Safety Technology, Distracted Driving, and Fatal Car Accidents

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Abstract

Safety Technology, Distracted Driving, and Fatal Car Accidents

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This thesis presents the analysis conducted on the National Highway Traffic Safety Administration (NHTSA) Fatal Accident Report System (FARS) data collected nationwide between 2007 and 2015 to determine if there was a decrease in fatal car accidents involving distracted driving in relation to changes in technology, laws, and social awareness. This thesis specifically looked at distracted driving related to cell phone usage. The purpose of this research is to determine if the data supports the thesis of the overall vehicle safety improvements and the efforts to prevent fatal accidents caused by cell phone usage decreased the number of fatal accidents as well as present the evidence in multiple useful and graphical forms. The data was broken down by model years instead of case years because the safety technology was released based on model years. T-tests were used to determine if there were changes corresponding to technology implementations and anti-distracted driving campaigns. The results of the analysis showed that there were only two changes that were statistically significant with a significance level of $\alpha=0.05$. The most significant change was the drop in the percentage of fatalities in vehicles which indicates that the safety technology phase-in released by the NHTSA during that model year may have made an impact.

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Overview

1.1 Introduction

This thesis presents the analysis conducted on the National Highway Traffic Safety Administration (NHTSA) Fatal Accident Report System (FARS) data collected nationwide between 2007 and 2015 to determine if there was a decrease in fatal car accidents involving distracted driving in relation to changes in technology, laws, and social awareness. This thesis specifically looked at distracted driving related to cell phone usage. The FARS raw data was queried for data pertaining to passenger cars and light trucks with model years 2008 through 2016. The safety improvement data included new legislation passed, new automobile safety technology releases, milestone cell phone releases, and the implementation of distracted driving campaigns. Additional data such as total number of mobile phone subscriptions per year and number of vehicles sold (per unit) will be used to normalize the data. The purpose of this research is to determine if the data supports the thesis of the overall vehicle safety improvements and the efforts to prevent fatal accidents caused by cell phone usage decreased the number of fatal accidents as well as present the evidence in multiple useful and graphical forms.

1.2 Literature Review

In Charles Kahane’s NHTSA Technical Report (2015), he analyzed the impact that vehicle safety technologies and associated Federal Motor Vehicle Safety Standards (FMVSS) had on the number of lives that were saved. The years that were analyzed in his report were from 1960 through 2012. His report excluded any technological advancements from the manufacturers that were implemented inside of the vehicle to decrease distracted driving. This is the most recent report analyzing the impact of safety technologies and comparing it to the FARS database.

The NHTSA analyzes the impact of cell phones on the safety of drivers and releases an annual Driver Electronic Device Use report. Pickrell and Ye's (2013) *Driver Electronic Device Use in 2011* report includes statistics concerning hand-held cell phone use, visible headset cell phone use, and visible manipulation of hand-held devices by drivers. Awareness campaigns have been implemented in an effort to stop distracted driving by educating the public about the harm that distracted driving has on the safety of the roads.

1.2.1 Technology in vehicles. The technology that will be referenced in the research of this thesis stem from the NHTSA as well as the automakers themselves during the years 2007 through 2015. The NHTSA (2013) states that there are three life-saving technologies that were mandated during that time period; Electronic Stability Control (ESC) became mandated in 2007, Tire Pressure Monitoring Systems (TPMS) in 2008 model years, and Rollover Curtain Air Bags (RCABs) (part of the "Ejection Mitigation") in 2011. Other safety technologies like air bags, door locks, and roof crush resistance were released previously and therefore they will be assumed that their impact has already been incorporated as standard for the purpose of this research. Previous research that has been completed groups them into the life-saving technologies category.

Kahane's report that analyzes the impact of the life-saving technologies on the number of lives saved will be used to explain the impact of the three life-saving technologies listed above. The safety technology, ESC, was implemented through the Federal Motor Vehicle Safety Standard (FMVSS) No. 126 released in 2007. This technology automatically applies brakes to the individual wheels and/or reduces the engine torque to help the driver stay on course once the system detects that the vehicle is about to lose traction (Kahane, 2015). The goal of this technology is to stabilize the vehicle and continue directional control without the brakes having to be applied. This technology is listed as a crash avoidance standard because this technology tries to decrease the chance of a crash. The year that this technology was fully implemented in all passenger cars and light truck vehicles (LTV) on the road was model year 2012 according to Kahane's report (2015). This is beneficial knowledge because it shows wait-time that the NHTSA gives automakers to phase-in the new technology to all of their vehicles.

TPMS were recognized by the NHTSA as a life-saving technology previously. However, the phase-in deadline required by FMVSS No. 138, issued in 2005, was for all vehicles to have this technology by model year 2008 (Kahane, 2015). This technology is worth giving information on because even though it was issued in 2005, not all vehicles were equipped with it. This technology notifies the driver that their tire pressure in one or more of the vehicle's tires are not inflated to the recommended pressure level (to a certain percent) (Kahane, 2015). This helps reduce the likelihood of tire malfunctions and even potential fires. Again, this is another crash avoidance standard. Kahane's (2015) report does not include any data on how this technology has impacted the number of lives saved because it is recent and there are a lot of human factors involved. These human factors involve not having the battery replaced or not calibrating the systems correctly.

NHTSA released the "Ejection Mitigation" standard in 2011 with a phase-in deadline set in 2016 under FMVSS No. 226 (Kahane, 2015). This report does focus on the estimated lives saved because the number of cars that have this implementation is very low. The report analyzed the test crash data to gather the results and impact of the technology. The specific technology that was required to be phased in by auto manufacturers is the rollover curtain air bags. This standard focused on decreasing the ejection as well as partial ejection of passengers during rollovers and other crashes by deploying the air bags from the sides of the vehicle (Kahane, 2015). This technology is different from the previous two because it is a crashworthiness standard.

The impact of all the FMVSS concerning the implementation of life-saving technology is shown in Kahane's report. According to NHTSA's evaluation of the ESC and rollover curtains, both of them have provided a statistically significant reduction in fatalities in cars as well as LTVs (Kahane, 2015). The other technology that was analyzed in his report are listed in Appendix A. Kahane's report found that the impact of all the NHTSA's life-saving technology caused the number of lives saved to reach a peak in 2007 with an estimated total of 30,312 lives saved, there was a decrease in the number of vehicle miles of travel during the timespan of 2007 through 2011 causing a decrease in lives saved (Kahane, 2015). The figure below is taken from his report and it shows the estimated lives saved per year by vehicle technologies (Kahane, 2015).

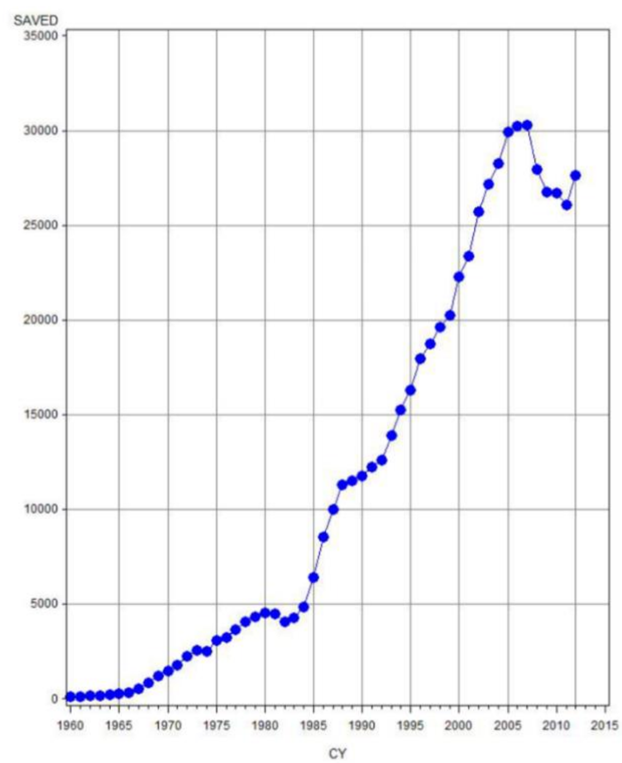


Figure 1. Lives Saved per Year by Vehicle Safety Technologies (1960 to 2012).

