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16. Abstract

This technical report describes the sample design, data collection, data coding, weighting, estimation methods, and findings of the Medium-Truck Special Study (MTSS), the purpose of which is to identify critical reasons for the critical events and causal factors in fatal crashes and to assess if crash avoidance technologies could have affected the crashes and injury severity of medium-truck crashes. Forty-two percent of the medium trucks in MTSS were pickup trucks, and the remaining 58 percent were single-unit straight truck or cab-chassis medium trucks. The Critical Reason for the Critical Event was assigned to a medium truck in 42 percent of the MTSS fatal crashes. In 56 percent of the total estimated vehicles involved in the fatal MTSS crashes, Forward Collision Warning and Automatic Emergency Braking, if available and not disabled, were deemed to have possibly or probably been effective in reducing the severity and/or preventing the crash. The braking technologies showed much higher potential than lane (18%) and blind spot (less than 1%) technologies.

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Acronyms, Abbreviations, and Initialisms

ACC	adaptive cruise control
ACN	automatic crash notification
AEB	automatic emergency braking
BAC	blood alcohol concentration
BSD	blind spot detection
CBE	cab behind engine
CDAN	Crash Data Acquisition Network
CDL	commercial driver's license
CIB	crash imminent braking
CID	Crash Investigations Division
CIREN	Crash Injury Research Engineering Network
CISS	Crash Investigation Sampling System – a replacement of CDS
COE	cab over engine
CRSS	Crash Report Sampling System – a replacement of GES
CSV	comma-separated value
DBS	dynamic brake support
DRL	daytime running lights
EDR	event data recorder
ESC	electronic stability control
FARS	Fatality Analysis Reporting System
FCW	forward collision warning
FMCSA	Federal Motor Vehicle Safety Administration
GCWR	gross combined weight rating
GVWR	gross vehicle weight rating
IT	information technology
KLD	KLD Associates, Inc.
LDW	lane departure warning
LKS	lane keeping support
LTCCS	Large Truck Crash Causation Study
MC ID	Motor Carrier Identification Number
MTSS	Medium Truck Special Study
NCSA	National Center for Statistics and Analysis
NMVCCS	National Motor Vehicle Crash Causation Survey

PAEB	pedestrian automatic emergency braking
PCR	police crash report
PJ	police jurisdiction
PSU	Primary Sampling Unit
RBIS	Record Based Information Solution
RSC	rollover stability control
SAS	Statistical Analysis System (a suite of analytics software)
SCI	Special Crash Investigations
SE and STE	standard error
SRSWOR	Simple Random Sampling Without Replacement
SUDAAN	SUrvey DAta ANalysis (a proprietary statistical software package for the analysis of correlated data, including complex sample survey data)
VIN	Vehicle Identification Number
WOR	without replacement
WR	with replacement

Executive Summary

The National Highway Traffic Safety Administration has identified increasing trends in the occurrence of fatal medium-truck (GVWR 10,001 - 26,000 lbs.) crashes in recent years. Based on data from the Fatality Analysis Reporting System medium trucks were involved in 2 percent of total fatal crashes in 2015. In 2019 this number increased to 4 percent. To gain further understanding of medium-truck crashes, the Medium Truck Special Study was conducted. The main objectives of MTSS were to:

- Identify the critical reasons for the critical events and causal factors in fatal crashes involving at least one medium truck to better align research programs and focus efforts on appropriate countermeasures, and
- Assess if crash avoidance technologies could have affected the crash and injury severity of medium-truck crashes.

Since data was needed in a compressed time frame, NHTSA elected to leverage the FARS as a starting point for the project. NHTSA believed details needed to meet the objectives of the MTSS could be determined based on the original data coded in FARS along with supplemental information gathered from the investigating law enforcement agency such as the crash report, reconstruction reports, photographic images of the scene and involved vehicles, and other information collected by police at the crash site. The information was requested, collected, and coded by trained personnel with familiarity and experience in similar studies.

Using the 1,286 crashes involving medium trucks from the 2018 FARS file, NHTSA developed a scalable simple random sample of 400 medium-truck crashes, and ultimately coded 219 MTSS cases for the project.

Some of the key findings of the MTSS focused on the Critical Reason for the Critical Event. The critical event is the action or event that placed the vehicle on a course that made collision unavoidable. In other words, the critical event makes the crash inevitable (Mynatt, 2013). The Critical Reason is the immediate reason for the Critical Event and describes why the Critical Event occurred. The foundation of the entire Critical Event and Critical Reason approach is that there is no single specific cause of a given crash; rather, it views a crash as a process consisting of interrelated events and conditions (Perchonok, 1972). As described in later sections of this paper, Critical Reason for the Critical Event is one of the most important elements to analyze with respect to crash causation. NHTSA has collected Critical Reason for the Critical Event in two previous in-depth crash causation studies, the Large Truck Crash Causation Study (Starnes, 2006) and the National Motor Vehicle Crash Causation Survey (NHTSA, 2008). It should be noted that although Critical Reason for Critical Event was collected in the LTCCS, NMVCCS, and MTSS, the crash population for each of the studies and methods used to collect the data were different. The LTCCS criteria included crashes involving at least one large truck, defined as a truck with a GVWR of 10,001 pounds or more and the crash involved at least one fatality, incapacitating, or non-incapacitating but evident injury. Some of the qualifications for inclusion in the NMVCCS were Emergency Medical Service dispatch, and one of the first three vehicles must be a towed light vehicle. The MTSS population differed in that they were only fatal crashes which involved a medium truck and relied solely on documentation provided by law enforcement to code the cases.

Key findings of the MTSS include:

- The Critical Reason for the Critical Event in the MTSS fatal crash was assigned to a medium truck in 42 percent of the MTSS cases compared to 55 percent of Critical Reasons assigned to large trucks in the LTCCS (Starnes, 2006).
- Driver-related Critical Reasons for medium-truck drivers in the MTSS was higher (91%) compared to those for truck drivers (87%) in the LTCCS but lower than those found for all drivers in the NMVCCS (94%) (Singh, 2015).
- Forty-two percent of the medium trucks in the MTSS were pickup trucks, the remaining 58 percent were single-unit straight trucks or cab-chassis medium trucks
- In 56 percent of the total estimated vehicles involved in the fatal MTSS crashes, forward collision warning and automatic emergency braking, if available and not disabled, were deemed to have possibly or probably been effective in reducing the severity and/or preventing the crash.
- The braking technologies showed much higher potential than lane (18%) and blind spot (less than 1%) technologies.

Because medium trucks reside in the space between light passenger vehicles and heavy trucks, they present a different set of safety challenges. Medium trucks encompass a wide range of body styles and weights such as large pickups like the Ford F-350, pickup-based bodies with aftermarket cargo and/or storage areas, more-traditional delivery trucks, and many other body styles. In the MTSS, 42 percent of the medium trucks were pickup-based, while the remaining 58 percent were single-unit straight trucks or cab-chassis medium trucks. This high percentage of pickups in the MTSS likely describes why the Critical Reasons for the Critical Event more closely resemble NHTSA's light-vehicle causation survey, the NMVCCS, as compared to the large-truck causation study, the LTCCS. Efforts to reduce medium-truck crashes will likely need to incorporate countermeasures appropriate to the light-passenger vehicle segment as well as those intended for heavy trucks.

The MTSS study methodology, using existing databases supplemented by topic-specific variables coded from law enforcement documentation, was effective in providing high-level information to NHTSA. The methodology was especially effective when short time frames and limited funding for data collection and analysis are required. However, reviewing the police material and images it's clear law enforcement and agency research-related goals are somewhat different. Police reconstruction reports sometimes delve into driver factors, but in most cases information in this important area was limited. For increasingly in-depth details, additional data collection efforts would be required.

Introduction

NHTSA has identified increasing trends in the occurrence of fatal medium-truck (GVWR 10,001 - 26,000 lbs.) crashes in recent years. Based on data from the FARS medium trucks were involved in 2 percent of total fatal crashes in 2015. In 2019 this number increased to 4 percent. To gain further understanding of medium truck crashes, the Medium Truck Special Study (MTSS) was conducted.

The objectives of the MTSS were to:

- Identify the critical reason for the critical event and causal factors in fatal crashes involving at least one medium truck to better align research programs and focus efforts on appropriate countermeasures, and
- Assess if crash avoidance technologies could have affected the crash and injury severity of medium-truck crashes.

Since data was needed in a compressed time frame, the NHTSA elected to leverage the FARS as a starting point for the project. The FARS program collects a wealth of information at the crash, vehicle, and person levels. However, to effectively conduct the study more details specific to medium-truck crashes, in addition to the FARS source documents and coded data, were required. Based on previous similar data collection efforts, NHTSA believed the details needed to meet the objectives of the project could be determined based on the police crash report, reconstruction reports, photographic images of the scene and involved vehicles, and other information collected by law enforcement at the crash site.

The development of the MTSS began in early 2020. This document describes the sampling plan, data collection, data coding, weighting procedure, and estimation method, and results for the MTSS.

The goal of the MTSS was to acquire supplemental information from law enforcement on at least 200 cases. Criteria for study inclusion was the ability to obtain images of the crash scene and involved vehicles and the presence of the crash report from the investigating law enforcement agency. Both images and the crash reports were required for study inclusion because, without them, there would not be sufficient details to code any additional information other than what was already collected in the FARS.

NHTSA initially considered oversampling medium-truck crashes with high-interest characteristics such as rollovers, but ultimately elected to include any medium-truck crash involving a fatality regardless if the fatality occurred in a medium truck, other vehicles, or non-occupant (e.g., pedestrian or pedalcyclist). Another important crash characteristic of note is if the medium truck and its driver were regulated by the Federal Motor Vehicle Safety Administration. FMCSA regulates commercial vehicles in interstate commerce, motor vehicles used for transporting goods or paying passengers. Some medium trucks in the study are regulated by the FMCSA and others are not. Again, NHTSA elected to include all crashes involving medium trucks in the study to provide nationally representative results.

