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ANALYSIS OF SERIOUS TRUCK CRASHES IN THE UNITED STATES

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ABSTRACT

Hazmat heavy truck shipments represent less than eight percent of all commodity shipments. However, the consequences from a hazmat crash can be greater than that for a non hazmat truck shipment. In addition to crash impacts associated with non-hazmat shipments, hazmat crash impacts may result in: more fatalities and injuries, additional environmental consequences, higher property damage and clean up costs and longer incident delay. Presently, the Federal Motor Carrier Safety Administration of the U.S Department of Transportation relies on the Motor Carrier Management Information System (MCMIS) to provide data for analyzing serious crashes. 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.

Objectives

The objectives of this project were: to enhance the current methodology for identifying and characterizing serious hazmat truck crashes in the U.S. and to support the implementation of hazmat truck transportation risk reduction strategies. The project's approach was to enhance the serious hazmat truck crash identification, data collection, and analysis process. Data from roughly half the hazmat crashes reported in MCMIS for 2002, were supplemented with data from police accident reports, conversations with the carriers and HM spill data from the Hazardous Materials Information System (HMIS). This data was entered into a separate hazmat database. The enhanced data provided insights into the nature of hazmat crashes and was analyzed to help develop more in depth analyses of the hazmat crashes.

Discussion

The Hazmat Database design and data entry system provides a methodology by which hazmat crash data can be collected, validated, and utilized in support of motor carrier

safety policy analysis. The process utilizes MCMIS and then enhances the accuracy, completeness, and breadth of crash records, by incorporating information collected from other sources. As a result, significant findings were identified with fewer crashes and more comprehensive safety analysis can be performed.

INTRODUCTION

Although hazardous materials (HM) heavy truck shipments represent less than eight percent of all commodity shipments, the consequences from a HM crash can be greater than that for a non HM truck shipment. The release of the hazardous materials can result in additional fatalities, injuries, serious environmental consequences, higher clean up costs, higher property damage, and longer incident delay. In part, because of these greater crash impacts, the Federal Motor Carrier Safety Administration (FMCSA) has been interested in identifying the factors that influence HM shipment safety. FMCSA relies on the Motor Carrier Management Information System (MCMIS) to provide data for analyzing HM and non-HM large truck serious crashes. So as to insure the focus is on serious crashes, for a crash to be entered into the MCMIS database it must result in a fatality, an injury requiring transport to a facility for immediate medical attention, or one of the vehicles must be towed from the scene.

APPROACH/METHODOLOGY

The project's approach was to enhance the serious HM truck crash identification, data collection, and analysis process. The first phase designed and tested tools and methods to enhance MCMIS HM crash information. In the second phase, the data from 1000 HM crashes, roughly half the HM crashes reported in MCMIS for 2002, were supplemented with additional data and information from police accident reports (PARs), calls to carriers and from the Hazardous Materials Information System (HMIS). These additional data and information were merged with the MCMIS data into a one of the tools developed in Phase I, a separate enhanced database.

This project, sponsored by the FMCSA, had five 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 HM crashes.
- Support the implementation of HM truck transportation safety and risk reduction strategies for packages, vehicles, and drivers.
- Demonstrate the feasibility of collecting additional information for over half the MCMIS reported HM crashes on a routine basis
- With the greater number of analyzed crashes, develop findings, possibly statistically significant, on the nature of HM crashes and from these findings potential methods to improve truck transport risk.

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. As shown in Table 1, five types of explanatory variables were used, vehicle, driver, packaging, infrastructure, and situational characteristics. For HM crashes, the impact of concern was a spill.

Table 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 of 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. If a crash involved two separate HM vehicles, 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 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. For other classes, crash data for more than one year would be needed to perform HM class-specific spill analyses.

The findings listed below are organized by the five types of explanatory variables listed in Table 1.

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.

Table 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

- The most common vehicle configuration used in transporting HM involved in crashes is the tractor/semi-trailer. This configuration is involved in 60 percent of all crashes. The next most common configuration is the straight truck, being involved in 30 percent of all HM crashes. The tractor/semi-trailer configuration is the dominant vehicle configuration for all classes of HM 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 because the straight truck configuration is dominated by Division 2.1 shipments, which have a much lower spill-to-crash ratio, 8 percent versus 18 percent, respectively.

Driver. Driver age and experience are among the factors closely related to HM safety.

- The average age of a HM driver involved in a crash was 44. 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 spill to crash percentage of 14 percent. The highest age 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 have the lowest spill to crash percentage.

