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PEDESTRIAN SAFETY

A Comparative Study of Pedestrian Fatalities and New Car Assessment Programs in the U.S. and Japan

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Results in Brief

In this report, as shown in the *Pedestrian Traffic Fatalities by State 2018 Preliminary Data* conducted by Governors Highway Safety Association (GHSA), we found there is a consistently increasing trend in the number of pedestrian fatalities and pedestrian fatalities per 100,000 population in the United States in the time period 2008 to 2017, even after controlling for several traffic indicators. We specified this time frame for detailed study because we found it may have been a turning point for the increasing trend in U.S. pedestrian fatalities.

We collected and analyzed national and state data from Fatality Analysis Reporting System (FARS) operated by the National Highway Traffic Safety Administration (NHTSA), which is an executive agency of the U.S. federal government and part of the Department of Transportation (DoT). We found there are only seven states not suffering from the increasing number of pedestrian fatalities from 2008 to 2017. We believe it could be potentially helpful for states with a higher growth rate of pedestrian fatalities to learn from states with a decreasing number on how policies and actions were implemented to tackle the problem.

We used Japan for a cross-country comparison to examine what possible factors contributed to changing the similarly high fatalities they had back in 1970 and 1980. Most fatality data and policy information came from The White Paper issued by National Police Agency (NPA). We found that when facing increasing number of pedestrian fatalities, Japan initiated a national campaign known as the “traffic war” to combat the high number of pedestrian fatalities. The Traffic Wars involved an array of collective policies across different national agencies to address the problem, which may provide lessons for the U.S. in the future.

In the second part of the report, we outlined and analyzed all major differences in the U.S. and Japan’s New Car Assessment Program (NCAP). The respective NCAPs differ not only in the components of each NCAP but also the weight each component holds in the overall score. We collected data and evaluation methodology for the U.S. mostly from NHTSA website. For our case study in Japan, we collected data and examined their evaluation methodology from National Agency for Automotive Safety and Victims' Aid (NASVA). We discussed in the report about how different components in the NCAP could potentially make a huge impact on the vehicle rating system and pedestrian safety in the long term. We also examined different evaluation systems for the driving assisted technologies in the European NCAP and its implications for vehicle manufacturers in terms of vehicle design and technology features.

Based on what we found in the research, we provided policy recommendations to 1) start a national campaign ("Traffic War") to address the increasing trend of pedestrian fatalities. Specifically, we suggest states suffering from a higher growth rate of pedestrian fatalities can learn from states with a decreasing trend where feasible; 2) add pedestrian safety test in the U.S. NCAP and consider incorporating driver-assistive technologies test as part of the overall score for a new vehicle.

Background

Global Trends

According to the *Global Status Report on Road Safety 2018* by World Health Organization (WHO), the number of road traffic deaths continues to climb and reached 1.35 million in 2018 from 1.24 million in 2010. Road traffic injuries are currently estimated to be the ninth leading cause of death across all age groups globally, and are predicted to become the seventh leading cause of death by 2030. Despite the increase in absolute numbers, the rate of road traffic deaths has remained fairly constant at around 18 deaths per 100,000 people over the last 15 years. The report suggests more than half of global road traffic deaths are among vulnerable road users: pedestrians, cyclists and motorcyclists, who are often neglected in road traffic system design. At the current growth rate for traffic death, the United Nations Sustainable Development Goals (UNSDG) Target 3.6[1], to halve road traffic deaths by 2020, will not be met.

Pedestrian Fatalities Trends in the United States

Historically, 1980 marks the peak of pedestrian fatalities in the U.S. with more than 8,000 pedestrian deaths on the road. Despite some numbers fluctuating year from year, NHTSA data shows a decreasing trend generally from 1980 to the turning point of 2008 when the number of pedestrian fatalities started to increase again.

[1] https://www.who.int/sdg/targets/en/

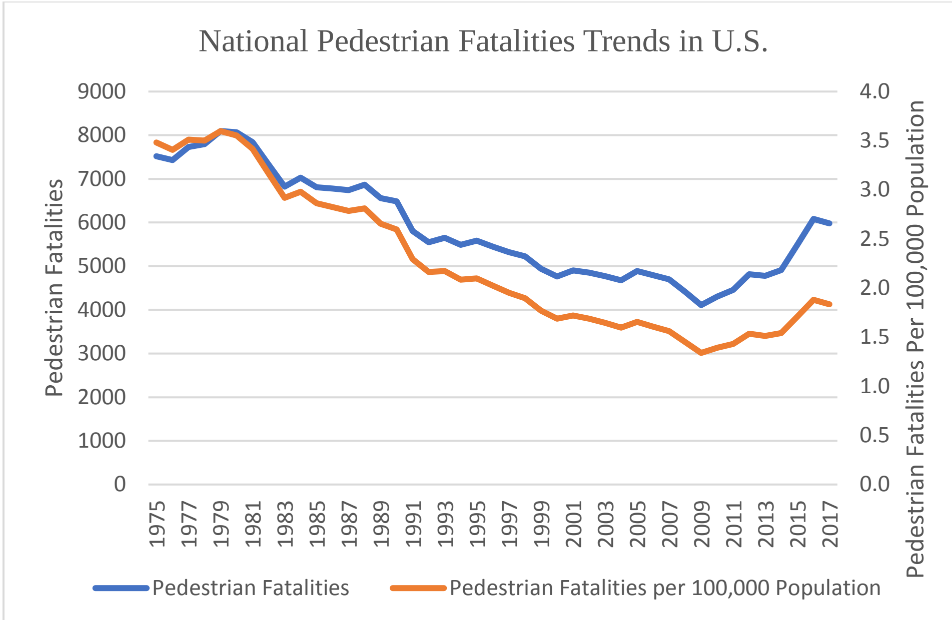

Chart 1: National Pedestrian Fatalities Trends in U.S. from 1975 to 2017
Source: NHTSA

In recent years, the number of pedestrian fatalities has grown sharply. During the 10-year period from 2008 to 2017, the number of pedestrian fatalities increased by 35% (from 4,414 deaths in 2008 to 5,977 deaths in 2017). Meanwhile, the combined number of all other traffic deaths declined by 6% (from 33,009 deaths in 2008 to 31,156 deaths in 2017). Along with the increase in the number of pedestrian fatalities, pedestrian deaths as a percentage of total motor vehicle crash deaths increased from 12% in 2008 to 16% in 2017.

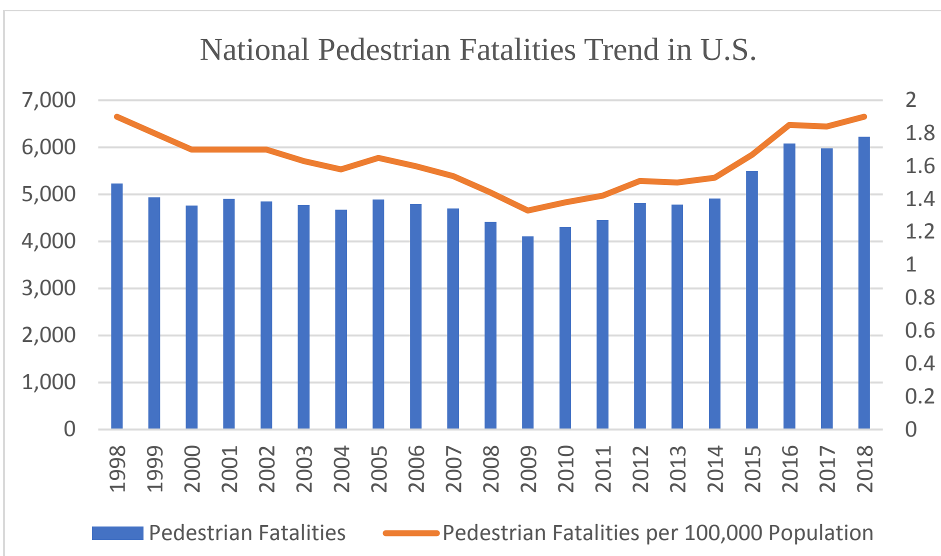

Chart 2: National Pedestrian Fatalities Trends in U.S. from 1998 to 2018
Source: NHTSA

According to Governors Highway Safety Association's (GHSA) estimate, the nationwide number of pedestrians killed in motor vehicle crashes in 2018 was 6,227, an increase of 4% from 2017. This projection represents a continuation of an increasing trend in pedestrian deaths going back to 2009 and is the largest annual number of pedestrian fatalities in the U.S. since 1990.

According to data from Fatality Analysis Reporting System (FARS) from NHTSA, there are five states showing the largest numbers of pedestrian fatalities: Arizona, California, Florida, Georgia and Texas. These five states accounted for almost half of all pedestrian deaths (41% in 2008, 43% in 2017). Those states also had some of the highest rates of population growth; together, they account for 33% of the total U.S. population. According to *Pedestrian Traffic Fatalities by State 2018 Preliminary Data* by GHSA, increases in pedestrian fatalities may be linked to population growth in specific cities and states. The 10 states with the highest population growth from 2017 to 2018 - Arizona, Colorado, Florida, Idaho, North Carolina, Nevada, South Carolina, Utah, Texas and Washington state - had an overall 5% increase in the number of pedestrian fatalities during the first six months of 2018 compared with the same period in 2017.

Trends in Japan

According to the National Police Agency (NPA), they are "an agency administered by the National Public Safety Commission of the Cabinet Office of the Cabinet of Japan, and is the central agency of the Japanese police system, and the central coordinating agency of law enforcement in situations of national emergency in Japan[2]." Japan experienced a rapid increase in the number of traffic accidents around 1955. The *White Paper on Police 2017* by NPA states it was partly due to the insufficient development of roads and traffic safety facilities, including traffic lights and road signs, combined with the rapid progress of post-war motorization. In 1970, the yearly traffic fatalities in Japan peaked at 16,765 and the period became known as the "Traffic War" due to the seriousness of the problem and determination from the state to stop the trend. After a decade of national efforts, the number of pedestrian fatalities decreased significantly from 5,761 deaths in 1970 to 2,767 deaths in 1980 due to the comprehensive promotion of traffic safety measures.

In 1980, the Japanese government initiated a "Second Traffic War" to tackle the increasing number of traffic accidents. The increase was partly due to a lack of budget for enough traffic officers and projects to improve traffic safety facilities while the number of driver's license holders and vehicle ownership steadily increased every year. In 1992, the number of pedestrian fatalities reached 3,128 with 2.52 pedestrian fatalities per 100,000 people.

[2] https://en.wikipedia.org/wiki/National_Police_Agency_(Japan)

Since then, the number has been decreasing due to the strengthened traffic safety measures and other considerations for pedestrian safety.