The following requirements were proposed to define the target population of this study.

- Fatal crashes involving medium trucks in the FARS 2018 file (the fatality does not have to be in the truck)

- Crashes must have images for inclusion.
- Fatal crashes involved medium trucks regardless of whether the truck is in transport

Whether the investigating police agency has the images of the crash scene and vehicles can only be determined after the sample is selected, data collection request is made to the police jurisdiction, and the data has been reported to NHTSA. Therefore, this condition is used as the unit non-response criteria but not as the scope definition. If the crash image data of a responded case is missing, then the sampled case is treated as non-responding case because the key crash image information is missing. Other causes of unit non-response include

- PJ is not cooperative,
- PJ does not have the documentation,
- PJ cannot send us the documentation (e.g., due to pending criminal litigation), or
- PJ did not take images of the crash.

In summary, the target population of this study is the total of all fatal crashes involving medium trucks regardless of whether the truck is in transport in the 2018 FARS file. When applied to motor vehicles, “in transport” means on a roadway or in motion in or outside the trafficway. Ultimately, 219 of the 400 potential MTSS cases were completed for the project.

Sample Design

A scalable simple random sample of fatal crashes was selected from the 2018 FARS file. There was no over-sampling of crashes with special characteristics. For example, the percentage of crashes with specific crash characteristics in the sample will be similar to the percentage of these crashes in the target population. The targeted responding sample size was 200. Because of the potential non-responding cases (cases without images, etc.), the actual selected sample size was larger than 200. An initial 400 cases were selected for data request.

The 2018 FARS files released on April 10, 2020, were used to create the frame and to select the sample.

First, the in-scope vehicles (medium trucks regardless of in transport) were identified from three different vehicle level files: VINDECODE, VEHICLE and PARKWORK.

From the VINDECODE file, we first used the following statement to identify vehicles with in-scope weight

```
IF 3<=GVWRANGE<=6
```

We then used the following statement to identify vehicles with in-scope body types. The intersecting part of these two files was the first batch of in-scope vehicles.

```
IF (BODY_TYP IN (60,61,62,64,66,67,71,78)) OR (BODY_TYP=79 AND
(1<=TOW_VEH<=4));
```

From the VEHICLE file, the GVWRANGE variable is not available, but GVWR is, therefore medium trucks were identified by the following statement.

```
IF GVWR=2 AND ((BODY_TYP IN (60,61,62,64,66,67,71,78)) OR
(BODY_TYP=79 AND (1<=TOW_VEH<=4)))
```

From the PARKWORK file, medium trucks were identified by a slightly different criterion because there was not a variable indicating whether a trailing unit is attached (TOW_VEH) in the PARKWORK file.

```
IF PGVWR=2 AND (PBODYTYP IN (60,61,62,63,64,66,67,71,72,78));
```

These in-scope vehicle records were then pooled together and duplicates among them removed. The resulting vehicle records were then merged to the ACCIDENT file to identify the in-scope crashes. In summary, 1,286 cases were identified from the 2018 FARS file, and these were the fatal crashes involved at least one medium truck regardless if the truck was in transport. These resulting records became the sampling frame.

The frame was then randomly sorted, and the first 400 cases were used as the initial sample.

The original MTSS sample was a simple random sample of 400 cases selected from a population of 1,286.

To reduce the burden of the related PJs, all the initial 400 sample cases were sent to the associated PJs. Upon receiving the data from the responding PJs, the responding cases were coded and weighted (see Section 7 for more details about weighting).

Data Collection

To request and collect required images and documents from the investigating law enforcement agencies, and to code the MTSS cases, NHTSA used the CISS (NHTSA, n.d.) Primary Sampling Unit operations contractor, KLD Associates, Inc. KLD employs personnel trained in NHTSA's investigation-based data collection programs, and many of the staff assigned to the MTSS had previous experience working on truck and causation programs such as the LTCCS and the NMVCCS.

Source Document Collection

The MTSS team requested data on the 400 selected fatal medium-truck crashes from the investigating police agencies. Initial contact included an introductory letter from NHTSA to the investigation agency followed by phone calls from the MTSS staff. Although the personnel making the requests were seasoned in gaining law enforcement cooperation, acquiring the needed material had many challenges. First was the COVID pandemic. During the data collection period, the pandemic forced many law enforcement agencies to work with limited records department employees, staff working remotely, or in some cases no records department personnel at all. This resulted in lengthy lag times to receive the necessary documents and images, and on some occasions, agencies simply refused to cooperate because of staffing limitations. Difficulties were also encountered when attempting to identify the correct crash report number from the FARS system. State crash report numbers were always in the FARS case, but in some instances the local investigating agency case numbers were not. Since a request for documents cannot be made without the investigating agency report number, the MTSS data collection staff sometimes had to perform web searches and make inquiries to police agencies to associate state crash report numbers with the coinciding local agency crash report number. Other examples of unsuccessful attempts to obtain the required information were because no images were taken at the crash scene by the investigating agency, pending litigation, or the law enforcement agencies no longer possessing the documentation from the crash. Even with the pandemic and other issues, MTSS data collection personnel eventually obtained the necessary documents and images for 219 MTSS cases.

Material Received

MTSS cast a wide net when requesting material and images from law enforcement agencies, asking for all documentation from the case. This resulted in a wide variety of material returned from the cooperating agencies based on the depth of the police investigation, level of expertise of officers assigned to the crash investigation, and if any criminal charges or violations were considered. Material received for qualifying MTSS cases ranged from basic police crash report with a handful of images to detailed reconstruction reports with hundreds of pages of documentation, hundreds of photographs, video footage, autopsies, phone logs, etc.

Format and size of the images received was an issue for the MTSS collection staff throughout the process. Some images were provided in traditional formats like JPEG or PNG image files, but others were embedded in PDF files or in other formats. Most images received from law enforcement were large files sizes which proved to be cumbersome, and time-consuming to review and import into the MTSS software. Ultimately the MTSS staff elected to compress the files using third-party software, which made the images more manageable. Image subject also varied greatly from case to case. Images taken by law enforcement and images required to meet NHTSA medium-truck research goals are not necessarily aligned since the two have very different roles in the safety community. MTSS staff found images of the same subject in the law enforcement images and would oftentimes filter through over 100 images to find 10 to 20 images worthy of inclusion in the MTSS case. In many crashes involving a medium truck and a passenger car, the fatality was in the passenger car, and law enforcement concentrated its images on the passenger vehicle, not the medium truck. Crashes occurring during nighttime hours also posed an issue; many of the images received from police were dark or blurry.

Data Coding

The MTSS data entry software was developed using the Records-Based Information Solution application on NHTSA's Crash Data Acquisition Network platform. The functionality of the data entry system mirrored FARS where applicable and elements already in FARS were pre coded in the MTSS RBIS system, saving a significant amount of time. Other MTSS-specific variables were added to the software with data entry efficiency in mind and ultimately the RBIS MTSS software proved to be a solid data entry solution.

NHTSA expanded upon data already in FARS to develop approximately 200 total variables and a coding manual for the study. High-level topic areas included the following.

- Crash location and environment
- Medium-truck characteristics
- Other vehicle information
- Precrash
- Driver
- Person
- Non-occupant
- Avoidance assessment

Many of the elements used in MTSS were borrowed from studies conducted by NHTSA in the past such as the LTCSS, the Truck Crashworthiness Data Special Study (NHTSA, 2015), and the CISS (NHTSA, n.d.). Some new elements were also designed specifically for this study. During MTSS variable development NHTSA attempted to walk the fine line between gathering enough data to meet the study objectives while still realizing the project was limited to information that could be coded based on images and reconstructions produced by law enforcement. As mentioned, the focus of law enforcement images and documentation are not necessarily the same as medium truck research efforts. The entire list of variables collected in MTSS can be found in Appendix B.

Most of the elements added to MTSS were related to details of the crash location, driver factors, truck characteristics, precrash, and avoidance assessments to focus on the study objectives: identifying causal factors in medium-truck crashes and assessing if crash avoidance technologies could have affected the crash and injury severity.

Crash location variables such as line types, rumble strip presence, shoulder size, and shoulder surface were added to MTSS to expand upon the wealth of environmental and roadway characteristic information already present in the FARS system. Satellite imagery was also beneficial when coding these elements.

Driver fatigue and illness are examples of driver-related variables added to MTSS. However, information on driver causal factors would have to be viewed as one of the shortcomings of the study. While police reconstruction reports sometimes delve into driver factors, in most cases information in this important area was limited. To truly get in-depth causal information on the drivers, data collection protocols, like those used in LTCCS and NMVCCS where detailed driver interviews occurred at the crash scene or shortly after, would be required.

Medium truck characteristics were by far the area with the most information collected in MTSS. Over 30 medium-truck-specific elements were added to the vehicle data already present in FARS. These were mostly borrowed from previous NHTSA truck studies LTCCS and TCDSS. Crashworthiness subjects such as underride guards, detailed rollover assessments, and intrusion locations and severity were evaluated. Conspicuity and visibility features on the truck such as tape colors and locations, mirror positions, field of view, and sight lines were coded.

Substantial effort also went into identifying the presence of equipment on the vehicle. MTSS staff used the Vehicle Identification Number and images as the starting point to check several sources to determine if the vehicles in the crash were equipped with features like electronic stability control, rollover stability control, and event data recorder. Additionally, presence of the following advanced safety features for each vehicle in the crash model year 2010 and newer was entered.

