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Analysis of Real-World Crashes Where Involved Vehicles Were Equipped With Adaptive Equipment

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16. Abstract

Approximately 56.7 million people (18.7%) of the 303.9 million in the civilian, noninstitutionalized United States population had disabilities in 2010. People with disabilities are often unable to drive or ride in vehicles such as passenger cars or vans, unless they have been specially modified to accommodate their conditions. Some modifications, such as the installation of mechanical hand controls or a left-foot accelerator, are relatively simple. Others, such as the installation of a joystick that controls steering, acceleration and braking, or a lowering of the vehicle floor, can be complex. In some cases, altering or even removing Federally required safety equipment to make those special modifications is necessary. In those cases, enabling people with disabilities to have the opportunity to drive or ride in motor vehicles as well as to receive benefits from the full array of Federally required safety features may not be possible.

The purpose of this paper is to better explain the potential safety risk of vehicles adapted to accommodate people with disabilities. The real-world crash data was analyzed to identify the scope of the crash problem, and a detailed review of the data to characterize the potential risk was conducted. To understand the scope of the safety problem, a review of the Fatality Analysis Reporting System data from 2007 to 2015 was conducted. The results identified, on average, four fatal crashes per year involving vehicles coded as being equipped with adaptive equipment. To further understand the safety risk, an in-depth review of the National Automotive Sampling System – Crashworthiness Data System for 2006 to 2015 was conducted. Every crash where an involved vehicle was coded as modified and equipped with adaptive (assistive) driving equipment was analyzed to assess potential safety trends in the data. There were 59 unique cases identified where involved vehicles were coded as equipped with adaptive (assistive) driving equipment. Cases were grouped based upon if the subject vehicle was equipped with operational or non-operational equipment. Note: These cases are not mutually exclusive. There were 50 cases identified where vehicles were equipped with operational adaptive equipment and 19 cases identified as equipped with non-operational adaptive equipment.

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Executive Summary

Approximately 56.7 million people (18.7%) of the 303.9 million in the civilian, noninstitutionalized United States population had disabilities in 2010.[1] People with disabilities are often unable to drive or ride in vehicles such as passenger cars or vans, unless they have been specially modified to accommodate their conditions. Some modifications, such as the installation of mechanical hand controls or a left-foot accelerator, are relatively simple. Others, such as the installation of a joystick that controls steering, acceleration and braking, or a lowering of the vehicle floor, can be complex. In some cases, altering or even removing Federally required safety equipment to make those special modifications is necessary. In those cases, enabling people with disabilities to have the opportunity to drive or ride in a motor vehicle as well as to receive benefits from the full array of Federally required safety features may not be possible.

All motor vehicles sold in the United States must, at the time of the first retail sale, meet applicable Federal Motor Vehicle Safety Standards (FMVSS). The removal of equipment or alteration of a motor vehicle that takes a vehicle out of compliance with these standards violates a statutory provision, which prohibits certain parties from making such equipment and features inoperative. Section 30122 of Title 49 of the United States Codes states that manufacturers, distributors, dealers,[2] rental companies,[3] and repair businesses[4] may not knowingly make inoperative any part of a device or element of design installed on or in a motor vehicle in compliance with an applicable standard.

On February 27, 2001, the National Highway Traffic Safety Administration published a final rule[5] to facilitate the modification of motor vehicles so people with disabilities can drive or ride in them as passengers. In that final rule, the agency issued a limited exemption from a statutory provision prohibiting specified types of commercial entities from either removing safety equipment or features installed on motor vehicles pursuant to the FMVSSs or altering equipment or features that adversely affect their performance. The exemption is limited in that it allows repair businesses or dealers to modify certain types of Federally required safety equipment and features under specified circumstances.

The purpose of this paper is to better explain the potential safety risk of vehicles adapted to accommodate people with disabilities. The real-world crash data was analyzed to identify the scope of the crash problem, and a detailed review of the data to characterize the potential risk was conducted. The analysis will include the following.

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[1] Brault, M. W. (2012). Americans With Disabilities: 2010. *Current Population Reports*, P70-131. Suitland, MD: Census Bureau. Available at www.census.gov/library/publications/2012/demo/p70-131.html

[2] Section 30102 of 49 U.S.C. defines "dealer" as "a person selling and distributing new motor vehicles or motor vehicle equipment primarily to purchasers that in good faith purchase the vehicles or equipment other than for resale."

[3] Section 30102 of 49 U.S.C. defines "rental company" as a person who is engaged in the business of renting rental vehicles and uses for rental purposes a motor vehicle fleet of 35 or more rental vehicles, on average, during the calendar year.

[4] Section 30122(a) of 49 U.S.C. defines "motor vehicle repair business" as "a person holding itself out to the public to repair for compensation a motor vehicle or motor vehicle equipment."

[5] 66 FR 12638.

- Quantify the average number of fatal crashes and fatalities (per year).
- Identify and classify the most common type of modification/equipment present.
- Describe driver, environmental, vehicle, pre-crash/crash, and roadway characteristics for these crashes.
- Determine if the presence of adaptive equipment contributed to crashes.
- Determine if the presence of adaptive equipment contributed to injuries.
- Identify any potential safety trends or concerns.

To understand the scope of the safety problem, a review of the Fatality Analysis Reporting System (FARS) data for 2007 to 2015 was conducted. The results identified, on average, 4 fatal crashes per year involving a vehicle coded as being equipped with adaptive equipment. By comparison, there are more than 30,000 highway fatalities a year during that same interval and crashes involving vehicles equipped with adaptive equipment represent less than 0.01 percent of fatal vehicle crashes.

To further understand the safety risk, an in-depth review of the 2006 through 2015 National Automotive Sampling System – Crashworthiness Data System was conducted. All crashes where an involved vehicle was coded as modified and equipped with adaptive (assistive) driving equipment were analyzed to assess potential safety trends in the data.

There were 59 unique cases identified where an involved vehicle was coded as equipped with adaptive (assistive) driving equipment. Cases were grouped based upon if the subject vehicle was equipped with operational or non-operational equipment. Note: These cases are not mutually exclusive. There were 50 cases identified where vehicles were equipped with operational adaptive equipment and 19 cases identified as equipped with non-operational adaptive equipment.

The 50 operational adaptive equipment cases generally involved vehicles modified with equipment intended to assist the drivers with operational control of the vehicles.[6] The operational adaptive equipment identified in these cases were hand controls, steering knobs, low effort steering systems, raised accelerator/brake pedals, and relocation of the accelerator pedal. The most frequent modifications identified were the addition of hand controls for braking/acceleration (31 cases) followed by the addition of a steering knob attached to the steering wheel (25 cases). There were 16 cases where the vehicles were equipped with both hand controls and steering knobs. Descriptive statistics for the driver, environment, vehicle, pre-crash/crash related, and roadway were calculated and analyzed, including an assessment of the data in the case files. After a careful review of these cases, there were no safety trends identified where it appeared the installed operational adaptive equipment was an obvious factor in the crash.

[6] There were 44 unique cases analyzed. Based upon how the data was grouped with respect to the unique operational adaptive equipment installed on the subject vehicle, 5 cases are duplicative but analyzed as distinct cases. The 50 cases including the 4 duplicates and operational adaptive equipment grouping are provided in Table A2 of the appendix.

The 19 non-operational adaptive equipment cases, generally involved vehicles that were altered or modified to transport disabled occupants such as those in wheelchairs. Fifteen cases generally involved significant alteration to standard vehicles, such as the vehicle's floor being lowered to provide access to a wheelchair-seated occupant or driver. The other 4 cases included 2 situations where the driver seating positions were equipped with seat belt extenders, one where the vehicle was equipped with an air bag on-off switch, and one where the driver's seat cushion was replaced with what appeared to be an orthopedic cushion and lap belt.

These cases included equipment that modified the crashworthiness of the vehicles or occupant protection in crashes. After a careful review of crash severity, crash type, injury source, and injury type, including all cases involving a fatality, there were no safety-related trends identified attributed to the non-operational adaptive equipment. There were a few concerns identified related to improperly restrained wheelchair-seated occupants or indications wheelchairs may not have been intended to be used as seats in moving vehicles, but the data did not indicate a safety problem.

The limitations of this study need to be acknowledged. It is not known if the adaptive equipment identified was in use at the time of the crash or if potential problems with the equipment were identified during the crash investigation. How physical limitations of drivers may have affected the use of the operational adaptive equipment leading up to the crashes, such as a delayed reaction time or potentially lacking the strength during an emergency to operate the equipment, could not be assessed. Furthermore, the type or severity of the disability is not known, including how the occupants' physical state may have made them more susceptible to injury in crashes independent of the non-operational adaptive equipment. Even acknowledging these limitations, the analysis of the available real-world crash data did not identify any safety trends where vehicles were equipped with adaptive equipment to accommodate people with disabilities.

I. Background

Approximately 56.7 million people (18.7%) of the 303.9 million in the civilian, noninstitutionalized United States population had a disability in 2010.[7] People with disabilities are often unable to drive or ride in vehicles such as passenger cars or vans, unless they have been specially modified to accommodate their conditions.

Some modifications, such as the installation of mechanical hand controls or leftfoot accelerators, are relatively simple. Others, such as the installation of a joystick that controls steering, acceleration and braking, or a lowering of the vehicle floor, can be complex. In some cases, altering or even removing Federally required safety equipment to make those special modifications is necessary. In those cases, enabling people with disabilities to have the opportunity to drive or ride in a motor vehicle as well as to receive benefits from the full array of Federally required safety features may not be possible.

All motor vehicles sold in the United States must, at the time of the first retail sales meet applicable FMVSS. The removal of equipment or alteration of a motor vehicle that takes a vehicle out of compliance with these standards violates a statutory provision, which prohibits

[7] Brault, 2012.

certain parties from making such equipment and features inoperative. Section 30122 of Title 49 of the United States Codes states that manufacturers, distributors, dealers,[8] rental companies,[9] and repair businesses[10] may not knowingly make inoperative any part of a device or element of design installed on or in a motor vehicle in compliance with an applicable standard.

On February 27, 2001, NHTSA published a final rule[11] to facilitate the modification of motor vehicles so that people with disabilities can drive or ride in them as passengers. In that final rule, the agency issued a limited exemption from a statutory provision prohibiting specified types of commercial entities from either removing safety equipment or features installed on motor vehicles pursuant to the FMVSSs or altering the equipment or features that adversely affect their performance. The exemption is limited in that it allows repair businesses or dealers to modify only certain types of Federally required safety equipment and features, under specified circumstances. The regulation is found at 49 CFR Part 595 Subpart C, "Vehicle Modifications to Accommodate People with Disabilities."

Commercial entities who modify vehicles after the first retail sale and who wish to use exemptions offered under this regulation are required to provide NHTSA with a document stating the name and address of the business and a prescribed statement they modify vehicle for people with disabilities and intend to avail themselves of exemptions. This information is used by the agency to track entities involved in vehicle modification for people with disabilities and is available to the public on the NHTSA website.

Modifiers must also provide each customer, whose vehicle modification involves the use of the make inoperative exemptions, with a list of the exemptions used in the process of modifying that vehicle. The simplest form of this document is an annotated invoice. A copy of this document must be retained by the modifier for 5 years. This document is used by the consumer to understand modifications made to the vehicle and their effect on vehicle safety. It may also be used by NHTSA in the event of an inquiry about the safety of vehicles modified by the commercial entity.

II. Introduction

The purpose of this paper is to better understand the potential safety risk of vehicles adapted to accommodate people with disabilities as there appears to be sufficient data available to conduct such an analysis.[12] The real-world crash data was analyzed to identify the scope of the crash problem, and a detailed review of the data to characterize the potential risk was conducted. The analysis will include the following.

- Quantify the average number of fatal crashes and fatalities (per year).
- Identify and classify the most common type of modification/equipment present.

[8] Section 30102 of 49 U.S.C., "dealer."
[9] Section 30102 of 49 U.S.C., "rental company."
[10] Section 30122(a) of 49 U.S.C., "motor vehicle repair business."
[11] 66 FR 12638.
[12] In NHTSA's 2013 Traffic Safety for Older People – 5-Year Plan, NHTSA stated it will identify a set of data needs specific to adaptive equipment and identify high-risk subpopulations related to adaptive equipment in the context of older vehicle occupants. www.nhtsa.gov/sites/nhtsa.dot.gov/files/older_people_811873.pdf

- Describe driver, environmental, vehicle, pre-crash/crash, and roadway characteristics for these crashes.
- Determine if the presence of adaptive equipment contributed to crashes.
- Determine if the presence of adaptive equipment contributed to injuries.
- Identify any potential safety trends or concerns.

III. Crash Problem Definition

To understand the scope of the safety problem involving vehicles adapted to accommodate people with disabilities, an analysis of the FARS data was conducted. FARS contains data derived from a census of fatal traffic crashes within the 50 States, the District of Columbia, and Puerto Rico. To be included in FARS, a crash must involve a motor vehicle traveling on a trafficway customarily open to the public and must result in the death of at least one person (occupant of a vehicle or a non-motorist) within 30 days of the crash. In 2015 there were 35,092 fatalities in the United States, an increase of 7 percent from 2014 (32,744).[13]

Since 2007, FARS[14] includes a "Vehicle Factor" variable to denote vehicles that have adaptive equipment installed prior to the time of the crash. Using the most recent data at the time, an analysis of the 2007 through 2015 crash data was conducted and is presented in Table 1.

[13] National Center for Statistics and Analysis (2017, June). *Traffic Safety Facts, State Traffic Data: 2015 Data* (Report No. DOT HS 812 412). Washington, DC: National Highway Traffic Safety Administration.
[14] National Center for Statistics and Analysis. (2016, August). *Fatality Analysis Reporting System (FARS) Analytical User's Manual 1975-2015* (Report No. DOT HS 812 315). Washington, DC: National Highway Traffic Safety Administration.

Table 1: Vehicles Involved in Fatal Crashes, by Adaptive Equipment Vehicle Factor 2007 to 2015 FARS

Year	Fatal Crashes Involving Vehicles With Adaptive Equipment	Occupant Fatalities in Vehicles With Adaptive Equipment	Total Fatalities in Crashes Where an Involved Vehicle Was Equipped with Adaptive Equipment
2007	3	2	3
2008	3	2	3
2009	6	8	8
2010	3	3	3
2011	5	5	6
2012	3	4	4
2013	6	5	6
2014	7	6	7
2015	4	3	4
Total	40	38	44
Average	4	4	5

On average, there were 4 fatal crashes per year involving vehicles coded as equipped with adaptive equipment and, on average, 4 occupants sustaining fatal injuries in the vehicles with the adaptive equipment. Moreover, on average, there were 5 fatalities per year in crashes involving vehicles coded as being equipped with adaptive equipment. This represents less than 0.01 percent of traffic fatalities.

FARS also captures physical impairments to the driver or non-motorist, which may have contributed to the cause of the crash as identified by law enforcement. FARS can indicate the driver was "paraplegic or restricted to a wheelchair." While most likely true, an indication of a driver in a wheelchair does not indicate if a vehicle was equipped with adaptive equipment. For that reason, the adaptive equipment "Vehicle Factor" was believed to be more reliable because modifications to a vehicle were coded and would not have to be inferred.

The limitation of FARS data in understanding crashes involving adaptive equipment is that, it is not known what equipment was installed on the vehicle or if the equipment may have contributed to the cause of the crash or injuries sustained by an occupant. The data presented is only a census accounting of crashes where an involved vehicle was equipped with adaptive equipment.

IV. National Automotive Sampling System – Crashworthiness Data System Analysis

A. Methodology

To better understand the real-world crash problem of vehicles equipped with adaptive equipment, the crash data collected in the 2006 to 2015 NASS-CDS was used. This crash database is a nationally representative sample of tow-away crashes occurring on U.S. roads. Every year, detailed information on vehicle damage, injury, and injury mechanism is collected on approximately 4,500 of these light passenger motor vehicle crashes. The data consists of more than 600 variables describing crash events, damage to vehicle, crash forces involved, injuries to the victim, and injury causation mechanisms for frontal, side, rear, and rollover crashes.

The NASS-CDS contains the variable “adaptive (assistive) driving equipment,”[15] which is defined as equipment whose primary purpose is to assist people with disabilities in the operation of a vehicle. This variable is designed to capture those vehicles with this type of after-market adaptive driving equipment installed. Use of the equipment at the time of the crash is not verified.

The NASS-CDS coding manual identifies the following adaptive driving equipment:

- Hand controls for braking/acceleration,
- Steering control devices (attached to OEM steering wheel),
- Steering knob[16] attached to steering wheel,
- Low effort power steering (unit or device),
- Replacement steering wheel (i.e. reduced diameter),
- Joy stick steering controls,
- Wheelchair tie-downs,
- Modifications to seat belts (specify),
- Additional or relocated switches (specify),
- Raised roof,
- Wall mounted head rest (used behind wheelchair),
- Pedal extender,
- Other adaptive device (specify),
- Unknown type of adaptive device,
- Unknown if adaptive driving equipment installed.

For this analysis, 10 years of real-world crash data were compiled from the 2006 to 2015 NASS-CDS database for crashes that were coded at the time of the investigation as being equipped with adaptive driving equipment. No other constraints were placed on the case selection criteria. Fifty-nine cases were identified where an involved vehicle was coded as being equipped with adaptive driving equipment.

[15] National Center for Statistics and Analysis. (2015, October). *National Automotive Sampling System - Crashworthiness Data System 2014 coding and editing manual* (Report No. DOT HS 812 195). Washington, DC: National Highway Traffic Safety Administration.

[16] A steering knob is an essential component of many adaptive control modifications for disabled drivers. For example, if the throttle and brakes are controlled with a hand operated lever by drivers with lower limb impairments who cannot use foot pedals, such a knob is often required to facilitate effective steering with only one hand.

Using a technique similar to Bean, Kahane, Mynatt, Rudd, Rush, and Wiacek,[17] a detailed review of real-world crashes was conducted by a multidisciplinary team. The review focused on coded and non-coded data (photographs, summaries, crash diagrams, etc.) and resulted in the identification of adaptive driving equipment crash attributes that would be used to better understand and explain the real-world crash data.

As discussed above, there are numerous adaptive driving equipment modifications with which the subject vehicle may be equipped at the time of the crash. Many cases were coded as having multiple adaptive equipment modifications (See Table A1 of the Appendix). For those reasons, cases were grouped into two categories where cases were not mutually exclusive. The first category is modifications that were operational adaptive equipment in nature or equipment directly related to driving the vehicle and maintaining operational control. Operational adaptive equipment cases generally involved vehicles that were modified and equipped with hand controls or low effort steering systems. The consideration of these types of modifications is an attempt to understand if these modifications may contribute to the crash event.

