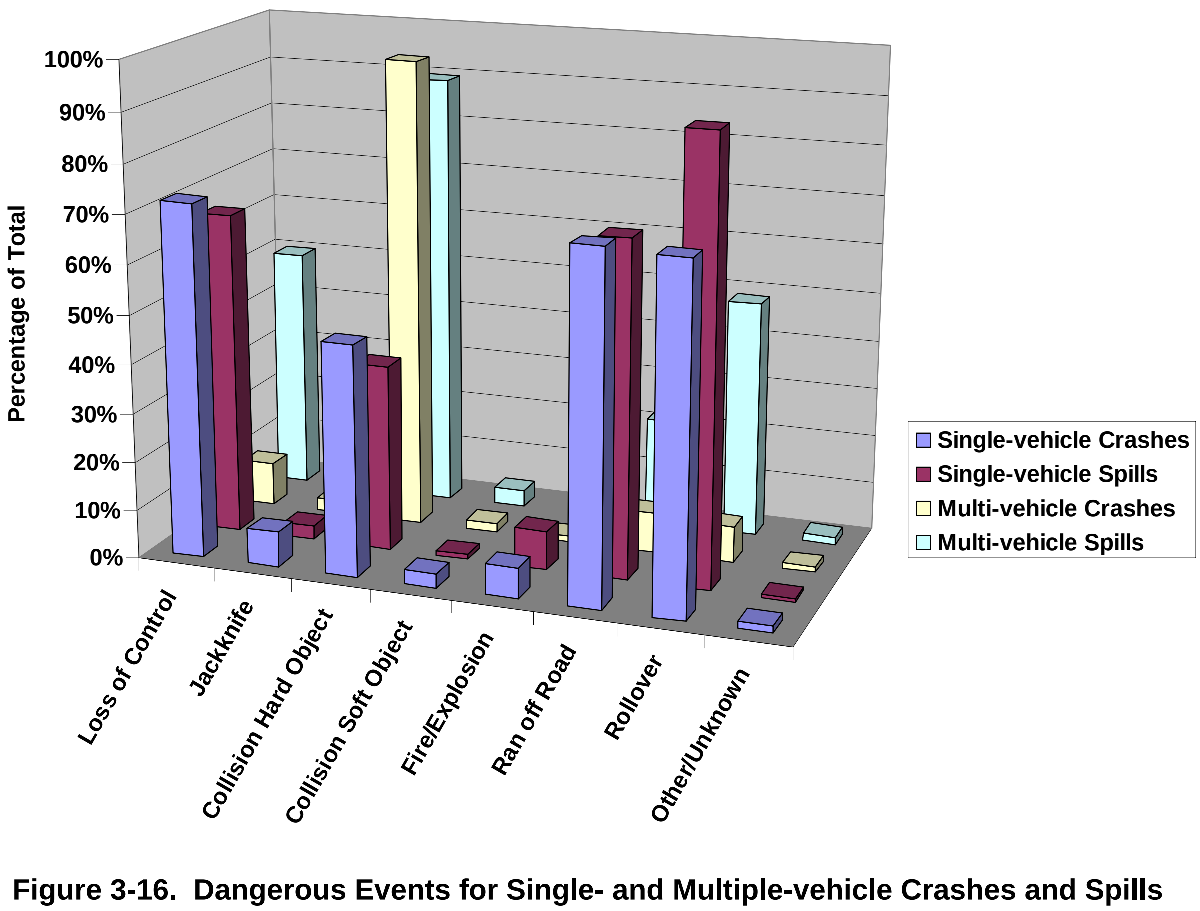

Figure 3-16. Dangerous Events for Single- and Multiple-vehicle Crashes and Spills

Figure 3-17 shows the results of an analysis to demonstrate the importance of the dangerous event *rollover* when looking at the probability of a spill. The probability of a spill is clearly much greater when the vehicle experiences a rollover. The figure also presents an analysis of the cargo tank loading showing that the more hazardous material that is shipped, the more likely the vehicle is to rollover and spill the material. The spill probability is much lower if the vehicle does not experience a rollover. This is true at all tank loadings.

3.6.3 Vehicle Speed

Table 3-15 displays the distribution of crashes by vehicle speed and HM group. This is a parameter that is not captured in MCMIS but is obtainable from about one-half of the PARs. Although it can be seen that HM crashes occur routinely while the vehicle is traveling at a variety of different speeds prior to the onset of the crash event, if more data were available it might be possible to correlate speed with other parameters such as cargo and vehicle configuration and road characteristics.

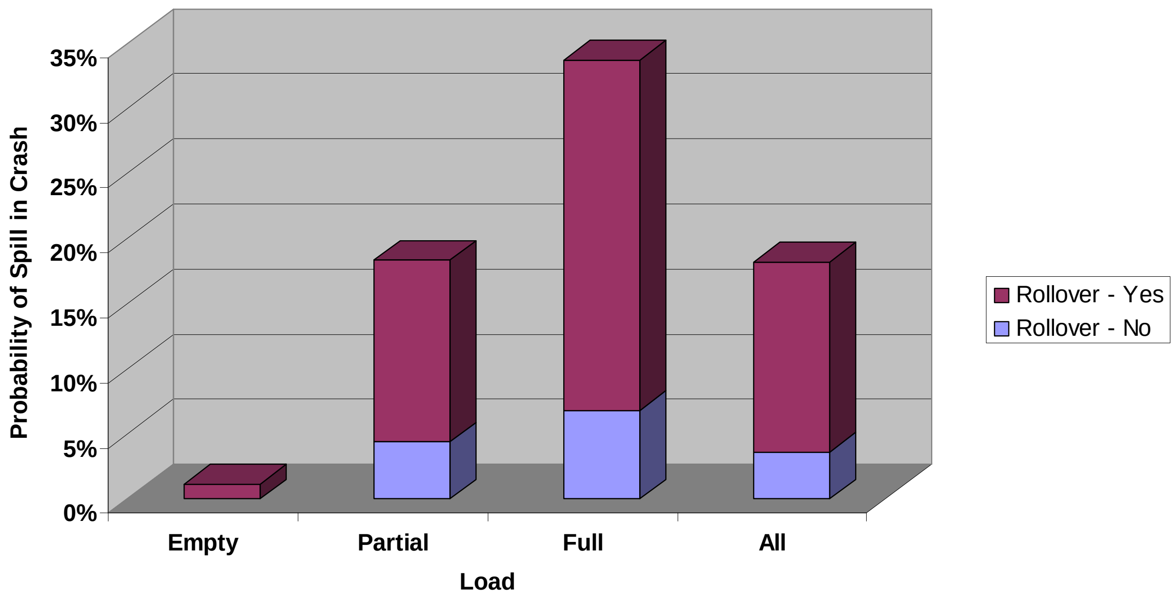

Figure 3-17. Spills as a Function of Cargo Tank Loading and Rollover

For crashes in which vehicle speed was provided, the spill-to-crash ratio averages 19 percent. For speeds between 10 and 70 mph, the spill-to-crash ratio is close to the average. However, below 10 mph, the spill-to-crash ratio is 8 percent and 70 mph and above, it is 32 percent.

Table 3-15. Crashes by Vehicle Speed

HM Group	0 mph	1-9 mph	10-19 mph	20-29 mph	30-39 mph	40-49 mph	50-59 mph	60-69 mph	70-75 mph	Total
2.1	15	17	10	15	23	23	17	9	4	131
2.2	5	0	4	2	5	5	17	11	1	50
3.0	51	30	36	39	46	65	119	48	21	455
8.0	6	8	2	6	4	14	15	11	7	73
9.0	7	0	7	7	5	6	22	3	2	60
Other/Unknown	12	6	2	4	8	8	15	9	11	75
Total	97	60	62	73	90	120	206	91	45	844

Of greater interest, perhaps, is the analysis of spills relative to vehicle speed and access control. This information is presented in Figure 3-18. The spill-to-crash ratios are relatively low for crashes in which the vehicle was traveling under 10 mph, and is relatively high for speeds above 10 mph. Again, these results are intuitive, as one would expect serious consequences to be more likely when crashes involve a vehicle operating at higher speeds. The figure also displays the percentage of spills that occur on limited access roadways, showing that, as one would expect, spills occur more frequently at higher speeds on limited access roadways.

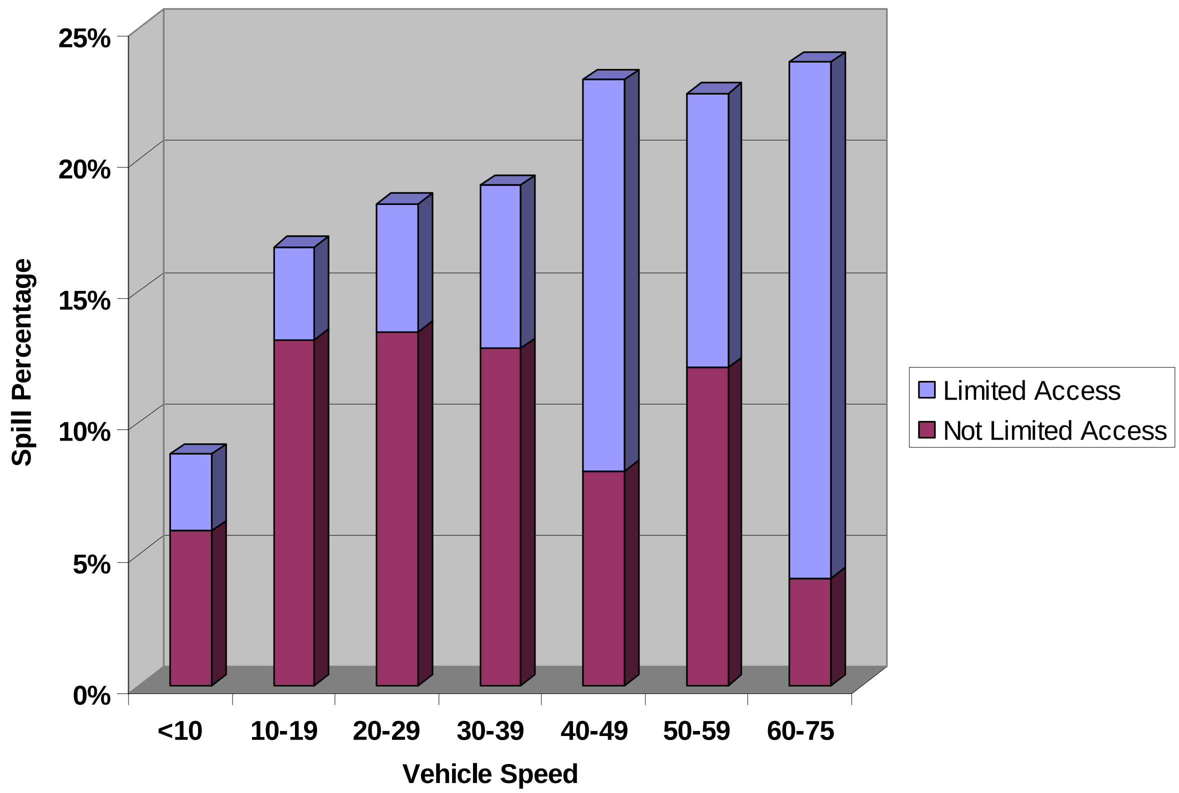

Figure 3-18. Spill Percentage by Vehicle Speed and Access Control

3.6.4 Primary Reason

Table 3-16 shows the primary reason associated with crashes by HM group. **Perhaps one of the more interesting results is the number of cases in which the crash is believed to have been caused by another vehicle** (46 percent). If one were to sum all of the primary reasons associated with the driver (error, performance/non-performance, and recognition), the number of instances that the driver is considered the primary reason (44 percent) for the crash roughly equals the number of crashes where the other vehicle is considered the primary reason for the crash. Also note that the package, highway, vehicle, and weather are all represented, but are not prevalent as primary reasons. While the primary reasons are about equally split between the driver of the hazmat vehicle and the other vehicle-induced category, this result is somewhat misleading because if the crash involves multiple vehicles, the dominant reason is *other vehicle* *induced*. Since 61 percent of all hazmat crashes are single-vehicle crashes and 66 percent of all cargo tank crashes involve a single vehicle, for those crashes, driver error dominates. In single-vehicle crashes, the dangerous event *ran off road* was present 88 percent of the time. Driver error was the primary reason for such crashes, implying that driver error was the primary reason for running off the road.

Of all crashes, 26 percent are single-vehicle crashes. Of those single-vehicle crashes, *driver recognition*, *decision*, and *performance* errors were judged to be the primary cause of 66 percent of crashes. If *driver non-performance* (about 9 percent of the total) is added, then almost 75 percent of the single-vehicle crashes are the result of driver error. In multi-vehicle crashes, the other vehicle was responsible for over 60 percent of the crashes. However when the hazmat vehicle is responsible for the crash, the primary cause is listed as *driver decision error* in almost 86 percent of the crashes.

Figure 3-19 explores the relationship between the spill percentages in specific primary reason categories for single- and multiple-vehicle crashes. Of particular note is the exceeding low spill-to-crash ratio for crashes where the primary reason is other vehicle-induced, in contrast to the relatively high spill-to-crash ratio when driver error is involved. The key finding here is that although crashes occur frequently where the other vehicle is at fault, serious crashes are far more likely to occur when the truck driver is at fault.[11]

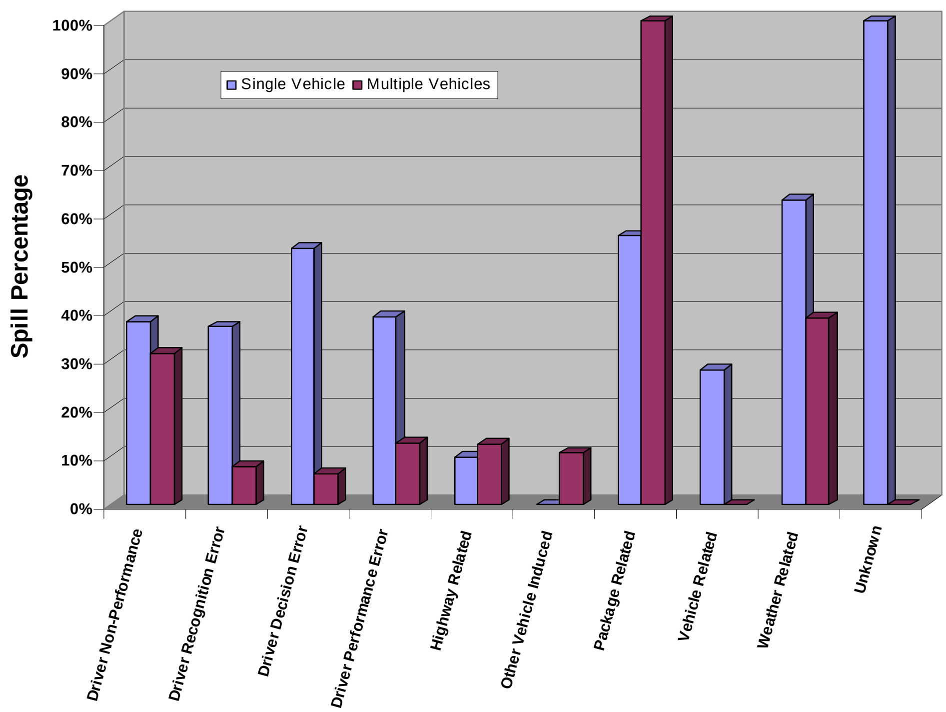

Figure 3-19. Spill Percentage by Primary Reason for Single- and Multi-vehicle Crashes

[11] Note that there was only one multi-vehicle crash that was package-related and it resulted in a spill, accounting for the 100 percent value shown in Figure 3-19. Similarly, there were three single-vehicle crashes that all resulted in a spill with an unknown primary reason.

Table 3-16. Crashes by Primary Reason

HM Group	Driver Decision Error	Driver Non-Performance	Driver Performance Error	Driver Recognition Error	Highway Related	Other Vehicle Induced	Package Related	Vehicle Related	Weather Related	Unknown	Total
2.1	68	4	1	37	13	119	4	0	6	5	256
2.2	38	1	4	11	0	43	2	1	4	0	102
3.0	227	19	26	109	27	445	5	7	35	13	912
5.1 - 5.2	13	0	0	4	0	16	1	0	2	0	36
8.0	38	4	5	25	4	45	2	7	6	2	139
9.0	24	7	4	4	0	40	3	0	2	0	84
Other/Unknown	23	7	0	9	2	44	1	0	6	2	93
Total	431	43	40	198	46	753	17	15	60	22	1,622

Table 3-17. Crashes by Accident Type

HM Group	Backing Up	Head-on	Hit Object in Road	No Impact	Ran Off Road	Rear-end	Side-swipe	Turning	Vehicle Going Straight	Other/ Unknown	Total
2.1	7	14	7	6	77	55	27	32	27	4	256
2.2	0	7	2	2	29	25	22	14	2	0	102
3.0	14	48	24	23	191	224	201	82	83	21	912
5.1 - 5.2	0	3	0	0	14	9	7	4	1	0	36
8.0	2	8	2	2	47	29	25	4	17	3	139
9.0	0	2	0	2	27	16	22	1	15	0	84
Other/Unknown	0	8	3	4	20	24	19	14	2	0	94
Total	24	89	38	39	405	382	323	151	146	28	1,624

3.6.5 Accident Type

Table 3-17 provides information on crashes as a function of crash type by HM group. The most frequent crash types are where the vehicle ran off the road, it was rear-ended, or it was involved in a sideswipe crash. Crashes involving vehicles turning and vehicles going straight were also commonly reported. In short, there appears to be no dominant accident type characterizing HM crashes.

Figure 3-20 shows that the spill-to-crash ratio is significantly higher for running-off-the-road crashes than for any other category, corroborating common perceptions. This is a clear indication that keeping the HM truck on the road infrastructure is an important mitigation strategy for preventing serious crash consequences.

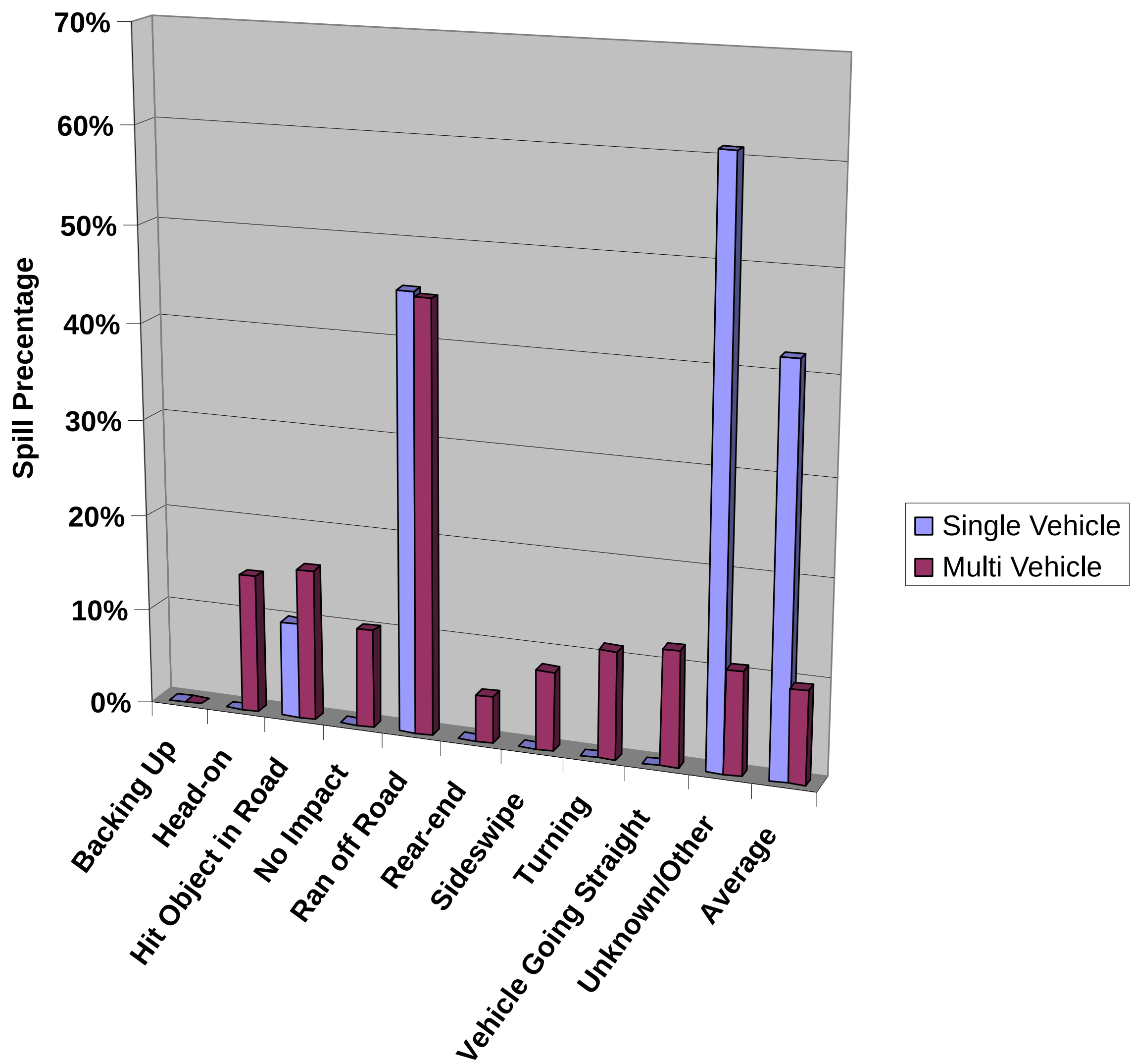

Figure 3-20. Spill Percentages by Accident Type for Single- and Multi-vehicle Crashes

3.6.6 Weather Condition

Table 3-18 shows the number of crashes occurring as a function of weather condition by HM group. As expected, no adverse condition dominates as the primary weather condition across all HM groups. Conditions of rain/sleet or snow are present in a number of cases, while crashes involving fog and high winds are rare. There were no remarkable findings associated with the relationship between weather condition and spills for Class 3 crashes.