- Forward collision warning
- Crash imminent braking
- Lane departure warning
- Lane keeping support
- Blind spot detection
- Adaptive cruise control
- Pedestrian automatic emergency braking
- Dynamic brake support
- Daytime running lights
- Advanced lighting
- Automatic crash notification

The list of advanced safety features collected in MTSS mirrors those collected in NHTSA's investigation-based data collection programs. The MTSS staff collected vehicle availability information on four separate forward crash warning and intervention technologies independently for model year 2010 and newer vehicles: FCW, CIB, PAEB, and DBS. NHTSA specifies there are two types of automatic emergency braking systems that meet NHTSA's performance specifications: dynamic brake support and crash imminent braking. In the MTSS results an assessment of AEB potential effectiveness was made.

Even though MTSS staff could determine in most cases if the vehicle was equipped these technologies there are drawbacks in a study using police reconstruction-based methodology for this type of analysis. Vehicles where the technologies were optional, as opposed to standard or not available, posed a problem and had to be coded unknown. Additionally, when a technology was present the status, i.e., if the equipment had been manually disabled, was not reported by law enforcement.

Precrash information was obviously a very important aspect of the project. The same core precrash variables in MTSS are present in all NHTSA data collection efforts including record-based studies FARS and the CRSS, as well as the investigation-based studies CISS (NHTSA, n.d.), Special Crash Investigation, and the Crash Injury Research and Engineering Network. The precrash elements describe the precrash phase of the crash in further detail based on the concept of a critical crash envelope which was originally outlined by Perchonok in the early 1970s (Perchonok, 1972). It’s important to note that when the precrash methodology was introduced in NHTSA data systems, NHTSA elected not to use the methodology in its purest form, instead implementing adaptations of the ideas updated for use in large scale nationally representative data collection systems. The cornerstone of the critical crash envelope is the critical event. The critical event is the action or event that placed the vehicle on a course such that the collision was unavoidable. In other words, the critical event makes the crash inevitable (Mynatt, 2013).

The basic precrash data elements are designed to identify the following:

- What was this vehicle doing just prior to the critical precrash event?
- What made this vehicle's situation critical?
- What was the avoidance response, if any, to this critical situation? and
- What was the movement of the vehicle just prior to impact?

MTSS took precrash coding a step further by adding another component of Perchonok’s causal methodology which was present in LTCCS and NMVCCS, the variable Critical Reason for the Critical Event. The Critical Reason is the immediate reason for the Critical Event and describes why the Critical Event occurred. The foundation of the entire Critical Event and Critical Reason approach is that there is no single specific cause of a given crash; rather, it views crashes as a process consisting of interrelated events and conditions (Perchonok, 1972). This series of events leading to a crash is commonly referred to as the causal chain. Remove any one of the links in the chain, and a crash may not have occurred. It should be noted, in most crashes, only one involved vehicle receives the Critical Reason for the Critical Event, but in rare cases the Critical Reason can be assigned to several participants in the crash. Figure 1 shows the chronological order of the elements used to describe a single crash envelope in MTSS.

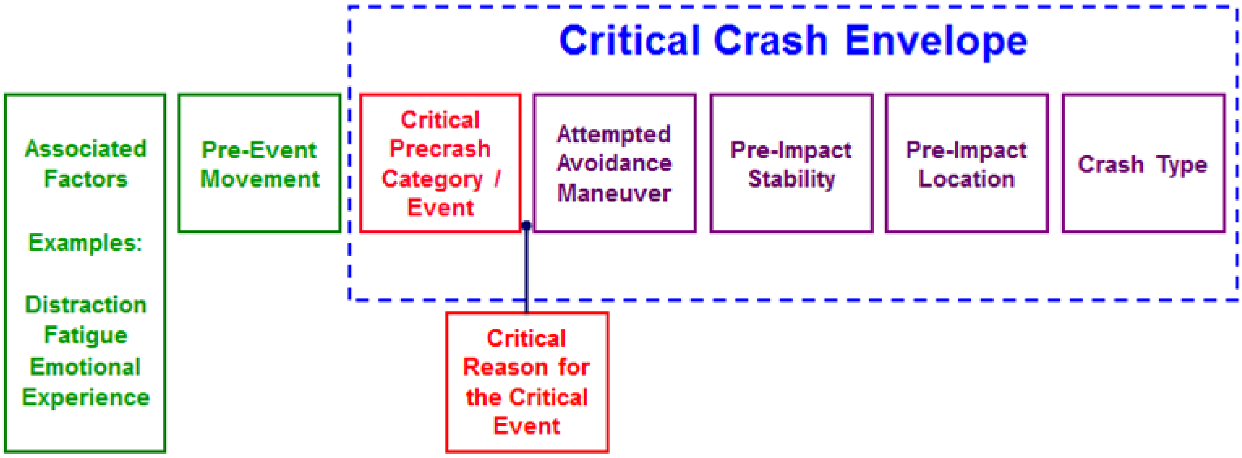

Figure 1. Chorological Order of a Single Crash Envelope in Causation Studies

The last step in the initial MTSS data coding process was an avoidance assessment for each vehicle in the crash. These elements considered all other data and attempted to ascertain the likelihood the following five technologies, if present, would have been helpful in preventing or mitigating the severity of the crash.

- FCW
- AEB
- LDW
- LKS
- BSD

The initial avoidance assessment was made by MTSS contractor staff before a final evaluation was completed by NHTSA subject-matter experts. The avoidance assessment was assigned based on the subject matter experts understanding of the technologies in their current state. The likelihood of the avoidance technology being helpful evaluation was somewhat judgement-based and others reviewing the cases may have differing opinions.

Eight cases involved vehicles with FCW and/or LDW available on the vehicle. Seven of the eight were available in light vehicles and not the medium truck. Some of the crash avoidance technology can be turned off by the driver. For example, technologies like AEB likely cannot be turned off, whereas LDW likely can be turned off. None of the material in these cases had any information on the status of the avoidance equipment, if it was on or off, or if the equipment activated during the crash. Because of the lack of information, one of the drawbacks of this study methodology, the assessment of avoidance technology effectiveness was handled in the same manner as vehicles that were not equipped with avoidance equipment.

After all coding was completed, the MTSS senior staff conducted quality control of the cases and made any necessary changes. In addition, NHTSA staff performed a final review paying particular attention to the precrash and avoidance assessment coding. After the MTSS file was finalized, SAS and CSV files were created for further analysis.

Example Cases

Three cases are provided to give examples of the information available in MTSS using this follow-on data collection method. Included in the case examples are:

- Case summary and discussion,
- Police scene diagram,
- Images of the crash scene and vehicles obtained from the investigating police agency,
- Core precrash variable coding, and
- Crash avoidance feature assessment.

MTSS Example Case 071

The crash occurred on a straight, level, north/south interstate at 0315 in the early morning. Conditions were dry, dark, and partially illuminated by streetlights. The interstate had five southbound lanes and shoulders, with the first (far right) lane serving as an exit-only lane to a truck weigh station. The second lane was designed to be used as an exit lane to the weigh station or a through lane to continue straight on the interstate. The police diagram is shown in Figure 2.

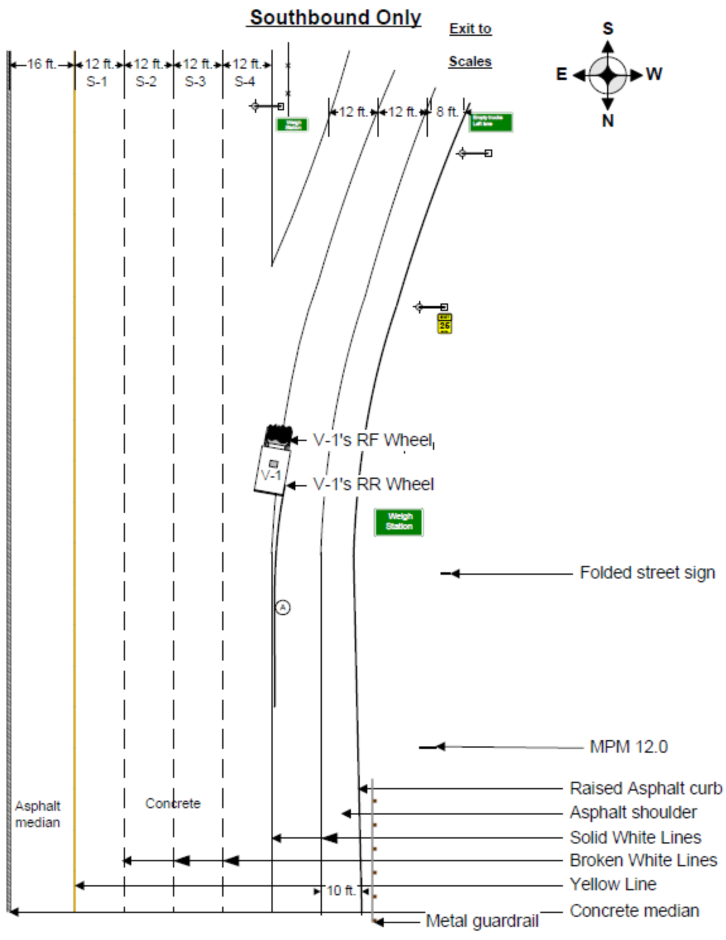

Figure 2. MTSS Case 071 Police Scene Diagram

Vehicle 1, the case vehicle, was a 2017 Isuzu cab-over-engine entry box truck carrying refrigerated produce with a Class 5 gross vehicle weight rating of 19,500 pounds, and a gross combined weight rating of 25,500 pounds. Vehicle 2 was a 2018 Freightliner cab-behind-engine tractor pulling a 53-foot Great Dane van trailer. The owners of both vehicles were DOT-regulated carriers. The posted speed limit for vehicles configured like the Isuzu medium truck (V1) was 70 mph (113 kph), while the speed limit for commercial vehicles configured like the tractor trailer (V2) was 55 mph (89 kph).

