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ANALYSIS OF PEDALCYCLIST CRASHES

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13. ABSTRACT (Maximum 200 words)

This report analyzes the problem of pedalcyclist crashes in the United States to support the development and assessment of effective pedalcyclist crash avoidance systems as part of the U.S. Department of Transportation's Intelligent Vehicle Initiative. This study describes pre-crash scenarios most prevalent in pedalcyclist crashes by identifying vehicle maneuvers and pedalcyclist action combinations. This analysis is based on data from the 1995-1998 National Automotive Sampling System/General Estimates System and Fatality Analysis Reporting System databases. In 1998, about 58,000 pedalcyclist crashes, or 0.9% of all police-reported crashes, occurred in the United States, resulting in 760 fatal crashes, or 2.1% of all fatal motor vehicle crashes that year. Pedalcyclist crashes were broken down into 8 pre-crash scenarios. Most pedalcyclist-involved crashes occurred on straight non-hillcrest roadways and on the roadway. Almost 75% of the crashes occurred on roadways with speed limits between 25 mph and 35 mph. Nearly 12% of the drivers and over 50% of the pedalcyclist were under 20 years old. 72% of the pedalcyclist crash population fell into the 5-29 year old age range.

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PREFACE

The National Highway Traffic Safety Administration (NHTSA), in conjunction with the Research and Special Programs Administration Volpe National Transportation Systems Center (Volpe Center), is conducting an analysis of pedalcyclist crashes in support of the Intelligent Vehicle Initiative (IVI). The IVI focuses on solving traffic safety problems through the development and deployment of vehicle-based and vehicle-infrastructure cooperative crash countermeasures that address rear-end, roadway departure, lane change, crossing paths, driver impairment, reduced visibility, vehicle instability, pedestrian, and pedalcyclist crashes.

This report presents the results obtained for the analysis of pedalcyclist crashes using a four-year data set from the 1995-1998 National Automotive Sampling System/General Estimates System (NASS/GES) and Fatality Analysis Reporting System crash databases. In 1998, there were about 58,000 pedalcyclist crashes or 0.9% of all police-reported crashes in the United States.

The authors of this report are Marco P. daSilva, Brittany N. Campbell, John D. Smith, and Wassim G. Najm of the Volpe Center.

The authors acknowledge the technical contribution of Dr. David L. Smith of NHTSA. Also acknowledged is Dan Cohen of Mitretek for reviewing the report and providing valuable comments. Kate Klotz of Planners Collaborative edited the report.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC	METRIC TO ENGLISH
LENGTH (APPROXIMATE)	**LENGTH** (APPROXIMATE)
1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA** (APPROXIMATE)
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)	
MASS - WEIGHT (APPROXIMATE)	**MASS - WEIGHT** (APPROXIMATE)
1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = 0.45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg)
	= 1.1 short tons
VOLUME (APPROXIMATE)	**VOLUME** (APPROXIMATE)
1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)	**TEMPERATURE** (EXACT)
[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

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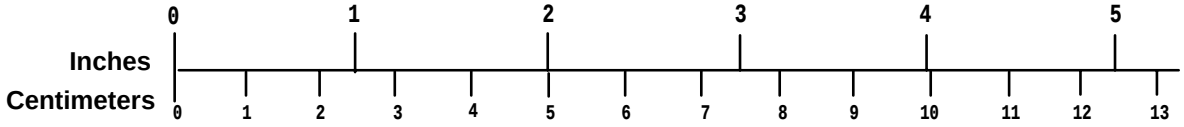

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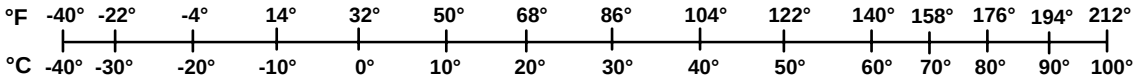

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EXECUTIVE SUMMARY

This report analyzes the problem of pedalcyclist crashes in the United States to support the development and assessment of effective pedalcyclist crash avoidance systems as part of the *Intelligent Vehicle Initiative*. A pedalcyclist crash occurs when a moving motor vehicle strikes or is struck by a pedalcyclist. In 1998, about 58,000 such crashes, or 0.9% of all police-reported crashes, occurred in the United States. These crashes resulted in 760 fatal crashes or 2.1% of all fatal motor vehicle crashes during that year. This analysis identifies and counts these crashes by their pre-crash scenarios that represent vehicle maneuvers and pedalcyclist actions immediately prior to impact. Moreover, these pre-crash scenarios are individually described in terms of their physical setting, crash contributing factors, and crash characteristics such as the age of people involved and maximum injury severity. The analysis was conducted using a four-year data set from the 1995-1998 *National Automotive Sampling System/General Estimates System* (NASS/GES) and *Fatality Analysis Reporting System* (FARS) crash databases of the *National Highway Traffic Safety Administration*.

The analysis of pedalcyclist crashes is concerned with understanding the pre-crash scenarios in order to aid in the development of concepts, functional requirements, performance guidelines, test procedures, and the safety assessment of potential pedalcyclist crash avoidance systems. This report breaks down pedalcyclist crashes into eight pre-crash scenarios, as follows (percentages shown below refer to the frequency of each scenario relative to the size of all pedalcyclist crashes):

1. Vehicle traveling straight on a crossing path with the pedalcyclist (40.2%),
2. Vehicle traveling straight on a parallel path with the pedalcyclist (15.4%),
3. Vehicle turning right on a crossing path with the pedalcyclist (9.7%),
4. Vehicle turning right on a parallel path with the pedalcyclist (7.0%),
5. Vehicle turning left on a parallel path with the pedalcyclist (7.0%),
6. Vehicle starting in traffic lane on a crossing path with the pedalcyclist (3.0%),
7. Vehicle turning left on a crossing path with the pedalcyclist (2.9%),
8. Other (14.8%).

The last scenario, "other", encompasses cases where the vehicle performed a other maneuver (i.e., passing, changing lanes, backing, parking) and/or the pedalcyclist was on a path other than a crossing or parallel path.

The crash statistical description provided in this report focuses on the above eight specific pre-crash scenarios. The majority of these scenarios occurred on straight, non-hillcrest roadways (94%), with posted speed limits between 25 mph and 35 mph (75%). About 55% of these crashes occurred at locations where there were no traffic control devices present. Nearly 23% of the crashes were reported at intersections marked with stop signs and 20% of the crashes happened at intersections equipped with 3-color signals.

The analysis of crash contributing factors for the pre-crash scenarios revealed that a relatively high percentage of drivers reported vision obscurity in the scenario where the

vehicle was turning left while on a parallel path with the pedalcyclist (scenario 5) and the scenario where the vehicle was starting in the traffic lane on a crossing path with the pedalcyclist (scenario 6). Over 9% of the drivers reported vision obscurity and over 20% were charged with violating the sign or signal in each of the scenarios. Moreover, these scenarios reported high frequencies (over 5%) of crashes occurring under nighttime and adverse weather conditions. Over 43% of fatal pedalcyclist crashes occurred at nighttime based on FARS data, whereas only 20% of all pedalcyclist crashes occurred under the same conditions according to GES data. Based on this observation, pedalcyclists involved in crashes with motor vehicles at nighttime have a greater probability of resulting in a fatality than under daytime conditions. Alcohol and/or drug use by the driver was reported in 6% of the crashes where the vehicle was traveling straight on a parallel path with the pedalcyclist (scenario 2). Over 50% of the pedalcyclists who where traveling on a crossing path with a vehicle traveling straight (scenario 1) were cited with failure to yield the right of way.

Drivers aged 30-34 years old represented the largest age group involved in pedalcyclist crashes, accounting for about 13% of all drivers involved in such crashes. Older drivers, especially those age 55-64 years old, had a higher involvement in cyclist-related crashes compared to their overall involvement in all crashes. Such drivers comprise about 6.6% of the overall crash population and yet were involved in 8.6% of the pedalcycle crashes. Younger pedalcyclists, especially those aged from 10 to 14 years old, were most susceptible to crashes accounting for nearly 27% of all pedalcyclists involved in pedalcyclist crashes. Approximately 72% of the pedalcyclist crash population fell into the 5-29 year-old age range, which was over-represented relative to the U.S. population.

Overall, about 550 pedalcyclist fatalities per year were reported in the 1995-1998 GES. The highest frequency of incapacitating and fatal injuries occurred in cases where the vehicle was traveling straight on parallel paths with the pedalcyclist (scenario 2). Roughly 22% of pedalcyclist related crashes in this scenario also occurred at nighttime. Nearly 12% of the drivers and over 50% of the pedalcyclists were under 20 years old. The least injury was reported in scenario 6 that involves a vehicle starting in a traffic lane on a crossing path with the pedalcyclist. Roughly 49% of the crashes in this scenario resulted in no injuries or possible injuries due to the low speeds of starting vehicles.

The results obtained from this analysis are intended to support effective countermeasure concept development and provide data for design effectiveness assessments. This study helps researchers visualize and quantify the different conditions present in pedalcyclist crashes by identifying vehicle maneuver and pedalcyclist action combinations most prevalent in such crashes.

1. INTRODUCTION

This report defines the problem of pedalcyclist crashes and provides a basis for related future research under the United States Department of Transportation's (U.S. DOT's) *Intelligent Vehicle Initiative* (IVI). The IVI focuses on solving traffic safety problems through the development and deployment of vehicle-based and vehicle-infrastructure cooperative countermeasure systems using advanced technologies. A pedalcyclist crash occurs when a moving motor vehicle strikes or is struck by a pedalcyclist. In 1998, about 58,000 such crashes occurred in the U.S. based on estimates in the *National Automotive Sampling System/General Estimates System* (NASS/GES) crash database of the *National Highway Traffic Safety Administration* (NHTSA). Pedalcyclist crashes accounted for about 1% of all police-reported crashes in 1998. An aggregate of four years of data from the GES database (1995-1998) is used in this report due to the relatively low frequency of this crash problem. This report identifies and counts pedalcyclist crashes by pre-crash movements, as defined in the NASS/GES, which denote vehicle maneuvers and pedalcyclist actions prior to the crash.

This report analyzes pedalcyclist crashes to aid in the development of concepts, functional requirements, performance guidelines, and test procedures, as well as the safety assessment of potential pedalcyclist crash avoidance systems. This analysis begins with the breakdown of pedalcyclist crashes into common pre-crash scenarios that represent vehicle dynamics and pedalcyclist actions immediately prior to impact. These scenarios form the foundation to describe the physical setting of these crashes, the factors that might have contributed to the cause of the crash, and crash consequences such as pedalcyclist age, number of pedalcyclists struck per crash, and maximum injury severity. The analysis of causal factors and pre-crash scenarios allows the development of crash countermeasure concepts and essential functional requirements. Information on pre-crash scenarios and their physical setting helps develop performance guidelines, objective test procedures and test scenarios for crash avoidance systems. Such information also helps researchers collect the appropriate data on driver and pedalcyclist performance with and without the assistance of crash avoidance systems. Such data are essential to the design of effective warning algorithms, driver-vehicle interfaces, and estimation of safety benefits for crash avoidance systems. Statistics like pedalcyclist age, number of pedalcyclists struck, and injury severity support the projected safety benefits in terms of injury severity reduction due to the use of pedalcyclist crash avoidance systems.

The beginning of this report provides a review of previous work, domestic as well as international, which addressed the pedalcyclist crash problem. This is followed by a discussion on possible data sources for this study, including a general description of the GES that was selected for this analysis.

1.1. Previous Work

Previous studies relating to the pedalcyclist crash problem have been performed both in the U.S. and abroad. A study of pedalcyclist crash types was performed by the

University of North Carolina under the direction of the Federal Highway Administration (FHWA) using crash data from the early 1990s from six states [1]. This work identified and coded 3,000 pedalcyclist crashes taken from 1991-1992 crash files from California, Florida, Maryland, Minnesota, North Carolina, and Utah. Because the organization had access to detailed crash reports with crash schematics, the report provides details on vehicle and pedalcyclist movements and conditions at the instant of the crash. The crash sample was evenly distributed among the six states and there was no effort to create a national pedalcyclist crash representation.

Another study aimed at quantifying the pedalcyclist crash problem used hospital emergency department data collected at eight hospitals over a one-year period to more accurately describe pedestrian and pedalcyclist crashes [2]. The report findings show that 64% of reported pedestrian injury events and 70% of reported bicycle injury events did not involve a motor vehicle. It also concludes that fewer pedalcyclist crash cases are reported in police-based files than in hospital databases.

Other studies focus on bicycle helmet use and safety impact. One such study determined that head injury is the primary or contributing factor in 70 to 85% of bicycle-related deaths [3]. The use of bicycle helmets can lower the risk of bicycle-related head injuries by as much as 85% [4]. It should be noted that these statistics refer to the overall bicycle injury realm and not just the vehicle-related set.

Studies performed in The Netherlands also confirm that police-reported crash statistics underestimate injuries to pedestrians and bicyclists [5]. This is attributed to police underreporting of non-vehicle crash events, crashes occurring off the roadway, and crashes that result in less serious injuries.

1.2. Possible Data Sources - Analysis Databases

A host of state and national vehicle crash databases are kept in the U.S. to aid researchers in the study of the motor vehicle crash problem. A wide selection of these databases was examined in order to determine the best suitable data source for the research presented herein.

The most encompassing data source, and most widely used in crash problem analyses, is the NASS. The NASS is based upon a large sample of Police Accident Reports (PARs) that are sorted into two systems: the *Crashworthiness Data System* (CDS) and the GES. The CDS is a nationally representative sample of about 5,000 police reported crashes. For inclusion in the CDS, at least one light vehicle in the crash must have been towed away from the scene due to damage. This database is used primarily for vehicle crashworthiness studies, as the database title suggests. The GES is a nationally representative sample of police reported crashes involving all vehicle types and all severities and results in about 55,000 cases each year. It includes about 90 data elements, known as variables, collected from police reports which describe the vehicle, physical settings, and all of the people involved in the crash. The GES is limited by the content

and accuracy of police reports and, since it is a national estimate of crashes, it has inherent potential sampling errors.

The *Fatality Analysis Reporting System* (FARS) is another national crash database that contains data on all fatal crashes occurring on U.S. public roads. To be included in the FARS, a crash must involve a motor vehicle traveling on a traffic way and result in the death of a person, either a vehicle-occupant or a non-motorist, within 30 days of the crash. This database includes over 100 attributes of the crash, vehicle, and people involved. It gives an accurate national description of fatal crashes because it includes data on all fatal crashes, not just a representative sample.

Yet another crash database system is the *Highway Safety Information System* (HSIS), funded by the FHWA and kept by the University of North Carolina. This system is a multi-state collection of crash databases. Presently, it contains crash data from California, Illinois, Maine, Michigan, Minnesota, North Carolina, Utah, and Washington. Other states also have crash databases but only these were selected for inclusion into the HSIS based on the quality of available data. Since states keep different kinds of data, not all data from each state database is included in the HSIS. Only a selection of common data available from the participating states is included in the HSIS. The system contains data only on the state-maintained highway systems from the participating states since the individual state databases only keep records of crashes on state-maintained roadways. This means that the state databases are not proportional to the size of the state for which each is kept since only state-owned roadways crash data is collected. Overall, the HSIS is not a nationally representative sample of crashes.

Some individual state crash databases that are part of the HSIS were also reviewed to determine if they could provide some useful information for the analysis of the pedalcyclist crash problem. The reviewed databases were obtained from Michigan, California, Washington, and North Carolina. This examination was performed because the actual state-maintained crash databases contain more information than what is supplied to the HSIS.

The analysis presented mainly uses the NHTSA NASS/GES. The GES was selected due to its characteristic of being a broader, more populated sample of nationally representative crashes. The combination of 1995–1998 GES databases was utilized for pedalcyclist crash count estimates due to the relative low frequency of the annual pedalcyclist crash problem. The GES vehicle-pedalcyclist pre-crash maneuver breakdowns, as well as the fatality demographics, were compared to statistics from the 1995-1998 FARS. This selection took into account previous crash analysis work performed by the U.S. DOT's Bureau of Transportation Statistics, which determined that the "FARS and GES have proven to be useful databases for tracking trends and for national studies of crash characteristics, causes, and potential countermeasures" [6].

2. PROBLEM SIZE

Pedalcyclist crashes involve a moving motor vehicle that strikes or is struck by one or more pedalcyclists. The GES crash database identifies such crashes by the code "6" in the *Person Type* variable from the "Person File" [7]. Each individual involved in a crash has his/her own "Person File" in the GES (e.g., driver and pedalcyclist). Some GES crash cases contain multiple "Person Files" coded as a "pedalcyclist," meaning that more than one pedalcyclist was involved in the crash or that more than one person was riding the bicycle. This report provides frequency estimates of pedalcyclist crashes based on a four-year aggregate sample from the 1995-1998 GES.