Another analysis report was conducted by Glassbrenner (2012) for the NHTSA that analyzed the improved safety of newer vehicles and its impact on low fatality and injury rates through statistical model analysis. This report used Kahane's 2004 safety analysis report along with the FARS database. This thesis will be modeled following the layout of Glassbrenner's report. The findings concluded that "the likelihood of crashing in 100,000 miles of driving has decreased from 30 percent in a model year 2000 car to 25 percent in a model year 2008 one" (Glassbrenner, 2012). This aligns with Kahane's report that safety features are lowering fatality rates.

In comparison to the technology that the NHTSA has been approving and issuing, the automobile manufacturers have been focusing on innovating behavioral technology that will focus on decreasing the impact of distracted driving. The technology that will be taken into consideration will be from Cadillac, Volvo, Mercedes-Benz, and Ford. These companies were chosen because they provided their innovations via a timeline with descriptions of the technology. Though there has not been research conducted on the impact these innovations caused, they are still worth mentioning as possible factors.

Cadillac released one new technology during 2007 through 2015. It is their Cadillac User Experience (CUE) released in 2012 to help reduce the distraction of drivers through decreasing radio buttons, including natural voice recognition, and allowing Bluetooth technology ("Cadillac CUE," n.d.). The goal of the technology is to decrease the amount of time that the driver spends trying to operate the radio as well as dial their phone.

Volvo released two different crash avoidance systems and one distracted driving injury prevention technology during the years that are being analyzed. The first is a laser detection system released in 2008 called City Safety that will automatically brake the vehicle if a front collision is detected (“A Heritage,” n.d.). The goal of this technology is to help prevent front collisions in city environments because of the speed limit of the system. The next technology is another automatically braking technology focused on preventing pedestrian fatalities. Volvo released their Pedestrian Detection with Auto Brake in 2010 that warns the driver and brakes the vehicle automatically if the radar and cameras sense a person in front of the car (“A Heritage,” n.d.). The final technology that Volvo released was focused on drowsy driving and distracted driving. In 2014, Volvo’s Run-off Road Protection equipment was implemented in their cars to help mitigate spine injuries during a road departure crash (“A Heritage,” n.d.). This is not an avoidance safety feature; however, it is focusing on decreasing the probability of a crash becoming a fatal crash due to a spinal injury.

Mercedes-Benz took a different approach to crash avoidance technology than Volvo. Mercedes focused on avoiding the crash due to distracted driving rather than implementing a safety technology to decrease the impact of the crash. In 2010, they released their Attention Assist which alerts the driver if there are signs of drowsiness through analyzing their steering behavior and lack of interaction with the dashboard controls (“Leading Through Innovation,” n.d.). This is not a lane-keeping system, it is an alert system that allows the driver to know that they are not operating the vehicle at their best.

The three areas that Ford focused their technology on were driver blind spots and distracted driving. The first of this technology was their Blind Spot Information System released in 2008 which alerted the driver when an object was in the area out of their line of sight (“History of Autonomy,” 2016). This technology’s goal was to avoid accidents by aiding the driver’s vision with the blind spot alert. The next innovation focused on alerting the driver that they were drifting out of their lane. In 2011, Ford debuted their Lane Keeping System which included three features: Driver Alert, Lane Keeping Alert, and Lane Keeping Aid ("Sustainability 2011/12", 2012). The three features notify the driver through the use of light-up icons and chimes when the technology senses that they are swaying out of their lane or if it detects signs of drowsiness. Ford then turned their focus away from aiding drowsy driving to the problem of distracted driving due to phones. In 2011, Ford released their MyKey technology that can "block incoming phone calls and deter text messages when teens are behind the wheel" ("Sustainability 2011/12", 2012). This technology aimed to prevent teens from texting behind the wheel as well as decrease the number of accidents due to distracted driving.

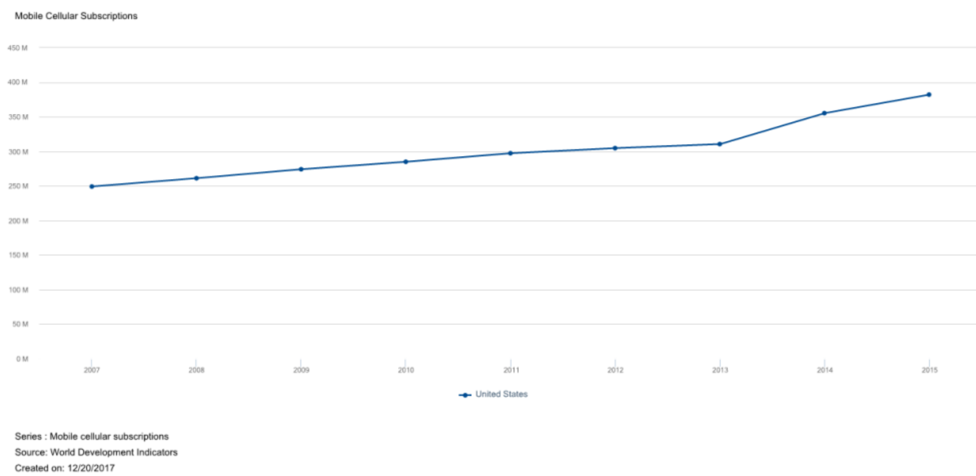


Figure 2. International Telecommunication Union, World Telecommunication/ICT Development Report and database.

1.2.2 Cell phones. The smartphone manufacturing race began in 2007 with the emergence of Apple's iPhone (Telegraph, 2014). Other mobile manufacturers like Google and Samsung followed close behind Apple, and the availability of smartphones for the general public increased. The number of mobile cellular subscriptions increased from 249,300,000 in 2007 to 382,307,000 in 2015 (International Telecommunication Union, 2016). The data that is shown above in Figure 2 is from the World Bank data center. The graph shows the increase from 2007 to 2015 confirming the claim that the demand for having a cell phone has increased throughout the years. The demand and increased use of smartphones has led to a society that allows the obsession and extreme use of smartphones to look like an addiction (South University, 2013). This increase in use has become an easy distraction for people from everyday tasks like driving.

1.2.3 Distracted driving. NHTSA releases a report concerning driver electronic device use every year. The report pulled data from the National Occupant Protection Use Survey (NOPUS) and was analyzed by the National Center for Statistics and Analysis (NCSA). In the 2007 report, the rate for the number of vehicles being operated by a driver using a hand-held phone was 1,005,000 at any given daylight moment (Pickrell, 2008). This is from NOPUS's observational data. That number decreased to 542,073 vehicles at any given daylight moment with drivers operating hand-held cell phones in 2015, however the percentage of those manipulating the phone increased as shown below (Pickrell, 2016). The Figure 3 is pulled from Pickrell's (2016) report to show the decrease in hand-held cell phone usage and the increase in manipulation.