Table 3-18. Crashes by Weather Condition

HM Group	No Adverse Condition	Rain/Sleet	Snow	Fog	High Winds	Other	Unknown	Total
2.1	202	30	16	0	4	2	4	256
2.2	77	11	6	4	0	3	0	100
3.0	755	84	44	14	4	11	3	914
5.1 - 5.2	28	4	3	0	2	0	0	36
8.0	119	12	6	2	0	0	0	139
9.0	74	4	3	4	0	2	0	86
Other/Unknown	69	16	7	0	3	0	0	95
Total	1,324	160	84	24	12	17	6	1,627

4.0 Project Findings and Implications

As a result of this project, a credible HM crash analysis database has been created. The HAZMAT Accidents Database design and data entry system provide a foundation upon which HM crash data can be collected, validated, and utilized in support of safety policy analysis. The data collection process utilizes MCMIS as the originating data, and then enhances the crash record with information collected from other sources. This results in an HM crash database that contains more accurate information than what MCMIS has to offer as well as creating new crash attributes that enable more comprehensive safety analysis. The improvement in data quality gained through implementing this process is considered significant in terms of the validity of analysis results.

By populating the HAZMAT Accidents Database with a crash sample of nearly 1,000 records, enhanced capability already exists from which the cause and effect of HM crashes can be evaluated. This is evidenced by the analyses that were performed as part of this study, which led to a number of findings. For consistency with other sections of this report, they are categorized by Vehicle, Driver, Package, Infrastructure, and Situational.

Vehicle

- Across all vehicle configurations, the spill percentage increases as trailers are added to the configuration. Straight trucks with trailers have a spill-to-crash ratio of 22.9 percent, versus 15.4 percent for straight trucks alone. Tractors with two or more trailers have a spill-to-crash ratio of 21.3 percent, versus 18.6 percent for tractors with a single trailer.

- The most common vehicle configuration used in transporting hazardous materials involved in crashes is the tractor/semi-trailer. This configuration is involved in 60 percent of all crashes. The next most common configuration involved in hazardous material crashes is the straight truck, being involved in 30 percent of all crashes. The tractor/semi-trailer configuration is the dominant vehicle configuration for all classes of hazardous material except for Division 2.1, where 69 percent of the crashes involve the straight truck configuration.

- The straight truck vehicle configuration has a somewhat lower spill-to-crash ratio than the tractor/semi-trailer configuration, 13 percent versus 18 percent, respectively. This lower ratio is not because of the vehicle configuration but because the straight truck configuration is dominated by Division 2.1 shipments, which have a significantly lower spill-to-crash ratio, 8 percent versus 18 percent, respectively.

Driver

- The average age of a hazmat driver involved in a crash was 44. Examining spill percentage (the weighted number of spills divided by the weighted number of crashes) as a function of driver age shows that the highest category was the 18 to 24 year-old group at 32 percent, the next was the greater than 65 year-old group at 27 percent. Even though they represented the largest segment of the driver population, middle-aged drivers all had a below-average spill percentage with the lowest being the 45 to 54 year-old group at 14 percent. Essentially, the spill-to-crash ratio by driver age follows an upside-down bell shaped curve, with drivers 45 to 54 years old having the lowest rate of spills.

- An HM crash is likely to be more severe if it involves a driver with less experience. Inexperience often leads to problems with recognition and decision-making. Using the spill percentage (the weighted number of spills divided by the weighted number of crashes) as an indicator of severity for the crashes in which driver experience was obtained, spills occurred in about 20 percent of the crashes. However this percentage is close to 30 percent for drivers with less than three years experience and about 10 percent for drivers with more than six years experience. While the data were limited, there is a clear trend toward a lower percentage of crashes that result in a spill as driver experience increases.

- Spills occur in approximately 18 percent of all crashes. In over 94 percent of all crashes, the driver appeared normal and the spill percentage was about 15 percent. Based on the limited data available for drivers whose driving ability is physically or mentally impaired, the percentage of crashes with spills when the driver was ill, fatigued, or asleep increased to about 30 percent and increased to above 50 percent when the driver was under the influence of drugs or alcohol. There was also an unknown category with an even higher spill percentage. In reviewing several of these crashes, the driver condition at the time of the crash was unknown because the driver was fatally injured in the crash.

- There is an extremely low spill-to-crash ratio for crashes where the primary reason is "other vehicle induced," in contrast to a relatively high spill-to-crash ratio when driver error is involved. Although crashes occur frequently where the other vehicle is at fault, spills are far more likely to occur in crashes where the truck driver is at fault.

- Of all serious crashes, 26 percent are single-vehicle crashes that involve only the hazmat vehicle. Of those single-vehicle crashes, driver recognition, decision, and performance errors were judged to be the primary cause of 66 percent of crashes. If driver non-performance (about 9 percent of the total) is added, then almost 75 percent of the single-vehicle crashes are the result of driver error. In multi-vehicle crashes, the other vehicle was responsible for over 60 percent of the crashes. However when the hazmat vehicle is responsible for the crash, the primary cause is listed as driver decision error in over 85 percent of the crashes.

<u>Packaging</u>

- When the DOT406 specification tank was involved in a serious crash, hazardous material was spilled 13 percent of the time as compared to MC306 tanks, which experienced spills 20 percent of the time. The difference is even larger when comparing the DOT407 and MC307 specification designs. With these two designs, spills occurred in 26 percent of the crashes involving the DOT407 and 37 percent of the crashes involving the MC307.

The introduction of the DOT406 and DOT407 designs have clearly enhanced container integrity.

- The annual estimate for the number of crashes for MC306 cargo tanks is 2.2 times that of DOT406 cargo tanks (283 and 130, respectively). With the assumption that the crash rates for these cargo configurations are relatively equal, this implies that the DOT406 containers have not fully penetrated the market.

- The spill-to-crash ratio is higher for crashes where the impact occurred in the HM cargo region. Impacts in the cargo region resulted in spills in 23 percent of crashes; whereas, impacts elsewhere resulted in spills in 12 percent of crashes. As expected, a direct impact on the HM cargo region would subject the cargo body and/or packaging to a more severe impact, increasing the likelihood of a breach of the packaging and resulting in a release of the hazardous material to the environment.

- Seventy-eight percent of all spills involved cargo tanks, which is slightly lower than the percentage of all crashes they comprise (85 percent).

- Of serious cargo tank crashes, 25 percent are single-vehicle crashes. The single-vehicle crashes account for 66 percent of the spills, 76 percent of the rollovers, and 77 percent of the crashes that result in both rollover and spill. This cargo configuration is commonly used for Class 2, 3, 8, and 9 shipments. Driver recognition and driver performance errors were frequently listed as the primary cause for these single-vehicle crashes.

- Rollovers occur in approximately 24 percent of all serious crashes and there does not seem to be much difference among the heavy truck cargo configurations. An analysis of rollover percentage as a function of the loading (empty, part full, and full), showed a linear increase and not the stability problem that is often associated with partial loads. Thus it is difficult to conclude that cargo tank stability is a major cause of crashes. That being said, there is a very strong correlation between rollovers and spills. One of the most likely locations for a rollover is on entrance and exit ramps, in which more than 87 percent of all rollovers result in a spill.

<u>Infrastructure</u>

- Spills occur in about 14 percent of the serious crashes on Interstates. On average, however, spills occur in 18 percent of all crashes. This slight difference may be attributable to design elements associated with Interstate construction such as medians, shoulders, and guardrails that reduce the likelihood that a truck will be involved in a rollover. The results show that rollover events occur in 19 percent of all crashes on Interstates, compared to an average of 23 percent when considering all road types.

- On divided highways there are about 15 hazmat spills for every 100 crashes. This low spill rate is counterbalanced by the high spill rate on entrance and exit ramps, almost 50 hazmat spills per 100 crashes. On undivided highways, there are about 20 hazmat spills per 100 crashes, just slightly above the average of 18 hazmat spills per 100 crashes. The lower spill rate for divided highways is to be expected given the high correlation between Interstates and divided highways.

Situational

- Two pre-crash conditions dominate, *in traffic lane* and *maneuvering*. *In traffic lane* is the pre-crash condition for over 70 percent of all crashes and leads to about 65 percent of all spills. While *maneuvering* is the primary cause for fewer crashes (about 25 percent), it results in a larger percentage of the spills (about 35 percent). One plausible explanation is that a crash that begins with a driver performing a maneuvering action is more likely to lead to the driver losing control of the vehicle, resulting in a *rollover*. While *rollovers* occur in only 24 percent of all hazmat crashes, they account for over 75 percent of all spills.

- Only 25 percent of all serious crashes are single-vehicle crashes. However, over 60 percent of all spills result from single-vehicle crashes. Sixty percent of all crashes are multiple-vehicle crashes that occur while the hazmat vehicle is within the traffic lane. These dominate the crash total. The multiple-vehicle maneuvering crashes, and the single-vehicle crashes that occur while maneuvering and when within traffic lanes are more equally distributed, each contributing about equally to the crash total. Spills occur in approximately 18 percent of all crashes and the contributions are about equal (about one-third each) from single-vehicle crashes that occur while the vehicle is in its traffic lane, single-vehicle crashes that occur when maneuvering, and multiple-vehicle crashes that occur while the vehicle is in its traffic lane.

- Data analysis confirms the widely held belief that the spill-to-crash ratio is significantly higher for rollover events than for other crash types. The lower spill probability for all tanks is probably attributable to the differences in tank designs, Class 2 tanks typically being more robust because they must contain either a low temperature liquid or a gas under pressure. With more data, it might eventually be possible to examine the effect of the tank specification on the spill probability in rollover and non-rollover crashes. Keeping the HM truck upright appears to be an important mitigation strategy for preventing serious consequences in a hazardous materials crash.

- The data also show that the spill-to-crash ratio increases for cargo tanks as their loading increases, with fully loaded tanks resulting in spills 34 percent of the time.

- For crashes in which vehicle speed was provided, the spill-to-crash ratio averages 19 percent. For speeds between 10 and 70 mph, the spill-to-crash ratio is close to the average. However, below 10 mph, the spill-to-crash ratio is 8 percent and above 70 mph it is 32 percent.

While these analyses were limited by sample size problems, the opportunity exists for FMCSA to collect additional crash data using the same methodology and tools in order to construct a larger sample. One such approach is for FMCSA to implement an annual data collection and analysis program, enabling the agency to amass a HM crash sample of sufficient size that more comprehensive studies of HM motor carrier safety can be performed. An added benefit of this approach would be the ability for FMCSA to monitor HM crash trends over time.

<u>Recommendations for Future Work</u>

Several future initiatives have been identified that would add significant value to the foundation established through the HM serious crash analysis efforts to date. They are described below.

1. Initiate a Phase 3 of the HM Serious Crash Analysis project. The data collection, enhancement and analyses would include additional HM crashes sampled from 2003 and 2004 MCMIS Crash File data.
    a. The data analysis would combine the results from 2002 with the results from the subsequent years to enable more in-depth analyses. This would especially apply to the "rare HM classes" such as HM groups 1, and 4 through 7 that require additional data to supplement the 2002 data. The additional data would also enable comparison of performance among HM groups while meeting the sampling threshold for a wide variety of parameter studies.
    b. Consideration could be given for performing targeted analyses. For example, all HM tank trucks involved in rollovers during 2002 through 2004 could be selected in addition to the "random" sample.
    c. "Data mining" techniques could be applied to identify additional relationships that would produce new insights into HM truck shipment safety.

2. From the insights gained during this project, it would be possible to develop a set of recommendations for improving the quality of MCMIS reporting. The recommendations would be directed at enhancing the effectiveness of data collection. One might be able to make greater use of commercial vehicle supplement pages which 30 states now use. To supplement project insights, officials from states that are providing an accurate record of hazmat crashes could be contacted to further identify the key components of their success.

3. The current analyses used the five HM-related fields in the MCMIS Crash file to identify serous hazmat crashes. There are many indications that this process was not very efficient. Out of the sampled crashes, almost 20 percent turned out to be non-hazmat and it is likely that there many hazmat crashes that could not be identified as such. Furthermore, hazmat-related parameters are not used in the identification of a serious crash. A multi-pronged approach is proposed. On one side, the project would continue to do a quick screen of MCMIS to identify those crashes that are clearly hazmat because three or more of the five HM-related fields are well-populated. Using the motor carrier names from this first quick screen, those that probably carry hazmat almost exclusively, would be identified and PARs for all those crashes would be requested. A parallel track would look at HMIS and available state databases to identify high-volume hazardous material carriers. Lastly, daily Internet searches would be done to identify news reports of hazardous material crashes. Over time, the key words being used for this search would become refined, improving its effectiveness. Through such efforts, it might be possible

to identify as many as 3,000 potential HM crashes on an annual basis while reducing the error rate from its current 20 percent.

4. The analysis capabilities of the HAZMAT Accident Database would be greatly enhanced if the data tables were imported into an appropriate statistical analysis package. While Microsoft Access is the appropriate tool for data collection and management, the graphical tools and SQL base on which Microsoft Access is built makes analytical work complex, relatively inefficient, and difficult to document. In contrast, statistical analysis software provides a tool set optimized for analytical purposes. Most analytical packages, such as SAS, SPSS, and Stata, can readily import Microsoft Access tables and then analyze the data using the software's tools. Statistical analysis packages are more efficient and readily produce documentation to show the set of filters and aggregation that were used to produce the results.

Appendix A. Description of HAZMAT Accidents Database

The HAZMAT Accidents Database is designed to capture and augment information about crashes involving hazardous materials contained in HMIS and MCMIS records. Organized as a relational database, it stores supplemental data obtained from the PARs and from phone calls to the carrier. What follows is a description of the database design.

The starting screen presents the user with several options (see Figure A-1). The "Incident Notification" button initiates data entry for a crash. "UN Number" allows the user to change the two-digit HM Code and division code for a given UN number. "Commodities" enables the user to enter or change the definition of a particular commodity, the two digit HM code, UN number, short and long name, the reportable quantity (RQ) limit or if the material is "poisonous by inhalation." The basis for this information is the Hazardous Materials Table presented in 49 CFR 172.101. "Accident Record Status" summarizes the completeness of the records and permits access to an overall Status Summary of all the crashes entered into the database. "Agencies" permits the user to enter the name of the agency providing the crash information. "DOT Numbers" permits the user to enter a carrier's DOT number, address, phone number, or fax number. "Packages" allows the user to enter the name and description of a package that was used for the HM shipment (e.g., MC 306 cargo tank for transporting gasoline).

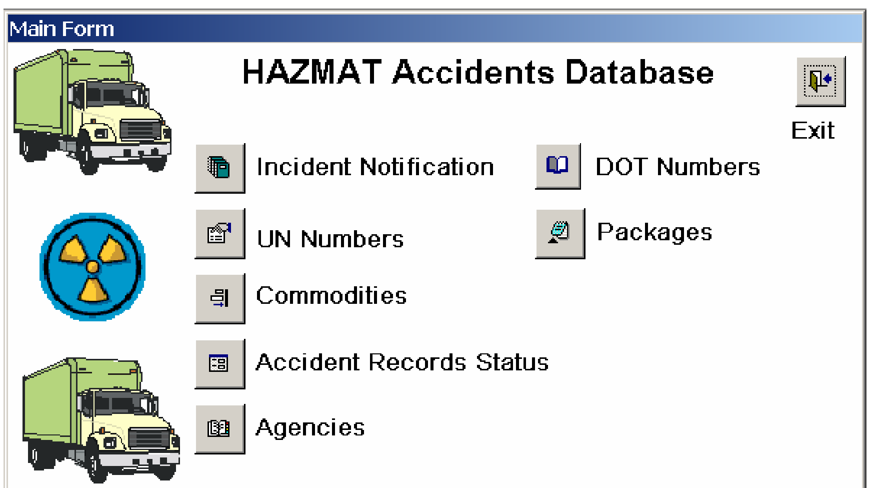

Figure A-1. Main Entry Screen for the Crash Database

The buttons shown in Figure A-1 provide a means of entering standard information about the commodity being shipped and the carrier. When a new crash is being entered, these buttons provide a means of checking to ensure that the carrier is listed by DOT number and the commodity and packaging information are already in the database. If they are not shown, these items can be entered with this screen if the carrier and hazardous material screens are populated.

Of the options presented in Figure A-1, only the "Incident Notification" selection prompts several additional screens required to fully describe the crash sequence and associated details. When the "Incident Notification" button is pressed, the screen shown in Figure A-2 appears.

Any fields that have been pre-populated using queries of MCMIS and HMIS reports will appear filled as the screens pop up.

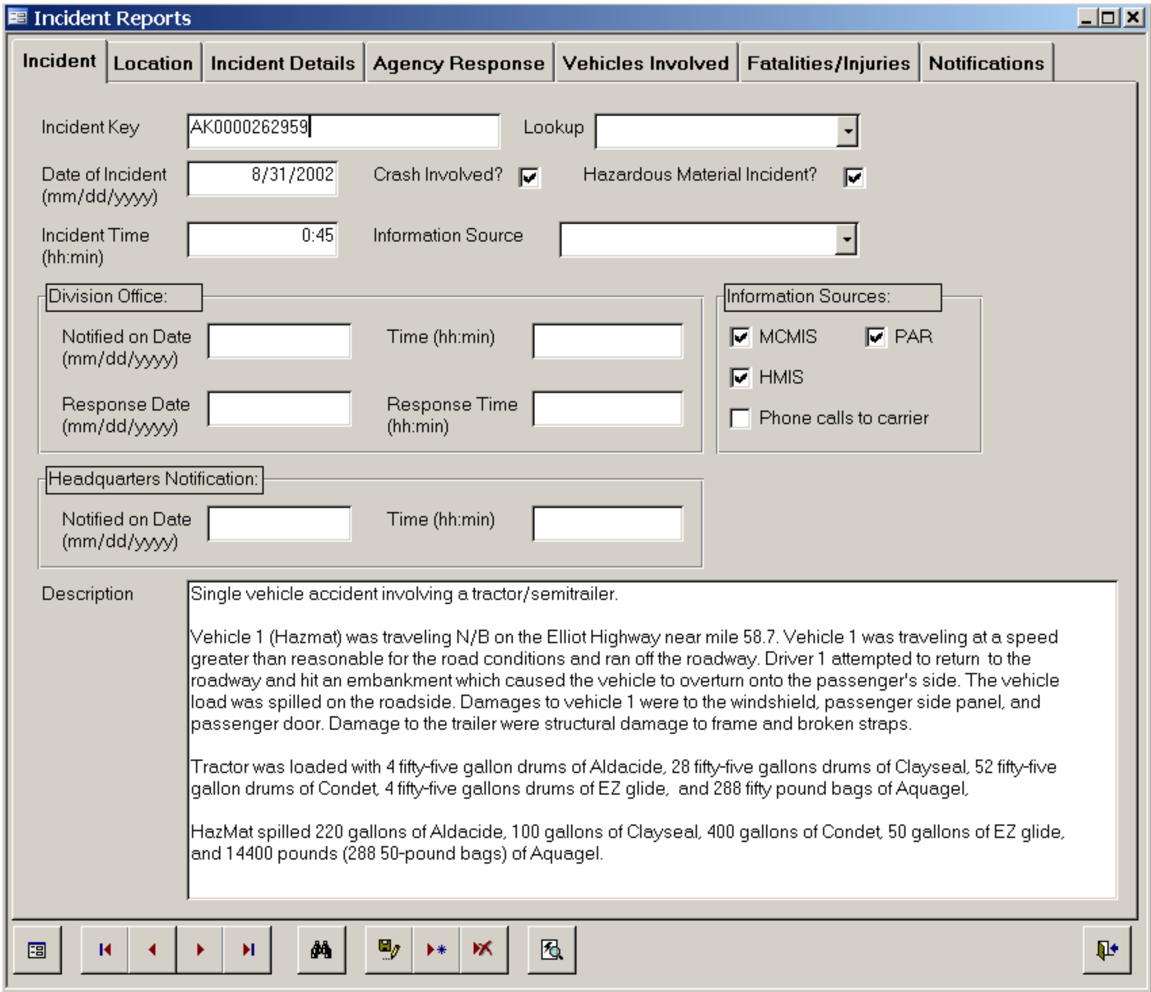

Figure A-2. Crash Summary

Most of the fields appearing in Figure A-2 are self-explanatory. "Incident Key" is the MCMIS report number. The notification fields were designed for use by DOT personnel, but were not populated as part of this project. If the crash appeared in the HMIS database, the remarks from the HMIS record are provided in the "Description" field. Otherwise, the descriptions were obtained from the PAR, if available. At the bottom of this screen, there are a series of navigation buttons that enable the user to move from one record to another. Delete, print and exit options are also provided. When the print button is selected, a complete report for the specified crash is created and sent to the printer.