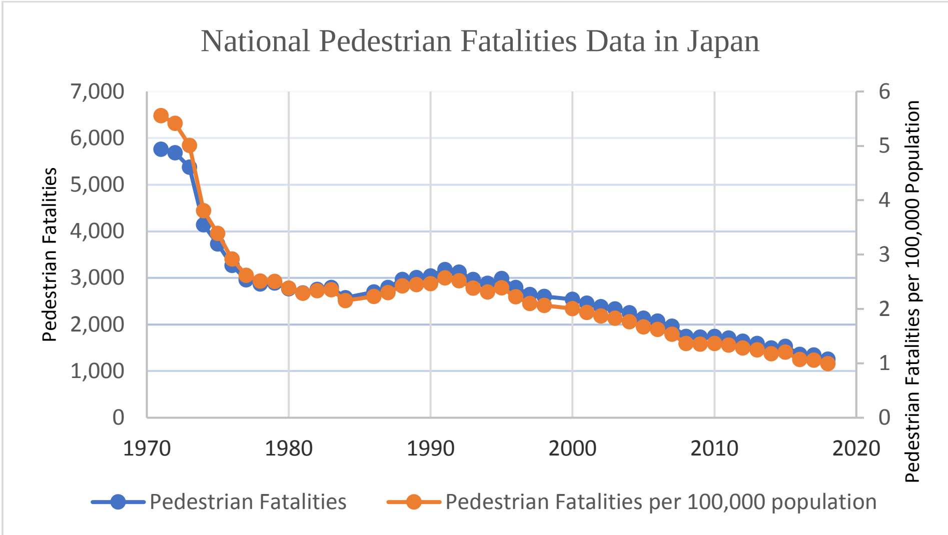

Chart 3: National Pedestrian Fatalities Trends in Japan from 1970 to 2017
Source: NPA

Potential Causes/Explanations

Pedestrian Traffic Fatalities by State 2018 Preliminary Data points out that many factors beyond the control of traffic safety officials contribute to the observed year-to-year changes in the number of pedestrian fatalities including economic conditions, population growth demographic change, weather, fuel prices, the amount of motor vehicle travel, and the amount of time people spend walking.

Trends in Vehicle Type: Increase in Sports Utility Vehicles
Pedestrian Traffic Fatalities by State 2018 Preliminary Data highlighted increased sales of SUVs as a potential cause of the recent increase of pedestrian fatalities. The GHSA reported that the number of pedestrian deaths involving SUVs increased by 50% between 2013 and 2017, while the number of pedestrian deaths caused by passenger cars increased by 30% over that same period. These statistics reflect the interplay of two trends: sales of SUVs are increasing and pedestrians are much less likely to survive the impact of an SUV as compared to a passenger car.

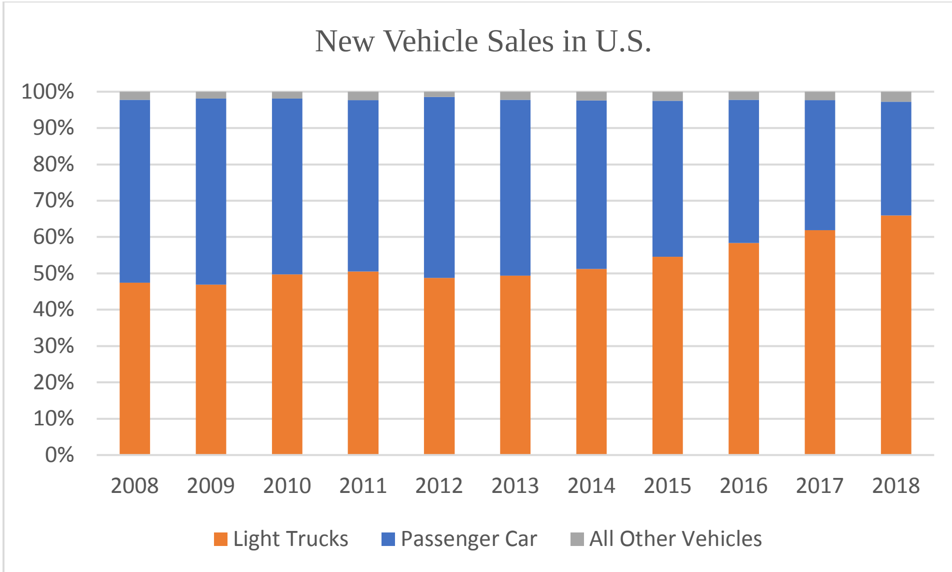

Chart 4: New Vehicle Sales in U.S. from 2008 to 2018
Source: Marklines

SUV sales topped sedans in 2014; pickups and SUVs now account for 60% of new vehicle sales. Many manufactures have responded to these trends with strategic changes. For example, Ford recently announced plans on April 25, 2018 to discontinue U.S. sales of most passenger cars by 2022, while Fiat Chrysler has already done so starting in 2017 their U.S. plants shifted to focus entirely on pickups and SUVs for the Ram and Jeep brands. Previous research has found that after adjusting for impact speed and pedestrian age, the probability of death for pedestrians struck by light truck vehicles (LTVs, including SUVs and light trucks) was significantly higher than for those struck by passenger vehicles. Authors also suggest the need to reconsider vehicle front end design, especially for LTVs, in motor vehicle safety standards (Lefler & Gabler, 2004; Roudsari, Mock, and Kaufman, 2004).

SUVs sales have consistently increased and account for a steadily growing proportion of deaths. With their higher front-end profile, SUVs are at least twice as likely as cars to kill the walkers, joggers and children they hit, yet regulations have done little to reduce deaths or publicize the danger. This is also attested by E. Desapriya, S. Subzwari (2010), Hu, W., & Cicchino, J. B. (2018).

Lighting Condition

Evidence has shown that improved street lights can help reduce the pedestrian fatalities. Data from NHTSA shows that between 2013 and 2017, the percentage of pedestrian fatalities occurring in dark lighting conditions has increased.

In the city of Detroit, pedestrian deaths plummeted from an average of 24 per year to just one, largely because of a two-year project that replaced 65,000 lights in a city where 40% were not working in 2014.

Research conducted in China concludes traffic crashes at night tended to result in serious injuries or death, with even higher risk in the absence of street lighting (Zhang, G., Yau, K. K. W., & Zhang, X. 2014). This result is consistent with the conclusions from the studies of Kim et al. (2008a, 2010), where the author highlights that darkness, with or without streetlights, leads to a significant increase in the probability of fatal injury (148.0%) and incapacitating injury (338.1%) for pedestrians. Lighting conditions affect crash risk but this shows visibility also affects injury severity since a driver's ability to notice pedestrians is reduced by darkness, which can lead to drivers braking later or taking less effective avoidance maneuvers, leading to greater severity if a crash occurs.

Alcohol & Drug Use

Another influential factor is alcohol impairment. An estimated 32% of fatal pedestrian crashes involved a pedestrian with a blood alcohol content (BAC) of 0.08 or higher, and an estimated 17% of drivers involved in these crashes had a BAC of 0.08 or higher. Higher crash rates were found in the model-calendar years in which more alcohol was found in drivers, as expected in Robertson, L. S. (1996). Arrests for driving while impaired substantially increase the risk of eventual death in an alcohol-related crash. Aggressive intervention in the cases of people arrested for driving while impaired may decrease the likelihood of a future fatal alcohol-related crash (Brewer, R. D., Morris, P. D. (1994).

Cell Phone Usage

Although the surge in smartphone use coincides with a sharp rise in pedestrian fatalities during the same period (Saltos, A., Smith, D., Schreiber, K., Lichenstein, S., & Lichenstein, R. 2015), there is a lack of evidence to establish a definitive link. This may be due in part to the inability of police crash investigators to accurately capture momentary distraction caused by smartphones, many of which are mounted on vehicle dashboards and windshields. According to *Driver Electronic Device Use in 2017* by NHTSA, based on the survey results of National Occupant Protection Use Survey (NOPUS), passenger vehicle driver handheld cell phone use decreased from 3.3 percent in 2016 to 2.9 percent in 2017. This data is challenged by many reports including *Undercounted is Underinvested: How Incomplete Crash Reports Impact Efforts to Save Lives* by National Safety Council (NSC), as it mentions that, 26 state crash reports lack fields to capture texting while 32 states lack fields to record hands-free cell phone use. *Understanding the Distracted Brain: Why Driving While Using Hands-Free Cell Phones Is Risky Behavior* by NSC points out 53% of drivers believe if manufacturers put "infotainment" dashboards and hands-free technology in vehicles, they must be safe. However, even when talking hands-free, drivers can miss seeing up to half of what's around them because they are engaged in a cell phone conversation, leading to a fatal distracted driving situation.

Other Factors
More research is needed for future policy implementation. These factors may include but not limited to roadway design, intersection design, traffic signs, regulations, driving education program.

New Car Assessment Program & Pedestrian Fatalities

Pedestrian Safety Tests in J-NCAP

Head Protection Testing Method
This is designed to evaluate the impact on a dummy pedestrian's head when a crash is occurred at a given speed. An adult or a child pedestrian head simulated impactor (head impactor) is projected toward the car bonnet/front windshield from the testing machine. The impact received by the head impactors is measured and then evaluated using head injury criterion (HIC). The projecting speed in the domestic technical regulation is 20 mph (32km/h). The impact speed received by the pedestrian against the car is equivalent to 25mph (40km/h). Impact angles differ according to the shape of the front part of 3 types of vehicles; sedan, SUV, and One Box (smallest highway-legal passenger cars like a box).

The distance between the ground and the evaluated areas of the cars i.e. Wrap Around Distance is measured according to the length of the area where the pedestrian's head hits in accidents. Impact location area for adults and children's head is set based on the data of actual accidents.

In the crosswise direction, the side line of the impact test area is from the line obtained by tracing the contact points between a straight edge and the side of the bonnet where the straight edge contacts the bonnet bumper at 45 degrees (Bonnet Side Reference Line) to the inside half diameter of the head impactor. Test vehicles are divided by the vehicle type. Tests are done in each testing area under each impact condition.

