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A Study of Vehicle Factors Related to Type and Severity of Pedestrian Injury

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16. Abstract

An estimated 188,000 pedestrian accidents are reported each year involving about 8000 fatalities. The peak age group for pedestrian fatalities includes children aged 4-8, but there is a strong second peak among youth aged 16-21. Males are two-and-a-half times as likely as females to be killed in pedestrian accidents.

This study used police-reported pedestrian accidents in New York State for 1978-79 and in Pennsylvania for 1979 to try to identify vehicle factors which relate to the severity or body location of pedestrian injury. It was found that large trucks, pickups, and vans are more likely to kill the pedestrian than are passenger cars, but within passenger cars there was no direct relationship between vehicle weight and injury severity. In a detailed comparison of passenger car front-end configurations the most meaningful finding was a decrease in child injury severity with a greater horizontal slope from the bumper edge to the above-bumper contact point. Further study of this and other front-end styling variations need to be tested under controlled conditions in the laboratory.

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INTRODUCTION

This report describes pedestrian accident research carried out by the Highway Safety Research Institute under the sponsorship of the Motor Vehicle Manufacturers Association. The basic research task was to explore mass accident data files to ascertain any vehicle factors which were related to types and severities of pedestrian injuries.

Before presenting the results of this research, it is appropriate to indicate the magnitude of the pedestrian accident problem in the United States. Table 1 demonstrates that in recent years about 8,000 pedestrians have been killed in traffic crashes each year, about one-sixth of all road traffic fatalities. Table 2 uses data from Michigan, Washington, New York, and Pennsylvania to show that, on the average, a little over four percent of police-reported pedestrian accidents in these states involve the death of the pedestrian. These states may not provide a perfect representation of the national pedestrian accident picture, but, to the extent that they can be regarded as typical, their data projects to an annual total of about 188,000 police-reported pedestrian accidents. There are probably many more unreported pedestrian accidents each year. However, since a pedestrian accident usually involves an injury to the pedestrian, these accidents probably are less likely to go unreported than are minor property-damage-only accidents.

Figure 1 shows the age and sex distribution of pedestrian fatalities for the years 1975-1979. The peak ages for pedestrian fatalities are 4-8, but there is a very high secondary peaking for ages 16-21, while the upper elementary and junior high years seem to be relatively safe. Nevertheless, pedestrian accidents account for about 10 percent of all deaths of children aged 5-14.

Figure 2 shows similar data based on the 1976 pedestrian deaths per million persons in each age group. This demonstrates even more dramatically that many more males than females are killed in pedestrian accidents in every age group except infants, a difference which is even

Table 1 - U.S. Pedestrian Deaths Shown in the Fatal Accident Reporting System, 1975-1980*

Year	Total Deaths in Traffic Accidents	Percent of Motor Vehicle Deaths	Pedestrian Deaths
1975	45,021	17.2	7,748
1976	46,020	16.7	7,666
1977	48,375	16.4	7,943
1978	50,683	15.7	8,005
1979	51,083	15.8	8,090
1980	51,077	15.8	8,071
TOTAL	292,439	16.3	47,523

Average Per Year = 7,921.

*These figures are taken from FARS computer data files or FARS annual reports provided by the National Highway Traffic Safety Administration. There are small differences in some years between the computerized and published data. Also the figures on pedestrian deaths are substantially smaller than the National Safety Council estimates (up to 14% lower).

greater throughout adulthood than in the childhood years. Overall, the male pedestrian death rate per million males was 51 in 1976 compared to a female pedestrian death rate of 21 per million females, a five to two ratio.

Table 3 and Figure 3 demonstrate the strong relationship between age and death in pedestrian accidents. Data on police-reported pedestrian accidents in Michigan, Washington, New York, and Pennsylvania all agree that 9-14 is the age group least likely to be killed when involved in a pedestrian accident, and that the likelihood of death when involved in a pedestrian accident rises markedly throughout the adult years. Even in New York, which has the lowest fatality rate among these

Table 2 - Total and Fatal Pedestrian Accident Victims in Four States and a Projection of the National Annual Count of Police-Reported Pedestrian Accident Victims

	Total Persons in Pedestrian Accidents	Total Pedestrian Fatalities	Fatalities Percent	Average Pedestrian Fatalities Per Year	State Percent of National Average Annual Ped.Fatalities
Michigan 1976-79	25,434	1,378	5.4	345	4.3
Washington 1974-78	9,235	515	5.6	103	1.3
New York 1978-79	38,344	1,114	2.9	557	7.0
Pennsylvania 1979	7,205	338	4.7	338	4.3
Four States Combined	80,218	3,345	4.2	1,343	17.0

Estimate of National Average Annual Number of Pedestrians in Police-Reported Accidents = 188,000.

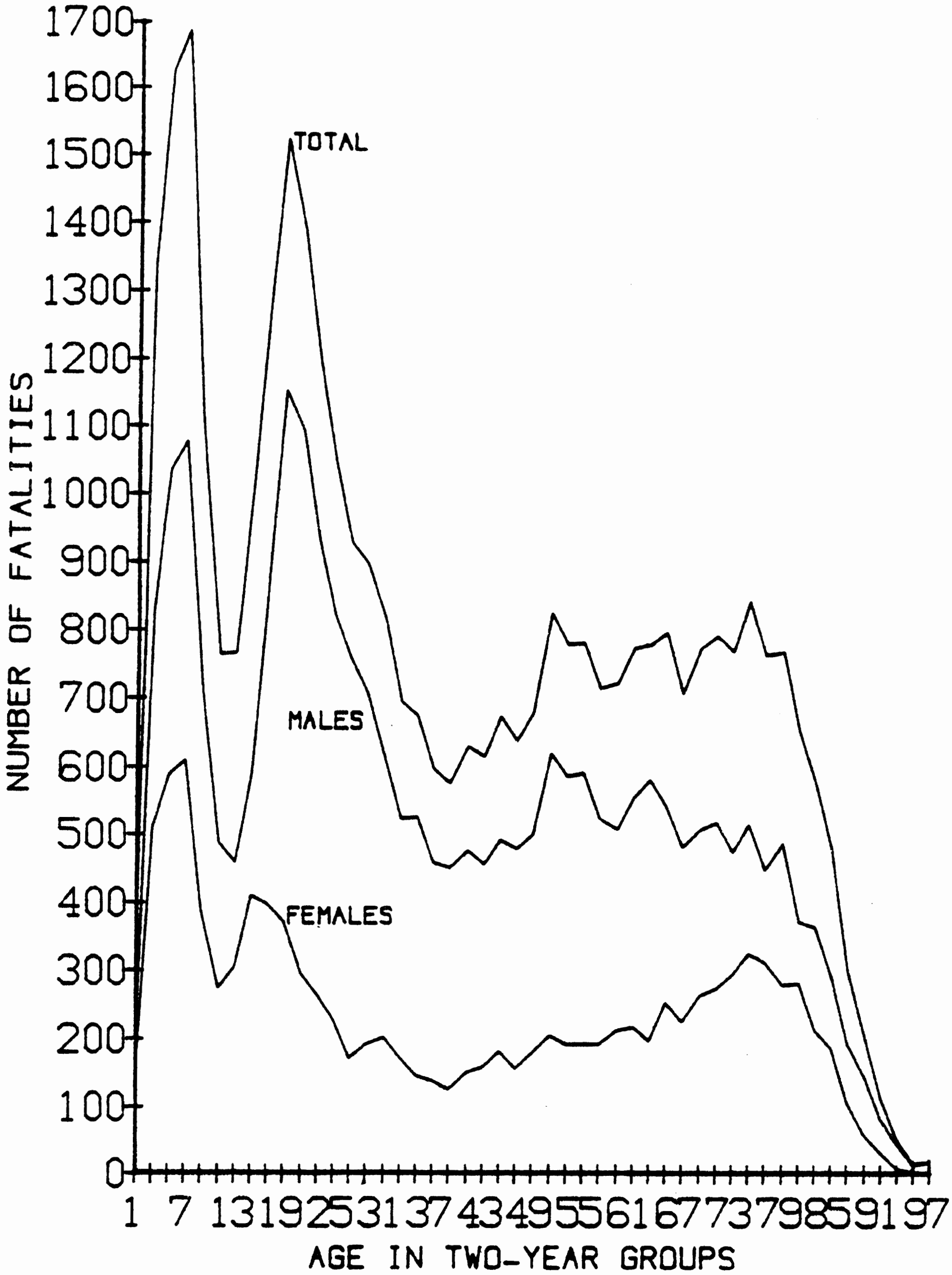

Figure 1

U.S. Pedestrian Fatalities by Age and Sex, 1975-1979 four states, more than one out of nine pedestrian accident victims over 75 years of age is killed.