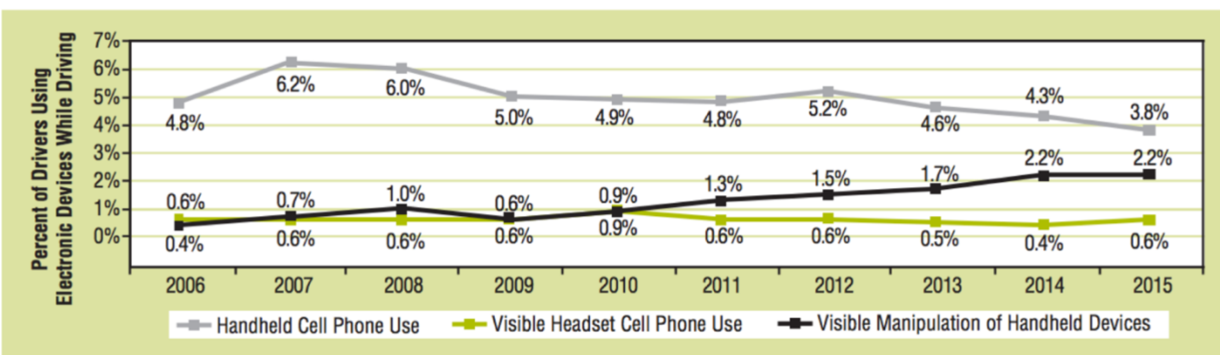


Figure 3. Driver Use of Electronic Devices (2006-2015)

Beauchamp's (2017) study stated that 52 percent of crashes were caused by distracted driving. This confirms the NHTSA's concern that distracted driving due to cell phones is still a problem on the road. Beauchamp took into consideration which states have anti-distracted driving laws. The report found that the laws did not prevent the driver from using their phone, only the amount of time they spent using it (Beauchamp, 2017). Some laws ban only the use of hand-held devices behind the wheel. This led to the emergence of Bluetooth headsets and Bluetooth technology. However, a study conducted by Ishigami (2009) found that there was not a significance difference between the way the individual was using the phone. Rather, the act of talking on the phone is what caused the distraction. This brings into question if the anti-texting and driving campaigns led by the NHTSA made any impact.

The NHTSA began their nationwide campaign against distracted driving in 2009 with their Distracted Driving Summit. Their first pilot campaign “Phone in One Hand. Ticket in the Other.” took place in Connecticut and New York (Alair, 2010). The campaign was a media campaign released during April in each of the two states. The next campaign was the first nationwide advertising and law enforcement campaign implemented in 2014. This campaign is called “U Drive. U Text. U Pay.” and again focused on decreasing the number of drivers using their phones while driving (Ucles, 2014). With these two major campaigns, the NHTSA began the push for other campaigns to begin from other companies. This thesis will only focus on the timing of these two campaigns because they are the first local campaign and national campaign implemented by the NHTSA.

Research Methodology

The raw data was gathered from the FARS database query for each year following the procedure explained in Appendix B. The data was cleaned through the query to ensure that the car has a model year 2008 through 2016, was a passenger car or LTV (excluding service vehicles, motorcycles, and three-wheeled vehicles). The query was also told to only extract cases where the driver was present or left the scene to only have data that ensured there was a driver. The data was then imported and analyzed using R Studio and Excel (code is published on https://github.com/madelinew/HON400Thesis).

Results

3.1 NHTSA Technology

The data was analyzed by using the number of fatal accident cases per calendar year for each vehicle model year. Once total number of fatal accident cases were found for each vehicle model year, it was categorized into the three NHTSA technologies based on the technology's model year phase-in period. The reason that the data was analyzed based on vehicle model year instead of calendar year was due to it not being possible to account for the number of vehicles sold by model year for each calendar year. In order to compare across the model years, the data was converted to percentages. The percentages shown in Table 1 were found by dividing the cumulative number of cases that either involved a fatality in the vehicle or that involved distracted driving via a cell phone by the cumulative number of cases for each model year. The cumulative number of cases was found by adding the number of fatal accident cases per vehicle model year over time for the calendar years 2007 to 2015 (formula shown in Appendix C.1). Table 1 shows the percentage of cumulative number of cases that involved a fatality in the vehicle (Fatalities In Vehicle Cases), the percentage of cumulative number of cases that involved distraction by cell phones (Cell Phone Cases), and technology phase-in group (Technology Phase) for each model year.

Table 1 also shows the NHTSA technology that was being implemented during the model year. TPMS technology was in all cars after 2008 model year (MY) which is the beginning model year that was in the dataset. Therefore, it is safe to assume that all vehicles had this technology already. ESC technology phase-in timeline was from 2007 MY to 2012 MY. The EM technology phase-in timeline was from 2011 MY to 2016 MY. Following the same grouping rules for TPMS, 2012 MY and on was grouped with the EM technology phase-in.

Table 1: Analysis of Fatalities, Cell Phone Usage, and Technology Phase by Model Year

Model Year (MY)	Fatalities in Vehicle Cases (%)	Cell Phone Cases (%)	Technology Phase
2008	46.8	1.40	ESC
2009	47.4	1.23	ESC
2010	43.4	1.04	ESC
2011	39.7	1.03	ESC
2012	41.5	1.05	EM
2013	39.3	1.06	EM
2014	38.5	0.70	EM
2015	38.6	1.11	EM
2016	37.0	1.00	EM

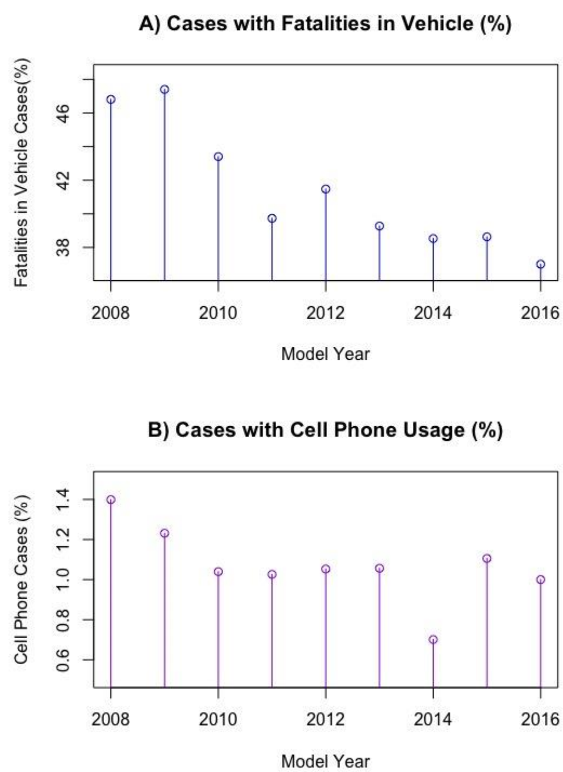


Figure 4. Percentage of Cases by Model Year.
a) Percentage of cases with fatalities in the vehicle by model year. The model years contain the data from the calendar years 2007 through 2015. b) Percentage of cases that involved distracted driving due to cell phone usage by model year.

3.1.1 Analysis of fatalities in vehicles. To determine if there was a change between the two technology phases, the percentage of cases with fatalities in the vehicle was analyzed. The graph in Figure 4a shows a slight decrease in the 2011 MY then it increases again in the following model year. A t-test was conducted to determine if this change was a significant change in the percentage of fatalities in vehicles from before 2011 MY and after 2011 MY (Appendix D). The mean of the percentage of cases with fatalities in the vehicles before the 2011 MY was approximately 45.9% and the mean for the percentage of cases with fatalities in the vehicles after 2011 MY was approximately 39.0%, and the difference that is statistically significant (p-value, 0.013).