The second category is non-operational adaptive equipment. In these cases, the vehicle had been altered or modified to transport a disabled occupant, such as those in wheelchairs, and the focus is placed on the performance of the vehicle in protecting the occupant in a crash. For example, a van's floor may be lowered to accommodate the ingress and egress of someone seated in a wheelchair, a wheelchair tie-down system, and aftermarket seat belts installed to properly secure the occupant during transport. Or, the factory driver's seat may be removed for the installation of a wheelchair docking-securement device to accommodate a wheelchair seated driver. In certain cases, when applicable, safety equipment may be deactivated in ways such as providing an air bag on-off switch to accommodate a medical condition or disability. It should be noted: some cases in this category may include operational adaptive equipment, but the analysis focused on the crashworthiness of the vehicle and relevant modifications, occupant attribute, crash configuration, and severity and not on potential control issues leading to the crash event. This analysis will review the cases to understand how these types of modifications perform in a crash and how well they protect those with disabilities from injury. Control issues will be considered in the analysis and discussion on operational adaptive equipment.

B. Operational Adaptive Equipment

Fifty-one cases were identified where it appeared unique modifications were made to the vehicle with the intent to aid a potentially disabled occupant to drive.[18] Descriptive statistics for the driver, environment, vehicle, pre-crash/crash related, and roadway are provided below for 50 of the cases. The operational adaptive equipment identified in these cases were hand controls, steering knobs,[19] low effort steering systems, raised accelerator/brake pedals, and relocation of the accelerator pedal.

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[17] Bean, J. D., Kahane, C. J., Mynatt, M., Rudd, R. W., Rush, C. J., & Wiacek, C. (2009, September). *Fatalities in frontal crashes despite seat belts and air bags* (Report No. DOT HS 811 202). Washington, DC: National Highway Traffic Safety Administration..

[18] Case counts are used throughout this analysis and not NASS-CDS case weights. The sample size was believed to be insufficient to be nationally representative.

[19] For the purposes of this study, any device attached to a steering wheel that facilitates one arm manual steering control is categorized as a steering knob. This includes traditional spinner type steering knobs generally used by the driver's hand or other the tri-pin style where a driver will use their hand and wrist as leverage to steer the vehicle. It

It should be noted: One case (Case No. 2008-11-095) was excluded from the data presented below because, after a review of the crash, the vehicle was parked and without a driver at the time of the crash. The subject vehicle was equipped with hand controls and a steering knob. Given the vehicle was not occupied at the time of the crash, it was concluded that the adaptive equipment would not have contributed to the crash event and was excluded from the tabulation of the descriptive data below.

Of the 50 cases grouped by the type of installed operational adaptive equipment, there were 44 unique cases analyzed. Based upon how the data was grouped with respect to the unique operational adaptive equipment installed on the subject vehicle, 6 cases are duplicative but analyzed as distinct cases. For example, Case Nos 2007-05-002, 2008-13-021, 2014-05-035 and 2014-05-040 the subject vehicles were equipped with low-effort steering and Case Nos. 2010-02-066 and 2010-11-165 the vehicles were equipped with relocated accelerator pedal to left side. These 6 cases were also equipped with other operational adaptive equipment. The 50 grouped cases including the 6 duplicates and operational adaptive equipment grouping are provided in Table A2 of the appendix.

One limitation of the data presented in this section is not knowing whether the vehicle at the time of the crash was driven by a disabled driver or if the hand controls or steering knob were in use. What is certain is the vehicle was coded as equipped with operational adaptive equipment with an attempt made to verify was present from the data provided in each case file. Therefore, the data is characterized below as an involved vehicle equipped with adaptive driving equipment at the time of the crash event. Last, the statistics to be presented were compiled for the 50 cases which include the 6 cases discussed above. Any analysis of the data will note when the duplicate cases are excluded.

1. Driver attribute statistics

The most common operational adaptive equipment identified in the dataset as an aggregate was hand controls for braking/acceleration with 31 total cases (62%) followed by steering knob attached to steering wheel with 25 cases (50%) as shown in Table 2. There were only 9 cases (19%) where the steering knob was not installed with hand controls for braking/acceleration, however, there were 15 cases (30%) where the hand controls were not installed in conjunction with the steering knob. There were 16 cases (32%) involving vehicles with both modifications.

Table 2 shows the age of the driver involved in the crash with the adaptive equipment by type of equipment. The age of an involved driver as an aggregate ranged from 19 to 77 years old. The age of the involved driver was generally evenly distributed across age bins with an average age of 45 when excluding the 6 duplicative cases.[20]

should be noted: steering spinner knobs in this study are not indicative of a disability and can be installed to the vehicle for general convenience or other reasons. Most devices in this study were the spinner type knob. For a complete list see www.mobilityworks.com/hand-controls/spinner-knobs.php

[20] All low effort steering and relocated accelerator pedal to left side cases in the tables are duplicative.

Table 2. Age of Driver of Vehicle With Operational Adaptive Equipment

Age of Driver	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
15-19	0	2	1	0	0	0	3
20-29	0	0	4	1	1	0	6
30-39	7	1	2	1	0	0	11
40-49	4	1	3	1	0	0	9
50-59	3	0	3	0	1	0	7
60-69	1	3	3	1	2	2	12
70-79	0	2	0	0	0	0	2
Total	15	9	16	4	4	2	50

As Table 3 illustrates, males were over-represented for all operational equipment categories except for where the vehicle was equipped with both hand controls and a steering knob. Excluding the 6 duplicative cases, in 61 percent of all crashes, the vehicle was driven by a male.

Table 3: Gender of Driver of Vehicle With Operational Adaptive Equipment

Sex of Driver	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Male	10	7	7	3	3	2	32
Female	5	2	9	1	1	0	18
Total	15	9	16	4	4	2	50

The potential contribution of alcohol was limited in the operational adaptive equipment cases reviewed. As shown in Table 4, there were only three crashes where the driver of the adaptive vehicle was coded as being under the influence of alcohol. The blood alcohol concentration (BAC) of the driver in the hand controls, steering knob, and raised pedal cases[21] was, .32 g/dL, .157 g/dL, and .243 g/dL, respectively. The BAC for each of the alcohol involved cases was well above the national limit of .08 g/dL.

Table 4: Alcohol Involvement for Driver of Vehicle With Operational Adaptive Equipment

Alcohol Involved	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Yes	1	1	0	0	1	0	3
No	14	8	16	4	3	2	47
Total	15	9	16	4	4	2	50

In approximately half the cases excluding the duplicate cases, the driver was coded as “attentive or not distracted” at the time of the crash. For 16 of the cases, the attentiveness of the driver was “unknown.” However, for 6 of the cases, the driver was coded as “inattentive or distracted” at the time of the crash.

[21] Case Nos. 2011-13-038, 2006-43-094 and 2006-11-026.

Table 5: Attentiveness of Driver of Vehicle With Operational Adaptive Equipment

Distraction / Inattention to Driving	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Unknown	4	4	6	0	2	0	16
Attentive or not distracted	9	3	8	4	2	2	28
Inattentive or distracted	2	2	2	0	0	0	6
Total	15	9	16	4	4	2	50

The distribution of injuries to the driver of the adaptive vehicle by Maximum Abbreviated Injury Scale (MAIS) is presented in Table 6. The data does not reflect all injuries associated with the crash, only the maximum AIS injury. Excluding the duplicative cases, the driver sustained no or minor injuries in 33 of the crashes (AIS-2 or below). There were 11 cases with severe AIS-3+ injuries, including one fatal MAIS injury. Note: these are AIS coded injuries for the driver, and a detailed discussion on fatal[22] crashes will be presented later in the document.

Table 6: Injury of Driver of Vehicle With Operational Adaptive Equipment

MAIS-Injury	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
None	4	1	4	0	3	0	12
1	6	6	7	3	0	2	24
2	1	0	1	0	0	0	2
3	3	1	2	1	0	0	7
4	0	0	1	0	0	0	1
5	0	1	1	0	1	0	3
6	1	0	0	0	0	0	1
Total	15	9	16	4	4	2	50

2. Environmental and roadway condition statistics

To characterize the environmental conditions at the time of the crashes, lighting and roadway condition data were compiled. As Table 7 shows, as an aggregate of the operational adaptive equipment cases, a majority of the crashes occurred when it was daylight (27 of 44 cases) when excluding the duplicate cases. Approximately one-third (15 cases) of the crashes occurred when it was dark or occurred under dark but lighted conditions.

[22] There were 8 cases identified where there was a fatality in an involved vehicle.

Table 7: Lighting Conditions at Time of Crash

Lighting	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Daylight	6	7	11	3	3	2	32
Dark, but lighted	5	0	2	0	1	0	8
Dark	3	2	2	1	0	0	8
Dusk	0	0	1	0	0	0	1
Dawn	1	0	0	0	0	0	1
Total	15	9	16	4	4	2	50

As for the roadway surface conditions, as Table 8 illustrates, two-thirds (33 of 44 cases) of the crashes occurred when the roads were dry. However, there were 11 crashes that occurred on road surfaces coded as wet or icy.

Table 8: Roadway Conditions at Time of Crash

Road Condition	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Dry	11	8	12	2	2	1	36
Wet	4	1	3	1	2	1	12
Ice	0	0	1	1	0	0	2
Total	15	9	16	4	4	2	50

3. Vehicle statistics

The average model year of vehicles in the dataset was 2004. Excluding the duplicate cases, as Table 9 shows, there were 9 vehicles involved in crashes that were 2000 model year or older, representing 20 percent of the cases. The most frequently occurring model year was 2006. There were only 2 vehicles involved crashes that were 2013 model year or newer.

Table 9: Model Year of Vehicle With Operational Adaptive Equipment

Model Year of Vehicle	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Prior to 2001	4	1	4	1	0	0	10
2001	5	0	0	0	1	0	6
2002	0	0	0	0	1	0	1
2003	2	1	1	0	1	0	5
2004	0	0	2	0	0	0	2
2005	1	1	1	0	0	0	3
2006	1	2	4	1	1	1	10
2007	0	0	1	0	0	0	1
2008	0	2	1	0	0	1	4
2009	0	0	1	0	0	0	1
2010	2	1	0	2	0	0	5
2011	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0
2013	0	1	0	0	0	0	1
2014	0	0	1	0	0	0	1
2015	0	0	0	0	0	0	0
Total	15	9	16	4	4	2	50

Excluding the duplicate cases, approximately two-thirds of vehicles modified with operational adaptive equipment were either vans or passenger cars (Table 10). Only 8 vehicles modified with operational adaptive equipment were SUVs, and 6 were pickup trucks.

Table 10: Body Style of Vehicle With Operational Adaptive Equipment

Bodystyle of Vehicle	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Van	6	1	8	4	0	0	19
Passenger Car	5	3	6	0	1	2	17
Sport Utility Vehicle	2	3	1	0	2	0	8
Pickup Truck	2	2	1	0	1	0	6
Total	15	9	16	4	4	2	50

4. Pre-crash and crash statistics

The posted speed limit at the location of the crash ranged from 35 mph to 70 mph. On average, for all the cases (Table 11), the approximate posted speed limit was 45 mph when the duplicate cases were excluded.

Table 11: Posted Speed of Roadway at Time of Crash

Posted Speed (MPH)	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
25	1	1	1	0	0	0	3
30	1	0	1	0	1	0	3
35	1	1	3	0	0	0	5
40	1	1	5	1	0	0	8
45	5	2	3	1	2	1	14
50	0	1	0	0	0	0	1
55	2	3	1	1	1	1	9
60	0	0	1	0	0	0	1
70	4	0	1	1	0	0	6
Total	15	9	16	4	4	2	50

Figure 1 graphically shows the distribution (excluding duplicate cases) of the posted speed limit at the time of the crash. The most frequently occurring posted speed limit was 45 mph (12 cases), and 31 of the cases (70%) occurred below a posted speed limit of 55 mph. There were 13 cases (30%) where the posted speed limit was 55 mph or greater, 5 of which occurred at a posted speed limit of 70 mph.

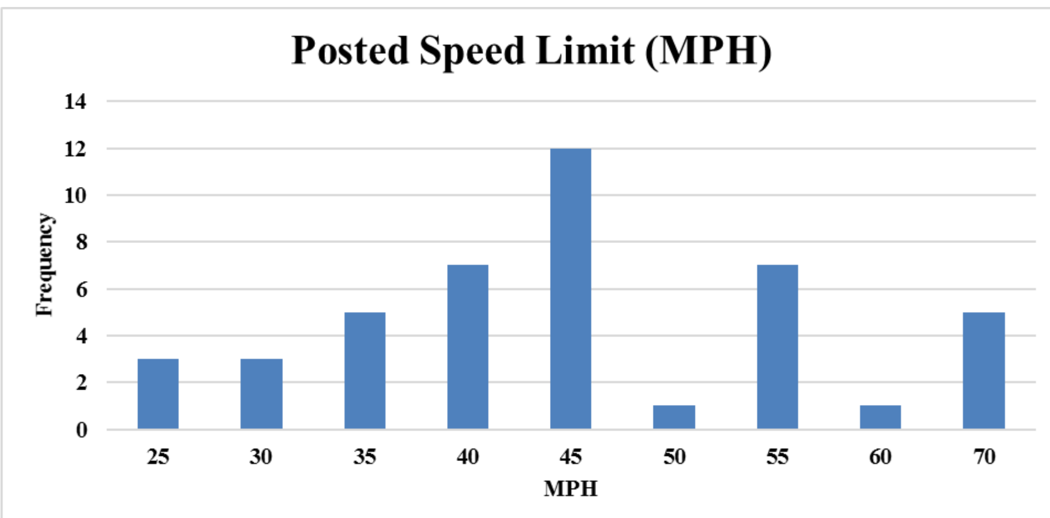

Figure 1: Posted Speed Limit and Frequency

For the driver of the vehicle with the operational adaptive equipment, the pre-event movement of the vehicle, or the movement of the vehicle prior to the recognition of the critical crash event, was tabulated. Excluding the duplicate cases, in 31 of the 44 cases (70%), the driver was "going straight" as shown in Table 12. In 11 (25%) of the cases the driver was "negotiating a curve." In only 4 of the cases was the driver making a turn, specifically, turning left.

Table 12: Pre-Crash Movement of Vehicle With Operational Adaptive Equipment

Pre-Crash Movement	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Going Straight	9	6	8	3	4	2	32
Negotiating a curve	5	3	3	1	0	0	12
Turning left	1	0	3	0	0	0	4
Passing or overtaking another vehicle	0	0	1	0	0	0	1
Successful avoidance maneuver to a previous critical event	0	0	1	0	0	0	1
Total	15	9	16	4	4	2	50

The critical pre-crash category, or the action by this vehicle, another vehicle, person, animal, or object that was critical to this driver with the operation adaptive equipment becoming involved in the crash, was tabulated. Excluding the duplicate cases, the most frequently occurring category was, "this vehicle traveling" with 20 cases followed by other motor vehicle encroaching into lane at 15 cases (Table 13). There were 3 cases coded where the subject vehicle lost control, "this vehicle loss of control," and 5 cases coded "other motor vehicle in lane." Finally, there was only 1 case where the critical pre-crash category was coded as "Object or animal."

Table 13: Critical Pre-Crash Category of Vehicle With Operational Adaptive Equipment

Critical Pre - Crash Category	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
This vehicle traveling	7	4	8	1	1	0	21
Other motor vehicle encroaching into lane	7	2	4	1	2	1	17
This vehicle loss of control	0	1	2	2	0	0	5
Other motor vehicle in lane	1	1	2	0	1	0	5
Object or animal	0	1	0	0	0	1	2
Total	15	9	16	4	4	2	50

The critical pre-crash event was tabulated for each of the 50 cases. The critical pre-crash event is the action by this vehicle, another vehicle, person, animal, or nonfixed object which was critical to this vehicle's crash. For presentation purposes, a critical pre-crash event with an occurrence of two or less were consolidated in "Other." There were 11 cases captured under "Other" as shown in Table 14 when the duplicate cases were excluded. There were 7 cases where the critical pre-crash event was coded as "crossing over (passing through) junction" or identifies the vehicle's travel as proceeding through the junction without any planned turning. There were 5 cases coded as from "opposite direction — over left lane line," identifying a situation where the other vehicle crossed the left lane line while traveling in the opposite direction from this vehicle. Five cases were coded as "off the edge of the road on the right/left side," which identified a situation where the initial pre-crash event occurred beyond the right/left side shoulder area. This also included departure into a median. Five cases were coded as "from crossing street," which was selected by the investigator when the other vehicle was turning from another roadway. Overall, there was a diverse distribution of coding for the critical pre-crash event.

Table 14: Critical Pre-Crash Event for Vehicle With Operational Adaptive Equipment

Critical Pre - Crash Event	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Crossing over (passing through) junction	2	0	4	0	1	0	7
From opposite direction-over left lane line	3	0	1	1	1	0	6
Off the edge of the road on the right/left side	5	0	0	1	0	0	6
From crossing street	3	1	0	0	1	0	5
Over the lane line on right/left side of travel lane	0	4	1	0	0	0	5
From driveway, turning into opposite/same direction	0	1	2	0	0	1	4
Travelling in same direction	1	0	1	0	1	0	3
Other	1	3	7	2	0	1	14
Total	15	9	16	4	4	2	50

The avoidance response of the driver of the operational adaptive equipment vehicle, if any, to this critical situation was tabulated. Excluding the duplicate cases, in 18 of the 44 cases (41%) as shown in Table 15, the driver attempted to either brake or steer or both to avoid the crash. In 10 of the cases (23%), the driver tried to steer only. In 5 of the cases, drivers braked only, and in 4 cases, they tried to steer and brake to avoid the crash. However, for 16 cases (36%), the driver was coded as not taking any action to try to avoid the crash, "no avoidance maneuver."

Table 15: Attempted Avoidance Maneuver of Driver With Operational Adaptive Equipment

Attempted Avoidance Maneuver	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
No avoidance maneuver	3	3	8	1	2	0	17
Unknown	3	4	2	0	1	0	10
Steering left	4	0	1	0	0	0	5
Steering right	0	1	3	0	0	1	5
Braking (lockup)	1	1	1	0	0	1	4
Braking and steering right	2	0	1	1	0	0	4
Braking (no lockup)	1	0	0	1	1	0	3
Braking and steering left	1	0	0	1	0	0	2
Total	15	9	16	4	4	2	50

Crash type data was also compiled for the subject vehicles (Table 16). The most frequent crash type for vehicles equipped with operational adaptive equipment was "change trafficway vehicle turning - turn across path. This is where two vehicles were initially on the same trafficway when one vehicle tried to turn onto another trafficway and pulled in front of the other vehicle. The second most frequent crash type was “single driver - right/left roadside departure - drive off road” in 6 cases when duplicates are excluded. These were a single vehicle, roadway departure crash. The third most frequent crash type at 6 cases was “intersecting paths - straight paths.” This occurred when two vehicles were proceeding (or attempting to proceed) straight ahead and collided when their paths intersected. For presentation purposes, crash types with an occurrence of two or less were consolidated as “Other,” for a total of 6 cases.