VEHICLE TYPE AND PEDESTRIAN INJURY

Data from three states, Washington, New York, and Pennsylvania, show clearly that it is more dangerous to be hit by a pickup, van, or other truck than by a passenger car. The combined data are shown in Figure 4 and Table 4, which shows that both fatalities and severe injuries are more likely when the striking vehicle is a pickup, van, or other truck.

Table 5 uses the New York accident data to look at the severity of the pedestrian injury in relation to the impact area on the striking vehicle. The area of impact is only coded for about two-fifths of the reported New York pedestrian accident cases. Of the accidents with known impact area, almost half involved the front or hood and a little over a quarter involved the front fenders. However, the front fender impacts were more than three times as likely as the front and hood accidents to result in a fatality. The only impact areas which were more serious than the front fenders in the severity of pedestrian injury were the roof and the undercarriage, and these accounted for less than two percent of the accidents with a known impact area. Side and rear collisions were much less likely to cause serious injury than were front and front-fender collisions.

Table 6 presents the interrelationships between injury severity (coded as fatal, severe, moderate, and minor) and body location of the most severe injury for different vehicle impact areas in New York pedestrian accidents. The principal entries in the table are the row percents; for example, the first row shows that 47.7 percent of the most serious injuries to persons killed in a front or hood impact were to the head, 4.5 percent were to the face/eye/neck, etc. For each impact area the head was the most frequent location of the most severe injury in fatal accidents, and "entire body" ranked second. Overall, almost half of the fatalities had the most severe injury to the head, while two-thirds of the remaining fatalities had "entire body" injuries. Among severe injuries also, the head was the most frequent location, but the

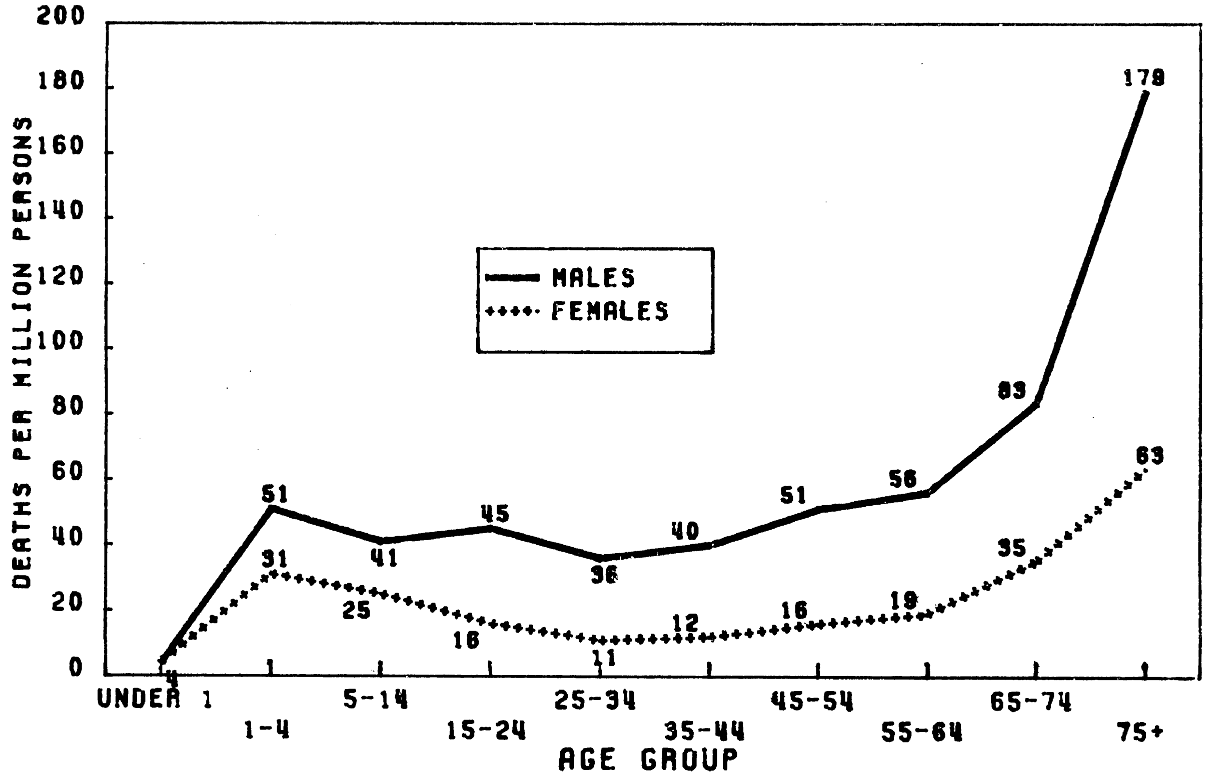

Figure 2

U.S. Pedestrian Fatality Rates Per Million Persons by Age Group and Sex in 1976

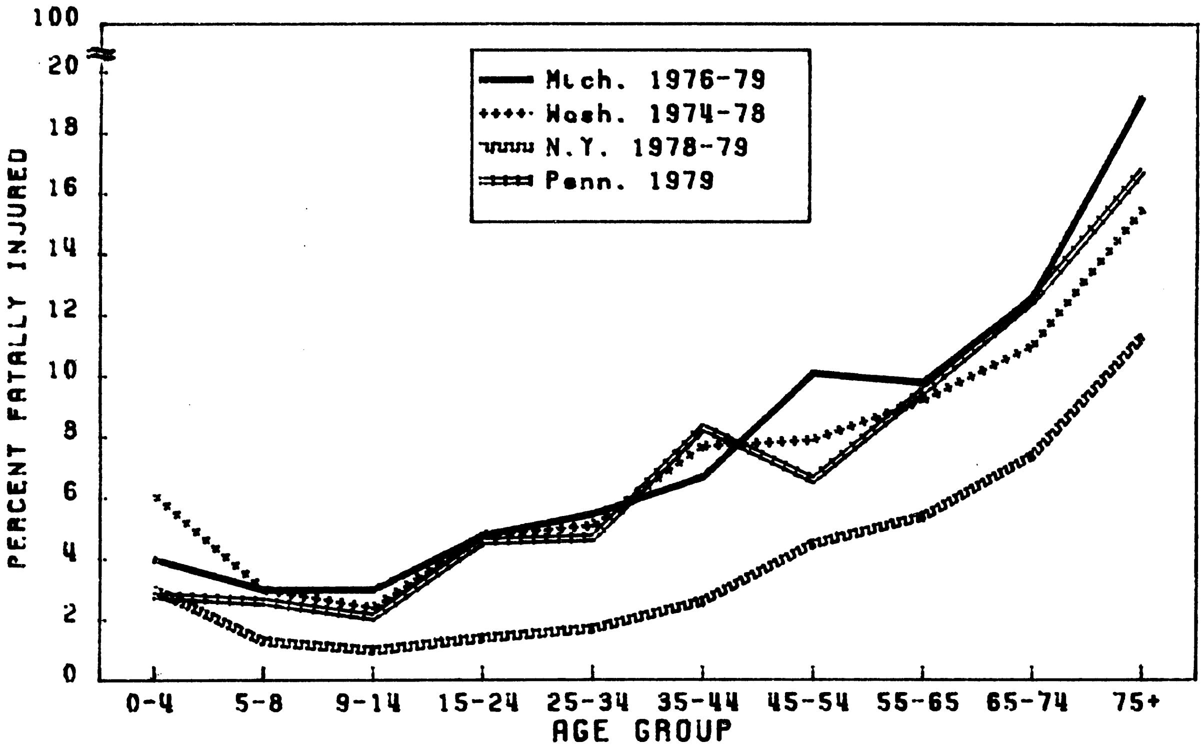

Figure 3

Fatality Percent by Age Group in Police-Reported Pedestrian Accidents From Four States