Seven tabs are located at the top of the "Incident Notification" screen. When any of these tabs is selected, an additional data entry screen is displayed. Some tabs have sub-screens. The following discussion provides more detail on these features.

Figure A-3 shows the information contained on the Location screen. For many of the entries shown, a drop-down pick list is provided. For example, once the abbreviation of the state is selected, the county selection is made from among the counties associated with that state. Similarly, the selected place is populated from the list of places under the selected state. The county and place pick lists are based on the U.S. Bureau of the Census FIPS listings.

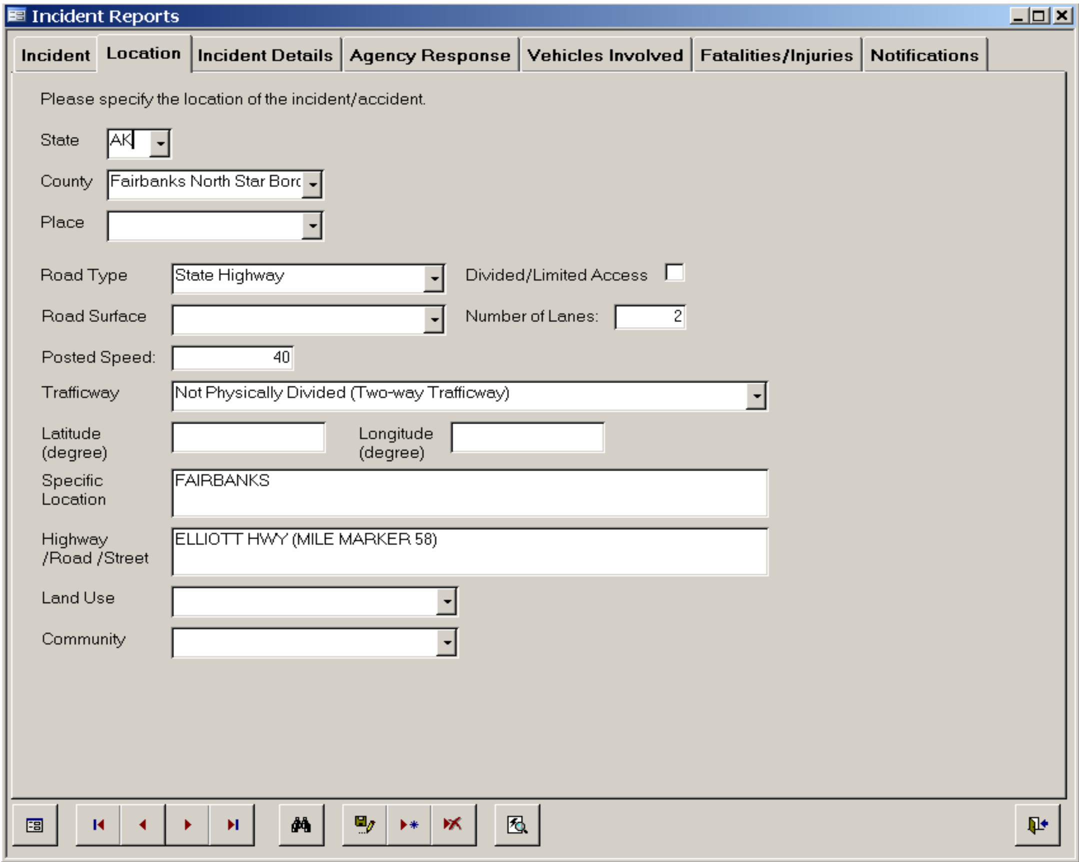

Figure A-3. Crash Location

Many of the remaining entries are also made from pre-selected lists. In almost all cases, these lists coincide with eligible entries for that field in MCMIS. As a result, a more consistent and accurate database is realized. There are some fields, particularly those associated with the crash location, that are not associated with pick lists. In addition, the longitude and latitude coordinates were not always populated; utilizing GIS to complete these fields was not pursued as part of this project.

Figure A-4 shows a screen entry for additional incident details. The drop-down lists are based on standard terminology used in MCMIS. "Event Details" provides an opportunity to include additional information that was not included in the accident description field on the Crash screen. The intent is that the information on this screen focuses more on crash sequences and causes.

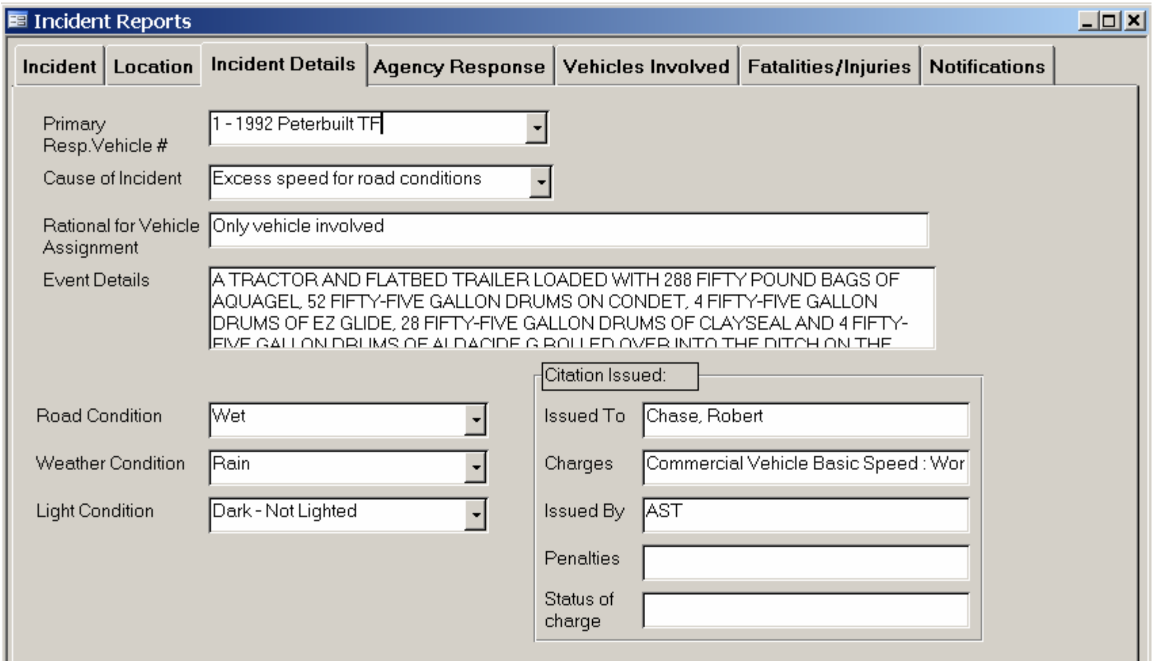

Figure A-4. Crash Details Data Entry

Information about the responding agency appears in Figure A-5. Multiple entries are permitted for each responding agency against a specific crash. These entries are considered informative, but optional.

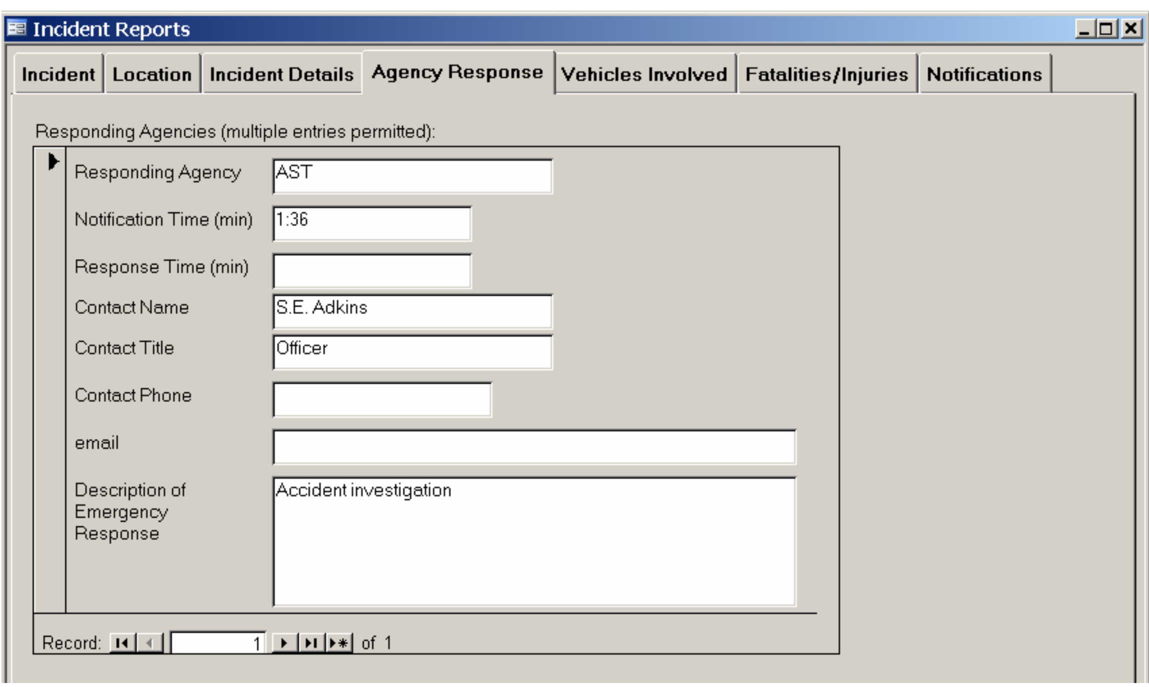

Figure A-5. Agency Response Information

Figure A-6 represents the first of several screens intended to capture data for each vehicle involved in the crash. If there were multiple vehicles involved in a single crash, then this screen would be completed once for each vehicle. For each vehicle, there are additional screens for entering carrier, driver, HM information and event details related to the crash.

For each vehicle, the first entry is the vehicle number. This is normally the number assigned to the vehicle in the PAR. The next entry is the designation of the vehicle, also typically taken from the PAR. The configuration, impact location, obstructed vision, and cargo body type are all selected from pick lists. Estimated vehicle speed, gross weight, number of axles and trailer description are also entered, predominately from information contained in the PAR.

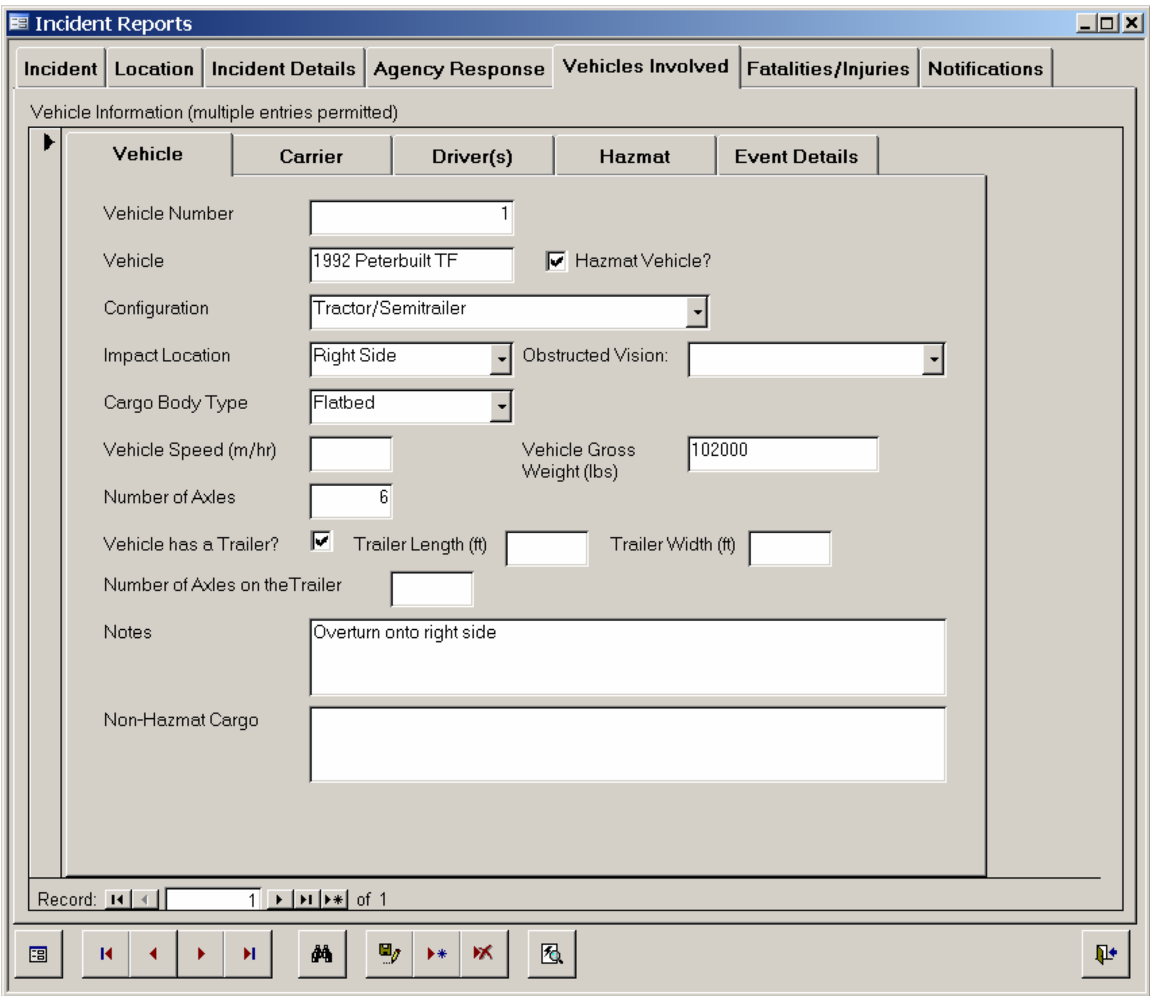

Figure A-6. Information on Crash-Involved Vehicles

If there is something noteworthy about the vehicle configuration or the vehicle's non-HM cargo as listed in the PAR, it can be entered as part of the vehicle description as well.

If the carrier was one of the carriers entered initially into the database or if the carrier information was entered as part of another crash, then all of the information shown in Figure A-7 will be displayed when the DOT number is entered. The “Lookup US DOT#” and “Add US DOT#” features allow the user to edit/enter carrier related information. Typically, a crash involving a certain vehicle owned by a certain carrier will carry the home office address, but in case the vehicle of concern belongs to a regional office of the carrier, that address can be carried along with each vehicle record.

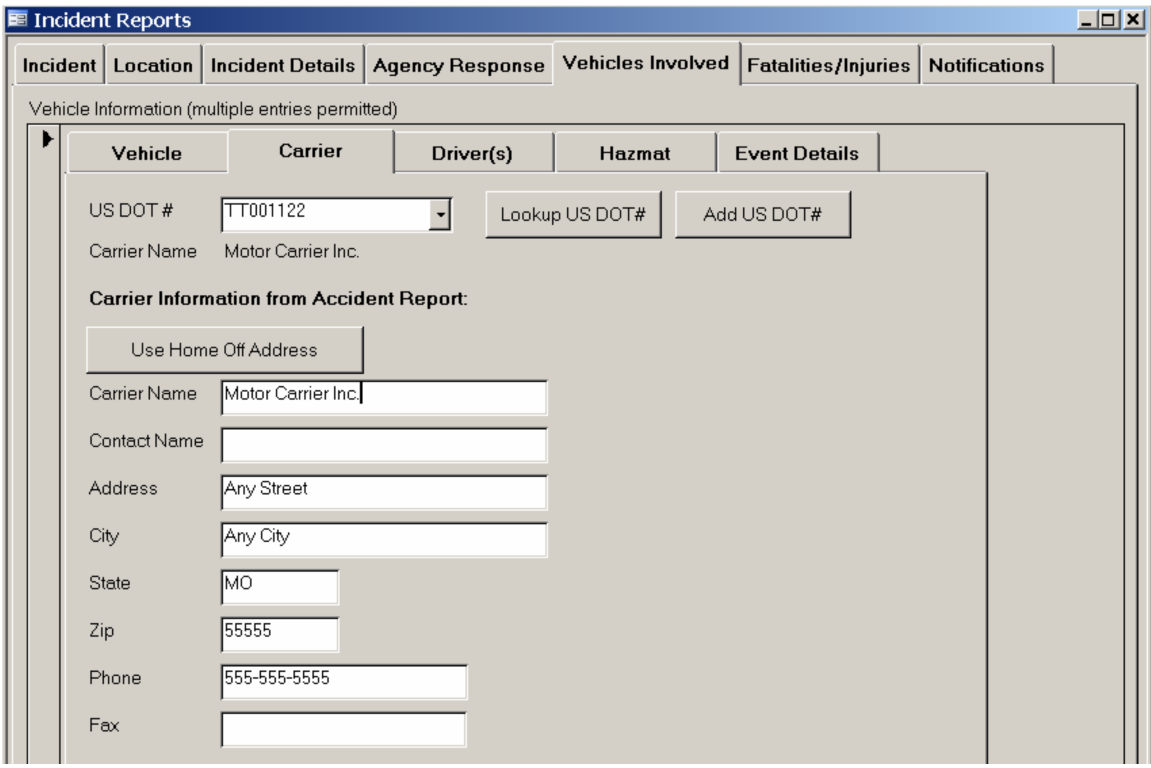

Figure A-7. Carrier Information

The driver information shown in Figure A-8 is just for the driver associated with the carrier and vehicle that were described on the previous entry screens. Normally there would be just one driver. However, if there is a co-driver that was not driving at the time of the crash, then information on that individual can be entered on a separate screen. Frequently, the PAR will not provide all of the information shown in Figure A-8.

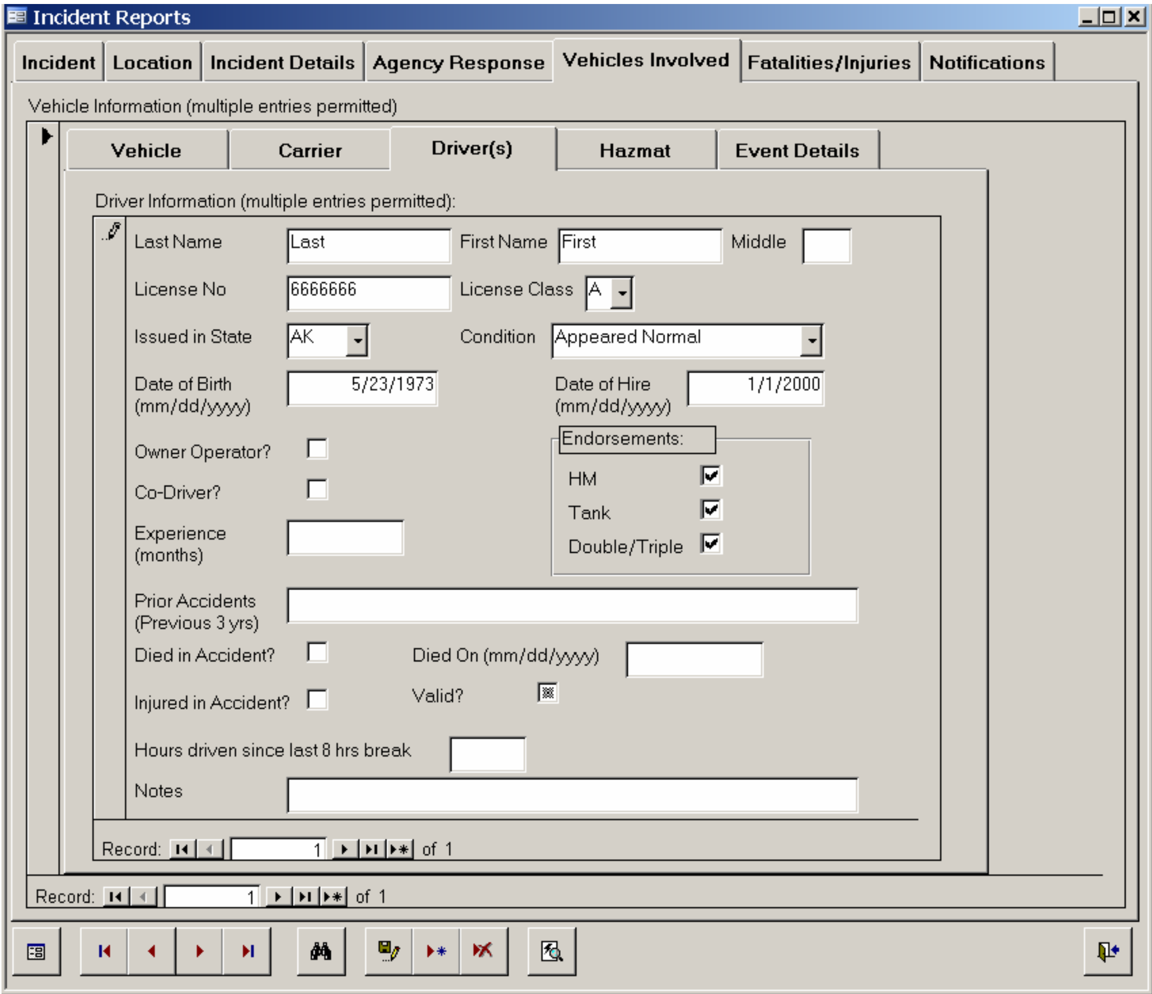

Figure A-8. Driver Information

Figure A-9 is the first of a series of screens that describe characteristics of the cargo. The upper part of the screen describes the hazardous material being shipped. In most cases, this information will already be part of the list of hazardous materials entered initially in the database. If not, by clicking the “Add Material” button, a new material can be added.

