THE EMERGING THREAT OF LIGHT TRUCK IMPACTS WITH PEDESTRIANS

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ABSTRACT

In the United States, passenger vehicles are shifting from a fleet populated primarily by cars to a fleet dominated by light trucks and vans (LTVs). Because light trucks are heavier, stiffer, and geometrically more blunt than passenger cars, they pose a dramatically different type of threat to pedestrians. This paper will investigate the effect of striking vehicle type on pedestrian fatalities and injuries. The paper will present and compare pedestrian impact risk factors for sport utility vehicles, pickup trucks, vans, and cars as developed from analyses of U.S. accident statistics.

INTRODUCTION

In 1999, 4906 pedestrians were killed in traffic accidents in the United States [1]. As the number of LTVs on U.S. highways continues to increase, a new area of concern regarding pedestrian safety has emerged. With dramatically different size, shape, and stiffness than passenger cars, LTVs may pose a more serious risk of injury and fatality for vulnerable road users such as pedestrians.

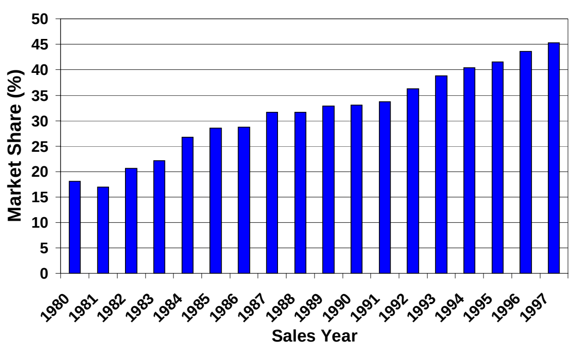

Figure 1. U.S. Sales of Light Trucks and Vans

Figure 1 shows that sales of LTVs in 1997 were almost 50 percent of all vehicles sold [2]. With such a profound change in the fleet of United States vehicles, it is important to investigate the safety repercussions on motorists and pedestrians. Several studies have shown that LTVs are incompatible with cars in LTV-to-car collisions. In fatal LTV-to-car collisions, 81% of the fatally injured occupants are in the car [3]. Uninvestigated however is how the growing fleet of LTVs may affect the safety risk for pedestrians.

OBJECTIVE

This study examines the effect of striking vehicle type on pedestrian fatalities and injuries in frontal impacts. The study is based on an analysis of U.S. traffic accident statistics from the Fatality Analysis Reporting System (FARS), the General Sampling System (GES), and the NASS Pedestrian Crash Data Study (PCDS). By combining these three databases, this paper compares and contrasts the impact risk factor for pedestrians struck by sport utility vehicles, pickup trucks, vans, and passenger cars. The paper analyzes pedestrian fatality trends and pedestrian injury response for passenger cars and LTVs. The results will be used to determine the threat of light truck and van (LTV) impacts with pedestrians.

Previous studies [4] have addressed the idea that LTVs may pose a more serious threat to pedestrian safety by investigating injury severity, but no detailed analysis has been conducted thus far. This study is the first to deal with pedestrian fatality trends and injury patterns in relation to vehicle type.

APPROACH

For the purposes of this study, only accidents involving single vehicle and pedestrian interaction were examined. Accidents in which multiple vehicles struck a pedestrian were excluded as in these cases it is unclear which vehicle to associate with the pedestrian's injury. Similarly, cases of multiple vehicles striking multiple pedestrians were excluded. As shown in Table 1, this approach did not compromise the data analysis, as 91% of all cases involved single vehicle interaction with pedestrians, and a significant number of cases were still available to perform a detailed analysis.

Table 1. U. S. Pedestrian Fatalities, 1995-1999

	Fatalities	Percent
Single Vehicle-Pedestrian Collisions	23, 953	91.9
1 Pedestrian-Multiple Vehicles	2, 027	7.8
Multiple Vehicles-Multiple Pedestrians	77	0.3

The analysis performed incorporated three major sources of data, the Fatality Analysis Reporting System (FARS), the General Estimates System (GES), and the Pedestrian Crash Data Study (PCDS). Pedestrian fatality numbers were obtained from FARS. FARS is a comprehensive census of all traffic related fatalities in the U.S. GES was analyzed to determine the number of pedestrians who were struck - both fatally and non-fatally - in traffic accidents. GES is a comprehensive database containing information on approximately 60,000 randomly sampled police reported accidents each year. Cases from GES are assigned weights that can be used to estimate the number of similar accidents that may have taken place that year that were not sampled. Because GES is a sample of police reported accidents, it is important to note that these estimates can be subject to sampling errors [5].