The change shown occurs after the 2011 MY which could correspond to the change in technology that was being implemented during that model year. The technology phase changed around the 2011 (model year) with the EM phase-in beginning with this model year and the ESC phase-in ending in the 2012 (model year). The decrease in the percentage of cases with fatalities in the vehicles could be in part due to the life-saving technologies that were being mandated by the NHTSA.

3.1.2 Analysis of cell phone usage. The percentage of cases that involved distracted drivers using cell phones was also analyzed to see if there was any change corresponding to the introduction of new NHTSA safety technology. The graph in Figure 4b shows a slight decrease in the 2010 MY and another in the 2014 MY. A t-test was conducted to determine if this change was a significant change in the percentage of cases using cell phones from before 2010 MY and after 2010 MY as well as before 2014 MY and after 2014 MY (Appendix D). Neither of the changes shown in two model years were statistically significant. The difference between the vehicles with model years prior to 2010 and vehicles with model years after 2010 had a p-value of 0.079 and the difference between the vehicles with model years prior to 2014 and vehicles with model years after 2014 had a p-value of 0.37.

Both the 2010 MY and 2014 MY are in the middle of an implantation phase of an NHTSA safety technology, it is inconclusive to determine if the technologies had an impact on safety in terms of fatal accidents due to cell phone usage. However, vehicles with the 2010 MY were put on the market during the calendar years 2009 to 2010 and the vehicles with the 2014 MY were put on the market during the calendar years 2013 to 2014. During the calendar years 2009 and 2014 there were campaigns released by the NHTSA against distracted driving. The decrease in the percentage of cases does align during when either campaign was released but the data does not support the claim that the campaigns corresponded with significant changes in the outcomes related to distracted driving.

3.2 Manufacturer Technology

To analyze the impact of the safety technology that was introduced by the vehicle manufactures, each make was analyzed using the same method used for analyzing the NHTSA technology, meaning that, the data was analyzed by model year and the percentage of cases were calculated by using the cumulative number of cases from the calendar years 2007 up to 2015 for each model year.

The following tables for each make show the percentage of cumulative number of cases that involved a fatality in the vehicle (Fatalities in Vehicle Cases) and the percentage of cumulative number of cases that involved distraction by cell phones (Cell Phone Cases) for each model year. The percentages were found by dividing the cumulative number of cases that involved the specified make and that either involved a fatality in the vehicle or that involved distracted driving via a cell phone by the cumulative total of cases that had the specified make for each model year (Appendix C).

3.2.1 Ford Technology. Ford had two technological safety advancements during the selected time period; one released with the 2008 MY vehicles and the other in 2011 MY. Since the data was analyzed by model years starting with 2008, it was assumed that vehicles after the 2008 MY contained the safety technology released in the 2008 MY vehicles. To measure how the technology has helped by using the percentage of cases that had fatalities in the vehicle and the percentage of cases that involved cell phones that involved a Ford (Table 2). The 0% percentage of cases shown in the 2016 MY can be attributed to the fact that there were relatively fewer 2016 MY vehicles sold compared to other MY's during the year considered.

Table 2: Analysis of Ford Fatalities Cases and Cell Phone Cases by Model Year

	Fatalities in Vehicle Cases (%)	**Cell Phone Cases (%)**
2008	41.4	1.49
2009	41.7	1.17
2010	35.1	0.67
2011	32.5	1.16
2012	37.9	0.99
2013	36.0	0.81
2014	35.7	1.02
2015	35.3	1.76
2016	27.3	0.00

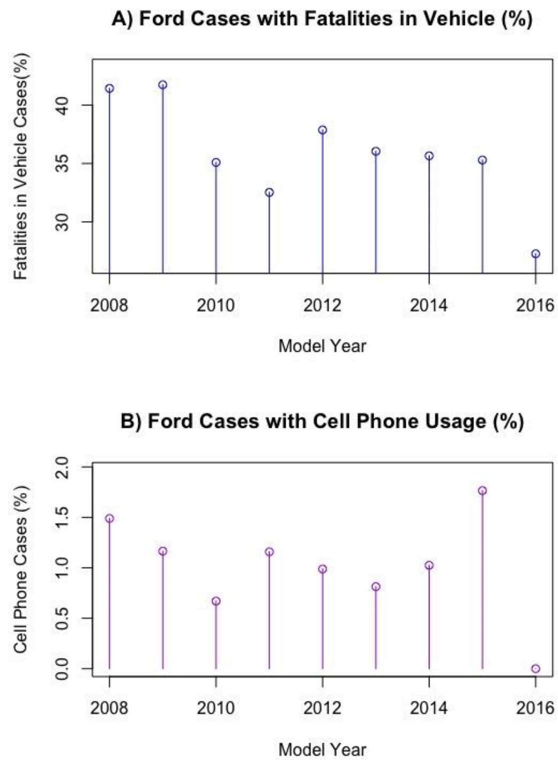


Figure 5. Ford Percentage of Cases by Model Year.
a) The percentages of cases that involved a Ford vehicle and involved a fatality in the vehicle by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015. b) The percentages of cases that involved a Ford vehicle and involved cell phone usage by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015.

3.2.1.1 Analysis of fatalities in Ford vehicles. To determine if there was a change due to the new safety technology, the percentage of cases with fatalities in the vehicle was analyzed. The graph in Figure 5a shows a slight decrease in the 2011 MY then it increases again in the following model year. Since Ford released a safety technology in the 2011 MY vehicles, a t-test was initially conducted to determine if there was a significant change in the percentage of fatalities in vehicles surrounding this model year. The mean for the percentage of cases with fatalities in the vehicles from before 2011 MY was compared to the mean from the percentage of cases with fatalities in vehicles after 2011 MY (Appendix E.1). The difference between the means was not statistically significant (p-value of 0.1431), i.e., the data does not support the claim that there was a significant change in the percentage of cases with fatalities in the vehicles prior and after the release of the Ford safety technology.

3.2.1.2 Analysis of cell phone usage in Ford vehicles. The percentage of cases that involved distracted drivers using cell phones was also analyzed to see if there was any change corresponding to the introduction of new Ford safety technology. The graph in Figure 5b shows a slight decrease in the 2010 MY, another in the 2013 MY, and a large increase in the 2015 MY. A t-test was conducted to determine if this change was a significant change in the percentage of cases using cell phones from before and after of the 2010 MY and the 2013 MY (Appendix E.1).

Neither of the changes shown in the two model years were statistically significant. The difference between the vehicles with model years prior to 2010 and vehicles with model years after 2010 had a p-value of 0.2496 and the difference between the vehicles with model years prior to 2013 and vehicles with model years after 2013 had a p-value of 0.7822.

Both 2010 MY and 2013 MY occurred after a technology was released by Ford and it is inconclusive to determine if the technologies had an impact on safety in terms of fatal accidents due to cell phone usage. However, again the vehicles with the 2010 MY were put on the market during the calendar years 2009 to 2010 which corresponds to the 2009 NHTSA distracted driving campaign release in 2009. The decrease in the percentage of cases does align with the campaign but the data does not support the claim that the campaign corresponded with a significant change in distracted driving-related outcomes.