- A serious HM crash is likely to be more severe if it involves a driver with less experience (see Figure 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. 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.

- 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 HM truck driver is at fault.

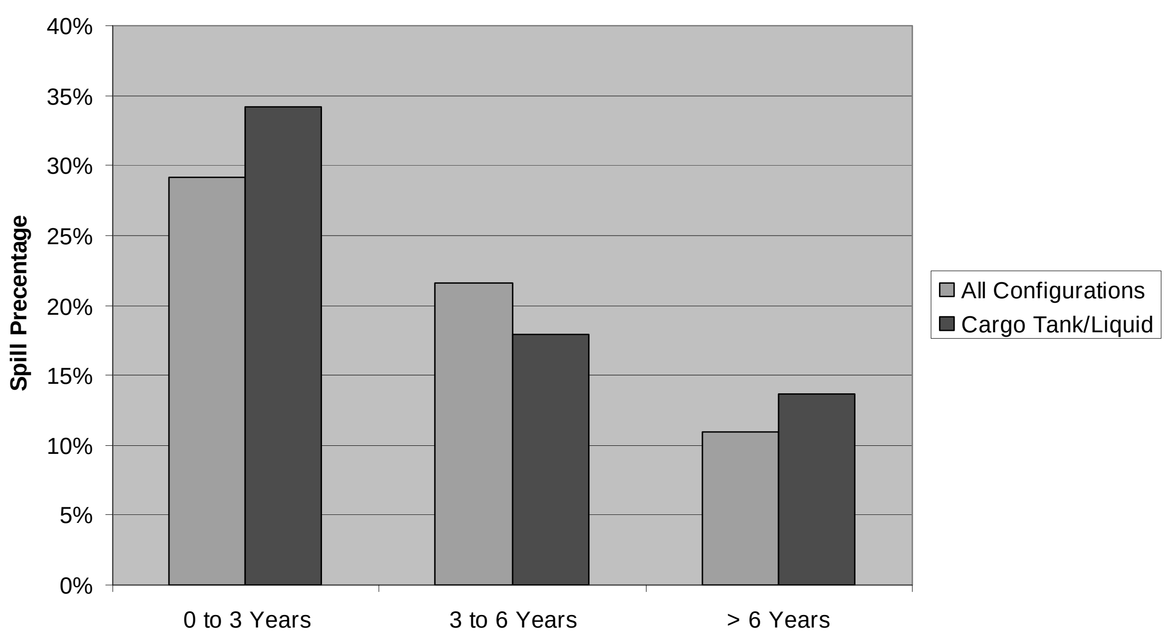

Figure 1. Cargo Tank Spill-to-Crash Ratio versus Driver Experience

Packaging. The type of cargo tank is closely related to the percentage of crashes with spills.

- 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. Spills occurred in 26 percent of the crashes for the DOT407 and 37 percent of the crashes for the MC307. The introductions of the DOT406 and DOT407 designs have enhanced container integrity (See Figure 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.