One of the key pieces of information contained on the Hazmat screen is the quantity shipped. Neither MCMIS nor HMIS capture this information. Consequently, the effectiveness of the packaging to resist spillage cannot be determined. An effort was made to obtain this information for the majority of crashes through contact with the involved carrier.

The bottom part of Figure A-9 displays the first of several package screens, one that focuses on package type. Additional screens can be brought up concerning the behavior of the package in the crash environment. The Actions, Objects, How, Area and What tabs capture all of the container damage fields in the HMIS database. These screens are shown in Figures A-10 through A-14, respectively.

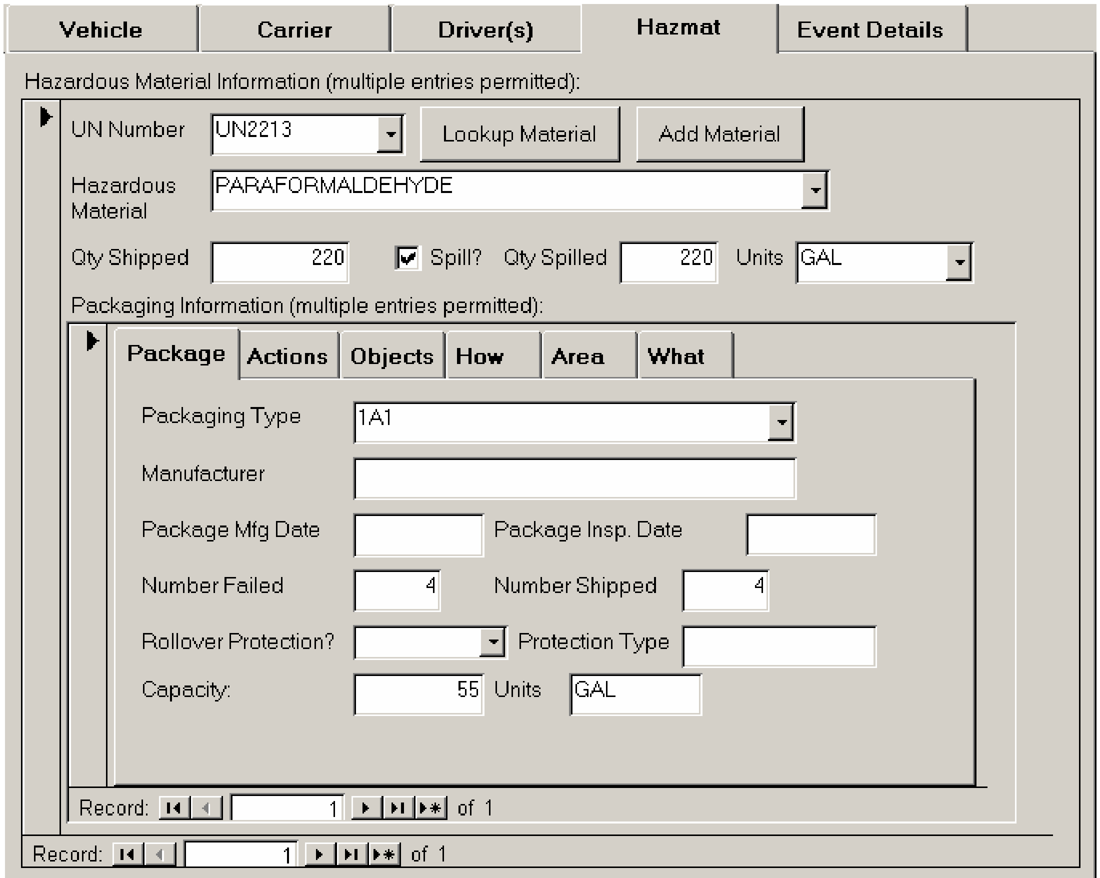

Figure A-9. Hazardous Material and Shipping Package Description

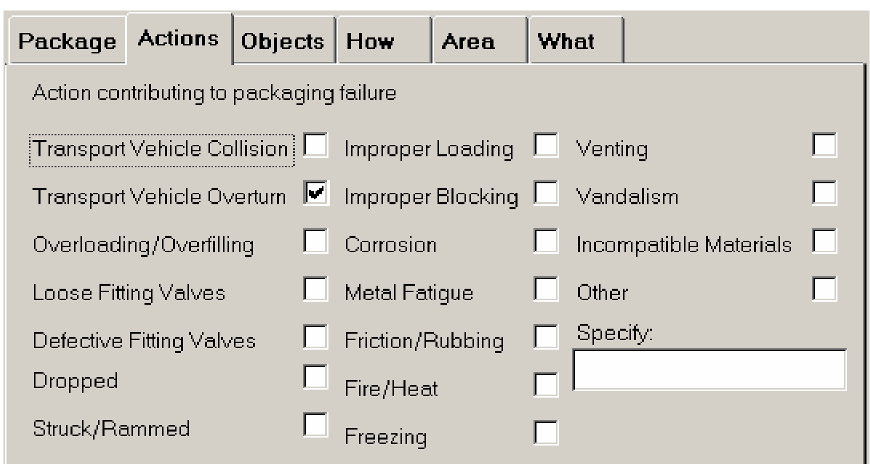

Figure A-10. Action Entries Under the Package Behavior Screen

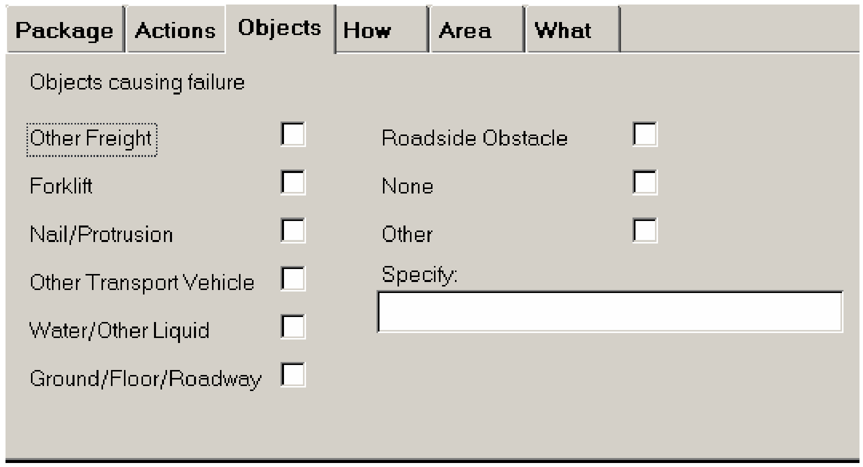

Figure A-11. Object Entries Under Package Behavior Screen

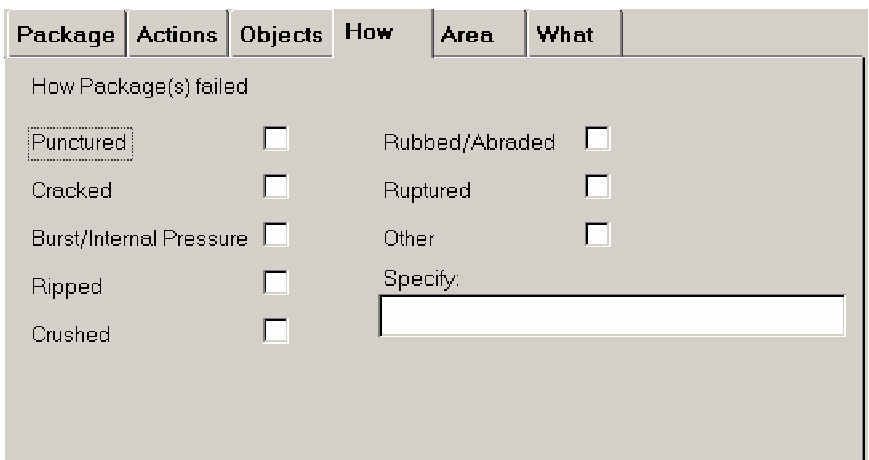

Figure A-12. How Package Failed Under Package Behavior Screen

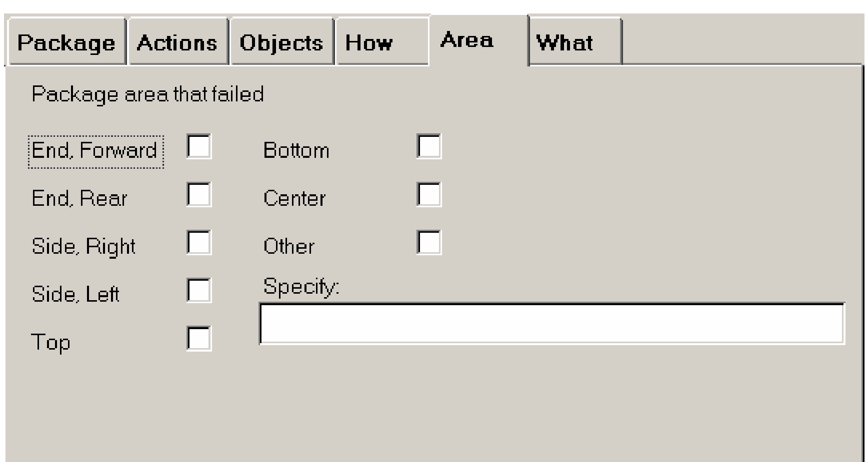

Figure A-13. Areas Failed Entries Under Package Behavior Screen

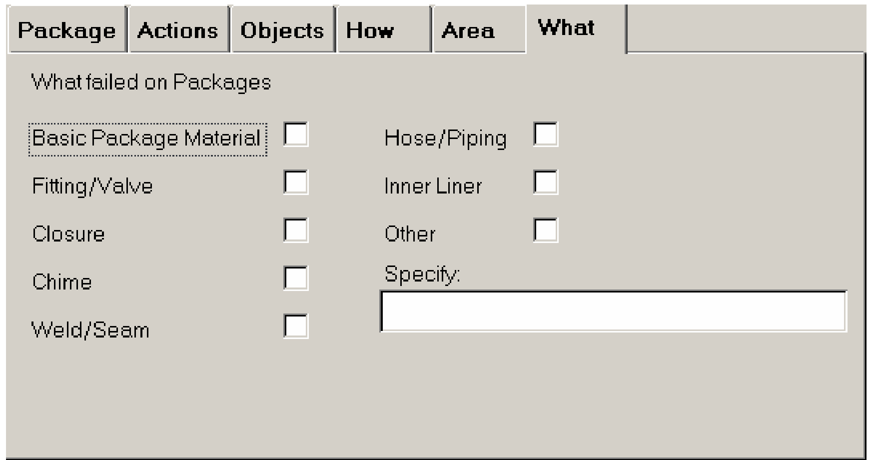

Figure A-14. Failed Components Under Package Behavior Screen

Figure A-15 below shows the data fields captured under Event Details. This allows data entry for harmful event sequence and provides additional fields to handle crashes that involve multiple vehicles.

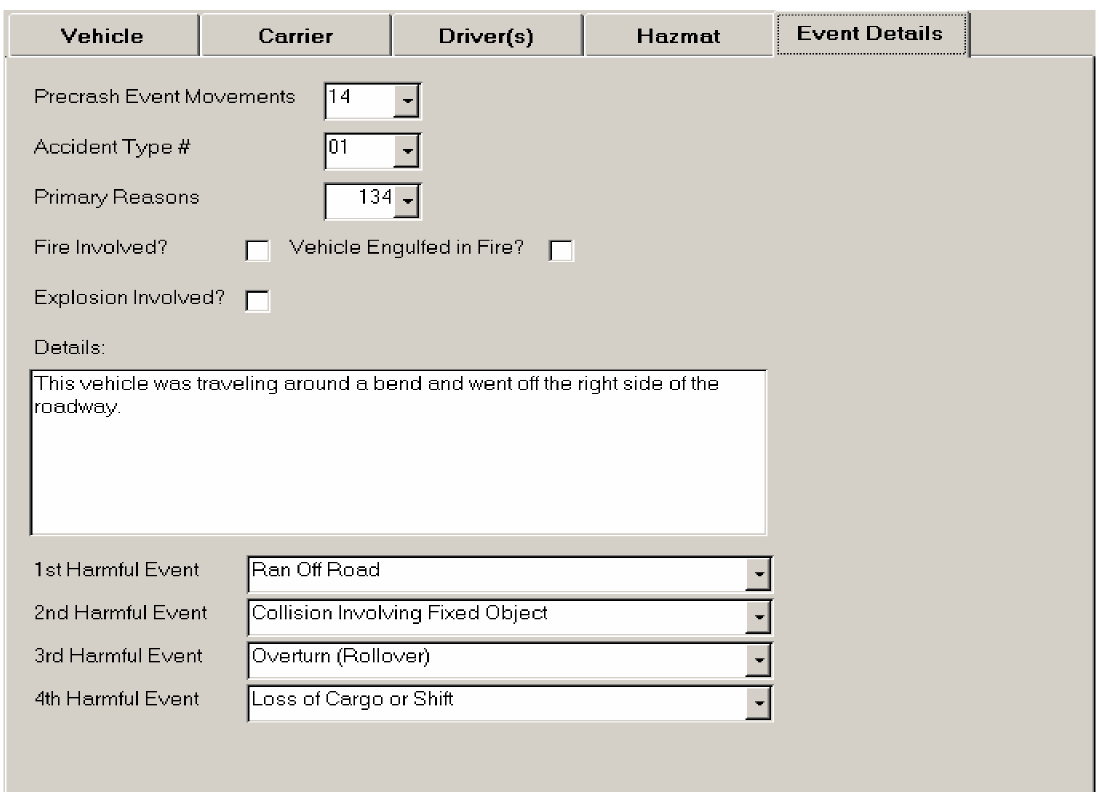

Figure A-15. Event Details

The fatalities and injuries information is captured as shown in Figure A-16. This section is completed for each fatality and injury across multiple vehicles and pedestrians that may have been involved in the crash. The Notifications tab enables the user to capture the notification methods and the agencies notified.

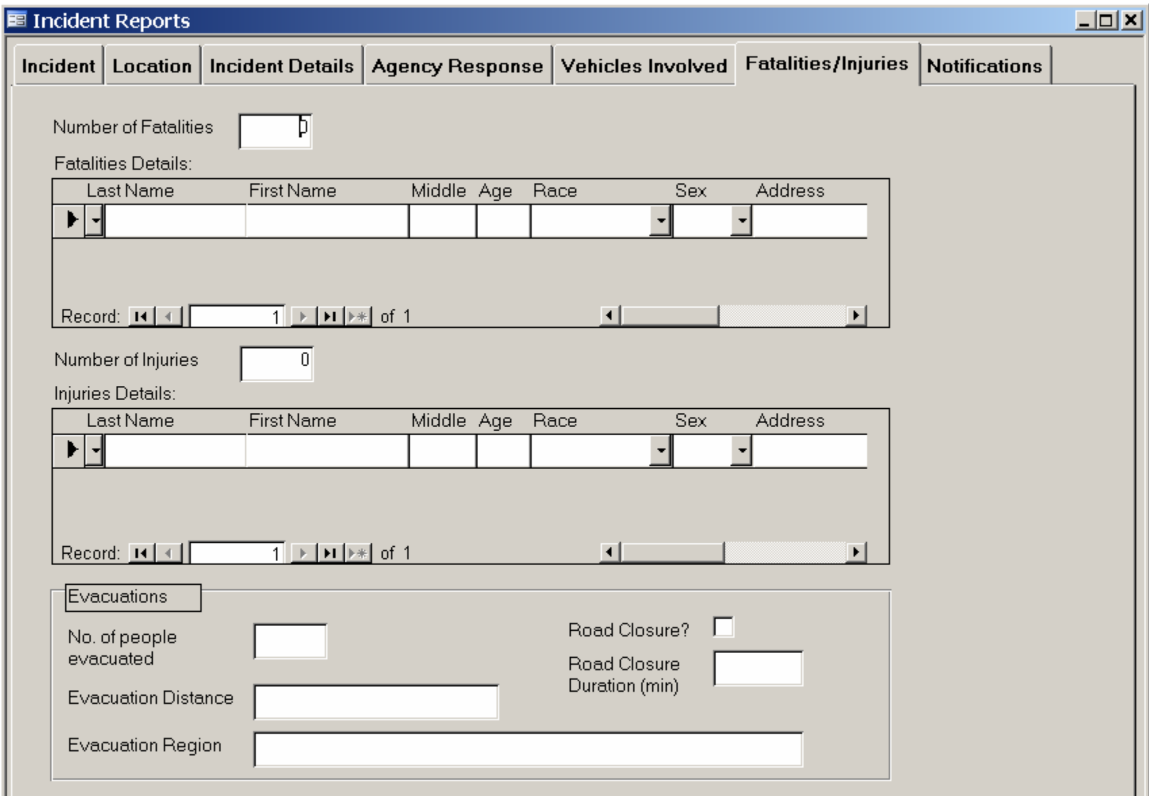

Figure A-16. Fatalities/Injuries

Appendix B. Selecting, Populating, and Validating Crash Records

B.1 Selection of Crash Records

The process of selecting records to include in the HAZMAT Accidents Database began with the approximately 105,000 MCMIS crash records for calendar year 2002 obtained from FMSCA. In the crash record, there are 5 fields that could be used to determine whether the crash involved a truck carrying hazardous materials: HAZ_PLAC, HAZ_4DIG, HAZ_NAME, HAZ_1DIG, and HAZ_CARG. HAZ_PLAC is a Y/N field that is marked Y if the shipment is placarded. HAZ_4DIG contains the four digit UN Code that is often shown across the center of the diamond shaped placard. HAZ_NAME is the commodity name such as Gasoline, or may also designate a hazard, such as Corrosive. HAZ_1DIG is the hazard class for the commodity, normally displayed at the bottom of the placard. Finally, HAZ_CARG is another Y/N field that is flagged Y if hazardous material is spilled.

If hazardous material is involved in an accident, all five fields are required to be filled out. Typically, however, most of these fields are not populated. To make the task more difficult, a "9" entered in the HAZ_1DIG field can either mean that the hazardous material entry on the accident form is blank or that the material being shipped is a miscellaneous hazardous material (Class 9). The former is dominant, making this field meaningless whenever the field contains a "9."

Of the roughly 105,000 crashes reported in MCMIS for 2002, 1,607 had "Y" in the HAZ_PLAC field, 1,500 had an entry in the HAZ_4DIG field, 828 had an entry in the HAZ_NAME field, 13,263 had an integer entry in the HAZ_1DIG field and 423 had a "Y" in the HAZ_CARG (spill) field. Because 13,000 hazardous material accidents identified in the HAZ_1DIG field far exceeded the expected number of annual hazmat truck crashes, for reasons explained previously only entries from 1 through 8 in the HAZ_1DIG were considered in the screening. Using a "Y" in the PLACARD field, a non-blank entry in the HAZ-4DIG field, an entry that was not a "9" in the HAZ_1 DIG field, a non-blank entry the HAZ_NAME field or a non-blank entry in the HAZ_CARG field, it was possible to identify 2,084 crashes that might involve a hazardous material. The total number of vehicles represented by these records was 2,255 taking into account that there were multiple trucks involved in several of the accidents. Since there were a few records submitted twice, the actual number of accidents suspected of being HM crashes was reduced to 2,030. A search was made to match each of the HMIS records with one of the MCMIS records and as a result of that matching process, 96 HMIS–MCMIS record matches were identified. Of the crashes identified, 29 had not previously been identified as being hazmat because the respective MCMIS hazmat fields were blank. Thus, a total of 2,059 crashes were identified as potential HM crashes. For these crashes, PAR's were requested from the states.