3.2.2 Cadillac Technology. Cadillac had one technological safety advancement that was released during the 2012 MY. To analyze if there was an impact of their CUE technology, the data from the model years before 2012 MY were compared to the data from the model years after 2012 MY. To measure how the technology has helped, the percentage of cases that involved cell phones and the percentage of cases that had fatalities in the vehicle will be used again (Table 3).

Table 3: Analysis of Cadillac Fatalities Cases and Cell Phone Cases

	Fatalities in Vehicle Cases (%)	**Cell Phone Cases (%)**
2008	48.1	0.63
2009	40.0	1.25
2010	35.8	1.49
2011	38.7	0.00
2012	34.3	0.00
2013	43.4	1.89
2014	31.3	0.00
2015	0.0	0.00
2016	0.0	0.00

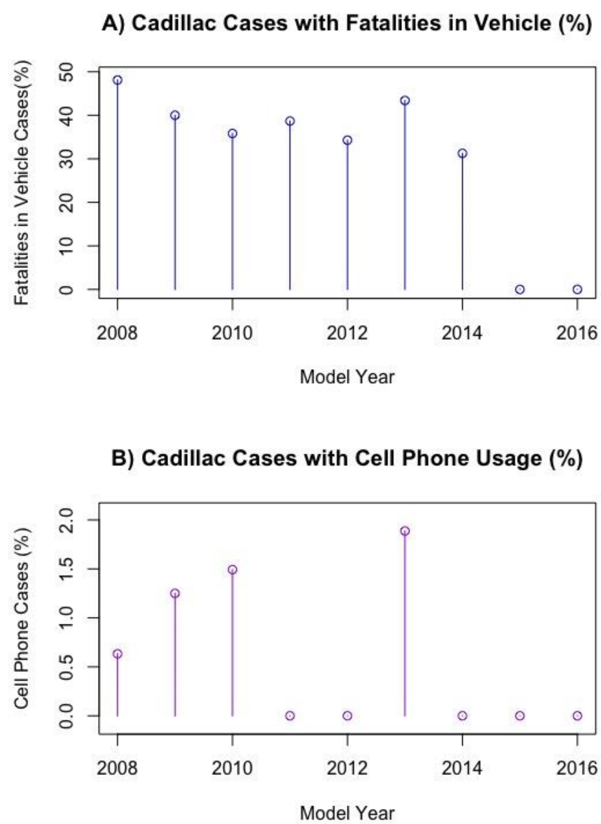


Figure 6. Cadillac Percentage of Cases by Model Year. a) The percentages of cases that involved a Cadillac vehicle and involved a fatality in the vehicle by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015. b) The percentages of cases that involved a Cadillac vehicle and involved cell phone usage by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015.

3.2.2.1 Analysis of fatalities in Cadillac vehicles. The percentage of cases that involved a Cadillac with fatalities within the vehicle was used again to analyze if there was a significant change around the release of Cadillac's CUE technology. As stated previously, the CUE technology was released in the 2012 MY. To determine if there was a statistically significant change surrounding the release of the technology, a t-test was conducted. The t-tested compared the means of percentage of cases with fatalities in the vehicle from model years before the 2012 MY and after the 2012 MY (Table E3, Appendix E.2). The difference between the means was not statistically significant (p-value of 0.1391). Therefore, the data does not support the claim that the CUE technology caused a statistically significant change in the percentage of cases with fatalities in the vehicles.

The graph in Figure 6a shows two slight increases during the 2011 MY and 2013 MY vehicles. A t-test was also conducted to determine if either of the increases or spikes were statistically significant. The model years before 2011 MY were compared to the model years after 2011 MY. The same was done with the model years before 2013 MY and the model years after 2013 MY. The results of both t-tests showed that there was not a statistically significant difference in either of the model years due to both of the p-values being greater than the significance level (Table E3, Appendix E.2). However, the t-value from the comparison of the model years before 2013 MY and the model years after 2013 MY is the larger t-value out of the three t-tests with the value of 2.7088. This means that there is a larger difference between the 2013 MY groups than the 2011 MY and 2012 MY groups.

3.2.2.2 Analysis of cell phone usage in Cadillac vehicles. The percentage of cases that involved distracted drivers using cell phones was also analyzed to see if there was any change corresponding to the introduction of new Cadillac safety technology or the nationwide anti-distracted driving campaigns. The graph in Figure 6b shows a slight increase from 2008 MY to 2010 MY, but then there is a very sharp decrease in 2011 MY. There is also another spike in the percentage of cases during 2013 MY. A t-test was conducted to determine if this change was a significant change in the percentage of cases using cell phones from before and after of the 2011 MY and the 2013 MY (Appendix E.2). However, neither of the changes shown in the two model years were statistically significant. The difference between the vehicles with model years prior to 2011 MY and vehicles with model years after 2011 MY had a p-value of 0.1522 and the difference between the vehicles with model years prior to 2013 MY and vehicles with model years after 2013 MY had a p-value of 0.09439 which, even though it is more significant than the change in the based around the 2011 MY, it is also greater than the significance level. Therefore, due to the spike in the 2013 MY that happened the model year after Cadillac released their technology, there is not a significant change according to the data.

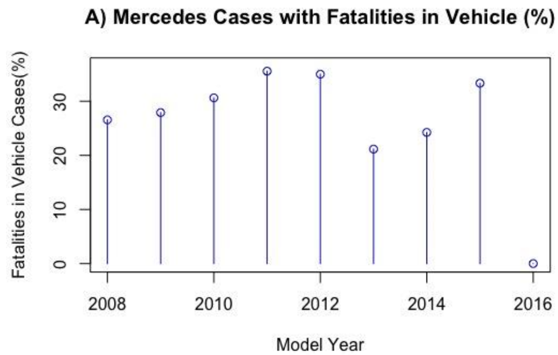
The model year that occurred after a technology was released by Cadillac showed the same spike in the percentage of cases with cell phone usage and the percentage of cases with fatalities in the vehicles. The research found an article released from Cadillac stating that "Cadillac's 2013 total U.S. sales increased 22 percent, the best total sales year for Cadillac since 2007" (2014). The increase in the calendar year 2013 which could be used to explain the spike shown in the percentage of fatal accidents in the 2013 MY.

3.2.3 Mercedes Technology. Mercedes had one technological safety advancement that was released in the 2010 MY vehicles. To analyze if there was any impact of their Attention Assist technology, the data from the model years before 2010 MY were compared to the data from the model years after 2010 MY. Other model years that had a change in the rise or fall of the percentage will also be analyzed. Table 4 shows the percentage of cases that had fatalities in the vehicle and the percentage of cases that involved cell phones used to measure if there was any impact from the technology released by Mercedes.

Table 4: Analysis of Mercedes Fatalities Cases and Cell Phone Cases

	Fatalities in Vehicle Cases (%)	**Cell Phone Cases (%)**
2008	26.6	3.13
2009	27.9	2.33
2010	30.6	0.00
2011	35.6	0.00
2012	35.0	0.00
2013	21.2	0.00
2014	24.2	3.03
2015	33.3	0.00
2016	0.0	0.00

3.2.3.1 Analysis of fatalities in Mercedes vehicles. The percentage of cases that involved a Mercedes with fatalities within the vehicle was used again to analyze if there was a significant change around the release of Mercedes' Attention Assist technology. To determine if there was a statistically significant change surrounding the release of this technology, a t-test was conducted. The t-tested compared the means of percentage of cases with fatalities in the vehicle from model years before the 2010 MY and after the 2010 MY (Table E5, Appendix E.3). The difference between the means was not statistically significant (p-value of 0.6903). It makes sense that the p-value would be so high because the graph shown in Figure 7a does not show any change during that model year.