Table 16: Crash Type for Vehicle With Operational Adaptive Equipment

Crash Type	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Change Trafficway Vehicle Turning - Turn Across Path	6	1	8	1	1	1	18
Single Driver - Right/Left Roadside Departure - Drive Off Road	5	1	0	1	0	0	7
Intersecting Paths (Vehicle Damage) - Straight Paths	1	1	2	0	2	0	6
Same Trafficway Opposite Directions - Head-On	0	3	1	1	0	0	5
Same Trafficway Same Direction - Rear-End	1	1	1	0	1	0	4
Single Driver - Right/Left Roadside Departure - Control/Traction Loss	0	1	1	1	0	0	3
Other	2	1	3	0	0	1	7
Total	15	9	16	4	4	2	50

5. Roadway statistics

The Trafficway-Relation to Junction variable, or the characteristics of the roadway environment just prior to the critical pre-crash event for the subject vehicle, was also tabulated for the operational adaptive equipment cases.

The two most common locations were “non-interchange area and non-junction” (17 cases when duplicates excluded) and “intersection related/non-interchange” at 17 occurrences. A “non-interchange area and non-junction” is when the vehicle’s environment just prior to the critical pre-crash event does not occur within an interchange area or within a junction. An interchange is the area around a grade separation, which involved at least two trafficways including all ramps connecting roadways.

An “intersection related/non-interchange” roadway is the vehicle’s environment just prior to the critical pre-crash event, such as when the vehicle is in an intersection or is approaching or exiting an intersection.

Table 17: Trafficway-Relation to Junction for Vehicle With Operational Adaptive Equipment

Trafficway - Relation Junction	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Non-interchange area and non-junction	4	7	4	3	2	1	21
Intersection related / non-interchange	8	1	8	1	0	0	18
Driveway, alley access related / non-interchange	0	1	2	0	2	1	6
Interchange area related	3	0	2	0	0	0	5
Total	15	9	16	4	4	2	50

For the vehicle equipped with operational adaptive equipment, the relation to the trafficway flow (Relation to Flow) at the location of the crash was also tabulated (Table 18). A majority of the cases, 28 crashes when duplicates are excluded, occurred on roadways coded "not physically divided (two-way traffic)." This is a type of road without a median. The next most frequent trafficway was "divided trafficway-median strip without positive barrier" with 10 cases. This occurred where a trafficway is physically divided; however, the division is unprotected (e.g., vegetation, gravel, paved medians, trees, water, embankments and ravines that separate a trafficway [i.e., all non-manufactured barriers]).

Table 18: Relation to Flow for Vehicle With Operational Adaptive Equipment

Relation to Flow	Hand Controls for Braking/Acceleration	Steering Knob Attached to Steering Wheel	Both Hand Controls and Steering Knob	Low Effort Steering	Raised Accelerator and/or Brake Pedal	Relocated Accelerator Pedal To Left Side	Total
Not physically divided (two way traffic)	7	8	9	2	4	2	32
Divided trafficway-median strip without positive barrier	5	0	5	1	0	0	11
Divided trafficway-median strip with	3	0	0	1	0	0	4
Not physically divided with two-way left turn lane	0	1	1	0	0	0	2
One way traffic	0	0	1	0	0	0	1
Total	15	9	16	4	4	2	50

C. Non-Operational Adaptive Equipment

The descriptive statistics for the second category of cases, those vehicles equipped with non-operational adaptive equipment, will be presented in this section. In these cases, the vehicle has been altered or modified to transport a disabled occupant, such as those in wheelchairs, and the focus is placed on the performance of the vehicle in protecting the occupant in a crash. For example, cases were identified where substantial alterations or modifications were made to a vehicle, such as a van's floor being lowered and equipped with a ramp to accommodate the ingress and egress of someone seated in a wheelchair. In addition, wheelchair tie-downs and aftermarket seat belts were installed to properly secure the occupant during transport. The factory driver's seat may be removed for the installation of a wheelchair docking-securement device to accommodate a wheelchair-seated driver. In certain cases, when applicable, safety equipment may be deactivated, such as providing an air bag on-off switch, or the seat belt routing may be modified to accommodate for a disability. It should be noted: some cases in this category may include operational adaptive equipment, but the data presented focuses on the crashworthiness of the vehicle and relevant modifications, occupant attribute, crash configuration, and severity and not on the environmental factors of the crash.

There were 19 of 59 cases identified to have been modified/altered and equipped with non-operational adaptive equipment (Table 19). Fifteen of these cases generally involved significant alterations to standard vehicles, such as the vehicle's floor is lowered to provide access to a wheelchair-seated occupant or driver. The other 4 cases included 2 cases where the driver's seating position was equipped with seat belt extenders, one where the vehicle was equipped with an air bag on-off switch, and one where the driver's seat cushion was replaced with what appears to be an orthopedic cushion and lap belt. This section will focus on data involving vehicles altered and modified to accommodate wheelchair-seated occupants because more data was available to present.

Table 19: Non-Operational Adaptive Equipment Cases by Type of Modification

Non-Operational Adaptive Equipment	Counts
Altered and Modified for Wheelchair Accessibility	15
Other	4
Total	19

Again, there were 15 cases where the vehicle was significantly altered and modified to transport someone in a wheelchair. Six of the 15 cases were altered and modified to accommodate wheelchair-seated drivers, and the vehicles were driven from wheelchairs at the times of the crashes (Table 20). In 9 of the 15 cases, the vehicles were altered to be accessible for occupants other than drivers. Of these, only 1 vehicle was altered to accommodate a front passenger wheelchair seat, which was occupied during the crash. In the remaining 8 cases, the second-row seats were removed to accommodate wheelchair-seating positions. In only one case, could it be confirmed the position was occupied by a wheelchair-seated occupant at the time of the crash, and in another case, it was unclear based upon available evidence. These types of vehicles were also altered to provide restraints and wheelchair securement systems to be used by the wheelchair seated occupants when the vehicles are in motion.

Table 20: Seating Position Modified for Altered Vehicle Cases

Vehicle Alteration/Modifiation	Occupied	Unoccupied	Unk	Total
Wheelchair Accessible Driver	6	0	0	6
Wheelchair Accessible Front Passenger	1	0	0	1
Wheelchair Accessible Rear Passenger	1	6	1	8
Total	8	6	1	15

For the 15 cases where the subject vehicles were altered and modified for wheelchair accessibility, Table 21 identifies the general area of damage to the subject vehicles and the severity of the crashes. The most frequently occurring type of crash involved front-end damage with 12 cases identified. Generally, the crash severity[23] was well under the current[24] regulated crash test speed of 56 km/h specified in FMVSS No. 208, "Occupant crash protection," and only one case where that severity was exceeded. There were only 3 cases where a subject vehicle was struck in the rear or on the side. For completeness, the limited data is presented in Table 21. It should be noted: there may have been other occupants in the vehicle at the time of the crash.

Table 21: General Area of Damage for Modified or Altered Vehicle Cases by Crash Severity

General Area of Damage	Count	Max Delta-V	Min Delta-V	Avg Delta-V	Unk
Front	12	62	12	25	2
Rear	2	34	11	23	0
Side	1	32	32	32	0
Total	15				

For all 15 cases, the altered and modified vehicles with non-operational adaptive equipment were vans. The average model year of the vehicle involved in the study was 2004 and ranged from 1997 to 2014.[25]

For those occupants seated in a wheelchair at the time of the crash, the MAIS injury is presented in Table 22. There were 6 cases where the occupant was driving from a wheelchair. The drivers in Case Nos. 2008-75-027 and 2007-05-002 sustained serious AIS-3 injuries. Both cases will be discussed in more detail later in the report.

[23] The crash severity for the 10 frontal cases where the delta-v was estimated (km/h): 12, 12, 12, 16, 18, 19, 23, 30, 47, and 62.

[24] The crash test speed was increased to 56 km/h from 48 km/h when the requirements were amended in a final rule published in 2001 (66 FR 65377). There are some older vehicles in this study that were certified to the previous requirements of 48 km/h.

[25] Model year of altered subject vehicles: 2014, 2012, 2010, 2010, 2007, 2006, 2006, 2003, 2000, 2000, 2000, 1999, 1998, 1998, and 1997.

Table 22: Wheelchair Seated Occupant by Location, Age, Sex and Injury

Case No.	Wheelchair Seated Occupant Location at Time of Crash	Age	Sex	Injury	Fatal
2009-11-131	Unknown Rear Seated Occupant	62	M	AIS-5: Rib cage flail chest bilateral flail with or without lung contusion (OIS Grade V)	Y
2014-05-040	Wheelchair Accessible Driver	47	M	AIS-1: Skin/subcutaneous/muscle, face, laceration, minor; superficial	N
2014-05-035	Wheelchair Accessible Driver	36	F	AIS-1: Strain, cervical spine, acute, with no fracture or dislocationCervical Spine Strain	N
2011-74-166	Wheelchair Accessible Driver	54	F	AIS-2: Tibia fracture, proximal, complete articular; plateau; bicondylar; Schatzker 4, 5, 6	N
2008-79-016	Wheelchair Accessible Driver	40	M	AIS-1: Lower Extremity Skin contusion	N
2008-75-027	Wheelchair Accessible Driver	45	F	AIS-3: Rib cage fracture >3 ribs on one side and <=3 ribs on the other side, stable chest or NFS Left, L Rib 3, L Rib 4, L Rib 5, L Rib 6, L Rib 7	N
2007-05-002	Wheelchair Accessible Driver	24	M	AIS-3: Tibia fracture condyles open/displaced/comminuted	N
2009-45-021	Wheelchair Accessible Front Passenger	61	F	AIS-2: Rib fractures, multiple, NFSRib cage multiple rib fractures NFS	Y
2007-11-197	Wheelchair Accessible Rear Passenger	41	M	None reported	N

There were two cases where cumulative injuries to the wheelchair-seated occupant were fatal. The first case (Case No. 2009-45-021) with the highest delta-v[26] of 62 km/h involved a wheelchair seated front passenger. The other fatal case (Case No. 2009-11-131) was an occupant seated in the rear where it could not be concluded if the occupant was in a wheelchair or unrestrained in the third row. Both cases will be discussed in detail later in the document.

Excluding Case No. 2009-11-131, the average age of the wheelchair seated occupant was approximately 44 years old, and 50 percent of the occupants were split male/female. It should be noted: there were no cases where alcohol was coded to the driver of the subject vehicle whether in a wheelchair or not.

Last, only 12 of 15 cases were coded in the case file data as having a post-manufacturer modification made to the vehicle. Case Nos. 2008-75-027, 2007-47-154, and 2007-05-002 appear to have been modified to transport people with disabilities; however, the cases were not coded as having post-manufacturer modifications made. This variable is coded for the case if it is determined during the investigation that the vehicle has been modified so that the handling and crashworthiness characteristics are affected, such as smaller or larger tires, body lift kit, lowered body, altered suspension, and composite front body panels. In the 3 cases identified, it was clear upon review of the data that modifications were made that fit the above criteria.

[26] It should be noted: All delta-v data cited in the report are NASS-CDS calculated estimates. Event data recorder data generally was not captured.

D. Other

This analysis captured all real-world cases coded using the NASS-CDS variable "adaptive (assistive) driving equipment." Upon review of the case data, there were 10 cases that did not appear relevant to adaptive equipment for people with disabilities. Table 23 provides the types of modifications made to a subject vehicle but were not considered adaptive equipment to accommodate people with disabilities or specifically related to Operational or non-operational adaptive equipment defined for this analysis. For example, there were 4 cases where a passenger side brake pedal was installed, such as those used for driver's education training. In one case, it appeared the horn was relocated on an older vehicle as a repair. One case (Case No. 2006-11-026) a vehicle clearly was a conversion van and coded with a raised roof modification. Upon inspection of the case photos, there were no additional modifications to accommodate people with a disability, such as a wheelchair-seated occupant. It should be noted: The subject vehicle in Case No. 2008-43 251 was equipped with a modified parking brake handle. The 1998 Infiniti Q45 was also equipped with an automatic transmission. Though it is possible, the modification could have been made to accommodate a disability; for this analysis, the parking brake is not used to operate the vehicle and for that reason was included with these cases.

Last there were some cases coded as having adaptive equipment that were clearly racing modifications, including one case (Case No. 2007-49-105) where the driver of the subject vehicle sustained fatal injuries. In that case, a 2005 Ferrari was coded as being modified and equipped with additional or relocated switches with specificity. The Ferrari, after negotiating a right curve, started to rotate clockwise and departed the roadway. The front of the vehicle struck a tree, and the left side struck another tree. The vehicle was split in half from the impact, and both sections kept rotating and moving west. The right rear section struck a third tree. The gas tank ruptured and caused a fire, partially burning the engine. Both occupants were ejected and the driver sustained fatal injuries. There will be no further discussion of these cases as they are outside the scope of this study.

A list of these cases is provided in Table A2 of the Appendix.

Table 23: Other Cases Coded as Adaptive Equipment

Other: Description	Cases
Other: Passenger Brake Pedal	4
Other: After-market pedal covers	1
Other: Attached hand control for emergency brake	1
Other - Relocated horn	1
Other: Racing Modifications	1
Other - Conversion Van	1
Other - Racing seat belts (Driver's seat)	1
Total	10

V. Exemplar Cases

Examples of various crashes will be provided to illustrate the type of operational and non-operational adaptive equipment cases captured in this study. All the cases where the adaptive equipment was the coded source of an involved occupant's injuries will be presented for completeness. Also, those cases, where some observed anomaly or concern with the adaptive equipment was assessed during the case review, including the potential improper use of the adaptive equipment will be presented. Last, for completeness, an overview of cases where there was a fatality in an involved vehicle will be provided.

A. Operational Adaptive Equipment

Cases involving vehicles equipped with both a steering knob and hand controls will be presented by the four most frequently occurring in relation to the trafficway flow variable described in Table 18. This will help illustrate the wide scope of roadway locations and circumstances under which crashes occurred. In addition, an example of cases involving low effort steering, raised accelerator and/or brake pedal, and relocated accelerator pedal to the left side will be presented.

1. Non-interchange area and non-junction (low-effort steering, steering knob, and hand controls)

A 2006 Dodge Ram pickup truck (Case No. 2008-13-021) was coded as equipped with a steering knob, hand controls, and a low effort steering system (Figure 2). The vehicle was traveling on a divided icy highway and lost control (Figure 3). It subsequently went off the right side of the road and rolled over. The posted speed limit at the location of the crash was 70 mph. The restrained 60-year-old male driver sustained minor rib contusions during the four-quarter turn rollover. The pre-crash movement was going straight with the critical event traveling too fast for conditions. The driver of the Dodge was coded as attentive or not distracted.

Figure 2: Case No 2008-13-021 Steering Knob and Hand Controls

Figure 3: Case No 2008-13-021 Scene Photo

2. Intersection-related/non-interchange (steering knob and hand controls)

In this example of an intersection crash (Case No. 2008-12-099), a 2004 Chevrolet Venture was equipped with a steering knob and hand controls. Another vehicle was traveling east intending on turning left onto an expressway entrance ramp under dark but lighted conditions with a posted speed limit of 45 mph. The Chevrolet was traveling west as the other vehicle turned into it (Figure 4). The Chevrolet was coded as going straight and did not take an avoidance maneuver. The frontal crash severity was 28 km/h. The unrestrained 50-year-old male driver of the Chevrolet sustained minor spine injuries, and the unrestrained front passenger sustained serious lower leg injuries. The frontal air bags deployed in the crash. The driver of the Chevrolet was coded as attentive or not distracted.

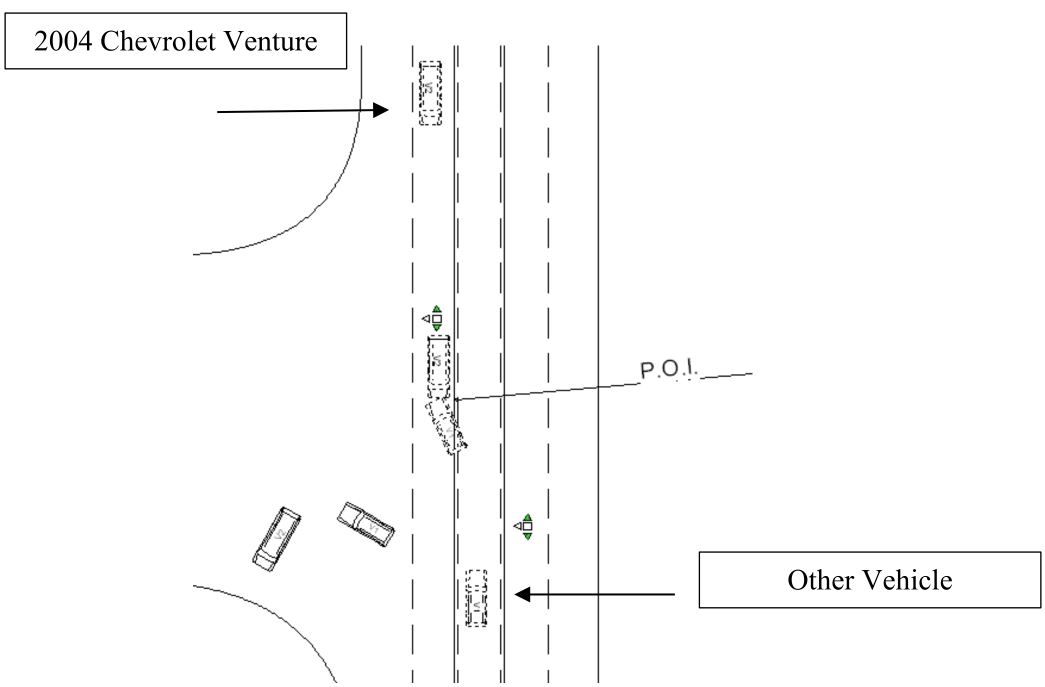

Figure 4: Case No. 2008-12-099 Scene Diagram (P.O.I. = Point of Impact)

3. Driveway, alley access related/non-interchange (steering knob and hand controls)
Case No. 2008-79-016 occurred on a not physically divided (two-way traffic) roadway with a posted speed limit of 35 mph. Another vehicle was exiting a driveway traveling northbound. A 2000 Ford E-Series van modified to accommodate a wheelchair seated driver, and equipped with a steering knob and hand controls (Figure 5), was traveling eastbound as it approached the driveway (Figure 6). The other vehicle was attempting a right turn onto the roadway when its left plane was contacted by the subject vehicle's front plane. The Ford's pre-crash movement was going straight, and the driver did not take an avoidance maneuver. The 40-year-old male driver was properly restrained while sitting in a wheelchair. In the 12 km/h delta-v frontal crash the driver sustained minor lower extremity contusions from contact with the knee bolster. The frontal air bags did not deploy in the crash. The driver of the Ford was coded as attentive or not distracted.

