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Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update

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16. Abstract

Hybrid electric (HE) passenger vehicles first became available to consumers in 2000, and their numbers as well as their proportion of the passenger vehicle fleet have risen every year since their introduction. Advocacy groups have raised pedestrian safety concerns regarding HE vehicles because a vehicle using the electric motor may be relatively quieter than a vehicle using an internal combustion engine (ICE) and may not emit the sounds that non-motorists rely on for warning as vehicles approach them.

In 2009 the National Highway Traffic Safety Administration released the report "Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles" with the finding that an HE vehicle was two times more likely to be involved in a pedestrian crash than an ICE vehicle in situations involving low-speed maneuvers (Hanna, 2009). This report aims to update the previous report with more data by adding additional years of State crash files as well as by increasing the number of States included in the analysis from 12 to 16.

This analysis was conducted on a total of 24,297 HE and 1,001,000 ICE Honda and Toyota selected vehicles in 16 States. A total of 186 and 5,699 HE and ICE vehicles respectively were involved in pedestrian crashes, and a total of 116 and 3,052 HE and ICE vehicles respectively were involved in bicycle crashes. Overall, the odds ratios indicate that the odds of an HE vehicle being in either a pedestrian or bicycle crash are greater, 35 percent and 57 percent respectively, than the odds of an ICE vehicle being in a similar crash.

The crash factors of speed limit, vehicle maneuver, and location were examined to determine the relative incidence rates of HE versus ICE vehicles and whether the odds ratio (OR) was different under different circumstances. While the results did not provide an apparent set of scenarios for bicycle crashes, the findings provide a clearer picture regarding pedestrian crashes. The largest differences between the involvement of HE and ICE vehicles in pedestrian crashes occur with speed limits of 35 mph and lower (OR = 1.39), during low-speed maneuvers (OR = 1.66) and when the crash is on the roadway (OR = 1.50). This update further extends the analysis to various other vehicle samples with similar results. For example a comparison of all HE versus ICE passenger vehicles regardless of makes and models indicates that the odds of any HE passenger vehicle being in a pedestrian crash are 22 percent greater than the odds of any ICE passenger vehicle.

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1. EXECUTIVE SUMMARY

Hybrid electric (HE) passenger vehicles first became available to consumers in 2000, and their numbers as well as their proportion of the passenger vehicle fleet have risen every year since their introduction. By 2009 the number had grown to comprise 0.6 percent of the passenger vehicle fleet. Advocacy groups have raised pedestrian safety concerns regarding HE vehicles because a vehicle using the electric motor may be relatively quieter than a vehicle using an internal combustion engine (ICE) and may not emit the sounds that non-motorists rely on for warning as vehicles approach.

In 2009 the National Highway Traffic Safety Administration released the report "Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles" with the finding that an HE vehicle was two times more likely to be involved in a pedestrian crash than an ICE vehicle in situations involving low-speed maneuvers (Hanna, 2009). This report aims to update the previous report with more data by adding additional years of State crash files as well as by increasing the number of States included in the analysis from 12 to 16.

This analysis was conducted on a total of 24,297 HE and 1,001,100 ICE Honda and Toyota selected vehicles in 16 States. A total of 186 and 5,699 HE and ICE vehicles respectively were involved in pedestrian crashes. A total of 116 and 3,052 HE and ICE vehicles respectively were involved in bicycle crashes. Overall, the odds ratios indicate that the odds of an HE vehicle being in either a pedestrian or bicycle crash are greater than the odds of an ICE vehicle being in a similar crash with odds ratios of 1.35 and 1.57 respectively, both of which are statistically significant with p-values under 0.01 percent.

The crash factors of speed limit, vehicle maneuver and location were examined to determine the relative incidence rates of HE versus ICE vehicles and whether the odds ratio (OR) was different under different circumstances. While the results did not provide an apparent set of scenarios for bicycle crashes, the findings provide a clearer picture regarding pedestrian crashes. The largest differences between the involvement of HE and ICE vehicles in pedestrian crashes occur with speed limits of 35 mph and lower (OR = 1.39), during low-speed maneuvers (OR = 1.66) and when the crash is on the roadway (OR = 1.50). This update further extends the analysis to various other vehicle samples with similar results. For example a comparison of all HE versus ICE passenger vehicles regardless of makes and models indicates that the odds of any HE passenger vehicle being in a pedestrian crash are 22 percent greater than the odds of any ICE passenger vehicle. A comparison of particular pairs of HE and ICE vehicles in pedestrian crashes indicated that under low-speed maneuvers, the odds ratio for the HE Prius versus the ICE Corolla was 1.54, and the odds ratio for the HE Civic versus the ICE Civic was 2.14.

While this study provides useful information about the differences in the incidence rates of HE versus ICE vehicles involved in pedestrian crashes, there are two important limitations to consider. First, the analysis of 16 States cannot be used to directly estimate the national problem size. Secondly, as indicated in an analysis of statistical power, there is not enough data to draw conclusions in all scenarios of interest such as for specific low-speed maneuvers or in parking lots.

2. INTRODUCTION

HE passenger vehicles first became available to consumers in 2000, and their numbers as well as their proportion of the passenger vehicle fleet have risen every year since their introduction. According to the R. L. Polk and Company National Vehicle Population Profile, there were only 18,628 registered HE passenger vehicles in 2001. By 2004 there were 145,194 registered HE vehicles comprising 0.1 percent of the passenger vehicle fleet. By 2009 the number had grown to 1,382,605 registered HE vehicles comprising 0.6 percent of the fleet.

An HE vehicle has a conventional engine, usually fueled by gasoline, as well as an electric motor powered by a large battery. Sometimes the internal combustion engine drives the wheels of the vehicle, and sometimes the electric motor drives the wheels. Different hybrid vehicles have different algorithms for handling the electric motor and the ICE. For example the source of power may depend upon the speed of the vehicle, the state of charge of the batteries, the temperature of the engine, and the level of acceleration requested by the driver.

Advocacy groups have raised pedestrian safety concerns regarding HE vehicles because a vehicle using the electric motor may be relatively quieter than a vehicle using an ICE and may not emit the sounds that non-motorists rely on for warning as vehicles approach them on the street or at an intersection. In addition to the hypothesized higher risk of pedestrian and bicyclist crashes, the National Federation of the Blind has expressed concern that these “quieter cars” are a danger to blind pedestrians. Blind and visually impaired pedestrians often rely on hearing an approaching vehicle to judge the vehicle’s speed and proximity while navigating intersection crosswalks and other traffic situations. In response to these concerns, Congress passed Public Law 111-373 “Pedestrian Safety Enhancement Act of 2010,” which was signed into law by the President on January 4, 2011. The law directs “the Secretary of Transportation to study and establish a motor vehicle safety standard that provides for a means of alerting blind and other pedestrians of motor vehicle operation.”

In 2009 NHTSA released the report “Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles” with the finding that an HE vehicle was two times more likely to be involved in a pedestrian crash than a vehicle with only an ICE in situations involving certain low-speed vehicle maneuvers (Hanna, 2009). The report also concluded that the findings would be updated when additional crash data became available. This report aims to update the previous report with more data by adding additional years of State crash files (usually 2007 and 2008 calendar year files) as well as by increasing the number of States included in the analysis from 12 to 16. Similar to the previous study, the purpose of the report is to compare the crash experience of HE and ICE vehicles; it is not to make national estimates of problem size.

3. DATA SOURCE AND DESCRIPTION

State crash files in the State Data System (SDS) were used to measure the incidence rates of pedestrian and bicyclist crashes by HE vehicles and to compare the incidence rates with their peer ICE vehicles. Since the early 1980s, NHTSA has been obtaining electronic data files from States on a voluntary basis that contain information from State-reported police accident reports. The State crash files describe the characteristics of the crash, the vehicles and the people involved. While the SDS currently contains 32 States, not all States collect the same information. Of particular importance for this study is the vehicle identification number or VIN, which is needed to determine whether the crash involved an HE or ICE vehicle. As detailed below, 16 States provided VINs and other information necessary to complete the study. The Fatality Analysis Reporting System (FARS) is not used for this study because there are relatively few pedestrian fatalities involving HE vehicles, especially involving low-speed maneuvers, and the National Automotive Sampling System - General Estimates System (NASS-GES) is not used because of the large proportion of missing VINs.