Table B-1. State Count of All Crash Records and HM Estimate

State	# MCMIS Records 2002	# MCMIS Records HM	% MCMIS Records HM	State	# MCMIS Records 2002	# MCMIS Records HM	% MCMIS Records HM
AK	21	3	14.3%	MT	620	21	3.4%
AL	3405	113	3.3%	NC	4432	37	0.8%
AR	1620	15	0.9%	ND	291	14	4.8%
AZ	2383	18	0.8%	NE	1111	61	5.5%
CA	6730	289	4.3%	NH	77	0	0.0%
CO	1476	16	1.1%	NJ	6911	103	1.5%
CT	946	25	2.6%	NM	225	18	8.0%
DC	1	0	0.0%	NV	589	19	3.2%
DE	241	5	2.1%	NY	2872	131	4.6%
FL	4562	119	2.6%	OH	4774	222	4.7%
GA	203	0	0.0%	OK	1439	33	2.3%
HI	89	1	1.1%	OR	1079	42	3.9%
IA	1413	3	0.2%	PA	20	1	5.0%
ID	653	4	0.6%	RI	161	4	2.5%
IL	3516	67	1.9%	SC	2603	14	0.5%
IN	3563	93	2.6%	SD	217	5	2.3%
KS	1460	23	1.6%	TN	915	24	2.6%
KY	2604	78	3.0%	TX	10971	8	0.1%
LA	3171	8	0.3%	UT	1219	1	0.1%
MA	846	37	4.4%	VA	2468	32	1.3%
MD	1315	5	0.4%	VT	41	4	9.8%
ME	305	18	5.9%	WA	1368	11	0.8%
MI	2923	28	1.0%	WI	2744	78	2.8%
MN	2253	34	1.5%	WV	588	23	3.9%
MO	3844	105	2.7%	WY	782	35	4.5%
MS	1997	35	1.8%				

Table B-1 shows wide variation in the number of crash records reported by each state into MCMIS. While some variation would be expected because of a state's size and location, the differences are much larger and are likely attributable to underreporting. For example, there are nearly 5,000 crash records reported for Ohio and only 20 for Pennsylvania. There is also evidence that the number of hazmat crashes is grossly underreported by some states. For example, Texas reported nearly 11,000 truck crashes and none could be identified as involving hazardous materials. The 8 HM crashes shown for Texas were actually identified in the HMIS database and then tracked to the corresponding record in the MCMIS Crash file.

The final step was to select 1,000 crashes for more detailed analysis. For the purpose of trying to achieve statistical confidence in analyzing crashes across all HM groups, it was decided to include all Class 1, 4, 5, 6, and 7 crashes in the sample. This represented 55 crashes. The remaining 945 crashes were randomly sampled from among the remaining 2,004 crashes.

The breakdown of crashes into hazmat categories was considered to be preliminary because it was developed using the aforementioned hazmat fields in the MCMIS crash file that were often left blank. The inaccuracy of the selection was soon realized when not all states supplied the requested PARs and the sample size was 77 short. Then a first reading of the remaining sampled PARs revealed that an additional 183 did not involve any hazmat vehicle. As a result, an additional 260 HM crashes were randomly selected from among the remaining PARs to bring the total analysis sample back to 1,000 hazardous material crashes. When all of the PARs for second sample of 260 were analyzed, many more were found to involve no hazardous materials. Therefore, the final analysis sample consisted of 941 crashes which involved a total of 947 vehicles carrying hazardous material and 984 hazmat records. A hazmat record was generated for each type of hazardous material being shipped. Thus if there were two different Class 3 commodities in the shipment, two hazmat records would be generated. Multiple hazmat records are not generated if the shipment consists of multiple packages containing the same hazardous commodity.

As discussed later, once the PARs were entered into the database and many of the carriers involved in the crash were contacted, there were significant changes to the population of hazardous material crashes assigned to each hazard class.

B.2 Populating Crash Records

Once the crash records that are likely to involve hazardous materials were identified, the first step was to import the relevant fields from the MCMIS crash file into the Incident table of the HAZMAT Accidents Database. The imported fields are shown in Table B-2.

The MCMIS parameter list shown in the above table is for the version of MCMIS that was used to provide the 2002 truck crash records. The latest version of MCMIS has a different parameter list and separates the file into several tables.

In addition to distributing the parameters across the Incident table, information from the MCMIS Crash file was also distributed across the Vehicle, Hazmat, Driver and Hazmat Packaging tables. For a given crash, the vehicles involved were related to the parameters in the Incident table by the *Incident ID*, an autonumber uniquely assigned by the Access program when the crash records were input. The other tables, since they are related to the vehicle, contained the *VehicleID* autonumber since the hazmat and driver information were unique to the vehicle. The Hazmat_Packaging table was related to the Hazmat and Vehicle table by the *HazmatID* and *VehicleID* autonumbers. Table B-3 shows the parameters in the Vehicle table and which fields were populated from the MCMIS Crash file.

Table B-2. Incident Table Variables Input From MCMIS Crash File

Incident Table	MCMIS Crash Table	Incident Table	MCMIS Crash Table
Name	Name	Highway	LOCATION
		Milepost	
IncidentID		Latitude	
IncidentKey	RPTNUM	Longitude	
IncidentDate	ACDT_DATE	EventDetails	
IncidentTime	ACDT_TIME	WeatherConditionID	WEATHER
MCMIS	Yes	LightConditionID	LIGHT
HMIS		VehiclesInvolved	
PAR		Preparer	
PCC		NotificationMethod	
Crash	Yes	CitationIssuedTo	
HMIncident	Yes	CitationCharges	
InformationSource		CitationBy	
DivNotificationDate		StatusOfCharge	
DivNotificationTime		Penalties	
DivResponseDate		Name	
DivResponseTime		Status	
HQNotificationDate		ComplianceReview	
HQNotificationTime		ComplianceReviewDate	
Description		LandUseID	
EnteredOn		CommunityID	
ModifiedOn		RoadSurfaceID	RD_SURF
VehicleID		Access	RD_ACCESS
CauseID		NumLanes	
Fatalities	FATALITY	PostedSpeed	
Injuries	INJURY	AgencyID	
EvacuationDistance		PARReceived	
EvacuationRegion		PAREntered	
Evacuations		PAREnteredBy	
RoadClosure		PARCheckedBy	
RoadClosureDuration		Interview	
State FIPS	RPT_ST	InterviewDate	
County FIPS	ACDT_CNTY	InterviewBy	
Place FIPS	ACDT_MUN	InterviewPerson	
RoadTypeID		InterviewEntered	
TrafficwayID	RD_TWAY	CheckedBy	
RoadConditionID	DRV_COND	FinalizedBy	

Table B-3. Vehicle Table Variables Input From MCMIS Crash File

Vehicle Table	MCMIS Table	Vehicle Table	MCMIS Table
VehicleID	autonumber	Fire	
IncidentID	(from Incident Table)	Explosion	
Vehicle		FireEngulfed	
VehicleNum	SEQ_NUM	Details	
VehicleConfigurationID	VEHIC_CONF	CarrierName	CARR_NAME
CargoBodyID	VEHICCARGO	ContactName	
USDOT	CARRID_NO	Address	CARR_STR
Hazmat	Yes	City	CARR_CITY
Notes		State	CARR_STAT
Cargo		Zip	CARR_ZIP
VehicleSpeed		Phone	
VehicleGWT	VEHIC_GVW	FAX	
NumAxles		1EventID	SEQ_ONE
Trailer		2EventID	SEQ_TWO
TrailerLength		3EventID	SEQ_THRE
TrailerWidth		4EventID	SEQ_FOUR
NumAxlesTrailer		PrecrashID	
ImpactID		AccidentClassID	
VisionID		PrimaryReasonsID	

When inputting the carrier information, the carrier's reported USDOT registration number, name and address were imported into the Vehicle table. There is also a Carrier table in the database that was developed by taking the USDOT numbers from the MCMIS Crash file and linking them to the MCMIS Registration file to obtain the associated carrier name and address from that table. Subsequently, the carrier information in the Vehicle table was made consistent with the information in the PAR, with minor adjustments to make the entry consistent with the Registration table information.

The Driver table was also populated from the MCMIS Crash table. The table contains common biographical information such as name, address, license number and state issuing the license. All of this information is contained in the MCMIS Crash file and was imported directly into the Driver table, again keeping track of the *IncidentID* and *VehicleID* autonumbers so that the correct driver could be related back to the correct vehicle and incident. The population of the Hazmat table was much more indirect because so many of the Hazmat fields in the MCMIS crash file were left blank. Since the common parameter field was the UN Number field in both MCMIS and the Hazmat database, this number was imported into the Hazmat Table. Because this was the common tie between the databases and often this field was not filled out in MCMIS, prior to importing the hazmat data into the database, as many of the records with blank UN Numbers were filled out. Sometimes it was as simple as putting 1075 in the field if propane was listed in the HAZ_NAME field. Other times, more creative methods were used, such as using the generic UN Number for flammable gases (1954) when the HAZ_NAME field lists "flammable gas." As the PAR information was being input, any changes required to make the Hazmat table consistent with the PAR information were made. This included selecting the proper commodity name from among the possible entries that were displayed when the cursor was placed on the UN Number.

A similar process was used for crashes with an HMIS record. Because the HMIS fields are all populated, any fields in the database that were common to HMIS and MCMIS were overwritten by the HMIS information. The Hazmat Packaging table variables correspond exactly to the HMIS packaging table so these data were transferred directly into the database and related to the Hazmat table by the *HazmatID* autonumber. Text in the Remarks table associated with the HMIS file was imported into the *Incident Details* field in the Incidents table. The Incidents table also has a *Description* field. That field was reserved for the accident description from the PARs. This enabled crashes to be described by the reporting police officer in the *Description* field and by the carrier in the *Incident Details* field. The different perspectives were often very insightful when trying to identify the primary responsible vehicle and the primary reason the vehicle was involved in the crash.

The next step was to begin to input the PAR data. Typically all the sampled PARs from a single state were input at the same time by the same data entry person. This was done because each state has a different PAR format and once the data entry person became familiar with the data entry key to the state PAR, the rate of data entry became much faster.

As the information was being filled in from the PAR, the data entry form showed the default values for any parameters that were the values entered from the MCMIS Crash and HMIS files. Any inconsistencies were changed. Frequently changes were not due to inconsistencies but rather because more complete information was available from the PAR. For example, many PARs list the actual Gross Vehicle Weight of the vehicle and in those cases that number was input in lieu of a general weight category.

The final step in populating the HAZMAT Accidents Database was the carrier calls. The most valuable benefit from the calls was in verifying the accuracy of the entered information. Then the conversation was directed at information that only the carrier could supply, such as the amount of material being shipped, whether there was a spill and, if so, how much was spilled, the manufacturer and specification number of the packaging, and the year the packaging was fabricated. In the case of shipments with multiple packages, such as a welding supply truck with numerous types of bottled gases, the age or the inspection history of all the packages on the vehicle is never known. No carrier could provide the specification number either. The same held true for shipments of multiple packages in van enclosed boxes. The carrier might be able to disclose how much was being shipped and the number of packages but nothing else about the package design. However, for cargo tanks the situation was much different. The carriers were frequently able to provide the specification number for the tank, the year it was manufactured, the manufacturer, type of rollover protection on the cargo tank, and the test and inspection history. Many could estimate the amount of material being shipped and if any was spilled. Some would ask what direction the vehicle was traveling and the time of day, and would then state that the cargo tank would be empty or full. The type of damage to the cargo tank could sometimes be recalled, usually only if there was a spill. Most carriers were also willing to provide information on the driver’s experience. At a minimum, the carrier would provide the date of hire and if the company required any prior driving experience as a condition of hire.

Overall, responses were received from about two-thirds of the carriers. If the carrier did not consent to providing the information, it was usually for legal reasons. If consent was given, then it was simply a matter of making several calls before the information would be provided. Some promised the information and never provided it. Others simply refused to return follow-up calls. While the process was time consuming, much useful information was obtained.

B.3 Quality Control Checks

There were many quality control checks built into the database development process. This included the ability to print out a summary of any crash record for reviewing the entered information and to use as a reference during carrier correspondence. The following discussion describes the types of checks that were performed on the database to ensure accuracy, identify blank records, and maintain information consistency.

Accuracy checks were performed three times during the process of developing the information summary for each crash. After the data from the PAR was entered for the accident, another person reviewed the data entered and compared the information with the information on the PAR. Any missed information was added to the record. The second accuracy check was performed after the carrier calls were completed and a reviewer checked that the information was correctly entered into the database. The final accuracy check was a review of the records generated using a form launched by the F10 key. Whenever a reviewer changed an entry, that individual was to press the F10 key and justify the rationale for changing the database record. If the justification was not accepted, the data was changed back to its original form. Once all of the above conditions were met, the record was considered finalized and documented as such.

Because a relational database structure was used, blank records can make summary queries of the database inaccurate and misleading. To guard against these circumstances, several scenarios were defined and error-trapped to address such problems. This included a quality check for non-hazmat trucks with hazmat records. It also included the reverse condition, namely hazmat trucks without hazmat records. Checks were also made to: (1) ensure that there were no orphan vehicles, i.e. vehicles that are assigned to no crash, (2) verify that the *spill* entry was checked for every known spill and left unchecked for non-spill crashes, (3) ensure that *fire*, *explosion* and *vehicle engulfed* boxes, when checked, were consistent with the data in the PAR and in the Hazmat Packaging table, and (4) identify blanks in any of the accident and vehicle description fields such as *trafficway*, *road type*, *incident location*, *speed limit*, *vehicle configuration* and *cargo body*. When blanks were found, the PARs were reviewed to see if the information was available. "Unknown" was used to fill in a field as a last resort.

The final and perhaps most difficult checks were for consistency. There were many such queries, including the following:

- Interstates that were not flagged as *controlled access.*
- State and U.S. highways that were listed as having 4 or more lanes and should be flagged as *controlled access.*
- Crashes which occurred at intersections and the route was flagged as *controlled access.*

- Hazmat vehicles with no event sequences
- Vehicles with rollover as one of the event sequences but with no rollover check in the hazmat packaging record.
- Vehicles with fire/explosion listed as one of the event sequences but no fire, explosion, or vehicle involved check under event details tab of the vehicle tab.
- The validity of assigning the hazmat vehicle as being primarily responsible for the crash.

Appendix C. Database Attribute Descriptions

Table C-1. Vehicle Configuration

VehicleConfigurationID	VehicleConfiguation	Aggregate Class
1	Bus	Non Truck
2	Light Truck or Utility Vehicle	Light Truck/Van
3	Straight Truck, No Trailer	Straight Truck
4	Straight Truck, One Trailer	Straight Truck with Trailer
5	Bobtail	Other Truck Configuration
6	Tractor/Semitrailer	Tractor/Trailer
7	Tractor, Two Trailers	Tractor/Trailer
8	Tractor, Three Trailers	Tractor/Trailer
9	Other Truck Configurations	Other Truck Configuration
10	Unknown	Unknown
11	Passenger Car	Non Truck
12	Bicycle	Non Truck
13	Motorcycle	Non Truck
14	Van	Light Truck/Van
15	Construction Equipment	Non Truck
16	Pedestrian	Non Motorist
17	Ambulance	Non Truck
18	RV	Non Truck

Table C-2. Cargo Body

CargoBodyID	CargoBody	Aggregate Class
1	Bus	Not applicable
2	Van	Van
3	Cargo tank/liquid	Tank
4	Flatbed	Flatbed
5	Dump	Dump
6	Concrete mixer	Other
7	Auto carrier	Other
8	Garbage/refuse	Other
9	Unknown	Unknown
10	Dry box semi trailer	Van
11	Open top van, sides are permanent	Other
12	Refrigerated van	Van
13	Livestock carrier	Van
14	Lowboy	Flatbed
15	Flatbed with removable sides	Flatbed
16	Flatbed with permanent equipment	Flatbed
17	Pole/logging	Other
18	Cargo tank/refrigerated liquid	Tank
19	Cargo tank/gaseous	Tank
20	Cargo tank/dry bulk	Tank
21	Bottom dump/hopper bottom	Hopper
22	Utility trailer	Other
23	Single truck and trailer	Unknown
24	Cargo tank/compressed liquid	Tank
25	Double truck trailer	Unknown
26	No trailer	Not applicable
27	Other	Other
28	Van enclosed box	Van
29	Hopper	Hopper

Table C-3. Driver Condition

DriverConditionID	DriverCondition
1	Appeared Normal
2	Had been Drinking
3	Illegal Drug Use
4	Sick
5	Fatigue
6	Asleep
7	Medication
8	Unknown or Blank

Table C-4. Packaging Type

PackagingID	DOT Specification Number	Package Type	Aggregate Class
1	17H	Drum	Drum
2	2SL	Other	Other
11	31H1	IBC Tank	Tank
73	1A2	Drum	Drum
94	DOT406	Tank	Tank
95	MC306	Tank	Tank
96	MC307	Tank	Tank
97	MC312	Tank	Tank
98	MC331	Tank	Tank
99	MC338	Tank	Tank
100	TANK PRT	Tank	Tank
101	Cargo Tank/Refrigerated	Tank	Tank
105	Bulk Cargo Tank	Tank	Tank
106	Cargo Tank/Liquid	Tank	Tank
107	3AAX	HP Gas Cylinders	Cylinders
108	DOT407	Tank	Tank
109	BOTL	Other	Other
110	BAG	Other	Other
111	BOX FBR	Other	Other
112	CONT	Other	Other
113	1A2	Drum	Drum
114	Unknown	Other	Other
115	PAIL PLS	Can/Pail	Can/Pail
116	Carboy	Cylinder	Cylinder
117	HOPPER T	Tank	Tank
118	CYL	Cylinder	Cylinder
119	Unknown	Cylinder	Cylinder
121	Unknown	Drum	Drum
122	Unknown	Other	Other
123	PAIL MTL	Can/Pail	Can/Pail
127	Tru-Pact	Other	Other
128	Unknown	Tank	Tank
135	Double Walled Tank	Tank	Tank
137	MC301	Tank	Tank
138	1A2	Drum	Drum
139	DRUM	Drum	Drum

PackagingID	DOT Specification Number	Package Type	Aggregate Class
140	MC301-77	Tank	Tank
142	1A1	Drum	Drum
147	DOT412	Tank	Tank
154	Dewar	Dewar	Other
156	Cartons	Cartons	Other
158	Non-spec	Cargo tank	Tank
159	Metal Totes	Tote	Other
160	Bulk Tank	Tank	Tank
161	Aluminum	Cargo Tank	Tank
162	DOT407	Cargon Tank	Tank
163	Cartons	Cartons	Other
166	MC330	Tank	Tank
167	Pneumatic	Tank	Tank
169	Cylinder	Cylinder	Cylinder
170	Canister	Canisters	Other
172	Pallets	Pallets	Other

Table C-5. Road Surface

RoadSurfaceID	RoadSurface	Aggregate Class
1	Concrete	Paved
2	Asphalt	Paved
3	Brick	Paved
4	Unpaved	Unpaved
5	Unknown	Unknown

Table C-6. Road Condition

RoadConditionID	Road Condition	Aggregate Class
1	Dry	Dry
2	Wet	Wet
3	Water (Standing or Moving)	Wet
4	Snow	Snow/ice
5	Slush	Snow/ice
6	Ice	Snow/ice
7	Sand, Mud, Dirt, Oil or Gravel	Loose Material
8	Other	Other
9	Unknown or Blank	Unknown
11	Construction	Construction Area
16	Loose Material	Loose Material

Table C-7. Road Type

RoadTypeID	Road Type	Aggregate Class
1	State Highway	Primary
2	County Road	Secondary
3	Interstate	Interstate
4	U.S. Highway	Primary
5	Township	Secondary
6	Municipality	Secondary
7	Frontage Road	Secondary
8	Other	Secondary
9	Unknown	Unknown
14	Forest Highway	Secondary
15	Local or Rural	Secondary

Table C-8. Trafficway

TrafficwayID	Traffic	Aggregate Class
1	Not Physically Divided (Two-way Trafficway)	Undivided
2	Divided Highway, Median Strip, w/o Traffic Barrier	Divided Highway
3	Divided Highway, Median Strip with Traffic Barrier	Divided Highway
4	One-way Trafficway	One-Way Trafficway
6	Exit or On Ramp	Exit/On Ramp
7	Blank	Unknown
8	Not Reported	Unknown
9	Unknown	Unknown
10	Divided Highway, Medium Strip, Barrier Status Unknown	Divided Highway
11	Exit or On Ramp, One-way Traffic	Exit/On Ramp
12	Exit or On Ramp, Two-way Traffic with Traffic Barrier	Exit/On Ramp
13	Exit or On Ramp, Two-way Traffic without Traffic Barrier	Exit/On Ramp

Table C-9. Access Control

AccessControlID	Controls
1	No Control (Unlimited Access)
2	Full Control (Only Ramp Entry and Exit)
3	Other
4	Blank

Table C-10. Pre-Crash Condition

PrecrashID	Precrash	Precrash Condition	Aggregate Class
1	00	No driver present	Parked
2	01	Going Straight	Within traffic lane
3	02	Decelerating in traffic lane	Within traffic lane
4	03	Accelerating in traffic lane	Within traffic lane
5	04	Starting in traffic lane	Within traffic lane
6	05	Stopped in traffic lane	Within traffic lane
7	06	Passing or overtaking another vehicle	Maneuvering
8	07	Disabled or parked in traffic lane	Within traffic lane
9	08	Leaving a parking position	Maneuvering
10	09	Entering a parking position	Maneuvering
11	10	Turning right	Maneuvering
12	11	Turning left	Maneuvering
13	12	Making a U turn	Maneuvering
14	13	Backing up (other than for parking position)	Maneuvering
15	14	Negotiating a curve	Maneuvering
16	15	Changing lanes	Maneuvering
17	16	Merging	Maneuvering
18	17	Successful avoidance maneuver to a previous critical event	Maneuvering
19	99	Unknown	Unknown
20	18	Stopped in breakdown lane	Parked