The later portion of this paper includes findings from the PCDS. This study is a five-year compilation of pedestrian accident data collected from six major United States cities from 1994-1998. The database focuses on late model year vehicles which strike pedestrians. The PCDS contained 543 cases with detailed information regarding the collision including injury severity, vehicle characteristics, and accident configuration. The study was done to identify areas of concern in pedestrian safety and to compare data to previously conducted pedestrian reports to determine any modifications in trends over the years.

The PCDS was invaluable for this analysis because it is a database dealing only with pedestrian accidents, both fatal and non-fatal. Each accident was investigated in detail, and provided information unavailable through either FARS or GES, including detailed descriptions of injuries. [6].

ANALYSIS

Pedestrian Fatality Trends

To determine pedestrian fatality trends FARS 1991-99 data was analyzed. In 1999, 4906 pedestrians were fatally injured. This is a 15% decrease from 1991. Figure 2 shows the overall trend in pedestrian fatalities from 1991 to 1999.

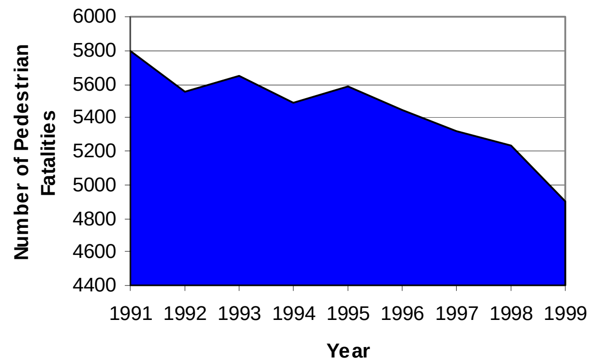

Figure 2. Pedestrian Fatality Trend 1991-1999

When broken down by vehicle type and restricted to single vehicle collisions, the decrease in fatalities occurs mainly in the passenger car category as shown in Figure 3. The number of pedestrian fatalities resulting from LTV impacts increased slightly from 1991 to 1999.

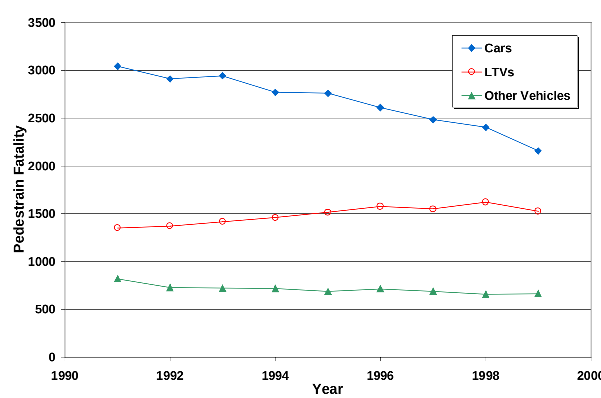

Figure 3. Pedestrian Fatality Trend by Vehicle Type for Single Vehicle-Pedestrian Collisions

To take a closer look at the effect the striking vehicle has on pedestrian fatalities, fatality counts were extracted from FARS 1995-99 and the accident involvement counts were estimated from GES 1995-

99 for a variety of impact vehicle types. To determine the risk of fatality by striking vehicle type, a Pedestrian Risk Metric (PRM) was computed for each vehicle category as shown below:

$$PRM = \frac{\text{Total Pedestrian Fatalities by Vehicle Type}}{\text{Pedestrian Accidents Involving Vehicle Type}}$$

Figure 4 shows that all categories of LTVs have a higher pedestrian risk than cars. Large vans have the highest risk, PRM = 259, while passenger cars have the smallest, PRM = 49. One of every four pedestrian accidents involving a large van resulted in a pedestrian death. In contrast, only one out of every 20 pedestrian accidents involving a car resulted in a pedestrian death. For large SUVs, one out of every 7 pedestrian accidents resulted in a pedestrian fatality.