Even though an analysis of the crash experience in 16 States does not provide a national estimate of the problem size, there are several reasons to use the State Data System. One is that the SDS files include all police-reported traffic crashes within the State, regardless of injury or crash severity, and thus provide a large number of cases for comparison. The second reason is that the crash reports in the States selected for analysis contain the VINs for almost all passenger vehicles. The third reason is that the purpose of the study is to compare the crash experience of two different types of vehicles. If an observed difference between the incidence rates for HE and ICE vehicles exists across a wide variety of States, there is reason to believe that it would hold across the entire country.

The noise produced by a vehicle in motion depends upon many different factors including its shape, type of tires, cruising speed, wind direction towards the car and the natural wind condition. Of these factors, shape is the most important and the only controllable factor for the wind noise (Ono, Himeno, & Fukushima, 1999). Therefore this study includes three vehicle models that were offered as both HE and ICE versions to control for differences in vehicle shape: the Honda Accord, the Honda Civic and the Toyota Camry. The study also includes the Toyota Prius, which is an HE vehicle, and the Toyota Corolla, which is an ICE vehicle. Because of similarities in the vehicle shape, the Corolla was selected as the ICE peer for the Prius. The analysis is limited to vehicles of model year 2000 and later. Make and model, as well as HE versus ICE, was determined for each vehicle using information decoded from the VIN using R. L. Polk's PC-VINA software. Vehicles with unknown or invalid VINs were excluded from the analysis.

Table 1 lists the 16 States and calendar years included in the analysis. While the calendar years included in the analysis ranged from 2000 through 2008, the years of data availability varied across States. The total number of vehicles included from each State thus depended upon both the number of crashes in the State as well as the number of calendar years available for analysis. Overall, 2.4 percent of the vehicles in the study were HE vehicles. The percent of HE vehicles also varied across States from a low of 0.9 percent in Georgia to 5.5 percent in Washington.

Table 1: Total Vehicles in Study by State

State	Years Available	HE Vehicles	ICE Vehicles	Total Vehicles
Alabama	2000 to 2008	895	60,558	61,453
Florida	2002 to 2007	1,277	99,325	100,602
Georgia	2000 to 2006	1,037	112,740	113,777
Illinois	2000 to 2008	6,488	196,073	202,561
Kansas	2001 to 2008	590	17,651	18,241
Kentucky	2000 to 2007	557	37,560	38,117
Maryland	2000 to 2008	1,473	59,506	60,979
Michigan	2004 to 2007	1,282	30,674	31,956
North Carolina	2000 to 2006	1,116	79,303	80,419
North Dakota	2003 to 2008	46	1,383	1,429
New Mexico	2001 to 2008	616	12,605	13,221
New Jersey	2004 to 2008	3,539	161,818	165,357
Pennsylvania	2000 -01, 2003- 08	1,282	53,151	54,433
Washington	2002 to 2007	2,282	39,062	41,344
Wisconsin	2000 to 2008	1,718	37,221	38,939
Wyoming	2000 to 2007	99	2,370	2,469
Total		*24,297*	*1,001,000*	*1,025,297*

Table 2 and Figure 1 demonstrate the distribution of HE vehicles by calendar year. While the number of HE vehicles in the study dips in 2008 because the number of States with 2008 data available for analysis is 5 fewer than the number in 2007, the percent of HE vehicles among those in the study steadily increases over each calendar year.

Table 2: HE Vehicles in Study and Percentage by Year

Year	Number of States	HE Vehicles	Total Vehicles	Percent HE Vehicles
2000	9	8	15,241	0.05
2001	11	60	34,364	0.17
2002	12	317	61,080	0.52
2003	14	751	90,649	0.83
2004	16	1,753	148,998	1.18
2005	16	3,140	176,732	1.78
2006	16	5,147	196,973	2.61
2007	14	6,752	172,535	3.91
2008	9	6,369	128,725	4.95
Total		*24,297*	*1,025,297*	

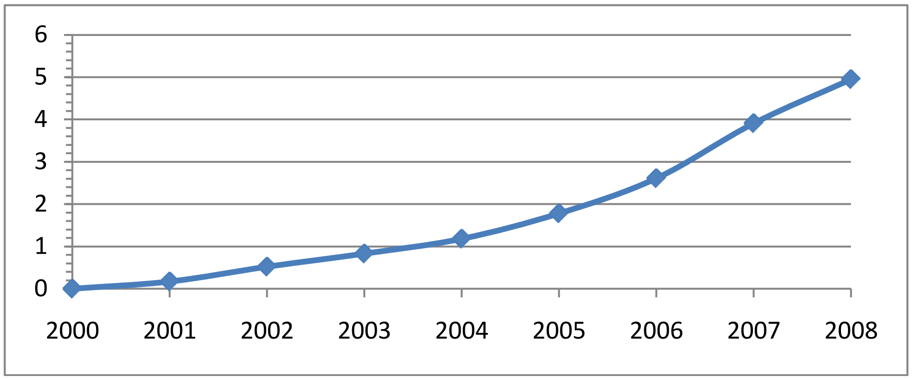

Figure 1: HE Share (%) Among Toyota and Honda Models in Study

Table 3 shows the vehicle models included in the analysis by make and model. The most common HE vehicle in the analysis is the Toyota Prius, and the most common ICE vehicle is the Honda Accord.

Table 3: Vehicle Models in Study by Engine Type

Model	HE Vehicles	ICE Vehicles	Total Vehicles
Honda Accord	1,060	276,246	277,306
Honda Civic	6,496	244,197	250,693
Toyota Camry	1,832	276,272	278,104
Toyota Corolla		204,285	204,285
Toyota Prius	14,909		14,909
Total	*24,297*	*1,001,000*	*1,025,297*

Data reporting from States is not uniform. Common data attributes were created for the variables included in this analysis to allow aggregation of data across States. Some States do not report certain data fields. The numbers of cases that have not been reported by States or reported as unknown are noted under each table throughout this report.

In this analysis it was important to control for vehicle speed, which can be related both to vehicle noise and the source of power for an HE vehicle. However, due to the fact that vehicle travel speed is not reliably reported in most police accident reports, we used speed limit as a proxy for vehicle travel speed prior to the crash. A speed limit of 35 mph was used as a cut-off; pedestrian and bicyclist crashes were examined at speed limits less than or equal to 35 mph versus speed limits greater than 35 mph.

The vehicle maneuver prior to the crash also was examined because in some cases the speed limit may be a poor proxy for actual vehicle speed such as when a vehicle starts from a stopped position in a zone with a speed limit greater than 35 mph. Crash location also was examined because slower speeds may be associated with crashes at intersections. Note that while crashes occurring off the roadway include those in parking lots, most States do not enter parking lot crashes into their State crash file, and therefore most State Data System files do not include these crashes. In this analysis only two States (Kentucky and North Carolina) include these crashes in their State files.

Tables 4, 5, and 6 summarize the distribution of speed limit, vehicle maneuver and crash location for HE and ICE vehicles in relevant crashes. Table 4 indicates that for HE and ICE vehicles with a known speed limit, most crashes occur where the speed limit is over 35 mph. Table 5 shows that the most common vehicle maneuver for both types is "going straight," and Table 6 points out that the most common crash location is on the roadway.

