

Evaluation of Light Vehicle Side Underride Collisions into Combination Trucks

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ABSTRACT

Field data is used to evaluate the number of light vehicle occupants injured or killed in side underride crashes with "combination trucks". Statistical analyses were performed of federal crash data files for side underride crashes with passenger compartment intrusion (PCI) in the light vehicle, and an in-depth review of combination truck crashes was performed using photographs, scene diagrams, and other vehicle and occupant data. Results show that, annually, fewer than 4% of all occupant fatalities and approximately 5.5% of all occupant injuries sustained in light vehicles that have collided with combination trucks can be attributed to side impact underride with PCI.

INTRODUCTION

The Society of Automotive Engineers (SAE, 2003) defines underride as the instance in which a light vehicle is positioned at least partially underneath a large truck at sometime during a crash. In 1995, the National Highway Traffic Safety Administration (NHTSA) published in the Federal Register a final rule establishing two Federal Motor Vehicle Safety Standards (FMVSS) that operate together to reduce the number of injuries and fatalities resulting from collisions of light vehicles into the rear ends of heavy trailers and semi trailers. The two standards, FMVSS 223 and 224, relate solely to rear impact guards. In 1991, as part of the Preliminary Regulatory Evaluation that led to establishing these standards, NHTSA rejected extending requirements to a guard that might address injuries and fatalities due to light vehicles colliding with the sides of heavy trailers and semi trailers, stating: "combination truck side underride countermeasures have been determined not to be cost effective" (NHTSA, 1991).

STUDY OBJECTIVES AND APPROACH - A statistical study using recent, best available, field data obtained from NHTSA was undertaken to estimate the number of occupants with fatalities and injuries associated with two-vehicle side underride crashes involving a light vehicle (passenger car or light truck) striking the side of a combination truck (Class 7 or 8 medium/heavy truck with one trailer unit). The analytical approach used for this

study is comparable to that used by NHTSA (1995) for the rear guard analysis. The current study updates some of the injury and fatality data used in NHTSA's 1995 analysis and provides an additional in-depth review of 48 side underride cases involving combination trucks.

LITERATURE REVIEW - Fatalities from large truck crashes have declined each year since 1997. In 1997, there were 5,398 such fatalities; in 2003, the number was 4,986 (Federal Motor Carrier Safety Administration, 2002 and 2004). However, the number of these fatalities attributable to underrides remains a point of contention. In recent years, several key studies of underride-involved fatalities have been published. NHTSA (2003) conducted a study using Fatality Analysis Reporting System (FARS) data, along with Truck-Involved Fatal Accident (TIFA) survey data collected by the University of Michigan Transportation Research Institute (UMTRI), to identify the characteristics of fatal crashes involving large trucks. In addition, Blower and Campbell (2002) examined the occurrence of underride for straight trucks and tractor-trailer combinations, concluding that "underride occurs in a substantial fraction of all rear-end fatal crashes regardless of power unit type."

A number of studies undertaken from the 1970s through the 1990s attempted to understand and classify underride crashes and to address the underreporting of underride collisions in accident databases for the years through 1993 (Minahan and O'Day, 1977; Braver et al., 1997a; and Braver et al., 1997b). In one study, Braver et al. (1997b) examined photographs of fatal crashes between large trucks and passenger vehicles in Indiana during 1993 and compared the underride incident rates to those obtained using FARS codes. The authors concluded that "the incidence of underride reported in FARS was much lower than in the photograph-based study." The undercount of underride in FARS was attributed to three problems: police reports often did not contain sufficient information for coding underride; the coding of underride itself was inconsistent from report to report; and, finally, FARS did not have an underride/override variable until 1994. The study's conclusions were based on data from FARS prior to 1994 and photos from only one state (Indiana). In addition, the majority (63%) of underride crashes

examined involved the front of a large truck colliding with the side of a passenger vehicle, as opposed to side underride crashes (16%), in which the passenger vehicle collides with the side of a truck. The photo study included only nine side underride cases involving combination trucks. The authors also noted that high speed was involved in many of the crashes and that lack of restraint use was a serious problem.

In 1994, FARS revised the coding of underride crashes based on comments NHTSA received from other safety researchers and based on their own research. The new FARS underride variable included coding options to identify "PCI" (passenger compartment intrusion), "no PCI", and "PCI unknown". Although there have been several studies addressing rear underride fatalities using earlier years of FARS and National Automotive Sampling System / Crashworthiness Data System (NASS/CDS) data, estimates of fatalities and injured occupants for light vehicle occupants involved in side underride crashes have not been developed using more recent field data. The goal of the study reported here was to develop such estimates.