Table 3 - Pedestrian Fatality Percent by Ten Age Groups in Four States

Age Group	Michigan 1976-79	Washington 1974-78	New York 1978-79	Pennsylvania 1979	Four States Combined		
					Fatal % of Total Involved Pedestrians	% of All Pedestrian Fatalities In Group	% of All Pedestrian Victims In Group
0-4	4.0	6.1	3.0	2.8	3.9	5.1	5.3
5-8	3.0	3.0	1.3	2.6	2.3	8.5	15.2
9-14	3.0	2.4	1.0	2.1	1.8	9.0	20.1
15-24	4.8	4.8	1.4	4.6	3.1	18.3	24.2
25-34	5.5	5.1	1.7	4.7	3.9	9.7	11.1
35-44	6.7	7.7	2.6	8.3	4.9	6.9	5.7
45-54	10.1	7.9	4.5	6.6	6.9	9.2	5.4
55-64	9.8	9.2	5.4	9.5	7.7	9.5	5.0
65-74	12.6	11.0	7.4	12.5	10.0	10.8	4.4
75+	19.2	15.5	11.3	16.8	14.9	13.2	3.6
Total	5.5	6.1	2.4	5.2	4.4	100.0	100.0
Known Age N	24,707	8,509	35,276	6,450	74,942		
Missing Age	727	726	3,019	575	4,844		

Table 4 - Severity of Pedestrian Injury by Type of Striking Vehicle in Three States

	Severity of Pedestrian Injury in Percent				Total N	Percent of Pedestrians Struck By Vehicle Type
	Fatal	Disabling/ Severe/ Major	Non-Disabling Moderate/ Moderate	Possible/ Minor/ Minor		
Washington 1974-78						
Passenger Cars	5.1	34.1	38.1	22.7	6,642	71.9
Pickups	7.1	33.9	37.8	21.1	1,197	13.0
Vans	9.9	34.5	31.7	23.8	252	2.7
Other Trucks	11.4	38.4	34.2	16.0	263	2.8
Other, Unknown	4.1	29.6	41.3	25.0	881	9.5
New York 1978-79						
Passenger Cars	2.0	15.9	32.9	49.2	29,748	77.7
Pickups	4.8	22.3	33.8	39.1	1,002	2.6
Vans	4.0	16.7	29.9	49.4	1,463	3.8
Other Trucks	9.2	16.7	29.4	44.7	575	1.5
Other, Unknown	2.3	17.8	32.2	47.6	5,506	14.4
Pennsylvania 1979						
Passenger Cars	4.4	10.6	33.9	51.1	5,221	80.5
Pickups	5.7	12.5	38.9	42.9	424	6.5
Vans	5.1	10.9	33.5	50.5	275	4.2
Other Trucks	18.0	16.1	28.4	37.4	211	3.2
Other, Unknown	8.5	13.3	35.6	42.7	354	5.5
Total Three States						
Passenger Cars	2.8	18.2	33.9	45.2	41,611	77.0
Pickups	6.0	26.0	36.5	31.5	2,623	4.9
Vans	4.9	18.1	30.6	46.3	1,990	3.7
Other Trucks	11.5	22.0	30.4	36.0	1,049	1.9
Other, Unknown	2.9	19.1	33.6	44.4	6,741	12.5

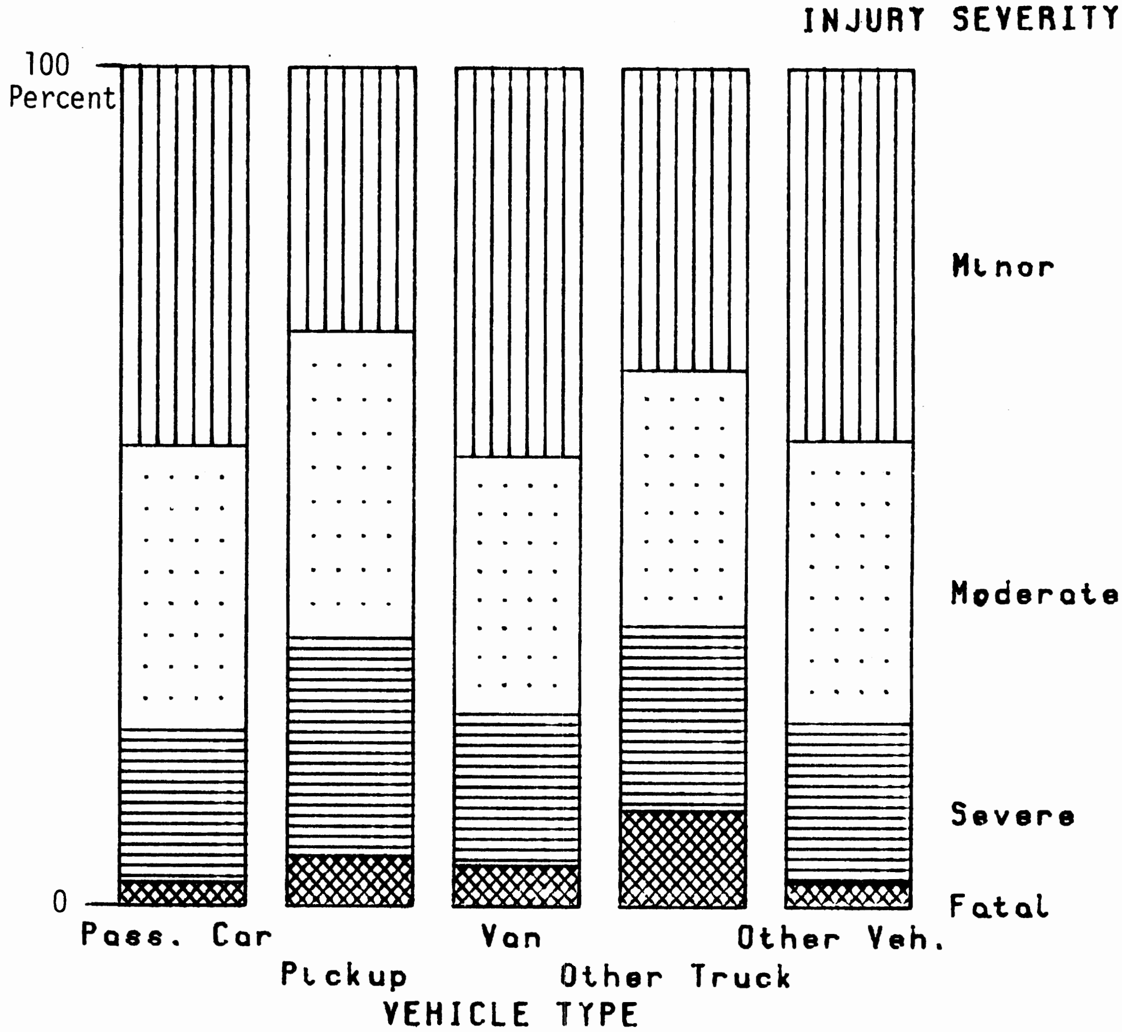

Figure 4

Injury Severity by Type of Striking Vehicle in Police-Reported Pedestrian Accidents, Combined Data From Washington 1974-78, New York 1978-79, and Pennsylvania 1979