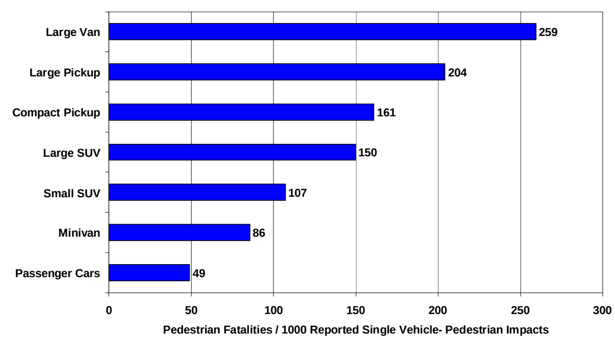

Figure 4. Pedestrian Risk by Vehicle Type (FARS and GES 1995-99)

Injury Responses

The PCDS database was examined to determine the distribution of injury responses for pedestrians struck by passenger cars and LTVs. Injury levels in the PCDS are characterized by the Abbreviated Injury Scale (AIS) – a measure of threat to life where AIS=0 represents no injury and AIS=6 represents a fatal injury. The PCDS contains 371 (68.3%) cases involving passenger cars and 172 (31.6%) cases involving LTVs. This sampling reflects the U.S. vehicle mix as currently LTVs comprise one third of the entire United States passenger vehicle fleet.

Figure 5 presents the distribution of the maximum AIS value by vehicle type for each pedestrian case in the PCDS. The figure demonstrates that most injuries are of minor severity (AIS 1), and that persons struck by passenger cars are more likely to incur an AIS 1 injury than are persons struck by an LTV. However, persons struck by LTVs are more likely to sustain a maximum injury level of AIS 4 or greater than are pedestrians struck by cars.

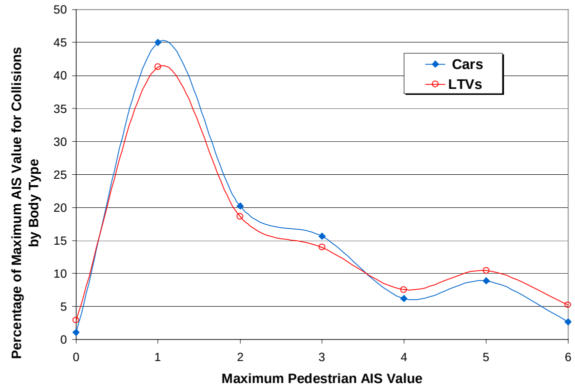

Figure 5. Frequency of Maximum AIS Value by Vehicle Type

Figure 6 shows the distribution of injury severity by vehicle type. In this figure the LTV category is broken down into its constituent types: large pickups, small pickups, large vans, minivans, and SUVs. Note that pedestrians struck by large pickups and SUVs are more likely to have AIS 3 and greater injuries than are persons struck by passenger cars.

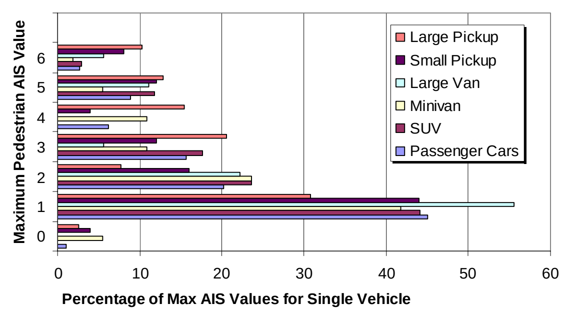

Figure 6. Frequency of Maximum AIS Values by Vehicle Type

Injury Risk by Body Region

When struck by a vehicle, a pedestrian can suffer injuries to a wide range of body regions. Due to the different height and frontal geometry of cars and LTVs, pedestrians are impacted at different areas of the body and respond differently kinematically after being struck. Both of these factors influence the injuries that a pedestrian sustains. The PCDS database was examined to determine the effect vehicle type has on the severity of injury level to each body region.