Table 4: Speed Limit at Crash Location

Speed	HE Vehicles	HE Percent	ICE Vehicles	ICE Percent
<= 35 mph	6,104	25%	224,192	22%
> 35 mph	6,817	28%	276,636	28%
Unknown or missing	11,376	47%	500,172	50%
Total	*24,297*	*100%*	*1,001,000*	*100%*

Table 5: Vehicle Maneuvers

Vehicle Maneuver	HE Vehicles	HE Percent	ICE Vehicles	ICE Percent
Going straight	9,785	40%	412,780	41%
Making a turn	2,677	11%	108,923	11%
Slowing/stopping	3,179	13%	110,043	11%
Backing	903	4%	30,000	3%
Entering/leaving parking space/driveway	219	1%	10,286	1%
Starting in traffic	280	1%	9,188	1%
Other or unknown	7,254	30%	319,780	32%
Total	*24,297*	*100%*	*1,001,000*	*100%*

Table 6: Crash Locations

Location	HE Vehicles	HE Percent	ICE Vehicles	ICE Percent
On roadway	10,697	44%	481,396	48%
Intersection/interchange	1,839	8%	78,605	8%
Off roadway including parking lot	1,960	8%	68,508	7%
Other or unknown	9,801	40%	372,491	37%
Total	*24,297*	*100%*	*1,001,000*	*100%*

4. METHODS

This analysis was conducted on a total of 24,297 HE and 1,001,000 ICE vehicles that met the selection criteria. Involvement in a pedestrian or bicyclist crash reflects the first harmful event in the crash. The first harmful event (FHE) indicates the first event to cause injury or damage in the crash. Incidence rates were calculated as the number of vehicles of a given type involved in crashes where the FHE was a collision with a pedestrian or bicyclist under certain scenarios, divided by the total number of that type of vehicle that were in any crashes under the same scenarios. State crash files from the SDS do not include information on pedestrian vision status, and this analysis provides data on pedestrian crashes regardless of pedestrian vision status.

The basic method of analysis in this report is the calculation of relative risk and odds ratios using a case-control approach where the HE vehicles are the "case" or "exposed" group and the ICE vehicles are the "control" or "unexposed" group (Breslow & Day, 1980). Table 7 demonstrates the basic two by two table design that forms the basis of the analysis.

Table 7: Case-Control Study of HE Versus ICE Vehicles

	Vehicle in Crash of Interest	Vehicle in Other Crash	Total
Case (HE)	A	B	A+B
Control (ICE)	C	D	C+D
Total	A+C	B+D	A+B+C+D

A total of 5,885 vehicles were involved in crashes with the first harmful event being a collision with a pedestrian: 186 involving HE vehicles and 5,699 involving ICE vehicles. Similarly a total of 3,168 vehicles were involved in crashes with the first harmful event being a collision with a bicyclist: 116 involving HE vehicles and 3,052 involving ICE vehicles. Table 8 provides these numbers for vehicles in pedestrian crashes in the same format as Table 7.

Table 8: Case-Control Study of Vehicles in Pedestrian Crashes

	Vehicle Involved in Pedestrian Crash	Vehicle Involved in Other Crash	Total
HE Vehicle	186 (A)	24,111 (B)	24,297
ICE Vehicle	5,699 (C)	995,301 (D)	1,001,000
Total	5,885	1,019,412	1,025,297

The concepts of "Incidence," "Relative Risk," "Attributable Risk," and "Odds Ratio" are important for the analysis of a case-control design. These concepts are best illustrated using the numbers in Table 8 as an example. Table 9 demonstrates these concepts as well as the statistics commonly presented in case-control and epidemiological studies (Koepsell & Weiss, 2003).

Table 9: Risks and Odds Ratio for Vehicles in Pedestrian Crashes

Statistic	Definition	Example from Table 8 Data
Incidence in exposed group (HE)	$\mathbf{I_e}$ = A / (A+B)	186/24,297=0.0077 (0.77%)
Incidence in unexposed group (ICE)	$\mathbf{I_u}$ = C / (C+D)	5,699/1,001,000=0.00570 (0.57%)
Relative Risk	**RR** = I_e / I_u	0.0077/0.0057=1.35
Odds Ratio	**OR** = $\{I_e/(1-I_e)\}\div\{I_u/(1-I_u)\}$ = (AD)/(BC)	(186x995301)/(24,111x5699)=1.35
Incidence in population (HE & ICE)	$\mathbf{I_p}$ = (A+C) / (A+B+C+D)	5,885/1,025,297 =0.00574 (0.57%)
Attributable Risk (Risk Difference)	**AR** = $I_e - I_u$	0.0077-0.0057=0.0020 (0.20%)
Attributable Risk %	**AR%** = (AR/I_e)*100	(0.0020/0.0077)x100=26%
Attributable Risk to the Population	**PAR** = $I_p - I_u$	0.00574-0.00570=0.00004 (0.004%)
Attributable Risk to the Population %	**PAR%** = (PAR/I_p)*100	(0.00004/0.0057)x100 =0.7%

The interpretations for above calculations are as follows:

- The incidence and the odds of HE vehicles being involved in a pedestrian crash are 1.35 times (35% higher) as much as the corresponding incidence and odds of an ICE vehicle being involved in a similar crash (OR=1.35, RR=1.35).
- If all HE vehicle drivers gave up their HE vehicles and switched to ICE vehicles, their incidence of pedestrian crash would decrease by 0.20 per 100 (AR=0.20%), which would represent a 26 percent reduction in their pedestrian crash incidence rate (since the current I_e of 0.77 percent would be reduced to 0.57%).
- If all vehicles were ICE or all HE vehicles were turned into ICE (PAR=0.004%), a reduction of 0.004 new cases of vehicles involved in pedestrian crashes per 100 combined vehicles (ICE and HE) would be expected. Such reduction represents a 0.7 percent reduction of all vehicles involved in pedestrian crashes (since I_p will be reduced to 0.570 percent from current 0.574%). Note that the HE vehicle sample size available in this study is relatively small (2.4 percent of all vehicles), and hence the HE sample has a very small impact on the overall incidence rate.

While all of the above statistics are commonly used in case-control designs, this analysis focuses on three: I_e, I_u, and OR. The remaining statistics can be derived from the data presented in the tables. Table 10 summarizes these key statistics for pedestrian and bicycle crashes.

Table 10: Odds Ratios for HE Versus ICE Vehicles

	Vehicles Involved in Pedestrian Crashes	Vehicles Involved in Bicycle Crashes
Incidence Rate for HE ($\mathbf{I_e}$)	0.77%	0.48%
Incidence Rate for ICE ($\mathbf{I_u}$)	0.57%	0.30%
Odds Ratio (**OR**)	1.35	1.57
95% Confidence Interval (C.I.) of OR	1.16 to 1.56	1.30 to 1.89
Statistical Significance of OR vs. One	<0.0001	<0.0001

Since the ratios of vehicles involved in pedestrian and bicyclist crashes to total vehicles are very small (under 1%), the statistical power associated with the analysis could also be low. Low statistical power means that it may be difficult to reject the null hypothesis of no difference in the risk for HE versus ICE vehicles. If a minimum 80 percent statistical power is required for this study and a conventional statistical significance level of 5 percent is used, the minimum sample sizes required for the case-control studies can be estimated. For example, if the size ratio (ICE to HE) is 30 due to many more ICE than HE vehicles in the study, then the minimum sample size needed for HE vehicles is 13,203, and the 24,297 HE vehicles in the analysis are enough to meet the 80 percent power requirement. Therefore, even though the sample sizes appear low, they should be adequate for the required analysis. With more HE vehicles available in the future, it is more desirable to perform some statistical comparisons between ICE and HE with much smaller size ratio (ICE to HE), for example, 10:1, 5:1 or, even 1:1 comparison. More details about statistical power and sample size calculations associated with Tables 8 through 10 can be found in Appendix One.

5. PEDESTRIAN CRASH DETAILS

This section examines the circumstance surrounding pedestrian crashes involving HE versus ICE vehicles and determines circumstance under which the largest differences in relative risk exist.