Table 5 - Severity of Pedestrian Injury by Vehicle Impact Area For 1978-79 New York Pedestrian Accident Victims

Vehicle Impact Area	Total N	Severity of Pedestrian Injury In Percent				Percent of Each Impact Type
		Fatal	Severe	Moderate	Minor	
Front, Hood	7,469	1.7	20.0	33.4	44.9	19.5
Front Fender	4,166	5.9	20.8	35.8	37.5	10.9
Side Doors	2,144	0.8	17.2	40.3	41.7	5.6
Rear Fenders	697	0.9	13.3	41.9	43.9	1.8
Rear, Trunk	760	0.7	10.9	32.6	55.8	2.0
Roof	169	13.6	30.2	27.2	29.0	0.4
Undercarriage	119	5.9	20.2	31.9	42.0	0.3
Unknown	22,755	2.0	14.5	30.9	52.7	59.4
Total	38,279	2.3	16.4	32.7	48.6	100.0

knee and lower leg were a close second, the hip and upper leg were third, and the arms were fourth. However, for all degrees of injury severity, the knee and lower leg were the most frequent location of the most severe injury with almost one-third of the total, while about one-fifth had the most serious injury to the head. The hip and upper leg and the upper limbs each had about one-seventh of the most severe injuries. The patterns of body location in relation to severity were similar for each impact area except that side and rear fender impacts were less likely to involve the legs or the entire body and were much more likely to involve the upper extremities.

PASSENGER CAR WEIGHT AND PEDESTRIAN INJURY

Having observed that truck-type vehicles cause more serious pedestrian injuries than passenger cars given an accident, one might expect differential vehicle weight to play a major role in explaining this difference in severity. However, when the FARS data are analyzed for differences in pedestrian fatality rates for different weight classes of passenger cars, there is no direct relationship apparent. Table 7 compares the percentages of passenger car pedestrian fatalities in 1976-1977 in each of six weight classes with the percentages of

Table 6
Body Location of Most Severe Injury in Relation to Vehicle Impact Area and Severity of Injury for Pedestrians in 1978-1979 New York Accidents

VEHICLE IMPACT AREA	INJURY SEVERITY	BODY LOCATION OF MOST SEVERE INJURY IN PERCENT									TOTAL N	COLUMN %
		HEAD	FACE, EYE, NECK	CHEST	BACK	UPPER LIMBS	ABDOMEN, PELVIS	HIP, UPPER LEG	KNEE, LOWER LEG	ENTIRE BODY		
FRONT, HOOD	FATAL	47.7	4.5	0.9	0.9	0	0.9	0	2.7	42.3	111	1.6
	SEVERE	34.2	4.9	1.5	2.1	7.8	1.4	12.7	25.2	10.2	1,458	21.1
	MODERATE	27.5	9.7	1.3	2.9	15.1	0.7	9.9	28.6	4.3	2,443	35.3
	MINOR	10.6	2.7	1.3	9.6	11.9	2.6	20.7	32.7	7.9	2,911	42.0
FRONT FENDERS	FATAL	54.4	2.4	4.9	0	0.5	1.9	1.9	1.0	33.0	206	5.3
	SEVERE	33.4	4.9	1.1	1.6	10.3	2.0	11.6	26.0	9.0	851	21.8
	MODERATE	25.2	10.6	0.6	2.4	17.4	0.9	9.4	29.8	3.8	1,462	37.5
	MINOR	10.2	2.0	2.1	8.9	14.3	2.0	19.6	34.2	6.5	1,380	35.4
SIDE DOORS, REAR FENDERS	FATAL	47.4	0	5.3	0	0	10.5	0	0	36.8	19	0.7
	SEVERE	28.8	8.4	1.8	1.8	19.5	1.8	6.6	25.9	5.5	452	17.0
	MODERATE	21.8	8.3	1.1	3.7	29.5	1.0	7.1	25.0	2.5	1,139	42.9
	MINOR	11.1	3.4	2.6	10.0	20.5	2.3	15.4	28.7	6.0	1,048	39.4
REAR, TRUNK, ROOF, UNDER.	FATAL	55.6	0	0	0	3.7	0	0	0	40.7	27	2.8
	SEVERE	27.3	4.0	2.0	4.0	13.3	4.0	10.7	28.0	6.7	150	15.6
	MODERATE	21.2	9.5	2.1	4.0	17.5	0.6	10.1	32.2	2.8	326	33.8
	MINOR	8.9	3.0	2.8	11.5	11.5	2.0	17.1	38.4	4.8	461	47.8
UNKNOWN	FATAL	46.3	2.7	4.1	2.7	0.8	3.3	3.0	4.7	32.3	365	1.9
	SEVERE	28.4	4.7	1.5	2.5	10.7	2.2	11.7	29.8	8.5	2,981	15.7
	MODERATE	22.3	9.0	0.9	2.9	17.8	0.9	11.2	31.6	3.4	6,422	33.8
	MINOR	9.1	2.4	1.7	9.6	13.6	2.7	20.7	34.5	5.8	9,247	48.6
TOTAL	FATAL	49.2	2.7	3.7	1.5	0.7	2.6	2.1	3.0	34.5	728	2.2
	SEVERE	30.5	5.0	1.5	2.3	10.7	2.0	11.5	27.8	8.8	5,896	17.6
	MODERATE	23.6	9.3	1.0	3.0	18.3	0.9	10.3	30.1	3.5	11,798	35.2
	MINOR	9.6	2.5	1.8	9.6	13.7	2.6	20.1	33.8	6.2	15,051	45.0
GRAND TOTAL		19.1	5.3	1.5	5.8	14.5	1.9	14.7	30.8	6.3	33,473	100.0

MISSING ON BODY LOCATION: Front 552; Front Fenders 279; Side 186; Rear, etc. 85; Unknown 3767; Total 4,871 registered vehicles in each weight class in 1976.[1] It shows that the two lowest weight classes were least likely to be involved in a fatal pedestrian accident. However, the highest involvement rate was in the midweight class from 2901-3500, and the larger weight classes had declining involvement rates. Of course, number of registered vehicles is far from a perfect exposure measure, but it seems doubtful that the lack of monotonicity in this involvement pattern can be explained by differences in the amounts of driving by different sizes of passenger cars.

Table 7 - Involvement Ratios of Six Passenger Car Weight Classes in 1976-77 U.S. Single Vehicle Fatal Pedestrian Accidents

Passenger Car Weight Group	Pedestrian Accidents Involving 1966-1976 Passenger Vehicles		% of 1966-76 Passenger Vehicles in Weight Class*	Involvement Ratio
	N	%		
Under 2301	470	7.745	11.430	0.68
2301-2900	610	10.052	10.921	0.90
2901-3500	1540	25.375	21.690	1.17
3501-4100	1780	29.329	27.391	1.07
4101-4700	1276	21.024	21.663	0.97
Over 4700	393	6.475	6.987	0.93
Total	6069	100.000	100.082	

Missing weight data = 2080 (25.5%).
*Numbers of passenger vehicles in each weight class are compiled from K. Jatras and W. L. Carlson, "Frequency Distribution of Passenger Cars by Weight and Wheelbase by State: July 1, 1976," Washington: National Highway Traffic Safety Administration, June 1978.