Pedalcyclist crashes accounted for an average of 65,000 police-reported collisions per year or 1% of the total average of 6,615,000 crashes reported in the U.S. based on 1995-1998 GES statistics[1]. Table 1 lists the annual frequency of pedalcyclist crashes and the yearly number of pedalcyclists involved in these crashes over this four-year period from 1995 through 1998. On average, approximately 67,000 pedalcyclists were struck by moving vehicles per year with a ratio of 1.03 pedalcyclists per crash. Even though overall crashes dropped about 5.5% during this four-year period, pedalcyclist-related crashes dropped 20.5% from a high of 73,000 in 1995 to 58,000 in 1998.

From 1995 to 1998, 261,000 pedalcyclist crashes involving 268,000 pedalcyclists occurred in the U.S. It should be noted that the national estimates extracted from GES data might differ from the true values because they are based on a probability sample of crashes and not a nationwide census of all crashes. Generalized standard errors for GES estimates of totals are provided in Reference [7]. By accounting for the GES sampling standard error, the drop in pedalcyclist crashes as observed from Table 1 is not statistically significant based on the 95% confidence intervals of these estimates. Figure 1 shows the lower and upper bounds of annual pedalcyclist crash estimates, which indicate no change in the annual frequency of pedalcyclist crashes from 1995 through 1998 due to the overlap among all 95% confidence intervals.

Table 1. Pedalcyclist Crash Problem Size (Based on 1995-1998 GES)

Year	Total Crashes	Pedalcyclist Crashes	# of Pedalcyclists Involved
1995	6,690,000	73,000	75,000
1996	6,834,000	66,000	68,000
1997	6,612,000	63,000	65,000
1998	6,325,000	58,000	60,000
Total	26,461,000	261,000	268,000
Yr Avg	6,615,000	65,000	67,000

Note: Numbers in cells were rounded to the nearest 1,000.

[1] All GES crash statistics are weighted to provide a nationally representative sample.

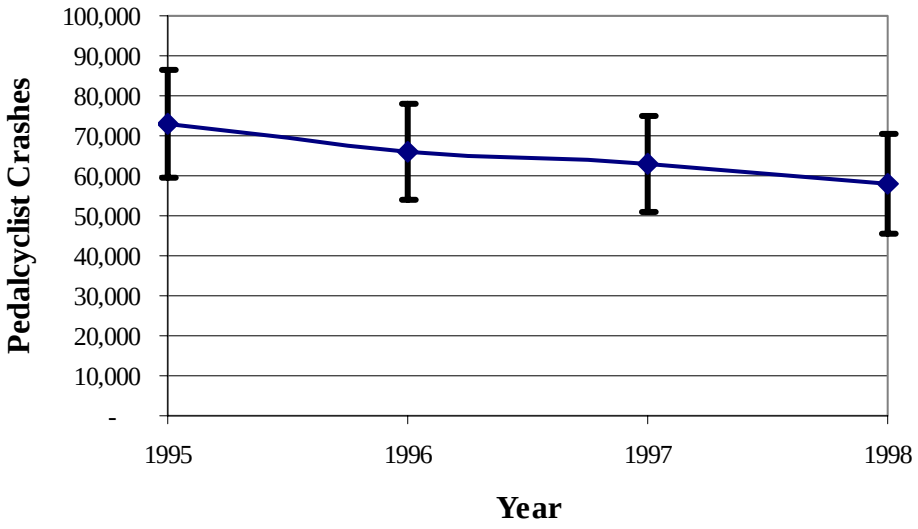


Figure 1. Pedalcyclist Crash Estimates and Concomitant 95% Confidence Intervals

3. PRE-CRASH SCENARIOS

Pre-crash scenarios denote vehicle maneuvers and pedalcyclist actions immediately prior to a pedalcyclist crash. The GES enables the definition of such scenarios by combining codes from the *Univariate Imputed Movement Prior to Critical Event* variable from the "Vehicle/Driver File," *Pedestrian/Cyclist Crash Type* variable from the "Accident File," and *Non-Motorist Action* variable from the "Person File" [7].

Figure 2 illustrates the distribution of vehicle maneuvers in pedalcyclist crashes based on 1995-1998 GES. The vehicle was going straight (traveling at constant speed) in about 62% of pedalcyclist crashes and making a turn in only 27% of these crashes. "Other" maneuvers refer to vehicles starting in the traffic lane, slowing, passing, or changing lanes.

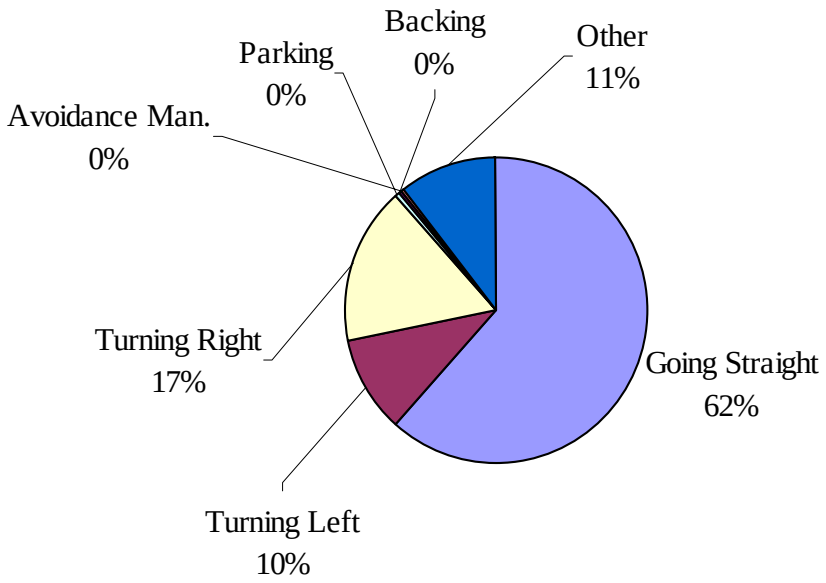


Figure 2. Distribution of Vehicle Maneuvers in Pedalcyclist Crashes (Based on 1995-1998 GES)

Table 2 shows the distribution of pedalcyclist actions prior to the crash based on 1995-1998 GES. The definitions and schematics of each code in Table 2 are attached in Appendix A. The *Pedestrian/Cyclist Crash Type* variable was later combined with the vehicle maneuver data in the GES to identify pre-crash scenarios.

Table 2. Distribution of Pedalcyclist Actions in Pedalcyclist Crashes (Based on 1995-1998 GES)

Pedalcyclist Action Code	Description[1]	4-year Total	% Dist.
1	Pedal. ride out, residential driveway	12,000	4.6%
2	Pedal. ride out, commercial driveway	2,000	0.9%
3	Pedal. ride out from sidewalk	3,000	1.3%
4	Pedal. ride out, midblock	20,000	7.7%
5	Pedal. ride out, stop sign	18,000	7.0%
6	Pedal. fail to clear intersection, motorist's view not obstructed	*	0.1%
7	Pedal. fail to clear intersection, motorist's view obstructed	*	0.1%
8	Motorist drive out, driveway/alley/midblock	19,000	7.4%
9	Motorist drive out, after stopping for stop sign	22,000	8.6%
10	Motorist drive out, right on red	8,000	3.2%
11	Motorist backing from driveway	2,000	0.8%
12	Motorist fails to stop at stop sign	6,000	2.2%
13	Motorist overtakes undetected Pedal.	4,000	1.6%
14	Motorist lost control while overtaking	1,000	0.3%
15	Motorist overtaking, counteractive evasive actions	1,000	0.4%
16	Motorist overtaking, misjudges passing space	2,000	0.7%
17	Motorist overtaking, path obstructed	*	0.1%
18	Pedal. left turn, facing traffic	4,000	1.5%
19	Pedal. left turn in front of traffic	2,000	0.6%
20	Pedal. lost control	4,000	1.4%
21	Pedal. right turn, wrong side of street	*	0.1%
22	Motorist left turn in front of Pedal.	3,000	1.3%
23	Motorist left turn, facing Pedal.	15,000	5.7%
24	Motorist right turn in front of Pedal.	17,000	6.7%
25	Vehicles collide at uncontrolled intersection, crossing path	4,000	1.5%
26	Head-on, wrong way Pedal.	8,000	3.2%
27	Pedal. overtaking	4,000	1.5%
28	Head-on, wrong way motorist	*	0.1%
29	Crash occurred in non-roadway location	2,000	0.8%
30	Head-on, counteractive evasive actions	*	0.2%
31	Pedal. cuts corner	1,000	0.5%
32	Pedal. swings wide	1,000	0.2%
33	Motorist cuts corner	*	0.1%
34	Motorist swings wide	1,000	0.4%
35	Motorist drive out, on street parking	*	0.2%
36	Weird	1,000	0.3%
39	Motorist overtaking, other	13,000	4.9%
40	Cyclist was riding a child's vehicle	*	0.0%
41	Pedal. strikes parked vehicle	*	0.1%
48	Motorist drive out, intersection	12,000	4.7%
49	Pedal. ride out, intersection	23,000	8.9%
55	Controlled intersection, other	12,000	4.7%
97	Unknown if paths are parallel or crossing	2,000	0.8%
98	Parallel paths unknown	3,000	1.3%
99	Intersecting paths unknown	3,000	1.1%
Totals		261,000	100.0%

[1] The descriptions provide additional information for each action code. The descriptions are examples only and do not reflect all possible situations to which the code can be applied.

- Pedal. = Pedalcyclist
- Numbers in cells were rounded to the nearest 1,000.
- The symbol * represents crash frequencies below 500.
- Refer to Appendix A for Pedalcyclist Action Code definitions.

As seen in Table 2, about 9% of the pedalcyclist crashes occurred in the case in which the bicyclist rides out at an intersection and collides with a vehicle (as denoted by the *Pedestrian/Cyclist Crash Type* variable code “49”). The case in which the motorist obeys the traffic sign at an intersection but fails to yield to the cyclist is the second most frequent, accounting for 8.6% of the total pedalcyclist crash population (code “9”). A total of 8.3% of all pedalcyclist crashes contain “unknown” or “other” information in the *Pedestrian/Cyclist Crash Type* variable information (codes 36, 37, 55, 97, 98, 99). The *Pedestrian/Cyclist Crash Type* and *Univariate Imputed Movement Prior to Critical Event* variables were determined to best identify pedalcyclist pre-crash scenarios because they offer a comprehensive picture of the pedalcyclist and motorist actions immediately prior to the crash, and contain little “unknown” information.

Table 3 breaks down the pedalcyclist crash problem into 15 combinations based on the vehicle movement prior to the critical event and the initial pedalcyclist approach path in relation to the vehicle's maneuver. The pedalcyclist's initial approach path was determined from the pedalcyclist action codes in Table 2. "Parallel Paths" were defined as cases where the cycle and motor vehicle were approaching each other on parallel paths, heading either in the same or in opposite directions. "Crossing Paths" include cases where the cycle and the motor vehicle were on intersecting paths. Cases were classified as "other" when it was unknown whether the vehicle's and cycle's initial approach paths were parallel or crossing, the crash was classified as "weird" (pedalcycle action code 36), or the crash involves a vehicle which was backing or occurred in a parking lot or other non-roadway location.

Table 3. Pre-Crash Scenario Breakdown of Pedalcyclist Crashes (Based on 1995-1998 GES)

Vehicle Maneuver	Initial Approach Paths		
	Parallel Paths	Crossing Paths	Other
Going Straight	40,000	105,000	3,000
Starting in Traffic Lane	*	8,000	0
Turning Right	18,000	25,000	*
Turning Left	18,000	8,000	*
Other Maneuver	10,000	22,000	4,000

- Numbers in cells were rounded to the nearest 1,000.
- The symbol * represents crash frequencies below 500.

Pedalcyclist crashes were separated into the following eight pre-crash scenarios:

1. Vehicle Traveling Straight/Crossing Paths (40.2%)
2. Vehicle Traveling Straight/Parallel Paths (15.4%)
3. Vehicle Turning Right/Crossing Paths (9.7%)
4. Vehicle Turning Right/Parallel Paths (7.0%)

5. Vehicle Turning Left/Parallel Paths (7.0%)
6. Vehicle Starting in Traffic/Crossing Paths (3.0%)
7. Vehicle Turning Left/Crossing Paths (2.9%)
8. Other (14.8%)

The eighth scenario, "other", encompasses all crashes in which the vehicle was performing an "other" maneuver or cases where the initial approach path was "other". Note that the eight pre-crash scenarios fully encompassed the entire pedalcyclist crash type.

The most frequent scenario accounted for about 40.2% of all pedalcyclist crashes and involved a vehicle traveling straight and cyclist crossing paths. The second most dominant scenario involved the cyclist approaching the vehicle on parallel paths and the vehicle traveling straight. Crossing paths (64%) accounted for more pedalcyclist crashes than parallel paths (25%) in most vehicle maneuvers, except when the vehicle was making a left turn.

The upper and lower 95% confidence intervals for each pre-crash scenario were calculated from the generalized standard error estimates given in the NASS/GES *Analytical User's Manual* for each of the eight pre-crash scenarios [7]. The upper and lower limits of the confidence interval reflect a 95% confidence that the actual crash population lies within that range. Clearly, scenario 1, Straight/Crossing Paths, is the most dominant, accounting for 40% of the total pedalcyclist crashes. Each scenario's crash frequency and 95% confidence interval values are displayed in Figure 3. (Note: the relative frequency was calculated based on the average yearly pedalcyclist crash population of 65,000.)

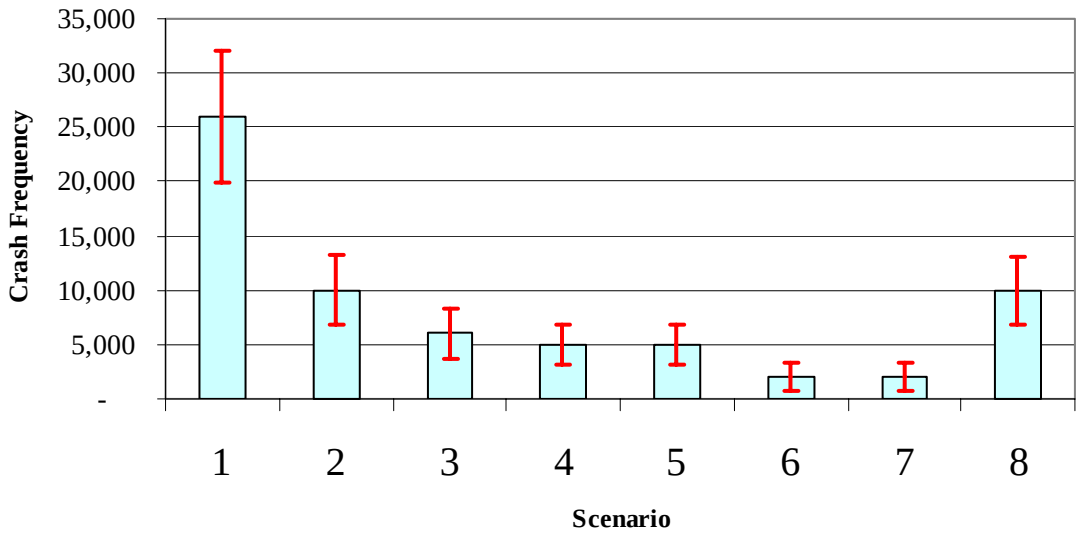


Figure 3. Crash Frequency of Pedalcyclist Pre-Crash Scenarios with 95% Confidence Interval Bars (Based on 1995-1998 GES)

4. PHYSICAL SETTING

This chapter presents statistics on the physical setting of pedalcyclist crashes based on the 1995-1998 GES, in order to develop a clearer picture of pedalcyclist pre-crash scenarios. Pre-crash scenarios were delineated in terms of roadway alignment, roadway profile, posted speed limit, and traffic control device present at these crash locations. The roadway alignment and profile describe the geometrical configuration of the crash location and might indicate whether or not the roadway configuration limited the detection distance of either the vehicle or the pedalcyclist. The posted speed limit might provide a perspective about the travel speed of vehicles.

4.1. Roadway Alignment and Profile

The *Univariate Imputed Roadway Alignment* and *Univariate Imputed Roadway Profile* variables from the GES "Accident File" refer to the horizontal alignment and the vertical alignment of the roadway in the immediate vicinity of the first harmful event in the crash, respectively [7]. These two variables have the following codes:

Roadway Alignment	*Roadway Profile*
Code 01 = Straight	Code 01 = Level
Code 02 = Curve	Code 02 = Grade
	Code 03 = Hillcrest
	Code 08 = Other

Table 4 provides GES statistics about the roadway alignment and roadway profile for each of the eight pre-crash scenarios. This analysis combines codes 01, 02, and 08 from the *Roadway Profile* variable into the category labeled as "Other" and distinguishes the presence of a hillcrest since the latter affects visibility. As seen in Table 4, most crashes in each scenario occurred on roads labeled as "Straight/Other."