			Area I	Area II	Area III
Impact			165mm, 4.5kg	165mm, 3.5kg	165mm, 3.5kg
WAD			1700-2100mm	1350-1700mm	1000-1350mm
Impact Velocity	Bonnet	Type 1 Type 2 Type 3	35km/h		
	Windshield	Type 1 Type 2 Type 3			
Impact Angle	Bonnet	Type 1 Type 2 Type 3	65º 90º 50º	65º 60º 25º	65º 60º 25º
	Windshield	Type 1	40º		
		Type 2 Type 3	45º		

Table 1: New Vehicle Sales in U.S. from 2008 to 2018
Source: NASVA

Each of Area I and II are each divided into six sections and Area III is divided into three sections in the crosswise direction of the vehicle, making a total of 15 divided evaluation areas. Each of the subdivided area is further divided into four sub-areas. For each of the 15 divided evaluation areas, J-NCAP selects one or two location(s) that is considered to produce the highest HIC value in the area to impact on this location (no two locations are selected from the same sub area). The resulting injury value is used as the typical value in evaluating the area, and counted using sliding scale. These test values are calculated to produce average score for each of 15 sub-areas, and then the total score average score is calculated.[3]

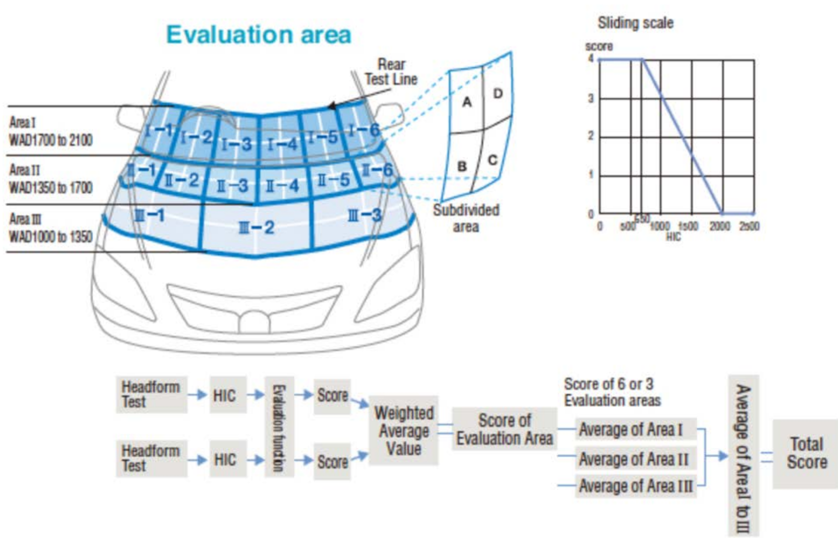

Chart 5: Pedestrian Head Protection Testing Methodology

[3] http://www.nasva.go.jp/mamoru/en/assessment_car/head_protection_test.html

Source: NASVA

The total score average is converted to the injury value. The score of a car with severe head injury (AIS4+) probability of about 50% (HIC 1,436) is 1.67 which becomes the minimum standard point value, and the score of a car with a probability of about 10% (HIC 876) is 3.33. This score and above becomes Level 5 which has been considered as safe for pedestrian. This range is then divided up into four equal parts to make five levels for evaluation. In regard to pedestrian protection, the pedestrian's head injury value inevitably becomes higher than that of the passengers, given the current vehicle technology. As for the evaluation coverage, it is expanded to cover wider range where certain life-saving effects are expected in order to promote development of pedestrian protection technology.

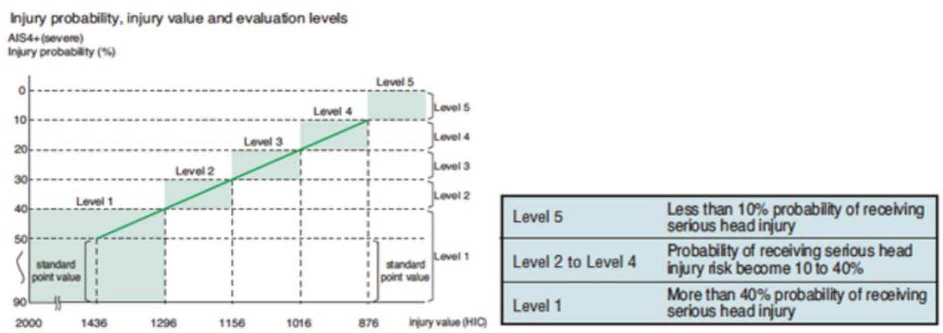

Chart 6: Head Injury Criterion Evaluation
Source:

Relationship Between NCAP and Fatality Reduction

Previous studies have found a correlation between NCAP test results and real-world injury outcomes. Most studies have been conducted using the Euro NCAP because it is the most advanced standard with comprehensive traffic accident data available. Generally, the higher the score a vehicle gets on the test, the safer the vehicle is considered to be. The largest difference in injury risk between 2- and 5-star rated cars in Euro NCAP was found for risk of fatality, confirming that car manufacturers have focused their safety performance on serious crash outcomes. In addition, Euro NCAP crash tests were shown to be highly correlated with serious crash performance, confirming their relevance for evaluating real-world crash performance. It is also confirmed by Lie, A., & Tingvall, C. (2002).

In addition, there is research that focuses specifically on pedestrian safety tests and pedestrian fatality reduction. Several studies have found higher pedestrian safety score is correlated with lower risk of fatal and incapacitating injuries. Significant injury reduction to both pedestrians and bicyclists was found between low and high performing cars in the Euro NCAP pedestrian test in Strandroth, J. (2014).

Analysis of Pedestrian Fatalities Trends

National & State Trend

We began our analysis on trends in pedestrian fatalities by looking at the data from year 2008 to 2017 in the United States. We collected data from Fatality Analysis Reporting System (FARS) by the National Highway Traffic Safety Administration (NHTSA). It contains both traffic fatality data and other related traffic indicators. The data indicates the U.S. has experienced a consistent increasing trend during the past decade despite there is a little decrease between 2012 and 2013, 2016 and 2017. There were 4,414 pedestrian fatalities in 2008 while the number climbed to 5,977 in 2017. That is a 35.41% increase from 2008 to 2017.

According to the NHTSA's estimation, the number continued to rise to 6,227 in 2018, the worst situation since 1990 (6,482 pedestrian deaths). Pedestrian fatalities per 100,000 population shows the same picture, which suggests the population growth, is unable to explain the death trend: 1.45 pedestrian fatalities per 100,000 population in 2008 and 1.84 in 2017, a 26.42% increase. Compared with all other traffic deaths, pedestrian fatalities have consistently increased within total traffic fatalities. Pedestrian fatalities as a percent of total traffic fatalities have increased from 11.79% in 2008 to 16.10% in 2017, a 4.3 percentage point increase. All other traffic fatalities decreased from 33,009 in 2008 to 31,156 in 2017, a 5.61% decrease.

We also examined other traffic indicators to see if they could sufficiently explain the phenomenon. We look at data including Vehicle Miles Traveled (VMT), number of Registered Vehicles and number of Licensed Drivers from FARS. All traffic indicators show an increasing trend during the period when controlling for these factors: pedestrian fatalities per 100 million Vehicle Miles Traveled increased from 0.15 to 0.19 (2017); pedestrian fatalities per 100,000 Registered Vehicles increased from 1.70 to 2.11 (2016); pedestrian fatalities per 100,000 Licensed Drivers increased from 2.12 to 2.74 (2016).

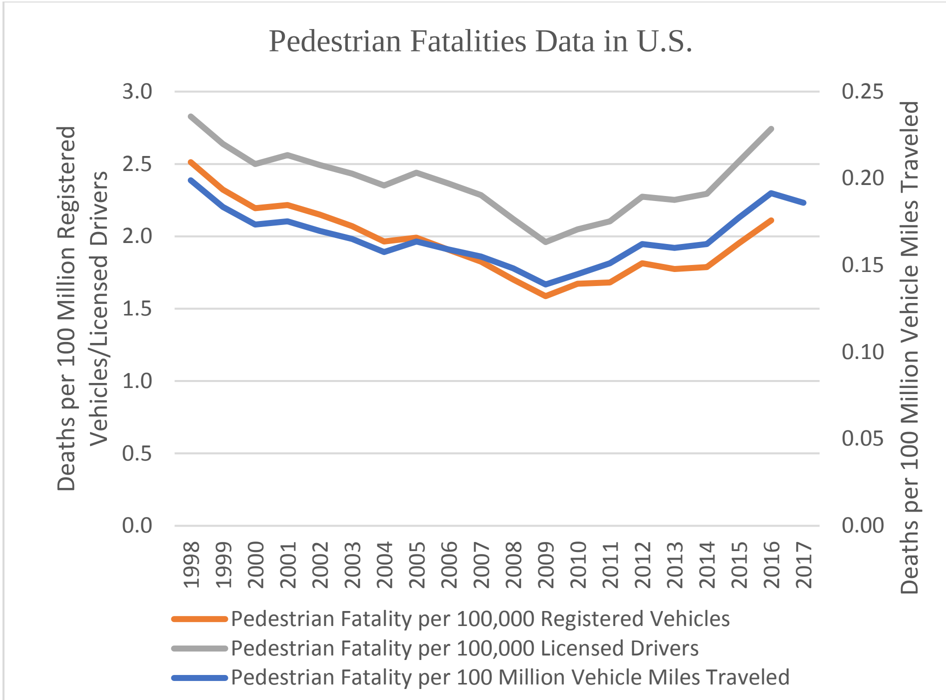

Chart 7: Pedestrian Fatalities Data in U.S. from 1998 to 2017
Source: FARS

Next, we took a closer look at state data. Generally, states with more population tend to have higher numbers of pedestrian fatalities. California, Texas, New York, and Florida, that make up 32.58% of total population in the U.S. (2010 Census Data), contributed to 41.57% of total pedestrian fatalities in 2008, although the number slightly declined to 39.5% in 2017 (mainly because of effective policies implemented and decreased number in New York). Today these "big four" states still account for almost 40% of total pedestrian fatalities. There are only seven out of 50 states with a decreasing number of pedestrian fatalities from 2008 to 2017: Arkansas (45 to 42), Hawaii (20 to 14), Maryland (116 to 114), Massachusetts (75 to 74), New York (294 to 242), North Dakota (6 to 5), Wyoming (7 to 6). Note that none of these states has experienced a consistent decreasing trend; there were fluctuations between year to year during the time period.

State	Pedestrian Fatalities 2008	Pedestrian Fatalities 2017	Pedestrian Fatalities Per 100,000 Population 2008	Pedestrian Fatalities Per 100,000 Population 2017	Rate of Decrease Per 100,000 Population
Hawaii	20	14	1.55	0.98	-37%
North Dakota	6	5	0.94	0.66	-30%
Wyoming	7	6	1.31	1.04	-21%
New York	294	242	1.51	1.22	-19%
Arkansas	45	42	1.58	1.4	-11%
Maryland	116	114	2.06	1.88	-9%
Massachusetts	75	74	1.15	1.08	-6%

Table 2: States with Negative Growth Rate of Pedestrian Fatalities in U.S. from 2008 to 2017
Source: NHTSA

To adjust for the different population size in each state, we looked at pedestrian fatalities per 100,000 population data in each state (number of pedestrian fatality/population in each state*100,000). In 2008, Florida was the most dangerous state for pedestrians with the largest biggest number (2.67), followed by Delaware (2.41), Louisiana (2.40), South Carolina (2.23), Nevada (2.15) and Maryland (2.06). However, in 2017, more states suffered from more than two pedestrian fatalities per 100,000 population: New Mexico (3.54), Delaware (3.43), Florida (3.12), Arizona (3.08), South Carolina (3.07), Nevada (3.04), Alabama (2.44), Georgia (2.43), Mississippi (2.38), California (2.38), Texas (2.14) and New Jersey (2.03).