This issue was also explored in the large New York State pedestrian accident file, and again there was no direct relationship. Table 8 shows that there were no consistent differences in injury severity by

[1]The registration data come from R. L. Polk's National Vehicle Population profile which contains counts of vehicles by make, model, and model year for each state. The weight data are from the Annual Automotive News Market Data Book series.

weight class either for child or adult pedestrian accident victims. In fact, the lowest percentage of serious injuries in each age group was found in the 3500-4499 pound weight class.

Table 8 - Passenger Car Curb Weight and Severity of Child and Adult Injury in 1978-79 New York Pedestrian Accidents

Curb Weight of Vehicle	Severity of Injury in Percent				Total N	Column %
	Fatal	Severe	Moderate	Minor		
Child						
1400-2400 lbs.	1.1	17.1	39.6	42.2	566	9.7
2500-3499 lbs.	1.3	17.2	40.0	41.6	1,919	32.8
3500-4499 lbs.	1.2	16.7	38.8	43.3	2,762	47.2
4500+ lbs.	1.2	18.1	34.4	46.3	602	10.3
Total	1.2	17.0	38.8	42.9	5,849	100.0
Adult						
1400-2499 lbs.	3.6	20.2	29.4	46.8	1,546	11.2
2500-3499 lbs.	3.5	18.9	27.9	49.7	4,594	33.2
3500-4499 lbs.	3.1	18.4	25.0	53.5	6,356	45.9
4500+ lbs.	2.9	20.7	24.9	51.5	1,360	9.8
Total	3.3	19.0	26.4	51.3	13,856	100.0
Total						
1400-2499 lbs.	2.8	19.2	31.2	46.8	2,288	10.6
2500-3499 lbs.	2.8	18.0	30.5	48.8	7,073	32.8
3500-4499 lbs.	2.4	17.4	27.9	52.3	10,049	46.6
4500+ lbs.	2.3	19.2	26.8	51.7	2,151	10.0
Total	2.6	18.0	29.0	50.5	21,561	100.0

Similarly, Table 9 finds no consistent relationship between injury severity and passenger car weight class when one looks separately at New York City, other urban areas, and rural areas. It is interesting to note that more than half of the reported New York State pedestrian accidents took place in New York City, while less than one-fifth took place in rural areas. However, the rural accidents tended to be much more severe in their consequences than the urban accidents. In rural pedestrian accidents 5.9% of the victims were killed and 25.6% were severely injured, compared to 1.8% killed and 15.3% severely injured in New York City. Presumably these differences were related to higher average vehicle speeds in the rural accidents.

Table 9 - Passenger Car Curb Weight and Severity of Pedestrian Injury by Urbanicity of Area in 1978-79 New York Pedestrian Accidents

Curb Weight of Vehicle	Severity of Injury in Percent				Total N	Column %
	Fatal	Severe	Moderate	Minor		
New York City						
1400-2499 lbs.	1.6	15.8	27.2	55.4	1,094	8.9
2500-3499 lbs.	1.8	15.2	26.9	56.1	3,710	30.1
3500-4499 lbs.	1.7	15.0	24.1	59.2	6,182	50.1
4500+ lbs.	1.9	16.6	25.1	56.4	1,344	10.9
Total	1.8	15.3	25.3	57.6	12,330	100.0
Other Urban Areas						
1400-2499 lbs.	2.2	19.6	33.2	45.0	644	12.2
2500-3499 lbs.	1.7	17.2	33.8	47.3	1,863	35.4
3500-4499 lbs.	2.0	18.7	33.0	46.3	2,270	43.1
4500+ lbs.	1.6	21.0	28.7	48.7	485	9.2
Total	1.9	18.5	32.9	46.7	5,262	100.0
Rural Areas						
1400-2499 lbs.	6.0	25.6	36.7	31.6	550	13.9
2500-3499 lbs.	6.3	25.9	35.3	32.5	1,497	37.8
3500-4499 lbs.	5.7	25.0	35.2	34.1	1,591	40.2
4500+ lbs.	5.0	27.2	31.3	36.6	320	8.1
Total	5.9	25.6	35.1	33.4	3,958	100.0

FRONT END CONFIGURATION AND PEDESTRIAN INJURY

In this analysis, nine different passenger car front end variables were run against severity of pedestrian injury and body location of injury, separately for child pedestrians (age 10 and under) and "adult" pedestrians (age 11 and up). This analysis plan is shown in Table 10.

The data analyzed were the 38,344 reported pedestrian accidents in New York State in 1978 and 1979 and the 7025 reported pedestrian accidents in Pennsylvania in 1979. In the New York data file there were 23,252 1966-1980 vehicles with a coded VIN number from which the make and model could be ascertained, a little over 60 percent of the total. In the Pennsylvania data file make and model information was available for only 2407 1966-80 passenger cars, a little over one-third of the vehicles involved in pedestrian accidents. Only the 12 major American nameplates plus Volkswagen had any model type information in the Pennsylvania data.

Table 10 - Variables Used in Analysis of Effect of Front-End Configuration on Pedestrian Injury in 1978-79 New York Pedestrian Accidents and 1979 Pennsylvania Pedestrian Accidents

Major Control: Front, Hood, Front Fenders, or Unknown Impact Area

Independent Variables	Bumper Height Contact Height Hood Height Bumper Projection From Contact Point Hood Length Slope (Ratio of Difference Between Contact Height and Bumper Height to Bumper Projection) Type of Contact Edge in Center Front Type of Contact Edge in Headlights Area Use of Soft Front End Materials
Dependent Variables	Severity of Pedestrian Injury Body Location of Most Severe Injury
Control Variable	Passenger Cars Child or Adult (10 and Under, 11 Up)

Code values for the first six variables (Bumper Height through Slope in Table 10) were derived from information available in the 1977-1980 Pedestrian Injury Causation Study (PICS) sponsored by the National Highway Traffic Safety Administration. In that study over 2,000 pedestrian accidents in five urban areas were investigated, and, for all front impacts, the investigating teams were asked to measure bumper height (from the ground to the top surface of the bumper), contact height (from the ground to the leading edge of the grille or hood), hood height (from the ground to the leading edge of the hood), bumper lead (the horizontal distance from the front edge of the bumper to the contact point), and hood length (the horizontal distance from the contact point to the edge of the windshield).

There were three problems in transferring these measurements to the vehicle makes and models in the New York accident file. The first problem was that PICS used the Collision Performance and Injury Report (CPIR) make/model code which was less specific than the New York and Pennsylvania make/model codes, often grouping similar vehicles (e.g., Chevrolet Bel Air, Biscayne, and Impala or the VW Beetle and Fastback) in the same code. The second was that the measurements reported by the PICS investigators varied somewhat for the different cases of the same make, model, and model year. For example, for the four cases of a 1977 Monte Carlo (which has a unique CPIR code), the reported bumper height varied from 20 to 24 inches, the contact height varied from 31 to 34 inches, the hood height varied from 34 to 36 inches, the bumper lead varied from 4 to 5 inches and the hood length varied from 67 to 70 inches. Thus it was necessary to use average PICS measurement values when there was more than one case vehicle in a particular make-model code, and sometimes it was necessary to treat two or more different vehicle models as if they were identical. When it was possible, two models with the same CPIR code were distinguished on the basis of differences in curb weight.

The third problem was that not all of the makes and models in the New York and Pennsylvania pedestrian accident file had corresponding front end measurements in the PICS file for the needed model year. It was possible to identify these measurements for only about three-fourths of the New York known-make-and-model vehicles. Over 95 percent of these were passenger vehicles, and this analysis is restricted to passenger vehicles only. It was mentioned previously that area of vehicle impact was reported in only about 40 percent of the New York cases, and that in those cases about three-fourths involved front or front fender impacts. It has been assumed that most of the cases with unknown area of impact were really front or front fender collisions, and all front, hood, front fender, and unknown impacts are used in the following front end analysis with the New York data.