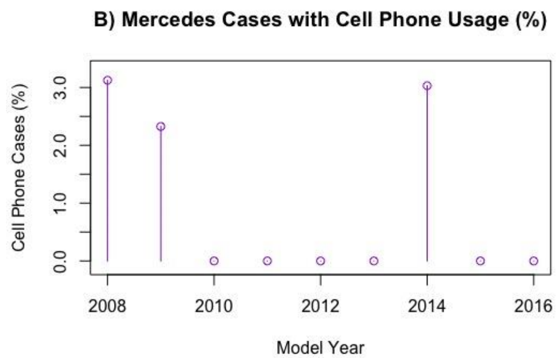


Figure 7. Mercedes Percentage of Cases by Model Year. a) The percentages of cases that involved a Mercedes vehicle and involved a fatality in the vehicle by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015. b) The percentages of cases that involved a Mercedes vehicle and involved cell phone usage by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015.

The graph in Figure 7a does show a change in 2013 MY with a decrease in the percentage of cases from the 2012 MY. Again, a t-test was conducted to determine if this change in percentages is statistically significant. The model years before 2013 MY were compared to the model years after 2013 MY. The results of t-test showed that there was not a statistically significant difference in the model year (p-value of 0.3526) (Table E5, Appendix E.3). Therefore, the decrease in percentage of cases is not able to support the claim that there was a significant decrease in fatalities in Mercedes vehicles after the technology was released.

3.2.3.2 Analysis of cell phone usage in Mercedes vehicles. The percentage of cases that involved distracted drivers using cell phones was also analyzed to see if there was any change corresponding to the introduction of new Mercedes safety technologies. The graph in Figure 7b shows a that there were only three model years that had cases with cell phone usage indicated. There was a decrease shown from 2008 MY to 2010 MY, where there were no cases that indicated that there was cell phone usage involved in the accident. Then in spiked in 2014 MY then falling back to 0% of cases for the 2015 MY and 2016 MY. However, following the same method of testing the significance of change surrounding the model year that the technology was released, a t-test was conducted. The t-test was used to analyze if there was a statistically significant change before 2010 MY and after 2010 MY. The means from the model years before 2010 MY and after 2010 MY were compared and produced a p-value of 0.02192, which indicates a significant change.

The spike in the percentage of cases during 2014 MY was also analyzed using a t-test. Unlike the change seen in 2010 MY, the change seen in 2014 MY was not statistically significant. The difference between the vehicles with model years prior to 2014 MY and vehicles with model years after 2014 MY had a p-value of 0.1804 (Table E6, Appendix E.3). Therefore, this quick spike is not significant nor is the spike seen in the percentage of cases with fatalities in the vehicle during that model year. The spike also does not correspond to either of the nationwide ant-distracted driving campaigns.

3.2.4 Volvo Technology. Volvo had two technological safety advancements that were released in 2008 MY and 2010 MY. Since the data begins with model year 2008, the technology that was released in 2008 MY will be assumed to be in the vehicles already. Therefore, there will not be a t-test conducted for this technology. However, the technology released in with the 2010

MY vehicles will be analyzed to see if there was any impact. To do this the data from the model years before 2010 MY were compared to the data from the model years after 2010 MY. Other model years that had a change in the rise or fall of the percentage will also be analyzed. Table 5 shows the percentage of cases that had fatalities in the vehicle and the percentage of cases that involved cell phones used to measure if there was any impact from the technology released by Volvo. Due to the data only showing one model year that had cases involving cell phone usage indicated, there was no analysis conducted based on the percentage of cases involving cell phone usage.

Table 5: Analysis of Volvo Fatalities Cases and Cell Phone Cases

	Fatalities in Vehicle Cases (%)	**Cell Phone Cases (%)**
2008	29.0	1.61
2009	57.1	0.00
2010	36.8	0.00
2011	33.3	0.00
2012	20.0	0.00
2013	25.0	0.00
2014	40.0	0.00
2015	50.0	0.00
2016	0.0	0.00

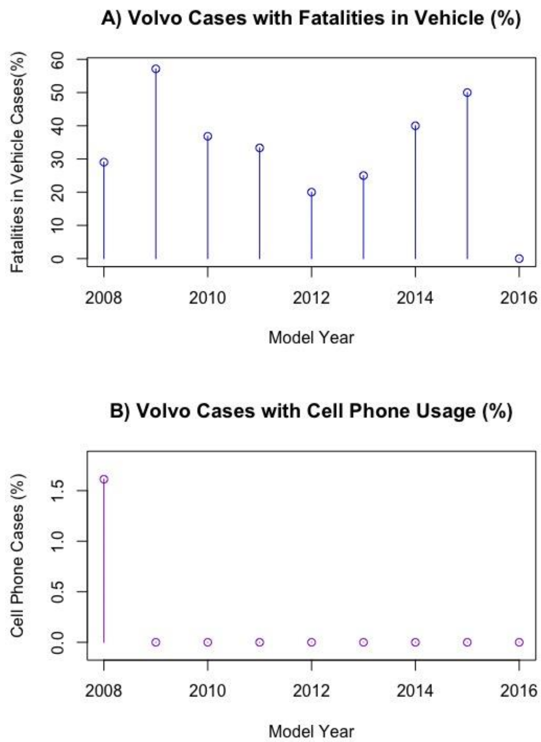


Figure 8. Volvo Percentage of Cases by Model Year. a) The percentages of cases that involved a Volvo vehicle and involved a fatality in the vehicle by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015. b) The percentages of cases that involved a Volvo vehicle and involved cell phone usage by model year. The model year data contains the percentage of cumulative data from calendar years 2007 to 2015.

3.2.4.1 Analysis of fatalities in Volvo vehicles. The percentage of cases that involved a Volvo with fatalities within the vehicle was used to analyze if there was a significant change between the data from model years before 2010 MY and data from model years after 2010 MY. To determine if there was a statistically significant change surrounding the release of this technology, a t-test was conducted. The mean of the percentage of cases with fatalities in the vehicle from before 2010 MY is 43.1% and the mean of the percentage of cases with fatalities in the vehicle after 2010 MY is 28.1% (Table E7, Appendix E.4). The difference between the means was not statistically significant (p-value of 0.4641). The graph in Figure 8a does show a change during the 2010 MY; however, it is not able to support the claim that the technology corresponded with a significant impact on the percentage of fatalities in Volvo vehicles.

The graph in Figure 8a does show a change in 2012 MY with a decrease in the percentage of cases prior to this model year then an increase in percentage of cases after the model year. Again, a t-test was conducted to determine if this change in percentages is statistically significant. The model years before 2012 MY were compared to the model years after 2012 MY. The results of t-test showed that there was not a statistically significant difference in the model year (p-value of 0.4486) (Table E7, Appendix E.4). Therefore, the decrease in percentage of cases is not able to support the claim that there was a significant decrease in fatalities in Volvo vehicles after the technology was released.

Discussion

The t-tests were conducted to determine if the changes seen in the data, as illustrated in the tables and graphs, and corresponding to the technology introduced in specific model years were statistically significant. There were only two changes that were found to be statistically significant. The first was in the percentage of fatalities in vehicles from before 2011 MY and after 2011 MY which corresponds to the safety technology phase-in released by the NHTSA. The sharp decrease shown in the Mercedes cell phone usage in the 2010 MY was also statistically significant. However, this sharp decrease is maintained until the 2014 MY where it then increased above 0% and then dropped to 0% afterwards. The data did not otherwise indicate that the technology and campaigns helped decrease the number of fatal accidents caused by cell phones however, slight changes did align with the campaigns in the overall analysis of the cell phone usage.