Analyzing changes in rates over time, aside from the seven states mentioned above as safer states, Louisiana joins the list as its rate controlled for population dropped from 2.40 in 2008 to 2.37 in 2017; Arkansas (1.58 to 1.40), Hawaii (1.55 to 0.98), Maryland (2.06 to 1.88), Massachusetts (1.15 to 1.08), New York (1.51 to 1.22), North Dakota (0.94 to 0.66), Wyoming (1.31 to 1.04).

Even though most of states experienced an increase in both pedestrian fatalities and pedestrian fatalities per 100,000 population, there are some states with higher increases over time with their rates than other states. In terms of pedestrian fatalities, Vermont (700%), Alaska (367%), Colorado (109%), Tennessee (107%), West Virginia (100%), New Mexico (90%), Indiana (87%), Arizona (80%), Alabama (80%), Kansas (74%), Georgia (73%) stand out due to a higher increasing growth rate. In addition, adjusted for the population size in each state, these states include Vermont (700%), Alaska (330%), Nebraska (271%), West Virginia (99%), Tennessee (91%), Colorado (84%), New Mexico (80%), Indiana (78%), Rhode Island (74%), and Alabama (72%).

States	2008	2017	Growth Rate
Vermont	0.16	1.28	700%
Alaska	0.44	1.89	330%
Nebraska	0.28	1.04	271%
West Virginia	0.72	1.43	99%
Tennessee	0.97	1.85	91%
Colorado	0.89	1.64	84%
New Mexico	1.97	3.54	80%
Indiana	0.85	1.51	78%
Rhode Isand	1.14	1.98	74%
Alabama	1.42	2.44	72%

Table 3: States with Higher Growth Rate of Pedestrian Fatalities per 100,000 Population in U.S. from 2008 to 2017
Source: NHTSA

Cross-Country Comparison
We collected and examined data from the NPA in Japan from 2008 to 2017. In contrast to the U.S., the number of pedestrian fatalities in Japan has dropped relatively steadily and consistently in recent years. During the 10-year period from 2008 to 2017, pedestrian fatalities declined from 1,745 deaths in 2008 to 1,348 deaths in 2017 (22.75% decrease). Pedestrian deaths as a percentage of total motor vehicle crash deaths in Japan slightly increased from 33% in 2008 to 36% in 2017 which highlighted the importance of protecting pedestrian around the world. Pedestrian fatalities per 100,000 people has declined from 1.37 in 2008 to 1.06 in 2017 (22.24% decrease). Although there has been some minor fluctuations between year 2009 and 2010 (both number of total pedestrian fatality and pedestrian fatality per 100,000 population increased slightly), the decreasing trend resumes since 2010 and there is no further fluctuations between any consecutive years.

When analyzing trends in two countries comparatively, we find another different picture; pedestrian fatalities per 100,000 population in the U.S. is indeed lower than Japan before 2007 (1.54 for both countries), however, the number in Japan decreases to below 1.00 in 2017 (0.99) while the number in U.S. increases to almost 2.00 (1.90). The different trends in recent years suggest there are new potential explanations and ways to address these worrisome trends.

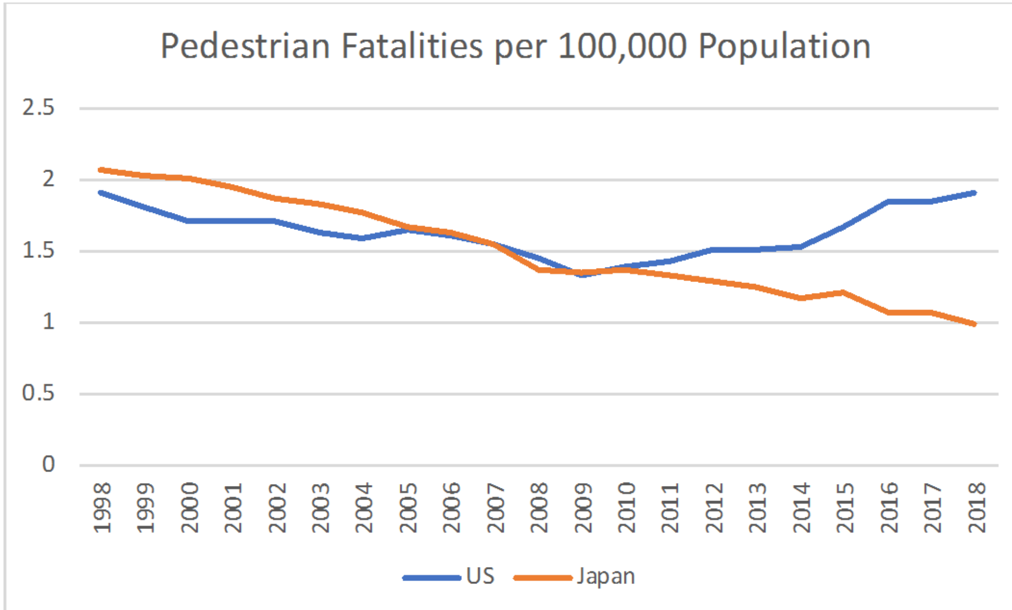

Chart 8: Pedestrian Fatalities per 100,000 Population in U.S. and Japan from 1998 to 2018
Source: NHTSA, NPA

Analyzing Potential Causes

SUV Sales Have Increased in Recent Period
Many industry experts have expressed their concerns towards the increasing sales of Light Truck Vehicles (including Sport Utility Vehicles, Pick-ups and Vans). With a high-profile bumper and hardened structure to deal with off-road situation, LTVs are known to cause more potential damages to pedestrians when a crash occurs. The risk for pedestrians of sustaining fatal injury is 50 percent greater in collisions with LTVs than in collisions with conventional cars according to an experiment (Desapriya, E., Subzwari, S., Sasges, D., Basic, A., Alidina, A., Turcotte, K., & Pike, I. (2010).).

We found a rapid increase in LTV sales from 2008 to 2017 compared with passenger cars. In 2008, LTVs only accounted for 47.4% of all new vehicles in the United States while passenger cars still dominated the market with more than 50% of total new vehicle sales (50.39%). However, two years later, LTVs became the best sellers in the market as it took up 49.74% of new vehicle sales while passenger cars shared 48.41%.

The gap between the two major types of vehicles began to widen since 2014. According to data from Marklines, in 2017, LTVs dominated the market with 61.93% share of total new vehicle sales, while the share of passenger cars has shrunk to 35.72%. NHTSA reported that in 2012 (the most recent year where data are available), the percentage of pedestrians killed in single-vehicle crashes by passenger cars in all pedestrian fatalities was 43.81% with LTVs accounting for 40.32% of those fatalities.

In 2017, the percentage of LTVs has increased to 42.72% while percentage of passenger cars involved with pedestrian fatalities declined to 41.82%. Of all LTVs, the percentage of pedestrian fatalities where a Sport Utility Vehicles (SUV) was involved has increased from 16.83% to 20.14%, which suggests more pedestrian fatalities are related to SUVs.

Many analysts have projected that SUVs are becoming the first choice when consumers consider a new vehicle. In response to the growing demands, many vehicle manufacturers have decided to discontinue their passenger cars and shift their capacity to focus on SUVs. Ford announced it would be shedding most of its North American passenger car lineup in 2018, while Fiat Chrysler's U.S. plants have been focusing entirely on pickups and SUVs for the Ram and Jeep brands since 2016. This trend raises new questions for manufacturers, typically for U.S. manufacturers who focus on SUVs: how can they design a safer SUV, not only for drivers but also pedestrians?

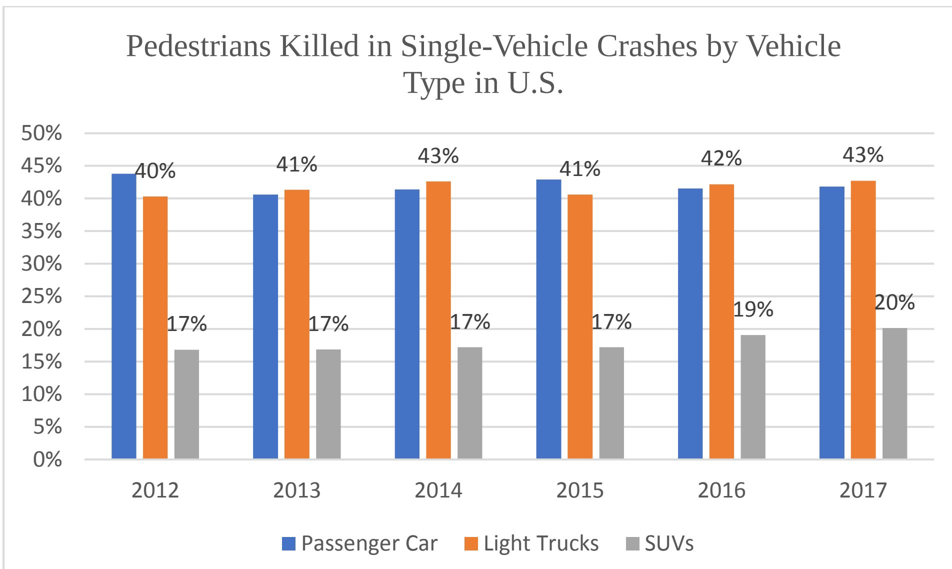

Chart 9: Pedestrians Killed in Single-Vehicle Crashes by Vehicle Type in U.S. from 2012 to 2017
Source: NHTSA
Note: Light Trucks category includes SUVs, pick-up trucks and vans.

Lighting Conditions Continue to Have Strong Impacts on Fatalities
According to *Pedestrian Traffic Fatalities by State 2018 Preliminary Data*, 75% of pedestrian fatalities occur after dark and increases in pedestrian fatalities are occurring largely at night. From 2008 to 2017, the number of nighttime pedestrian fatalities increased by 45%, compared to a much smaller, 11% increase in daytime pedestrian fatalities. The growing prevalence of nighttime pedestrian fatalities suggests a need to prioritize engineering and enforcement countermeasures that can improve safety at

night (e.g., improved street lighting, nighttime enforcement patrols). From Traffic Safety Facts issued by NHTSA, we did notice there is a consistent increase percentage point for pedestrian fatalities occurred in dark condition from 2013 (the most recent year data are available) to 2017. Also, as nighttime becomes more fatal to pedestrians, it suggests vehicle manufacturers should put more efforts into vehicle light design. Since many manufacturers have internal tests on vehicle lights, it is possible to add vehicle light test in the New Car Assessment Program.