5.1 Zone Speed Limit

In most cases, a vehicle's actual travel speed prior to the crash is unknown. Therefore, the speed limit was used as a proxy for vehicle travel speed. Of the 6,104 HE vehicles that were involved in crashes while traveling in a speed zone of 35 mph or less, Table 11 shows that 85 of these vehicles involved pedestrian crashes at an incidence rate of 1.39 percent. Of the 224,192 ICE vehicles that were traveling in zones of 35 mph or less, Table 11 shows that 2,264 of these vehicles involved pedestrian crashes at an incidence rate of 1.01 percent. The odds ratio of 1.39 for lower speed limit crashes is statistically different from one. However, HE vehicles do not appear more likely to be involved in pedestrian crashes while traveling in a speed zone of more than 35 mph than ICE vehicles.

Table 11: **Speed Limit for HE Versus ICE Vehicles in Pedestrian Crashes**

Speed Limit	HE Vehicle Involved in Pedestrian Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Pedestrian Crash	ICE Vehicle Incidence Rate	Odds Ratio
<= 35 mph	85	1.39%	2,264	1.01%	1.39*
> 35 mph	13	0.19%	786	0.28%	0.68
Known total	98		3,050		
Unknown	88		2,649		
Totals	*186*		*5,699*		5,885

Note: Odds ratios with an asterisk are statistically different from one at the 0.05 level.

5.2 Vehicle Maneuver

As seen previously in Table 5, going straight is the most common vehicle maneuver prior to pedestrian crashes for both HE and ICE vehicles. As indicated in Table 12, the incidence rate of pedestrian crashes while the vehicle was going straight was 0.75 percent for HE vehicles (73 of 9,785 vehicles) and was 0.78 percent for ICE vehicles (3,206 of 412,780 vehicles). The odds ratio was close to one and was not statistically different from one at the 0.05 level.

Incidence rates of pedestrian crashes that potentially have occurred at very low speed such as when a vehicle is making a turn, slowing or stopping, backing up, entering or leaving a parking space, or starting in traffic tend to be higher among HE vehicles when compared to ICE vehicles. However, the sample sizes associated with these individual maneuvers are relatively small, which may make it difficult to achieve statistical significance due to low power. In fact, among the low-speed maneuvers, only the maneuver of “making a turn” indicated a statistically significant difference at conventional levels. When these five types of maneuvers are combined into one category known as “low-speed maneuvers,” the resulting odds ratio of 1.66 is statistically significant at the 0.05 level (p-value < 0.0001).

Table 12: Vehicle Maneuver for HE Versus ICE Vehicles in Pedestrian Crashes

Vehicle Maneuver	HE Vehicle Involved in Pedestrian Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Pedestrian Crash	ICE Vehicle Incidence Rate	Odds Ratio
Going straight	73	0.75%	3,206	0.78%	0.96
Low-speed maneuvers	90	1.24%	2,015	0.75%	1.66*
Making a turn	*59*	2.20%	*1,251*	1.15%	
Slowing/stopping	*9*	0.28%	*211*	0.19%	
Backing	*13*	1.44%	*385*	1.28%	
Entering/leaving parking space/driveway	*3*	1.37%	*94*	0.91%	
Starting in traffic	*6*	2.14%	*74*	0.81%	
Other or unknown	23	0.32%	478	0.15%	
Totals	*186*		*5,699*		5,885

Note: Odds ratios with an asterisk are statistically different from one at the 0.05 level.

5.3 Crash Location

As seen previously in Table 6, "on roadway" was the most common location where pedestrian crashes occurred for both HE and ICE vehicles. Of the 10,697 HE vehicles that were involved in crashes on roadways, Table 13 indicates that 67 were involved in pedestrian crashes for an incidence rate of 0.63 percent. Of the 481,396 ICE vehicles that were involved in crashes on roadways, Table 13 indicates that 2,017 were involved in pedestrian crashes for an incidence rate of 0.42 percent. The resulting odds ratio of 1.5 was statistically significant from one at the 0.05 level. The odds ratios associated with intersection/interchange and off roadway crashes, however, were not statistically significant from one.

Table 13: Crash Location for HE Versus ICE Vehicles in Pedestrian Crashes

Location of Crash	HE Vehicle Involved in Pedestrian Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Pedestrian Crash	ICE Vehicle Incidence Rate	Odds Ratio
On roadway	67	0.63%	2,017	0.42%	1.50*
Intersection/interchange	11	0.60%	377	0.48%	1.25
Off roadway/parking lot	11	0.56%	553	0.81%	0.69
Other or unknown	97	0.99%	2,752	0.74%	
Totals	*186*		*5,699*		5,885

Note: Odds ratios with an asterisk are statistically different from one at the 0.05 level.

5.4 Additional Discussion of Pedestrian Crashes With Low-Speed Maneuvers

The odds ratios presented above are only one way to calculate the odds ratios, and there is at least one other way to calculate the odds ratios with different interpretations. The method above and the alternative method can best be illustrated using the odds ratio calculated for low-speed maneuvers described in Table 12.

The following example describes more details used in the above Table 12 for the same group of "low-speed maneuvers" that include turning, backing, slowing/stopping starting, and entering/exiting parking. A total of 7,258 HE vehicles were engaged in one of the low-speed maneuvers prior to the crashes; of them 90 vehicles involved pedestrians as the first harmful event (crash rate=90/7,258=1.24%). On the other hand, a total of 268,440 ICE vehicles were engaged in one of these maneuvers prior to the crashes; of them 2,015 vehicles involved pedestrians as the first harmful event (crash rate= 2,015/268,440=0.75%).

The odds ratio is thus calculated as shown in Table 14. The odds ratio of 1.66 indicates that the odds of an HE vehicle being involved in a pedestrian crash are 66 percent higher than the odds of an ICE vehicle being involved in a pedestrian crash, assuming that both HE and ICE vehicles are associated with low-speed maneuvers *prior to* crashes.

Table 14: Vehicle Counts for Low-Speed Maneuvers Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE	90	7,168	7,258
ICE	2,015	266,425	268,440
Total	2,105	273,593	275,698

Odds Ratio =1.66 (p-value < 0.0001), 95% C.I. = 1.34 to 2.05; RR=1.24 /0.75 = 1.65

The odds ratios and relative risk of Table 14 could be also calculated *visually* using probabilities conditional on a pedestrian crash occurring. The following Figure 2 illustrates this concept using a conditional probability tree and dividing *all* HE and ICE vehicles into three levels. Like Table 14, there were 90 pedestrian crashes among 7,258 HE vehicles with slow-speed maneuvers (Levels II and III), and the crash rate "p_3" was 1.24 percent. Similarly, there were 2,015 pedestrian crashes among 268,440 ICE vehicles with slow-speed maneuvers (Level III and Level II), and the crash rate "p_3" was 0.75 percent. Hence, the relative risk (RR) was 1.24/0.75 or 1.65. The value of RR (1.65) is very close to OR value (1.66) if crash rates are very small (less than 2%). The interpretation of this RR or odds ratio is as the same as Table 14, the HE pedestrian crash odds was 66 percent higher than ICE, given that both HE and ICE vehicles were associated the slow-speed maneuvers *prior to* crashes.