Table 4. Statistics of Roadway Profile and Alignment for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Alignment/ Profile	Scenario								Overall Scenarios	Crash Frequency
	1	2	3	4	5	6	7	8		
Straight/Hillcrest	1,000	*	*	*	*	*	*	*	1,000	1.4%
Curve/Hillcrest	*	*	*		*	*		*	-	0.2%
Straight/Other	24,000	9,000	6,000	4,000	4,000	2,000	2,000	9,000	61,000	93.6%
Curve/Other	1,000	1,000	*	*	*	*	*	*	3,000	4.8%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000	100.0%

- Numbers in cells were rounded to the nearest 1,000.
- Empty cells refer to categories that had no crashes in the 1995-1998 GES samples.
- The symbol * represents crash frequencies below 500.

4.2. Posted Speed Limit

The *Hot-deck Imputed Speed Limit* variable from the GES "Accident File" indicates the posted speed limit for the roadway on which the crash took place. Table 5 provides the distribution of posted speed limit statistics for each of the eight pedalcyclist pre-crash scenarios.

Approximately 75% of all pedalcyclist pre-crash scenarios in Table 5 occurred at speed limits of 25 mph, 30 mph, and 35 mph. The 25 mph speed limit was the most dominant overall and accounted for about 33% of all pedalcyclist crashes. The highest relative frequency of about 86% on roadways with speed limits between 25 mph and 35 mph was found in pre-crash scenario 7 where the vehicle performed a left turn in front of the cyclist's path. The highest relative frequency on roadways with posted speed limit of 55 mph was reported in 9.3% of pre-crash scenario 2 where the vehicle was traveling straight on a parallel path with the pedalcyclist.

Table 5. Distribution of Posted Speed Limit Statistics for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Speed Limit	Scenario								Total
	1	2	3	4	5	6	7	8	
No Statutory Limit	0.6%	0.1%	0.3%	1.5%	0.0%	0.4%	0.0%	0.9%	0.6%
5 mph	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.6%	0.1%
10 mph	0.2%	0.7%	0.0%	0.1%	0.2%	0.0%	0.0%	1.0%	0.3%
15 mph	2.7%	1.3%	0.0%	1.7%	1.5%	3.2%	0.5%	3.5%	2.1%
20 mph	1.6%	2.1%	1.1%	0.3%	1.1%	1.3%	1.0%	1.7%	1.5%
25 mph	38.8%	29.4%	34.4%	32.1%	24.1%	35.4%	37.3%	21.2%	32.7%
30 mph	14.4%	13.3%	19.7%	13.4%	20.3%	30.0%	23.3%	17.4%	16.3%
35 mph	24.8%	25.3%	23.8%	29.8%	31.0%	9.9%	25.1%	26.8%	25.4%
40 mph	6.9%	7.4%	8.9%	13.1%	10.8%	6.7%	5.7%	9.3%	8.2%
45 mph	5.8%	8.5%	10.0%	4.3%	5.5%	10.9%	5.8%	13.7%	7.8%
50 mph	0.9%	1.3%	1.3%	0.4%	2.0%	1.4%	0.3%	0.8%	1.0%
55 mph	3.1%	9.3%	0.2%	1.7%	3.1%	0.7%	1.0%	2.9%	3.5%
60 mph	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
65 mph	0.1%	1.2%	0.3%	1.7%	0.0%	0.0%	0.0%	0.0%	0.4%
70 mph	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
75 mph	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

4.3. Traffic Control Device

This study identified the type of traffic control device present for the pedalcyclist pre-crash scenarios occurring at intersections. The *Univariate Imputed Traffic Control Device* variable from the GES "Accident File" indicates whether or not a traffic control device was present at the location of the crash and the type of the device. The codes of this variable were rearranged into the following four device categories:

Traffic Control Device
Code 01 = "3-Color Signal"
Code 21 = "Stop Sign"
Code 00 = "No Controls"
All Other Codes = "Other/Unknown Signs"

Table 6 provides GES statistics on the distribution of the pedalcyclist pre-crash scenarios by traffic control device. The "3-color signal" was the most dominant device in pre-crash scenario 3, in which the vehicle performed a right turn crossing paths with the cyclist, accounting for 49.1% of all pedalcyclist crashes in that scenario. The "stop sign" was most dominant in scenario 6, being the traffic control device present at the location of 93% of the pedalcyclist crashes in which the vehicle was staring in traffic on crossing paths with the pedalcyclist. "No controls" was most dominant in scenarios 2 and 8.

Figure 4 illustrates the overall distribution of traffic control devices for the pedalcyclist pre-crash scenarios. As seen in Figure 4, the majority of the crashes occurred at locations where there were no traffic control devices present. About 23% of the crashes occurred at intersections marked with stop signs and about 20% of the crashes occurred at intersections equipped with 3-color signals.

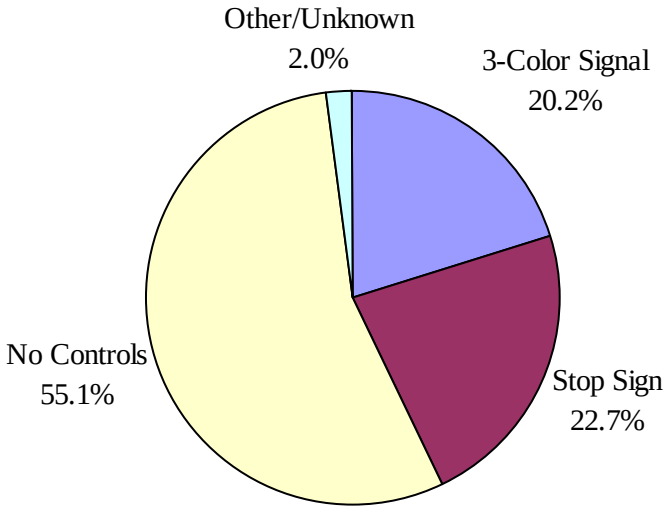


Figure 4. Distribution of Aggregate Traffic Control Device Statistics for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Table 6. Distribution of Traffic Control Device Statistics for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Traffic Control Device	Scenario								Total
	1	2	3	4	5	6	7	8	
3-Color Signal	5,000	*	3,000	1,000	1,000	*	1,000	*	13,000
Stop Sign	8,000	*	2,000	1,000	1,000	2,000	1,000	1,000	15,000
No Controls	12,000	9,000	1,000	2,000	2,000	*	*	8,000	36,000
Other/Unknown	1,000	*	*	*	*		*	*	1,000
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

- Numbers in cells were rounded to the nearest 1,000.
- Empty cells refer to categories that had no crashes in the 1995-1998 GES samples.
- The symbol * represents crash frequencies below 500.

4.4. Relation to Roadway

The *Relation to Roadway* variable from the GES "Accident File" indicates the location with respect to the roadway of the first harmful event in the crash. This variable was broken down into five categories as follows:

Relation to Roadway
Code 01 = "On Roadway"
Code 02 = "On Shoulder or Parking Lane"
Code 03 = "Off Roadway/Shoulder/Parking Lane"
Code 04 = "On Median"
All Other Codes = "Other/Unknown"

Table 7 displays GES relation to roadway statistics for the pedalcyclist pre-crash scenarios. Overall, 97.6% of all these crashes occurred on the roadway. About 10.2% of the crashes in pre-crash scenario 8, described as vehicle performing other maneuvers, occurred off the roadway, shoulder, or parking lane. This scenario exhibited the largest relative frequency of "Off Roadway" crashes among the eight scenarios. Crashes in which the vehicle is backing or parking are included in the category "other" maneuvers for scenario 8; therefore, it is understandable that scenario 8 has the largest frequency of "Off Roadway" crashes.

Table 7. Relation to Roadway Statistics for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Relation to Roadway	Scenario								Total
	1	2	3	4	5	6	7	8	
On Roadway	100.0%	98.1%	99.9%	97.8%	98.7%	100.0%	99.5%	87.5%	97.6%
On Shoulder or Parking Lane	0.0%	0.8%	0.1%	1.9%	0.5%	0.0%	0.0%	1.9%	0.6%
Off Roadway/Shoulder/Parking Lane	0.0%	1.0%	0.0%	0.3%	0.8%	0.0%	0.5%	10.2%	1.8%
On Median	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

5. CONTRIBUTING FACTORS AND CIRCUMSTANCES

The GES crash database includes many variables that point to driver and pedalcyclist factors that might have contributed to pedalcyclist crashes. Also included in the GES are variables describing the environmental conditions at the crash sites. Unfortunately, the GES does not contain variables that directly indicate the primary cause of the crash. Thus, the GES variables were investigated in an attempt to identify one dominant factor that might have contributed to the cause of each crash. The association of one dominant contributing factor with a crash was achieved by using a priority scheme as described below. Driver and pedalcyclist factors were separately examined.

5.1. Priority-Based Contributing Factors

A priority-based scheme was devised to deduce one dominant contributing factor for each crash by ranking driver or pedalcyclist factors in a descending order where the top factor superseded all other factors below it on the list. For instance, alcohol or drugs superseded other factors such as impairment, distraction, and speeding. In turn, the impairment factor superseded the distraction and speeding factors. Thus, this analysis first determined the portion of crashes that involved alcohol or drugs and then adopted a process of elimination to quantify the involvement of other factors. The remaining crashes were secondly examined to identify the portion of crashes that were attributed to impairment. The involvement of each of the other factors such as distraction or speeding was then sequentially determined from the remaining crashes.

5.1.1. *Priority-Based Driver Contributing Factors*

The following list ranks driver contributing factors that are available from GES variables:

1. Alcohol/Drugs
2. Impaired
3. Driver Distracted By
4. Driver Vision Obscured By
5. Speeding/Reckless Driving
6. Sign/Signal Violation
7. Driver Lost Control
8. Other Violation Charged
9. Hit & Run

The *Hotdeck Imputed Police Reported Alcohol Involvement* variable indicates that a driver had consumed an alcoholic beverage. The *Person's Physical Impairment* variable attempts to identify driver physical impairments that might have contributed to the cause of the crash such as illness, blackout, drowsiness, fatigue, or impairment due to previous injury. The *Driver Distracted By* variable attempts to capture distractions that might have influenced driver performance and contributed to the cause of the crash. These

distractions include passengers, vehicle instrument display, phone, other internal distractions, other crash, or external distractions. The *Driver's Vision Obscured By* variable refers to visual circumstances that might have contributed to the cause of the crash such as rain, snow, fog, bright sunlight, other vehicles, trees, or other physical obstructions. Driver or witness statements are not considered unless verified by the investigating police officer. The *Imputed Violations Charged* variable indicates the type of violation charged to the driver of a vehicle involved in the crash such as speeding/reckless driving and sign/signal violation. The *Critical Event* variable indicates whether or not the driver lost control prior to the crash. The *Imputed Hit and Run* variable is coded when a motor vehicle in transport or its driver departs from the scene of the crash. If the driver leaves the scene, with or without the vehicle, the police accident report typically contains little information about the drivers' actions, and therefore contributing factors are generally unknown. However, very few cases of hit and run crashes in the GES might contain information on whether or not the driver was drunk or impaired typically reported by eyewitnesses.

Other pedalcyclist crashes not linked to any of the contributing factors listed above were separated by the following environmental factors to establish other circumstances that may have potentially contributed to the crash:

- Day/Clear
- Day/Adverse
- Night/Clear
- Night/Adverse

This priority-based scheme identifies dominant factors that may have contributed to the cause of the crash by deductive reasoning and generally does not describe the environmental conditions at the time of the crash. This analysis considers the combination of the *Imputed Light Condition* and *Imputed Atmospheric Conditions* variables from the GES. The *Imputed Light Condition* variable denotes general light conditions at the time of the crash, taking into consideration the existence of external roadway illumination fixtures. All non-daylight conditions, including dark but lighted, dusk and dawn, were grouped as "night." The *Imputed Atmospheric Conditions* variable points to general atmospheric conditions at the time of the crash such as clear or adverse weather. All adverse weather conditions that include rain, sleet, snow, fog, and smog were categorized as "adverse." The lighting and weather conditions in combination constitute another important crash contributing factor, both of which might make it difficult for the driver to see pedalcyclists. Note: the Washington State Department of Transportation crash database contains pedalcyclist clothing color data ("Dark," "Light," "Mixed," "Retro-Reflective," and "Other Reflective Apparel") that might be useful in providing insight into the development of additional vehicle-based and vehicle-infrastructure cooperative countermeasure systems.

Figure 5 illustrates the distribution of crash contributing factors in all pedalcyclist pre-crash scenarios defined in Table 3. The relative frequency of each factor was determined following our priority-based scheme, starting clockwise from "Alcohol/Drugs" as the top

factor. The sum of all relative frequencies shown in Figure 5 adds up to 100% since one contributing factor was attributed to each driver. About 65,000 drivers were involved in crashes with pedalcyclists per year based on 1995-1998 GES. Approximately 33% of all crashes covered in Figure 5 were attributed to alcohol/drugs, impairment, distraction, vision obscuration, speeding, traffic violations, driver losing control, or hit and run. The other 66% of the crashes were described in terms of the environmental conditions at the time of the crash. About 15% of these crashes occurred at night and/or in adverse weather, indicating that visibility might have played a dominant role in the crash. The remaining 51% of crashes in which no other contributing factors were catalogued happened in clear day conditions. One can deduce from this last statistic that the driver might have been inattentive or distracted, or that the pedalcyclist might have contributed to the cause of the crash.

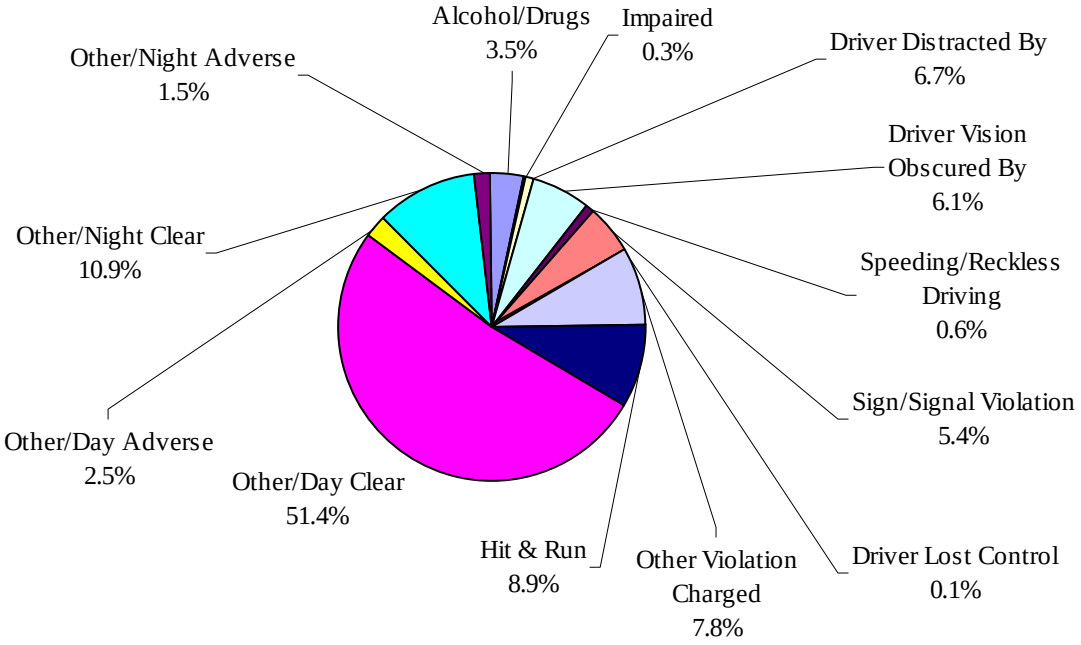


Figure 5. Distribution of Priority-Based Driver Contributing Factors in Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Table 8 breaks down the driver contributing factors for each scenario. Alcohol or drugs accounted for 3.5% of all pedalcyclist crashes in the pre-crash scenarios as illustrated in Figure 5. The highest relative frequency of this factor was about 6% in pre-crash scenario 2 that involved a vehicle traveling straight on parallel paths with the pedalcyclist. Overall, driver impairment (excluding alcohol or drugs) was negligible and accounted for merely 0.3% of all crashes in the pedalcyclist pre-crash scenarios, having the highest relative frequency of 0.5% of crashes in scenario 1 (vehicle traveling straight/crossing paths). Driver distraction accounted for merely 1.0% of all crashes. The highest contribution of obscured driver vision was reported as 10.4% in pre-crash

scenario 6, in which the vehicle was starting in a traffic lane and crossed paths with the pedalcyclist. A high contribution of speeding or reckless driving was found in 1.2% of the crashes in scenario 2 (vehicle traveling straight and parallel path) and 1.7% in scenario 8 (vehicle performs an other maneuver). Overall, driver control loss was negligible and account for only 0.1% of all pedalcyclist crashes.