In the Pennsylvania data the five PICS measurements were codable for 69 percent of the known make-and-model 1966-80 cars. Fortunately, area of impact had little missing data, and thus there remained 1137 front impact cases with the PICS measurement information available for the Pennsylvania analysis of pedestrian injury severity and body location.

Another problem in the analysis of the data was that speed of impact information was not available. The analysis had to assume that speed distributions were fairly uniform among the different types of front end configurations, an assumption which may or may not be correct. It is possible that even the few statistically significant relationships which were found were spurious ones caused by differences in speed distributions or other significant variables.

Tables 11-14 use the New York data to present examples of the tables resulting from this analysis, with separate subtables for children and adults. Table 11 shows severity of injury in relation to bumper height. There is a positive relationship between bumper height and fatal injury for adults which is statistically significant at the six percent level (chi-square of 3.75 for bumper heights over 22 inches with one degree of freedom). Tables 12, 13, and 14 show the body location of the most severe injury in relation to bumper height, hood height, and hood length. With both higher bumper height and higher hood height, there is a substantial increase in most severe injuries to the upper extremities (chi-squares of 5.75 and 17.44, respectively, with $p<.02$ and $p<.001$, respectively) and a decrease in injuries to the knee and lower leg for adults. However, no meaningful differences in injury patterns are apparent for children in these tables or in Table 14. Table 14 does indicate a strong tendency for shorter hoods to be associated with more head injury for adults (chi-square of 17.71 for hood lengths less than 45 inches, with p<.001).

Table 11 - Bumper Height and Severity of Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fender, or Unknown Impact Areas

Bumper Height	Severity of Injury in Percent				Total N	Column %
	Fatal	Severe	Moderate	Minor		
Child						
14-18"	3.2	22.2	34.2	40.5	158	4.0
19-20"	1.5	15.7	38.5	44.3	1,566	40.0
21-22"	0.7	16.7	39.9	42.6	1,857	47.5
23-24"	1.9	16.7	37.7	43.6	257	6.6
25-27"	1.4	27.4	31.5	39.7	73	1.9
Total	1.2	16.7	38.8	43.2	3,911	100.0
Adult						
14-18"	3.3	20.5	26.0	50.2	420	4.8
19-20"	3.0	18.3	26.2	52.5	3,780	43.0
21-22"	3.5	18.9	25.7	51.9	3,781	43.0
23-24"	4.4	18.0	27.9	49.7	595	6.8
25-27"	4.8	18.8	25.1	51.2	207	2.4
Total	3.4	18.6	26.1	51.9	8,783	100.0

Table 15 presents New York data from a new variable derived from the PICS measures. Slope is the ratio of the difference between the contact height and the bumper height to the bumper projection. There seems to be a meaningful relationship between little slope and more head injuries for children (chi-square of 10.32, p = .001) for a height-to-bumper-projection slope ratio of more than 3:1 (the none, slight, and little categories), but nothing in this table is significant for adults. There is also a significant chi-square (4.45, p<.04) relating little slope to the severity of child injuries in pedestrian accidents (fatal or severe injury). About one percent of the vehicles were coded on the

Table 12 - Bumper Height and Body Location of Most Severe Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fender, or Unknown Impact Areas

Bumper Height	Body Location of Most Severe Injury in Percent									N
	Head	Face, Eye, Neck	Chest	Back	Upper Limbs	Abdomen, Pelvis	Hip, Upper Leg	Knee, Lower Leg	Entire Body	
Child										
14-18"	32.4	8.6	2.9	3.6	7.2	0.7	16.5	21.6	6.5	139
19-20"	28.9	7.9	1.0	6.0	9.8	3.1	13.6	23.0	6.8	1,372
21-22"	27.6	9.0	1.2	4.1	8.3	2.6	14.4	25.3	7.6	1,629
23-24"	26.7	7.3	1.3	7.8	10.8	1.7	14.7	22.8	6.9	232
25-27"	33.3	10.0	3.3	5.0	8.3	0	10.0	18.3	11.7	60
Total	28.4	8.4	1.3	5.1	9.0	2.6	14.1	23.9	7.2	3,432
Adult										
14-18"	20.1	5.7	0.5	6.0	11.2	1.3	15.6	32.6	7.0	384
19-20"	17.4	3.9	1.1	6.3	10.4	1.5	18.3	34.3	6.6	3,418
21-22"	17.4	3.5	0.9	6.5	11.7	2.0	18.9	31.9	7.1	3,395
23-24"	19.1	3.4	0.9	6.2	13.5	1.3	18.4	27.2	9.9	533
25-27"	22.3	5.6	1.1	7.8	15.6	2.2	16.8	20.1	8.4	179
Total	17.8	3.8	1.0	6.4	11.3	1.7	18.4	32.4	7.1	7,909

Table 13 - Hood Height and Body Location of Most Severe Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fenders, or Unknown Impact Areas

Hood Height	Body Location of Most Severe Injury in Percent									Total N	Column %
	Head	Face, Eye, Neck	Chest	Back	Upper Limbs	Abdomen, Pelvis	Hip, Upper Leg	Knee, Lower Leg	Entire Body		
Child											
Up to 28"	32.6	9.3	0	4.7	9.3	0	18.6	20.9	4.7	43	1.3
29-31"	27.2	7.5	1.0	3.9	7.7	2.7	13.5	28.4	8.2	415	12.3
32-34"	29.1	8.2	1.2	5.4	90.0	2.6	14.6	22.7	7.1	1,891	55.9
35-37"	26.3	8.3	1.8	5.0	10.2	2.6	13.9	24.7	7.2	914	27.0
38-44"	36.2	14.5	1.4	4.3	10.1	2.9	8.7	17.4	4.3	69	2.1
45-55"	32.1	13.1	0	3.8	1.9	1.9	9.4	28.3	9.4	53	1.6
Total	28.3	8.4	1.3	5.1	9.1	2.6	14.2	23.9	7.2	3,385	100.0
Adult											
Up to 28"	16.9	5.1	0.8	7.6	11.0	1.7	19.5	32.2	5.1	118	1.5
29-31"	18.9	4.5	0.6	5.8	11.2	1.8	16.6	34.9	5.8	1,020	13.2
32-34"	17.7	3.5	1.2	6.3	11.1	1.8	18.9	32.2	7.3	4,045	52.2
35-37"	16.3	4.3	0.9	6.5	10.5	1.6	19.6	32.9	7.3	2,137	27.6
38-44"	18.5	6.0	0.4	7.8	19.0	2.6	11.2	25.4	9.1	232	3.0
45-55"	22.8	3.0	1.5	8.9	15.8	1.0	14.4	25.7	6.9	202	2.6
Total	17.6	3.9	1.0	6.4	11.3	1.7	18.5	32.4	7.1	7,754	100.0

Table 14 - Hood Length and Body Location of Most Severe Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fender, or Unknown Impact Areas