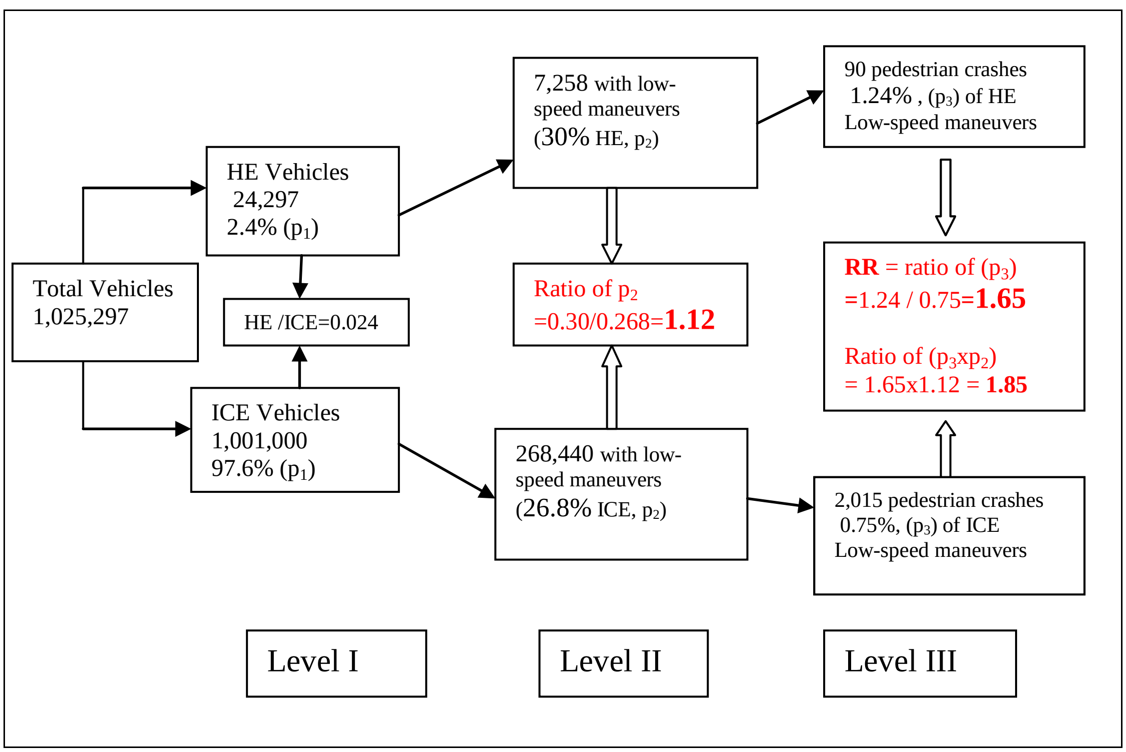

Figure 2: Three Levels of Crashes: All Crashes (I), Vehicles Involving Low-Speed Maneuvers (II), and Pedestrian Crashes with Low-Speed Maneuvers (III)

If *all* HE and ICE vehicles (Level I, II and to III) are considered, the probability of an HE vehicle involved in a pedestrian crash with a low-speed maneuver can be calculated backward, as (p_3 x p_2) = 0.0124 x 0.3 =0.0037 (0.37%), or approximately 4 per 1,000 of *all* HE vehicles in police-reported crashes. Similarly, the probability of an ICE vehicle involved in a pedestrian crash with a low-speed maneuver is (p_3 x p_2) = 0.0075 x 0.27 or 0.0020. The relative risk (RR) was therefore 0.0037/0.002 or 1.85. The interpretation is that an HE vehicle had 85 percent higher crash odds than ICE vehicle, given that a vehicle was *both* with low-speed maneuvers *and* involved a pedestrian crash.

The RR value of 1.85 in Figure 2, using *all* HE and ICE vehicles, provides the *structural* data insight about how the characteristics of pedestrian crashes involving HE vehicles differ from those involving ICE vehicles. However, the odds ratio or RR value of 1.66, using vehicles with *low-speed maneuvers* only, is the one used throughout this report, since the main purpose of this study is to understand the circumstances, low-speed maneuvers, under which pedestrian crashes involving HE vehicles are more likely compared to their ICE peers.

5.5 Pedestrian Crashes From Various Data Samples

The earlier sections discuss the crashes of the five models that were initially used in NHTSA's 2009 report (Hanna, 2009): Honda Accord, Toyota Camry, Honda Civic, Toyota Corolla, and Toyota Prius (or "Sample One"). This section explores the pedestrian crashes using various samples, for instance, to include all passenger vehicles from all manufacturers during the same period (in addition to the original five models from Toyota and Honda) for the purpose of better understanding the *general crash patterns* (or "Sample Two"). However, note that the hybrid electric and the purely electric vehicles are combined in this analysis. The number of purely electric vehicles among the 33,851 hybrid electric and purely electric vehicles used in Sample Two is miniscule and is not sufficient to analyze these vehicles separately.

After looking at all passenger vehicles, the focus turns to specific models. The comparison between Prius and Corolla alone was made, since Prius counts for 61 percent of all HE vehicles in the study ("Sample Three"). A similar approach is also applied to the Civic, which accounts for 27 percent of the HE vehicles in the study ("Sample Four").

- ***Sample Two: Comparing HE with ICE for All Passenger Vehicles***

When all passenger vehicles are considered from the same 16 States during the same period, the following Table 15 provides the numbers of passenger vehicles by whether they were involved in a pedestrian crash. A total of 66,867 passenger vehicles were involved in crashes with the first harmful event being a collision with a pedestrian: 244 involving HE vehicles and 66,623 involving ICE vehicles.

Table 15: Passenger Vehicle Counts Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE	244	33,607	33,851
ICE	66,623	11,183,287	11,249,910
Total	66,867	11,216,894	11,283,761

Odds Ratio = 1.22 (p-value = 0.021), OR 95% C.I. = (1.07 to 1.38)

One interesting thing to note is that the original four hybrid models selected for the study comprise 72 percent of the total hybrid passenger vehicles identified in these States. In fact, the Prius accounted for 44 percent, the hybrid Civic 19 percent, the hybrid Camry 5 percent, and the hybrid Accord 3 percent. Adding all passenger vehicles to the analysis reduces the odds ratio for HE versus ICE involvement in pedestrian crashes from 1.35 to 1.22, but the lower odds ratio is still significantly different from one at the conventional 0.05 level.

Furthermore, a total of 10,320 HE vehicles were engaged in one of the low-speed maneuvers prior to the crashes; of them 114 vehicles involved pedestrians as the first harmful event. On the other hand, a total of 2,987,005 ICE vehicles were engaged in one of these maneuvers prior to the crashes; of them 24,026 vehicles involved pedestrians as the first harmful event. These numbers and crash odds ratio are summarized in Tables 16. The odds ratio using all passenger vehicles instead of the five models used in the initial study reduced from 1.66 to 1.38 but was still statistically significant.

Table 16: Passenger Vehicle Counts
For Low-Speed Maneuvers Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE	114	10,206	10,320
ICE	24,026	2,962,979	2,987,005
Total	24,140	2,970,147	2,997,325

Odds Ratio (OR) = 1.38, p-value< 0.0007, OR 95% C.I. = (1.14 to 1.66)

- ***Sample Three: Comparing Prius With Corolla***

About 61 percent of all HE vehicles selected under the original study design, and about 44 percent of all hybrid vehicles from these 16 States during 2000 through 2008 are Priuses. The following analysis focused on the comparison of the Prius with its similar vehicle, Corolla. Table 17 provides the numbers of Priuses and Corollas by whether they were involved in a pedestrian crash. Table 18 shows similar counts for low-speed maneuvers. In Table 17 the odds ratio for all pedestrian crashes was not statistically different from one meaning that the odds of the Prius and Corolla being involved in any pedestrian crash are similar. However, Table 18 indicates that the odds ratio for Priuses involved in pedestrian crashes during low-speed maneuvers versus Corollas being involved in similar crashes is statistically greater than one. In fact the odds ratio of 1.54

is similar to the odds ratio of 1.66 found using the initial five models during low-speed maneuvers.

Table 17: Prius and Corolla Counts Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE (Prius)	117	14,792	14,909
ICE(Corolla)	1385	202,900	204,285
Total	1502	217,692	219,194

Odds Ratio = 1.16 (p-value = 0.13), Odds Ratio 95% C.I. = (0.96 to 1.40)

Table 18: Prius and Corolla Counts For Low-Speed Maneuvers Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE (Prius)	58	4,434	4,492
ICE(Corolla)	478	56,183	56,661
Total	536	60,617	61,153

Odds Ratio = 1.54 (p-value= 0.002), OR 95% C.I. = (1.17 to 2.02)

- ***Sample Four: Comparing Civic HE With Civic ICE:***

The following analysis compares Civic HE with Civic ICE vehicles, from the same 16 States during 2000 through 2008. Table 19 provides the numbers of HE and ICE Civics by whether they were involved in a pedestrian crash. Table 20 shows similar counts for low-speed maneuvers. In both cases, the odds ratio indicates that the odds of the HE Civic being involved in a pedestrian crash are significantly higher than its ICE counterpart.