Table 8. Breakdown of Priority-Based Driver Contributing Factors by Individual Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Contributing Factor	Scenario							
	1	2	3	4	5	6	7	8
Alcohol/Drugs	2.8%	6.1%	4.3%	2.9%	3.9%	1.0%	1.3%	3.4%
Impaired	0.5%	0.4%	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%
Driver Distracted By	1.1%	0.7%	1.0%	1.0%	0.8%	0.3%	0.7%	1.3%
Driver Vision Obscured By	7.4%	1.5%	4.1%	4.6%	9.3%	10.4%	9.2%	6.4%
Speeding/Reckless Driving	0.3%	1.2%	0.4%	0.5%	0.0%	0.0%	0.0%	1.7%
Sign/Signal Violation	2.4%	0.3%	8.5%	6.4%	25.2%	21.4%	7.0%	3.5%
Driver Lost Control	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%
Other Violation Charged	6.5%	6.3%	11.6%	11.7%	7.3%	6.2%	15.6%	7.7%
Hit & Run	7.4%	14.6%	9.7%	14.1%	4.5%	0.7%	6.7%	8.0%
Other/Day Clear	57.0%	51.8%	49.8%	41.3%	30.4%	51.3%	29.1%	55.5%
Other/Day Adverse	1.9%	4.6%	2.1%	0.5%	1.1%	0.6%	1.9%	4.3%
Other/Night Clear	11.5%	10.5%	8.2%	16.7%	13.6%	2.7%	16.9%	7.6%
Other/Night Adverse	1.1%	1.6%	0.3%	0.1%	3.5%	5.4%	11.7%	0.4%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000

The driver was charged with other traffic violations significantly in pre-crash scenarios 3 (11.6%) and 4 (11.7%) in which the vehicle was turning right, and in 8 (15.6%). A relatively high frequency of 25.2% of the crashes in scenario 5, vehicle turning left while on parallel paths with the cyclist, involved a sign/signal violation; although a violation of the traffic control device occurred in only 5.4% of the overall crashes.

The driver was not drunk, impaired, distracted, speeding, or charged with any violations; did not see pedalcyclist due to vision obstruction; or hit pedalcyclist and fled the scene in about 66% of all crashes covered in Table 8. The atmospheric conditions of these crashes were examined to find out whether visibility or inattention, not mentioned in police-accident reports, might have played a role in the crash. Among all pre-crash scenarios, scenarios 1, 2, 3, 6 and 8 had crash frequencies of approximately 50% or higher attributed to day and clear weather conditions. On the other hand, daylight and clear weather were reported individually in only about 30% of the crashes in scenario 5 and scenario 7. Under day and clear weather conditions, the driver might have been inattentive or the pedalcyclist might not have seen or misjudged the distance to the vehicle.

5.1.2. *Priority-Based Pedalcyclist Contributing Factors*

This analysis also investigates pedalcyclist conditions or actions that might have contributed to pedalcyclist crashes. A priority-based scheme was adopted to identify one dominant pedalcyclist contributing factor for each crash based on the following list:

1. Alcohol/drugs
2. Impaired
3. No lights when required
4. Operating without required equipment
5. Improper/erratic lane change
6. Failing to keep in lane/running off road
7. Improper entry/exit from trafficway
8. Operating vehicle (bicycle) in erratic, reckless, negligent manner
9. Fail to yield right of way
10. Fail to obey traffic signs/control devices/officers/safety zone
11. Making other improper turn
12. Driving on wrong side of road

The alcohol/drugs factor indicates that the police reported alcohol or drug involvement for the pedalcyclist. The impaired factor indicates if the pedalcyclist was physically impaired, including drowsiness, illness, or physical impairment. The other factors were extracted from the *Non-Motorist Action* variable in the "Person File" for each pedalcyclist and are self-explanatory. Figure 6 shows the overall breakdown of pedalcyclist contributing factors for the eight scenarios starting clockwise from "Alcohol/drugs" as the most important factor. These statistics were based on the number of pedalcyclists involved in pedalcyclist crashes and not on the number of crashes since one crash might involve more than one pedalcyclist. Based on 1995-1998 GES statistics, the number of pedalcyclists involved in motor vehicle crashes amounted to 67,000 per year over the pre-crash scenarios. Overall, 2.2% of the pedalcyclists were under the influence of alcohol or drugs at the time of the crash. In comparison, about 3.5% of drivers were under the influence of alcohol or drugs in pedalcyclist crashes. Of the remainder, about 0.3% of the pedalcyclists were impaired at the time of the crash. A little over 24% of the pedalcyclists failed to yield right of way. In comparison, about 12% of the pedalcyclists in fatal crashes, as determined from analysis of the FARS 1995-1998 databases, were determined to have failed to yield the right of way to the vehicle. Also of significance, approximately 17% of the pedalcyclists were cited with driving on the wrong side of the road. About 39% of the pedalcyclists did not have any associated contributing factors.

Table 9 breaks down pedalcyclist contributing factors by each of the pedalcyclist pre-crash scenarios. About 13% of pedalcyclists performed an improper entry or exit from the trafficway in pre-crash scenario 1 that involved the vehicle traveling straight on an intersecting path with the pedalcyclist(s). Over 50% of pedalcyclists in scenario 1 also failed to yield the right of way to the vehicle before the crash. Over 50% of the pedalcyclists in scenario 6 (vehicle starting in traffic lane/crossing paths) and approximately 42% of the pedalcyclist in scenario 3 (vehicle turning right/crossing paths)

were charged with driving on the wrong side of the road. Approximately 25% of the pedalcyclists in scenario 7, vehicle turning left on crossing paths with pedalcyclist, were charged with failing to yield the right of way. Little can be discerned from the data for the other scenarios aside from the "Fail to yield right of way" and "Driving on wrong side of road" contributing factors. This is especially true of scenario 5 in which approximately 75% of the pedalcyclists did not have a contributing factor associated with them. Also listed in Table 9 is the "All other pedalcyclists" category that includes the pedalcyclists who did not have one of the listed contributing factors associated with them.

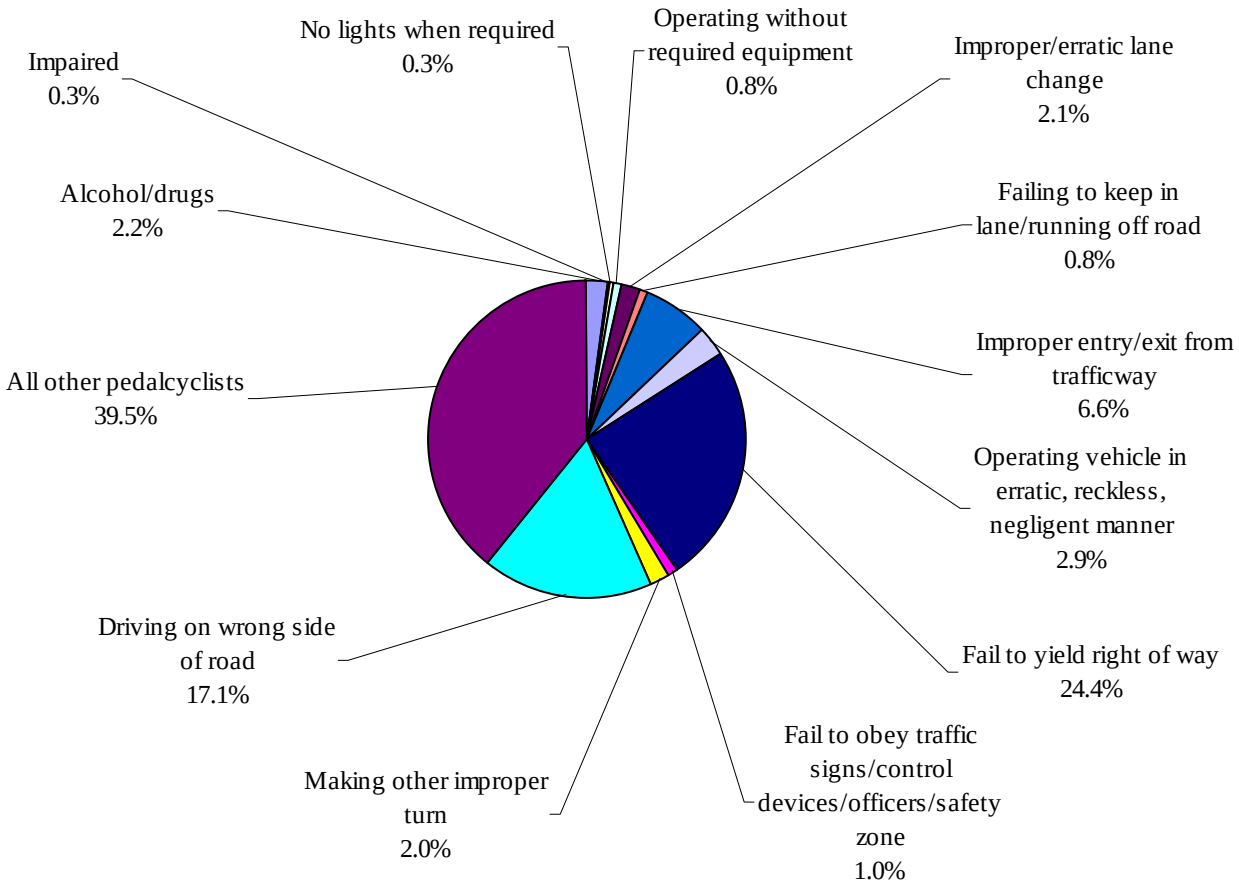


Figure 6. Breakdown of Priority-Based Pedalcyclist Contributing Factors for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Table 9. Breakdown of Priority-Based Pedalcyclist Contributing Factors by Individual Pre-Crash Scenario (Based on 1995-1998 GES)

Contributing Factor	Scenario								Total
	1	2	3	4	5	6	7	8	
Alcohol/drugs	2.3%	3.8%	1.6%	0.6%	2.6%	1.8%	4.9%	0.5%	2.2%
Impaired	0.1%	0.3%	1.1%	0.2%	0.2%	1.2%	0.0%	0.3%	0.3%
No lights when required	0.0%	0.1%	0.2%	0.0%	0.5%	0.4%	2.7%	0.8%	0.3%
Operating without required equipment	0.1%	1.9%	0.4%	0.2%	1.1%	0.8%	0.0%	1.7%	0.8%
Improper/erratic lane change	0.7%	11.1%	0.0%	0.6%	0.2%	0.0%	0.0%	0.7%	2.1%
Failing to keep in lane/running off road	0.7%	2.3%	0.3%	0.3%	0.5%	0.0%	0.3%	0.3%	0.8%
Improper entry/exit from trafficway	12.7%	4.3%	1.2%	4.1%	2.1%	0.3%	0.6%	1.9%	6.6%
Operating vehicle in erratic, reckless, negligent manner	1.4%	7.5%	1.2%	4.1%	2.4%	0.6%	0.0%	4.0%	2.9%
Fail to yield right of way	50.5%	6.3%	12.8%	0.2%	0.1%	7.1%	25.3%	6.1%	24.4%
Fail to obey traffic signs/control devices/officers/safety zone	1.8%	0.0%	0.3%	0.3%	2.3%	0.7%	1.4%	0.0%	1.0%
Making other improper turn	0.7%	9.4%	0.1%	0.1%	0.8%	0.0%	0.7%	1.0%	2.0%
Driving on wrong side of road	4.2%	13.8%	41.9%	29.2%	12.7%	52.5%	22.4%	27.5%	17.1%
All other pedalcyclists	24.6%	39.1%	38.8%	60.1%	74.5%	34.7%	41.7%	55.0%	39.5%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	27,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	67,000

5.2 Atmospheric Conditions

In an effort to determine additional conditions that could have contributed to pedalcyclist crashes other than the factors that are detailed above, an analysis of atmospheric conditions present at these crashes was performed. Atmospheric conditions relate to whether the crash took place during the daytime or nighttime and in clear or adverse weather conditions. Table 10 lists the results of this analysis for each of the pedalcyclist pre-crash scenarios.

Based on GES statistics, most pedalcyclist crashes occurred in daytime under clear weather conditions, accounting for over 76% of all crashes in the eight pre-crash scenarios. Moreover, clear weather was reported in 94.3% of these crashes. Daytime was reported in almost 80% of these crashes. As expected, adverse weather conditions were reported in merely 5.7% of all crashes in the pre-crash scenarios due to the fact that fewer people ride their bikes in these conditions.

Table 10 presents the breakdown of atmospheric conditions for each pedalcyclist pre-crash scenario independently. Scenario 7 (vehicle turning left/crossing paths) contained the highest relative frequency of nighttime crashes as well as crashes in adverse weather over the other scenarios. It should be noted that scenario 7 also had a high relative frequency of driver vision obscurity (9.2%). Although small in relative frequency terms, over five and a half times as many crashes in scenario 4, involving a vehicle turning right across the path of the pedalcyclist from the same parallel direction, occurred under "day/adverse" conditions than in "night/adverse" conditions.

Table 10. Breakdown of Atmospheric Conditions Statistics for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Atmospheric Conditions	Scenario								Total
	1	2	3	4	5	6	7	8	
Day Clear Conditions	77.1%	71.7%	79.8%	73.5%	71.4%	88.4%	57.9%	80.2%	76.1%
Day Adverse Conditions	2.5%	5.9%	2.3%	2.8%	2.1%	1.7%	4.5%	5.6%	3.5%
Night Clear Conditions	18.6%	20.4%	17.4%	23.1%	21.6%	3.8%	25.0%	12.8%	18.2%
Night Adverse Conditions	1.8%	2.0%	0.5%	0.5%	5.0%	6.1%	12.6%	1.3%	2.2%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

6. AGE INVOLVEMENT

6.1. Driver Age

The age of the driver at the time of the crash, with respect to the person's last birthday, is found in the *Hot-deck Imputed Age* variable located in the driver's "Person File" from the GES crash databases [7]. This variable replaces the unknown values using information from other correlated variables, thus eliminating all unknown information. The distribution of driver age within each pre-crash scenario is shown in Table 11, with the "Total" row reflecting number of drivers. Note that the "Under 20" age category is composed of drivers aged from 14 years to 19 years old. This information is valuable in determining which driver age groups are most susceptible to each scenario analyzed.

Table 11. Driver Age Distribution for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

AGE (years)	Scenario								Total
	1	2	3	4	5	6	7	8	
Under 20	9.6%	11.6%	7.9%	11.7%	15.8%	10.5%	9.0%	8.7%	10.2%
20-24	10.4%	9.3%	13.3%	15.2%	12.1%	12.6%	11.2%	11.6%	11.2%
25-29	12.2%	11.1%	6.0%	13.1%	7.9%	9.4%	10.7%	9.8%	10.7%
30-34	12.8%	15.8%	13.9%	14.4%	10.3%	16.8%	9.5%	9.7%	12.9%
35-39	14.5%	13.3%	10.4%	9.1%	6.1%	13.2%	15.9%	13.1%	12.7%
40-44	8.3%	10.6%	10.4%	9.3%	9.6%	8.9%	8.1%	15.9%	10.2%
45-49	9.4%	5.7%	7.1%	4.7%	9.4%	7.8%	11.5%	6.8%	7.9%
50-54	4.8%	7.0%	8.5%	5.5%	4.1%	7.5%	7.9%	8.0%	6.1%
55-59	3.1%	4.6%	6.0%	3.7%	9.4%	2.9%	3.5%	4.8%	4.4%
60-64	4.5%	3.0%	7.0%	5.4%	2.0%	4.0%	5.1%	3.4%	4.3%
65-69	3.3%	1.8%	2.7%	3.3%	4.0%	0.9%	1.2%	2.9%	2.9%
70-74	2.8%	2.1%	1.5%	2.0%	1.3%	4.2%	1.3%	2.9%	2.4%
75-79	2.2%	1.1%	0.9%	1.2%	3.5%	0.0%	0.0%	1.9%	1.7%
80-84	0.7%	1.1%	1.9%	0.7%	1.8%	0.3%	0.9%	0.4%	0.9%
85+	1.3%	1.8%	2.6%	0.7%	2.7%	0.9%	4.0%	0.2%	1.5%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

Figure 7 provides an age comparison between the drivers involved in pedalcyclist crashes and drivers involved in all crashes. The driver age distribution for all crashes was obtained from NHTSA's yearly publication of *Traffic Safety Facts* [8]. The breakout of driver age shown in Table 11 was reorganized to directly compare with the age groupings used in NHTSA's report. Overall, the age group of 25-34 years old enveloped the greatest frequency of drivers involved in pedalcyclist crashes, accounting for almost 24% of the total drivers involved in the pedalcyclist crash problem. When compared to the national age distribution for drivers involved in all crashes, all age groups under 45 years old were under-represented. Conversely, age groups over 55 years old were over-represented. Older drivers, especially those aged 55-64, had a higher frequency of involvement in pedalcyclist crashes compared to their overall involvement in all crashes. Moreover,

younger drivers were less likely to be involved in pedalcyclist crashes compared to other crash types.