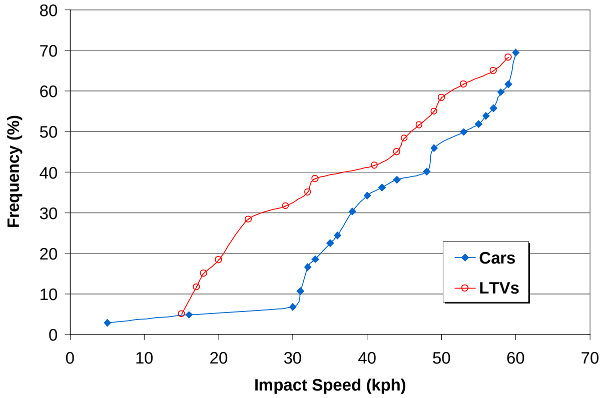

Figure 7. Frequency of Severe Head Injury AIS 3 or Greater by Vehicle Type as a Function of Impact Speed

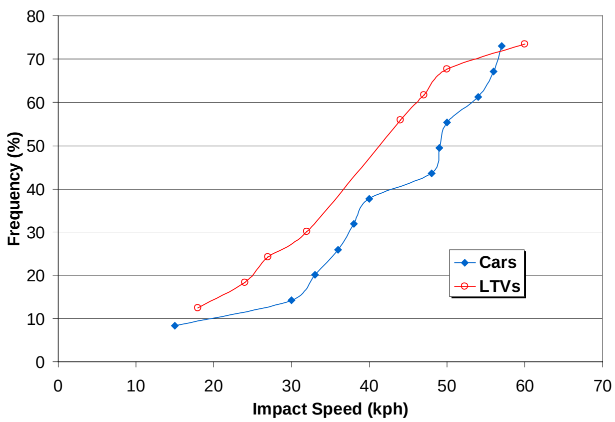

Figure 8. Frequency of Severe Chest Injury AIS 3 or Greater by Vehicle Type as a Function of Impact Speed

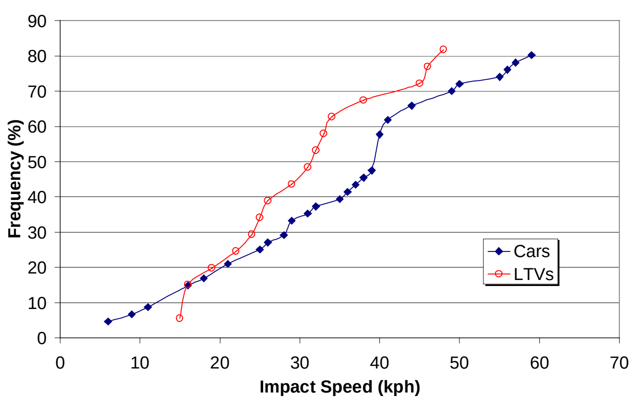

Figure 9. Frequency of Severe Lower Extremity Injury AIS 3 or Greater by Vehicle Type as a Function of Impact Speed

Injury severity was examined for AIS levels of 3 and greater because these injuries pose a serious threat to a pedestrian. Figures 7 though 9 show the relationship between impact speed and AIS values of greater than or equal to 3 for the head, chest, and lower extremities.

These figures suggest that at any given impact speed, the probability of serious head, chest, and lower extremity injury is higher for persons struck by LTVs than for persons struck by cars. However, as the distribution of LTV impact speeds is not identical to the distribution of impact speeds for cars, a second estimate of serious injury probability was calculated as shown below.

Figures 10 through 12 show the probability of sustaining an injury of AIS 3 or greater to different body regions by vehicle type. For these plots, the probability of serious injury for each of three speed ranges was estimated by dividing the number of AIS 3 and greater injured body regions over each speed range by the number of pedestrian involvements over the same speed range.

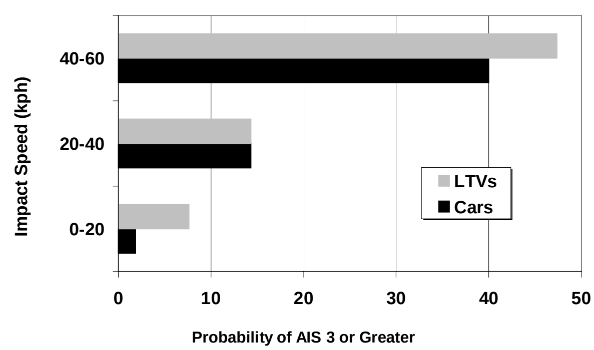

Figure 10. Probability of Severe Head Injury AIS 3 or Greater

Figure 10 illustrates the probability of a head injury AIS 3 or greater for three impact speed ranges. With lower and higher impact speed ranges, there is a higher probability of severe head injury from LTVs than with passenger cars, while the moderate impact speed range shows similar probability of injury level for both vehicle types.