Vehicle 2 (Freightliner) was traveling south in the second lane from the right and stopped due to congestion just north of the weigh station exit ramp. Police images of vehicles approach can be seen in Figure 3. Based on the driver's statement to police, Vehicle 2 had been stopped for approximately 30 seconds prior to impact. The weigh station facility uses a camera system and can change an electronic regulatory sign board to close the scale to commercial traffic if the flow of traffic inside the facility starts to back up onto the freeway. At the time of the crash the electronic signage was still directing trucks to enter the weigh station. Vehicle 1 came upon the stopped traffic and its front struck the rear of Vehicle 2's trailer. Skid marks at the scene indicate the Isuzu braked just prior to impact. The damage to Vehicle 1 is shown in Figure 4. Figure 5 and Figure 6 display the damage to Vehicle 2's trailer.

Figure 3. MTSS Case 071 Approach

Figure 4. MTSS Case 071 Vehicle 1 Medium Truck

Figure 5. MTSS Case 071 Vehicle 2 Trailer

Figure 6. MTSS Case 071 Vehicle 2 Trailer

The 52-year-old male driver of the Isuzu medium truck was killed in the crash. He was not wearing the lap and shoulder belt equipped in the vehicle. The police reconstruction of the crash was detailed, but a precise timeline of the driver’s movements leading up to the crash was not provided. However, based on police discussions with his family and company it was established he was on a multi-hour trip prior to the collision. The driver met all applicable commercial driving license requirements and had a good driving record. Alcohol and drug tests were negative. It is unknown if the driver was distracted, inattentive, fatigued, or fell asleep prior to the crash, so further details on crash causation could not be determined. The police did not provide a precrash travel speed, but the speed limit for the Isuzu was 70 mph (113 kph).

The post-crash truck inspection found there were no prior mechanical conditions that would have caused or contributed to the collision. However, the vehicle total weight at the time of the crash was 30,200 pounds, which is above the vehicles GCWR of 25,500 pounds. Police concluded the exceeded weight limit may have contributed to the driver’s inability to properly stop or slow the vehicle. Table 1 shows some of the coded information for Vehicle 1. NHTSA subject-matter experts determined FCW and AEB would have been helpful in preventing or mitigating the severity of the crash.

Table 1. MTSS Case 071 Precrash and Avoidance Assessment Coding

Vehicle 1 Medium Isuzu Truck

Variable	Precrash Case Coding
Pre-Event Movement	Decelerating in road
Critical Event Category	Other motor vehicle in lane
Critical Event	Other vehicle stopped
Attempted Avoidance	Braking
Crash Type	(20) Same trafficway, same direction
Critical Reason for the Critical Event Category	Driver-related factor
Critical Reason for the Critical Event	Too fast for conditions to be able to respond to unexpected actions of other roadway users
Critical Reason for Critical Event Assigned to Medium Truck	Yes
Variable	**Avoidance Equipment Assessment Coding**
Forward Collision Warning Helpful	Probable
Automatic Emergency Braking Helpful	Probable
Lane Departure Warning Helpful	No
Lane Keeping Support Helpful	No
Blind Spot Detection Helpful	No

MTSS Example Case 348

The crash occurred on an east/west, straight, level, two-lane rural highway in the afternoon. Conditions were dry, daylight, and cloudy. There was a slim paved shoulder with open plains on either side of the road. The posted speed limit was 65 mph (105 kph). The police diagram is shown in Figure 7.

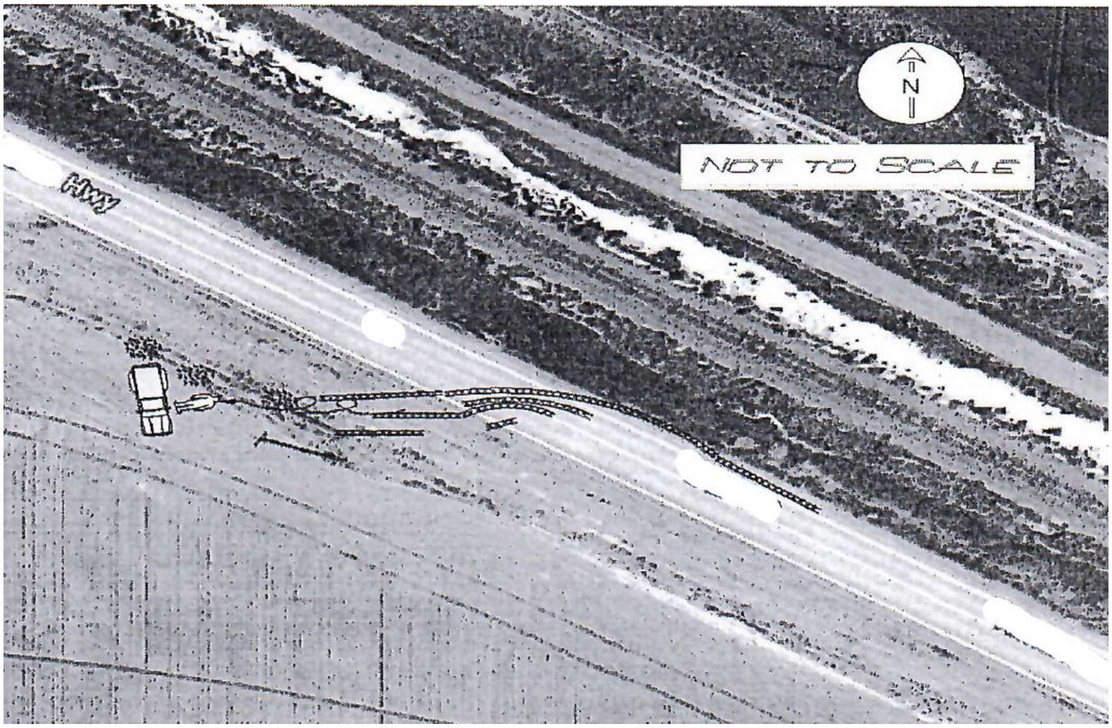

Figure 7. MTSS Case 348 Police Scene Diagram

Vehicle 1 was a 2004 Ford F-450 pickup with a Class 4 GVWR of 14,001 – 16,000 pounds. The pickup was being used by a State transportation department and was configured with a van-type cargo box and was carrying truck repair tools and equipment. The truck was traveling westbound and for unknown reasons edged off the right (north) side of the road. The driver overcorrected, steering left, and the vehicle began a counterclockwise rotation as it crossed over both lanes and departed the left (south) edge of the road. Once on the south roadside, the truck tripped over and rolled right four quarter turns, coming to rest on its wheels facing south. The vehicles path of travel can be seen in Figures 8-11. Final rest is shown in Figure 12.

Figure 8. MTSS Case 348 Approach 1

Figure 9. MTSS Case 348 Approach 2

Figure 10. MTSS Case 348 Approach 3

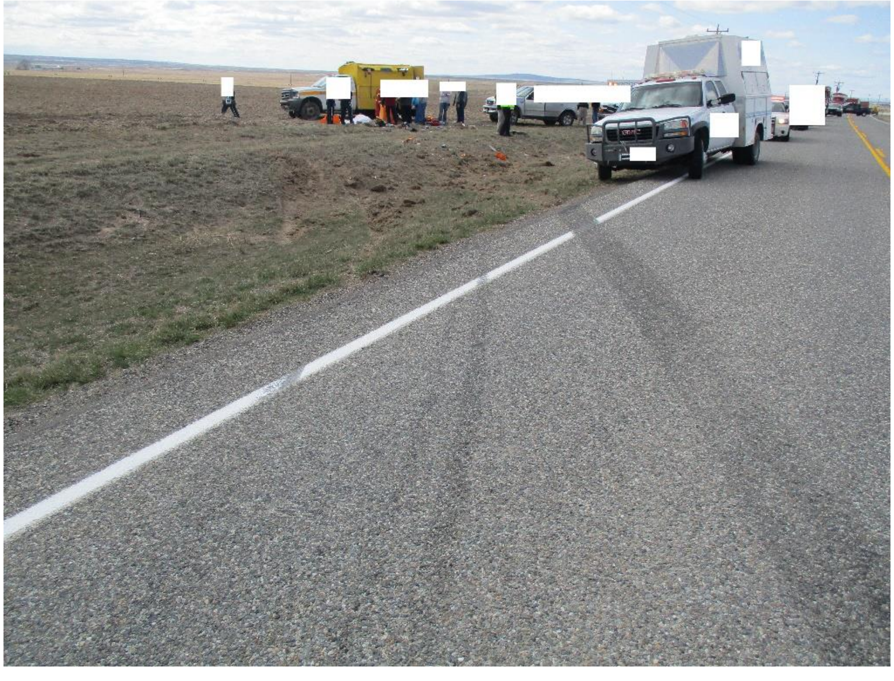

Figure 11. MTSS Case 348 Approach 4

Figure 12. MTSS Case 348 Truck at Final Rest

During the crash sequence the 55-year-old male unbelted driver was ejected and fatally injured. He came to rest just east of the vehicle. The driver had a good driving record and valid CDL. Alcohol and drug tests were negative. Police were unable to determine why the driver lost control.

Table 2. MTSS Case 348 Precrash and Avoidance Assessment Coding

Vehicle 1 Medium Isuzu Truck

Variable	Precrash Case Coding
Pre-Event Movement	Going Straight
Critical Event Category	This vehicle traveling
Critical Event	Off the edge of the road on the right side
Attempted Avoidance	Unknown
Crash Type	(98) Miscellaneous
Critical Reason for the Critical Event Category	Driver-related factor
Critical Reason for the Critical Event	Overcompensation
Critical Reason for Critical Event Assigned to Medium Truck	Yes
Variable	**Avoidance Equipment Assessment Coding**
Forward Collision Warning Helpful	No
Automatic Emergency Braking Helpful	No
Lane Departure Warning Helpful	Probable
Lane Keeping Support Helpful	Probable
Blind Spot Detection Helpful	No

MTSS Example Case 286

The crash occurred on a straight, level, east/west urban arterial roadway at 0418 in the early morning. Conditions were wet, dark, and partially illuminated by streetlights. The road had three lanes in each direction, separated by a painted median. The posted speed limit was 45 mph (72 kph). The police diagram is shown in Figure 13.