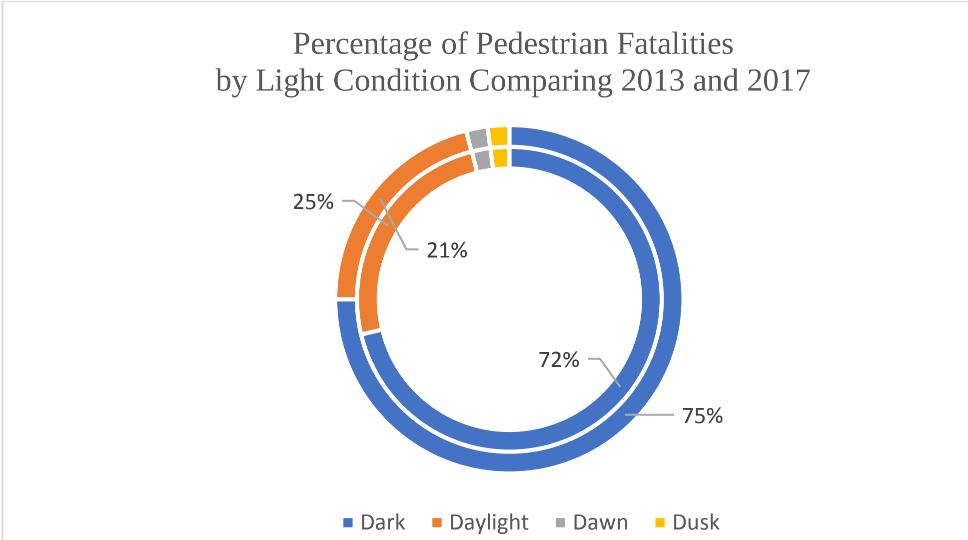

Chart 10: Percentage of Pedestrian Fatalities by Light Condition in U.S. in 2013 and 2017
Source: NHTSA

Alcohol Usage May Not be Significant Factor in Recent Increase
Many reports and publications have expressed their concerns toward drunk driving and its potential damage to pedestrians. However, based on the data analysis from *Traffic Safety Test* by NHTSA from year 2008 to 2017, we did not find a statistically significant increase in terms of pedestrian fatalities involving alcohol as the percentage of total accidents. Even the number of the alcohol-involved pedestrian fatalities has increased from 2,216 in 2008 to 3,098 in 2017, the percentage of total pedestrian fatalities involving alcohol is staying relatively stable. The percentage of alcohol-related pedestrian fatalities was 48.49% in 2008 and decreased to 47.4% in 2017. This suggests alcohol might not be a major factor in this 10-year-period death trend.

We did notice that the percentage of accidents where alcohol was involved solely by the driver increased from 8% of total pedestrian fatalities in 2008 to 11% in 2017, while the percentage of accidents where alcohol was involved solely by the pedestrian decreased from 31% of total pedestrian fatalities in 2008 to 27% in 2017. This suggests drunk driving still plays an important role in the period and new policies concerning drunk driving are needed to solve the problem. It also suggests that drunken pedestrians are at a substantial risk of fatal crashes.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Only Pedestrian Alcohol Involvement	8%	9%	9%	9%	10%	10%	10%	10%	9%	11%
Only Driver Alcohol Involvement	31%	30%	28%	31%	30%	29%	29%	30%	31%	27%
Both Alcohol Involvement	9%	9%	10%	8%	8%	10%	9%	8%	8%	9%
Non Alcohol Involvement	52%	52%	53%	52%	52%	51%	52%	52%	52%	53%

Table 4: Pedestrian Fatalities by Alcohol Involvement in U.S. from 2008 to 2017
Source: NHTSA

Analysis on New Car Assessment Programs

We found that the U.S. and Japan NCAP differs primarily in 1) how vehicle crash tests are conducted and 2) whether any pedestrian safety test is included.

U.S. NCAP

A New Car Assessment Program (NCAP) is a government car safety program tasked with evaluating new automobile designs for performance against various safety threats. The first NCAP was created in 1979, by the United States National Highway Traffic Safety Administration (NHTSA). Started in 1993, NHTSA began using the 5-Star Safety Ratings system to help consumers make informed safety choices when buying new vehicles. Despite the fact that other organizations test crash vehicles (i.e. Insurance Institute for Highway Safety, IIHS), NHTSA is the only organization in the U.S. that includes rollover resistance test in addition to frontal and side crash tests. It consists of three parts to provide an overall score for a testing vehicle: full-wrap frontal crash test scenario, side crash test scenario and rollover resistance test scenario.

		Scenario	Details
Overall Rating (Collision Test)	Frontal Crash	Full-wrap head-on-head with another vehicle	A vehicle crashes into a fixed barrier at 35 mph. Evaluation of injury to the occupant's head, neck, chest, and leg.
	Side Crash	Side Barrier: Driver-side collision with another vehicle	A 3,015 lb. moving barrier crashes at 38.5 mph into a standing vehicle. Evaluation of injury to the occupant's head, chest, abdomen, and pelvis.
		Side Pole: Driver-side collision with a telephone pole	Vehicle, angled at 75 degrees, is pulled sideways at 20 mph into a 25cm diameter pole at the driver's seating location Evaluation of injury to the occupant's head, chest, lower spine, abdomen, pelvis
	Rollover Resistance	Vehicle departs the road and starts to roll over	Static Stability Factor (SSF)

Table 5: Overall Structure of New Car Assessment Program in U.S.
Source: NHTSA

In the frontal crash test scenario, the vehicle will be launched into a fixed barrier at 35 mph. The result is based on an evaluation of injury to the head, neck, chest, and leg of the dummy occupant.

The side crash test scenario consists of two tests: 1) In side barrier test scenario, a 3,015 lb. moving barrier crashes at 38.5 mph into a standing vehicle. The result will base on evaluation of injury to the head, chest, abdomen, and pelvis of the dummy occupant; 2) In side pole test scenario, the testing vehicle, angled at 75 degrees, is pulled sideways at 20 mph into a 25cm diameter pole at the driver's seating location. Same strategy from side barrier test will be applied to evaluate the injury of the dummy.

The rollover resistance test is based on an at-rest laboratory measurement known as the Static Stability Factor (SSF). The results are based on completion of a driving maneuver that tests whether a vehicle is vulnerable to tipping up on the road in a severe maneuver.

U.S. NCAP testing results may also recommend equipping the vehicle with new driver assistance technologies including forward collision warning, lane departure warning, rearview video system, automatic emergency braking. All new technologies will be tested under NHTSA standard. They are shown alongside the final score of a tested vehicle. This is a separate part from the rating system and thus will not count toward the final score of a testing vehicle.

Japan NCAP

Japan NCAP (J-NCAP) is operated by the National Agency for Automotive Safety and Victims' Aid (NASVA), an independent agency under the

Ministry of Land, Infrastructure, Transport and Tourism, started in 1995. The pedestrian head protection performance test was added to the program in 2003 and pedestrian leg protection performance test was added in 2011. The overall evaluation is based on passenger protection performance (crash test) with a maximum score of 59, pedestrian safety performance with a maximum score of 37 and seat belt reminder with a maximum score of 4 to add up to an overall score based on 100 scale.

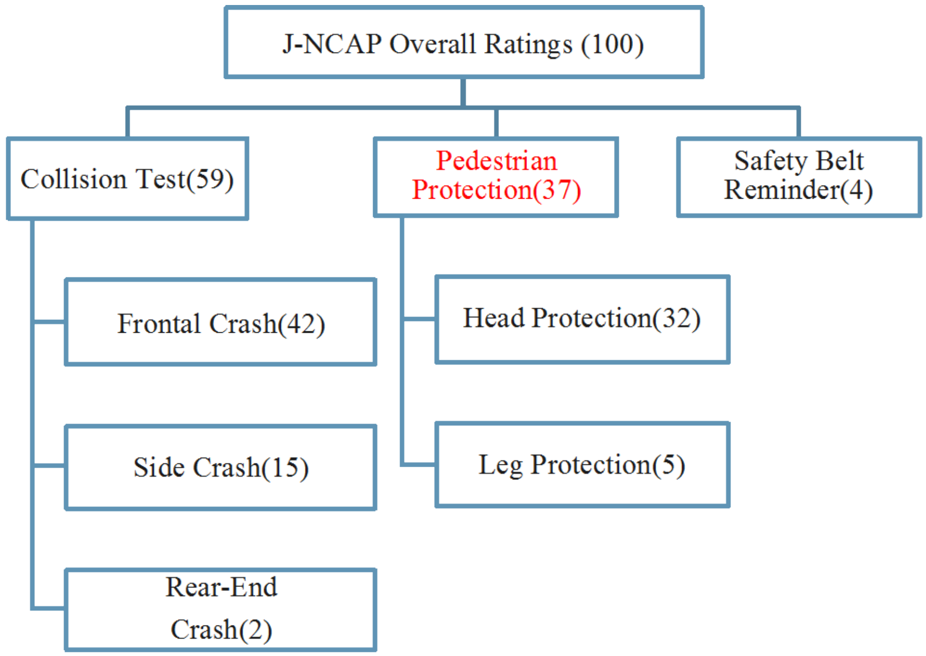

Chart 11: Rating Structure of New Car Assessment Program in Japan
Source: NASVA

For vehicles scores more than 82, they will be awarded five-star rating. The crash test consists of three scenarios: frontal crash test scenario (42% of total score), side crash test scenario (15% of total score) and rear-end crash test scenario (2% of total score). Frontal crash test scenario consists of two tests, each shares 21% of total score: 1) Full-wrap crash test where the testing vehicle crashes into a fixed barrier at 55 km/h (35mph). The result will base on the evaluation of injury to the head, neck, chest, and leg of the dummy occupant. 2) Off-set crash test where the testing vehicle crashes into a fixed barrier at 65 km/h (40mph) with 40% of vehicle offset. Same evaluation strategy applies. The side crash scenario is similar to the U.S. side barrier test where a 3,015 lb. moving barrier crashes at 55km/h (35 mph) into a standing vehicle. The result will base on evaluation of injury to the head, chest, abdomen, and pelvis of the dummy occupant. Unlike the rollover resistance test in U.S. NCAP, the rear-end crash test scenario in Japan NCAP evaluates the neck injury in the testing vehicle when hit by another vehicle from the rear-end side at 20km/h (12mph). In addition, there is a safety-belt reminder test in Japan NCAP where safety-belt reminders are tested for all passenger seats.