Figure 5: Case No. 2008-79-016 Steering Knob (Tri Pin) and Hand Controls

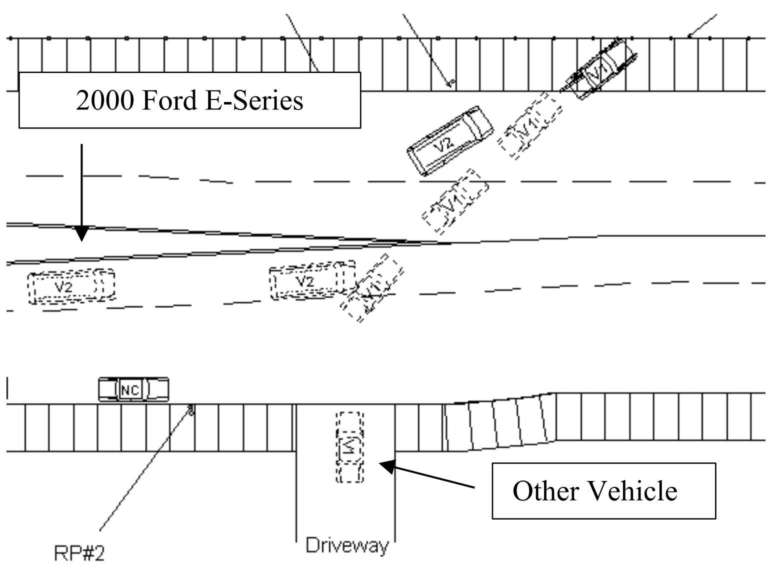

Figure 6: Case No. 2008-79-016 Scene Diagram

4. Interchange area related (steering knob and hand controls)
The last example occurred on a not physically divided roadway (two-way traffic) at an interchange (Case No. 2010-75-103). A 2003 Dodge Caravan equipped with a steering knob and hand controls was traveling northbound approaching an intersection (Figure 7) with a posted speed limit of 40 mph. Another vehicle was westbound approaching the same intersection. The Dodge entered the intersection going straight. The other vehicle turned left at the intersection. The front of the Dodge struck the left side of the other vehicle. The pre-crash movement for the subject vehicle was going straight, and the driver tried to avoid the crash by steering left. The 38-year-old, properly restrained male driver sustained a moderate severity ulna fracture in the 12 km/h delta-v frontal impact. The frontal air bags deployed in the crash. The driver of the Dodge was coded as inattentive or distracted.

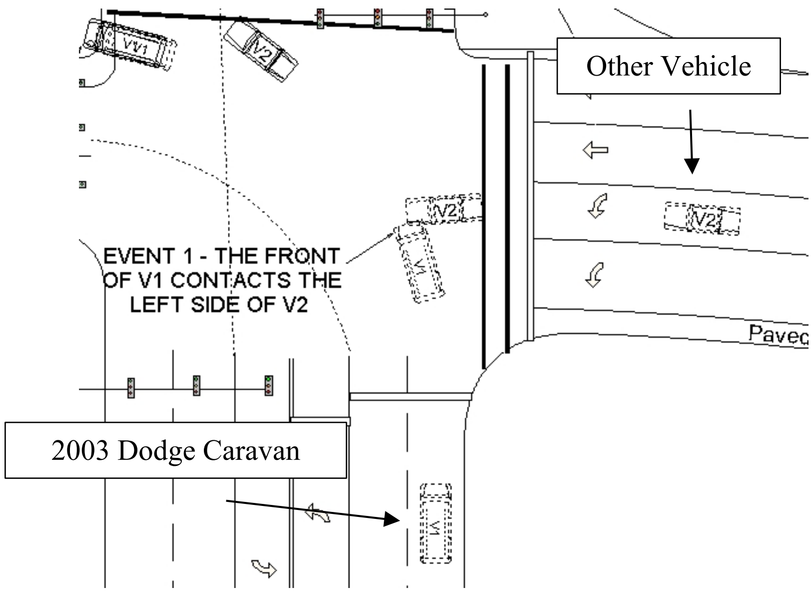

Figure 7: Case No. 2010-75-103 Scene Diagram

5. Driveway, alley access related/non-interchange (raised accelerator and/or brake pedal)
Four[27] cases were identified with vehicles modified to have a raised accelerator and/or brake pedal. There was one crash (Case No. 2009-11-094) where a 2009 Saturn Vue was also equipped with what appears to be special purpose pedal extenders for a small-statured 24-year-old female who was 109 cm tall. In the other cases, the pedal modifications were rudimentary, such as attaching a block of wood or metal to raise the pedals for smaller statured drivers. Case No. 2014-12-010, which involved the subject driver sustaining fatal injuries in a crash, will be discussed later.

With respect to Case No. 2009-11-094, the Saturn and a 1996 Ford medium/heavy vehicle were traveling in the same direction on a road that was not physically divided (two-way traffic) with a posted speed limit of 45 mph. The Ford was in front of the Saturn and was turning right into a private drive (Figure 8). The front of the Saturn struck the rear of the Ford. The properly restrained

[27] 2009-11-094, 2010-45-239, 2011-13-038, and 2014-12-010.

Saturn driver was in a minor impact, and the air bags did not deploy because they were suppressed by an air bag switch (this case will be discussed again in this document). The driver, who was the sole occupant, did not sustain any reported injuries. The driver of the Saturn was coded as attentive or not distracted.

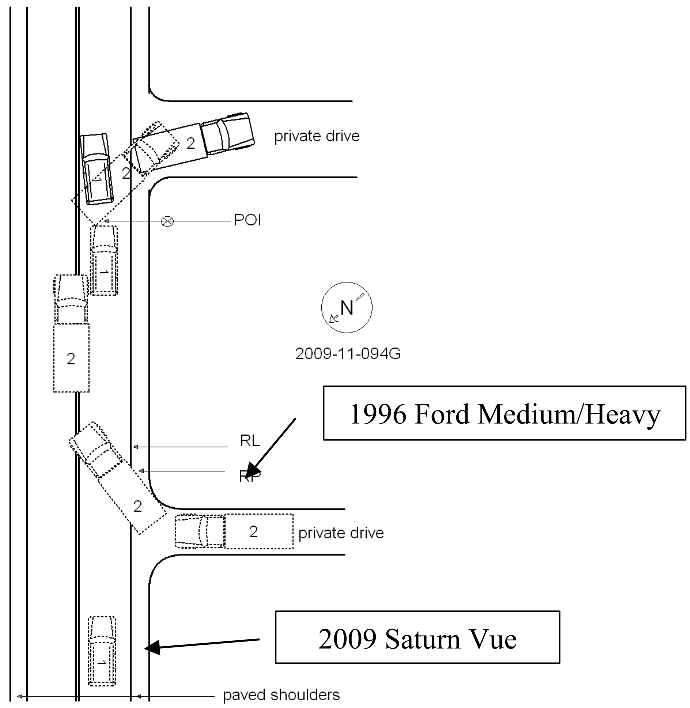

Figure 8: Case No. 2009-11-094 Scene Diagram

Figure 9 shows the bracket for the pedal extenders that were removed prior to the investigation. The brackets are consistent with products on the market[28] to allow people of small stature to operate a vehicle. The vehicle was also equipped with a step to assist the driver when entering the vehicle.

[28] http://drivemastermobility.com/products/pedals/

Figure 9: Case No. 2009-11-094 Bracket for Pedal Extender (removed) and Step

6. Driveway, alley access related /non-interchange (relocated accelerator pedal to the left side)

There were two cases identified where the vehicles' accelerator pedals were relocated to the left side of the brake pedals (Case Nos. 2010-02-066 and 2010-11-165). In Case No. 2010-11-165, a 2010 Jeep Liberty was traveling south out of a commercial driveway to turn left onto a roadway with a posted speed limit of 45 mph. The subject vehicle, a 2006 Ford Focus, was equipped with the relocated accelerator pedal and was traveling eastbound (Figure 10) and coded going straight on a not physically divided roadway with two-way left turn lane (Figure 11). The front of the Ford contacted the left side of the Jeep in the roadway. The attempted avoidance maneuver by the 63-year-old male driver of the Ford was braking. The driver of the Ford was coded as attentive or not distracted. However, the driver of the Jeep was coded as looked but did not see.

Figure 10: Case No. 2010-11-165 Relocated Pedals Removed

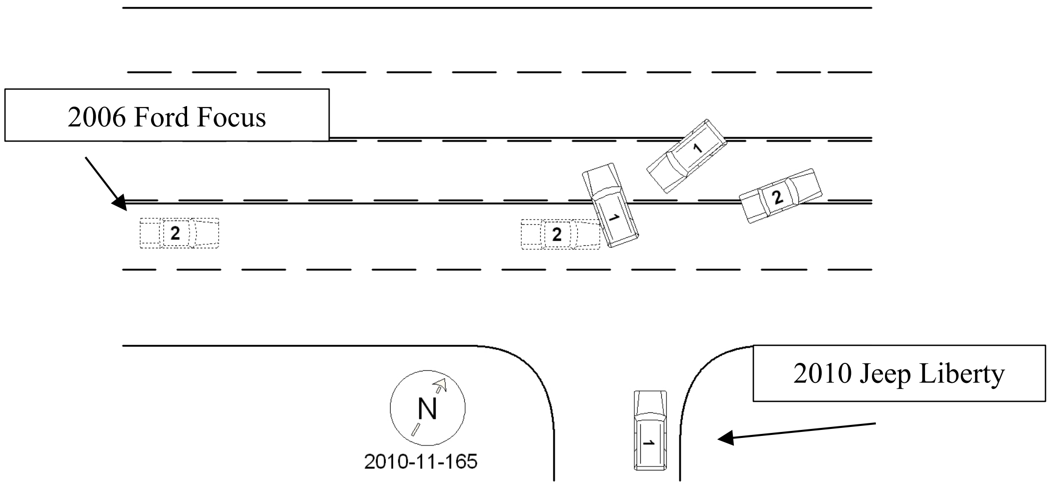

Figure 11: Case No. 2010-11-165 Scene Diagram

Case No. 2010-02-066 involved a 2008 Toyota Yaris, which was equipped with a relocated accelerator pedal (Figure 12). A deer jumped off an embankment on the left side of the road onto the roadway, which had a posted speed limit of 55 mph. The attentive driver of the Yaris was coded as going straight; however, the driver tried to avoid the deer by steering right. The driver struck the deer and then went off the right side of the road. This case will be discussed further in the non-operational adaptive equipment section below because it was also equipped with a driver's side seat belt extender.

Figure 12: Case No. 2010-02-066 Relocated Pedals

B. Non-Operational Adaptive Equipment

Examples of cases involving vehicles equipped with non-operational adaptive equipment will be presented. Generally, the subject vehicle in these cases are significantly altered or modified, which may include lowering the floor to provide access for a wheelchair-seated occupant. These types of vehicles are also altered to provide a restraint system and wheelchair securement system to be used by the wheelchair-seated occupant. This includes proper use of the equipment.

Exemplar cases will be discussed based upon the seated location of the wheelchair-seated occupant. In addition, other modifications, which were less extensive, will be presented. The focus of the discussion will be on the type of crash and its severity, including any injuries sustained by the occupant of interest.

1. Altered vehicle to accommodate a wheelchair seated driver

There were 6 cases identified where wheelchair-seated drivers were involved in crashes. Case No. 2011-74-166 is an example of an altered vehicle that was also extensively modified. This case documented and photographed all the necessary labels per the 49 CFR Part 595 regulation. In this case, an involved vehicle was turning left at an intersection. The subject vehicle, a 2006 Dodge Caravan, was traveling straight through the same intersection. The front of the Dodge struck the left of the other vehicle within the intersection. The driver of the Dodge was seated in a motorized wheelchair, and the vehicle was altered to provide accessibility and securement for the wheelchair (Figure 13).

The Dodge was altered by Braun Corporation (Figure 14) to be driven by a wheelchair-seated driver. Subsequently, the vehicle was further modified and used the 49 CFR 595 exemption regulation because changes to the vehicle took the vehicle out of compliance with the FMVSSs. Both required labels were documented with this crash (Figure 14).

The 54-year-old female drive was properly restrained in the vehicle's seat belt system. In this 23 km/h delta-v frontal crash, the driver sustained an AIS-2 tibia fracture sourced to the knee bolster air bag door under the instrument panel (Figure 15).

Figure 13: Case No. 2011-74-166 Wheelchair Docking-Securement Device and Wheelchair

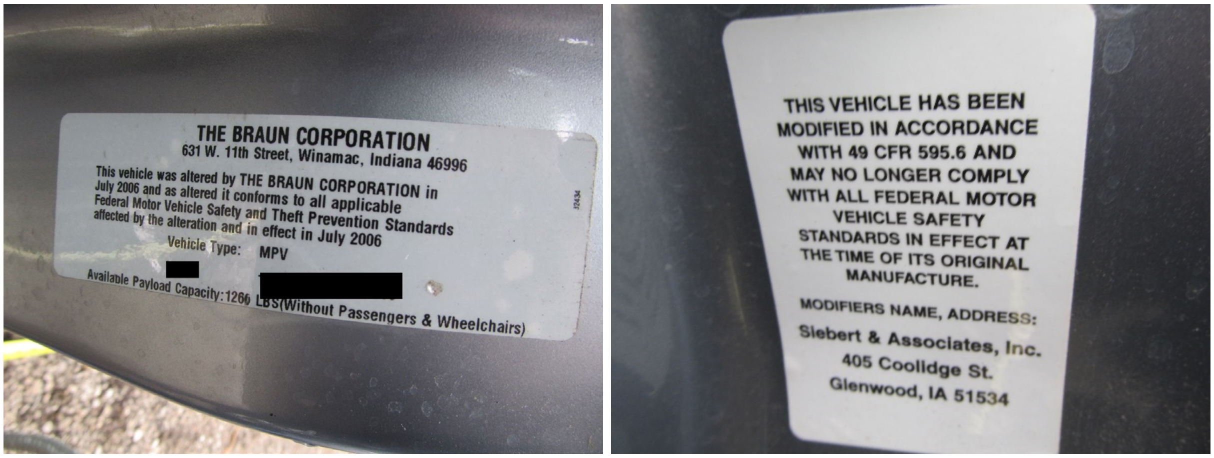

Figure 14: Case No. 2011-74-166 Certification Label of Alterer and 49 CFR 595 Modifier Label

Figure 15: Case No. 2011-74-166 Damage and Knee Bolster Air Bag

2. Altered vehicle to provide accessibility and accommodate a wheelchair seated occupant

There were eight cases identified where the vehicle was altered and modified to provide accessibility and accommodate a wheelchair-seated occupant in the second row. Excluding the one case where the disposition and seated position of the occupant was not conclusively known,[29] only one[30] case was identified where a wheelchair-seated occupant was involved in a crash and 6[31] where the rearward positions were unoccupied.

Case No. 2007-11-197 was a multi-vehicle crash where a properly restrained 41-year-old male was seated in a wheelchair in the second row (Figure 16) of a 2003 Ford E Series altered van. The occupant was seated in a motorized wheelchair. From the photo, the seat belt strap is visible in addition to the four wheelchair tie-downs on the floor.

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[29] Case No. 2009-11-131.
[30] Case No. 2007-11-197.
[31] Case Nos. 2007-47-154, 2008-02-148, 2008-12-131, 2008-72-083, 2013-03-089, and 2014-81-033.

Figure 16: Case No. 2007-11-197 Seated Position and Wheelchair

A 2004 Pontiac Vibe was traveling northbound. A 1994 Chevrolet Lumina was traveling southbound with the 2003 Ford E Series van traveling behind the Chevrolet. The front of the Pontiac contacted the left side of the Chevrolet causing the Pontiac to rotate counterclockwise, where the right side of Pontiac contacted the front of Ford. The Chevrolet then drove off the right side (west) of the roadway and came to rest facing south, while the Ford drove off the right (west) side of the roadway and came to rest facing southwest.

Figure 17: Case No. 2007-11-197 Front End Damage and Wheelchair Lift

The impact with the Pontiac resulted in a total delta-v for the Ford of 16 km/h (Figure 17). For the wheelchair-seated occupant, no injuries were reported. For comparison, the properly restrained 46-year-old male driver of the van also did not sustain injuries in the crash. The frontal air bags deployed in the event.

For additional examples, Figures 18, 19, and 20 are photos where subject vehicles in the cases were altered and modified to accommodate a wheelchair-seated occupant in the second row and were unoccupied during the crash. As noted in the figures, the vehicles were equipped with a lift or ramp that provided ingress and egress, tie-downs for the wheelchair, and a restraint system.

Generally, these vehicles also have the floor lowered, and the seat base for the driver and front passenger are also modified to account for the lowered floor (Figure 21).

Figure 18: Case No. 2007-47-154 Wheelchair Lift and Second Row Restraints

Except for Case No. 2008-02-148 where the driver sustained severe injuries, generally the driver of the subject vehicle, and, when applicable, front row passengers, either were not injured or sustained only minor injuries in the observed crashes. Case No. 2008-02-148 will be discussed later in the injury discussion of the report. Case No. 2014-81-033 will also be discussed in more detail because of an observed anomaly with the raised seat base to accommodate the lowered floor for the driver's seating position.