The results gathered from all of the data selected for this experiment does not provide an overarching, concrete conclusion. The data could have been seriously limited to the fact that it could not be normalized to the number of vehicles sold by model year for each calendar year. It was also impacted by limiting the data to only have vehicles with model years between 2008 and 2016. Although a majority of the results were not determined statistically significant it raised additional questions that could be further researched. It would be interesting to see if the same trends would be shown if the data was analyzed and normalized by calendar years or on a different geographic scale, such as by county.

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Appendix A

List of Vehicle Safety Technology Found in Kahane's Report

Below is the full list of safety technology that was analyzed and recorded in Kahane's 2015 report. The starred (*) technologies are the ones that were mandated during the years that this thesis focused on.

- Windshield defrosting and defogging
- Impact protection from the steering control
- Windshield mounting
- Hydraulic brake systems
- Steering control rearward displacement
- Child restraint system
- Light vehicle brake systems
- Glazing materials
- Child restraint anchorage system
- Lamps, reflective devices
- Door locks
- Side impact protection
- Air brake systems (ABS)
- Seating systems
- Roof crush resistance
- Electronic stability control (ESC)*
- Occupant crash protection
- Rear impact guards for heavy trailers
- Occupant protection in interior impact
- Tire pressure monitoring system (TPMS)*
- Seat belt assemblies
- Ejection mitigation (rollover curtains)*
- Head restraints
- Seat belt assembly anchorages
- Fuel system integrity

Appendix B

FARS Data Query Methods and Variables

The data from the FARS Query was downloaded as a case listing TXT file and then imported into Excel. From the XLSX file, it was imported into R. The FARS Coding and Query system was changed for the calendar years 2010-2015. The forms added an additional category for Precrash information (distracted driver, attempted avoidance maneuver, etc.). The query system separated out the different ways to obtain the data. For this thesis Option 3 (Crash/Vehicle/Driver/Precrash/Occupant) was selected. The variables selected and edited in the FARS Query are as follows:

B.1 Calendar Years 2007- 2008

- City
- County
- Crash Date (mmddyyyy)
- Crash Day
- Crash Month
- Crash Year
- Drowsy Driver
- Latitude (decimal)
- Longitude (decimal)
- Age
- Air Bag Availability/Function
- Person Related Factors 1-3
- Protection System Use
- Body Type (DOT, 2007)
    - Edited:
        - 1 Convertible
        - 2 2-door Sedan, hardtop, coupe
        - 3 3-door/2-door hatchback
        - 4 4-door sedan, hardtop
        - 5 5-door/4-door hatchback
        - 6 Station Wagon
        - 7 Hatchback, number of doors unknown

        - 8 Sedan/Hardtop, number of doors unknown
        - 9 Other or Unknown automobile type
        - 10 Auto-based pickup
        - 11 Auto-based panel
        - 14 Compact utility
        - 15 Large utility
        - 16 Utility station wagon
        - 19 Utility Vehicle, Unknown body type
        - 20 Minivan
        - 21 Large Van
        - 22 Step-van or walk-in van
        - 28 Other van type
        - 29 Unknown van type
        - 30 Compact pickup
        - 31 Standard pickup
        - 32 Pickup with slide-in camper
        - 33 Convertible pickup
        - 39 Unknown (pickup style) light conventional truck type
        - 48 Unknown light truck type
        - 49 Unknown light vehicle type
- Gross Vehicle Weight Rating
- Number of Fatal in Vehicle
- Vehicle Make
- Vehicle Model
- Vehicle Model Year
    - Edited:
        - 2008-2016
- Vehicle Related Factors 1-2
- Driver Presence
    - Edited:
        - 1 Driver-Operated Vehicle
        - 3 Driver Left Scene
- Driver Related Factors 1-4

B.2 Calendar Year 2009

- City
- County
- Crash Date (mmddyyyy)
- Crash Day

- Crash Month
- Crash Year
- Drowsy Driver
- Latitude (decimal)
- Longitude (decimal)
- Age
- Air Bag Availability/Function
- Person Related Factors 1-3
- Protection System Use
- Body Type (DOT, 2010)
    - Edited:
        - 1 Convertible
        - 2 2-door Sedan, hardtop, coupe
        - 3 3-door/2-door hatchback
        - 4 4-door sedan, hardtop
        - 5 5-door/4-door hatchback
        - 6 Station Wagon
        - 7 Hatchback, number of doors unknown
        - 8 Sedan/Hardtop, number of doors unknown
        - 9 Other or Unknown automobile type
        - 10 Auto-based pickup
        - 11 Auto-based panel
        - 14 Compact utility
        - 15 Large utility
        - 16 Utility station wagon
        - 19 Utility Vehicle, Unknown body type
        - 20 Minivan
        - 21 Large Van
        - 22 Step-van or walk-in van
        - 28 Other van type
        - 29 Unknown van type
        - 30 Compact pickup
        - 31 Standard pickup
        - 32 Pickup with slide-in camper
        - 33 Convertible pickup
        - 39 Unknown (pickup style) light conventional truck type
        - 48 Unknown light truck type
        - 49 Unknown light vehicle type
- Gross Vehicle Weight Rating
- Number of Fatal in Vehicle

- Vehicle Make
- Vehicle Model
- Vehicle Model Year
    - Edited:
        - 2008-2016
- Vehicle Related Factors 1-2
- Driver Presence
    - Edited:
        - 1 Yes
- Driver Related Factors 1-4

B.3 Calendar Years 2010-2015

- City
- County
- Crash Date (mmddyyyy)
- Crash Day
- Crash Month
- Crash Year
- Drowsy Driver
- Latitude (decimal)
- Longitude (decimal)
- Age
- Air Bag Deployed
- Person Related Factors 1-3
- Restraint System/Helmet Use
- Body Type (DOT, 2011)
    - Edited:
        - 1 Convertible
        - 2 2-door Sedan, hardtop, coupe
        - 3 3-door/2-door hatchback
        - 4 4-door sedan, hardtop
        - 5 5-door/4-door hatchback
        - 6 Station Wagon
        - 7 Hatchback, number of doors unknown
        - 8 Sedan/Hardtop, number of doors unknown
        - 9 Other or Unknown automobile type
        - 10 Auto-based pickup
        - 11 Auto-based panel
        - 14 Compact utility

        - 15 Large utility
        - 16 Utility station wagon
        - 19 Utility Vehicle, Unknown body type
        - 20 Minivan
        - 21 Large Van
        - 22 Step-van or walk-in van
        - 28 Other van type
        - 29 Unknown van type
        - 30 Compact pickup
        - 31 Standard pickup
        - 32 Pickup with slide-in camper
        - 33 Convertible pickup
        - 39 Unknown (pickup style) light conventional truck type
        - 48 Unknown light truck type
        - 49 Unknown light vehicle type
- Gross Vehicle Weight Rating
- Number of Fatal in Vehicle
- Vehicle Make
- Vehicle Model
- Vehicle Model Year
    - Edited:
        - 2008-2016
- Vehicle Related Factors 1-2
- Driver Presence
    - Edited:
        - 1 Yes
- Driver Related Factors 1-4
- Driver Distracted By

Appendix C

Cumulative Number and Percentage Formulas

The cumulative number of cases is defined as the number of unique cases per case year for each vehicle model year. In other terms, the cumulative number of cases includes the total number of cases that involved a vehicle with the model year XXXX from the case year 2007 to the case year 2015. The formulas below show how the cumulative numbers and percentages were found following the logic above. The same logic was followed for finding the cumulative number of cases by make for each vehicle model year.