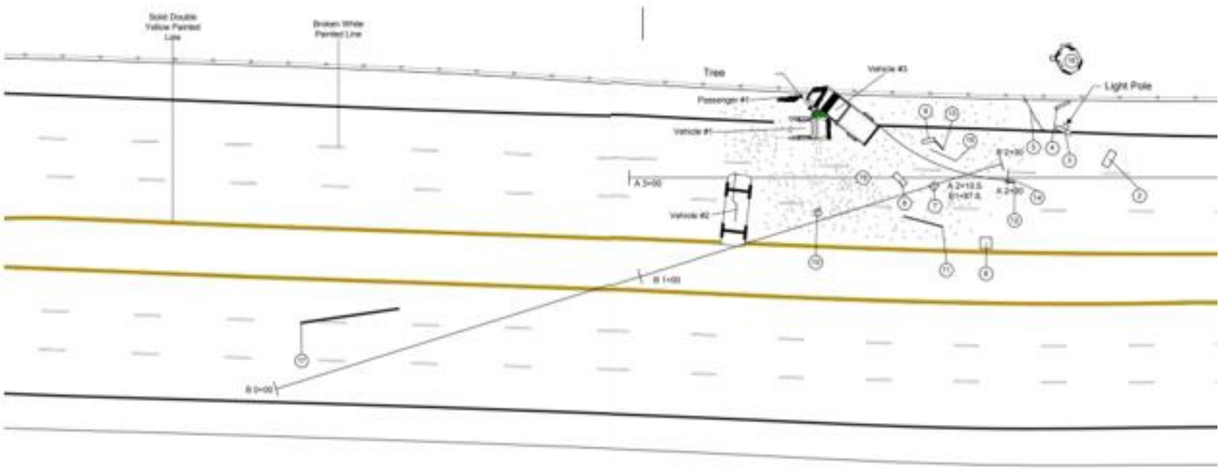

Figure 13. MTSS Case 286 Police Scene Diagram

Vehicle 1 was a 2014 Ford Fusion passenger vehicle traveling eastbound in the right lane and involved in an illegal street race with a non-contact BMW. Police estimated the Fusion's speed at 80 mph (129 kph). Vehicle 1's approach is shown in Figures 14-15. Vehicle 2 was a 2002 Chevrolet Avalanche traveling westbound in the left lane at a police-estimated speed of 40 mph (64 kph). Vehicle 3 was a 2015 Chevrolet 3500-series pickup traveling in the center westbound lane at 35 mph (56 kph) slightly behind Vehicle 2. Vehicle 2 and Vehicle 3's approach is displayed in Figure 16. Vehicle 1 (Ford Fusion) lost control as it approached a left curve and a slight dip in the roadway, began a counterclockwise yaw, and crossed the painted median into the eastbound lanes. Its right side was struck by the front of Vehicle 2 (Chevrolet Avalanche), the impact of which sheared Vehicle 1 in half. The front section was then struck by the front of Vehicle 3 (Chevrolet 3500-series). This impact caused Vehicle 3 to veer to the right (north) onto the raised sidewalk and collide with a tree, where it came to rest facing west. The front half of Vehicle 1 came to rest facing east against the left side of Vehicle 3. The rear half came to rest further east off the north side of the road. The initial impact caused Vehicle 2 to rotate clockwise and roll over, coming to rest on its roof facing north. An overview of the final rests of each vehicle is shown in Figures 17-19.