Figure 19: Case No. 2008-72-083 Wheelchair Ramp and Second Row Tie-downs

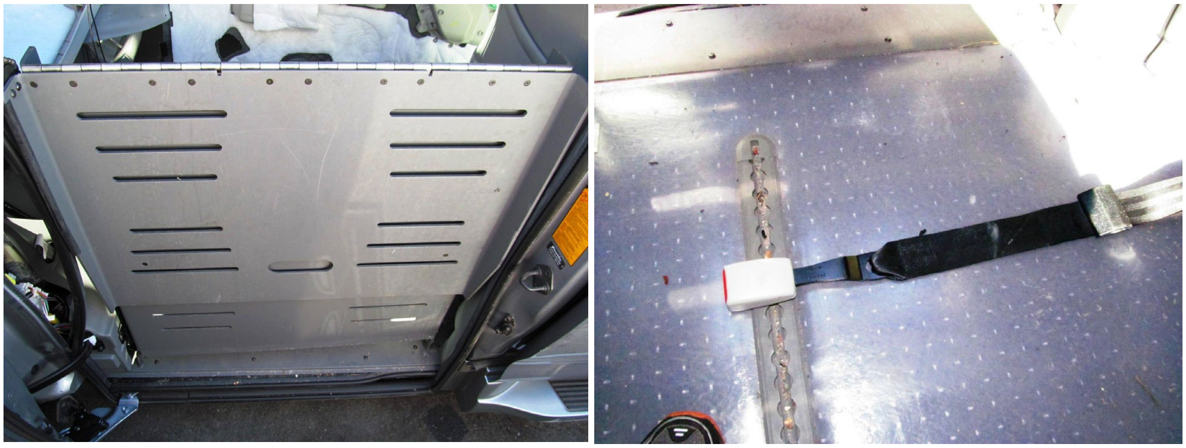

Figure 20: Case No. 2013-03-089 Wheelchair Ramp and Second Row Tie-downs

Figure 21: Case No. 2008-02-148 Driver's Seat Base Adaption to Account for Lowered Floor

3. Altered vehicle to accommodate a wheelchair-seated front passenger

There was only one case where the front row passenger side seat position was modified to accommodate a wheelchair and was occupied at the time of the crash. Case No. 2009-45-021 involved a 2000 Chrysler Town & Country van altered and modified to accommodate a wheelchair-seated front row passenger (Figure 22). In this case, the Chrysler was traveling south, and a 2003 Ford Ranger was traveling north on a two-lane rural roadway. While negotiating a curve, the two vehicles struck head-on. This case resulted in the death of occupants in both vehicles. A more detailed discussion of the case, including the crash severity and injuries, will be presented in the section reviewing all the fatal cases.

Figure 22: Case No. 2009-45-021 Front Row Passenger

4. Other non-operational adaptive equipment

This section will present examples of various types of non-operational adaptive equipment identified in the data that did not require significant alteration to the vehicle. However, given the nature of the modifications and the potential impact on occupant protection, for completeness, the cases will be presented.

4a. Seat belt extenders

There were two cases (Case Nos. 2011-11- 221 and 2010-02-066) where the subject vehicles were equipped with a driver's side seat belt extender. In Case No. 2011-11- 221 (Figure 23), the 48-year-old male driver weighed 145 kg and did not sustain an injury after striking a deer with his vehicle. For this crash, the delta-v was not calculated, but a review of the photos indicates the severity was minor as there was no visual damage to the vehicle. Last, the 63-year-old male driver in Case No. 2010-02-066 weighed 150 kg and sustained an AIS-1 lower extremity skin abrasion in a 15 km/h delta-v frontal crash with an embankment after striking a deer with his vehicle.

Figure 23: Case No. 2011-11-221 Seat Belt Extender

4b. Air bag on-off switch

There was one crash (Case No. 2009-11-094) previously discussed in the context of operational adaptive equipment where a 2009 Saturn Vue was equipped with an air bag on-off switch in addition to pedal extenders for a small statured (109 cm tall) 24-year-old female. The driver was in a minor impact, and the air bags did not deploy because they were suppressed by the air bag switch (Figure 24). The driver, who was the sole occupant, did not sustain any reported injuries. The delta-v was not calculated for the crash.

Figure 24: Case No. 2009-11-094 Air Bag On-Off Switch

4c. Modified seat cushion

As discussed earlier, Case No. 2010-75-103 was equipped with both Operational and non-operational adaptive equipment. The subject vehicle was a 2003 Dodge Caravan modified with an aftermarket orthopedic seat cushion for the driver and an additional lap belt (Figure 25). The vehicle was also equipped with a hoist, which appeared to be used to transport a wheelchair installed in the rear cargo area. It should be noted: the vehicle was not altered with a lowered floor to accommodate a wheelchair-seated occupant.

In the frontal 12 km/h crash, a 38-year-old properly restrained male driver sustained an AIS-2 ulna fracture. It appears the factory driver's seat belt was worn by the driver. However, it should be noted: the additional lap belt and aftermarket seat cushion bottom did not appear to contribute to the AIS-2 right ulna fracture coded in the case.

Figure 25: Case No. 2010-75-103 Modified Driver's Seat Cushion and Rear Mounted Wheelchair Lift

C. Injured by Adaptive Equipment and Fatal Cases

1. Cases coded adaptive equipment contributed to injuries

There were five cases out of the 59 reviewed where the occupant of the vehicle sustained injuries coded as being attributed to the installed adaptive equipment. Table 24 shows the type of injuries and source of injuries by case. With exception, the severity of the injuries were generally minor superficial lacerations, bone fracture, or contusions attributed to the hand controls or steering knob except for Case No. 2007-05-002 where the driver sustained an AIS-2 internal liver laceration sourced to a reduced diameter steering wheel and an AIS-3 tibia fracture sourced to the hand controls. In Case No. 2008-45-002, the driver sustained an AIS-3 lower leg injury sourced to the hand controls.

Table 24: Adaptive Equipment Coded Source of Injuries

Case No.	Injury	Source
2014-49-082	AIS-1: Skin/subcutaneous/muscle, abdomen, [except rectus abdominus], laceration, minor; superficial	Hand controls for braking/acceleration
2014-05-040	AIS-1: Skin/subcutaneous/muscle, face, laceration, minor; superficial	Joy stick steering controls
2008-45-002	AIS-3: Fibula fracture, bimalleolar or trimalleolar, open/displaced/comminuted AIS-1: Chest Skin contusion (OIS Grade I) AIS-1: Finger fracture	Hand controls for braking/acceleration Steering knob attached to steering wheel Hand controls for braking/acceleration
2008-03-074	AIS-1: Neck/Throat Skin contusion	Steering knob attached to steering wheel
2007-05-002	AIS-1: Abdomen Skin abrasion AIS-2: Kidney, laceration, <=1cm parenchymal depth of renal cortex, no urinary extravasation; minor; superficial [OIS II]Kidney laceration minor (OIS Grade II)	Replacement steering wheel (i.e., reduced diameter)

In Case No. 2007-05-002, a 2000 Dodge Caravan altered to accommodate a wheelchair-seated driver was traveling southbound on a five-lane, undivided, wet roadway. A 2006 BMW 3 Series was traveling northbound on a five-lane, undivided, wet roadway. The Dodge lost control on the wet roadway and hydroplaned into the northbound lane of travel striking the BMW. The front right bumper corner of the Dodge contacted the front left bumper corner of the BMW.

The total delta-v for the Dodge was 19 km/h (Figure 26). The 24-year-old male driver was seated in a wheelchair and reported to have been only wearing a shoulder belt at the time of the crash, and was likely improperly restrained.

Figure 26: Case No. 2007-05-002 Subject Vehicle Damage

As shown in Figure 27, the original equipment steering wheel along with the driver's side frontal air bag was removed. During the event, the passenger side air bag deployed.

Figure 27: Case No. 2007-05-002 Adaptive Equipment

Case No. 2008-45-002 involved the subject 1998 Chevrolet Cavalier equipped with a steering knob and hand controls and a 1994 Toyota Camry. As the two vehicles approached an intersection, the front of the Chevrolet and left side front of the Toyota contacted. After the initial impact, the Chevrolet's right side back and the Toyota's left side back contacted during post impact rotation. The Chevrolet then traveled southeast of the intersection and struck a utility pole with its front.

The total delta-v for the Chevrolet was 25 km/h (Figure 28). The 54-year-old female driver was restrained at the time of the crash and the frontal air bag deployed.

Figure 28: Case No. 2008-45-002 Subject Vehicle Damage

The driver of the Chevrolet sustained various injuries sourced to the adaptive equipment installed on the vehicle (Figure 29). The driver sustained AIS-1 left hand injuries sourced to the hand controls and a minor AIS-1 chest contusion sourced to the steering knob. The serious left AIS-3 fibular fracture was coded as "Other adaptive device" but likely involved contact with the support rods, which are attached to the hand control lever as shown in Figure 29.

Figure 29: Case No. 2008-45-002 Hand Controls and Steering Knob

2. Cases assessed adaptive equipment contributed to injuries

There were 6 cases out of the 59 reviewed where there was an observed anomaly related to the installed adaptive equipment that may have contributed to the injuries of the occupants. There were three cases where the drivers of the vehicles may not have been properly restrained at the time of the crashes. In two cases, there was observed deformation of the seat bases during the crashes. In both cases, the original equipment seats and bases were removed and replaced with aftermarket seats to account for the lowered floor. There was one crash, Case No. 2010-75-103, where the driver sustained an ulna fracture, which may have been attributed to a steering assist device on the wheel (previously discussed). The cases are summarized in Table 25.

Table 25: Adaptive Equipment Related Anomalies

Case No.	Maximum Injury	Observed Concern
2014-81-033	AIS-1: Strain, cervical spine, acute, with no fracture or dislocationCervical Spine Strain	Seat base deformation
2014-05-040	AIS-1: Skin/subcutaneous/muscle, face, laceration, minor; superficial	Improperly restrained
2010-75-103	AIS-2: Ulna fracture, distal	Arm posture interacting with steering assist device
2008-75-027	AIS-3: Rib cage fracture >3 ribs on one side and <=3 ribs on the other side, stable chest or NFS Left, L Rib 3, L Rib 4, L Rib 5, L Rib 6, L Rib 7	Improperly restrained
2008-02-148	AIS-3: Cerebrum subarachnoid hemorrhage	Seat base deformation
2007-05-002	AIS-3: Tibia fracture condyles open/displaced/comminuted	Improperly restrained

Case No. 2014-81-033, a 2014 Subaru Forester and a 2014 Chrysler Town & Country were traveling southbound in lane four of a five-lane roadway, with the Chrysler in front of the Subaru. The front of the Subaru struck the back of the Chrysler. The Subaru then rolled over its longitudinal axis and came to rest on its top. The Chrysler departed the left side of the roadway, and the front plane struck a metal guardrail.

The Chrysler was an altered vehicle with a lowered floor. The posted speed limit at the location of the crash was 60 mph. For the Chrysler, the delta-v of the crash was estimated to be 34 km/h. During the impact, the driver's side seat deformed rearward (Figure 30). This was a relatively severe impact resulting in the driver of the Chrysler sustaining a minor neck strain.

Figure 30: Case No. 20014-81-033 Post-Crash Damage to Seat Base and Vehicle

Case No. 2008-02-148 was the second observance of a seat base deformation in an aftermarket seat in an altered vehicle for a lowered floor vehicle. A 2006 Dodge Caravan was traveling north. An animal ran into the roadway. The driver swerved to the left, and the vehicle went off the left side of the road. The front of the Dodge struck a 10 by 10 cm wood post (Figure 31). The delta-v for the crash was estimated to be 47 km/h. The properly restrained driver sustained an AIS-3 Cerebrum subarachnoid hemorrhage sourced to contact with the A-pillar. Even with the driver's side air bag deployed, it is possible the deformation of the seat may have increased the occupant's excursion and allowed for the contact with the A-pillar resulting in the serious head injuries.

Figure 31: Case No. 2008-02-148 Post Crash Damage to Seat Base and Vehicle

For the next three cases, it was assessed, based upon the evidence, that the driver of the subject vehicle may not have been properly restrained at the time of the crash event. The first, Case No. 2014-05-040, a 2010 Toyota Sienna was altered for a restrained, wheelchair-seated driver. The subject vehicle was traveling on a highway with a posted speed limit of 55 mph. According to the case summary, the shoulder belt for the 47-year-old male driver came loose, and the driver began falling forward. To prevent a direct hit on another vehicle, the driver negotiated the Toyota into a concrete barrier; then the front of the Toyota contacted the left side of another vehicle. According to the case file, the occupant was properly restrained. The air bags deployed, and the driver only sustained minor injuries in the 18 km/h delta-v crash. It is unclear from the case if the summary was referring to a postural belt attached to the wheelchair that came loose instead of the vehicle's shoulder belt. A postural belt aids in positioning the upper body in a wheelchair as it holds the shoulders back to prevent slouching and adds stability to the upper body while seated. If the postural belt became loose, this may have likely caused the driver to fall forward, resulting in the crash. A vehicle's seat belt is generally not used to prevent the wheelchair-seated driver from slouching.

The next case involves a potentially improperly restrained driver (Case No. 2008-75-027). The subject vehicle, a 1997 Chrysler Town & Country, was altered and modified for a wheelchair-seated driver. The Chrysler entered an intersection. The front of the Chrysler contacted the left side of another vehicle as it was turning. The inattentive 45-year-old female driver was coded as only using the lap portion (Figure 32) of the seat belt assembly in this 30 km/h crash that deployed the frontal air bags. The driver sustained AIS-3 chest injuries sourced to the steering wheel. The seat belt D-ring on the B-pillar appears to have been damaged, and the webbing may have been cut post-crash. However, the driver's injuries are consistent with excess upper body excursion and contact with the steering wheel from the lack of upper body restraint. It is not known if the lap portion was available or why it may not have been used. The subject vehicle was more than 10 years old at the time of the crash.

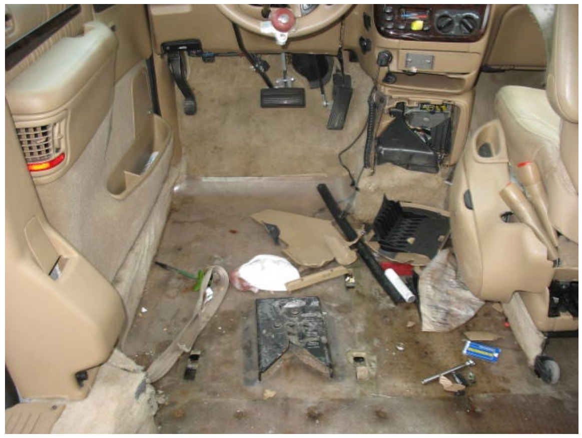

Figure 32: Case No. 2008-75-27 Driver's Seat Position

As previously discussed, Case No. 2007-05-0002 was included because the 24-year-old driver was coded as wearing only the shoulder portion of the restraint system and may have been improperly restrained during the crash, which is indicative because of the AIS-2 kidney laceration sourced to the replacement steering system (Figure 33). In addition, if the occupant's lower body was not properly restrained, this may have led to excess excursion and loading of the tibia resulting in the AIS-3 injury. A lap buckle assembly is not shown in the photo, and it is unknown if the lap belt was removed, not equipped, or encumbered the ingress and egress of the driver and not used.

Figure 33: Case No. 2007-05-002 Modified Steering Wheel With Air Bag Removed

Last, Case No. 2010-75-103, which has also previously been discussed, a 38-year-old properly restrained male driver sustained an AIS-2 ulna fracture in a 12 km/h severity frontal crash.

According to the case, the source of the ulna fracture was not coded. It appeared the driver may have been using the steering assist device shown in Figure 34 at the time of the crash. During the crash event, the driver's forearm may have loaded the steering wheel, resulting in the fracture.

Figure 34: Case No. 2010-75-103 Driver's Seat Position

3. Fatal cases

Of the 59 cases in this study, there were 8 cases identified where occupants in involved vehicles sustained fatal injuries. In 4 of the cases,[32] the drivers of the vehicles with adaptive equipment sustained fatal injuries, in 2 cases[33] the subject occupants were passengers, and in 1 crash[34] the occupant sustaining the fatal injuries was in another involved vehicle. Last, there was one crash[35] where there was a fatality for a passenger in the adaptive equipment vehicle and in the struck vehicle. For completeness, all fatal cases will be summarized.

3a. Driver of adaptive vehicle sustained fatal injuries

In the 4 cases where the drivers were the fatalities, 2 involved alcohol. In Case No. 2006-43-094, a 2001 Mercury Grand Marquis was equipped with hand controls, where the 39-year-old male driver was unrestrained and had a BAC of .32 g/dL. The front and left side of the Mercury contacted the right side of another vehicle, departed the roadway where the right side contacted a utility pole. The reported travel speed at the time of the crash was 105 mph where the posted speed limit for the roadway was 45 mph. The driver sustained fatal injuries from the intrusion (Figure 35).

[32] Case Nos. 2006-43-094, 2008-45-142, 2011-13-038, and 2014-75-041.
[33] Case Nos. 2008-09-108 and 2009-11-131.
[34] Case No. 2015-49-53.
[35] Case No. 2009-45-021.

Figure 35: Case No. 2006-43-094 Subject Vehicle Damage

The other case involving alcohol use by the driver was Case No. 2011-13-038. An unrestrained 67-year-old female driver of a 2002 Ford Escape was coded as having alcohol present without specifying the BAC. The Ford was going west, and another vehicle was going south on an intersecting roadway (Figure 36). The front of the other vehicle struck the right side of the Ford, resulting in the vehicle rolling over. The driver of the Ford was ejected, sustaining fatal injuries from contact with the ground.

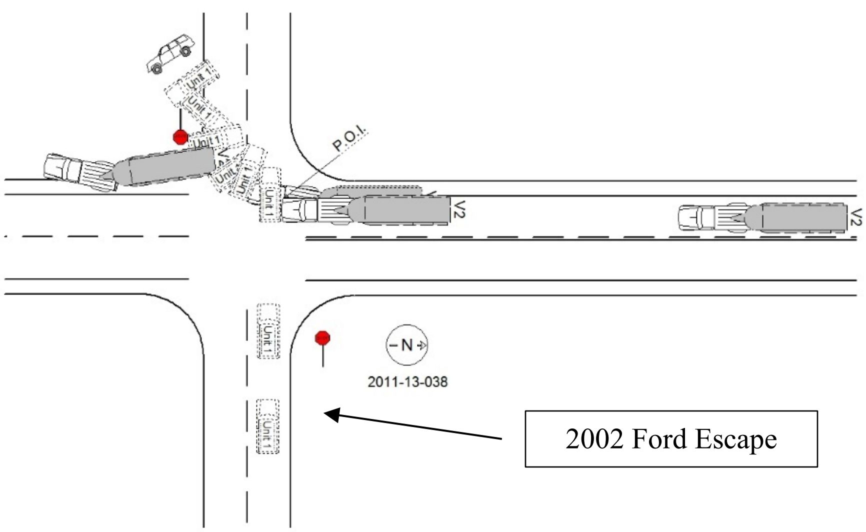

Figure 36: Case No. 2011-13-038 Scene Diagram

The 2002 Ford Escape was modified with the addition of a wooden block on top of the accelerator pedal[36] as shown in Figure 39. The female driver was 147 cm tall.

Figure 39: Case No. 2011-13-038 Wooden Block

Case No. 2008-45-142 involved a 1994 GMC Jimmy driven by an unrestrained 77-year-old male. The GMC was equipped with a steering knob (Figure 40). The GMC was eastbound on a two-lane road under dry/daylight conditions. Another vehicle was westbound on the same roadway directly in front of the GMC moving in the opposite direction. As the GMC exited a left curve (Figure 41), it crossed over the center line and struck the front of the other vehicle.

The GMC was not equipped with a frontal driver's side air bag in the 32 km/h delta-v impact. The unrestrained driver sustained fatal chest injuries attributed to impact with the steering wheel. The driver's attentiveness was coded as unknown.