Table 19: Civic Counts Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE (Civic)	52	9,444	6,496
ICE(Civic)	1156	243,041	244,197
Total	1208	252,485	250,693

Odds Ratio = 1.70, p-value < 0.0001, OR 95% C.I. = (1.28 to 2.24)

Table 20: Civic Counts for Low-Speed Maneuvers Prior to a Pedestrian Crash

	First Harmful Event Involved a Pedestrian	First Harmful Event Did Not Involve a Pedestrian	Total
HE (Civic)	24	1,819	18,43
ICE(Civic)	390	63,117	63,507
Total	414	64,936	65,350

Odds Ratio = 2.14, p-value < 0.0002, OR 95% C.I. = (1.41 to 3.23)

In summary, the following Figure 3 shows the overall pedestrian crash rates and odds ratios of HE versus ICE vehicles in the four different analyses. The following Figure 4 summarizes the pedestrian crash rates and odds ratios of HE versus ICE vehicles with low-speed maneuvers. The HE sample sizes of Honda Accord and Toyota Camry, however, are too small to make any significant comparisons with the similar ICE vehicles and are not presented here (see Table 3 for sample sizes).

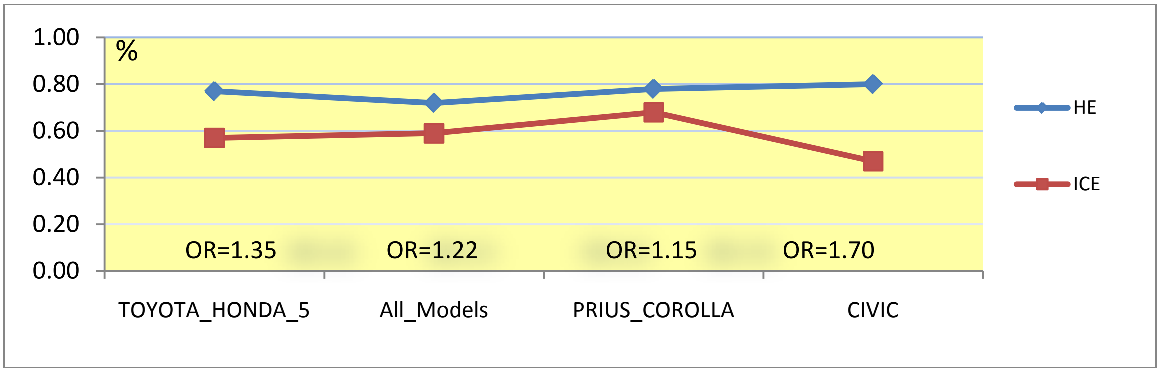

Figure 3: Overall Pedestrian Crash Rates and OR From Four Samples

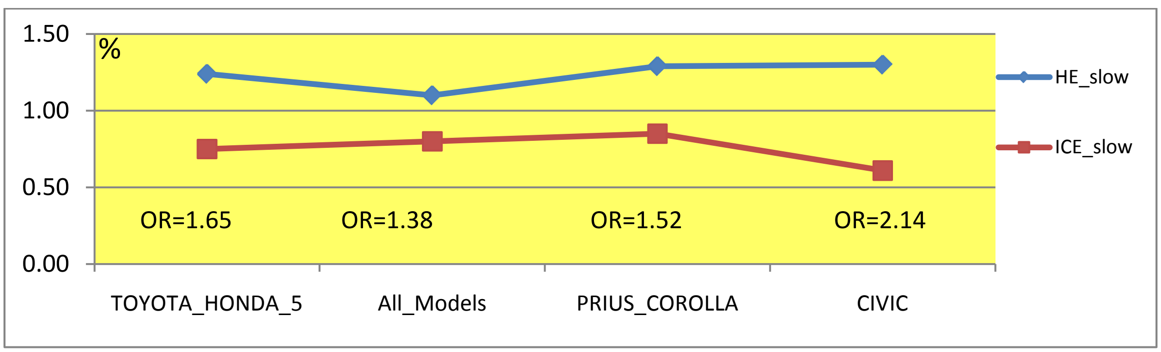

Figure 4: Pedestrian Crashes Involving a Low-Speed Maneuver From Four Samples

6. BICYCLIST CRASH DETAILS

This section examines the circumstances surrounding bicyclist crashes involving HE versus ICE vehicles and determines the circumstances under which the largest differences in relative risk exist. A total of 116 HE vehicles were involved in crashes with bicyclists, accounting for 0.48 percent (116/24,297) of all HE vehicles included in this analysis. A total of 3,052 ICE vehicles were involved in crashes with bicyclists, accounting for 0.3 percent (3,052/1,001,000) of all ICE vehicles included in this analysis. As indicated in Table 21, this produced an odds ratio of 1.57, which is statistically different from 1 at the 0.05 level (p-value < 0.0001). The following Table 21 summarizes the result.

Table 21: Case-Control Study of Vehicles in Bicyclist Crashes

	Vehicle Involved in Bicyclist Crash	Vehicle Involved in Other Crash	Total
HE Vehicle	116	24,181	24,297
ICE Vehicle	3,052	997,948	1,001,000
Total	3,168	1,022,129	1,025,297

OR=1.57; 95% C.I. = (1.30 to 1.89); p-value < 0.0001

6.1 Zone Speed Limit

Overall most bicyclist crashes involving either HE or ICE vehicles occurred in low-speed-limit zones. As shown in Tables 22 and Table 4, of the 6,104 HE vehicles that were traveling in speed zones of 35 mph or less, 37 of them involved bicycle crashes with an incidence rate of 0.61 percent. On the other hand, of the 224,192 ICE vehicles involved in crashes in speed zones of 35 mph or less, 999 vehicles involved bicycle crashes with an incidence rate of 0.45 percent. However, unlike the finding for pedestrian crashes, the odds ratio for crashes at speed limits of 35 mph or less was not statistically significant from one at the 0.05 level (Odds Ratio=1.36 with a non-significant *p*-value = 0.07).

Table 22: Speed Limit at the Bicycle Crash Location

Speed Limit	HE Vehicle Involved in Bicycle Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Bicycle Crash	ICE Vehicle Incidence Rate	Odds Ratio
<= 35 mph	37	0.61%	999	0.45%	1.36
> 35 mph	17	0.25%	424	0.15%	1.67*
Known Total	54		1,423		
Unknown Total	62		1,629		
Total	*116*		*3,052*		

Note: Odds ratios with an asterisk are statistically different from one at the 0.05 level

6.2 Vehicle Maneuver

Most bicyclist crashes in this analysis involving either HE or ICE vehicles occurred while the vehicles were going straight. As indicated in Table 23, the odds ratio is 1.59, which is significantly different from one at the 0.05 level. Incidence rate of a bicyclist crash that potentially has occurred at low speed such as when a vehicle makes a turn, slows or stops, backs up, or enters or leave a parking space was significantly higher among HE vehicles when compared to ICE vehicles. Tables 5 and 23 indicate that a total of 7,258 HE vehicles that were engaged in one of these maneuvers prior to the crashes, 50 crashes involved bicyclists as the first harmful event at an incidence rate of 0.69 percent. On the other hand, a total of 268,440 ICE vehicles were engaged in one of these maneuvers prior to the crashes; of them 1,394 vehicles involved bicyclists as first harmful event at an incidence rate of 0.52 percent. The resulting odds ratio of 1.33 was marginally and statistically significant at the 0.05 level (*p*-value = 0.05).