Hood Length	Body Location of Most Severe Injury in Percent									Total N	Column %
	Head	Face, Eye, Neck	Chest	Back	Upper Limbs	Abdomen, Pelvis	Hip, Upper Leg	Knee, Lower Leg	Entire Body		
Child											
14-29"	34.5	10.3	1.7	5.2	8.6	0	5.2	25.9	8.6	58	1.7
30-44"	25.2	7.0	0.9	6.1	7.8	4.3	14.8	26.1	7.8	115	3.4
45-49"	26.1	9.6	0	3.2	9.6	2.7	16.0	26.1	6.9	188	5.6
50-54"	28.4	6.2	2.4	3.4	8.9	2.1	16.8	24.7	7.2	292	8.7
55-59"	29.0	7.0	0.7	5.3	9.1	2.7	12.9	26.4	7.0	704	21.0
60-64"	28.7	9.8	1.5	5.3	9.0	2.5	14.0	22.0	7.2	1,415	42.3
65-70"	28.2	7.9	1.5	5.3	8.9	2.5	15.1	24.0	6.6	471	14.1
70-78"	24.5	8.5	0	6.6	10.4	2.8	16.0	18.9	12.3	106	3.2
Total	28.4	8.5	1.3	5.1	9.0	2.6	14.2	23.8	7.3	3,349	100.0
Adult	26.4	4.6	1.0	7.1	21.3	2.0	13.7	17.3	6.6	197	2.6
14-29"	26.4	4.6	1.0	7.1	21.3	2.0	13.7	17.3	6.6	197	2.6
30-44"	23.4	3.7	0.7	5.4	12.0	2.0	15.1	31.1	6.7	299	3.9
45-49"	18.9	4.3	1.1	6.4	12.7	1.3	14.4	36.3	4.7	466	6.1
50-54"	20.1	3.9	0.7	4.7	14.4	1.9	16.3	31.0	7.0	675	8.9
55-59"	17.1	4.2	1.0	6.4	11.3	1.7	18.0	33.8	6.4	1,545	20.3
60-64"	16.0	3.9	1.2	6.7	10.1	1.8	19.8	32.8	7.8	3,172	41.6
65-69"	18.3	3.7	0.9	6.8	10.0	1.7	19.5	31.9	7.1	1,038	13.6
70-78"	16.4	2.1	0.4	5.9	12.6	1.3	21.4	30.3	9.7	238	3.1
Total	17.6	3.9	1.0	6.4	11.3	1.8	18.5	32.4	7.1	7,622	100.0

basis of the PICS measurements as having zero bumper projection from the contact edge.

The next two variables analyzed were front end shapes identified from photographs in the World Car Catalogues, the AMA Auto Identification Manual, or the MVMA Motor Vehicle Identification manuals. The full codes for this variable, "Type of Front Contact Striking Edge," are shown below:

1. Pointed or rounded or narrow blunt (under one inch) striking edge with little vertical slope above

2. Pointed or rounded or narrow blunt (under one inch) striking edge with considerable vertical slope above.

3. Wide blunt striking edge (over one inch) with little vertical slope above.

4. Wide blunt striking edge (over one inch) with considerable vertical slope above.

5. Continuous rounded edge with a vertical grill below.

6. Continuous rounded edge with a sloping grill below.

7. Continuous sloped hood directly from the bumper.

8. Rounded headlamps with no edges in front of them.

This variable was coded for most of the almost 2,000 1966-1980 models and model years of vehicles sold in the U.S. by the 15 major domestic makes and 12 of the major foreign makes (about 290 models averaging about seven model years each). For each vehicle model two codes were assigned, one for the striking edge in the center front area and one for the striking edge in the headlights area.

Table 16 shows the relationship of this variable to severity of pedestrian injury for known front and hood impacts in the New York data file. If there were any relationship between type of striking edge and injury severity, one might have expected the third and fourth categories with their relatively blunt edges to be safer than the first and second categories, respectively, with their relatively sharp edges. However, no significant differences were found in the fatality rates for either children or adults in relation to type of contact edge. A similar analysis (not tabulated here) for front fender impacts using the type of

Table 15 - Slope From Bumper Edge to Contact Edge and Body Location of Most Severe Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fender, or Unknown Impact Areas

Slope	Body Location of Most Severe Injury in Percent									Total N	Column %
	Head	Face, Eye, Neck	Chest	Back	Upper Limbs	Abdomen, Pelvis	Hip, Upper Leg	Knee, Lower Leg	Entire Body		
Child											
None	19.4	9.7	0	3.2	12.9	0	12.9	38.7	3.2	31	0.9
Slight	34.1	9.1	1.6	4.4	7.7	3.5	11.7	21.0	6.8	428	12.8
Little	30.5	8.4	1.5	3.4	9.7	1.9	14.6	22.6	7.5	797	23.9
Some	27.2	8.1	1.3	6.5	9.0	2.8	14.0	24.2	7.0	1,600	48.0
Considerable	23.8	10.3	0.6	4.4	9.1	2.1	16.1	27.6	6.2	341	10.3
Quite a bit	24.1	6.3	1.3	1.3	8.9	2.5	19.0	25.3	11.4	79	2.4
A lot	27.3	7.3	0	1.8	3.6	3.6	16.4	29.1	10.9	55	1.7
Total	28.4	8.5	1.3	5.0	8.9	2.6	14.2	24.0	7.1	3,331	100.0
Adult											
None	23.9	1.4	0	11.3	14.1	1.4	15.5	28.2	4.2	71	0.9
Slight	19.6	3.8	1.3	7.1	11.5	1.9	20.2	27.0	7.5	1,013	13.4
Little	17.3	3.3	1.0	6.3	11.4	2.1	20.6	30.9	7.2	1,775	23.5
Some	16.6	4.1	1.1	6.3	11.3	1.7	17.6	33.8	7.3	3,622	48.0
Considerable	19.9	4.2	0.9	5.8	9.4	1.6	15.6	35.5	7.0	755	10.0
Quite a bit	19.7	4.5	0.5	5.6	14.1	2.0	17.7	31.3	4.5	198	2.6
A lot	16.5	5.2	0.9	7.0	14.8	0	13.0	37.4	5.2	115	1.5
Total	17.6	3.9	1.0	6.4	11.3	1.8	18.4	32.3	7.2	7,549	100.0

striking edge in the headlights area likewise showed no meaningful differences in injury severity or body location in relation to the type of striking edge.

The final variable analyzed has to do with the types of materials used on the front ends of the striking vehicles. As early as 1968 some models began using somewhat softer-than-steel materials for the grille opening panel, the front center panel, the bumper, or the whole fascia. These materials included cast urethane over steel, molded urethane over steel, injection molded urethane, reaction injection molded urethane, and injection molded EPDM. About five percent of the vehicles in 1978-79 New York pedestrian accidents were coded as having some type of "soft" material somewhere in their front ends.

Tables 17 and 18 present the relationship of this variable to the severity and body location of pedestrian injury for the front, hood, front fender, and unknown impacts. The numbers of cases for the different locations of the "soft" materials are too small for meaningful analysis, but it is possible to compare the total "soft" vehicles with the total "non-soft" vehicles. Looking first at the child subtable in Table 17, one can see that there were somewhat fewer fatalities associated with the "soft" front ends. In the adult subtable, however, the data show the opposite tendency--more fatalities with the "soft" front ends. However, both differences are too small to be statistically significant (chi-squares of .58 and .82 respectively). Likewise in Table 18, there do not appear to be any consistent patterns of relationship between the softer materials and the body location of the most severe pedestrian injury. This is not surprising, since experimental studies have shown that the types of "soft" front ends used in U.S. production vehicles have not been designed to absorb enough energy to expect any significant reduction in their injury effects.