Table C-11. Event Type

EventID	Event	Aggregate Class
1	Ran Off Road	Ran Off
2	Jackknife	Jackknife
3	Overturn (Rollover)	Rollover
4	Downhill Runaway	Loss of Control
5	Loss of Cargo or Shift	Loss of Control
6	Explosion or Fire	Explosion/Fire
7	Separation of Units	Loss of Control
8	Cross Median Centerline	Loss of Control
9	Equipment Failure (Brake failure, blown tires etc)	Loss of Control
12	Collision Involving Pedestrian	Collision - Soft Object
13	Collision Involving Motor Vehicle in Transport	Collision - Hard Object
14	Collision Involving Parked Motor Vehicle	Collision - Hard Object
15	Collision Involving Train	Collision - Hard Object
16	Collision Involving Pedalcycle	Collision - Soft Object
17	Collision Involving Animal	Collision - Soft Object
18	Collision Involving Fixed Object	Collision - Hard Object
19	Collision With Work Zone Maintenance Equipment	Collision - Hard Object
20	Collision With Other Movable Object	Collision - Hard Object
21	Collision With Unknown Movable Object	Collision - Hard Object
22	Rapid Lane Shift	Loss of Control
23	Loss of Control	Loss of Control
24	Other	Other/Unknown
25	Unknown	Other/Unknown
27	Skidding/Sliding	Loss of Control
29	Avoiding	Loss of Control
31	Ditch	Collision - Hard Object
36	Over Corrected	Loss of Control
41	Collision Involving Debris	Collision - Soft Object
42	Collision Involving Spilled Material	Loss of Control

Table C-12. Impact Location

ImpactID	Impact Location	Aggregate Class
1	Head on	Impact - non-HM cargo region
2	Right Fender	Impact - non-HM cargo region
3	Left Fender	Impact - non-HM cargo region
4	Left Side	Impact - HM cargo region
5	Right Side	Impact - HM cargo region
6	Rear End	Impact - HM cargo region
7	Roof	Impact - non-HM cargo region
8	Trunk	Impact - non-HM cargo region
9	Hood	Impact - non-HM cargo region
10	Undercarriage	Impact - HM cargo region
11	Left Side of Trailer	Impact - HM cargo region
12	Right Side of Trailer	Impact - HM cargo region
13	Rear of Trailer	Impact - HM cargo region
14	Front of Trailer	Impact - HM cargo region
15	Top of Trailer	Impact - HM cargo region

Table C-13. Primary Reason

ReasonID	Reason	Primary Reason	Aggregate Class
1	10	Human error	Unknown Driver Error
2	20	Package failure	Package Related
3	30	Vehicular accident/derailment	Reassign
4	40	Other	Other
13	100	Driver asleep	Driver Non-Performance
30	101	Driver heart attack	Driver Non-Performance
73	102	Under the influence of drugs or alcohol	Driver Non-Performance
74	107	Driver incapacitated by illness	Driver Non-Performance
31	108	Driver passed out	Driver Non-Performance
19	109	Driver incapacitated, reason unknown	Driver Non-Performance
36	110	Inattention (daydreaming)	Driver Recognition Error
32	111	Internal distraction	Driver Recognition Error
33	112	External distraction	Driver Recognition Error
34	113	Inadequate surveillance	Driver Recognition Error
20	114	Loss of control - driver inattention	Driver Recognition Error
27	116	Ran red light or stop sign	Driver Decision Error
35	118	Other recognition error	Driver Recognition Error
23	120	Too fast for conditions	Driver Decision Error
56	121	Too slow for traffic flow	Driver Decision Error
57	122	Misjudgment of gap or other's speed	Driver Decision Error
28	123	Following too closely to respond to traffic ahead	Driver Decision Error
59	124	False assumption on other road user's actions	Driver Decision Error
60	126	Failure to turn headlamps on	Driver Decision Error
61	127	Inadequate evasive action	Driver Decision Error
62	128	Aggressive driving behavior	Driver Decision Error
22	131	Unable to avoid accident involving others	Other Vehicle Induced

ReasonID	Reason	Primary Reason	Aggregate Class
12	132	Improper lane shift	Driver Decision Error
24	133	Improper turn	Driver Decision Error
9	134	Excess speed for road conditions	Driver Decision Error
15	135	Unable to stop for traffic ahead	Driver Decision Error
63	136	Illegal maneuver	Driver Decision Error
64	139	Driver decision error - unable to classify	Driver Decision Error
54	141	Panic or freezing	Driver Performance Error
7	142	Overcompensation	Driver Performance Error
55	143	Poor directional control	Driver Performance Error
29	144	Lane change to avoid oncoming vehicle collision	Other Vehicle Induced
10	151	Ran off road	Driver Performance Error
11	152	Excess speed on curve/turn	Driver Decision Error
72	153	Failure to implement safety system	Driver Decision Error
65	159	Driver performance - unable to classify	Driver Performance Error
50	200	Tire, wheel or tie rod failure	Vehicle Related
17	201	Brakes failed	Vehicle Related
51	202	Steering failure	Vehicle Related
18	203	Cargo shift	Package Related
14	204	Trailer attachment failed	Vehicle Related
53	205	Suspension failed	Vehicle Related
52	206	Lights failed	Vehicle Related
49	208	Sudden change in vehicle performance	Vehicle Related
16	210	Mechanical failure - fire	Vehicle Related
21	220	Loss of control - truck trailer dynamics	Vehicle Related
66	229	Vehicle related - unable to classify	Vehicle Related
37	500	Signs or signals missing	Highway Related
38	501	Signs or signals defective or erroneous	Highway Related
71	502	Pedestrian on roadway	Highway Related
70	503	Animal on roadway	Highway Related
69	504	Object on roadway	Highway Related
42	505	Poor roadway design - sharper than expected curves	Highway Related
39	506	Poor roadway design - limited sight distance	Highway Related
40	508	Inadequate roadway maintenance	Highway Related
41	509	Poor roadway design - unexpected slick areas	Highway Related
68	519	Highway related - unable to classify	Highway Related
43	521	Rain or snow	Weather Related
44	522	Fog	Weather Related
45	523	High cross winds	Weather Related
48	528	Sudden change in ambience	Weather Related
46	530	Glare	Weather Related
47	531	Blinding snow, dust or debris	Weather Related
67	539	Weather related - unable to classify	Weather Related
8	700	Human error - driver of other vehicle	Other Vehicle Induced
26	800	Mechanical failure on other vehicle	Other Vehicle Induced
5	999	Unknown	Unknown

Table C-14. Accident Type

ClassID	Class #	Accident Class	Accident Type	Aggregate Class	Super Aggregation
1	01	Right side departure	Drove off roadway	Ran off road	Ran off road
2	02	Right side departure	Loss of traction or control	Ran off road	Ran off road
3	03	Right side departure	To avoid vehicle, pedestrian, animal	Ran off road	Ran off road
4	05	Right side departure	Specifics unknown	Ran off road	Ran off road
5	06	Left side departure	Drove off roadway	Ran off road	Ran off road
6	07	Left side departure	Loss of traction or control	Ran off road	Ran off road
7	08	Left side departure	To avoid vehicle, pedestrian, animal	Ran off road	Ran off road
8	10	Left side departure	Specifics unknown	Ran off road	Ran off road
9	11	Forward impact	Collision with parked vehicle on roadway	Hit object in road	Hit object in road
10	12	Forward impact	Collision with stationary object on roadway	Hit object in road	Hit object in road
11	13	Forward impact	Collision with pedestrian or animal on roadway	Hit object in road	Hit object in road
12	14	Forward impact	Ran off end of roadway	Ran off road	Ran off road
13	16	Forward impact	Forward impact - specifics unknown	Hit object in road	Hit object in road
14	20	Rear end	Vehicle that impacted rear end of stopped vehicle	Rearend, this veh striking	Rearend
15	21	Rear end	Vehicle stopped waiting to go straight when impacted in rear end	Rearend, this veh struck	Rearend
16	22	Rear end	Vehicle stopped waiting to turn left when impacted in rear end	Rearend, this veh struck	Rearend
17	23	Rear end	Vehicle stopped waiting to turn right when impacted in rear end	Rearend, this veh struck	Rearend
18	24	Rear end	Vehicle going straight that impacted rear end of a slower vehicle	Rearend, this veh striking	Rearend
19	25	Rear end	Vehicle going slower, going straight when impacted in rear end	Rearend, this veh struck	Rearend
20	26	Rear end	Vehicle going slower, negotiating a left turn when impacted in rear end	Rearend, this veh struck	Rearend
21	27	Rear end	Vehicle going slower, negotiating a right turn when impacted in rear end	Rearend, this veh struck	Rearend
22	28	Rear end	Vehicle going straight that impacted rear end of a decelerating vehicle	Rearend, this veh striking	Rearend
23	29	Rear end	Vehicle decelerating, going straight when impacted in rear end	Rearend, this veh struck	Rearend

ClassID	Class #	Accident Class	Accident Type	Aggregate Class	Super Aggregation
24	33	Rear end	Rearend collision - specifics unknown	Rearend, other	Rearend
25	34	Vehicles moving forward in same direction - maneuvering	While attempting to avoid another vehicle - lane change and rear impact with a second vehicle	Rearend, this veh striking	Rearend
26	35	Vehicles moving forward in same direction - maneuvering	Rearend impact by vehicle which changed lanes to avoid rearend collision with a second vehicle	Rearend, this veh struck	Rearend
27	36	Vehicles moving forward in same direction - maneuvering	Lane change to avoid another vehicle results in loss of traction or control and rear impact with an object	Rearend, this veh striking	Rearend
28	37	Vehicles moving forward in same direction - maneuvering	Rearend impact by vehicle which lost traction or control while changing lanes to avoid an object	Rearend, this veh struck	Rearend
29	38	Vehicles moving forward in same direction - maneuvering	Vehicle which lost traction or control while changing lanes to avoid a second vehicle impacts a vehicle in rearend	Rearend, this veh striking	Rearend
30	39	Vehicles moving forward in same direction - maneuvering	Vehicle rearended by vehicle which lost traction or control while maneuvering around a second vehicle	Rearend, this veh struck	Rearend
31	40	Vehicles moving forward in same direction - maneuvering	While attempting to avoid a fixed object - loss of traction or control and rear impact with a second vehicle	Rearend, this veh striking	Rearend
32	41	Vehicles moving forward in same direction - maneuvering	Rearend impact by vehicle which lost of traction or control while maneuvering to avoid a fixed object	Rearend, this veh struck	Rearend
33	43	Vehicles moving forward in same direction - maneuvering	Frontal impact with rearend of vehicle in another lane while maneuvering around another vehicle or object in lane ahead - specifics unknown	Rearend, other	Rearend
34	44	Vehicles moving forward in same direction - sideswiping	Vehicle in sideswiping accident - even though neither vehicle intended to change lanes	Sideswipe, same dir, this veh encroach	Sideswipe
35	45	Vehicles moving forward in same direction - sideswiping	Vehicle traveling in its lane and sideswiped by vehicle that changed lanes	Sideswipe, same dir, other veh encroach	Sideswipe
36	46	Vehicles moving forward in same direction - sideswiping	Vehicle started moving into right lane resulting in sideswiping of vehicle occupying that lane	Sideswipe, same dir, this veh encroach	Sideswipe

ClassID	Class #	Accident Class	Accident Type	Aggregate Class	Super Aggregation
37	47	Vehicles moving forward in same direction - sideswiping	Vehicle started moving into left lane resulting in sideswiping of vehicle occupying that lane	Sideswipe, same dir, this veh encroach	Sideswipe
38	49	Vehicles moving forward in same direction - sideswiping	Sideswiping accident occurs - specifics unknown	Sideswipe, same dir, other	Sideswipe
39	54	Vehicles moving - approaching each other - one maneuvering	While attempting to avoid another vehicle - lane change and frontal impact with a second vehicle	Headon, this veh encroach	Headon
40	55	Vehicles moving - approaching each other - one maneuvering	Frontal impact by vehicle which changed lanes to avoid rearend collision with a second vehicle	Headon, other veh encroach	Headon
41	56	Vehicles moving - approaching each other - one maneuvering	Lane change to avoid another vehicle results in loss of traction or control and frontal impact with a second vehicle	Headon, this veh encroach	Headon
42	57	Vehicles moving - approaching each other - one maneuvering	Frontal impact by vehicle which loss of traction or control while changing lanes to avoid a second vehicle	Headon, other veh encroach	Headon
43	58	Vehicles moving - approaching each other - one maneuvering	While attempting to avoid another vehicle - loss of traction or control and frontal impact with a second vehicle	Headon, this veh encroach	Headon
44	59	Vehicles moving - approaching each other - one maneuvering	Frontal impact by vehicle which lost of traction or control while maneuvering around a second vehicle	Headon, other veh encroach	Headon
45	60	Vehicles moving - approaching each other - one maneuvering	While attempting to avoid a fixed object - loss of traction or control and frontal impact with a second vehicle	Headon, this veh encroach	Headon
46	61	Vehicles moving - approaching each other - one maneuvering	Frontal impact by vehicle which lost of traction or control while maneuvering to avoid a fixed object	Headon, other veh encroach	Headon
47	63	Vehicles moving - approaching each other - one maneuvering	Frontal impact with oncoming vehicle while maneuvering around another vehicle or object in lane - specifics unknown	Headon, other	Headon
48	50	Head-on	Vehicle crossed centerline into lane of oncoming traffic resulting in head-on impact	Headon, this veh encroach	Headon
49	51	Head-on	Vehicle traveling in its lane struck head-on by vehicle crossed centerline	Headon, other veh encroach	Headon

ClassID	Class #	Accident Class	Accident Type	Aggregate Class	Super Aggregation
50	53	Head-on	One or both vehicles moved across centerline resulting in a head-on impact - specifics unknown	Headon, other	Headon
51	64	Vehicles moving - approaching each other - sideswipe	Vehicle crossed centerline into lane of oncoming traffic resulting in sideswiping incident	Sideswipe, opp dir, this veh encroach	Sideswipe
52	65	Vehicles moving - approaching each other - sideswipe	Vehicle traveling in its lane sideswiped by vehicle crossed centerline	Sideswipe, opp dir, other veh encroach	Sideswipe
53	67	Vehicles moving - approaching each other - sideswipe	One or both vehicles moved across centerline resulting in sideswiping impact - specifics unknown	Sideswipe, opp dir, other	Sideswipe
54	68	Turn across path	Vehicle turning left impacts vehicle traveling in opposite direction	This veh turn across path	Turning
55	69	Turn across path	Vehicle going straight impacted by vehicle turning left in front of vehicle	Other turn across path	Turning
56	70	Turn across path	Vehicle in left lane turns right in front of vehicle traveling in right lane	This veh turn across path	Turning
57	71	Turn across path	Vehicle strikes vehicle that turned right, crossing its lane, directly in front of vehicle	Other turn across path	Turning
58	72	Turn across path	Vehicle in right lane turns left in front of vehicle traveling in left lane	This veh turn across path	Turning
59	73	Turn across path	Vehicle strikes vehicle that turned left, crossing its lane, directly in front of vehicle	Other turn across path	Turning
60	75	Turn across path	Vehicles traveling in same direction collide when one vehicle attempts to turn across others lane - specifics unknown	Turning, other details	Turning
61	76	Turn into path	Vehicle turning left from a different trafficway impacts vehicle traveling from right to left in its lane	This veh turn across path	Turning
62	77	Turn into path	Vehicle traveling in its lane impacted by vehicle from a different trafficway making a left hand turn into its lane of travel	Other veh turn across path	Turning
63	78	Turn into path	Vehicle turning right from a different trafficway impacts vehicle traveling from left to right in its lane	This veh turn across path	Turning
64	79	Turn into path	Vehicle traveling in its lane impacted by vehicle from a different trafficway making a right hand turn into its lane of travel	Other veh turn across path	Turning

ClassID	Class #	Accident Class	Accident Type	Aggregate Class	Super Aggregation
65	80	Turn into path	Vehicle on a different trafficway crosses centerline during right hand turn and impacts oncoming vehicle	This veh turn across path	Turning
66	81	Turn into path	Vehicle going straight ahead impacted when vehicle on a different trafficway turns right and crosses the centerline	Other veh turn across path	Turning
67	82	Turn into path	Vehicle on different trafficway makes left hand turn in front of vehicle in its lane coming from left	This veh turn across path	Turning
68	83	Turn into path	Vehicle going straight ahead impacted by vehicle on another trafficway turning left across lane of travel	Other veh turn across path	Turning
69	85	Turn into path	Vehicles on different trafficways impact with each other - specifics unknown	Turning, other details	Turning
70	86	Straight paths - side impact	Vehicle going straight ahead strikes vehicle crossing in its path from the left	Straight, this veh into other veh	Vehicle going straight
71	87	Straight paths - side impact	Vehicle going straight struck on its right side by a vehicle crossing its path	Straight, other veh into this veh	Vehicle going straight
72	88	Straight paths - side impact	Vehicle going straight ahead strikes vehicle crossing in its path from the right	Straight, this veh into other veh	Vehicle going straight
73	89	Straight paths - side impact	Vehicle going straight struck on its left side by a vehicle crossing its path	Straight, other veh into this veh	Vehicle going straight
74	91	Straight paths - side impact	Two vehicles traveling straight ahead impact while crossing - specifics unknown	Straight, other details	Vehicle going straight
75	92	Backing	Vehicle backing up strikes other vehicle or object	This veh backs into other veh	Backing Up
76	93	Backing	Vehicle struck by backing vehicle	Other veh backs into this veh	Backing Up
77	99	Unknown	Can not classify impact	Unknown	Other/Unknown
78	00	No impact	No impact	No impact	No Impact
79	30	Rear end	Vehicle decelerating to negotiate a left turn when impacted in rear end	Rearend, this veh struck	Rearend
80	31	Rear end	Vehicle decelerating to negotiate a right turn when impacted in rear end	Rearend, this veh struck	Rearend
81	94	Sideswipe Impact	Vehicle sideswipes stopped vehicle	Sideswipe - unknown	Sideswipe
82	95	Sideswipe Impact	Vehicle stopped sideswiped by another vehicle	Sideswipe - unknown	Sideswipe
83	98	Other	Not included in accident type table	Other	Other/Unknown
84	04	Right side departure	Specifics other	Ran off road	Ran off road

ClassID	Class #	Accident Class	Accident Type	Aggregate Class	Super Aggregation
85	09	Left side departure	Specifics other	Ran off road	Ran off road
86	15	Forward impact	Specifics other	Hit object in road	Hit object in road
87	32	Rear end	Rearend collision - specifics other	Rearend, other	Rearend
88	42	Vehicles moving forward in same direction - maneuvering	Frontal impact with rearend of vehicle in another lane while maneuvering around another vehicle or object in lane ahead - specifics other	Rearend, other	Rearend
89	52	Head-on	One or both vehicles moved across centerline resulting in a head-on impact - specifics other	Headon, other	Headon
90	62	Vehicles moving - approaching each other - one maneuvering	Frontal impact with oncoming vehicle while maneuvering around another vehicle or object in lane - specifics other	Headon, other	Headon
91	66	Vehicles moving - approaching each other - sideswipe	One or both vehicles moved across centerline resulting in sideswiping impact - specifics other	Sideswipe, opp dir, other	Sideswipe
92	74	Turn across path	Vehicles traveling in same direction collide when one vehicle attempts to turn across others lane - specifics other	Turning, other details	Turning
93	84	Turn Into path	Vehicles on different trafficways impact with each other - specifics other	Turning, other details	Turning
94	90	Straight paths - side impact	Two vehicles traveling straight ahead impact while crossing - specifics other	Straight, other details	Vehicle going straight
95	97	Backing	Untripped rollover - result of vehicle instability	Untripped rollover	Untripped rollover
96	48	Vehicles moving forward in same direction - sideswiping	Sideswiping accident occurs - specifics other	Sideswipe, same dir, other	Sideswipe

Table C-15. Weather Condition

WeatherConditionID	Weather Condition	Aggregate Class
1	No Adverse Condition	No Adverse Condition
2	Rain	Rain/Sleet
3	Sleet (Hail)	Rain/Sleet
4	Snow or Slush	Snow
5	Fog	Fog
6	Blowing Sand, Soil, Dirt or Snow	High Winds
7	Severe Crosswinds	High Winds
8	Other	Other
9	Unknown or Blank	Unknown

Table C-16. Land Use at Accident Location

LandUseID	LandUseType
1	Industrial
2	Commercial
3	Residential
4	Agricultural
5	Undeveloped

Table C-17. Community Type at Accident Location

CommunityID	CommunityType
1	Urban
2	Suburban
3	Rural

Table C-18. Light Condition

LightConditionID	Light Condition	Aggregate Class
1	Daylight	Daylight
2	Dark - Not Lighted	Dark
3	Dark – Lighted	Dark - Lighted
4	Dark - Unknown Roadway Lighting	Dark
5	Dawn	Dawn/Dusk
6	Dusk	Dawn/Dusk
8	Other	Other
9	Unknown or Blank	Unknown

Table C-19. HM Class Grouping

UNKey	HM Class	HM Group
1	11	1.1 - 1.6
2	12	1.1 - 1.6
3	13	1.1 - 1.6
4	14	1.1 - 1.6
5	15	1.1 - 1.6
6	16	1.1 - 1.6
7	21	2.1
8	22	2.2
9	23	2.3 & 6.1
10	30	3.0
11	41	4.1 - 4.3
12	42	4.1 - 4.3
13	43	4.1 - 4.3
14	44	4.1 - 4.3
15	51	5.1 - 5.2
16	52	5.1 - 5.2
18	61	2.3 & 6.1
19	62	6.2 & 6.5
20	65	6.2 & 6.5
21	70	7.0
22	80	8.0
23	90	9.0
24	00	Unknown
25	40	4.1 - 4.3
26	50	5.1 - 5.2
27	60	Unknown

Appendix D. Change History of Incident and Vehicle Tables

This appendix presents a history of the changes that were made to parameter values in the Incident and Vehicle tables between the time that information was imported from the MCMIS crash file and its final status in the HAZMAT Accidents Database.