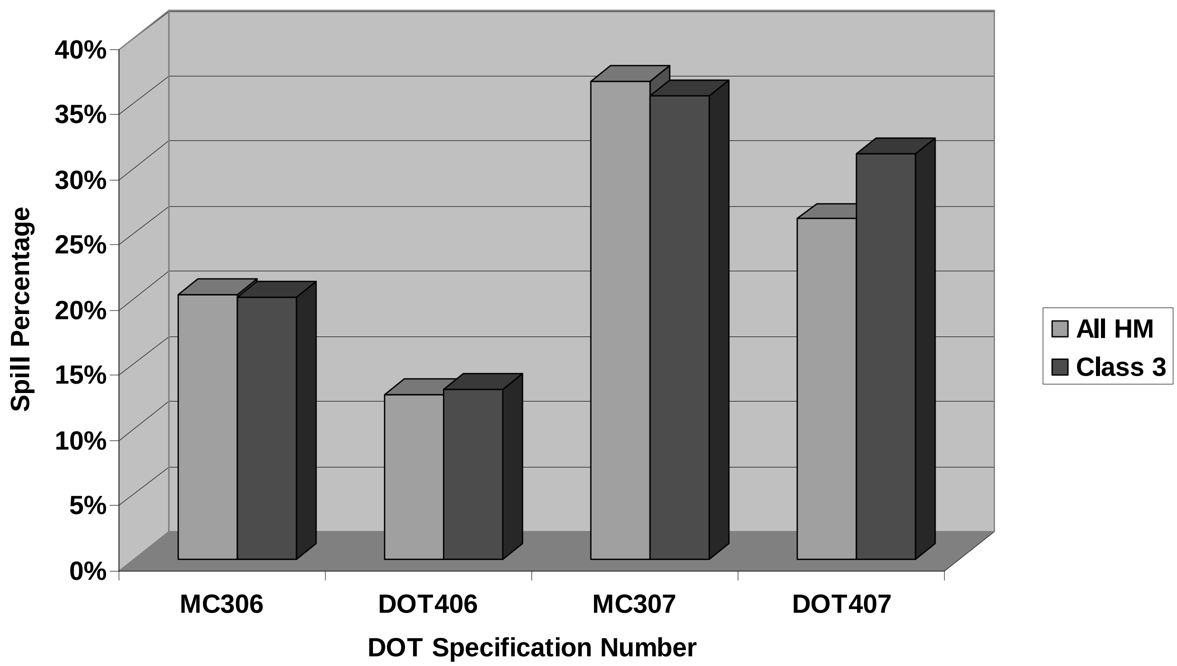

Figure 2. Spill Performance versus Cargo Tank Specification

- Of all 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. The higher the center of gravity of a full tanker truck may be the reason why full tanker trucks are more likely to rollover. HM tanker truck rollovers are important for safety and risk analyses because of the strong correlation between rollovers and spills. Rollovers are most likely on entrance and exit ramps, where over 87 percent of all rollovers result in a spill.

Infrastructure. Crashes with spills are correlated with road type in the analysis.

- Spills occur in about 14 percent of the serious crashes on Interstates. On average, however, spills occur in 18 percent of all crashes. The results also 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. These differences may be associated with Interstate design elements such as medians, shoulders, and guardrails that reduce the likelihood that a truck will be involved in a rollover.

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

Situational. Pre-crash conditions as well as the level of HM in a cargo tank are discussed below.

- 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 HM 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 3, 60 percent of all crashes are multiple-vehicle crashes that occur while the HM 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 that the spill-to-crash ratio is significantly higher for rollover events than for other crash types. Figure 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 are more robust because they contain either a low temperature liquid or a gas under pressure. With more data, it might 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 HM crash.