Table 23: Vehicle Maneuvers Prior to Bicycle Crashes

Vehicle maneuver	HE Vehicle Involved in Bicycle Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Bicycle Crash	ICE Vehicle Incidence Rate	Odds Ratio
Going straight	50	0.51%	1,335	0.32%	1.59*
Low-speed maneuvers	50	0.69%	1,394	0.52%	1.33*
Making a turn	*37*	1.38%	*1,060*	0.97%	
Slowing/stopping	*4*	0.13%	*172*	0.16%	
Backing	*2*	0.22%	*36*	0.12%	
Entering/leaving parking space/driveway	*4*	1.83%	*54*	0.52%	
Starting in traffic	*3*	1.07%	*72*	0.78%	
Other and unknown	16	0.22%	323	0.10%	
Total	*116*		*3,052*		

Note: Odds ratios with an asterisk are statistically different from one at the 0.05 level.

6.3 Crash Location

On the roadway was the most common location where bicycle crashes occurred for both HE and ICE vehicles. Of the 10,697 HE vehicles that were involved in crashes on the roadway, 43 of them were involving bicyclists in the first harmful event of the crash at an incidence rate of 0.4 percent. Of the 481,396 ICE vehicles that were involved in crashes on roadways, 1,275 of them involved bicyclists in the first harmful event of the crash at an incidence rate of 0.26 percent (see Tables 6 and 24). The odds ratio of 1.52 for on roadway crashes was significantly different from one. The incidence rate of bicyclist crashes involving HE vehicles at intersections or interchanges was 1.03 percent compared to 0.65 percent for ICE vehicles. In this instance the odds ratio was significantly different from one at the 0.05 level.

Table 24: Location of Bicycle Crashes

Location of Crash	HE Vehicle Involved in Bicycle Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Bicycle Crash	ICE Vehicle Incidence Rate	Odds Ratio
On roadway	43	0.40%	1,275	0.26%	1.52*
Intersection/Interchange	19	1.03%	508	0.65%	1.58*
Off roadway/parking lot	13	0.66%	381	0.56%	1.18
Other and Unknown	41	0.42%	888	0.24%	
Total	*116*		*3,052*		

7. CONCLUSIONS AND DISCUSSION

- This analysis was conducted on a total of 24,297 HE and 1,001,000 ICE Honda and Toyota vehicles in 16 States. A total of 186 and 5,699 HE and ICE vehicles selected for the study respectively were involved in pedestrian crashes. A total of 116 and 3,052 HE and ICE vehicles selected for the study respectively were involved in bicycle crashes. Since the HE vehicle share among all of the vehicles in the study is small (2.4%), special attention is paid to sample size calculations prior to any statistical comparisons between HE and ICE vehicle crash involvement. However, the sample size of HE vehicles in this update is 2.9 times the HE sample size in the report published in 2009 (Hanna, 2009).

- Statistical methods of relative risk, odds ratio, and case-control studies are applied to the analysis of both pedestrian and bicyclist crashes. Overall, the odds ratios indicate that the odds of an HE vehicle being in either a pedestrian or bicycle crash are greater than the odds of an ICE vehicle being in a similar crash. The odds ratio for an HE versus an ICE vehicle involved in a pedestrian crash was 1.35, and the odds ratio for an HE versus an ICE vehicle involved in a bicycle crash was 1.57. Both odds ratios were statistically different from one with a p-value of less than 0.01 percent. The interpretations of odds ratios or relative risks, in terms of different data samples, were also visually explained.

- A variety of crash factors were examined to determine the relative incidence rates of HE versus ICE vehicles and whether the odds ratio was different under different circumstances. This paper focused on speed limit, vehicle maneuver and crash location.

- The results for speed limit indicated that the odds ratio for the involvement of HE versus ICE vehicles was statistically different from one in pedestrian crashes when the speed limit was 35 mph or less. However, the odds ratio was not statistically different from one for bicycle crashes where the speed limit was 35 mph or less, which is likely the result of a small sample size and low power.

- When the passenger vehicle's maneuver was "going straight," the odds ratio for pedestrian crashes involving HE vehicles compared to ICE vehicles was not statistically different from one. However, the statistically significant odds ratio for vehicles going straight indicated that HE vehicles were more likely to be involved in a bicycle crash than ICE vehicles.

- The largest difference between the incidence rates of HE versus ICE vehicles in this study occurred in low-speed passenger vehicle maneuvers: those in which a vehicle is turning, slowing or stopping, backing up, or entering or leaving a parking space. Similar to the results presented in NHTSA's previous study (Hanna, 2009), the odds of an HE vehicle being involved in a pedestrian crash was 1.66 times the odds of an ICE vehicle being involved in a similar crash. It is hypothesized that these low-speed vehicle maneuvers may provide the largest difference between the vehicle sounds, in terms of both sound level and frequency, produced by the HE versus ICE vehicles, and this sound difference may further contribute to the crash rate difference between HE and ICE vehicles. This similar finding also held in bicycle crashes but with a lower odds ratio of 1.33.

- The analysis of crash location indicated that the odds of an HE vehicle being involved in a pedestrian crash were statistically higher than the odds of ICE vehicle being involved in similar crash when the crash occurred on the roadway. However, the odds of an HE vehicle being involved in a bicycle crash were statistically higher than the odds of ICE vehicle being involved in similar crash when the crash occurred at an intersection.

- While the results do not provide an apparent set of scenarios surrounding when the odds of an HE vehicle being involved in a bicycle crash are greater than those of an ICE vehicle, the findings provide a clearer picture regarding involvement in pedestrian crashes. The largest differences between the involvement of HE and ICE vehicles in pedestrian crashes occur with speed limits of 35 mph and lower (OR = 1.39), during low-speed maneuvers (OR = 1.66) and when the crash is on the roadway (OR = 1.50).

- This updated analysis further explores pedestrian crashes, especially associated with low-speed maneuvers, using various samples, for instance, to include all passenger vehicles during the same period for the purpose of better understanding the general crash pattern. On the other hand, the comparison between Prius and Corolla only was also made, since Prius accounts for 61 percent of all HE vehicles among the five models in the original study. A similar approach was also applied to Civic HE and ICE version. The results from the various samples share the similar trends as the results obtained from the original five Toyota and Honda models.

- While this study provides useful information about the differences in the incidence rates of HE versus ICE vehicles involved in pedestrian crashes, there are two important limitations to consider. First, as stated in the purpose of this study, the use of data from 16 States cannot be used to directly estimate the national problem size or target population. Secondly, as indicated in power analysis, there is still not enough data to draw conclusions in all scenarios of interest such as for specific low-speed maneuvers or in parking lots.

- Overall, the results from this updated analysis share the similar trends as the 2009 report, while this update pays special attentions to these areas: the greater statistical power with a three times large HE vehicle sample size; methodological applications of odds ratio, relative risk, and case-control studies to various crash scenarios; modeling of pedestrian crashes from four different samples; and detailed interpretations of the odds ratios and relative risks with numerical and graphical presentations, furthermore, with a focus on the pedestrian crash rate comparison between HE and ICE vehicles associated with low-speed maneuvers.

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9. ACKNOWLEDGEMENT

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10. APPENDIX ONE: SAMPLE SIZE CALCULATIONS

One important part of comparing the incidence rates of any two groups is to make sure that the study sample size is large enough, so that a sufficiently statistical power, at least 80 percent, can be reached (or a smaller p-value can be obtained, see Piantadosi, 1997), the sample size is especially important if the incidence rates are very small, such as the pedestrian crash rates from either HE or ICE vehicles (often under 1.5%).

The sample size of each group of HE and ICE is obtained as following Equation (1), assuming 2-sided test and two equal sizes:

$$n=\frac{[p_0(1-p_0)+p_a(1-p_a)]\left\{Q_z^{1-\beta}+Q_z^{1-\frac{\alpha}{2}}\right\}^2}{((p_o-p_a)^2)} \qquad \text{Eq. (1)}$$

Where "p_o" is the incidence rate of HE vehicles, and "p_a" of the rate of ICE Vehicles, these rates can be obtained from Tables 8-9: A total of 186 out 24,297 HE vehicles were involved in crashes with pedestrians, accounting for 0.77 percent of all HEVs included in the analysis. A total of 5,699 out of 1,001,000 ICE vehicles were involved in crashes with pedestrians, accounting for 0.57 percent of all ICE vehicles included in the analysis. If a minimum 80% statistical power is required for this study and a statistical significant level of 5% is used, then $Q_z^{1-\beta}=0.84$, $Q_z^{1-\alpha/2}=1.96$, the following Table 25 and Figure 5, based on Eq. (1), show minimum sample sizes required for this study including both cases of unequal sizes or equal sizes of HE and ICE vehicle groups, and Figure 5 is the total sample size of two equal groups. For example, if size ratio of (ICE/HE) is 30 due to more ICE vehicle available than HE, then the minimum sample size for HE vehicles is 13,203 (Design 4 of Table 25), and current of 24,297 HE vehicles are large enough to meet 80 percent power requirement.