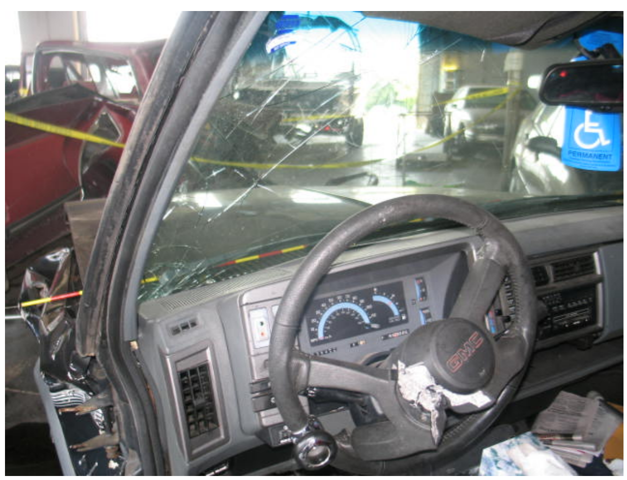

Figure 40: Case No. 2008-45-142 Steering Knob

[36] It is understood that a wooden block is a rudimentary means to raise the accelerator pedal. But its functional intent is consistent with a professionally installed commercial available raised pedal system. For that reason, this case was included with the other cases where the pedals were raised.

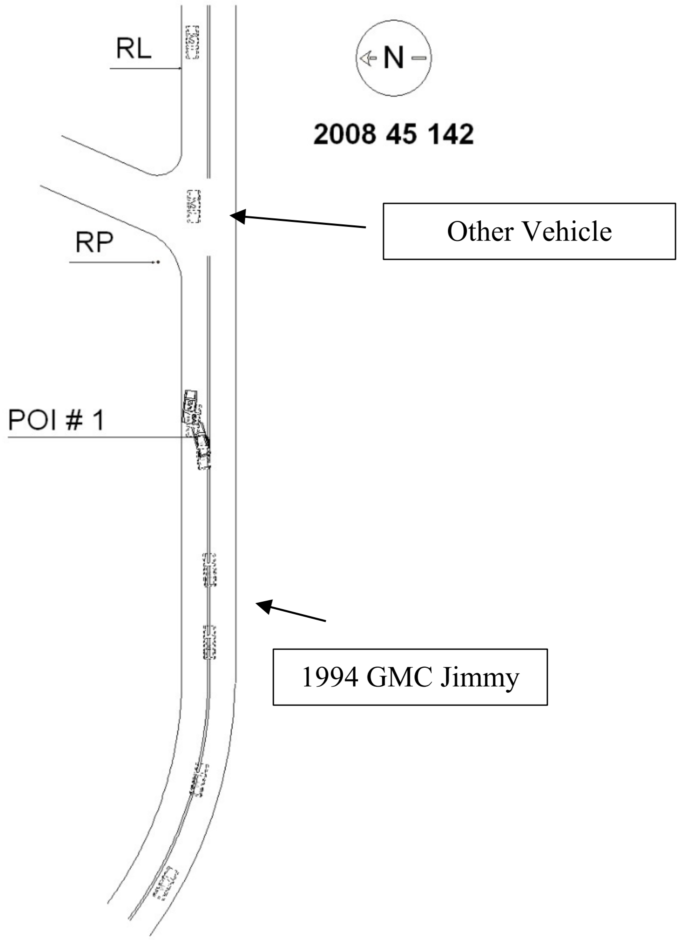

Figure 41: Case No. 2008-45-142 Scene Diagram

Case No. 2014-75-041 involved a 2013 Subaru Forester equipped with a steering knob. The Subaru was eastbound on a mountain road, traveled into the westbound lane and then departed the road to the left. The undercarriage of the vehicle struck a boulder, then traveled over the edge of an embankment, became airborne, went over a creek, and struck an embankment on the far side of the creek. The Subaru then rolled over onto the top plane and came to rest in the creek (Figure 42). The injuries coded to the 74-year-old restrained male driver were drowning, with cardiac arrest documented by medical personnel. The pre-crash movement was coded as negotiating a curve. It was unknown if the driver was distracted.

Figure 42: Case No. 2014-75-041 Scene Photos

3b. Passenger in adaptive vehicle sustained fatal injuries

There were two cases where occupants sustained fatal injuries in adaptive vehicles. In Case No. 2008-09-108, a 2000 Lincoln Town Car was equipped with hand controls. The Lincoln was traveling east when it departed the roadway to the left and contacted a metal guardrail with its front (Figure 43). The vehicle then climbed the guardrail, rotated counterclockwise, and struck a concrete/stone overpass support with its right side. The Lincoln then came down on the guardrail with its undercarriage before coming to rest in the roadway, where it was subsequently struck by a second vehicle (Figure 44).

Figure 43: Case No. 2008-09-108 Scene Photos of Approach

The posted speed limit at the location of the crash was 55 mph. It was dark and raining when the crash occurred. The pre-crash movement was coded as negotiating a curve. It was unknown if the driver attempted an avoidance maneuver or was distracted prior to the crash. There were no injuries coded to the 32-year-old male driver. However, the 15-year-old female front seat passenger sustained unspecified fatal injuries.

Figure 44: Case No. 2008-09-108 Subject Vehicle Damage

Case No. 2009-11-131 involved a 2006 Dodge Caravan altered to accommodate a wheelchair-seated occupant and modified for a steering knob, hand controls, and driver's seat that appears to rotate allowing the driver to transfer from a wheelchair (Figure 45).

Figure 45: Case No. 2009-11-131 Hand Controls, Steering Knob, and Modified Seat Base

The Dodge was traveling northbound in lane three turning left at the intersection to travel westbound. A 2005 Chevrolet Tahoe was traveling southbound in lane two, approaching the intersection. A 2008 Chevrolet pickup truck was traveling southbound in lane two behind the Tahoe. The Tahoe steered around the Dodge turning left, and the front of the pickup truck contacted the right side of the Dodge in the intersection (Figure 46).

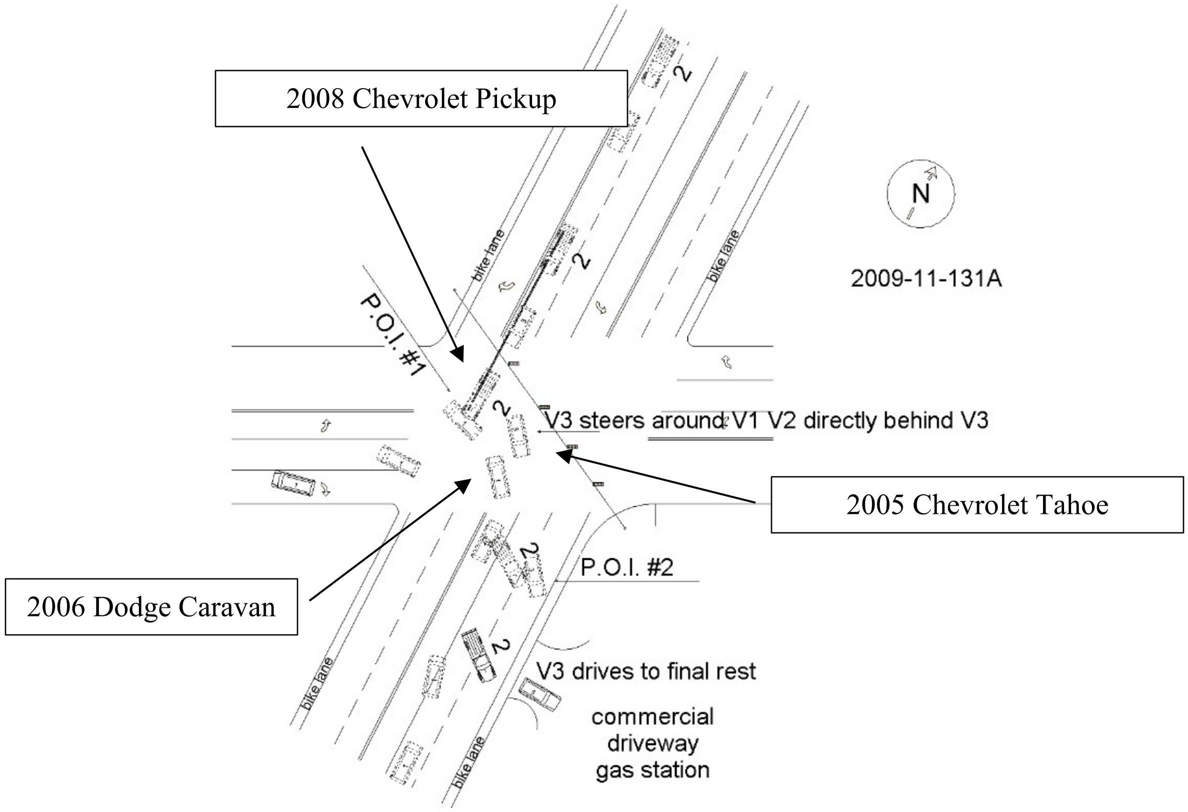

Figure 46: Case No. 2009-11-131 Scene Diagram

The 62-year-old female driver of the Dodge sustained an AIS-3 humerus fracture. An unrestrained 62-year-old male seated in the rear (Figure 47) sustained numerous injuries with MAIS-5 rib cage flail chest injuries that were fatal. From the case, it is unclear if the occupant was seated in the third row as the second row was removed for wheelchair accessibility, or it was possible the passenger may have been in a wheelchair that was not tied down and the occupant unrestrained. Based upon contact marks and the seat back damage to the right side third row seat, the occupant may have been seated in that position. Furthermore, given the non-operational adaptive equipment added to the vehicle and the modifications made to the driver's seat, it was also possible, that a wheelchair-seated person transferred to the driver's position, and the rear wheelchair seating location was unoccupied. The evidence and data in the case file were inconclusive.

Figure 47: Case No. 2009-11-131 Subject Vehicle Damage and Third Row Seat

3c. Occupant in other involved vehicle sustained fatal injuries

Case No. 2015-49-053 involved a 2009 Chevrolet HHR adapted with both a steering knob and hand controls (Figure 48). The vehicle was being driven by a restrained 41-year-old female. The Chevrolet was southbound, approaching an intersection. A 2013 Hyundai Elantra was eastbound, approaching the same intersection. In the intersection, the front of the Chevrolet struck the left side of Hyundai. The Hyundai struck another vehicle, departed the roadway, and its front struck a wooden pole.

Figure 48: Case No. 2015-49-053 Chevrolet HHR Damage and Adaptive Equipment

The pre-crash movement for both the Chevrolet and Hyundai were coded as going straight. The avoidance maneuver and distraction were both coded as unknown. The driver of the Chevrolet did not have any coded injuries. However, the 76-year-old female driver of the Hyundai sustained fatal injuries from the intrusion (Figure 49). The total delta-v for the Hyundai was 36 km/h.

Figure 49: Case No. 2015-49-053 Hyundai Elantra Damage

3d. Fatality in all involved vehicles

Case No. 2009-45-021 was a two-vehicle crash where a passenger in each vehicle sustained fatal injuries. A 2000 Chrysler Town & Country was altered to accommodate a wheelchair-seated front passenger (Figure 50). The Chrysler was traveling south and a 2003 Ford Ranger north on a two-lane rural roadway. While negotiating a curve, the two vehicles struck head-on (Figure 51). The total delta-v for the Chrysler was 62 km/h and 84 km/h for the Ford.

Figure 50: Case No. 2009-45-021 Chrysler Town & Country Damage

It should be noted: it appears the Chrysler was not equipped with hand controls or any other operational adaptive equipment. From the scene diagram, it appears the 63-year-old male driver of the Chrysler drifted out of his lane into oncoming traffic. The restrained 61-year-old female front passenger seated in a wheelchair sustained fatal injuries in the crash. It should be noted the front passenger sustained numerous AIS-1 and AIS-2 injuries, which were fatal. The unrestrained driver sustained multiple nonfatal serious injuries including MAIS-5 chest injuries.

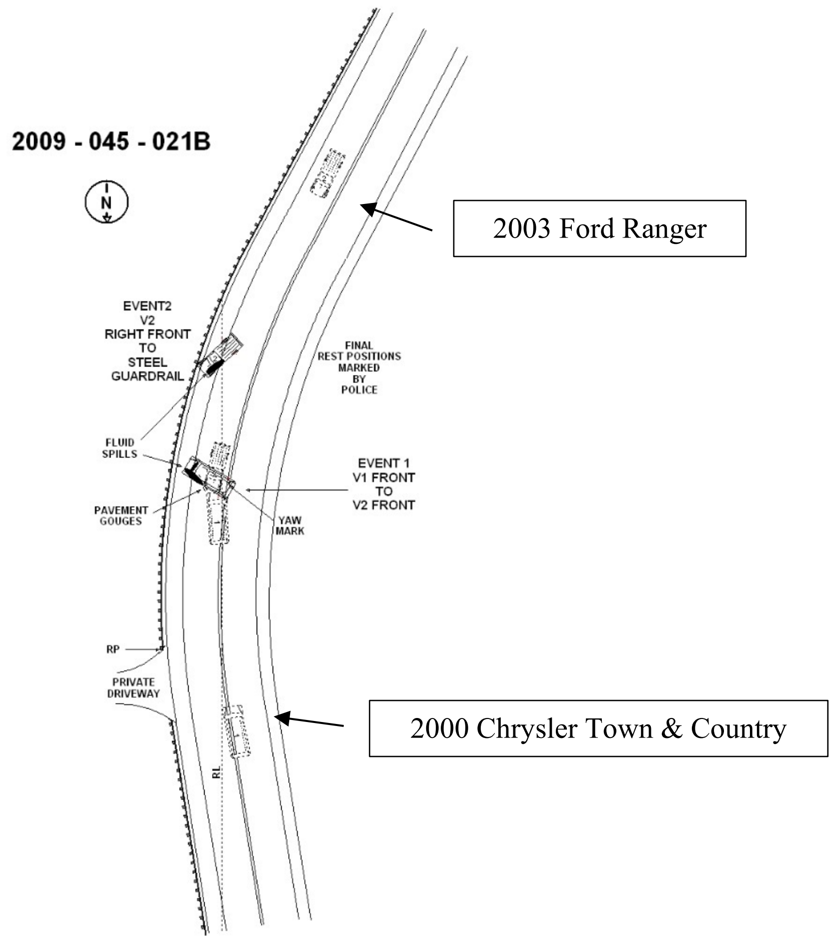

Figure 51: Case No. 2009-45-021 Scene Diagram

The 59-year-old male driver of the Ford sustained multiple minor to moderate nonfatal injuries with an MAIS-3 tibia facture. The 58-year-old female front seat passenger sustained fatal injuries (Figure 52).

Figure 52: Case No. 2009-45-021 Ford Ranger Damage

VI. Discussion

The purpose of this paper is to:

- Quantify the average number of fatal crashes and fatalities (per year);
- Identify and classify the most common type of modification/equipment present;
- Describe driver, environmental, vehicle, pre-crash/crash, and roadway characteristics for these crashes;
- Determine if the presence of adaptive equipment contributed to crashes;
- Determine if the presence of adaptive equipment contributed to injuries; and
- Identify any potential safety trends or concerns.

The discussion below will focus on fatal cases and on the 50 operational and 19 non-operation adaptive equipment cases identified in this study. Furthermore, the discussion will focus on identifying potential safety risks with installed adaptive equipment and whether the adaptive equipment contributed to the crash or injuries; additionally, any associated trends will also be discussed.

A. Fatal Cases

The 2007 to 2015 FARS data identified, on average, 4 fatal crashes per year involving vehicles coded as being equipped with adaptive equipment and on average 4 occupants sustaining fatal injuries in the vehicles with the adaptive equipment. Moreover, on average, there are 5 fatalities per year in incidents that involved vehicles coded as being equipped with adaptive equipment. From the 2006 to 2015 NASS-CDS, there were 8 cases in the dataset that involved fatalities in involved vehicles. The discussion below will identify the adaptive equipment installed on the vehicles and discuss if the equipment was assessed to contribute to the crashes or injuries. Finally, trends in the data will be discussed.

In Case Nos. 2006-43-094 and 2011-13-038, there was clear indications that alcohol may have factored into the fatal crashes. Clearly, in Case No. 2006-43-094, involving a 2001 Mercury Grand Marquis equipped with hand controls, excessive speed was a factor in the severity of the crash. The driver of the Mercury had a BAC of .32 g/dL, four time the legal per se limit in every State. The 2002 Ford Escape in Case No. 2011-13-038 was modified with the addition of a wooden block on top of the accelerator pedal. The wooden block was coded as adaptive equipment; however, the modification was consistent with professionally installed raised pedals. The crash occurred at an intersection, and it appeared the driver likely did not adequately survey the roadway because of the use of alcohol (BAC unspecified). In both cases, intoxication and the resulting impairment to the driving task appear to contribute to the fatal crashes and not the modifications.

There were 4 cases where it appears the drivers drifted out of their lanes prior to the crashes . Three cases involved operational adaptive equipment and one with non-operational adaptive equipment. Case No. 2008-45-142 involving a 1994 GMC Jimmy, Case No. 2014-75-041 involving a 2013 Subaru Forester equipped with a steering knob, and Case No. 2008-09-108 involving a 2000 Lincoln Town Car equipped with hand controls are similar in that in all three, for unexplained reasons, the drivers drifted out of their lanes, resulting in crashes. There was no overwhelming evidence that the use of the operational adaptive equipment was the direct cause of the crashes. According to the cases, it was not known if the drivers of the GMC and Lincoln were distracted prior to the crashes; however, some type of inattention likely contributed to drifting out of the lane. The 76-year-old driver of the Subaru Forester may have suffered cardiac arrest as documented in the case, which led to the drifting out of the lane, subsequent rollover, and drowning. In all three cases, it did not appear the drivers attempted abrupt changes in the dynamic states of the vehicles, either steering, accelerating, or braking which could have indicated there were issues operating the adaptive driving equipment.