				Scenario	Details
Overall Rating (100)	Collison Test (59)	Frontal Crash (42)	Full-wrap (21)	Full-wrap head-on-head with another vehicle	A vehicle crashes into a fixed barrier at 35mph. Evaluation of injury to the occupant's head, neck, chest, and leg.
			Offset (21)	40% Offset with an aluminum Object	A vehicle crashes into a fixed barrier at 40mph. Evaluation of injury to the occupant's head, neck, chest, and leg.
		Side Crash (15)		Driver-side collision with another vehicle	A 3,015 lb. moving barrier crashes at 35mph into a standing vehicle. Evaluation of injury to the occupant's head, chest, abdomen, and pelvis.
		Rear-end Crash (2)		Rear collision by another vehicle	A vehicle hit by another vehicle from rear side at 12mph. Evaluation of occupant's injury to the neck.
	Pedestrian Protection (32)			Head & Leg Protection Test	
	Safety Belt Reminder (5)			Passenger Seat Belt Reminders (PSBR)	

Chart 6: Overall Structure of New Car Assessment Program in Japan
Source: NASVA

The major difference between the two NCAPs is the pedestrian safety test. It accounts for 37% of total score in J-NCAP whereas does not account for any part of the final score in the U.S. NCAP. Interestingly, although Euro NCAP was modeled on the U.S. NCAP when it was first established in 1997, Euro NCAP incorporated the pedestrian safety test as part of the program when it was first created.

Test	Scenario	U.S. NCAP	Japan NCAP
Collision Test	Frontal Crash	Yes	Yes
	Side Crash	Yes	Yes
	Rollover Resistance Test	Yes	No
	Rear-End Crash	No	Yes
Pedestrian Protection Test		No	Yes
Recommended Safety Technology		Yes	Yes

Table 7: Comparison of New Car Assessment Program in Japan and U.S.
Source: NHTSA, NASVA

The pedestrian safety test in J-NCAP consists of two tests:

1) Pedestrian head protection test (32% of total score) which simulates the impact the pedestrian's head received when hit by a vehicle at the speed of 22mph (35km/h). The result is based on the evaluation of injury to the head

using Head Injury Criterion (HIC). HIC is a measure of the likelihood of head injury arising from an impact (experts agree that HIC value above 1,000 is life threatening). The lower the HIC a tested vehicle receives during the test, the higher scores it will get at the end of test. It is an inverse linear relationship between the HIC and testing score: If a testing vehicle has a HIC lower than 650, it will be given the maximum score for pedestrian safety component of the test. Any HIC above 1,750 will receive a 0 score in the test. Impact angles differ according to the shape of the front part of different types of vehicles.

Score	HIC
0	1,750
1	1,450
2	1,250
3	750
4	650

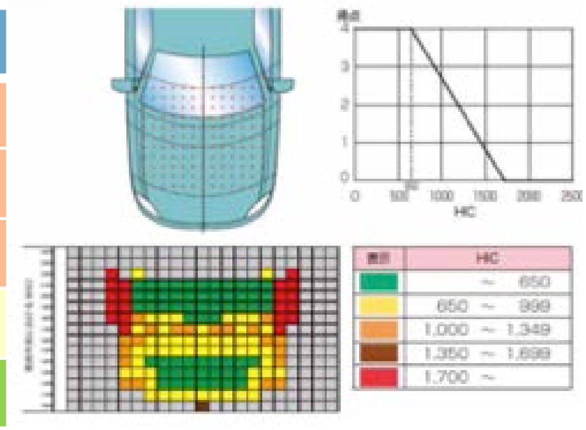

Chart 12: Pedestrian Head Protection Test of New Car Assessment Program in Japan
Source: NASVA

2) Pedestrian leg protection test (5% of total score) which simulates the impact the pedestrian's legs (including four different positions on tibia) and knees (including three different positions, anterior cruciate ligament (ACL), posterior cruciate ligament (PCL) and lateral collateral ligament (LCL)) received when hit by a vehicle at the speed of 25mph (40km/h). Based on the movement values of sensors attached to the leg simulator, the final score is weighted by different positions. The tibia receives more weight (2.92% of total score) and knee receives less weight (1.08% of total score). Generally, the less movement the leg simulator receives (suggesting less impact), the higher score a tested vehicle can receive at the end of the test.

	Positions	Score	Weight	Total Score
Leg	Tibia 1	0-4 (Lowest Score from 4 tests)	0.73	2.92
	Tibia 2			
	Tibia 3			
	Tibia 4			
Knee	Medial Collateral Ligament (MCL)	0-4 (Lowest Score from 3 tests)	0.27	1.08
	Anterior Cruciate Ligament (ACL)			
	Posterior Cruciate Ligament (PCL)			

Table 8: Pedestrian Leg Protection Test of New Car Assessment Program in Japan
Source: NASVA

When considering the relative weight of the pedestrian safety test in Japan's NCAP (37% of the total score), we can see it is quite substantial and thus creates a strong incentive for car manufacturers to protect against pedestrian injuries. In Euro NCAP, the pedestrian safety test shares 32% of total scores, which makes J-NCAP (37% of total score) the most 'pedestrian-friendly' new car assessment program in the world. If a vehicle manufacturer pays no attention at all to pedestrian protection when designing a vehicle, even if the vehicle is safe enough for occupants, it will not be able to receive the five star rating in the J-NCAP. In fact, among all four tested vehicle in J-NCAP this year, not one received a pedestrian safety score higher than 30 (81% of total pedestrian protection score) and the worst overall crash test score was 54 (91% of total crash test score). This suggests that even when vehicle manufacturers pay attention to the pedestrian protection when designing the vehicle, there is still a long way to improve.

Designing Safer Vehicles for Pedestrians

Bumper Design

Bumper height: 49 CFR Part 581, also known as the "Bumper Standard", prescribes bumper standards for passenger motor vehicles in order to reduce economic loss resulting from damage to passenger motor vehicles involved in motor vehicle accidents. In July 2008, the Insurance Institute for Highway Safety (IIHS) petitioned the National Highway Traffic Safety

Administration to amend 49 CFR Part 581 Bumper Standard to extend applicability to light trucks, vans, and multipurpose passenger vehicles based on their test result. Manufacturers can easily reduce the amount of damage caused by SUVs in low-speed collisions with cars by repositioning the bumper bar of the vehicle without any change to vehicle ground clearance height or approach and departure angles (thus ensure the original off-road ability as a SUV is made for). Apart from causing damage to other vehicles by restricting the bumper height, the main reason of pedestrian leg injuries is the stiffness and height of bumper during accidents involving pedestrians.

Several studies have also shown that bumper with different heights can cause different types of injuries and damage to pedestrians. Although no studies have confirmed that a lower bumper is correlated with less damage to pedestrians as the real-world situation is far more complex to simulate, some papers do mention to avoid high fractures close to the knee joint. For pedestrians, the draw-under mechanism of the lower leg within certain limits seems to have a positive effect as it lowers the position of the fracture.

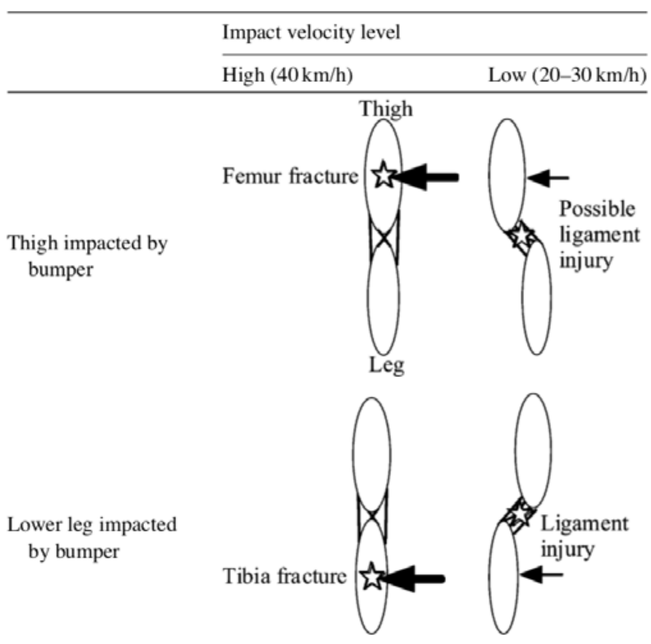

Chart 13: Bumper Height and Types of Injuries
Source: Matsui, Y. (2005)

Materials matter too, as the foam materials around the rigid front cross member have a significant effect on reducing the lower extremity injury risks and especially tibia fracture risk against collisions with a vehicle bumper center.

Hood Design

The research conducted by Wayne State University proves that a considerable reduction in strain with increased under-hood distances.

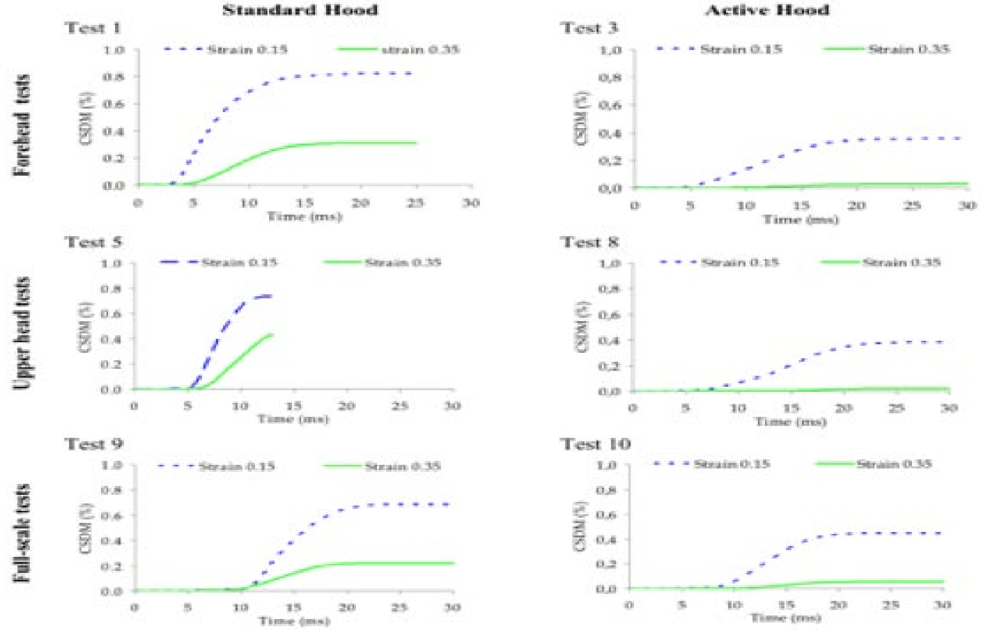

Chart 14: Relation between Standard Hood, Active Hood and HIC Strain
Source: Fredriksson, R., Zhang, L., & Bostrom, O. (2009)

This indicates a reduction of risk for brain injuries if the under-hood distance was increased. Keeping pedestrians away from hitting directly into the engine compartment can reduce the HIC. Based on the result, some vehicles (typically sold in European and Japanese market) are equipped with active hood design (deployable hood design).