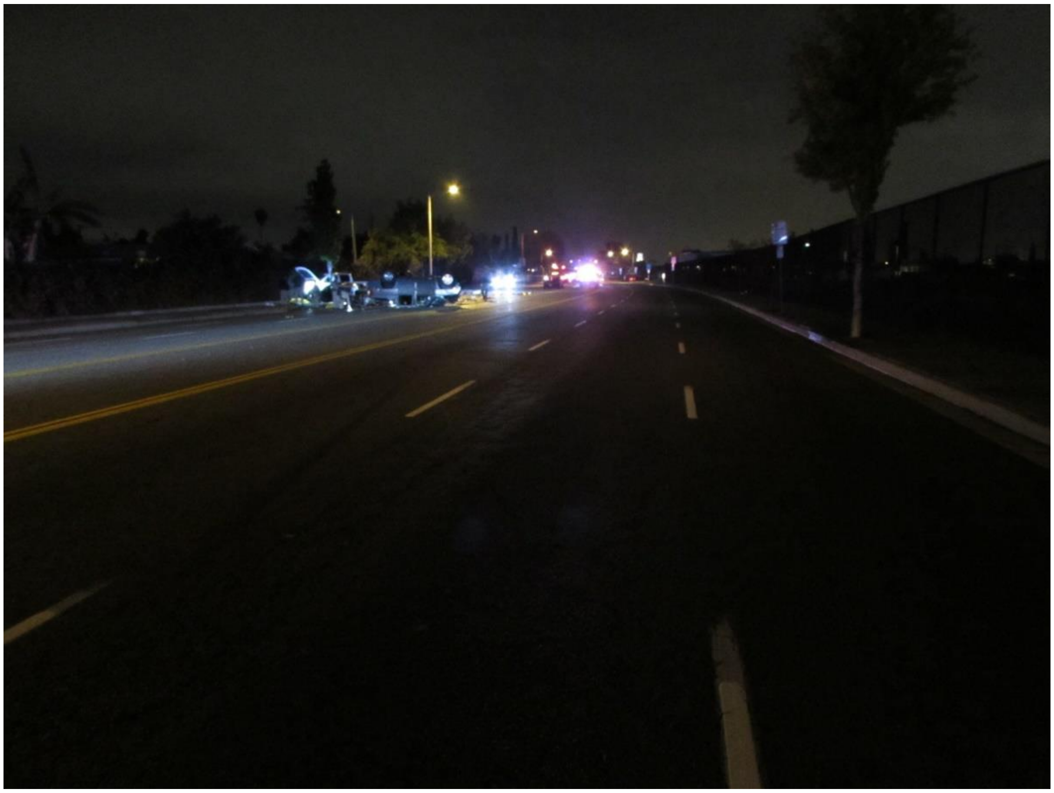

Figure 14. MTSS Case 286 Vehicle 1 Approach

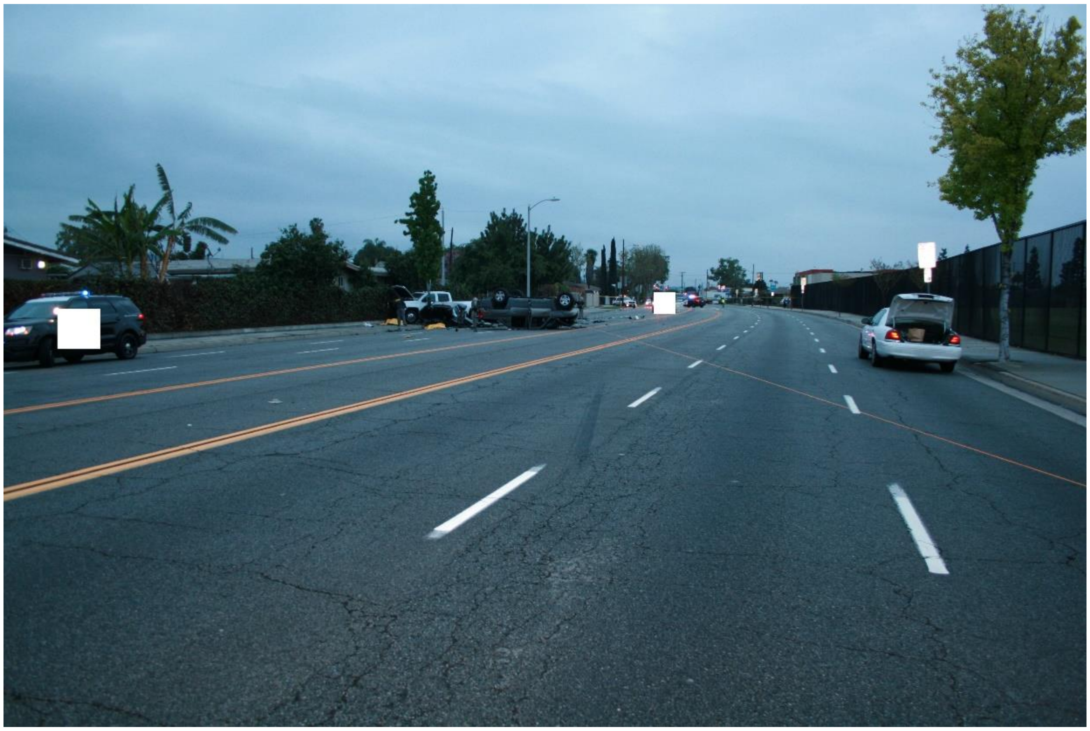

Figure 15. MTSS Case 286 Vehicle 1 Approach

Figure 16. MTSS Case 286 Vehicle 2 and Vehicle 3 Approach

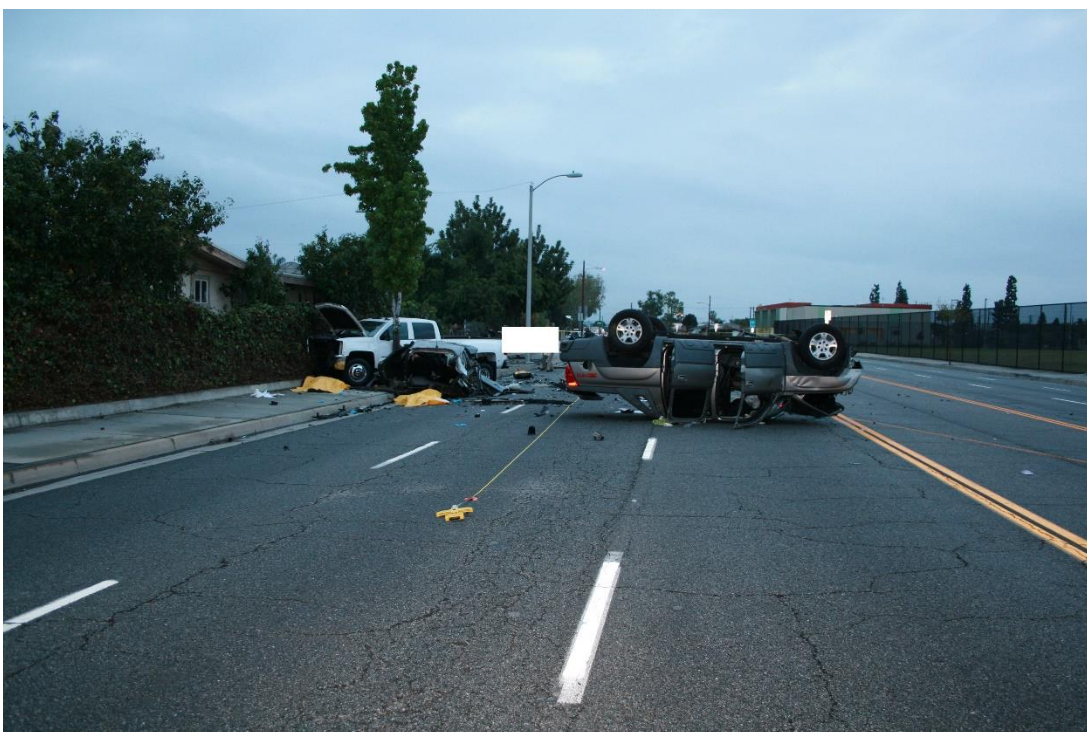

Figure 17. MTSS Case 286 Final Rest Facing East

Figure 18. MTSS Case 286 Final Rest Facing North

Figure 19. MTSS Case 286 Final Rest Facing East (Closeup)

The 28-year-old belted male driver of Vehicle 1 (Ford Fusion) had a blood alcohol concentration of .16 g/dL and was killed in the crash. The right front passenger in Vehicle 1, a 30-year-old male, also sustained fatal injuries. Of note, although the passenger was belted, he was ejected in the crash. The vehicle had a NHTSA safety recall (16V875000) from November 2016 that had not been completed. The recall summary stated, “driver and front passenger seat belt assemblies may not adequately restrain the occupant in a crash.” Police determined the passenger seat belt latch was secured in the buckle, with the seat belt still threaded through the latch. The seat belt showed signs of loading (cupping) and there were plastic burrs embedded in the seat belt fabric from the latch, and from the upper restraint loop. The lower seat belt anchor point was separated from the seat belt pretensioner. Images of the passenger seat belt are shown in Figure 20 and 21. The belted drivers of Vehicle 2 and Vehicle 3 sustained minor injuries.

Figure 20. MTSS Case 286 Vehicle 1 Passenger Seat Belt

Figure 21. MTSS Case 286 Vehicle 1 Passenger Seat Belt

Vehicle 3 (Chevrolet 3500-series) was a Class 3 medium truck with GVWR of 10,001 - 14,000 lbs. (4,536 - 6,350 kg). The pickup was owned and driven by a 53-year-old male with a valid basic driving license; the vehicle was not being used for commercial purposes. Police did not issue the pickup driver any citations and he was not tested for alcohol or drugs.

Table 3. MTSS Case 286 Precrash and Avoidance Assessment Coding

Vehicle 3 Medium Chevrolet Pickup Truck

Variable	**Precrash Case Coding**
Pre-Event Movement	Going straight
Critical Event Category	Other vehicle encroaching
Critical Event	From opposite direction
Attempted Avoidance	Unknown
Crash Type	(98) Other crash type
Critical Reason for the Critical Event Category	Critical event not coded to this vehicle
Critical Reason for the Critical Event	Critical event not coded to this vehicle
Critical Reason for Critical Event Assigned to Medium Truck	No
Variable	**Avoidance Equipment Assessment Coding**
Forward Collision Warning Helpful	Possible
Automatic Emergency Braking Helpful	Possible
Lane Departure Warning Helpful	No
Lane Keeping Support Helpful	No
Blind Spot Detection Helpful	No

Weighting

The initial MTSS sample is a simple random sample of size 400. To make total estimates from the sample about the target population of size 1,286, the estimates need to be "expanded" 1,286/400 = 3.215 times – this is the "design weight" of the initial 400 sampled cases. Design weight is the inverse of the selection probability. In the MTSS, 400 cases were randomly selected without replacement from the 1,286 cases in the frame. Therefore:

$$selection\_probability = \frac{400}{1{,}286} \approx 0.311$$

$$design\_weight = \frac{1{,}286}{400} = 3.215$$

Among the initial full sample of 400 selected cases, 219 of them responded with image files, resulting a unit response rate of 219/400 = 55%. In the MTSS, a sampled case becomes a unit non-responding case if the case didn't respond to the data request, or the PJ responded without images. MTSS data collection was performed during the pandemic. Among other reasons, many police jurisdictions were working with skeleton crews and did not have the manpower to search, collect, copy, and submit information for the MTSS.

Because of the unit non-response, the number of cases in the MTSS file that can be used for analysis dropped from 400 to 219. Therefore, another expansion through weight calculation is needed to compensate for the missing cases. This weight adjustment is called unit non-response adjustment. Similar to the selection probability and the design weight used to expand the initial sample to the population, we estimate the response probability and calculate the non-response adjustment factor to expand the 219 responded cases to the 400 cases in the initial sample.

It should be noted that non-response adjustment is necessary even for non-total estimates if the missing mechanism is correlated to the underlying study variables.

Estimating the response probability is much harder than calculating the selection probability because the non-response mechanism is beyond our control and is unknown. To estimate the response probability, we first created the following response status variable to the 400 cases in the initial sample as a dependent variable:

$$respondent\_ID = \begin{cases} 1, & if\ this\ case\ responded \\ 0, & otherwise \end{cases}$$

We then identified 17 potential independent variables to predict the response status. We run a stepwise logistic regression process to identify the significant predictors among the 17 potential predictors. The following three independent variables turned out to be significant.

- x_1: 1 if crash happened on a weekday, 0 otherwise
- x_2: 1 if at least one person not in the motor vehicle was involved
- x_3: 1 if the crash happened not at an intersection

The estimated response probability for each case in the initial full sample is estimated by:

$$response\_probability = \frac{exp\left(\hat{\beta}_0 + \sum_{i=1}^{3} \hat{\beta}_i * x_i\right)}{1 + exp\left(\hat{\beta}_0 + \sum_{i=1}^{3} \hat{\beta}_i * x_i\right)}$$

Here $\hat{\beta}_i$ $(i = 0, 1, 2, 3)$ were estimated from SAS SURVEYLOGISTIC procedure with the three identified significant predictors. All three coefficient estimates are highly significant (*p*-value less than 0.025). The Hosmer and Lemeshow goodness-of-fit test *p*-value for the same but unweighted model is about 0.87 – no indication of lack of fit. All pairwise Person correlation coefficients among the independent variables are less than 0.1. The estimated response probabilities were for the cases in the sample that were used to fit the model. In addition, what we need is a good prediction of the response propensity, and we are not evaluating the effect of individual predictor to the response propensity. Therefore, the collinearity among the predictors, if any, does not impose a problem. The logistic regression model with three main effects becomes the final model.

The non-response adjustment factor is then calculated using the final model as the inverse of the response probability for each case in the initial full sample.

$$non\_response\_adj = \frac{1 + exp\left(\hat{\beta}_0 + \sum_{i=1}^{3} \hat{\beta}_i * x_i\right)}{exp\left(\hat{\beta}_0 + \sum_{i=1}^{3} \hat{\beta}_i * x_i\right)}$$

For each of the 219 responded cases, the final analysis weight is the product of the design weight and the non-response adjustment factor.

$$weight = design\_weight * non\_response\_adj$$

The summation of the final weight variable over the 219 responded cases equals to 1,286.46 – almost identical to the population size: 1,286. No further weight adjustment was performed.

It should be noted if we treat the non-response as another phase of sample selection, then although the MTSS sample started as a simple random sample without replacement sample of size 400 with equal selection probabilities, the resulting sample is a without replacement sample of size 219 with unequal selection probabilities. This observation has implication to the estimation method we shall see next.

Table 4. Weighted Total Estimates Versus Population Counts

Variable	Label	Population Count		Sample Estimates				
					Variable Adjustment Weight		Constant Adjustment Weight	
		N	Sum	n	Sum	Std Error of Sum	Sum	Std Error of Sum
VE_TOTAL	Number of Vehicle Forms Submitted	1,286	2,755	219	2,748	89	2,766	86
VE_FORMS	Number of Vehicle Forms Submitted for MV In Transport	1,286	2,588	219	2,592	89	2,625	88
PEDS	Number of Forms Submitted for Persons Not in Motor Vehicles	1,286	250	219	264	47	211	37
PERSONS	Number of MV Occupant	1,286	3,894	219	4,116	245	4,169	250
FATALS	Fatalities	1,286	1,443	219	1,453	39	1,450	32
PERNOTMVIT	Number of Persons Not in Motor Vehicles In-Transport	1,286	299	219	297	50	241	40

The last two columns of Table 4 are estimates weighted by a constant adjusted weight 1,286/219 ≈ 5.87 for the 219 responded cases. This is equivalent to assuming the non-responding cases were missing completely at random and applying a constant non-response adjustment: 400/219 to the design weight of all responding cases: (1,286/400)*(400/219) = 1,286/219. The variable adjusted weight is the weight adjusted by the estimated response probability described in the previous section. Using the variable adjusted weight is equivalent to assuming the non-responding cases were missing at random conditioning on those three significant predictors identified in the previous section. The estimates weighted by the variable weight are mostly better than or similar to the estimates weighted by the constant adjustment weight 5.87. The standard error estimates show the non-response adjustment didn't inflate the variance dramatically. Therefore, it is sensible to use the variable adjusted weight in the MTSS data analysis.