In Case No. 2009-45-021, the vehicle was altered to transport a wheelchair-seated front passenger who sustained fatal injuries in the crash. There was no indication there were operational adaptive controls for the driver, who was likely able-bodied. In this crash, it appears the able-bodied driver drifted out of the lane of travel, resulting in the head-on crash with a severity of 62 km/h mph delta-v (Figure 51). As discussed earlier, the wheelchair may not have been designed to be used while the vehicle was in motion. However, the adaptive equipment, as a system, appeared to have performed reasonably well given the exceedingly severe frontal impact. The crash was severe, and the likely vulnerable occupant succumbed to the injuries. The likely cause of the crash was attributed to the able-bodied driver, who sustained critical and serious injuries. Last, the 4 fatal cases just discussed are similar to the findings in recent studies that found crashes resulting from drifting out of the lane are attributed to drivers being incapacitated (sleeping, medical factor, or alcohol involved) or distracted.[37, 38]

Finally, there were 2 fatal crashes that occurred at intersections. The vehicles in Case Nos. 2009-11-131 (Figure 46) and 2015-49-053, a 2006 Dodge Caravan and a 2009 Chevrolet HHR, respectively, were modified and equipped with steering knobs and hand controls. In the case involving the Dodge, the vehicle was turning left and was struck by another vehicle on the right side, resulting in fatal injures of the right rear-most occupant. As discussed previously, it could not be determined if the occupant was in a wheelchair or seated in the third row. In the case of the Chevrolet, the vehicle struck another vehicle in the side, killing the driver. In both crashes, there was no conclusive indication that the use of the operational adaptive equipment caused the crashes. It appears the driver of the Dodge did not survey the roadway adequately or misjudged the distance and speed of the encroaching vehicle that lead to the crash. Furthermore, it is not known if the driver of the vehicle was using the adaptive controls. As for Case No 2015-49-053, one of the involved vehicles drove through a controlled intersection. Either one of the drivers involved could be at fault. From the case, there was no information whether either driver attempted an avoidance maneuver. Again, there was no indication from the data that the use of the adaptive controls was the cause of or contributed to the crash.

1. Summary of safety risk and trends in fatal cases

Overall, the fatal crashes identified in this study appear unrelated and generally unique. First, the data was limited as there were only 8 fatal crashes identified over the 10 years of data under review where involved vehicles were coded as equipped with adaptive equipment. As a result, no

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[37] Cicchino, J. B., & Zuby, D. S. (2016). Prevalence of driver physical factors leading to unintentional lane departure crashes, *Traffic Injury Prevention*. 18:5, 481-487, DOI: 10.1080/15389588.2016.1247446

[38] Wiacek, C., Fikentscher, J., Forkenbrock, G., Mynatt, M., & Smith, P. (2017). Real-world analysis of fatal run-out-of-lane crashes using the National Motor Vehicle Crash Causation Survey to assess lane keeping technologies (Report No. 17-220). *25th Enhanced Safety of Vehicles Conference*, Detroit, June 5-8, 2017.

high-level safety trends could be identified. Second, it appears the types of crashes from the NASS-CDS analysis appear to be infrequent, which is consistent with the analysis of the 2007 to 2015 FARS data. As discussed earlier, on average, there were 4 fatal crashes per year involving vehicles coded as equipped with adaptive equipment and on average 4 occupants sustaining fatal injuries in the vehicles with the adaptive equipment. Moreover, on average there are 5 fatalities per year in incidents that involved vehicles coded as equipped with adaptive equipment. Both the NASS-CDS and FARS data suggest that being involved in a fatal crash where a vehicle is equipped with adaptive equipment is generally a rare event.

B. Operational Adaptive Equipment

There were 44 unique cases grouped into 50 cases where the vehicles were modified and equipped with operational adaptive equipment. Forty cases were vehicles equipped with hand controls and/or steering knobs. The remaining 10 cases were vehicles equipped with low-effort steering and raised or relocated pedals. This section will discuss observations related to modifications and whether there were indications the crashes may be related to their use.

From the tabulated descriptive statistics presented in section IV, NASS-CDS Analysis, there generally were no high-level patterns in the data. This is partially attributed to how the data was grouped by common types of operational adaptive equipment in relation to the limited data available. The intent of binning the data by operational adaptive equipment was to try to isolate any contribution the equipment or driver using the equipment may have had in the crashes.

The average age of the drivers was 45 years old. There were only 3 crashes where alcohol was a contributing factor, 2 of which resulted in fatalities. Otherwise, impaired driving was not a concern. The drivers of the vehicles were coded as distracted in 6 cases. In 33 of the cases, the drivers sustained minor MAIS-2 or less injuries.

Generally, vehicles in the dataset were older with an average model year of 2004. There were 9 vehicles that were 2000 model years or older. Thirty vehicles had modifications, 15 vans and 15 passenger cars.

The crashes occurred under daylight or lighted conditions in 35 cases and dry conditions in 33 cases. The crashes occurred most frequently on roads with posted speed limits of 45 mph or less (30 cases), indicative of the low level of injuries sustained by the drivers in many of these crashes.

In 32 cases, the subject vehicles' pre-crash movement was going straight; in 17 of 29 of these cases the vehicles were equipped with either steering knobs or low-effort steering. This suggests that because a driver was not actively steering, the steering assist device may not have been a factor. In 18 of the cases, the drivers were coded as taking avoidance maneuvers. In 8 of the steering-assisted vehicles, the cases were coded as the drivers steered to avoid the crashes. Of the 31 cases where the vehicles were equipped with hand controls, there were 7 cases where the drivers attempted braking to avoid the crashes. However, in these same hand-control-equipped vehicles, the drivers were coded as either taking no avoidance maneuvers or unknown maneuvers in 16 of 31 cases. For vehicles equipped with steering assist devices alone or in conjunction with hand controls, the drivers were coded as taking some avoidance maneuvers in about half the cases. Although not definitive, it did not appear the adaptive equipment was a significant factor in these crashes.

There were 5 cases where the critical pre-crash category was coded loss of control for the subject vehicles. In 2 of the cases, vehicles were equipped with low-effort steering (Case Nos. 2008-13-021 and 2007-05-002). In Case No. 2008-13-021 (Figure 3) the driver was coded as traveling too fast for conditions, and in Case No. 2007-05-002 poor road conditions (puddle, pot hole, ice, etc.) were coded as the critical pre-crash event. There were 2 cases where the vehicles were equipped with steering knobs and hand controls (Case Nos. 2008-13-021 and 2006-12-119). In Case No 2008-13-021, the driver was coded as traveling too fast for conditions, and the vehicle in Case No. 2006-12-119 was coded as having a disabling failure, which appears unrelated to the adaptive equipment. That case involved a 2004 Chevrolet Impala equipped with a steering knob and hand controls. The case summary stated, "The steering became disabled and the vehicle left the roadway to the right and struck a utility pole with the front plane and came to rest." Upon review of the case data, the steering knob was mechanically fastened to the steering wheel, and it is unlikely to have "disabled" the steering system as a steering knob only provides leverage to the driver and does not provide mechanical assistance. Finally, Case No. 2014-75-041 was equipped with a steering knob only; however, the control loss appears to be related to a medical condition that may have incapacitated the driver. In these cases, there appear to be other factors that may have resulted in the drivers losing control of the vehicles that are unrelated to the adaptive equipment.

The causes of these crashes, though subjective, appear consistent with the analysis of the data in the 2005–2007 National Motor Vehicle Crash Causation Survey (NMVCCS).[39] The NMVCCS database defined the critical reason as the cause of the critical pre-crash event, defined as the event that made the crash inevitable. The study identified that 41 percent of the driver-related critical reasons were recognition errors including inattention, internal and external distractions, inadequate surveillance, etc. Of these, the most frequently occurring critical reason was inadequate surveillance, which refers to a situation in which a driver failed to look or looked but did not see when it was essential to safely complete a vehicle maneuver. This critical reason was assigned to drivers in 20 percent of crashes. Internal distraction as a critical reason was assigned to drivers in approximately 11 percent of crashes.

Although not definitive, generally, the review and assessment of the NASS-CDS data in this analysis appears consistent with the NMVCCS findings. NASS-CDS does not code for crash causation; however, crashes in the study appear unrelated to the modifications made to the vehicles to accommodate disabilities. Seventeen crashes were intersection-related, where one of the involved drivers appears to have some sort of recognition errors consistent with NMVCCS. As stated earlier, many of these crashes occurred at posted speed limits of 45 mph or less and resulted in minor to no injuries to the drivers of the adaptive vehicles.

In Case Nos. 2010-75-103 and 2008-075-027, the subject vehicles were equipped with steering knobs and hand controls. In both cases, the vehicles were traveling through controlled

[39] National Highway Traffic Safety Administration. (2008, July). *National Motor Vehicle Crash Causation Survey Report to Congress* (Report No. DOT HS 811 059), Washington, DC: Author. Available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811059

intersections and crashed into other vehicles. The drivers were coded as being inattentive. In Case No 2010-11-165, another vehicle was in the process of making a left turn and was struck by the subject vehicle equipped with a relocated accelerator pedal. The driver of the struck vehicle making the left turn was coded as looked but did not see. In case No. 2008-12-099, the subject vehicle equipped with a steering knob and hand controls was in the process of making a left turn across the path of an oncoming vehicle, which resulted in a crash. The driver of the subject vehicle was coded as attentive. It was not known if the other driver was attentive or distracted. Though not conclusive, it appears one of the involved drivers was not attentive, or the subject driver failed to look or looked but did not see. Case No. 2008-45-002 was also similar. The subject vehicle equipped with a steering knob and hand controls likely ran a stop sign, resulting in a crash in the intersection.

All the cases reviewed were generally similar in that even as NASS-CDS does not code for driver error, it was assessed that a driver's error for an involved vehicle was a plausible cause for the crash and was unrelated to the operational adaptive equipment. In Case No. 2009-11-094, it appears likely the subject vehicle equipped with pedal extenders for a small-statured driver was following too closely to the large truck as it may have unexpectedly turned right down a private driveway.

One of the limitations with this study is not knowing the extent of the driver's disabilities or if the adaptive equipment was in use at the time of the crash or if the driver was disabled. This is especially true for those cases of vehicles equipped only with steering knobs. For example, in Case No. 2012-48-162 a 2008 Dodge Ram driven by a 19-year-old male was equipped with a steering knob. The subject vehicle struck the rear of another vehicle. The pre-crash movement of the vehicle was coded as going straight. Figure 53, is a photo of the steering knob installed on the vehicle at the time of the inspection. Again, because of limitations with the data, whether the steering knob was being used at the time of the crash is unknown. Moreover, it is unknown if there was a legitimate need for the knob to accommodate a disability.

Figure 53: Case No. 2012-48-162 "Novelty" Steering Knob

With respect to the operational adaptive equipment cases identified in this study, there were no cases where the case summary or other data or information related to the case file indicated there was an issue or other problem with the adaptive equipment that may have led to the crash. Specifically, there were no cases identified where it appeared there were defects or long-term reliability problems with the installed hand controls. The data was similar to a study that conducted reliability testing of hand controls using the *SAE standard J1903 – Recommended Practice Automotive Adaptive Driver Controls Manual,* which did not identify reliability concerns.[40] Generally, these crashes appear to be consistent with the finding in NMVCCS where driver error for an involved vehicle contributed to the cause of the crash more so than the use of the adaptive equipment or potential dexterity issues by the driver.

Largely, the installed operational adaptive equipment did not cause serious injuries during the crash event. In the five cases[41] where the equipment was coded as the source of the injuries, there was only one case (Case No. 2008-45-002) that resulted in a AIS-3 leg injury from contact with the hand controls. Although the potential for minor leg injuries was identified in laboratory crash tests[42] with vehicles equipped with hand controls, this review of the real-world data only identified one case. Finally, it should be noted when vehicles were equipped with steering knobs, there were no cases where it appeared the devices adversely affected the deployment of the driver side air bags. The real-world observations of air bag performance were consistent with an earlier study,[43] which explored the potential degradation in crash safety because of steering control devices mounted to the steering wheel rims. Using computer simulations and laboratory testing, the study found steering control devices did not compromise air bag performance.

1. Summary of safety risk and trends for operational adaptive equipment cases

The most common operational adaptive equipment identified in the dataset as an aggregate were hand controls for braking/acceleration, with 31 total cases (62%) followed by steering knobs attached to steering wheels, with 25 cases (50%). There were only 9 cases (19%) where the steering knobs were not installed with hand controls for braking/acceleration. However, there were 15 cases (30%) where the hand controls were not installed in conjunction with the steering knobs. There were 16 cases (32%) involving vehicles with both modifications. The drivers sustained no or minor injuries in 33 of the crashes (AIS-2 or below). There were 11 cases with severe AIS-3+ injuries, including one fatal MAIS injury.

All 50 cases reviewed were generally similar in that it was assessed a driver's error for an involved vehicle was a plausible cause for the crash and was likely unrelated to the installed operational adaptive equipment (primarily hand controls, steering knob or both). There were no indications from assessments that equipment failed, was installed incorrectly, or was improperly used leading up to the crash. With exception, the operational adaptive equipment was generally not a source of injury to the driver, or, when identified, it was the source of minor injuries. Given there were 50 cases analyzed, there were no safety trends identified that appear to be related to the installed adaptive equipment.

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[40] Pilkey, W., Thacker, J., & Shaw, G. (2001, August). *Hand control usage and safety assessment* (Unnumbered report published under NHTSA Contract Number DTRS-57-97-C-00050, TTD#3). Washington, DC: National Highway Traffic Safety Administration.

[41] See Table 24.

[42] Pilkey, Thacker, & Shaw, 2001.

[43] Pilkey, W., Thacker, J., & Shaw, G. (1996, November). *Air bag interaction with and injury potential from common steering control devices* (Report No. DOT HS 808 580). Washington, DC: National Highway Traffic Safety Administration.

The limitations of this analysis need to be acknowledged. It is not known whether the adaptive equipment identified was used at the time of the crash or if potential problems with the equipment were not identified and noted during the investigation. It also could not be assessed how physical limitations of driver may have affected the use of the operational adaptive equipment leading up to the crash, such as a delayed reaction time or potentially lacking the strength during an emergency to operate the equipment.

C. Non-Operational Adaptive Equipment

There were 19 cases identified to have been equipped with non-operational adaptive equipment. This section will focus on the 15 cases where the vehicles were significantly altered and modified to transport people in wheelchairs. Because of the potentially significant changes to these vehicles, such as lowering the floor, the crashworthiness characteristic of the vehicle may have changed and affected the performance of the inflatable restraints and crashworthiness of the vehicle.

1. Vehicles crashworthiness and performance of the inflatable restraint system

In 12 cases, the subject vehicles were involved in frontal impacts, 2 were rear impacts, and 1 was a side impact. Specifically, the following discussion will focus on how the vehicles performed in the crashes, including air bag deployment.

From a review of the case files, in all the frontal crashes the vehicles performed as expected given the severity. There were 2 cases where the driver side air bags were removed to accommodate modified steering wheels (Case Nos. 2014-05-035 and 2007-05-002). In a low-severity 12 km/h delta-v crash, the passenger side air bag did not deploy (Case No. 2014-05-035), and, in a moderate severity impact with a total delta-v of 19 km/h, the passenger's side air bag deployed (Case No. 2007-05-002, Figure 54). The non-deployment or deployment of air bags were consistent with the level of severity of the crashes. As discussed earlier, only in Case No 2007-05-002 were the injuries sourced to the replacement steering wheel, and the occupant likely would have benefited from the air bag. However, based upon the type of disability the driver likely had, maintaining the air bag was probably not an option when decisions were made to modify the vehicle and remove the air bag.

Figure 54: Damage Case Nos. 2014-05-035 and 2007-05-002

In the remaining crashes,[44] there were only 3 where frontal air bags did not deploy.[45] However, upon inspection of the frontal damage and the severity of the crash, it can reasonably be assumed crash severity did not warrant the deployment of air bags. Figure 55 shows the damage to subject vehicles in which both were involved in 12 km/h delta-v crashes (Case Nos 2008-79-016 and 2008-72-083). The air bags did not deploy and both cases were consistent with Case No 2014-05-035 where the frontal air bags did not deploy. Overall, there was no indication occupants were not provided the proper protection from the original equipment air bags unless systems were deactivated or removed for aspecific occupant positions to accommodate disability.

Figure 55: Frontal Damage Case Nos. 2008-79-016 and 2008-72-083

There were no frontal crash cases identified where it was assessed that extensive modifications made to vehicle structure, such as lowering the floor, were an issue. Upon inspection of crash photos, it appeared in all cases, the vehicles' crush characteristics were consistent with that of the original equipment vehicles. This was concluded by comparing post-crash photos of the altered vehicle with the original equipment vehicle in a similar crash type and severity. As shown in Figure 56, even though the crash severity in the altered vehicle was more than 10 km/h greater than the reference vehicle (Case Nos. 2007-79-127**)**, the damage was consistent. In the reference vehicle, the driver sustained severe injuries. The vehicle was also compared to crash test data to identify anomalies (Figure 47).

Overall, vehicles involved in frontal impacts performed as expected. Except for the potential risk for removing the air bag, which at times may be necessary to accommodate a disability, no irregularities were identified.

[44] Case Nos. 2014-05-040, 2011-74-166, 2009-45-021, 2008-79-016, 2008-75-027, 2008-72-083, 2008-12-131, 2008-02-148, 2007-47-154, and 2007-11-197.
[45] Case Nos. 2008-79-016, 2008-72-083, and 2008-12-131.

Figure 56: Case Nos. 2007-79-127 and 2009-45-021 and 51 and 62 km/h Delta-V Frontal Impact Respectively

Figure 57: NHTSA Test No. 2997 1999 Dodge Caravan 56 km/h Frontal Crash Test

There were 2 crashes where the altered and modified vehicles were in rear impacts (Case Nos. 2014-81-33 and 2013-03-089). The 2014 Chrysler Town & Country in Case No. 2014-81-33 was involved in a 34 km/h delta-v rear impact and the 2012 Toyota Sienna in Case No. 2013-03-089 was involved in a less severe 10 km/h impact (Figure 58). Both crashes were not severe and did not result in post-crash fires or any other observed concern with the structures.

Figure 58: Rear Damage Case Nos. 2014-81-33 and 2013-03-089

There was only one crash identified (Case No. 2009-11-131) where a subject vehicle was involved in a side impact crash. Upon review of the case, the vehicle was likely not equipped with side impact head and/or chest protection air bags. As discussed earlier, the occupant in question sustained fatal injuries. However, it could not be determined with certainty where the occupant was seated and whether the occupant was in a wheelchair.

The average model year of the subject vehicles in the 15 significantly altered or modified vehicle cases was model year 2004. Few of the involved vehicles were designed to account for the latest safety improvements, as vehicle manufacturers may have implemented structural changes to light vehicles to comply with upgraded FMVSSs such as advanced air bags (FMVSS No. 208), side impact protection (FMVSS No. 214), and roof crush (FMVSS No. 216), as well as to improve performance in tests conducted by consumer information programs such as NHTSA's New Car Assessment Program (NCAP) and the Insurance Institute for Highway Safety (IIHS) safety rating. Both programs have undergone changes since many of the vehicles in this study were manufactured. NCAP was updated in 2010 to include advanced test dummies, new injury criteria, and a side pole test, as well as the IIHS safety rating adopted side impact, small overlap, and roof crush test protocols. The older vehicles in this study were not designed to the latest standards and consumer rating programs, but after assessing the performance of subject vehicles in real-world crashes, no overarching safety issues were identified. Encouragingly, it should be expected newer vehicles that are altered and modified for wheelchair accessibility will further reduce risk to occupants.