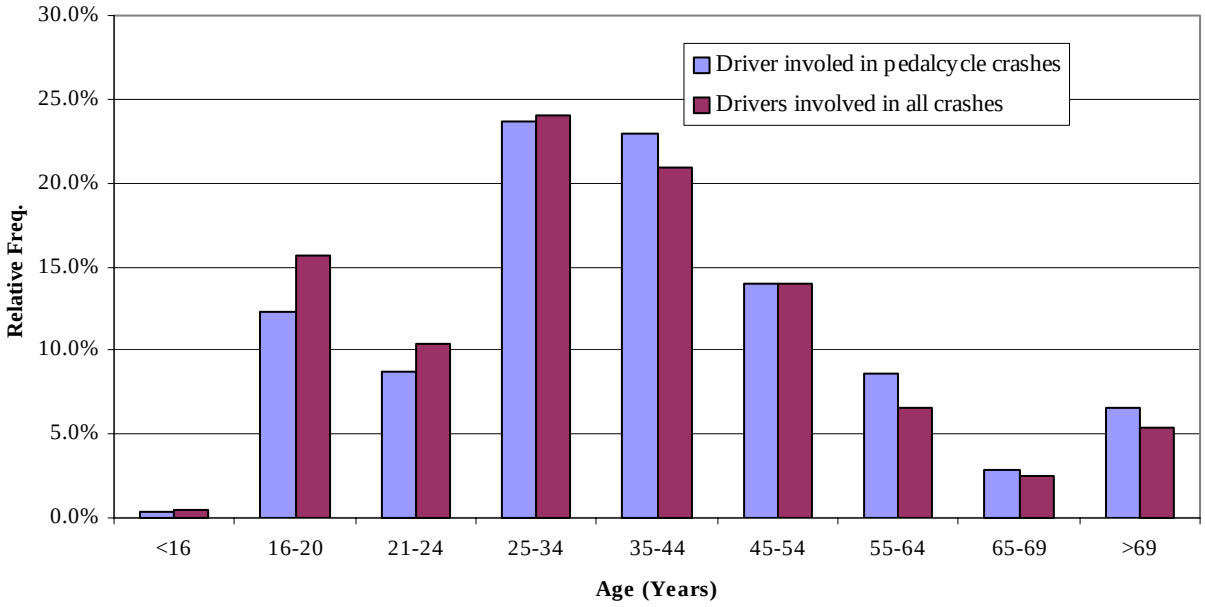


Figure 7. Driver Age Distributions for Pedalcyclist Crashes and Overall Crash Driver Age Distribution (Based on 1995-1998 GES)

A better way to compare driver age statistics would be to normalize the crash rate by driving exposure for each age group. Driving exposure for licensed driver age groups was obtained from the 1995 *National Personal Transportation Study* [9] to obtain a driver crash involvement rate per 100 million vehicle miles traveled (VMT) for all age categories. Table 12 displays the results of normalizing the crash rate by VMT's for each age group based on Reference [9]. The data in Table 12 reflect the driver involvement rate in pedalcyclist crashes per 100 million VMT. As shown in the column representing the overall driver involvement rate, there were about 5.0 yearly crashes per 100 million VMT across all scenarios and age groups. Drivers in the 85+ age group had the highest involvement rate at 29.0 crashes per 100 million VMT. The spike for driver involvement 85+ years of age may be a result of using the *Hot-deck Imputed Age* variable. The youngest segment of the driving population, those aged under 20 years old, retained the second-highest pedalcyclist crash involvement rate at 14.1 crashes per 100 million VMT. In general, the middle-age driving population tended to have the lowest crash involvement rate over all of the pre-crash scenarios. The driver crash involvement rate per VMT follows a "U" shape curve in which the youngest and oldest age groups tend to have a higher involvement rate than the middle-aged groups. The driver involvement rate is not as uniform in the latter scenarios, due to the relative small sample size of the crash population in those scenarios and the potential sampling errors associated with the GES database.

Table 12. Driver Involvement per 100 Million VMT per Age Group for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

AGE (years)	Scenario								Overall per Age Group
	1	2	3	4	5	6	7	8	
Under 20	5.2	2.4	1.0	1.2	1.7	0.4	0.4	1.8	14.1
20-24	2.6	0.9	0.8	0.7	0.6	0.2	0.2	1.1	7.0
25-29	2.2	0.8	0.2	0.4	0.3	0.1	0.1	0.7	4.8
30-34	2.1	1.0	0.5	0.5	0.3	0.2	0.1	0.6	5.4
35-39	2.3	0.8	0.4	0.3	0.2	0.2	0.2	0.8	5.0
40-44	1.3	0.6	0.4	0.3	0.3	0.1	0.1	1.0	4.1
45-49	1.6	0.4	0.3	0.2	0.3	0.1	0.2	0.5	3.5
50-54	1.1	0.6	0.5	0.3	0.2	0.1	0.1	0.7	3.7
55-59	0.9	0.5	0.4	0.2	0.5	0.1	0.1	0.6	3.3
60-64	1.8	0.5	0.6	0.4	0.2	0.1	0.2	0.5	4.3
65-69	1.7	0.3	0.3	0.3	0.4	0.0	0.0	0.6	3.8
70-74	2.1	0.6	0.3	0.3	0.2	0.2	0.1	0.8	4.6
75-79	3.0	0.6	0.3	0.3	0.9	0.0	0.0	1.0	6.0
80-84	2.0	1.2	1.3	0.4	1.0	0.1	0.2	0.5	6.8
85+	10.3	5.3	4.7	1.0	4.1	0.5	2.4	0.6	29.0
Overall	2.0	0.8	0.5	0.4	0.4	0.2	0.2	0.8	5.0
Total Crash Pop.	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

Yet another method of analyzing the driver age statistics would be to normalize them using the number of licensed drivers per age group. This can be accomplished by dividing the number of drivers that were involved in pedalcyclist crashes within each age group by the total number of licensed drivers in the same group. Table 13 shows the breakdown of the driver involvement rate per 1,000 licensed drivers for each age group across all eight scenarios per year based on 1995-1998 GES statistics. Overall, there were about 0.36 driver involved in pedalcyclist crashes per 1,000 licensed drivers. Drivers aged less than 20 years old held the highest probability of becoming involved in a crash with a pedalcyclist, almost 0.7 drivers per 1,000 licensed drivers. About 0.58 drivers per 1,000 licensed drivers in the 85+ age group were involved in crashes with pedalcyclists, the age group thus having the second-highest driver involvement rate based on the licensed driver population. Generally, the figures show that younger drivers had the highest crash involvement rate based on the licensed driver population in their own age group. The crash involvement rate declined with age until it climbed again for the oldest segment of driver population (85+).

Figure 8 displays the driver involvement rate in pedalcyclist crashes normalized by both VMT and total driver population. As seen in the figure, both curves follow a similar pattern in which the youngest and oldest driving populations both have the highest crash involvement rate and highest crash involvement likelihood.

Table 13. Driver Involvement per 1,000 Licensed Drivers per Age Group for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

AGE (years)	Scenario								Overall per Age Group
	1	2	3	4	5	6	7	8	
Under 20	0.25	0.12	0.05	0.06	0.08	0.02	0.02	0.09	0.69
20-24	0.18	0.06	0.05	0.05	0.04	0.02	0.01	0.08	0.48
25-29	0.18	0.06	0.02	0.04	0.02	0.01	0.01	0.05	0.39
30-34	0.17	0.08	0.04	0.04	0.03	0.02	0.01	0.05	0.44
35-39	0.18	0.06	0.03	0.02	0.01	0.01	0.02	0.06	0.40
40-44	0.11	0.05	0.03	0.02	0.02	0.01	0.01	0.08	0.33
45-49	0.13	0.03	0.02	0.01	0.03	0.01	0.01	0.04	0.29
50-54	0.08	0.05	0.03	0.02	0.01	0.01	0.01	0.05	0.26
55-59	0.07	0.04	0.03	0.02	0.04	0.00	0.01	0.04	0.24
60-64	0.12	0.03	0.04	0.03	0.01	0.01	0.01	0.04	0.30
65-69	0.10	0.02	0.02	0.02	0.02	0.00	0.00	0.03	0.23
70-74	0.10	0.03	0.01	0.01	0.01	0.01	0.00	0.04	0.22
75-79	0.10	0.02	0.01	0.01	0.03	0.00	0.00	0.03	0.21
80-84	0.06	0.03	0.04	0.01	0.03	0.00	0.01	0.01	0.19
85+	0.21	0.11	0.09	0.02	0.08	0.01	0.05	0.01	0.58
Overall	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.36
Total Crash Pop.	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

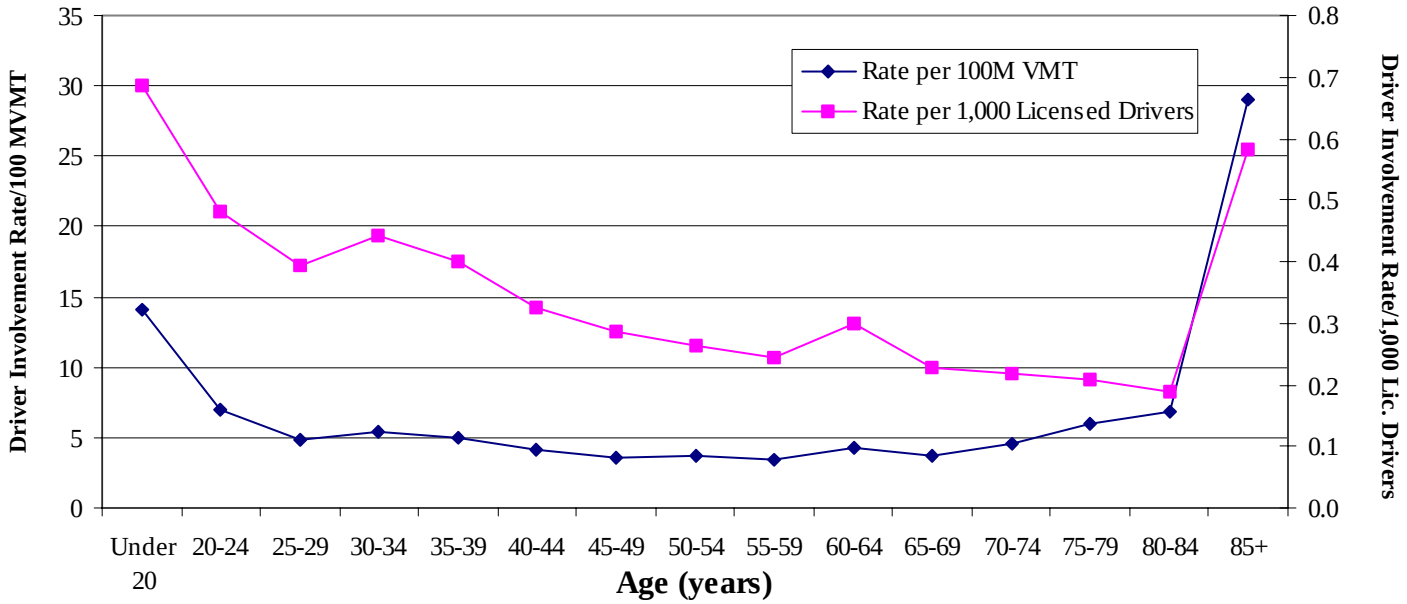


Figure 8. Driver Involvement Rate per 100M VMT and per 1,000 Licensed Drivers over All Pedalcyclist Crashes (Based on 1995-1998 GES)

6.2. Pedalcyclist Age

The age of the pedalcyclist at the time of the crash, with respect to the person's last birthday, is found in the *Hot-deck Imputed Age* variable located in the "Person File" from the GES crash databases [7]. The distribution of pedalcyclist age within each pre-crash scenario is shown in Table 14, with the "Total" row reflecting number of pedalcyclists, not crashes. This information is valuable in determining which pedalcyclist age groups are most susceptible to each scenario analyzed in this study.

Table 14. Pedalcyclist Age Distribution for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

AGE	Scenario								Overall
(years)	1	2	3	4	5	6	7	8	Scenarios
0-4	0.8%	0.3%	0.0%	2.5%	0.0%	0.5%	0.0%	1.3%	0.8%
5-9	19.2%	7.5%	3.5%	1.4%	5.6%	1.0%	8.7%	7.0%	11.0%
10-14	34.4%	30.0%	25.5%	15.9%	11.1%	18.1%	21.1%	18.0%	26.6%
15-19	14.4%	14.1%	13.4%	16.7%	10.2%	26.4%	15.4%	21.7%	15.6%
20-24	8.9%	7.7%	12.0%	12.9%	14.5%	11.2%	12.6%	10.6%	10.1%
25-29	5.7%	9.3%	5.5%	12.0%	10.3%	3.0%	10.7%	8.9%	7.5%
30-34	4.1%	6.7%	11.6%	9.8%	14.9%	10.1%	9.6%	6.5%	7.1%
35-39	3.7%	8.2%	7.4%	2.8%	10.7%	4.6%	9.8%	6.3%	5.7%
40-44	2.0%	5.4%	8.4%	5.4%	9.9%	12.5%	4.6%	7.4%	5.1%
45-49	2.3%	4.3%	2.8%	7.5%	5.1%	4.4%	2.4%	3.3%	3.4%
50-54	1.2%	2.8%	1.5%	0.4%	3.0%	3.0%	2.7%	2.9%	1.9%
55-59	1.1%	0.8%	0.9%	2.9%	1.3%	1.1%	0.0%	1.4%	1.2%
60-64	0.6%	0.5%	2.6%	5.3%	0.6%	0.5%	0.3%	1.9%	1.3%
65-69	0.4%	0.4%	1.7%	2.4%	2.0%	0.8%	0.3%	0.8%	0.9%
70-74	0.4%	0.4%	2.1%	1.5%	0.8%	1.5%	0.4%	1.0%	0.8%
75-79	0.5%	1.1%	0.6%	0.3%	0.0%	0.0%	0.9%	0.6%	0.6%
80-84	0.1%	0.2%	0.0%	0.0%	0.0%	0.9%	0.0%	0.4%	0.2%
85+	0.1%	0.2%	0.4%	0.2%	0.0%	0.5%	0.6%	0.0%	0.1%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	27,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	67,000

In addition to presenting the distribution of pedalcyclist age within each scenario, Table 14 also shows the age distribution for all pedalcyclists involved in motor vehicle crashes, as shown on the "Total" column to the right of the table.

Children accounted for a great portion of pedalcyclists in every pre-crash scenario based on GES statistics. In the scenario in which the vehicle is traveling straight on an intersecting path with the pedalcyclist (scenario 1), children less than 15 years old accounted for almost 55% of that scenario's pedalcyclists. Roughly three-fifths of those 0 to 14 year-olds, accounting for 34.4% of the total number of pedalcyclists in that scenario, were in the 10 to 14 year-old age group. Overall, children ranging from 0 to 14 years old accounted for nearly 38% of all pedalcyclists in this crash type. Moreover,

roughly two-thirds of the pedalcyclists involved in motor vehicle crashes were less than 25 years of age. The single highest age bin is the range of 10 to 14 year-olds, which accounted for about 27% of all pedalcyclists in this crash type. By contrast, pedalcyclists aged 60 years old or older accounted for approximately 4% of all crash-involved pedalcyclists.

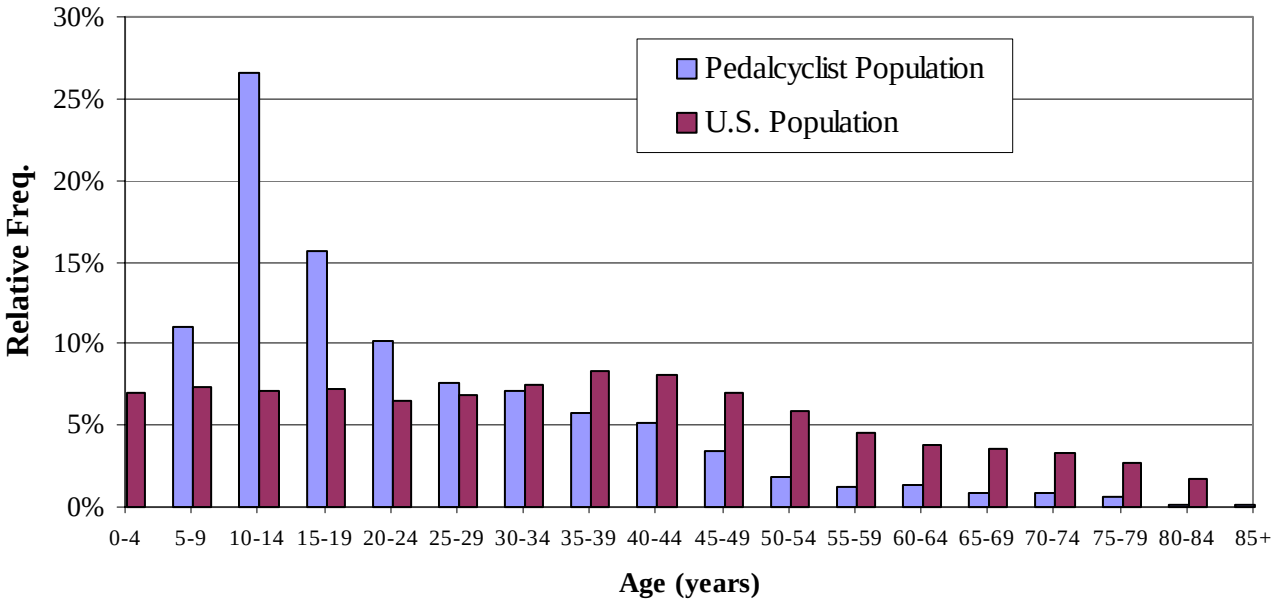


Figure 9. Pedalcyclist Age Distribution for Aggregate Crash Scenario Total and U.S. Population Distribution (Based on 1995-1998 GES)

The pedalcyclist age distribution was also compared to the age distribution of the U.S. population based on data estimated by the U.S. Bureau of the Census from 1998 [10]. Figure 9 displays the percent distribution of each age category for the overall pedalcyclist crash population, as well as the age distribution for the U.S. population. It shows the over-representation of young persons aged from 5 to 29 years old and the under-representation of all others in the pedalcyclist crash population. More specifically, pedalcyclists aged from 10-14 years old represented nearly 27% of the pedalcyclists in this crash type and yet they only make up about 7.1% of the U.S. population. (See Table C-2 in Appendix C for actual population distribution numbers as of 1998 estimated by the U.S. Bureau of the Census.) It should be noted that exposure data on bicycle riding by different age groups would be a better relative measure of risk by age group, but such data is not readily available. If it were readily available it could help in explaining why children are over-represented and seniors are under-represented in the pedalcyclist crash population. Anecdotally, children and teenagers tend to be the most frequent users of bicycles, especially those in the 10-19 year-old age groups. Quantitative data on this assumption could shed some light onto the reasons as to why there are so many children and teenagers involved in pedalcyclist crashes. Conversely, older cyclists are statistically under-represented in terms of the overall U.S. population but they could be well over-represented in terms of their bicycle riding exposure.