As many sample surveys, MTSS suffers severe unit non-response. Even with the non-response adjustment, for study variables that are correlated with the missing mechanism, the weighted estimates made from the 219 responded cases may still have non-response bias.

Combining the information collected for the MTSS and the existing information that can be matched from the FARS, MTSS data have many variates. However, with total 219 respondent cases, sample size may easily become too small for small domain analysis. MTSS data users should always be aware that small domain sample size may result in unstable estimates.

Among the 219 responded cases, each case may have some variables with missing values. These are called item non-response. Like the unit non-response, severe item non-response without treatment may bias the estimates. Item non-response treatment should be study/analysis specific. As in other NHTSA surveys, MTSS item non-response is left for the data users to handle. For more information about unit and item non-response treatments, see Brick and Kalton (1996).

Table 5 presents estimates of some coded accident (crash) level variables of the MTSS. More estimates of other coded variables of the MTSS can be found in Appendix A.

Table 5. Accident Level Coded Variable Estimates

	Frequency	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent (%)**	**Std Err of Percent**
TRUCK_CRREASON Critical Reason for Critical Event Assigned to Truck					
Yes	94	542	40	42	3
No	125	744	42	58	3
Total	219	1,286	15	100	
TYP_INT Type of Intersection					
Not an Intersection	171	940	32	73	3
Four-Way Intersection	29	212	34	17	3
T-Intersection	16	113	25	9	2
Y-Intersection	2	15	10	1	1
Five Point, or More	1	6	5	0	0
Total	219	1,286	15	100	
MAN_COLL Manner of Collision					
Not a Collision with Motor Vehicle In-Transport	72	447	41	35	3
Front-to-Rear	40	215	28	17	2
Front-to-Front	41	223	29	17	2
Angle	52	327	37	25	3
Sideswipe - Same Direction	6	32	12	2	1
Sideswipe - Opposite Direction	5	28	11	2	1
Rear-to-Side	1	5	4	0	0
Other	1	5	5	0	0

	Frequency	Weighted Frequency	Std Err of Wgt Freq	Percent (%)	Std Err of Percent
Not Reported	1	5	5	0	0
Total	219	1,286	15	100	
ROUTE Route Signing					
Interstate	40	223	29	17	2
U.S. Highway	41	246	32	19	2
State Highway	72	421	38	33	3
County Road	24	142	25	11	2
Local Street - Township	4	22	10	2	1
Local Street - Municipality	17	100	22	8	2
Local Street - Frontage Road	1	7	7	1	1
Other	9	54	16	4	1
Unknown	11	71	20	6	2
Total	219	1,286	15	100	
FUNC_SYS Functional System					
Interstate	39	218	29	17	2
Principal Arterial - Other Freeways and Expressways	13	70	17	5	1
Principal Arterial - Other	74	449	40	35	3
Minor Arterial	37	207	29	16	2
Major Collector	35	209	30	16	2
Minor Collector	4	30	14	2	1
Local	17	103	22	8	2
Total	219	1,286	15	100	

For Vehicle level or Person level estimates, the clustering effect is negligible because the average number of cluster size (average number of vehicles per crash or average number of persons per crash) is small. For this reason, we use the same option "`rate=0.1703`" to approximate the standard error at vehicle and person level analysis. For example, the following SAS code produces vehicle level estimates of three coded variables.

```
proc surveyfreq data=vehicle rate=0.1703;
     tables crreason acc_type under_override;
     weight;
     run;
```

The results of this procedure can be found in Table 12 (CRREASON), 13 (ACC_TYPE), and 14 (UNDER_OVERRIDE) of Appendix A.

Estimation

To see how the adjusted weight behaves, we first identified some existing FARS variables and used the 219 responded cases to calculate the weighted point estimates and compared them to the corresponding population counts calculated from the frame file using the following SAS code.

```
/* Frame counts */
proc means data=frame n sum;
     title "Frame Estimates";
     var ve_total ve_forms peds persons fatals pernotmvit;
     run;

/* Weighted respondent estimates */
proc surveymeans data=responded_with_frame rate=0.1703 nobs sum;
     title "Weighted Sample Estimates";
     var ve_total ve_forms peds persons fatals pernotmvit;
     weight weight;
     run;
```

The "proc means" procedure simply sum up those frame variables unweighted over the 1,286 cases in the frame file "frame." The results are the population counts.

The "proc surveymeans" procedure is one of the SAS SURVEY procedures for complex survey data analysis. SAS SURVEY procedures takes the complex survey design feature such as unequal weighting, without replacement sampling, stratification, and clustering into account in the data analysis procedure. MTSS started with a SRSWOR sample, but the unit non-response adjustment resulted in unequal weighting. In addition, MTSS's sampling rate after response is 219/1,286 ≈ 17.03%. Ignoring high sampling rate leads to the overestimation of the standard error. Because of this, using the SAS SURVEY procedures or other specialized software such as SUDAAN or R survey data analysis package allows the users to get weighted point estimates and smaller standard error estimates by taking the unequal weights and without-replacement into account. For more details about complex survey data analysis concepts and examples, see Zhang et al. (2019, September).

In the "proc surveymeans" procedure, the input data file "`responded_with_frame`" contains the 219 responded cases along with the weight variable WEIGHT and variables from the frame. SAS's default design option is With Replacement (WR). The "`rate=0.1703`" option specifies the crash sampling rate and lets SAS calculate standard error assuming without-replacement. Without this option, SAS would calculate the standard error assuming with-replacement. PROC SURVEYMEANS uses this sampling rate to adjust standard error estimates. Table 10 in the Results Section summarizes the results.

Results

Complete MTSS results are available in SAS and CSV formats from NHTSA at https://www.nhtsa.gov/file-downloads?p=nhtsa/downloads/CISS/Special Studies/MTSS for statistical analysis. Below are noteworthy findings from the 219 MTSS cases. The target population is all 2018 in-scope crashes defined in Section 2. This was the most recent final FARS data available when the sample was selected. All estimates in this section are weighted unless otherwise specified.

Vehicle and Body Types

- Vehicle Type
  - From the 219 (unweighted) responded crashes, 471 (unweighted) total vehicles were involved in MTSS which represent total 2,748 vehicles in the target population (Table 15).
  - Among the 471 (unweighted) vehicles:
    - 228 (unweighted) medium trucks represent 1,334 medium trucks in the target population (Table 15), and
    - 243 (unweighted) other vehicles (any vehicle NOT a medium truck) represent 1,414 other vehicles in the target population (Table 15).
- Medium Truck Body Types (Appendix A, Table 15)
  - 42 percent of the medium trucks were medium pickup trucks (>10,000 lbs. GVWR)
  - 58 percent were single-unit straight truck or cab-chassis medium trucks

Avoidance Technologies

After reviewing the entire case, MTSS coders and NHTSA subject matter experts attempted to determine the likelihood the following five technologies, if present, would have been helpful in preventing or mitigating the severity of the crash.

- FCW
- AEB
- LDW
- LKS
- BSD

The evaluation of the likelihood the avoidance technology would be helpful was somewhat judgement-based and others reviewing the cases may have differing opinions.

The vehicle technologies involving braking systems, FCW and AEB, ultimately showed the same results. In short, if a warning (FCW) was determined to have been possibly or probably helpful, automatic intervention by the vehicle (AEB) would have the same likelihood of being beneficial as well. The same was true for the lane technologies, LDW and LKS.

- FCW and AEB (Appendix A, Table 17, and Table 18)
    - In 56 percent of the total estimated 2,748 vehicles involved in the fatal crashes, FCW and AEB, if available and not disabled, were deemed to have possibly or probably been effective in reducing the severity and/or preventing the crash.
        - In 62 percent of estimated 1,334 medium trucks, it was determined FCW and AEB would possibly or probably been effective
        - In 51 percent of estimated 1,414 other vehicles, it was determined FCW and AEB would possibly or probably been effective
- LDW and LKS (Appendix A, Table 19, and Table 20)
    - In 18 percent of the total estimated 2,748 vehicles involved in the fatal crashes, LDW and LKS, if available and not disabled, was deemed to have possibly or probably been effective in reducing the severity and/or preventing the crash.
        - In 14 percent of estimated 1,334 medium trucks, it was determined LDW and LKS would possibly or probably been effective
        - In 22 percent of estimated 1,414 other vehicles, it was determined LDW and LKS would possibly or probably been effective
    - For LDW and LKS technologies to be effective lane lines must be available on the roadway for cameras to detect.
        - Left lines were available (solid or dashed) for 86 percent of the MTSS-involved vehicles (Appendix A, Table 24)
        - Right lines were available (solid or dashed) for 82 percent of the MTSS-involved vehicles (Appendix A, Table 24)
- Blind Spot Detection (Appendix A, Table 21)
    - In less than 1 percent of the total vehicles involved in the fatal crashes, BSD, if available and not disabled, was deemed to have possibly or probably been effective in reducing the severity and/or preventing the crash.
        - 1 percent of medium trucks BSD effective
        - Less than 1 percent of other vehicles BSD effective

Eight of the 219 (unweighted) MTSS cases involved vehicles with FCW and/or LDW available on the vehicle. Seven of the 8 were available in light vehicles and not the medium truck. None of the material in these cases had any information on the status of the avoidance equipment, if it was on or off, or if the equipment activated during the crash. Because of the lack of information, one of the drawbacks of this study methodology, the assessment of avoidance technology effectiveness was handled in the same manner as vehicles that were not equipped with avoidance equipment. A summary of the MTSS evaluation of potential effectiveness of avoidance technologies is shown in Table 6.