Similar child and adult tables were produced and analyzed using the Pennsylvania data file. Given the much smaller numbers of cases, one would expect to find fewer significant relationships between the front end variables and injury severity and body location of the most severe injury than in the New York data. The largest chi-square (4.91, p=.03) was found for increased adult arm injury with higher hood heights (over

Table 16 - Type of Front Contact Edge and Severity of Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front or Hood Impact Areas

Type of Front Contact Striking Edge	Severity of Injury in Percent				Total N	Column %
	Fatal	Severe	Moderate	Minor		
Child						
Narrow, No Vertical Slope Above	0.9	18.9	36.8	43.3	639	44.7
Narrow, Vertical Slope Above	0.8	17.4	40.2	41.6	512	35.8
Blunt, No Vertical Slope Above	0.6	18.9	37.3	43.2	169	11.8
Blunt, Vertical Slope Above	1.6	18.0	41.0	39.3	61	4.3
Rounded Edge Above Vert.Grille	0	28.6	14.3	57.1	7	0.5
Rounded Edge Above Sloped Grille	2.8	11.1	44.4	41.7	36	2.5
Continuous Hood From Bumper	0	28.6	28.6	42.9	7	0.5
Total	0.9	18.2	38.3	42.6	1,431	100.0
Adult						
Narrow, No Vertical Slope Above	3.1	24.1	24.1	48.7	1,415	44.9
Narrow, Vertical Slope Above	2.5	23.7	26.4	47.4	1,103	35.0
Blunt, No Vertical Slope Above	3.8	22.1	23.0	51.0	339	10.7
Blunt, Vertical Slope Above	1.3	22.0	30.0	46.7	150	4.8
Rounded Edge Above Vert.Grille	0	35.7	28.6	35.7	14	0.4
Rounded Edge Above Sloped Grille	3.5	27.2	27.2	42.1	114	3.6
Continuous Hood From Bumper	10.5	10.5	36.8	42.1	19	0.6
Total	2.9	23.7	25.3	48.1	3,154	100.0

Table 17 - Soft Front End Materials and Severity of Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fender, or Unknown Impact Areas

Soft Materials	Severity of Pedestrian Injury in Percent				Total N
	Fatal	Severe	Moderate	Minor	
<u>Child</u>					
Grille Panel	0	16.0	44.0	40.0	100
Bumper	0	13.8	32.3	53.8	65
Grille & Bumper	1.7	18.6	33.9	45.8	59
Front Panels	0	0	30.0	70.0	10
Fascia	4.2	16.7	41.7	37.5	25
Total Soft	0.8	15.5	38.0	45.7	258
Non-Soft	1.3	16.8	38.6	43.2	5,198
<u>Adult</u>					
Grille Panel	4.9	19.6	24.0	51.6	225
Bumper	3.5	17.4	29.1	50.0	172
Grille & Bumper	5.3	19.7	30.3	44.7	132
Front Panels	0	14.3	28.6	57.1	21
Fascia	1.2	18.6	29.1	51.2	86
Total Soft	3.9	18.7	27.5	49.8	636
Non-Soft	3.3	19.0	26.1	51.6	11,921

34 inches) which supports the similar finding in the New York data. Also supportive of the New York results--but at somewhat less than the five percent level of significance--were the Pennsylvania data relating bumper height to adult arm injuries, relating little slope to child head injuries, and relating little slope to the severity of child injuries.

However, the Pennsylvania data provide no support for the strong relationship found in the New York data between a shorter hood and adult head injury. And likewise there is no association between bumper height and the severity of adult injury in the Pennsylvania data. On the other hand, there is a significant relationship between bumper height and the severity of child injury (fatal and major injuries) in the Pennsylvania data (chi-square of 4.51, p=.04), a relationship which is also found in the New York data but at a less than statistically significant level.

Table 18 - Soft Front End Materials and Body Location of Most Severe Child and Adult Injury in 1978-79 New York Pedestrian Accidents Involving Passenger Cars for Front, Hood, Front Fender, and Unknown Impact Areas

Location of Soft Materials	Body Location of Most Severe Injury in Percent									Total N
	Head	Face, Eye, Neck	Chest	Back	Upper Limbs	Abdomen, Pelvis	Hip, Upper Leg	Knee, Lower Leg	Entire Body	
Child										
Grille Panel	35.2	13.6	1.1	5.7	4.5	1.1	18.2	17.0	3.4	88
Bumper	28.1	10.5	0	3.5	12.3	1.8	14.0	26.3	3.5	57
Grille & Bumper	30.6	8.2	0	2.0	8.2	4.1	12.2	30.6	4.1	49
Front Panels	40.0	0	0	0	10.0	10.0	30.0	10.0	0	10
Fascia	30.0	5.0	0	0	5.0	0	25.0	20.0	15.0	20
Total Soft	32.1	10.3	0.4	3.6	7.6	2.2	17.0	22.3	4.5	224
Non-Soft	28.1	8.3	1.2	4.9	9.3	2.9	13.7	23.9	7.8	4,570
Adult										
Grille Panel	15.1	3.4	1.5	5.9	12.2	2.0	19.0	34.1	6.8	205
Bumper	20.5	5.0	0	3.7	11.2	2.5	16.8	34.2	6.2	161
Grille & Bumper	16.8	2.5	2.5	8.4	10.1	3.4	16.8	32.8	6.7	119
Front Panels	14.3	4.8	0	4.8	4.8	0	19.0	47.6	4.8	21
Fascia	16.5	1.3	0	6.3	12.7	0	16.5	38.0	8.9	79
Total Soft	17.1	3.4	1.0	5.8	11.3	2.1	17.6	34.9	6.8	585
Non-Soft	17.8	3.9	1.2	6.3	11.4	1.6	18.3	32.5	7.0	10,733

As in the New York data, there were no meaningful findings regarding the two striking edge variables or the "soft" materials variable.

CONCLUSIONS

The purpose of this study was to identify any vehicle factors which relate to the severity or patterns of pedestrian injury, using available accident data from the current vehicle population. For this purpose an analysis was carried out of two large pedestrian accident data sets--38,344 1978-79 accidents in New York and 7,025 1979 accidents in Pennsylvania. Of particular interest were various aspects of the vehicle front end configuration which were derived from vehicle measurements made in the Pedestrian Injury Causation Study, data which are not readily available in published form. Some other front end data were coded for these cases using photographs of 1966-1980 model vehicles.

As is often the case with the analysis of police-reported accident files, missing information on key variables greatly reduced the numbers of cases available for analysis. Make and model information was available for only three-fifths of the New York accidents and a little over one-third of the Pennsylvania accidents. Point of impact data were missing for more than half of the New York accidents, so these unknown impact area cases were analyzed as if they were all front impacts. The PICS vehicle measurements were not available for all 1966-1980 makes and models, so the numbers of usable accident cases were further reduced. Also, substantial variations in the PICS measurements for the same make and model vehicle raise serious questions about the quality of these measurement variables. In addition the lack of speed of impact information required the analysis to assume that speed of impact was uniformly distributed among the different vehicle types and front end configurations.

These analyses did not find very much of practical significance relating current vehicle factors to pedestrian injury. The data do show that the type of vehicle makes a difference in the severity of pedestrian injury, with pickups and large trucks being particularly more likely to inflict severe injury than passenger cars. However, no direct relationship exists between passenger cars of different weights and the severity of pedestrian injury.

In regard to specific aspects of passenger car front end configurations a few relationships were found to be statistically significant. The strongest relationship in both the New York and Pennsylvania pedestrian accident data was between high hoods and most severe injury to the upper extremities for adults. There was also a strong relationship in the New York data between a short hood and most severe injury to the head for adults (presumably because of greater likelihood of hitting their heads on the windshield or its frame), but this relationship did not show up in the smaller Pennsylvania data file. Both data sets suggest a relationship between higher bumpers and severity of injury for both children and adults. Perhaps the most meaningful finding was that a more vertical slope from the bumper edge to the above-bumper contact edge was associated with more head injuries and more fatal and severe injuries for children. There were no clear relationships between type of striking edge or past production types of front end soft materials and either pedestrian injury body region or severity.

The basic conclusion of this exploration of police-reported pedestrian accidents in New York and Pennsylvania is that variations in the weight or front end styling of production passenger cars are not clearly related to body region or severity of pedestrian injury. Even in these large data bases the basic styling similarities of most passenger cars and the problems of missing data on important variables meant that there were rather small numbers of vehicles which were very distinctive in their front end styling. One needs to turn to the laboratory for the testing of a wide variety of vehicle front ends with pedestrian dummies under controlled conditions. The suggestion from the mass accident data that there is a safety benefit for child pedestrians in a greater horizontal slope from the bumper edge to the hood edge certainly should be one of the styling variations tested in the laboratory.