METHOD

The methodology used to perform the analysis is similar to that used by NHTSA in its Final Regulatory Evaluation on rear impact guards (1995). In addition, an in-depth (clinical) study was made using the detailed NASS/CDS data (1997-2001) for all side impact underride cases involving collision of a light vehicle and a combination truck.

FATAL CRASH DATA AND ANALYSES

Data Used - FARS data from 1994-2005 was used to estimate the number of fatalities. The FARS database, maintained by NHTSA, is a census of all vehicle crashes occurring on U.S. public trafficways that result in at least one fatality within 30 days of the crash. This is the database that was used by NHTSA (1995) to develop estimates of rear underride fatalities involving combination trucks. Because NHTSA added detailed FARS codes to identify underrides with PCI in 1994, the FARS side underride analysis focused on the years 1994-2005.

Analysis - The FARS data analysis included two-vehicle side impact crashes in which the struck vehicle, a combination truck, was impacted in the side by the striking vehicle, a passenger car or light truck. Crashes with more than two vehicles were excluded. Side impact crashes were defined as those in which the initial impact point for the struck vehicle corresponds to impact area clock-points of 2, 3, or 4 o'clock or 8, 9, or 10 o'clock. Crashes involving "underride with vehicle in transport" (including combination trucks stopped on a roadway, but *not* parked) and "underride with vehicle not in transport" (i.e., parked) were included. Underride fatalities with "PCI unknown" were distributed between "PCI" and "no PCI" to obtain estimates of the total number of "underride with

PCI" fatalities. These estimates did not include fatalities resulting from underride collisions involving parked combination trucks.

FARS has very limited information on parked vehicle collisions; data on vehicle body type (single unit truck or combination trucks) and impact point of contact are not coded in FARS for parked vehicles. Hence, the methodology NHTSA used in its final regulatory evaluation report on rear impact guards for truck trailers (NHTSA, 1995) was used in this study to estimate the number of side underride collision fatalities involving parked combination trucks. For 1994, NHTSA estimated there were 29 parked rear and side underride collisions (see Table IV-2; NHTSA, 1995). NHTSA estimated 80% (or 24) of these were combination trucks. Based on discussions with NHTSA and UMTRI, the study team made the assumption that 20% (5) of these underride crashes with parked combination trucks were side underrides, and 80% (19) were rear underrides. For each year from 1994 to 2003, 5 parked vehicle side underride fatalities were added to the estimates of side underrides with vehicle in transport.

INJURY CRASH DATA AND ANALYSES

Data Used - The NASS/CDS database was the primary source used for developing estimates on injuries associated with side underride crashes. NASS/CDS is a nation-wide representative sample of tow-away crashes for which about 5,000 crashes a year involving passenger cars, light trucks, vans, and utility vehicles are investigated in detail by NASS/CDS field research teams. Because it offers much more detail on the crash and occupants than FARS, NASS/CDS is widely used by NHTSA to examine injury mechanisms; nature of injuries by body region; and other occupant-, vehicle-, and crash-related factors.

NASS/CDS started coding side underrides for large trucks in 1995; prior to that year, underrides involving impacts to the sides of large trucks or light vehicles were usually not coded as such by NASS/CDS investigators. Hence, NASS/CDS data for the years 1995-2005 was used for this study.

In addition to a statistical analysis of NASS/CDS data, the study included an in-depth review (including photographs, descriptions, schematics, etc.) of individual 1997-2001 NASS/CDS case records (case details were made electronically available starting with 1997) for every side impact underride involving a light vehicle and a combination truck. This review was performed to identify the nature of underride (glancing blow, etc.) and the type of underride (under the wheels, under the tractor, under the trailer, etc.). The in-depth review formed the basis for deriving accurate estimates of the number of injured occupants associated with side trailer underride with PCI for collisions involving combination trucks.

Analyses - For the NASS statistical analysis, NASS/CDS data from 1995-2005 was used to estimate the number

of light vehicle occupants injured in collisions with combination trucks, with "injury" defined as non-fatal, with the *maximum* injury ranked between 1-5 on the Maximum Abbreviated Injury Scale (MAIS). To be included, the striking vehicle had to be a passenger car or light truck, and the struck vehicle had to be a combination truck. The NASS/CDS data does not identify impact points for combination trucks but contains information on accident configurations (frontal, rear, side swipe, etc.); accident configurations that would include possible side impacts and sideswipes were included in the study. The accident configurations selected for the study include Crash Configurations E-F and H-M of the NASS/CDS "General Vehicle Form." These configurations include multiple-vehicle forward, sideswipe/angle, and turning into/across path impacts. [Configurations A-D and G identify single-vehicle, rear-end, and head-on accident configurations and, therefore, were excluded from the study.] As in the FARS analysis, crashes with more than two vehicles were excluded, and estimates of injured occupants in crashes involving "underride with PCI" were derived.