Table D-1 provides a summary of the change history for parameters contained in the Incident table. In some cases, the changes reflect an opportunity to produce a more detailed breakdown of conditions than what was available in MCMIS. In other instances, such as *Highway* and *Milepost*, these changes do not necessarily reflect inaccuracies in the MCMIS crash file. In the conversion of such data from MCMIS to the HAZMAT Accidents Database, an attempt was made to standardize the entries under *Highway* so that most of the information regarding the exact location of the accident was under *Milepost*.

Table D-1. Incident Table Change History

FieldName	Final # Records	# Records at Start	# Records Changed
IncidentID	943	943	16
IncidentKey	943	943	0
IncidentDate	943	931	1
IncidentTime	943	930	5
MCMIS	943	943	212
HMIS	943	943	8
PAR	943	943	942
PCC	943	943	668
Crash	943	943	232
HMIncident	943	943	233
InformationSource	221	221	3
DivNotificationDate	0	0	0
DivNotificationTime	0	0	0
DivResponseDate	0	0	0
DivResponseTime	0	0	0
HQNotificationDate	0	0	0
HQNotificationTime	0	0	0
Description	942	0	0
EnteredOn	943	943	16
ModifiedOn	943	943	16
VehicleID	935	4	4
CauseID	942	0	0
Fatalities	943	931	0
Injuries	943	931	117
EvacuationDistance	1	0	0
EvacuationRegion	2	0	0
Evacuations	1	0	0
RoadClosure	943	943	45
RoadClosureDuration	33	0	0
State FIPS	942	931	0

FieldName	Final # Records	# Records at Start	# Records Changed
County FIPS	940	925	25
Place FIPS	630	371	139
RoadTypeID	941	598	521
TrafficwayID	932	673	119
RoadConditionID	937	685	9
Highway	942	912	863
Milepost	929	571	521
Latitude	141	0	0
Longitude	140	0	0
EventDetails	89	77	24
WeatherConditionID	941	898	47
LightConditionID	940	837	18
VehiclesInvolved	939	0	0
Preparer	0	0	0
NotificationMethod	0	0	0
CitationIssuedTo	387	0	0
CitationCharges	383	0	0
CitationBy	384	0	0
StatusOfCharge	1	0	0
Penalties	1	0	0
Status	0	0	0
ComplianceReview	943	943	0
ComplianceReviewDate	0	0	0
LandUseID	540	0	0
CommunityID	692	0	0
RoadSurfaceID	592	0	0
Access	943	943	397
NumLanes	904	0	0
PostedSpeed	780	0	0
AgencyID	942	943	2

The change history for parameters contained in the Vehicle table is provided in Table D-2. The carrier name was frequently changed to make it consistent with the PARs and/or the MCMIS registration file. This problem often occurred because the MCMIS Carrier name file is hand-entered for each crash and there can be considerable variability in the name shown.

Some fields, such as vehicle speed, show large changes because there is no comparable field in MCMIS. In other cases, the number of final records is an indication of the data availability from the PAR and carrier calls. For example, trailer width and length was only obtained for about 200 vehicles in the database.

Some fields were not imported into the database because it was decided to translate the information from an ID field into a text field as part of the conversion process. The VehicleGVW field is such an example. It shows no information was imported from MCMIS, when in fact an entry of “3” was converted to “greater than 26,000 lbs.” as part of the process.

Table D-2. Vehicle Table Change History

FieldName	Final # Records	# Records at Start	# Records Changed
VehicleID	900	900	0
IncidentID	900	900	0
Vehicle	900	0	0
VehicleNum	900	900	317
VehicleConfigurationID	900	188	171
CargoBodyID	890	0	0
USDOT	876	837	67
Hazmat	900	900	1
Notes	327	0	0
Cargo	4	0	0
VehicleSpeed	467	0	0
VehicleGWT	812	0	0
NumAxles	838	0	0
Trailer	900	900	629
TrailerLength	206	0	0
TrailerWidth	178	0	0
NumAxlesTrailer	586	0	0
ImpactID	865	0	0
VisionID	9	0	0
Fire	900	900	24
Explosion	900	900	2
FireEngulfed	900	900	12
Details	878	0	0
CarrierName	900	870	222
ContactName	632	0	0
Address	896	870	120
City	900	870	96
State	893	192	16
Zip	899	870	96
Phone	861	1	1
FAX	144	1	0
1EventID	899	180	21
2EventID	373	56	18
3EventID	236	26	4
4EventID	111	11	1
PrecrashID	900	0	0
AccidentClassID	852	0	0
PrimaryReasonsID	853	0	0
IncidentKey	855	855	0

Appendix E. Analysis Results

Overall Statistics

Table E-1 summarizes the total number of hazardous material crashes, spills, and spill percentage (spill-to-crash ratio expressed as a percentage), by HM group. These totals and the values in all tables in this Appendix are annual estimates based on the sample weighting discussed in Section 2.6. For many of the hazardous material groups, there are simply too few spills to obtain a valid ratio.

Note that the annual crash and spill estimates are actually based on vehicle-involvements and not crashes and spills directly. For example, if a crash involved two separate vehicles carrying hazardous materials, then that crash would have two vehicle involvements. As the number of such cases (four) is very small, treating the estimated totals as if they represented crashes and spills does not affect any results. Slightly more cases (38 vehicles) involved more than one hazardous material being carried on the same vehicle, which could lead to some double-counting when conducting an analysis across multiple HM groups.

Table E-1. Overall Crash, Spill, and Spill Percentage by HM Group

HM Group	Crashes	Spills	Spill Percentage
1.1 - 1.6	21	2	9.9%
2.1	256	21	8.1%
2.2	102	12	11.8%
2.3	18	2	11.9%
3.0	914	182	19.9%
4.1 - 4.3	8	2	26.1%
5.1 - 5.2	36	10	26.9%
6.1 - 6.2	16	2	12.9%
7.0	4	2	50.5%
8.0	139	23	16.3%
9.0	86	27	31.8%
Unknown	28	9	31.0%
Total	1,629	294	18.0%

Vehicle-Related

Vehicle Configuration

Table E-2. Crashes by Vehicle Configuration

HM Group	Tractor/Trailer	Tractor/Trailer (2 or more)	Straight Truck	Straight Truck with Trailer	Light Truck/Van	Other Truck Configuration	Unknown	Total
1.1 - 1.6	10	4	4	1	2			21
2.1	68	2	177	7	2		1	256
2.2	55	2	50	5	4		1	117
2.3	13	4	3					20
3.0	633	33	221	33	2	4	1	926
4.1 - 4.3	8							8
5.1 - 5.2	21	7	8	1				36
6.1 - 6.2	11	1	4					16
7.0	2	2	1					5
8.0	106	18	15	2		2	2	145
9.0	68	11	5	2		2	1	88
Unknown	19	1	9					28
Total	1,014	84	495	51	9	7	6	1,667

Table E-3. Crashes with Spills by Vehicle Configuration

HM Group	Tractor/Trailer	Tractor/Trailer (2 or more)	Straight Truck	Straight Truck with Trailer	Light Truck/Van	Other Truck Configuration	Unknown	Total
1.1 - 1.6			2					2
2.1	8		12				1	21
2.2	4		6	2	2			14
2.3		2						2
3.0	122	12	44	8	2		1	189
4.1 - 4.3	2							2
5.1 - 5.2	8		2					10
6.1 - 6.2	1		1					2
7.0		1	1					2
8.0	20		3					23
9.0	19	3	1	2		2	1	27
Unknown	5		4					9
Total	188	18	76	12	4	2	3	302

Cargo Body

Table E-4. Crashes by Cargo Body Type

HM Group	Van	Tank	Flatbed	Dump	Hopper	Other	Unknown	Total
1.1 - 1.6	9	7	3		1	1		21
2.1	10	199	35			9	4	256
2.2	18	67	9			6	3	103
2.3	7	5	5				2	18
3.0	74	813	8			4	17	916
4.1 - 4.3	4	1	1	2				8
5.1 - 5.2	15	11	4	5	1	1		36
6.1 - 6.2	10	4	1				1	16
7.0	3		2					5
8.0	51	72	6			2	8	139
9.0	11	66	1	6			3	86
Unknown	17	8	2	2				28
Total	228	1252	76	15	2	23	37	1,633

Table E-5. Crashes with Spills by Cargo Body

HM Group	Van	Tank	Flatbed	Dump	Hopper	Other	Unknown	Total
1.1 - 1.6		1			1			2
2.1	2	12	7					21
2.2	2	7				3		12
2.3	2							2
3.0	19	155	5				3	182
4.1 - 4.3			1	1				2
5.1 - 5.2	1	1	2	4	1	1		10
6.1 - 6.2	1		1					2
7.0	2							2
8.0	5	12	6					23
9.0	2	22	1	1			1	27
Unknown	4	2	2	2				9
Total	40	212	24	8	2	4	4	294

Table E-6. Cargo Tank Crashes by Vehicle Configuration

HM Group	Tractor/ Trailer	Tractor/Trailer (2 or more)	Straight Truck	Straight Truck with Trailer	Light Truck/Van	Other Truck Configuration	Unknown	Total
1.1 - 1.6	5		1	1				7
2.1	59		132	7			1	199
2.2	44		22	5	2			72
2.3	5							5
3.0	565	14	200	33	2	4		818
4.1 - 4.3	1							1
5.1 - 5.2	6	2	2	1				11
6.1 - 6.2	4							4
8.0	65		7					72
9.0	52	9	1	2		2		66
Unknown	6		2					8
Total	812	26	366	49	4	5	1	1,263

Table E-7. Cargo Tank Spills by Vehicle Configuration

HM Group	Tractor/ Trailer	Tractor/Trailer (2 or more)	Straight Truck	Straight Truck with Trailer	Light Truck/Van	Other Truck Configuration	Unknown	Total
1.1 - 1.6			1					1
2.1	4		7				1	12
2.2	1		3	2	2			7
2.3								
3.0	105	6	38	8	2			159
4.1 - 4.3								
5.1 - 5.2	1							1
6.1 - 6.2								
8.0	10		1					12
9.0	15	3	1	2		2		22
Unknown	2							2
Total	138	8	50	12	4	2	1	215

Table E-8. Cargo Tank Crashes by Cargo Tank Specification Number

HM Group	MC301	MC306	MC307	MC312	MC330	MC331	MC338	DOT406	DOT407	DOT412	Total
1.1 – 1.6			2								2
2.1		2			2	92	2	4			101
2.2						13	8				22
2.3			2								2
3.0	2	276	27	7		5		125	25	2	469
5.1 – 5.2		1									1
6.1 – 6.2			1	1					1		3
8.0			10	22					2	2	36
9.0	2	3	5	3					2		14
Total	4	281	47	32	2	111	10	128	30	4	648

Table E-9. Cargo Tank Spills by Cargo Tank Specification Number

HM Group	MC306	MC307	MC312	MC331	MC338	DOT406	DOT407	Total
2.1				6				6
2.2				1	1			2
3.0	57	10		2		16	7	91
8.0		5	3					8
9.0	1	2	1					4
Total	58	17	4	9	1	16	7	112

Driver-Related

Driver Age

Table E-10. Crashes by Driver Age

HM Group	18-24	25-34	35-44	45-54	55-64	65-74	>75	Total
1.1 - 1.6	1	6	1	4	6	1		19
2.1	5	64	81	62	37	5		255
2.2	5	17	29	29	15	5		101
2.3			1	13	5			18
3.0	21	194	284	228	150	16	5	898
4.1 - 4.3		2	3	2	1			8
5.1 - 5.2	1	12	12	9	3			36
6.1 - 6.2		1	4	7	3		1	16
7.0			1		4			5
8.0	10	22	49	34	18	2	1	137
9.0	4	17	24	24	10	4		83
Unknown		7	7	9	2	4		28
Total	48	343	495	421	253	36	7	1604

Table E-11. Crashes with Spills by Driver Age

HM Group	18-24	25-34	35-44	45-54	55-64	65-74	>75	Total
1.1 - 1.6		2						2
2.1	2	8	8	3				21
2.2		2	3	4	2	2		12
2.3				2				2
3.0	8	43	59	35	31	4		180
4.1 - 4.3		2						2
5.1 - 5.2	1	6	1	2				10
6.1 - 6.2				1			1	2
7.0			1		1			2
8.0	2	6	9	4	1			23
9.0	2	5	8	6	3	4		27
Unknown		2	4		2	2		9
Total	15	76	92	57	40	11	1	292

Driver Experience

Table E-12. Crashes versus Years of Driving Experience

HM Group	0-3	3-6	>6	Total
2.1	7	7	14	29
2.2	4		5	9
2.3			4	4
3.0	52	26	63	140
5.1 - 5.2	6			6
6.1 - 6.2	2		1	3
7.0	1		1	2
8.0	7	3	2	12
9.0	7	3	6	16
Total	85	39	96	220

Table E-13. Crashes with Spills versus Years of Driving Experience

HM Group	0-3	3-6	>6	Total
2.2			2	2
3.0	20	5	7	31
5.1 - 5.2	3			3
8.0	3	2	1	6
9.0		1	1	2
Total	25	8	10	44

Driver Condition

Table E-14. Crashes by Driver Condition

HM Group	Appeared Normal	Fatigue/Asleep	Illness	Under Influence Drugs/Alcohol	Unknown or Blank	Total
1.1 - 1.6	16					16
2.1	202	3	2		1	208
2.2	81	1				82
2.3	15	2				17
3.0	735	16	4	5	15	773
4.1 - 4.3	6	1				7
5.1 - 5.2	25					25
6.1 - 6.2	10	1			1	12
7.0	5					5
8.0	116	7			3	126
9.0	57	2		3		62
Unknown	20	4			2	25
Total	1287	35	5	8	24	1,359

Table E-15. Spills by Driver Condition

HM Group	Appeared Normal	Fatigue/Asleep	Illness	Under Influence Drugs/Alcohol	Unknown or Blank	Total
1.1 - 1.6	1					1
2.1	14				1	15
2.2	12					12
2.3	2					2
3.0	119	5	2	3	13	141
4.1 - 4.3	2					2
5.1 - 5.2	8					8
6.1 - 6.2		1			1	2
7.0	2					2
8.0	16	2			1	20
9.0	8	2		1		11
Unknown	5	2				7
Total	187	12	2	4	18	223

Table E-16. Cargo Tank Crashes by Driver Condition

HM Group	Appeared Normal	Fatigue/Asleep	Illness	Under Influence Drugs/Alcohol	Unknown or Blank	Total
1.1 - 1.6	6					6
2.1	150	3	2		1	155
2.2	57	1				58
2.3	4					4
3.0	657	12	4	5	13	691
5.1 - 5.2	9					9
6.1 - 6.2	3					3
8.0	55	4			1	60
9.0	40	1		3		44
Unknown	6	2				8
Total	986	23	5	8	15	1,037

Table E-17. Cargo Tank Spills by Driver Condition

HM Group	Appeared Normal	Fatigue/Asleep	Illness	Under Influence Drugs/Alcohol	Unknown or Blank	Total
1.1 - 1.6	1					1
2.1	7				1	8
2.2	7					7
3.0	101	3	2	3	11	121
5.1 - 5.2	1					1
8.0	6	2			1	9
9.0	5	1		1		7
Unknown	2					2
Total	130	6	2	4	13	156

Packaging-Related

Package Type

Table E-18. Crashes by Package Type

HM Group	Tank	Cylinder	Drum	Can/Pail	Other	Unknown	Total
1.1 - 1.6	7	2	1		1		11
2.1	130	22	4			1	157
2.2	45	18					63
2.3	4	4	2		2		11
3.0	626	2	21	9	11	1	669
4.1 - 4.3			1				1
5.1 - 5.2	5	2	1	1	10		19
6.1 - 6.2	3		1	1	2		7
7.0				1	2		3
8.0	51		10	2	10	2	75
9.0	41		5		9		54
Unknown	1		2				3
Total	917	50	46	15	47	4	1,080

Table E-19. Crashes that Result in Spills by Package Type

HM Group	Tank	Cylinder	Drum	Can/Pail	Other	Unknown	Total
1.1 - 1.6	2						2
2.1	7	4				1	12
2.2	7	2					9
3.0	124		6	7	5	1	144
4.1 - 4.3			1				1
5.1 - 5.2	3		1		5		9
6.1 - 6.2					2		2
7.0				1			1
8.0	10		4	2		2	18
9.0	13		1		2		16
Total	168	6	13	10	14	4	215

Infrastructure-Related

Road Surface

Table E-20. Crashes by Road Surface

HM Group	Paved	Unknown	Unpaved	Total
1.1 - 1.6	14	0	0	14
2.1	80	0	11	91
2.2	42	1	0	43
2.3 & 6.1	26	0	0	26
3.0	316	0	9	325
4.1 - 4.3	7	0	0	7
5.1 - 5.2	24	0	0	24
6.2 & 6.5	1	0	0	1
7.0	4	0	0	4
8.0	42	0	0	42
9.0	31	0	0	31
Unknown	3	0	0	3
Total	590	1	20	611

Table E-21. Crashes that Result in Spills by Road Surface

HM Group	Paved	Unpaved	Unknown	Total
1.1 - 1.6	2			2
2.1	14			14
2.2	8			8
2.3	2			2
3.0	111	7	9	126
4.1 - 4.3	1			1
5.1 - 5.2	8			8
6.1 - 6.2	1		1	2
7.0	2			2
8.0	16			16
9.0	18			18
Unknown	4			4
Total	186	7	10	202

Road Condition

Table E-22. Crashes by Road Condition

HM Group	Dry	Wet	Snow/ice	Construction Area	Loose Material	Other	Unknown	Total
1.1 - 1.6	12	3	5				1	21
2.1	178	49	28			2		256
2.2	81	12	6				2	102
2.3	15	2	2					18
3.0	706	136	62	2	4		5	914
4.1 - 4.3	4	4						8
5.1 - 5.2	27	5	4				1	36
6.1 - 6.2	13		3					16
7.0	4							4
8.0	107	19	8				4	139
9.0	69	12	4				2	86
Unknown	16	9	4					28
Total	1,232	250	125	2	4	2	14	1,629

Table E-23. Crashes that Result in Spills by Road Condition

HM Group	Dry	Wet	Snow/ice	Loose Material	Unknown	Total
1.1 - 1.6	2					2
2.1	13	5	3			21
2.2	8	2	2			12
2.3	2					2
3.0	142	25	12	2	1	182
4.1 - 4.3	1	1				2
5.1 - 5.2	7	3				10
6.1 - 6.2	2					2
7.0	2					2
8.0	20		2			23
9.0	23	3	2			27
Unknown	7	2				9
Total	230	41	20	2	1	294

Road Type

Table E-24. Crashes by Road Type

HM Group	Interstate	Primary	Secondary	Unknown	Total
1.1 - 1.6	11	8	2		21
2.1	38	115	102	2	256
2.2	34	58	10		102
2.3	10	5	4		18
3.0	262	434	212	7	915
4.1 - 4.3	4	3	1		8
5.1 - 5.2	19	16	2		37
6.1 - 6.2	8	4	4		16
7.0	2	2			4
8.0	64	48	26	1	139
9.0	30	41	15		86
Unknown	11	9	7	2	29
Total	491	742	385	12	1,630

Table E-25. Crashes that Result in Spills by Road Type

HM Group	Interstate	Primary	Secondary	Unknown	Total
1.1 - 1.6		2			2
2.1	1	9	10		21
2.2	2	10			12
2.3	2				2
3.0	41	91	47	3	182
4.1 - 4.3		2			2
5.1 - 5.2	4	5	1		10
6.1 - 6.2	1		1		2
7.0	1	1			2
8.0	10	9	2	1	23
9.0	7	18	3		27
Unknown	2	5	2		9
Total	71	153	66	5	295