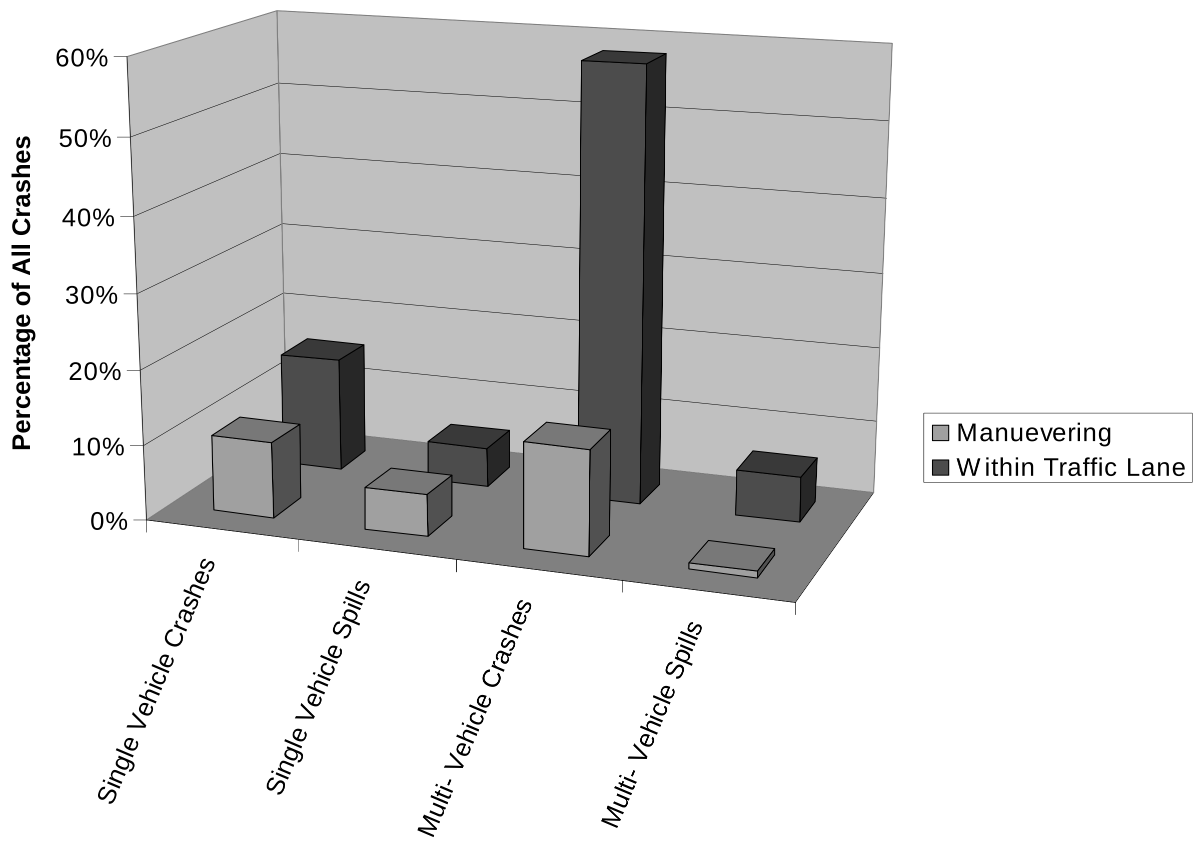

Figure 3. Statistics for Selected Pre-crash Conditions

DATA COLLECTION CHALLENGES

Beginning with the Motor Carrier Management Information System (MCMIS) Crash file for records entered in calendar year 2002, the project team identified approximately 2,100 possible HM crashes from among the approximately 105,000 MCMIS crash records recorded for 2002. These records were electronically transferred in to the enhanced database. Police accident reports (PARs) were requested from the states for all 2,100 selected crashes and approximately 1,800 were obtained. The HMIS database (which contains mostly HM spill accidents) was also searched and approximately 100 crashes that were also reported in HMIS were identified and the information electronically transferred to the enhanced database. Of the 2,100 selected crashes, 1,000 were selected for entry of the PAR data. Calls to carriers involved in the 1,000 crashes were also attempted.

- 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 HM. Data were entered for 966 HM crashes that involved 970 HM vehicles. Since some of these vehicles carried multiple types of hazardous material, over 1,000 hazardous material records were associated with these 970 vehicles.

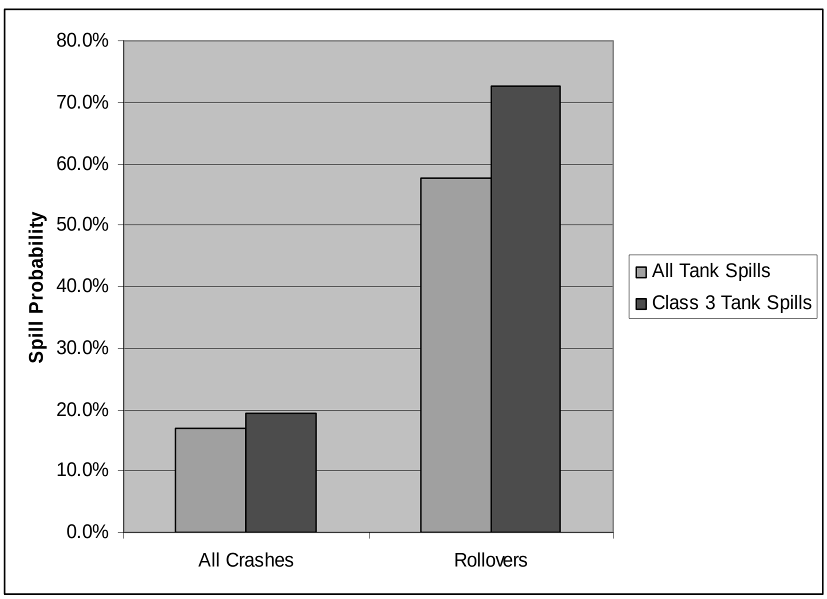

Figure 4. Comparison of Class 3 Tank Crashes and Those Involved in Rollovers

- Validated and supplemented the data by corresponding with the involved carriers. 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.

A major project finding is the amount of revision for MCMIS Crash file data to accurately portray the type of HM in serious truck crashes. For example, as shown in Table 3, the initial assignment of hazard class to vehicle crashes based on MCMIS Crash file data differed from the final assignment of hazard class to vehicle crashes in the HAZMAT Accidents Database. 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 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 for collecting, validating, and utilizing HM crash data to support 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, significant findings can be identified with fewer crashes as well and, more comprehensive safety analysis can be performed.

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. Because the data being analyzed are more complete, it is possible to place greater confidence in analysis results. In some cases, the results 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.

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