The derivation of underride with PCI involved in-depth case review of all available NASS/CDS (1997-2001) side impact cases coded as "underride" (an uneven damage pattern caused by unequal amounts of crush in different vertical zones of the front and/or rear planes of a light vehicle). NASS/CDS uses the same definitions of vertical regions as the SAE CDC Standard: "Collision Deformation Classification" (SAE, 1980).

Validation of underride codes was made by reviewing case photographs and scene diagrams and sketches. NASS/CDS data, with photographs and scene diagrams, was available electronically for the years 1997-2001, and the study team used this data to determine underride crashes with PCI. The detailed case review, which consisted of examination of each case (there were 48) to verify the extent and location of underride and whether PCI was present at/over the occupant's seat position, was made for 73 light vehicle occupants involved in side impact underride crashes. A vehicle was considered to have valid coded trailer underride if any portion of the vehicle had underridden any area of the trailer at any point during the crash. Based on review of photos, damage sketches/ measurements, and CDC coding, underride impacts with passenger compartment intrusion (typically into the greenhouse area; CDC vertical area = G) at the occupant's seated position were identified as PCI. The percentage of underride crashes with PCI was then estimated for each MAIS level and subsequently applied to the estimates of injured occupants in underride crashes obtained using the 1995-2005 dataset. Due to paucity of data, MAIS levels 2-5 were grouped to derive the percentages of underrides with PCI.

RESULTS

FATALITY ESTIMATES - According to the data available in FARS (1994-2005), an average of 2,254 fatalities

occur annually in light vehicles as a result of collisions with combination trucks. Of these, 393 occur in side impact crashes, including about 78 with side underride (Figure 1; figures are presented in Appendix A).

A breakdown of the estimated annual fatalities from side underride crashes with and without PCI is presented in Table 1A (tables are presented in Appendix B). As the table shows, over the 12-year period from 1994-2005, there were 932 light-vehicle occupant fatalities in 794 fatal side underride crashes involving a light vehicle and a combination truck. Hence, in FARS, there were 1.2 side underride fatalities per crash. Five hundred and sixty-two (562) of the occupant fatalities occurred in side underride crashes with PCI, 63 were in side underrides with no PCI, and 307 (approximately one third) were coded as "PCI unknown." In Table 1B, the unknown PCI cases were distributed using the known proportions of PCI/no PCI from Table 1A. In addition, estimates for fatalities due to underride of parked combination truck trailers (5 per year) were added, as discussed under Method. The final estimated number of fatalities from side underrides with PCI for light vehicle collisions involving combination trucks is 75 per year, as shown Table 1B. This result is consistent with NHTSA's estimate of 76 in calendar year 1994.

INJURY ESTIMATES - Figure 2 presents an overview of the estimated annual number of non-fatal, injured light vehicle occupants in side underside crashes, based on data available in NASS/CDS (1995-2005). Annually, about 28,274 occupants are injured in light vehicles that have collided with combination trucks — with approximately 5,085 of these occupants being injured in side underride crashes. Note that each occupant is counted only once, regardless of the number of injuries, based on each occupant's maximum injury. Of the estimated 5,085 occupants with side underride injuries each year, 4,408 sustain minor (MAIS 1) injuries, with the remaining 677 sustaining injuries that are moderate to severe (MAIS 2-5). The NASS/CDS analyses excluded MAIS 6/fatal since estimates of fatalities were derived using the FARS data and because previous studies done on NASS/CDS data have shown that over 98% of MAIS 6 injuries coded in NASS/CDS are fatalities (identified using "treatment mortality = 1"). This is the same methodology used by NHTSA to derive benefit estimates for rear underrides.

To obtain estimates of injured occupants in side underrides *with PCI*, detailed case reviews were made using NASS/CDS photographs, scene diagrams, and vehicle information. For the years 1997-2001, there were 48 side underride cases involving 73 light vehicle occupants. Each identified case available in the 1997-2001 database was then studied in-depth to confirm it was a side impact with underride and to identify underride cases with PCI. Using this information, an estimate of the percent of injured occupants in side underrides with PCI was calculated for each MAIS level (MAIS 2-5) coded. About 50% of the side underrides examined involved trailer underride, and about 40%