7. CRASH SEVERITY

7.1. Number of Pedalcyclists per Crash

According to GES statistics, about 67,000 pedalcyclists are involved in an average of 65,000 motor-vehicle crashes each year. Analyzing the severity of pedalcyclists' injuries for each pre-crash scenario gives insight as to the severity of each scenario relative to the overall pedalcyclist crash problem as well as relative to the other scenarios. Certain scenarios, as defined in this report, have a higher concentration of multiple pedalcyclists involved per crash than others. The GES databases can be queried in a manner that reveals how many were involved per crash by analyzing the number of "Person Files" associated with pedalcyclists (see Table 15). The percentage statistics relate the number of crashes within each scenario and the "Total" column accounting for the distribution of the number of pedalcyclists over all pedalcyclist crashes. As expected, most crashes involved a single pedalcyclist, accounting for over 97% of the crashes in the pre-crash scenarios. Crashes in which two pedalcyclists were involved accounted for 2.3% of the aggregate scenario population. Scenarios 4 and 8 show the highest relative concentration of two-pedalcyclist crashes among the eight scenarios, 3% and 4% of each scenario respectively. In terms of absolute crashes, scenario 1 has the highest number of two-pedalcyclist crashes, accounting for about 2,600 such crashes involving the vehicle going straight and crossing paths with the cyclist. Overall, about 1,500 multi-pedalcyclist crashes occurred per year, based on 1995-1998 GES statistics.

Table 15. Number of Pedalcyclists per Crash for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

# of Pedal.	Scenario								Total
Per Crash	1	2	3	4	5	6	7	8	
1	97.4%	98.3%	98.4%	96.9%	99.3%	98.7%	97.6%	96.0%	97.6%
2	2.5%	1.6%	1.2%	3.0%	0.7%	1.3%	2.4%	4.0%	2.3%
3	0.0%	0.1%	0.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

7.2. Pedalcyclist Injury Severity

The injury severity sustained by the pedalcyclist in a crash is determined by querying the GES database for the codes associated with the *Hot-deck Imputed Injury Severity* variable found in the "Person File" [7]. The codes for this variable indicate the maximum police reported injury severity for each pedalcyclist following a KABCO injury scale as shown below.

Injury Severity
Code 00 = "No Injury (O)"
Code 01 = "Possible Injury (C)"

Code 02 = “Non-Incapacitating Injury (B)”
Code 03 = “Incapacitating Injury (A)”
Code 04 = “Fatal Injury (K)”
Code 05 = “Injured, Severity Unknown (U)”
Code 06 = “Died Prior to Crash”

Figure 10 displays the aggregate pedalcyclist *Injury Severity* distribution over the pre-crash scenarios. Overall, 43.2% of pedalcyclists involved in a pedalcyclist crash had “non-incapacitating” injuries.

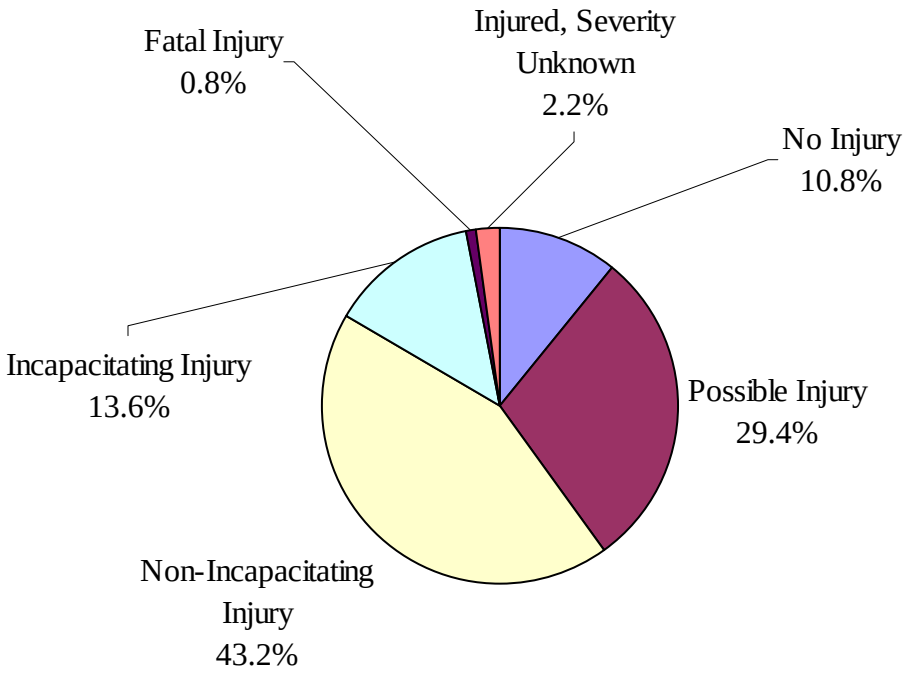


Figure 10. Distribution of Pedalcyclist Injury Severity over All Pedalcyclist Crashes (Based on 1995-1998 GES)

Table 16 shows the distribution of pedalcyclist *Injury Severity* for each pre-crash scenario. Combined, “Incapacitating” and “Fatal” injuries were the highest in scenario 2, where the vehicle was traveling straight on parallel paths with the pedalcyclist. A pedalcyclist was killed in 1.7% of the crashes in that scenario. This scenario also showed the highest relative frequency of alcohol and/or drug involvement over all scenarios. Referring to Table 8, while alcohol and/or drugs were present in only 3.5% of the total pedalcyclist crash population, they were a factor in 6.1% of the crashes in scenario 2. Overall, there were a little over 550 pedalcyclist fatalities per year between 1995 and 1998.

The highest frequency of “No Injury” or “Possible Injury” occurred in scenario 6 where about 49% of the pedalcyclists sustained these lowest injury severities. Specifically, this scenario is defined as a vehicle starting in a traffic lane and crossing paths with a pedalcyclist. Since scenario 6 describes vehicles starting, the relatively low serious

injury risk is most likely due to the low speeds involved in this scenario. As seen in Table 8, speed was not a primary factor in any of the scenario 6 crashes.

Table 16. Pedalcyclist Injury Severity Distribution for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 GES)

Injury Severity	Scenario								Total
	1	2	3	4	5	6	7	8	
No Injury	8.1%	10.5%	12.3%	9.6%	11.5%	16.9%	9.1%	16.5%	10.8%
Possible Injury	30.8%	18.8%	33.2%	36.6%	30.3%	31.8%	27.0%	30.0%	29.4%
Non-Incapacitating Injury	42.8%	48.6%	41.5%	42.2%	45.6%	43.2%	56.5%	36.3%	43.2%
Incapacitating Injury	15.7%	16.7%	10.5%	8.8%	12.2%	8.1%	7.5%	12.2%	13.6%
Fatal Injury	1.0%	1.7%	0.2%	0.2%	0.3%	0.0%	0.0%	0.7%	0.8%
Injured, Severity Unknown	1.6%	3.6%	2.2%	2.6%	0.1%	0.0%	0.0%	4.2%	2.2%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	26,000	10,000	6,000	5,000	5,000	2,000	2,000	10,000	65,000

8. FATAL PEDALCYCLIST CRASHES

8.1. Frequency of Fatal Pedalcyclist Crashes

A four-year set of data from the 1995-1998 FARS databases was queried to obtain counts of fatal pedalcyclist crashes. Over this four-year period, about 37,000 fatal crashes occurred on the nation's roads per year (see Table 17). It should be noted that a fatal crash sometimes results in multiple fatalities. Fatal pedalcyclist crashes accounted for slightly over 2% of all fatal crashes. In contrast, only 1% of all crashes (fatal and non-fatal combined) involved pedalcyclists by GES estimates.

Based on frequency data in Tables 1 and 17, about 1.2% of all pedalcyclist crashes from 1995 through 1998 resulted in at least one fatality compared to 0.6% of all police-reported crashes. Moreover, the likelihood of a pedalcyclist crash being fatal has increased steadily from about 1.1% in 1995 to about 1.3% in 1998.

Table 17. Fatal Pedalcyclist Crash Problem Size (Based on 1995-1998 FARS)

Year	Total Crashes	Pedalcyclist Crashes	# of Pedalcyclists	
			Involved	Killed
1995	37,241	831	867	828
1996	37,494	768	811	761
1997	37,324	817	846	811
1998	37,107	760	794	757
4-yr Total	149,166	3,176	3,318	3,157
Yearly Avg.	37,292	794	830	789

8.2. Fatal Pedalcyclist Pre-Crash Scenarios

The 1995-1998 FARS databases were utilized to characterize vehicle maneuvers and pedalcyclist actions immediately prior to a fatal pedalcyclist crash. The *LOCATION* variable in the FARS "Vehicle File" identified the crash's relation to junction. It reveals if the crash occurred at an intersection or at a location away from one. The *VEH_MAN* variable, also located in the "Vehicle File," discerns the vehicle maneuver. This variable describes the maneuver that the driver was executing just prior to entering a crash situation, not the avoidance maneuver. The *P_CF1*, *P_CF2*, and *P_CF3* variables in the FARS "Person File" identify the actions taken by pedalcyclists and the person-level contributing factors in the crash.

Figure 11 presents the distribution of junction relation for all 3,176 fatal pedalcyclist crashes over the four-year period from 1995-1998 taken from the FARS. Almost 69% of the fatal pedalcyclist crashes as coded in the FARS occurred at non-junction locations while only about 31% of the crashes occurred at intersections. A higher rate of fatal crashes occurred away from intersections, whereas most pedalcyclist crashes occur at intersections based on GES statistics. This suggests that a correlation between injury severity and vehicle speed exists. Generally, vehicles tend to travel at lower speeds in the proximity of intersections and at higher speed away from intersections.

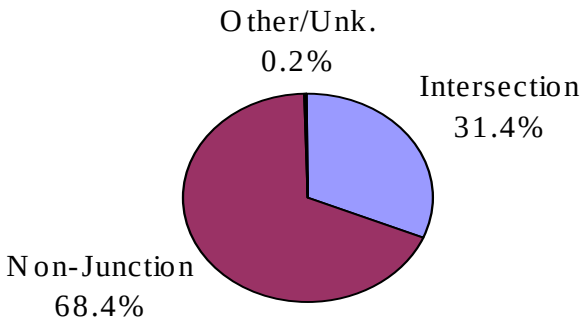


Figure 11. Relation to Junction Breakdown for Fatal Pedalcyclist Crashes (Based on 1995-1998 FARS)

The 997 fatal crashes that occurred at intersections over the four-year period were further broken down by vehicle maneuver and pedalcyclist contributing factors. It should be noted that the FARS pre-crash scenario analysis does not lend itself to comparison to the GES results since the variables are defined differently for the two databases. Figure 12 presents the distribution of vehicle maneuvers just prior to the crash for the fatal pedalcyclist crashes occurring at intersections as included in the 1995-1998 FARS databases. Going straight just prior to striking a pedalcyclist was reported in most fatal pedalcyclist intersection crashes, accounting for about 80.5% of all vehicle maneuvers. The relative frequency of this vehicle maneuver was higher in fatal pedalcyclist crashes than in all pedalcyclist crashes as reported by the GES. FARS reported a vehicle completing a turning maneuver in 14.8% of pedalcyclist crashes compared to the GES's police-reported estimate of 27%. Turning maneuvers resulted in lower pedalcyclist fatality rates compared to the vehicle traveling straight because vehicles generally make turns, especially right turns, at low travel speeds [11].

Pedalcyclist actions and contributing factors were determined from the analysis of the *P_CF1*, *P_CF2*, and *P_CF3* variables in the "Person File" for each pedalcyclist in the FARS databases over the four-year period. The lowest coded value found among the three variables for a given crash was used for the following tables. This procedure was followed since the FARS uses a prioritized scheme in descending order of importance (e.g. a value of 1 in the variable *P_CF1* would have priority over a value of 2 in the variable *P_CF2* for a given pedalcyclist). Table 18 details the distribution of pedalcyclist

actions and contributing factors just prior to the crash for fatal pedalcyclist crashes. It shows the yearly average of pedalcyclist crashes broken down by pedalcyclist actions and contributing factors as determined from the analysis of the 1995-1998 FARS databases. The pedalcyclist contributing factors were broken down by relation to junction (intersection-related or non-junction), and further dissected by vehicle maneuver within the intersection-related pedalcyclist crash population. See Appendix B for descriptions of the contributing factor values as shown in Table 18.

The following statistics for the pedalcyclist contributing factor variables were recorded:

- Not applicable (29.8%), Code 0
- Riding with or against traffic (16.4%), Code 4
- Improper crossing of roadway (12.3%), Code 3
- Failure to yield right of way (11.9%), Code 38

It should be noted that 29.8% of the cases were coded as "not applicable." The same pattern follows on the "relation to junction/vehicle maneuver" level with the major exception of the "failure to yield right of way" contributing factor. This factor is very prominent in the "Non-Intersection," "Intersection/Going Straight," and "Intersection/Other or Unknown" pedalcyclist crash subsets but is relatively insignificant in the other crash subsets. "Failure to yield right of way" makes up only 1.3% and 2.7% of the "Intersection/Turning Left" and "Intersection/Turning Right" pedalcyclist subsets, respectively.