2. Wheelchair docking-securement device /tie-down securement and restraint system

This section will discuss the performance of the wheelchair securement system and the restraint performance for 8 of the 15 significantly altered or modified vehicle cases where the wheelchair positions were occupied at the time of the crashes. In 6 cases,[46] the vehicles were driven by drivers in wheelchairs at the time of the crashes. There was one case (Case No. 2009-45-021) where the vehicle was altered to accommodate a wheelchair-seated front passenger, which was occupied during the crash, and only one case where a second-row position was occupied by a wheelchair-seated occupant at the time of the crash.

[46] Case Nos. 2014-05-040, 2014-05-035, 2011-74-166, 2008-79-016, 2008-75-027, and 2007-05-002.

After review of the case data, it appears the driver's seating position was modified and equipped with a docking-securement device that would secure the wheelchair to the vehicle in 6 cases. In two cases (Case Nos. 2014-05-040 and 2007-05-002), the docking-securement device was not shown as it may have been removed from the vehicle prior to the inspection by the investigator. Figures 59 - 61 show the driver's seating position and, when available, the docking-securement device. In all these cases, there was no evidence of any buckling of the floor where the device was attached, and, when photos of the docking-securement device were available to review, there did not appear to be any deformation or damage to the securement device resulting from the crash. One limitation of this analysis is there was no information or photos available for the wheelchair and the attachment mechanism to the docking-securement device. Even though the securement devices in this analysis appear undamaged, the wheelchair may have experienced deformation, which cannot be accounted for, during the event.

Figure 59: Docking-Securement Device Case Nos. 2014-05-040 and 2014-05-035

Figure 60: Docking-Securement Device Case Nos. 2011-74-166 and 2008-79-016

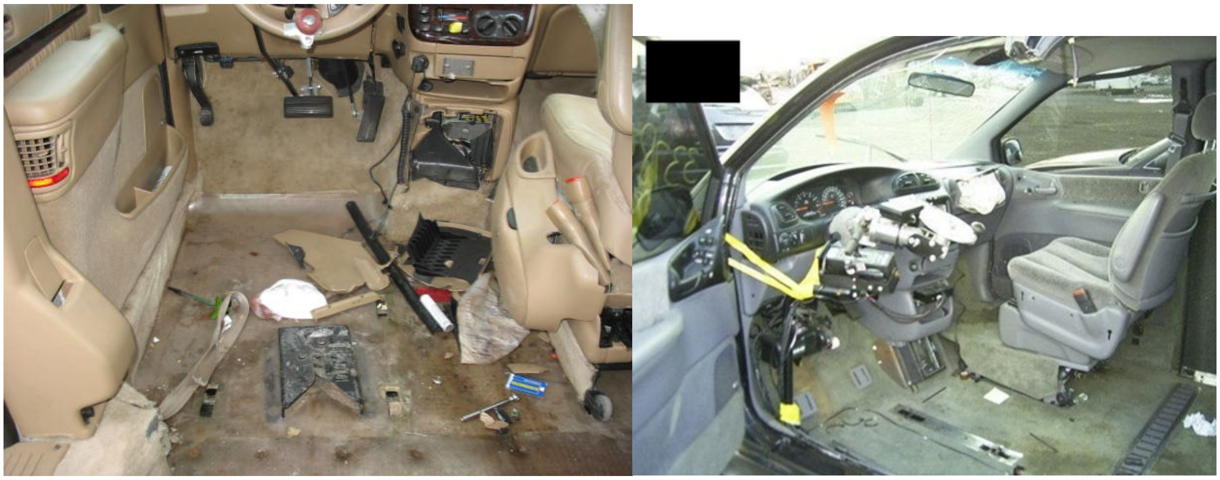

Figure 61: Docking-Securement Device Case Nos. 2008-75-027 and 2007-05-002

In Case No. 2009-45-021, the front passenger seat was modified to accommodate a wheelchair-seated driver. It appears from Figure 62 the wheelchair was secured with a docking-securement device similar to the examples presented for the driver's position. The subject vehicle in this case was involved in a severe 62 km/h delta-v frontal impact. This crash exceeded the crash test severity specified in FMVSS No. 208, which was conducted at 48 km/h, at the time the vehicle was manufactured.[47] In addition, the crash severity exceeded the industry standard test condition specified in ANSI/RESNA WC-4: Section 19 (WC19), for wheelchairs used as seats in vehicles. This standard requires wheelchairs to be successfully tested in a 48-km/h frontal sled test using a 4-point strap-type tie-down system to secure the occupied wheelchair. For docking-securement devices the industry standard ANSI/RESNA WC-4: Section 18 (WC18), *Wheelchair Tiedown and Occupant Restraint Systems for Use in Motor Vehicles* specifies a similar test condition.[48]

From Figure 62, the post-crash photo appears to show, the wheelchair and docking-securement device remain attached to the floor of the vehicle. There appears to be some deformation of the wheelchair base or securement device as the rear wheels of the chair are not sitting on the floor of the vehicle. However, severity of the crash is estimated to have exceeded the vehicle and wheelchair standards; there does not appear to be any obvious concerns with the performance of the wheelchair and docking-securement device in the crash. It should be noted whether the wheelchair was designed for use in a motor vehicle or if it was certified to industry requirements is unknown. However, there is a statement in the owner's manual[49] for a similar model (Pride Mobility 1113 Jazzy) indicating the wheelchair should not be used to transport an occupant in a motor vehicle. The following statement is from the owner's manual: "Pride recommends that you do not remain seated in your power chair while traveling in a motor

[47] The crash test speed was subsequently raised to 56 km/h, and the requirements phased-in after the subject vehicle was manufactured (66 FR 65377).

[48] ANSI/RESNA 2012 - *American National Standard for Wheelchairs Volume 4, Wheelchairs and Transportation*; Section 18: Wheelchair tiedown and occupant restraint systems for use in motor vehicles; Section-19: Wheelchairs used as seats in motor vehicles; Section 20: Wheelchair seating systems for use in motor vehicles, RESNA, Arlington, VA.

[49] www.pridemobility.com/pdf/owners_manuals/us_jazzy/us_jazzy_1113_ats_om.pdf

vehicle. The power chair should be stowed in the trunk of a car or in the back of a truck or van with the batteries removed and properly secured."

As discussed earlier, the occupant sustained fatal injuries in this severe crash. It is possible that, the wheelchair if not designed to industry standards or not intended by the manufacturer to be used while the vehicle is in motion, may have contributed to some excess excursion creating higher risk for injuries. However, the crash severity did exceed Federal requirements, and overall, the docking-securement device did appear to be secured to the wheelchair and vehicle from the available information.

Figure 62: Docking-Securement Device Case No. 2009-45-021

Last, the sole case where there was a wheelchair-seated occupant seated in the second row (Case No. 2007-11-197) was secured with a four-point, strap-type tie-down system as shown in Figure 63. From the available information, it appeared the wheelchair and securement system held in the crash. Also, it should be noted whether the wheelchair was tested and certified to industry standards is unknown.

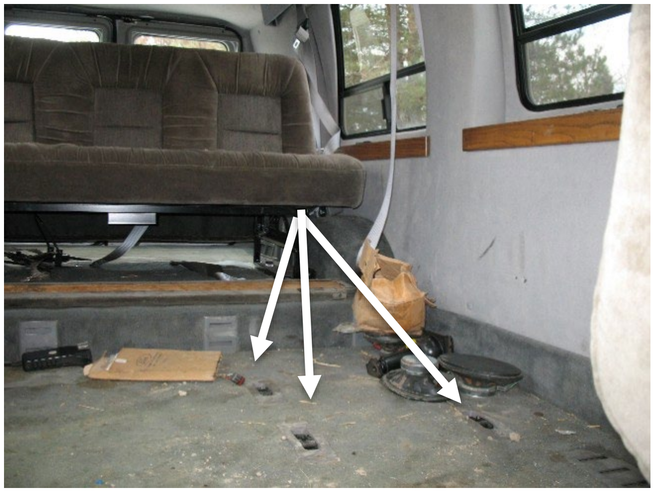

Figure 63: Four-Point, Strap-Type Tie-Down Case No. 2007-11-197

In addition to modifications made to the vehicle for the wheelchair securement device, further modification may be necessary to the three-point seat belt system to properly restrain the driver in the event of a crash. As discussed earlier, there were three cases where the wheelchair-seated drivers may not have been properly restrained at the time of the crashes.[50] In one case (Case No. 2014-05-040), the postural belt, which prevents slouching of the occupant in the wheelchair, may have come loose, and there may have been no issues with the vehicle's shoulder belt.

The wheelchair-seated drivers in Cases Nos. 2008-75-027 and 2007-05-002 appear to have experienced injuries associated with being improperly restrained. Based upon available data, intentional misuse because of comfort, improper installation of the seat belt assembly, interference with the wheelchair that caused poor routing, or a potential defect with the restraints could not be determined. These were only two examples identified of potential issues related to the seat belts; however, the identification of these concerns in this study were consistent with a larger study of crashes involving wheelchair-seated occupants, including vehicles outside the scope of NASS-CDS.[51]

The University of Michigan Transportation Research Institute (UMTRI) collected data[52] on 69 crash and non-crash events involving 74 occupants seated in wheelchairs. In the UMTRI study, 22 of the 74 occupants in wheelchairs were driving private vehicles, and all others were passengers, primarily in private and paratransit vans and minivans, with two of these seated in the front row (i.e., right-front passenger position).

The analysis of the data suggested a need to further improve the design of seat belt restraints used by occupants seated in wheelchairs. The study further stated results suggested a need to

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[50] Case Nos. 2014-05-040, 2008-75-027, and 2007-05-002.

[51] NASS-CDS investigates tow away crashes involving light vehicles including passenger cars, light trucks and multipurpose vehicles with a gross vehicle weight of 4,536 kilograms or less.

[52] Schneider L. W., Manary M. A, Orton N. R., Hu J. H., Klinich K. D., Flannagan, C.A., & Moore, J. L. (2016, July). Wheelchair Occupant Studies. (Report No. UMTRI-2016-8). Ann Arbor, MI: University of Michigan Transportation Research Institute.

improve the positioning of belt restraints on occupants in wheelchairs by designing wheelchairs so they better facilitate the proper positioning of vehicle-anchored belt restraints and improving education and training regarding the proper installation of aftermarket wheelchair tie-downs and occupant restraint equipment.

Overall, the crashworthiness performance of the vehicles in the NASS-CDS cases were consistent with a recent study where altered and modified vehicles for wheelchair-seat drivers were crash tested.[53] In that study, two 2015 Dodge Caravan BraunAbility EVII conversion vans, altered to accommodate drivers seated in wheelchairs, were crash tested by conducting 48-km/h full-width frontal barrier tests with a 50th percentile male anthropomorphic test device (ATD, "or "crash test dummy") seated in powered wheelchairs secured by WC18-compliant QLK-150 docking devices. In the first crash test, the frontal air bags were suppressed, and in the second test, air bags deployed. Power wheelchairs that met industry requirements that had a wheelchair securement adaptor for use with their QLK-150 auto-docking wheelchair-securement system were selected.

The results of the crash tests were generally directionally consistent with findings from sled tests and computer simulations conducted by the UMTRI.[54] Moreover, all the upper-body Injury Assessment Values (IAV) from the ATD measurements were lower in the test where the frontal air bags were deployed. Furthermore, the kinematics of the ATD in the crash test where the steering wheel air bag deployment were more controlled, the forward excursion of the head was lower, and contact of the ATD's torso and head with the steering wheel and upper IP were prevented. Additionally, the deploying air bag did not induce harm as measured by the IAVs. This was also consistent with the UMTRI findings and with results of this report, which analyzed the real-world crashes using the NASS-CDS data.

3. Summary of safety risk and trends for non-operational adaptive equipment cases

Overall, there were no safety trends or concerns found after analyzing the 15 cases where vehicles were altered and modified for wheelchair accessibility. Depending on the crash type and crash severity, it appears the air bag system performed as expected. Where the vehicle's structure was altered, it did not appear to adversely affect its performance in any of the crash modes. With some exceptions, the restraint system performed as intended, including the wheelchairs and the securement system. Last, given the above, generally the vehicles in this study were older, did not benefit from the implementation of the latest safety programs, and yet, a safety concern for the occupants could not be identified from the cases analyzed, especially if the occupant was properly restrained in an appropriate wheelchair and securement system.

The limitations of the data should be noted. First, whether a disabled occupant was in the vehicle at the time of the crash is unknown. Second, if the occupant was disabled, the type or severity of the disability was not known, including how the occupant's physical state may have made them more susceptible to an injury in a crash, independent of the non-operational adaptive equipment.

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[53] Wiacek, C., Prasad, A., Weston, D., Richie, N., & Schneider, L. (2017). *Assessing the performance of steering wheel air bags for drivers seated in wheelchairs during frontal crash tests* (Report No. 17-219). 25th Enhanced Safety of Vehicles Conference, Detroit, June 5-8, 2017.
[54] Schneider, et al.,2016.

VII. Conclusions

There were 59 cases identified where involved vehicles were coded as equipped with adaptive (assistive) driving equipment. The cases were grouped based upon whether the subject vehicle was equipped with operational or non-operational equipment. Note: These cases were not mutually exclusive. There were 50 cases identified with vehicles that were equipped with operational adaptive equipment and 19 cases identified as vehicles equipped with non-operational adaptive equipment.

The 50 operational adaptive equipment grouped cases generally involved vehicles modified with equipment intended to assist drivers with the operational control of the vehicles. The operational adaptive equipment identified in these cases were hand controls, steering knobs, low effort steering systems, raised accelerator/brake pedals, and relocation of the accelerator pedal. The most frequent modification identified were the addition of hand controls for braking/acceleration (31 cases) followed by the addition of a steering knob attached to the steering wheel (25 cases). It should be noted there were 16 cases where the vehicles were equipped with both hand controls and steering knobs. After a careful review of these cases, there were no safety trends identified where it appeared the installed operational adaptive equipment was an obvious factor in the crash.

The 19 non-operational adaptive equipment cases generally involved vehicles altered or modified to transport disabled occupants such as those in wheelchairs. Fifteen of these cases generally involved significant alteration to standard vehicles, such as the vehicle floor being lowered to provide access to a wheelchair-seated occupant or driver. The other four cases included two cases where the driver seating positions were equipped with seat belt extenders, one where the vehicle was equipped with an air bag on-off switch, and one where the driver's seat cushion was replaced with what appears to be an orthopedic cushion and lap belt.

These cases also included equipment that modified the crashworthiness of the vehicles or occupant protection in crashes. After a careful review of the crash severity, crash type, injury source, and injury type including all the cases involving a fatality, there were no safety-related trends identified attributed to the non-operational adaptive equipment. There were a few concerns identified related to improperly restrained wheelchair-seated occupants or indications a wheelchair may not have been intended to be used as a seat in a moving vehicle, but overall, the data did not suggest there was a safety problem.

The limitations of this study need to be acknowledged. Whether the adaptive equipment identified was used at the time of the crash or if potential problems with the equipment were not identified and noted during the investigation is unknown. How physical limitations of driver may have affected the use of the operational adaptive equipment leading up to the crash, such as a delayed reaction time, or potentially lacking the strength during an emergency to operate the equipment could not be assessed. Furthermore, the type or severity of the disability is not known, including how the occupant's physical state may have made the occupant more susceptible to an injury in a crash independent of the non-operational adaptive equipment. Even acknowledging these limitations, the analysis of the available real-world crash data did not identify any safety trends where a vehicle was equipped with adaptive equipment to accommodate people with disabilities.

Appendix A

Table A1: Adaptive Equipment as Coded in NASS-CDS

Adaptive Equipment - Optional Text	Total
Hand Controls for braking/acceleration	27
Steering knob attached to steering wheel	24
Other adaptive device (specify)	22
Additional or relocated switches (specify)	12
Wheelchair tie-downs	11
Modification to seat belts (specify)	8
Steering control devices	8
Pedal Extender	4
Low effort power steering (unit or device)	2
Raised roof	2
Replacement steering wheel (i.e. reduced diameter)	2
Joy-stick steering controls	1
Wall mounted head rest (used behind wheel chair)	1
Sum	124

Table A2: Summary of Adaptive Vehicle Cases (Note 2008-11-095 subject vehicle unoccupied)

Operational Adaptive Equipment: Hand Controls for Braking/ Acceleration	Operational Adaptive Equipment: Steering Knob Attached to Steering Wheel	Operational Adaptive Equipment: Both Hand Controls and Steering Knob	Operational Adaptive Equipment: Low Effort Steering	Operational Adaptive Equipment: Raised Accelerator and/or Brake Pedal	Operational Adaptive Equipment: Relocated Accelerator Pedal To Left Side
2006-13-011	2006-11-042	2006-12-119	2007-05-002	2009-11-094	2010-02-066
2006-43-094	2008-45-142	2007-05-002	2008-13-021	2010-45-239	2010-11-165
2007-11-197	2010-02-066	2008-03-074	2014-05-035	2011-13-038	
2007-47-154	2010-11-165	2008-11-095	2014-05-040	2014-12-010	
2007-82-048	2012-04-014	2008-12-099			
2008-08-163	2012-48-162	2008-13-021			
2008-09-108	2013-76-055	2008-45-002			
2008-12-131	2014-75-041	2008-45-045			
2009-02-051	2015-48-098	2008-75-027			
2010-75-043		2008-79-016			
2010-81-043		2009-11-131			
2011-74-166		2010-11-165			
2014-05-035		2010-73-028			
2014-05-040		2010-75-103			
2014-49-082		2014-41-028			
		2014-81-033			
		2015-49-053			
Non-Operational Adaptive Equipment: Altered Vehicle	**Non-Operational Adaptive Equipment: Other**	**Injury Coded To Adapted Equipment**	**Adaptive Equipment Assested Contributed to Injury**	**Fatal**	**Other: Non-Adaptive Equipment**
2007-05-002	2009-11-94	2007-05-002	2007-05-002	2006-43-094	2006-11-026
2007-11-197	2010-02-066	2008-03-074	2008-02-148	2008-09-108	2007-08-158
2007-47-154	2010-75-103	2008-45-002	2008-75-027	2008-45-142	2007-41-057
2008-02-148	2011-11-221	2014-05-040	2014-05-040	2009-11-131	2007-45-201
2008-12-131		2014-49-082	2014-81-033	2009-45-021	2007-49-105
2008-72-083				2011-13-038	2008-43-251
2008-75-027				2014-75-041	2009-09-158
2008-79-016				2015-49-053	2011-13-031
2009-11-131					2013-03-088
2009-45-021					2014-02-030
2011-74-166					
2013-03-089					
2014-05-035					
2014-05-040					
2014-81-033					

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