Trafficway

Table E-26. Crashes by Trafficway

HM Group	Divided Highway	Exit/On Ramp	One-way Trafficway	Undivided	Unknown	Total
1.1 - 1.6	15			6		21
2.1	62		2	187	5	256
2.2	46	4	2	50		102
2.3	11			7		18
3.0	456	21	16	409	13	914
4.1 - 4.3	4			4		8
5.1 - 5.2	20	3		14		36
6.1 - 6.2	9			7		16
7.0	3			1		4
8.0	79	2		56	2	139
9.0	44	5	2	35	2	86
Unknown	20			9		28
Total	768	34	21	784	22	1,629

Table E-27. Crashes that Result in Spills by Trafficway

HM Group	Divided Highway	Exit/On Ramp	One-way Trafficway	Undivided	Unknown	Total
1.1 - 1.6				2		2
2.1	6			15		21
2.2	3	2		7		12
2.3	2					2
3.0	77	9	5	89	2	182
4.1 - 4.3				2		2
5.1 - 5.2	3	2		5		10
6.1 - 6.2	1			1		2
7.0	1			1		2
8.0	11			10	1	23
9.0	8	3		17		27
Unknown	5			4		9
Total	117	16	5	152	3	294

Access Control

Table E-28. Crashes by Access Control

HM Group	Yes	No	Total
1.1 - 1.6	13	8	21
2.1	75	181	256
2.2	44	58	102
2.3	13	5	18
3.0	428	486	914
4.1 - 4.3	4	4	8
5.1 - 5.2	24	13	36
6.1 - 6.2	8	8	16
7.0	2	2	4
8.0	81	57	139
9.0	45	41	86
Unknown	13	16	28
Total	749	880	1,629

Table E-29. Crashes that Result in Spills by Access Control

HM Group	Yes	No	Total
1.1 - 1.6		2	2
2.1	3	18	21
2.2	2	10	12
2.3	2		2
3.0	80	102	182
4.1 - 4.3		2	2
5.1 - 5.2	7	3	10
6.1 - 6.2	1	1	2
7.0	1	1	2
8.0	11	11	23
9.0	14	14	27
Unknown	2	7	9
Total	123	171	294

Situational

Pre-Crash Condition

Table E-30. Multiple-vehicle Crashes by Pre-crash Condition

HM Group	Maneuvering	Within Traffic Lane	Parked	Unknown	Total
1.1 - 1.6	1	13	1		15
2.1	43	135	2		180
2.2	16	53	2		71
2.3	2	13			15
3.0	142	539	20	4	704
4.1 - 4.3		4			4
5.1 - 5.2	2	23			25
6.1 - 6.2	2	13			15
7.0	1	3			4
8.0	8	83		2	93
9.0	6	48	4		57
Unknown	5	18			23
Total	227	944	28	6	1,205

Table E-31. Single-vehicle Crashes by Pre-crash Condition

HM Group	Maneuvering	Within Traffic Lane	Parked	Total
1.1 - 1.6	4	2		6
2.1	30	45	2	76
2.2	10	21		31
2.3		4		4
3.0	81	124	4	208
4.1 - 4.3	3	1		4
5.1 - 5.2	3	9		12
6.1 - 6.2		1		1
8.0	17	28		45
9.0	16	12		29
Unknown		5		5
Total	165	251	5	416

Table E-32. Multiple-vehicle Crashes that Result in Spills by Pre-crash Condition

HM Group	Maneuvering	Within Traffic Lane	Parked	Total
2.1	2	14		16
2.2		3		3
2.3		2		2
3.0	8	61	4	73
5.1 - 5.2		4		4
6.1 - 6.2	1			1
7.0	1	1		2
8.0		3		3
9.0		5		5
Unknown	2	5		7
Total	13	99	4	112

Table E-33. Single-vehicle Crashes that Result in Spills by Pre-crash Condition

HM Group	Maneuvering	Within Traffic Lane	Total
1.1 - 1.6	2		2
2.1	4	1	5
2.2	4	5	9
3.0	54	55	109
4.1 - 4.3	2		2
5.1 - 5.2	3	3	6
6.1 - 6.2		1	1
8.0	9	10	19
9.0	13	9	22
Unknown		2	2
Total	91	86	177

Event Sequence

Table E-34. Multi-vehicle Crashes by 1st Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Ran Off Road	Roll-over	Other/ Unknown	Total
1.1 - 1.6			14			1		15
2.1	6		163	4	5		2	180
2.2			70		2			72
2.3			13				2	15
3.0	36	5	624	8	23	2	7	704
4.1 - 4.3			2		2			4
5.1 - 5.2	2		23					25
6.1 - 6.2	3		12					15
7.0			4				1	5
8.0	5	2	80	4	2			93
9.0			56		1			57
Unknown	2		21					23
Total	54	7	1,081	16	34	3	12	1,207

Table E-35. Single-vehicle Crashes by 1st Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Fire/ Explosion	Ran Off Road	Roll-over	Other/ Unknown	Total
1.1 - 1.6	2		1			1	2		6
2.1	14		5	2	2	49	4		76
2.2	8		3			16	2	2	31
2.3				2		2			4
3.0	53	7	11	7	7	111	13	2	210
4.1 - 4.3	1					3			4
5.1 - 5.2	5				1	5	1		12
6.1 - 6.2						1			1
8.0	14	2	2			25	3		45
9.0	8		3			15	2	1	30
Unknown		2				4			5
Total	105	11	25	11	10	232	26	5	424

Table E-36. Multi-vehicle Crashes that Result in Spills by 1st Dangerous Event

HM Group	Loss of Control	Jackknife	Collision - Hard Object	Collision - Soft Object	Ran Off Road	Rollover	Total
2.1			16				16
2.2			3				3
2.3			2				2
3.0	16	5	44		7	2	73
5.1 - 5.2	1		3				4
6.1 - 6.2	1						1
7.0			2				2
8.0	1			2			3
9.0			5				5
Unknown	2		5				7
Total	20	5	80	2	7	2	116

Table E-37. Single-vehicle Crashes that Result in Spills by 1st Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Fire/ Explosion	Ran Off Road	Roll-over	Other/ Unknown	Total
1.1 - 1.6	1						1		2
2.1	2					3			5
2.2	3		1			4	2		9
3.0	33	2	5	2		54	13		109
4.1 - 4.3						2			2
5.1 - 5.2	2				1	2	1		6
6.1 - 6.2						1			1
8.0	7	2				9	1		19
9.0	5		3			12	2	1	23
Unknown						2			2
Total	53	4	9	2	1	89	20	1	178

Table E-38. Single-vehicle Crashes by Presence of a Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Fire/ Explosion	Ran off Road	Roll-over	Other/ Unknown	Total*
1.1 - 1.6	4		2			3	5		6
2.1	43	2	40	4	4	55	58		76
2.2	16		16			25	20	2	31
2.3	4		2	2		2	2		4
3.0	168	17	99	7	22	140	141	4	210
4.1 - 4.3	3		4			4	3		4
5.1 - 5.2	11	1	3		1	8	8		12
6.1 - 6.2	4		1			1	1		1
7.0	2								
8.0	26	8	18			36	35		45
9.0	22	2	10			20	23	1	30
Unknown	2	2	5			5			5
Total	305	31	199	12	27	299	296	6	424

* As more than one dangerous event can be associated with a single crash, the Total column shows the total number of crashes in the HM group rather than the sum of the row.

Table E-39. Multi-vehicle Crashes by Presence of a Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Fire/ Explosion	Ran off Road	Roll-over	Other/ Unknown	Total*
1.1 - 1.6	1		14		1	1	1		15
2.1	17	4	172	4	1	16	12	2	180
2.2	2		72			11	4		72
2.3	4		13			2		2	15
3.0	67	17	679	15	8	56	56	9	707
4.1 - 4.3			4			2	2		4
5.1 - 5.2	3		23			2	2		25
6.1 - 6.2	3	2	14			2	2		15
7.0	2		4					1	5
8.0	7	4	89	4	2	2	3		93
9.0	3	4	57		1	4	4		57
Unknown	2	2	21			2	4		23
Total	110	33	1,162	23	13	98	89	13	1,210

* As more than one dangerous event can be associated with a single crash, the Total column shows the total number of crashes in the HM group rather than the sum of the row.

Table E-40. Single-vehicle Crashes Resulting in a Spill by Presence of a Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Fire/ Explosion	Ran off Road	Roll-over	Other/ Unknown	Total*
1.1 - 1.6	2						2		2
2.1	3		2		2	3	5		5
2.2	6		4			9	7		9
2.3									
3.0	73	3	46	2	11	71	100		109
4.1 - 4.3	2		2			2	2		2
5.1 - 5.2	5		1		1	3	5		6
6.1 - 6.2	1		1			1	1		1
7.0									
8.0	10	2	4			16	17		19
9.0	16		7			15	21	1	23
Unknown			2			2			2
Total	118	5	68	2	14	122	160	1	178

* As more than one dangerous event can be associated with a single crash, the Total column shows the total number of crashes in the HM group rather than the sum of the row.

Table E-41. Multi-vehicle Crashes Resulting in a Spill by Presence of a Dangerous Event

HM Group	Loss of Control	Jack-knife	Collision - Hard Object	Collision - Soft Object	Fire/ Explosion	Ran off Road	Roll-over	Other/ Unknown	Total*
1.1 - 1.6									
2.1	9		16		2	5	7		16
2.2	2		3			3	1		3
2.3	2		2						2
3.0	35	10	64	2	11	14	37	2	73
4.1 - 4.3									
5.1 - 5.2	2		3		1	1	4		4
6.1 - 6.2	1								1
7.0	1		2						2
8.0	3		3	2			1		3
9.0	1		5			1	3		5
Unknown	2	2	5			2	4		7
Total	58	12	103	4	14	26	56	2	116

* As more than one dangerous event can be associated with a single crash, the Total column shows the total number of crashes in the HM group rather than the sum of the row.

Table E-42. Crashes with Rollover by Package Type

HM Group	Tank	Cylinder	Drum	Can/Pail	Other	Unknown	Total
1.1 – 1.6	3				1		4
2.1	42	5					47
2.2	16	8					24
3.0	144		4	8	7	3	167
4.1 - 4.3			1				1
5.1 - 5.2	4				5		9
6.1 - 6.2					1		1
8.0	15		4	4		2	24
9.0	14		2		2		18
Total	238	14	11	12	16	5	296

Table E-43. Crashes with Rollover Resulting in Spills by Package Type

HM Group	Tank	Cylinder	Drum	Can/Pail	Other	Unknown	Total
1.1 - 1.6	2						2
2.1	6	2					8
2.2	7	3					10
3.0	106		4	8	7	3	129
4.1 - 4.3			1				1
5.1 - 5.2	3				5		8
6.1 - 6.2					1		1
8.0	10		4	4		2	20
9.0	11		2		2		16
Total	146	5	11	12	15	5	194

Table E-44. Rollovers by Cargo Tank Specification

HM Group	MC301	MC306	MC307	MC312	MC330	MC331	MC338	DOT406	DOT407	Total
1.1 - 1.6			1							1
2.1					2	24	2	2		30
2.2						6	1			7
3.0		60	12	2		2		21	7	103
8.0			7	3						11
9.0	2	1	3	1						7
Total	2	61	24	6	2	31	3	23	7	158

Table E-45. Rollovers Resulting in Spills by Cargo Tank Specification

HM Group	MC306	MC307	MC312	MC331	MC338	DOT406	DOT407	Total
2.1				5				5
2.2				2	1			3
3.0	46	9		2		14	5	76
8.0		5	3					8
9.0	1	2	1					4
Total	47	16	4	9	1	14	5	96

Vehicle Speed Prior to Crash

Table E-46. Crashes as a Function of Vehicle Speed (mph)

HM Group	<10	10-19	20-29	30-39	40-49	50-59	60-69	>70	Total
1.1 - 1.6	6		1	1	1	2			11
2.1	32	10	15	23	23	17	9	4	131
2.2	5	4	2	5	5	17	11	1	50
2.3		2	2				2	2	8
3.0	80	36	39	46	65	119	48	21	455
4.1 - 4.3	1				1	1			3
5.1 - 5.2	5		1	5	3	4	2	5	24
6.1 - 6.2	1				1	2	2	4	10
7.0					1	1			2
8.0	14	2	6	4	14	15	11	7	73
9.0	7	7	7	5	6	22	3	2	60
Unknown	5			2	1	5	3		17
Total	157	62	73	90	120	206	91	45	844

Table E-47. Crashes that Result in Spills as a Function of Vehicle Speed (mph)

HM Group	<10	10-19	20-29	30-39	40-49	50-59	60-69	>70	Total
2.1	4			1	2	1			8
2.2		2		2		1			5
2.3		2							2
3.0	6	6	7	10	19	29	12	5	94
4.1 - 4.3						1			1
5.1 - 5.2	1			3		1	1	3	9
6.1 - 6.2								1	1
7.0					1				1
8.0			2		1	5	3	4	15
9.0			4	1	5	5	2	2	19
Unknown	4					4			7
Total	14	10	13	17	28	46	18	14	161

Table E-48. Cargo Tank Crashes by Vehicle Speed (mph)

HM Group	<10	10-19	20-29	30-39	40-49	50-59	60-69	>70	Total
1.1 - 1.6	1		1	1					3
2.1	28	4	11	14	19	17	7	4	103
2.2		4	2	4	1	12	7	1	30
3.0	73	33	36	42	52	101	41	19	397
4.1 - 4.3	1								1
5.1 - 5.2	1		1	2		1	2	1	8
6.1 - 6.2						1		2	3
8.0	10	2	2		9	5	3	4	36
9.0	6	6	6	5	5	18	3	1	48
Unknown						2	3		5
Total	120	48	58	67	87	156	67	32	634

Table E-49. Cargo Tank Crashes that Result in Spills by Vehicle Speed (mph)

HM Group	<10	10-19	20-29	30-39	40-49	50-59	60-69	>70	Total
2.1				1	2	1			4
2.2		2				1			3
3.0	6	6	7	7	15	24	8	3	76
5.1 - 5.2							1		1
8.0			2		1	1	1	2	7
9.0			4	1	4	4	2	1	16
Unknown						2			2
Total	6	8	13	9	22	33	12	6	109

Impact Location

Table E-50. Crashes by Impact Location

HM Group	Impact - HM cargo region	Impact - non-HM cargo region	Total
1.1 - 1.6	12	9	21
2.1	144	102	246
2.2	60	41	100
2.3	7	9	16
3.0	493	389	883
4.1 - 4.3	6	2	8
5.1 - 5.2	19	17	35
6.1 - 6.2	4	12	16
7.0	2	1	3
8.0	63	67	130
9.0	52	28	80
Unknown	17	12	28
Total	879	687	1,565

Table E-51. Crashes that Result in Spills by Impact Location

HM Group	Impact - HM cargo region	Impact - non-HM cargo region	Total
1.1 - 1.6	12	9	21
2.1	144	102	246
2.2	60	41	100
2.3	7	9	16
3.0	493	389	883
4.1 - 4.3	6	2	8
5.1 - 5.2	19	17	35
6.1 - 6.2	4	12	16
7.0	2	1	3
8.0	63	67	130
9.0	52	28	80
Unknown	17	12	28
Total	198	82	281

Primary Reason

Table E-52. Multiple-vehicle Crashes by Primary Reason

HM Group	Driver Non-Performance	Driver Recognition Error	Driver Decision Error	Driver Performance Error	Vehicle Related	Package Related	Other Vehicle Induced	Highway Related	Weather Related	Unknown	Total
1.1 - 1.6	1	1	5		1		7				15
2.1		8	46		3		119	2	2		180
2.2		5	23				43				71
2.3					2		12				14
3.0	5	61	156	8	9	2	443	13	2	5	704
4.1 - 4.3		2					1				3
5.1 - 5.2			8				16				25
6.1 - 6.2		1	4				9		1		15
7.0		1			1		2				4
8.0		14	24		2		45	2		7	93
9.0	1	3	11				40				55
Unknown		2	8				13				23
Total	7	98	285	8	17	2	751	17	5	12	1,201

Table E-53. Single-vehicle Crashes by Primary Reason

HM Group	Driver Non-Performance	Driver Recognition Error	Driver Decision Error	Driver Performance Error	Vehicle Related	Package Related	Other Vehicle Induced	Highway Related	Weather Related	Unknown	Total
1.1 - 1.6		1	2		2				1		6
2.1	4	29	22	1	4	4		11	4		76
2.2	1	5	14	4	4	2				1	31
2.3	2							2			4
3.0	15	48	71	18	26	3	2	13	11	2	208
4.1 - 4.3	1		2			1					4
5.1 - 5.2		4	5		2	1					12
6.1 - 6.2		1									1
8.0	4	11	14	5	4	2		2	2		45
9.0	6	1	14	4	2	3					29
Unknown	4		2								5
Total	36	100	146	31	43	15	2	28	17	3	421

Table E-54. Multiple-vehicle Crashes that Result in Spills by Primary Reason

HM Group	Driver Non-Performance	Driver Recognition Error	Driver Decision Error	Driver Performance Error	Package Related	Other Vehicle Induced	Highway Related	Weather Related	Total
2.1			3			13			16
2.2						3			3
2.3						2			2
3.0	1	7	13	1	2	47		2	73
5.1 - 5.2			1			3			4
6.1 - 6.2						1			1
7.0		1				1			2
8.0						1	2		3
9.0	1					4			5
Unknown			2			5			7
Total	2	8	19	1	2	80	2	2	116

Table E-55. Single-vehicle Crashes that Result in Spills by Primary Reason

HM Group	Driver Non-Performance	Driver Recognition Error	Driver Decision Error	Driver Performance Error	Package Related	Vehicle Related	Highway Related	Weather Related	Unknown	Total
1.1 - 1.6			1			1				2
2.1		1	2		2					5
2.2		2	5			2			1	9
3.0	8	27	45	6	3	6	3	11	2	109
4.1 - 4.3			2							2
5.1 - 5.2		2	2		1	1				6
6.1 - 6.2		1								1
8.0		3	11	3		2				19
9.0	4	1	10	4	3					22
Unknown	2									2
Total	14	37	77	12	8	12	3	11	3	177

Accident Type

Table E-56. Crashes by Accident Type

HM Group	Backing Up	Head-on	Hit object in road	No Impact	Other/ Unknown	Ran off road	Rear-end	Side-swipe	Turning	Vehicle going straight	Total
1.1 - 1.6				1		6	9	2	1		19
2.1	5	7	4	4	2	44	30	17	17	16	146
2.2		3	1			18	15	13	7	1	58
2.3 & 6.1		3	2	1		6	9	5	4		30
3.0	13	15	16	12	13	122	133	115	52	39	530
4.1 - 4.3				1		4	2	1			8
5.1 - 5.2		1				13	7	5	4	1	31
6.2 & 6.5						1					1
7.0				1			2	1			4
8.0	1	2	1	1	2	24	16	12	2	8	69
9.0		1		1		17	11	13	1	8	52
Unknown		1				3		4	2	1	11
Total	19	33	24	22	17	258	234	188	90	74	959

Table E-57. Spills by Accident Type

HM Group	Head-on	Hit object in road	No Impact	Other/ Unknown	Ran off road	Rear-end	Side-swipe	Turning	Vehicle going straight	Total
1.1 - 1.6					2					2
2.1	3				3	1		1	4	12
2.2	1				6		1			8
2.3 & 6.1		1			3	1				5
3.0	3	2	1	5	77	7	12	8	4	119
4.1 - 4.3					2					2
5.1 - 5.2					7		1		1	9
6.2 & 6.5					1					1
7.0						1	1			2
8.0		1		1	11					13
9.0					13		1	1	1	16
Unknown					2			1	1	4
Total	7	4	1	6	127	10	16	11	11	193

Weather Condition

Table E-58. Crashes by Weather Condition

HM Group	No Adverse Condition	Rain/Sleet	Snow	Fog	High Winds	Other	Unknown	Total
1.1 - 1.6	14	3	3		1			21
2.1	202	30	16		4	2	4	256
2.2	77	11	6	4		3		100
2.3	16		2		1			18
3.0	755	84	44	14	4	11	3	914
4.1 - 4.3	3	4			1			8
5.1 - 5.2	28	4	3		2			36
6.1 - 6.2	15		1					16
7.0	4							4
8.0	119	12	6	2				139
9.0	74	4	3	4		2		86
Unknown	18	9	2					28
Total	1,324	160	84	24	12	17	6	1,627

Table E-59. Crashes that Result in Spills by Weather Condition

HM Group	No Adverse Condition	Rain/Sleet	Snow	Fog	High Winds	Other	Unknown	Total
1.1 - 1.6	2							2
2.1	12	5	2				2	21
2.2	4	2	2	2		3		12
2.3	2							2
3.0	146	17	7	6	4	2	1	182
4.1 - 4.3	1	1						2
5.1 - 5.2	7	3						10
6.1 - 6.2	2							2
7.0	2							2
8.0	20		2					23
9.0	23	2	3					27
Unknown	9							9
Total	230	30	16	7	4	5	3	294