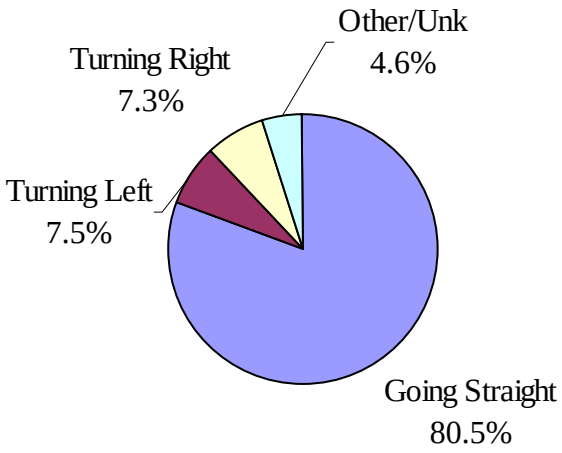


Figure 12. Vehicle Maneuver Breakdown for Fatal Pedalcyclist Crashes Occurring at Intersections (Based on 1995-1998 FARS)

Table 18. Pedalcyclist Contributing Factors Distribution in Fatal Intersection Crashes – Yearly Average (Based on 1995-1998 FARS)

Pedalcyclist Contributing Factor	Relation to Junction / Vehicle Maneuver					
	"Intersection/ Going Straight"	"Intersection/ Turning Left"	"Intersection/ Turning Right"	"Intersection/ Other or Unk."	"Non-Intersection"	**Overall**
0 Not applicable - driver/none - all other persons	22.2%	44.7%	31.1%	27.7%	32.0%	29.8%
1 Not visible	2.4%	6.6%	1.4%	0.0%	3.8%	3.4%
2 Darting, running or stumbling into roadway	3.0%	0.0%	0.0%	0.0%	3.5%	3.2%
3 Improper crossing of roadway or intersection	16.9%	7.9%	12.2%	10.6%	10.8%	12.3%
4 Walking/riding with or against traffic, standing in roadway	12.9%	14.5%	20.3%	25.5%	17.5%	16.4%
5 Interfering with driver	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6 Ill, passed out/blackout	0.6%	1.3%	0.0%	4.3%	0.9%	0.9%
8 Mentally challenged	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
10 Inattentive	3.5%	5.3%	5.4%	2.1%	2.6%	3.0%
14 Impaired due to previous injury	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
17 Other physical impairment	0.2%	1.3%	0.0%	0.0%	0.1%	0.2%
21 Over/improper loading of vehicle with passengers or cargo	0.2%	0.0%	1.4%	0.0%	0.3%	0.3%
23 Failure to dim lights or have lights on when required	0.0%	1.3%	0.0%	0.0%	0.7%	0.5%
24 Operating without required equipment	2.3%	5.3%	4.1%	0.0%	2.2%	2.3%
27 Improper or erratic lane changing	0.1%	0.0%	0.0%	0.0%	1.3%	0.9%
28 Failure to keep in proper lane	1.6%	1.3%	1.4%	0.0%	2.8%	2.4%
30 Making improper entry to or exit from trafficway	0.2%	0.0%	0.0%	2.1%	1.0%	0.8%
34 Passing on wrong side	0.0%	0.0%	2.7%	0.0%	0.1%	0.1%
35 Passing with insufficient distance/visibility	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
36 Operating vehicle in erratic/reckless/careless/negligent manner	0.6%	1.3%	1.4%	2.1%	4.4%	3.3%
37 Traveling on prohibited trafficways	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
38 Failure to yield to right-of-way	18.6%	1.3%	2.7%	14.9%	10.1%	11.9%
39 Failure to obey traffic sign, traffic control device, or traffic officer	11.2%	3.9%	5.4%	2.1%	0.4%	3.4%
42 Failure to signal intentions	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
44 Driving too fast for conditions or in excess of posted maximum	0.1%	1.3%	0.0%	0.0%	0.2%	0.2%
48 Making other improper turn	0.4%	0.0%	0.0%	0.0%	0.8%	0.6%
49 Driving wrong way on one-way trafficway	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%
50 Driving on wrong side of road	0.1%	0.0%	1.4%	2.1%	1.3%	1.0%
51 Operator inexperience	0.0%	1.3%	1.4%	2.1%	0.1%	0.2%
55 Getting off/out of or on/in to a transport vehicle	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
62 Vision obscured by curve, hill, or other design feature	0.0%	1.3%	0.0%	0.0%	0.1%	0.1%
64 Vision obscured by trees, crops, vegetation	0.0%	0.0%	1.4%	0.0%	0.1%	0.1%
65 Vision obscured by motor vehicle	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
66 Vision obscured by parked vehicle	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
68 Vision obscured by inadequate lighting system	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%
72 Other visual obstruction	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
75 Sliding due to slippery or loose surface	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
78 Sliding due to ruts, holes, bumps in road	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
82 Sliding due to pedestrian, pedalcyclist, or other non-motorist	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
99 Unknown	2.1%	0.0%	6.8%	4.3%	2.0%	2.1%
% Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total	207	19	19	12	572	828

Note: Pedalcyclist contributing factors are described in Appendix B.

8.3. Atmospheric Conditions in Fatal Crashes

Atmospheric conditions at the time of the crash were also examined for fatal crashes. The atmospheric conditions relate to whether the crash took place during the daytime or nighttime and in clear or adverse weather conditions. By examining the atmospheric conditions for fatal crashes, a comparison can be made between the severity of the crash and the time of day and weather conditions.

Table 19 lists the atmospheric conditions for each fatal pedalcyclist crash. The GES results for the same time period are provided in Table 10. Over 43% of fatal pedalcyclist crashes occurred at nighttime based on FARS data, whereas only 20.4% of all pedalcyclist crashes occurred under the same conditions according to GES data. Based on Table 10 and 19, the probability of a pedalcyclist crash resulting in one or more fatalities is 0.009 and 0.026 during the day and at night, respectively. These statistics are significant, showing that the risk of a pedalcyclist crash resulting in one or more fatalities is three times higher at night than during the day.

Table 19. Breakdown of Atmospheric Conditions Statistics for Pedalcyclist Pre-Crash Scenarios (Based on 1995-1998 FARS)

Atmospheric Conditions	Overall FARS 4-yr Avg.		Pedalcyclist FARS 4-yr Avg.	
	# Crashes	Freq.	# Crashes	Freq.
Day/Clear Conditions	16,298	43.7%	432	54.4%
Day/Adverse Conditions	2,188	5.9%	15	1.9%
Night/Clear Conditions	15,973	42.8%	312	39.3%
Night/Adverse Condition	2,574	6.9%	32	4.0%
Unknown Conditions	259	0.7%	4	0.4%
Totals:	37,292	100.0%	794	100.0%

9. CONCLUSIONS AND RECOMMENDATIONS

This report presents the results from an analysis of pedalcyclist-related crashes using a four-year set of GES and FARS databases, thus defining the pedalcyclist crash problem in the U.S. Specifically, it identifies prevalent pre-crash scenarios and provides statistics on driver and pedalcyclist age and pedalcyclist injury severity per scenario. This study also identifies possible contributing factors that might be prominent in pedalcyclist crashes. The following is a list of major observations and summary points obtained from the GES crash data analyzed in this study, unless otherwise noted.

1. According to GES statistics, there were about 65,000 vehicle-pedalcyclist crashes in the U.S. each year from 1995 to 1998. Roughly 67,000 pedalcyclists were involved in such crashes each year.

2. Pedalcyclist crashes were broken down into 8 pre-crash scenarios, which denote vehicle maneuvers and relation of the pedalcyclist to the vehicle immediately prior to the crash. The 8 scenarios analyzed encompass all pedalcyclist crashes.

3. Fatal pedalcyclist crashes accounted for 2.1% of all fatal motor vehicle crashes as determined from 1995-1998 FARS statistics. Nearly 69% of the fatal pedalcyclist crashes as coded in the FARS occurred at non-junction locations while only 31% occurred at intersections.

4. A relatively high percentage of drivers reported vision obscurity in pre-crash scenario 5 where the vehicle was turning left while on a parallel path with the pedalcyclist and scenario 6 where the vehicle was starting in the traffic lane on a crossing path with the pedalcyclist. Over 9% of drivers reported vision obscurity and over 20% were charged with violating the sign or signal in each of the scenarios. Scenarios 5 and 6 also reported high frequencies (over 5%) of crashes occurring under nighttime and adverse weather conditions.

5. Most pedalcyclist-involved crashes occurred on straight, non-hillcrest roadways and on the roadway surface. Over 10% of the crashes in scenario 8 occurred off the roadway, shoulder, or parking lane. Scenario 8 encompasses all crashes involving a vehicle performing an "other" maneuver or cases where the pedalcyclist is traveling on a path other than a parallel or crossing path. Crashes in which the vehicle is backing or parking are also included in scenario 8. Therefore, it is understandable that the largest frequency of off-roadway, shoulder, or parking lane crashes occurs in scenario 8, since most backing or parking maneuvers take place off the roadway.

6. Almost 75% of pedalcyclist crashes occurred on roadways with speed limits between 25 mph and 35 mph.

7. Over half of the pedalcyclist crashes occurred at locations with no traffic control devices while 23% occurred at intersections with stop signs and another 20% occurred at intersections with 3-color signals.

8. Over 43% of fatal pedalcyclist crashes occurred at nighttime based on FARS data, whereas only 20% of all pedalcyclist crashes occurred under the same conditions according to GES data. Based on this observation, pedalcyclists involved in crashes with motor vehicles at nighttime have a greater probability of resulting in a fatality than under daytime conditions.

9. Over 50% of the pedalcyclists in scenario 1 (vehicle traveling straight on a crossing path with the pedalcyclist) were reported as having failed to yield the right of way.

10. Overall, about 550 pedalcyclist fatalities per year were reported in the 1995-1998 GES. The highest frequency of incapacitating and fatal injuries occurred in cases where the vehicle was traveling straight on parallel paths with the pedalcyclist (scenario 2). Roughly 22% of pedalcyclist related crashes in this scenario also occurred at nighttime. Nearly 12% of the drivers and over 50% of the pedalcyclists were under 20 years old. About 18% of the pedalcyclists were in the 10 to 14 year-old age group.

11. The highest relative frequency of pedalcyclist fatalities occurred in scenario 2 involving a vehicle traveling straight on parallel paths with the pedalcyclist. 1.7% of the pedalcyclists involved in this scenario sustained fatal injuries. Scenario 2 also held the highest relative frequency of driver alcohol and/or drug involvement as seen in Table 8. Alcohol and/or drug use by the driver was reported in 6.1% of the crashes in this scenario.

12. The 30-34 years old age group had the greatest frequency of drivers involved in crashes with pedalcyclists, accounting for about 13% of all drivers involved in such crashes. Drivers under the age of 20 years old were most likely to be involved in pedalcyclist crashes. Such drivers comprise about 5.3% of the total licensed driver population and yet were involved in more than 10% of cyclist-related crashes. Drivers in the youngest age group also showed the highest crash probability in terms of VMT per age group (Table 12).

13. Younger pedalcyclists, especially those aged from 10 to 14 years old, were most susceptible to pedalcyclist crashes, accounting for nearly 27% of all pedalcyclists involved in pedalcyclist crashes. About 72% of the pedalcyclist crash population fell into the 5-29 year-old age range, which was the only age range over-represented relative to the U.S. population.

14. About one-fifth of the pedalcyclists involved in motor-vehicle crashes within pre-crash scenario 1 fell within the 5 to 9-year old age group; a little over one-third fell with the 10 to 14-year old age group. Scenario 1 is defined as vehicle traveling straight on crossing path with pedalcyclist. The highest relative frequency of 15-19

year old pedalcyclist involvement occurred in scenario 6. This age group accounted for over 26% of all pedalcyclists within this scenario (vehicle starting in traffic lane on crossing paths with pedalcyclist).

15. Scenario 6, involving a vehicle starting in the traffic lane on a crossing path with the cyclist, proved to be the least injury-prone scenario overall. About 49% of the crashes in this scenario were reported as resulting in no injuries or possible injuries. Since the physical description of this pre-crash scenario is of a vehicle starting in the traffic lane, the relatively low serious injury risk is most likely due to the low speeds involved in this scenario.

Some recommendations, based on the data presented herein, follow.

1. Bicycle riding exposure data could provide some further insight as to what age groups are most susceptible to the pedalcyclist crash type. Specifically, seniors are under-represented in both the driver and pedalcyclist crash populations as compared to the U.S. population but it could be that they also ride much less than the rest of the population. Conversely, children and teenagers are over-represented in the pedalcyclist crash population but they also tend to ride more often than many in other age groups. Comparing pedalcyclist-related crashes to such exposure data could prove more insightful.

2. A significant number of pedalcyclist-related crashes occurred at nighttime. Information on what types of clothes the pedalcyclists were wearing could provide further insight into the development of vehicle-based and vehicle-infrastructure cooperative countermeasure systems. The GES, CDS, and FARS database systems do not contain information on this attribute aside from the *Safety Equipment Use* variable in the GES. The Washington State Department of Transportation's crash databases contain a variable on clothes color which is divided into five categories: "Dark," "Light," Mixed," Retro-Reflective," and "Other Reflective Apparel." Thus, in future analysis, it should be taken into account that the Washington State Department of Transportation crash databases contain possible "added value" to the national databases used in this study.

The results obtained from this analysis are intended to support effective countermeasure concept development and provide data for design effectiveness assessments. This study helps researchers visualize and quantify the different conditions present in pedalcyclist crashes by identifying vehicle maneuver and pedalcyclist action combinations most prevalent in such crashes.

REFERENCES

[1] Hunter, W.W., Stutts, J.C., Pein, W.E. and Cox, C.L. *Pedestrian and Bicycle Crash Types of the Early 1990s*. Federal Highway Administration. Washington, D.C., 1996.

[2] Federal Highway Administration. *Injuries to Pedestrians and Bicyclists: An Analysis Based on Hospital Emergency Department Data.* U.S. Department of Transportation, Publication No. FHWA-RD-99-078. Washington, D.C., 1999.

[3] Fife, D., Davis, J., Tate, L., Wells, J., Mohan, D., and Williams, A. "Fatal Injuries to Bicyclists: The experience of Dade County, Florida," *Journal of Trauma*, 23, 1983.

[4] Thompson, R.S., Rivara, F.P., and Thompson, D.C. "A Cases-Control Study of the Effectiveness of Bicycle Safety Helmets," *New England Journal of Medicine*, 320, 1989.

[5] Maas, M.W. and Harris, S. "Police Recording of Road Accident In-Patients," *Accident Analysis & Prevention*, 16(3), 1984.

[6] U.S. Department of Transportation Bureau of Transportation Statistics *Bicycle and Pedestrian Data: Sources, Needs, & Gaps*, BTS00-02. Washington, D.C., 2000.

[7] National Center for Statistics and Analysis, *National Automotive Sampling System (NASS) General Estimates System (GES) Analytical User's Manual 1988-1999*. U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C.

[8] U.S. Department of Transportation, National Highway Traffic Safety Administration *Traffic Safety Facts (years 1996 to 1998)*, DOT HS 808 983. Washington, D.C., 1997.

[9] Federal Highway Administration. 1995 Nationwide Personal Transportation Survey, http://www.bts.gov/ntda/npts/.

[10] U.S. Census Bureau, Population Division, Population Distribution Branch, http://www.census.gov/population/www/estimates/st-99-10.html.

[11] Van Houten, Ron and J.E. Louis Malenfant. *Canadian Research on Pedestrian Safety*. Federal Highway Administration, U.S. Department of Transportation, Publication No. FHWA-RD-99-090. December 1999.

[12] Federal Highway Administration. *Highway Statistics 1998*. U.S. Department of Transportation, Publication No. FHWA-PL-99-017, November1999.

APPENDIX A

This appendix shows the descriptions and schematics of each code in the *Pedestrian/Cyclist Crash Type* variable in the GES databases [7]. Please note that no suitable schematic was available for code numbers 11, 29, 36, 37, 40, 97, 98, and 99.

Table A-1. *Pedestrian/Cyclist Crash Type* Variable Descriptions for Codes 1 - 7 (Based on 1995-1998 GES)

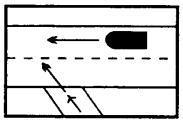
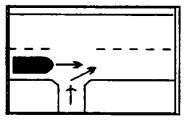
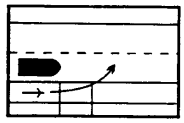
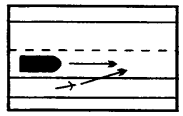
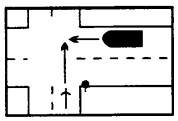
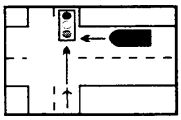
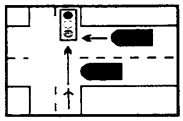
Var. Code	Specific Description	Physical Setting	4-Yr Total Crashes	% Dist.
Bicyclist rides out from a driveway, alley, or other mid-block location;				
1	Cyclist fails to yield to motorist at a residential driveway or alley; Pre-crash path perpendicular to roadway PED_ACC (A24) = 01		11,889	4.6%
2	Cyclist fails to yield to motorist at a commercial driveway or alley; Pre-crash path perpendicular to roadway PED_ACC (A24) = 02		2,461	0.9%
3	Cyclist turns or merges into the path of motorist from residential driveway or alley; Pre-crash path parallel to roadway PED_ACC (A24) = 03		3,380	1.3%
4	Cyclist fails to yield to motorist at mid-block location; Entry is over curb or shoulder PED_ACC (A24) = 04		20,041	7.7%
Bicyclist rides out from a controlled intersection;				
5	Cyclist fails to yield to motorist at an intersection controlled by a Stop Sign or Flashing Red Signal PED_ACC (A24) = 05		18,318	7.0%
6	Cyclist fails to clear intersection controlled by a signal before light turns green for cross traffic; Motorists' view of cyclist was not obstructed PED_ACC (A24) = 06		160	0.1%
7	Cyclist fails to clear intersection controlled by a signal before light turns green for cross traffic; Motorists' view of cyclist was obstructed by standing traffic PED_ACC (A24) = 07		248	0.1%

Table A-2. *Pedestrian/Cyclist Crash Type* Variable Descriptions for Codes 8-17 (Based on 1995-1998 GES)