C.1 Formula for Finding the Model Year Cumulative Number

This formula was used to find the cumulative number for the variables number of cases, number of cases with fatalities in the vehicle, and number of cases involving cell phone usage. The variables in the formula are defined below.

$$X = variable$$

$$MY = Model\ Year$$

$$CY = Case\ Year$$

$$\begin{aligned} &Cumulative\ Number\ of\ X\ for\ MY \\ &\qquad = number\ of\ MY\ cases\ from\ 2007CY \\ &\qquad + number\ of\ MY\ cases\ from\ 2008CY \\ &\qquad + number\ of\ MY\ cases\ from\ 2009CY + \cdots \\ &\qquad + number\ of\ MY\ cases\ from\ 2015CY \end{aligned}$$

C.2 Formula for Finding the Make Cumulative Number

This formula was used to find the cumulative number for the variables number of cases, number of cases with fatalities in the vehicle, and number of cases involving cell phone usage by vehicle make. The variables in the formula are defined below.

$$X = variable$$

$$MN = Make\ Number$$

$$MY = Model\ Year$$

$$CY = Case\ Year$$

$$\begin{aligned} &Cumulative\ Number\ of\ X\ involving\ a\ vehicle\ with\ MN\ for\ MY \\ &\quad = number\ of\ MY\ cases\ involving\ a\ MN\ from\ 2007CY \\ &\quad + number\ of\ MY\ cases\ involving\ a\ MN\ from\ 2008CY \\ &\quad + number\ of\ MY\ cases\ involving\ a\ MN\ from\ 2009CY + \cdots \\ &\quad + number\ of\ MY\ cases\ involving\ a\ MN\ from\ 2015CY \end{aligned}$$

C.3 Formula for Finding Percentages

This formula was used to find the percentage of the number of cases with fatalities in the vehicle and the percentage of the number of cases involving cell phone usage. The variables in the formula are defined below. This same formula is used for finding the percentage by vehicle make number.

$$X = number\ of\ cases\ with\ fatalities\ in\ the\ vehicle\ or$$

$$number\ of\ cases\ involving\ cell\ phone\ usage$$

$$MY = Model\ Year$$

$$\begin{aligned} &Percentage\ of\ Cumulative\ Number\ of\ X\ for\ MY \\ &\quad = \frac{Cumulative\ Number\ of\ X\ for\ MY}{Cumulative\ Number\ of\ Cases\ for\ MY} \end{aligned}$$

Appendix D

NHTSA Summary Tables

Table D1: Fatalities in Vehicle Cases (%)

Fatalities in Vehicle Cases (%)	Sample Size	Mean	Standard Deviation
Before 2011 MY	3	45.87	2.16
After 2011 MY	5	38.98	1.62
	df	**t-value**	**p-value**
Before 2011 MY vs. After 2011 MY	3.3935	4.7775	0.01309

Table D2: Cell Phone Cases (%)

Cell Phone Cases (%)	Sample Size	Mean	Standard Deviation
Before 2010 MY	2	1.32	0.12
After 2010 MY	6	0.99	0.15
Before 2014 MY	6	1.13	0.15
After 2014 MY	2	1.05	0.07
	df	**t-value**	**p-value**
Before 2010 MY vs. After 2010 MY	2.1569	3.1581	0.0792
Before 2014 MY vs. After 2014 MY	4.0401	1.0049	0.3713

Appendix E

Summary Tables by Make

E.1 Ford Summary Tables

Table E1: Ford Fatalities in Vehicle Cases (%)

Fatalities in Vehicle Cases (%)	Sample Size	Mean	Standard Deviation
Before 2011 MY	3	39.42	3.75
After 2011 MY	5	34.43	4.12
	df	**t-value**	**p-value**
Before 2011 MY vs. After 2011 MY	4.7103	1.7557	0.1431

Table E2: Ford Cell Phone Cases (%)

Cell Phone Cases (%)	Sample Size	Mean	Standard Deviation
Before 2010 MY	2	1.33	0.23
After 2010 MY	6	0.96	0.57
Before 2013 MY	5	1.09	0.30
After 2013 MY	3	0.93	0.89
	df	**t-value**	**p-value**
Before 2010 MY vs. After 2010 MY	5.0903	1.2991	0.2496
Before 2013 MY vs. After 2013 MY	2.276	0.31069	0.7822

E.2 Cadillac Summary Tables

Table E3: Cadillac Fatalities in Vehicle Cases (%)

Fatalities in Vehicle Cases (%)	Sample Size	Mean	Standard Deviation
Before 2011 MY	3	41.31	6.24
Before 2011 MY	5	21.79	20.38
Before 2012 MY	4	40.65	5.27
After 2012 MY	4	18.66	22.11
Before 2013 MY	5	39.37	5.38
After 2013 MY	3	10.42	18.04
	df	**t-value**	**p-value**
Before 2011 MY vs. After 2011 MY	5.0994	1.9913	0.102
Before 2012 MY vs. After 2012 MY	0.4207	1.227	0.1391
Before 2013 MY vs. After 2013 MY	2.2156	2.7088	0.1018

Table E4: Cadillac Cell Phone Cases (%)

Cell Phone Cases (%)	Sample Size	Mean	Standard Deviation
Before 2011 MY	3	1.13	0.44
After 2011 MY	5	0.38	0.84
Before 2013 MY	5	0.68	3.75
After 2013 MY	3	0.00	4.12
	df	**t-value**	**p-value**
Before 2011 MY vs. After 2011 MY	5.9909	1.6401	0.1522
Before 2013 MY vs. After 2013 MY	4	2.1834	0.09439

E.3 Mercedes Summary Tables

Table E5: Mercedes Fatalities in Vehicle Cases (%)

Fatalities in Vehicle Cases (%)	Sample Size	Mean	Standard Deviation
Before 2010 MY	2	27.23	0.95
After 2010 MY	7	24.88	13.57
Before 2013 MY	5	31.13	4.06
After 2013 MY	3	19.19	17.23
	df	**t-value**	**p-value**
Before 2010 MY vs. After 2010 MY	5.1427	0.42171	0.6903
Before 2013 MY vs. After 2013 MY	2.1345	1.1806	0.3526

Table E6: Mercedes Cell Phone Cases (%)

Cell Phone Cases (%)	Sample Size	Mean	Standard Deviation
Before 2010 MY	2	2.73	0.57
After 2010 MY	7	0.51	1.24
Before 2014 MY	5	31.13	4.06
After 2014 MY	3	19.20	17.23
	df	**t-value**	**p-value**
Before 2010 MY vs. After 2010 MY	4.4657	3.4472	0.02192
Before 2014 MY vs. After 2014 MY	2.1345	1.1806	0.3526

E.4 Volvo Summary Tables

Table E7: Volvo Fatalities in Vehicle Cases (%)

Fatalities in Vehicle Cases (%)	Sample Size	Mean	Standard Deviation
Before 2010 MY	2	43.09	19.88
After 2010 MY	7	28.06	17.40
Before 2012 MY	4	39.09	12.45
After 2012 MY	4	28.75	21.75
	df	**t-value**	**p-value**
Before 2010 MY vs. After 2010 MY	1.5556	0.95454	0.4641
Before 2012 MY vs. After 2012 MY	4.7766	0.82503	0.4486