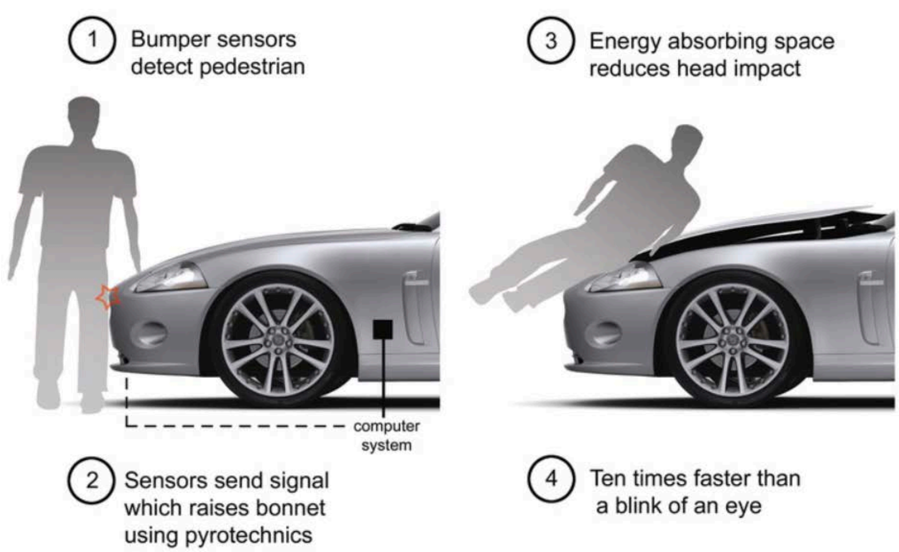

Chart 15: Demonstration on Active Hood
Source: Honda

The system automatically lifts the hood when the vehicle hits a pedestrian to reduce the damage. The NHTSA report on active hood system has concluded that although a vehicle without an active hood design could still achieve high scores in pedestrian protection test, generally vehicles with active hoods tend to achieve both head protection scores and overall scores compared with those without this technology. There are still some technical issues and debates on active hood design that need to be resolved before this technology becomes the mainstream, including the additional costs associated with the system (both installment and repair), verification of deployment threshold and sensors able to detect different crash scenarios. Still, we expect more vehicles to integrate this technology. Tesla has also equipped their Model S with this design in European and Australian markets, again not in the U.S. market.

Studies also have shown that when pedestrians are struck by a car with a short hood length, their heads are likely to strike into or around the windshield. The HIC rises from contact with the cowl, windshield frame or a pillar, and it lessens with increasing distance from these structural elements. To solve the problem some manufacturers have equipped their vehicles with windshield airbags (Volvo V40 in European market since 2012) while a 2017 issued U.S. patent shows that General Motors is intended to do so (namely ‘fender-located pedestrian protection airbag’).

Chart 16: Demonstration on Active Hood
Source: Volvo

New Technologies for Pedestrian Protection

Apart from vehicle design, there are some new technologies aim at improving pedestrian safety. NHTSA has incorporated a list of recommended technologies for customers’ reference alongside the overall score for a vehicle. It specifies optional driver assistance technologies on a vehicle that have met NHTSA performance tests. This includes brakes, back-up camera, forward collision warning, lane assist, blind spot detection and automatic crash notification systems.

For pedestrian safety, Automatic emergency braking (AEB) systems detect an impending forward crash with another vehicle in time to avoid or mitigate the crash. These systems first alert the driver to take corrective action and supplements the driver's braking to avoid the crash. If the driver does not respond, the AEB system may automatically apply the brakes to assist in preventing or reducing the severity of a crash. The AEB systems' engage dynamic brake support (DBS, which automatically supplements the driver's braking in an effort to avoid the crash if brakes are not hard enough to avoid the crash) or crash imminent braking (CIB, which applies the vehicle's brakes to slow or stop the car if no action is taken by the driver) to potentially save lives and reduce moderate and less severe rear-end crashes that are common on the roadways. The Pedestrian Automatic Emergency Braking (PAEB) system is another emerging safety technology that provides automatic braking for vehicles when pedestrians are in front of the vehicle and the driver has not acted to avoid a crash. The system uses information from forward-looking sensors to automatically apply or supplement the brakes when the system determines a pedestrian is in danger of being hit by a vehicle.[4]

Conclusions & Policy Recommendations

Based on what we found in both national data from 2008 to 2017, our first policy recommendation is for the U.S. to develop its own "Traffic War" by learning from the approach the Japanese federal government made back in the 1970s and 1980s. There are many policies that may be helpful to solve the problem, including increasing the national budget for traffic safety, increasing the number of traffic personnel and police officers, increasing the number of traffic signals, and redesigning roads and intersections to be more pedestrian-friendly. The historical trends of pedestrian fatalities in Japan demonstrate that with a well-organized national campaign to protect pedestrian on the roads, it is possible to reduce the number of pedestrian fatalities despite the various impacts influencing fatalities and trends across time. Even though it might not be advisable to simply replicate the specific policies Japan implemented to successfully solve the problem, the case

[4] https://www.nhtsa.gov/equipment/driver-assistance-technologies

study can provide some great lessons for how the U.S. can approach the issue – namely by addressing the issue directly with a coordinated effort between various agencies under federal control.

For states with a higher growth rate of pedestrian fatalities and pedestrian fatalities per 100,000 population, it is helpful to learn from states that have decreased their fatalities rates relative to population. Many state policies that can serve as a model for other states in this way. For example, the five-year New York State Action Plan provides $110 million to improve safety for pedestrians through infrastructure improvements, public education efforts and enforcement. It is "implemented cooperatively by the New York State Department of Transportation focusing on engineering improvements, the State Department of Health conducting public education and awareness campaigns, and the Governor's Traffic Safety Committee coordinating increased law enforcement[5]." In addition the Vision Zero Action program in New York State has a mission to "improve street safety in every neighborhood and in every borough – with expanded enforcement against dangerous moving violations like speeding and failing to yield to pedestrians, new street designs and configurations to improve safety, broad public outreach and communications, and a sweeping legislative agenda to increase penalties for dangerous drivers and give New York City control over the safety of our own streets[6]."

Based on what we found in the comparative study of the New Car Assessment Programs (NCAPs) in the U.S. and Japan, we conclude that the U.S NCAP should add a pedestrian safety test to the program to encourage more vehicle manufacturers to consider pedestrian safety when designing vehicles. In the long-term, this might result in a reduction of the number of pedestrian fatalities. Further research must be conducted to set the appropriate percentage for the pedestrian safety test as a part of overall score considering the potential impact on vehicle manufacturers and other parties involved.

The pedestrian safety test accounts for 37% of the overall score in Japan's NCAP and 32% of the overall score in the European Union's NCAP currently. These proportions might provide guidance for the U.S. to determine an appropriate proportion to allocate within the U.S. NCAP.

Additionally, the U.S. may consider the option to incorporate scores for safety technologies into the overall NCAP score instead of separating it. The Euro NCAP is testing assisted technology and it makes up 9% of the total score. Again, more discussion should be focus on the potential impact and implications of safety technologies on drivers and pedestrians.

[5] https://www.ny.gov/pedestrian-safety-action-plan/pedestrian-safety-action-plan
[6] https://www1.nyc.gov/site/visionzero/index.page

Appendix I: Objectives, Scope and Methodology

This project focuses on national trends in pedestrian fatalities and the references in current rating systems to pedestrian safety. In particular, the report examines: (1) the trends in pedestrian fatalities from 2008 through 2017 in the U.S. and each U.S. state along with several factors that may account for the trends and (2) the New Car Assessment Program (NCAP) conducted by NHTSA in the U.S. and how it differs from the NCAP conducted in Japan.

To determine the characteristics of pedestrian and cyclist fatalities in the United States, we reviewed data produced by the National Highway Traffic Safety Administration (NHTSA) on pedestrian and cyclist fatalities and injuries from 2008 through 2017, the 10 most recent years for which these data are available. NHTSA data came from one online database: the Fatality Analysis Reporting System (FARS). FARS is a census of all fatal traffic crashes in the United States that provides uniformly coded, national data on police-reported fatalities.

We then analyzed this data to determine the estimated number of fatalities involving pedestrians, both at the state level and national level. The number of total pedestrian fatalities in each state was compared to pedestrian fatalities numbers controlled for population - the pedestrian fatality per 100,000 people (total fatality number divided by population in each state ten times 100,000 to calculate an estimate fatality rate; Resident Population data also comes from FARS). We compared the number of pedestrian fatalities in each state from year 2008 to 2017 to examine their growth rate, then tried to find some effective methods and policies deployed by states to solve the problem in low fatality rate states.

We also conducted analysis on some states that suffered from high fatality rate to see their commonalities. Economic, demographic, political and other conditions may also have influenced these rates. We also looked at the data from FARS Web-Based Encyclopedia to find other relevant national rates to support our research including Vehicle Miles Traveled, Registered Vehicles and Licensed Drivers.

To narrow down the scope of potential causes influencing trends, factors were identified in the literature review. The three factors selected for further detailed research were vehicle type, lighting condition and alcohol involvement. We used the Automotive Information Platform MarkLines to collect information on vehicle sales, sorted by vehicle type in the U.S.

between 2008 to 2017. Data on the vehicle type involved in accidents with pedestrian fatalities comes from FARS and demonstrates the correlation between vehicle sales and accident rate.

For our cross-country comparison and case study in Japan, we collected data from Traffic Accident Statistics by National Police Agency (NPA) in Japan as well as both monthly and annual reports. The NPA is an agency administered by the National Public Safety Commission of the Cabinet Office of Japan. The NPA also provided us with historical pedestrian fatality data since 1971, which are included in the annual White Paper by the NPA each year.

To determine the effect of the pedestrian safety test within the New Car Assessment Program (NCAP), we analyzed programs in the U.S. and Japan in detail and examined the methodology used to evaluate the vehicle crash impacts. We also looked at how the program's overall score for assessing new vehicles is calculated and analyzed components related to pedestrian safety. We also examined the history of how the NCAP has evolved since implementation. We looked closely at how Japan's NCAP has changed over time and added substantial components relating to pedestrian protection. We also examined previous academic research about the correlation between the NCAP score and injury reduction.

To examine the effect of new technologies, we examined how NHTSA tests all new driver assisted technologies and its implications for vehicle manufacturers. We also looked for academic papers about vehicle design and new technologies.