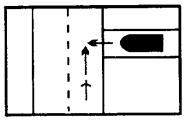
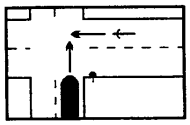
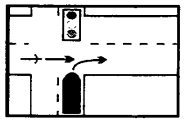
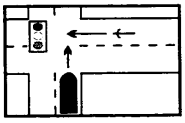
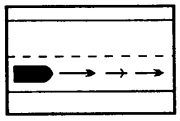
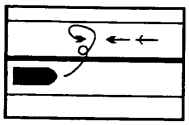
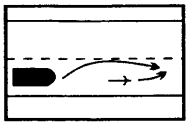
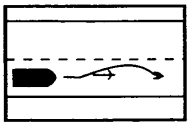
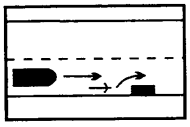
Var. Code	Specific Description	Physical Setting	4-Yr Total Crashes	% Dist.
Motorist turns or drives out in front of bicyclist;				
8	Motorist exiting from driveway, alley, or other mid-block location fails to yield to cyclist PED_ACC (A24) = 08		19,419	7.4%
9	At an intersection controlled by a stop sign or flashing red light, motorist obeys the sign but fails to yield to cyclist PED_ACC (A24) = 09		22,432	8.6%
10	At an intersection controlled by a signal, motorist obeys signal but fails to yield to cyclist while making right turn on red PED_ACC (A24) = 10		8,447	3.2%
11	Motorist backing from driveway fails to yield to cyclist PED_ACC (A24) = 11	**n.a.**	2,202	0.8%
12	Motorist fails to stop at an intersection controlled by a stop sign PED_ACC (A24) = 12		5,704	2.2%
Motorist overtakes bicyclist;				
13	Motorist fails to detect cyclist he/she is overtaking PED_ACC (A24) = 13		4,283	1.6%
14	Motorist loses control of vehicle while overtaking cyclist; in some cases motorist is in uncontrolled slide or spin, but more often, merely loses precise control and veers too far to right PED_ACC (A24) = 14		721	0.3%
15	The motorist and the cyclist counteract each other's evasive action PED_ACC (A24) = 15		1,100	0.4%
16	Motorist misjudges space required to pass cyclist PED_ACC (A24) = 16		1,712	0.7%
17	Cyclist's path is obstructed, causing cyclist to strike obstruction or overtaking motorist PED_ACC (A24) = 17		194	0.1%

Table A-3. *Pedestrian/Cyclist Crash Type* Variable Descriptions for Codes 18-27 (Based on 1995-1998 GES)

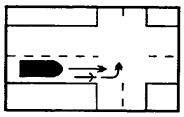
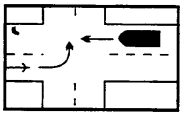
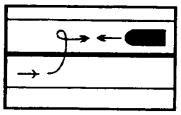
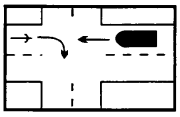
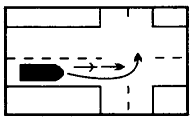
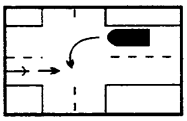
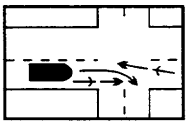
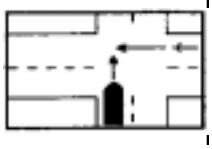
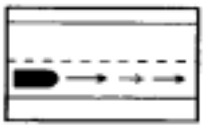
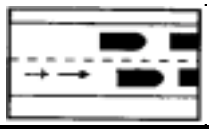
Var. Code	Specific Description	Physical Setting	4-Yr Total Crashes	% Dist.
Bicyclist makes unexpected turn or swerve;				
18	Cyclist turns left in front of motorist proceeding in the same direction PED_ACC (A24) = 18		3,815	1.5%
19	Cyclist turns left in front of motorist approaching from straight ahead PED_ACC (A24) = 19		1,614	0.6%
20	Cyclist loses control and swerves into the path of a motorist proceeding in the same direction PED_ACC (A24) = 20		3,543	1.4%
21	Cyclist riding on wrong side of street makes right turn in path of approaching motorist PED_ACC (A24) = 21		306	0.1%
Motorist makes unexpected Turn;				
22	Motorist makes left turn in front of cyclist proceeding in the same direction; In some cases cyclist was riding on wrong side of street PED_ACC (A24) = 22		3,305	1.3%
23	Motorist makes left turn in front of cyclist approaching from straight ahead PED_ACC (A24) = 23		14,888	5.7%
24	Motorist makes right turn in front of cyclist proceeding in parallel path; Byciclist either proceeding in same direction or from opposite direction (riding on the wrong side of the street) PED_ACC (A24) = 24		17,350	6.7%
Other / Infrequent				
25	Vehicles collide at uncontrolled intersection: crossing paths PED_ACC (A24) = 25		3,988	1.5%
26	Vehicles collide head-on: wrong-way bicyclist PED_ACC (A24) = 26		8,287	3.2%
27	Bicyclist overtaking motor vehicle PED_ACC (A24) = 27		3,885	1.5%

Table A-4. *Pedestrian/Cyclist Crash Type* Variable Descriptions for Codes 28 - 39 (Based on 1995-1998 GES)

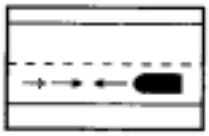
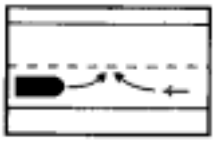
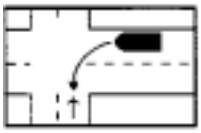
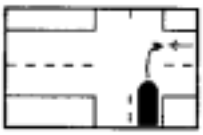
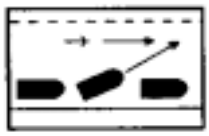
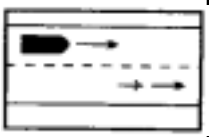
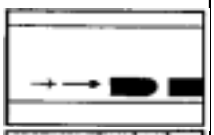
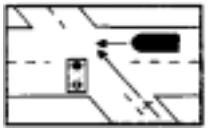
Var. Code	Specific Description	Physical Setting	4-Yr Total Crashes	% Dist.
Other / Infrequent				
28	Vehicles collide head-on: wrong-way motorist PED_ACC (A24) = 28		372	0.1%
29	Parking lot, other open area: crossing paths PED_ACC (A24) = 29	**n.a.**	1,958	0.8%
30	Vehicles collide head-on: counteractive evasive action PED_ACC (A24) = 30		418	0.2%
31	Bicyclist cuts corner when turning left: crossing paths PED_ACC (A24) = 31		1,377	0.5%
32	Bicyclist swings wide when turning right: crossing paths PED_ACC (A24) = 32		627	0.2%
33	Motorist cuts corner when turning left: crossing paths PED_ACC (A24) = 33		358	0.1%
34	Motorist swings wide when turning right: crossing paths PED_ACC (A24) = 34		1,005	0.4%
35	Motorist drives out from on-street parking PED_ACC (A24) = 35		531	0.2%
36	Weird PED_ACC (A24) = 36	**n.a.**	722	0.3%
37	Insufficient information to classify PED_ACC (A24) = 37	**n.a.**	-	0.0%
39	Motorist overtaking (Cyclist) PED_ACC (A24) = 37		12,825	4.9%

Table A-5. *Pedestrian/Cyclist Crash Type* Variable Descriptions for Codes 40 - 99 (Based on 1995-1998 GES)

Var. Code	Specific Description	Physical Setting	4-Yr Total Crashes	% Dist.
Other / Infrequent				
40	Play vehicle (Big wheel, other tricycle, or bicyclist with training wheels) PED_ACC (A24) = 40	**n.a.**	85	0.0%
41	Cyclist struck parked vehicle PED_ACC (A24) = 41		304	0.1%
48	Drive out - Intersection (Motorist drove out into or in front of cyclist) PED_ACC (A24) = 48		12,327	4.7%
49	Ride out - Intersection (Bicyclist) PED_ACC (A24) = 49		23,256	8.9%
55	Controlled intersection - other PED_ACC (A24) = 55		12,378	4.7%
97	Unknown if approach paths are parallel or crossing PED_ACC (A24) = 97	**n.a.**	2,120	0.8%
98	Parallel paths - unknown PED_ACC (A24) = 98	**n.a.**	3,451	1.3%
99	Crossing paths - unknown PED_ACC (A24) = 99	**n.a.**	2,985	1.1%
		4-Yr Total	**260,792**	**100%**

APPENDIX B

This appendix lists the pedalcyclist contributing factor codes and terminology as defined by the FARS (see Table 18 in section 8.2).

Variable = P_CF1, P_CF2, and P_CF3

VALUES

00 = Not Applicable – Driver/None – All Other Persons
01 = Not Visible
02 = Darting, Stumbling, or Running into Road
03 = Improper Crossing of Roadway or Intersection
04 = Walking/Riding with or Against Traffic, Playing, Working, Sitting Lying, Standing etc. in Roadway
05 = Interfering with Driver
06 = Ill/Passed Out/Blackout
07 = Emotional (e.g. Depression, Angry, Disputed)
08 = Mentally Challenged
09 = Construction/Maintenance/Utility Worker
10 = Inattentive (Talking, Eating, etc.)
11 = Walking with Cane or Crutches
12 = Restricted to Wheelchair
13 = Paraplegic
14 = Impaired Due to Previous Injury
15 = Deaf
16 = Blind
17 = Other Physical Impairment
18 = Mother of Dead Fetus
19 = Pedestrian

NON-MOTOR VEHICLE OPERATOR RELATED FACTORS

20 = Leaving Vehicle Unattended in Roadway
21 = Overloading or Improper Loading of Vehicle with Passengers or Cargo
22 = Towing or Pushing Vehicle Improperly
23 = Failing to Have Lights on When Required
24 = Operating Without Required Equipment
25 = Creating Unlawful Noise or Using Equipment Prohibited By Law
26 = Following Improperly
27 = Improper or Erratic Lane Changing
28 = Failure to keep in Proper Lane or Running off Road
29 = Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median
30 = Making Improper Entry to or Exit from Trafficway

33 = Passing where Prohibited by Posted Signs, Pavement or Curve, or School Bus Displaying Markings, Hill Warning Not to Pass
34 = Passing on Wrong Side
35 = Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle
36 = Operating the Vehicle in Other Erratic, Reckless, Careless or Negligent Manner
37 = Traveling on Prohibited Trafficway (Since 1995)
38 = Failure to Yield Right of Way
39 = Failure to Obey Traffic Signs, Traffic Control Devices or Traffic Officers, Failure to Observe Safety Zone Traffic Laws
40 = Passing Through or Around Barrier Positioned to Prohibit or Channel Traffic
41 = Failure to Observe Warnings or Instructions on Vehicles Displaying Them
42 = Failure to Signal Intentions
43 = Giving Wrong Signal
44 = Driving too Fast for Conditions or in Excess of Posted Speed Limit
45 = Driving Less than Posted Maximum
46 = Operating at Erratic or Suddenly Changing Speeds
47 = Making Right Turn from Left Turn Lane or Making Left Turn from Right Turn Lane
48 = Making Improper Turn
49 = Driving Wrong Way on One-Way Trafficway
50 = Driving on Wrong Side of Road [(Intentionally or Unintentionally) Since 1995]
51 = Operator Inexperience
52 = Unfamiliar with Roadway
53 = Stopping in Roadway (Vehicle not Abandoned)
54 = Underriding a Parked Truck
55 = Getting Off/Out of or On/In to Moving Transport Vehicle
56 = Getting Off/Out of or On/In to Non-Moving Transport Vehicle
57 = Improper Tire Pressure (Since 1995)
58 = Locked Wheel (Since 1995)
59 = Overcorrecting (Since 1995)

VISION OBSCURED BY

60 = Rain, Snow, Fog, Smoke, Sand, Dust
61 = Reflected Glare, Bright Sunlight, Headlights
62 = Curve, Hill, Or Other Design Features (including Traffic signs, Embankment)
63 = Building, Billboard, [Other Structure, Since 1995]
64 = Trees, Crops, Vegetation
65 = Motor Vehicle (including load)
66 = Parked Vehicle
67 = Splash or Spray or Passing Vehicle
68 = Inadequate Lighting System
69 = Obstructing Angles on Vehicle
70 = Mirrors - Rear View
71 = Mirrors - Other

72 = Head Restraints

AVOIDING, SWERVING, OR SLIDING DUE TO

73 = Severe Crosswind
74 = Wind from Passing Truck
75 = Slippery or Loose Surface
76 = Tire Blow-Out or Flat
77 = Debris or Objects in Road
78 = Ruts, Holes, Bumps in Road
79 = Animals in Road
80 = Vehicle in Road
81 = Phantom Vehicle
82 = Pedestrian, Pedalcyclist, or Other Non-Motorist
83 = Ice, Snow, Slush, Water, [Sand, Dirt, Oil, Wet Leaves, Since 1995] on Road

OTHER NON-MOTORIST FACTORS

84 = Jay walk (1982 to 1994 only)
85 = Jog (1982 to 1994 only)
86 = Carrying Hazardous Cargo Improperly
90 = Non-Motorist Pushing a Vehicle
99 = Unknown

APPENDIX C

This appendix shows the distributions of age of the United States licensed driver population as published by the FHWA [12]. This appendix also shows the pedalcyclist crash population age distribution as determined from the 1995-1998 GES databases.

Table C-1. United States Licensed Driver Population Distribution by Age - 1998

Age (years)	Number of Licensed Drivers	Percent of Total Drivers
Under 20	9,782,763	5.3%
20-24	15,366,212	8.3%
25-29	18,028,566	9.7%
30-34	19,180,411	10.4%
35-39	21,136,591	11.4%
40-44	20,462,716	11.1%
45-49	18,164,649	9.8%
50-54	15,324,931	8.3%
55-59	11,838,456	6.4%
60-64	9,447,046	5.1%
65-69	8,336,948	4.5%
70-74	7,431,062	4.0%
75-79	5,544,277	3.0%
80-84	3,178,530	1.7%
85+	1,757,018	0.9%
Total	184,980,176	100.0%

Table C-2. Pedalcyclist Crash Population (Based on 1995-1998 GES) and U.S. Population Distributions by Age

AGE (years)	Population Dist.	
	Pedalcyclist	U.S.*
0-4	0.8%	7.0%
5-9	11.0%	7.4%
10-14	26.6%	7.1%
15-19	15.6%	7.2%
20-24	10.1%	6.5%
25-29	7.5%	6.9%
30-34	7.1%	7.5%
35-39	5.7%	8.4%
40-44	5.1%	8.1%
45-49	3.4%	7.0%
50-54	1.9%	5.8%
55-59	1.2%	4.6%
60-64	1.3%	3.8%
65-69	0.9%	3.5%
70-74	0.8%	3.3%
75-79	0.6%	2.7%
80-84	0.2%	1.8%
85+	0.1%	1.5%
Total	66,000	270,248,000

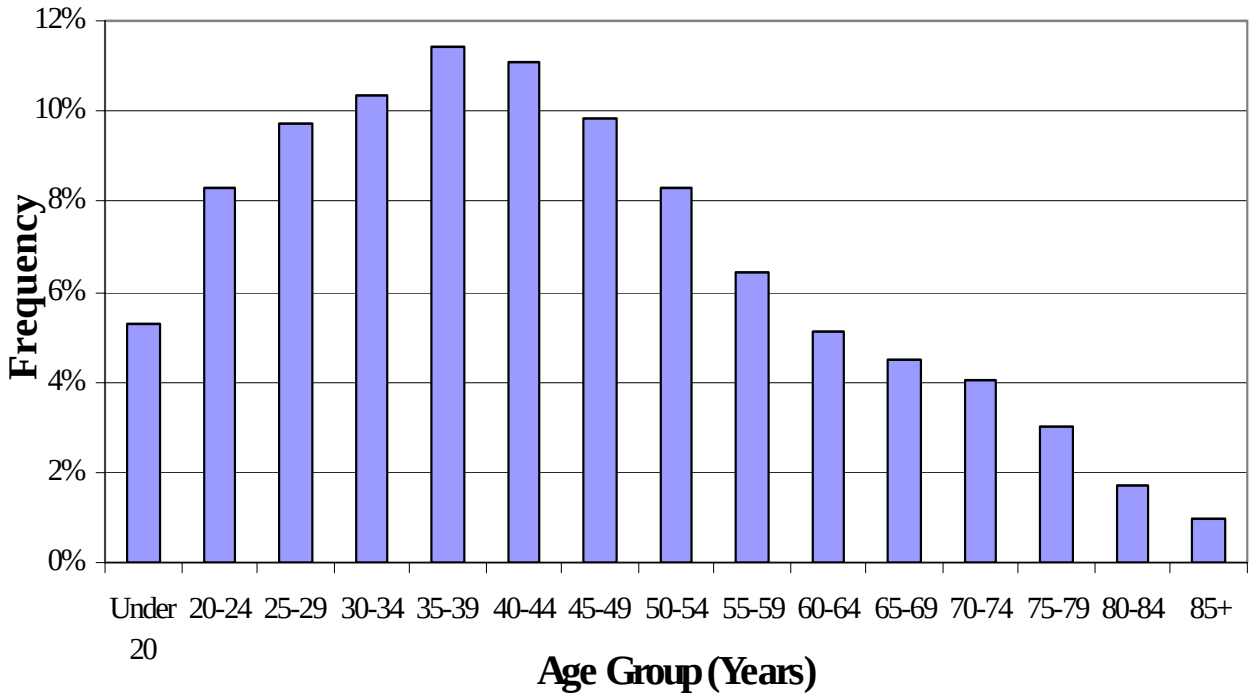


Figure C-1. United States Licensed Driver Age Distribution - 1998

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