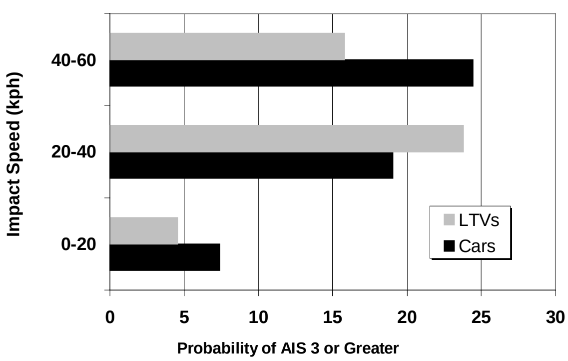

Figure 11. Probability of Severe Lower Extremity Injury AIS 3 or Greater

Figure 11 shows the probability of lower extremity injury AIS 3 or greater as a function of impact speed. The data here shows for lower and higher impact speed ranges there is a higher probability of severe lower extremity injuries from passenger cars, while at moderate impact speeds LTVs demonstrate a slightly higher probability of causing severe injury.

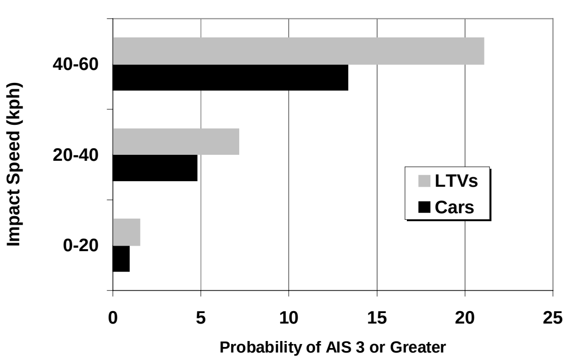

Figure 12. Probability of Severe Chest Injury AIS 3 or Greater

Figure 12 demonstrates the probability of sustaining a chest injury AIS 3 or greater. The data shows that for all impact speed ranges LTVs demonstrate a higher probability for severe chest injury.

FUTURE WORK

The preceding discussion has clearly demonstrated that pedestrians have a substantially greater likelihood of dying when struck by an LTV than when struck by a car. For large vans, one out of every four pedestrian accidents results in a pedestrian fatality. In contrast, when a car is the striking vehicle, only one out of every twenty pedestrian accidents results in a pedestrian death. Examination of pedestrian injury distributions reveals similar results. Given an impact speed, the likelihood of severe injury is substantially greater when the striking vehicle is an LTV rather than a car.

The remaining unanswered question is why? What engineering design features make striking LTVs more hazardous than striking cars? Physically, we would expect that striking vehicle mass is not a factor even though LTVs are much heavier than cars. As both cars and LTVs are an order of magnitude heavier than pedestrians, the pedestrian is at a severe disadvantage no matter what the mass of the striking vehicle. Two other likely candidates are vehicle stiffness and frontal profile. Future work will investigate the effect of these and other design parameters in two ways:

1) The pedestrian risk will be computed for high-volume late model production vehicles, and used to rank order the fleet by their relative threat to pedestrians. Vehicles with the highest pedestrian risk will be further analyzed to search for any common design features or vehicle parameters that may contribute to pedestrian fatalities.

2) MADYMO models will be developed to study and contrast the kinematic response of pedestrians struck by LTVs vs. passenger cars. The models will permit computational modeling of additional pedestrian accident parameters that may not be available in FARS, GES, or PCDS.

CONCLUSIONS

This paper has examined the effect of striking vehicle type on pedestrian fatalities and injuries in frontal impacts. The study was based on an analysis of U.S. traffic accident statistics from the Fatality Analysis Reporting System (FARS), the General Sampling System (GES), and the NASS Pedestrian Crash Data Study (PCDS). Analysis of these three databases has clearly demonstrated that pedestrians have a substantially greater likelihood of dying when struck by an LTV than when struck by a car. Furthermore, at any given speed of impact, the risk of serious injury to the head and chest has been shown to be greater in LTV impacts than in car impacts. Only for lower extremity impacts is the risk of serious injury greater for car impacts than for LTV impacts.

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