Appendix II: Datasets

	Pedestrian Fatalities	Total Traffic Fatalities	Pedestrian Fatalities as a Percent of Total Traffic Fatalities	All Other Traffic Death	Pedestrian Fatalities per 100,000 Population
1998	5,228	41,501	12.60%	36,273	1.9
1999	4,939	41,717	11.84%	36,778	1.8
2000	4,763	41,945	11.36%	37,182	1.7
2001	4,901	42,196	11.61%	37,295	1.7
2002	4,851	43,005	11.28%	38,154	1.7
2003	4,774	42,884	11.13%	38,110	1.63
2004	4,675	42,836	10.91%	38,161	1.58
2005	4,892	43,510	11.24%	38,618	1.65
2006	4,795	42,708	11.23%	37,913	1.6
2007	4,699	41,259	11.39%	36,560	1.54
2008	4,414	37,423	11.79%	33,009	1.44
2009	4,109	33,883	12.13%	29,774	1.33
2010	4,302	32,999	13.04%	28,697	1.38
2011	4,457	32,479	13.72%	28,022	1.42
2012	4,818	33,782	14.26%	28,964	1.51
2013	4,779	32,894	14.53%	28,115	1.5
2014	4,910	32,744	15.00%	27,834	1.53
2015	5,495	35,485	15.49%	29,990	1.67
2016	6,080	37,806	16.08%	31,726	1.85
2017	5,977	37,133	16.10%	31,156	1.84
2018	6,227			-5.61%	1.9

Table 1: Pedestrian Fatalities in U.S. from 1998 to 2018

	Pedestrian Fatalities	All Other Deaths	All Motor Vehicle Deaths	%	Population	Pedestrian Fatalities per 100,000 Population			GDP Annual Growth Rate(%)
1975	7516	37009	44525	16.9%	215973000	3.48			
1976	7427	38096	45523	16.3%	218035000	3.41	-1%	-2%	5%
1977	7732	40146	47878	16.1%	220239000	3.51	4%	3%	5%
1978	7795	42535	50330	15.5%	222585000	3.50	1%	0%	6%
1979	8096	42997	51093	15.8%	225055000	3.60	4%	3%	3%
1980	8070	43021	51091	15.8%	227225000	3.55	0%	-1%	0%
1981	7837	41464	49301	15.9%	229466000	3.42	-3%	-4%	3%
1982	7331	36614	43945	16.7%	231664000	3.16	-6%	-7%	-2%
1983	6826	35763	42589	16.0%	233792000	2.92	-7%	-8%	5%
1984	7025	37232	44257	15.9%	235825000	2.98	3%	2%	7%
1985	6808	37017	43825	15.5%	237924000	2.86	-3%	-4%	4%
1986	6779	39308	46087	14.7%	240133000	2.82	0%	-1%	4%
1987	6745	39645	46390	14.5%	242289000	2.78	-1%	-1%	3%
1988	6870	40217	47087	14.6%	244499000	2.81	2%	1%	4%
1989	6556	39026	45582	14.4%	246819000	2.66	-5%	-5%	4%
1990	6482	38117	44599	14.5%	249623000	2.60	-1%	-2%	2%
1991	5801	35707	41508	14.0%	252981000	2.29	-11%	-12%	0%
1992	5549	33701	39250	14.1%	256514000	2.16	-4%	-6%	4%
1993	5649	34501	40150	14.1%	259919000	2.17	2%	0%	3%
1994	5489	35227	40716	13.5%	263126000	2.09	-3%	-4%	4%
1995	5584	36233	41817	13.4%	266278000	2.10	2%	1%	3%
1996	5449	36616	42065	13.0%	269394000	2.02	-2%	-4%	4%
1997	5321	36692	42013	12.7%	272657000	1.95	-2%	-4%	4%
1998	5228	36273	41501	12.6%	275854000	1.90	-2%	-3%	4%
1999	4939	36778	41717	11.8%	279040000	1.77	-6%	-7%	5%
2000	4763	37182	41945	11.4%	282162411	1.69	-4%	-5%	4%
2001	4901	37295	42196	11.6%	284968955	1.72	3%	2%	1%
2002	4851	38154	43005	11.3%	287625193	1.69	-1%	-2%	2%
2003	4774	38110	42884	11.1%	290107933	1.65	-2%	-2%	3%
2004	4675	38161	42836	10.9%	292805298	1.60	-2%	-3%	4%
2005	4892	38618	43510	11.2%	295516599	1.66	5%	4%	3%
2006	4795	37913	42708	11.2%	298379912	1.61	-2%	-3%	3%
2007	4699	36560	41259	11.4%	301231207	1.56	-2%	-3%	2%
2008	4414	33009	37423	11.8%	304093966	1.45	-6%	-7%	0%
2009	4109	29774	33883	12.1%	306771529	1.34	-7%	-8%	-3%
2010	4302	28697	32999	13.0%	309338421	1.39	5%	4%	3%
2011	4457	28022	32479	13.7%	311644280	1.43	4%	3%	2%

Table 2: Pedestrian Fatalities in U.S. from 1975 to 2018

	Pedestrian Fatality per 100 Million Vehicle Miles Traveled	Pedestrian Fatality per 100,000 Registered Vehicles	Pedestrian Fatality per 100,000 Licensed Drivers
1998	0.20	2.51	2.83
1999	0.18	2.32	2.64
2000	0.17	2.19	2.50
2001	0.18	2.22	2.56
2002	0.17	2.15	2.49
2003	0.17	2.07	2.43
2004	0.16	1.96	2.35
2005	0.16	1.99	2.44
2006	0.16	1.91	2.36
2007	0.16	1.83	2.28
2008	0.15	1.70	2.12
2009	0.14	1.59	1.96
2010	0.14	1.67	2.05
2011	0.15	1.68	2.10
2012	0.16	1.81	2.27
2013	0.16	1.77	2.25
2014	0.16	1.79	2.29
2015	0.18	1.95	2.52
2016	0.19	2.11	2.74
2017	0.19		

Table 3: Pedestrian Fatalities in U.S. from 1998 to 2017

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cars	6802862	5428757	5701537	6144463	7319428	7730273	7854996	7695848	7070152	6305752	5587928
Light Trucks	6399970	4979543	5857619	6589980	7175370	7870513	8666224	9778700	10489000	10934140	11749286
Medium Trucks	164951	104888	110550	134831	15111	166953	186342	200654	207694	222790	237303
Heavy Trucks	133473	94798	107152	171358	194715	184784	220405	248804	192662	192252	250545
Total	13501256	10607986	11776858	13040632	14704624	15952523	16927967	17924006	17959508	17654934	17825062
Light Trucks	47.40%	46.94%	49.74%	51%	48.80%	49%	51%	55%	58%	61.93%	65.91%
Passenger Car	50.39%	51%	48.41%	47%	49.78%	48%	46%	43%	39%	35.72%	31.35%
All Other Vehicles	2%	2%	2%	2%	1%	2%	2%	3%	2%	2%	3%

Table 4: New Vehicle Sales in U.S. from 2008 to 2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alabama	1.42	1.36	1.27	1.64	1.6	1.22	1.98	2.02	2.28	2.44
Alaska	0.44	1.29	0.84	1.25	1.09	0.82	1.9	1.63	1.62	1.89
Arizona	1.85	1.82	2.28	2.27	1.86	2.28	2.09	2.24	2.74	3.08
Arkansas	1.58	1.25	1.27	1.43	1.49	1.52	1.21	1.44	1.47	1.4
California	1.69	1.52	1.6	1.66	1.61	1.83	1.8	1.9	2.21	2.17
Colorado	0.89	0.94	0.71	0.88	1.47	0.95	1.18	1.08	1.43	1.64
Connecticut	1.06	0.74	1.29	0.73	1	1	1.31	1.25	1.51	1.34
Delaware	2.41	1.69	2.45	1.98	2.94	2.7	2.67	3.7	2.84	3.43
DC	1.52	2.33	2.15	1.29	1.11	1.39	1.37	1.93	1.17	1.59
Florida	2.67	2.51	2.58	2.57	2.46	2.56	2.96	3.1	3.16	3.12
Georgia	1.51	1.53	1.73	1.32	1.68	1.76	1.61	1.89	2.25	2.43
Hawaii	1.55	1.24	1.91	1.67	1.87	1.64	1.69	1.75	2.03	0.98
Idaho	0.72	0.65	0.64	0.57	0.81	0.87	0.8	0.48	1.01	0.93
Illinois	1.05	0.86	0.9	1.04	1.07	0.97	0.95	1.17	1.16	1.13
Indiana	0.85	0.78	0.96	0.94	0.9	1.17	1.18	1.45	1.28	1.51
Iowa	0.57	0.7	0.59	0.82	0.65	0.65	0.61	0.8	0.7	0.73
Kansas	0.68	0.78	0.52	0.49	0.9	0.86	0.79	0.82	1.41	1.13
Kentucky	1.57	0.95	1.4	1.14	1.12	1.25	1.29	1.51	1.83	1.86
Louisiana	2.4	2.38	1.63	1.92	2.56	2.1	2.26	2.18	2.71	2.37
Maine	0.91	0.83	0.9	0.75	0.68	0.83	0.68	1.43	1.28	1.5
Maryland	2.06	1.98	1.75	1.75	1.63	1.82	1.69	1.53	1.73	1.88
Massachusetts	1.15	0.73	0.88	0.88	1.08	1.02	1.04	1.06	1.17	1.08
Michigan	1.14	1.18	1.3	1.4	1.31	1.5	1.49	1.67	1.63	1.57
Minnesota	0.5	0.8	0.66	0.73	0.71	0.59	0.27	0.71	1.05	0.68
Mississippi	1.7	1.96	1.68	1.58	1.61	1.77	1.77	2.11	1.94	2.38
Missouri	1.07	1.14	0.92	1.25	1.39	1.21	1.07	1.71	1.58	1.57
Montana	1.14	1.54	0.81	1.5	0.8	2.36	0.98	1.36	1.06	1.33
Nebraska	0.28	0.5	0.44	0.38	0.81	0.64	0.48	1	0.63	1.04
Nevada	2.15	1.32	1.33	1.69	1.96	2.33	2.47	2.28	2.72	3.04
New Hampshire	0.53	0.6	0.68	0.38	0.61	0.91	0.9	0.6	1.27	0.82
New Jersey	1.55	1.8	1.58	1.61	1.76	1.45	1.88	1.9	1.81	2.03
New Mexico	1.97	1.94	1.6	1.97	2.92	2.35	3.55	2.59	3.51	3.54
New York	1.51	1.57	1.56	1.47	1.52	1.7	1.33	1.55	1.54	1.22
North Carolina	1.73	1.56	1.77	1.66	2.02	1.76	1.73	1.81	1.97	1.93
North Dakota	0.94	0.62	1.04	1.32	1	0.14	1.22	0.92	0.92	0.66
Ohio	0.85	0.74	0.81	0.9	1	0.73	0.74	1	1.15	1.22

Table 5: Pedestrian Fatalities in U.S. states from 2008 to 2017

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