Table 25: HE and ICE Sample Sizes With Various Ratios Using Tables 8 and 9

Variable	Design 1	Design 2	Design 3	Design 4
alpha, α	0.050	0.050	0.050	0.050
One or two side	2	2	2	2
Rate 1, HE	0.008	0.008	0.008	0.008
Rate 2, ICE	0.006	0.006	0.006	0.006
RR= Rate2 / Rate1	0.739	0.739	0.739	0.739
Power, 1-β	80	80	80	80
HE Size (n1)	27,108	15,613	14,168	13,203
ICE Size (n2)	27,108	78,065	141,676	396,061
Ratio of ICE / HE	1	5	10	30

The result for (ICE/HE=1, equal size, Design 1) can be plotted as Figure 5 that also displays the relationship between statistical power with sample size (data from Tables 8 and 9):

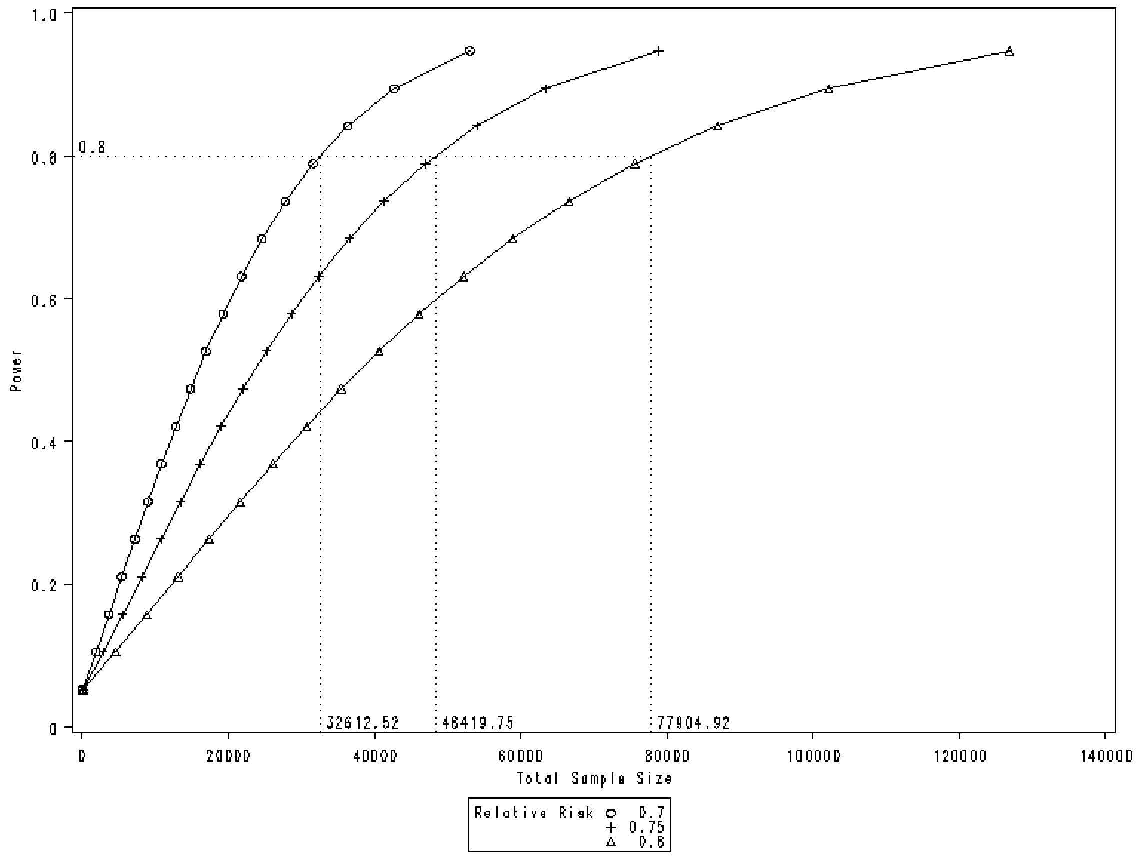

Figure 5: Sample Size and Statistical Power for Tables 8 and 9 Where ICE/HE=1

11. APPENDIX TWO: VARIOUS WEATHER AND LIGHT CONDITIONS

The following Tables 26 through 31 provide the additional vehicle counts with various conditions of weathers and lighting conditions using the original five models for pedestrian crashes, and for bicyclist crashes, respectively. While they are not discussed in this report, they are included for consistency with the previous NHTSA report (Hanna, 2009).

Table 26: **Light Condition During All Crashes**

Light Condition	HE Vehicles	Percent	ICE Vehicles	Percent
Daylight	17,383	72%	678,404	68%
Dark—street lights on	3,129	13%	148,257	15%
Dark—no lights	1,625	7%	63311	6%
Dawn/dusk	1,425	6%	47554	5%
Other and unknown	735	3%	63,474	6%
Total	**24,297**	**100%**	**1,001,000**	**100%**

Table 27: Weather Condition During All Crashes

Weather Condition	HE Vehicles	Percent	ICE Vehicles	Percent
Clear	16,611	68%	653,986	65%
Cloudy/foggy	2,172	9%	110,034	11%
Raining	3,067	13%	130,046	13%
Snowing	941	4%	30,261	3%
Other and unknown	1,506	6%	76,673	8%
Total	**24,297**	**100%**	**1,001,000**	**100%**

Table 28: Light Condition During Pedestrian Crashes

Light Condition	HE Vehicle Involved in Pedestrian Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Pedestrian Crash	ICE Vehicle Incidence Rate
Daylight	124	0.71%	3,821	0.56%
Dark—street lights on	33	1.05%	1,244	0.84%
Dark—no lights	13	0.80%	415	0.66%
Dawn/dusk	16	1.12%	179	0.38%
Other and unknown	0	0.00%	40	0.06%
Total	**186**		**5,699**	

Table 29: Weather Condition During Pedestrian Crashes

Weather Condition	HE Vehicle Involved in Pedestrian Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Pedestrian Crash	ICE Vehicle Incidence Rate
Clear	132	0.79%	4,237	0.65%
Cloudy/foggy	12	0.55%	513	0.47%
Raining	28	0.91%	711	0.55%
Snowing	6	0.64%	114	0.38%
Other and unknown	8	0.53%	124	0.16%
Total	**186**		**5,699**	

Table 30: Light Condition During Bicyclist Crashes

Light Condition	HE Vehicle Involved in Bicyclist Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Bicyclist Crash	ICE Vehicle Incidence Rate
Daylight	98	0.56%	2,452	0.36%
Dark—street lights on	11	0.35%	356	0.24%
Dark—no lights	2	0.12%	108	0.17%
Dawn/dusk	5	0.35%	125	0.26%
Other and unknown	0	0.00%	11	0.02%
Total	**116**		**3,052**	

Table 31: Weather Condition During Bicyclist Crashes

Weather Condition	HE Vehicle Involved in Bicyclist Crash	HE Vehicle Incidence Rate	ICE Vehicle Involved in Bicyclist Crash	ICE Vehicle Incidence Rate
Clear	96	0.58%	2,496	0.65%
Cloudy/Foggy	7	0.32%	311	0.47%
Raining	10	0.33%	157	0.55%
Snowing	0	0.00%	15	0.38%
Other and unknown	3	0.20%	73	0.16%
Total	**116**		**3,052**	

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