Table 6. MTSS Avoidance Technology Potential Effectiveness Assessment

	Medium Truck	Other Vehicle
Braking Technologies (FCW and AEB)	62%	51%
Lane Technologies (LDW and LKS)	14%	22%
Blind Spot Detection (BSD)	1%	0%

Critical Reason

As described earlier in the Data Collection Section of this paper, Critical Reason for the Critical Event is one of the most important elements to analyze with respect to crash causation. Critical Reason for the Critical Event has been captured in two previous NHTSA in-depth crash causation studies, the LTCCS and the NMVCCS. It should be noted that although Critical Reason for Critical Event was collected in LTCCS, NMVCCS, and MTSS the crash population for each of the studies and methods used to collect the data are different. LTCCS criteria included crashes involving at least one large truck, defined as a truck with a GVWR of 10,001 pounds or more and the crash involved at least one fatality, incapacitating, or non-incapacitating but evident injury. Some of the qualifications for inclusion in NMVCCS were EMS dispatch, and one of the first three vehicles must be a towed light vehicle. MTSS population differed in that they were fatal crashes which involved a medium truck and relied solely on documentation provided by law enforcement to code the cases.

In MTSS the Critical Reason for the Critical Event was assigned to a medium truck in 42 percent of the crashes. This is lower than the 55 percent of trucks assigned the Critical Reason in LTCSS (Starnes, 2006). The type of Critical Reasons for medium trucks and the other involved vehicles in MTSS are shown in Table 7 below. The groupings of the Critical Reasons for the Critical Event can be found in Appendix C.

Table 7. Critical Reasons by Vehicle Type in MTSS

	Medium Truck Critical Reasons	Other Vehicle Critical Reasons
Driver-Related Critical Reason	91%	95%
Vehicle-Related Critical Reason	3%	1%
Environment-Related Critical Reason	4%	3%
Unknown Critical Reason	1%	1%

Table 8 displays the type of Critical Reason for the Critical Event in MTSS medium trucks, LTCCS trucks, and all NMVCCS crashes. The driver-related Critical Reasons for medium-truck drivers in MTSS was higher (91%) compared to those for truck drivers (87%) in LTCCS (Starnes, 2006) but lower than those found for drivers in NMVCCS (94%) (Singh, 2015). Although data is much more limited in MTSS versus the other in-depth causation studies, and MTSS is only fatal crashes versus fatal and injury crashes in LTCCS and NMVCCS, the takeaway would be the overall percentage of driver-related critical reasons in medium trucks (91%) falls between light vehicles (94%) and large trucks (87%).

Table 8. MTSS Medium Truck, NMVCCS, and LTCCS Truck Types of Critical Reason

	MTSS Medium Truck Critical Reasons	**NMVCCS All Drivers Critical Reasons**	**LTCCS Truck Critical Reasons**
Driver-Related Critical Reason	91%	94%	87%
Vehicle-Related Critical Reason	3%	2%	10%
Environment-Related Critical Reason	3%	2%	2%
Unknown Critical Reason	1%	2%	0%

Table 9 shows a breakdown of the medium-truck driver-related Critical Reasons in MTSS. It should be noted in some of the driver-related critical reason categories MTSS coders could assign the driver-related error to a broad category, but they were not able to get more specifics based on the information provided by law enforcement. For example, 34 percent of driver-related recognition errors were coded Unknown Driver Recognition Error as opposed to being able to pin down the specific form of recognition error (i.e., internal distraction, inattention, external distraction). These findings again reinforce that the methodology used in MTSS can provide valuable high-level data, but more-in-depth causation information requires specialized data collection efforts conducted by NHTSA-trained investigators. A complete breakdown of the Critical Reasons for the Critical Event is available in Appendix A, Table 12.

Table 9. Medium Truck Driver-Related Critical Reasons in MTSS

	Medium Truck Driver-Related Critical Reasons
Recognition Error	34%
Decision Error	23%
Performance Error	12%
Critical Non-Performance Error	10%
Unknown Type of Driver Error	21%

Table 10 displays the comparison between driver-related Critical Reasons in MTSS medium-truck drivers, all drivers in NMVCCS, and LTCCS truck drivers. While difficult to make precise comparisons because of the high percentage of unknown driver errors in MTSS, the high-level distribution of the types of driver errors in MTSS medium-truck drivers more closely aligns with NMVCCS drivers than LTCCS truck drivers. For MTSS truck drivers and NMVCCS the most common driver-related Critical Reason for cases where the information was known were recognition errors, followed by decision errors, performance errors, and lastly critical non-performance driver-related errors. For LTCCS truck drivers the most common driver-related errors were decision errors, followed by recognition errors, critical non-performance errors, and lastly performance errors. A potential explanation for the medium-truck driver Critical Reason distributions more closely resembling NMVCCS than LTCCS truck drivers is due to the large percentage of pickup trucks (42%) within the MTSSS population.

Table 10. Driver-Related Critical Reasons in MTSS, NMVCCS, LTCCS

	MTSS Medium Truck Drivers Driver-Related Critical Reasons	**NMVCCS All Drivers Driver-Related Critical Reasons**	**LTCCS Truck Drivers Driver-Related Critical Reasons**
Recognition Error	34% (Known Rank=1)	41% (Known Rank=1)	32% (Known Rank=2)
Decision Error	23% (Known Rank=2)	33% (Known Rank=2)	44% (Known Rank=1)
Performance Error	12% (Known Rank=3)	11% (Known Rank=3)	10% (Known Rank=4)
Critical Non-Performance Error	10% (Known Rank=4)	7% (Known Rank=4)	13% (Known Rank=3)
Unknown Type of Driver Error	21%	8%	0%

To summarize the Critical Reason for the Critical Event results in the MTSS crashes, medium-based pickup trucks and their drivers likely share some characteristics with light vehicles and some characteristics with large trucks.

Crash Characteristics

- Override/Underride (Appendix A Table 14)
    - 7 percent of the medium trucks in the study experienced override or underride
    - 8 percent of the other vehicles in the study had override or underride
- Rollover (Appendix A, Table 16)
    - 14 percent of medium trucks rolled over
    - 9 percent of the other involved vehicles rolled over

Speed

Table 11 shows the travel and impact speed for the medium trucks involved in MTSS. The travel speed was unknown or not reported for 52 percent of the medium trucks in the MTSS crashes, and the impact speed was unknown or not reported for 55 percent of the medium trucks. The high percentage of unknown speeds highlights the need for more-in-depth studies if details that require reconstructions are needed.

Table 11. Medium Truck Travel and Impact Speeds

	Speed	Frequency	Weighted Frequency	Std Err of Wgt Freq	Percent	Std Err of Percent
Travel Speed	0-5 mph	15	90	21	7%	0.77
	6-20 mph	10	69	20	5%	0.74
	21-35 mph	9	56	17	4%	0.62
	36-50 mph	24	138	26	10%	0.93
	Greater than 50 mph	49	287	36	21%	1.31
	Unknown or Not Reported	121	695	51	52%	1.84
	Total	228	1,334	60	100%	2.13
Impact Speed	0-5 mph	29	178	30	13%	1.08
	6-20 mph	11	76	21	6%	0.78
	21-35 mph	8	41	13	3%	0.48
	36-50 mph	21	124	24	9%	0.89
	Greater than 50 mph	32	186	29	14%	1.07
	Unknown or Not Reported	127	729	52	55%	1.88
	Total	228	1,334	60	100%	2.13

Conclusion

To gain more insight into medium-truck crashes, NHTSA conducted the Medium Truck Special Study (MTSS) based on a simple random sample of 400 fatal crashes involving a medium truck (GVWR 10,001 -26,000 lbs.) from the 2018 FARS data file. NHTSA requested all available information from the investigating law enforcement agency, in particular images of the crash scene and involved vehicles. Using the FARS variables as a base, the study incorporated additional elements from previous NHTSA causation and truck studies as well as elements designed specifically for MTSS. Although the COVID pandemic posed problems with collection of the information from police, ultimately images and other material for 219 cases were collected and coded.

Key findings from MTSS included the following.

- The Critical Reason for the Critical Event in the crash was assigned to a medium truck in 42 percent of the cases. This was less than the 55 percent of Critical Reasons assigned to large trucks in LTCCS (Starnes, 2006).
- Driver-related Critical Reasons for medium-truck drivers in MTSS was higher (91%) compared to those for truck drivers (87%) in LTCCS but lower than those found for all drivers in NMVCCS (94%) (Singh, 2015).
- 42 percent of the medium trucks in MTSS were pickup trucks, the remaining 58 percent were single-unit straight trucks or cab-chassis medium trucks
- In 56 percent of the total estimated vehicles involved in the fatal MTSS crashes, FCW and AEB, if available and not disabled, were deemed to have possibly or probably been effective in reducing the severity and/or preventing the crash.
- The braking technologies showed much higher potential than lane (18%) and blind spot (less than 1%) technologies.

Because medium trucks reside in the space between light passenger vehicles and heavy trucks, they present safety challenges. Medium trucks encompass a wide range of body styles and weights such as large pickups like the Ford F-350, pickup-based bodies with aftermarket cargo and/or storage areas, more traditional delivery trucks, and many others. In MTSS, 42 percent of the medium trucks were pickup-based, while the remaining 58 percent were single-unit straight trucks or cab-chassis medium trucks. This high percentage of pickups in MTSS likely describes why the Critical Reasons for the Critical Event more closely resemble NHTSA's light vehicle causation survey, NMVCCS, as compared to the large truck causation study, LTCCS. Efforts to reduce medium-truck crashes will likely need to incorporate countermeasures appropriate to the light passenger vehicle segment as well as those intended for heavy trucks.

MTSS study methodology, using existing databases supplemented by topic-specific variables coded from law enforcement documentation, proved to be effective in providing high-level information to NHTSA. The methodology was especially effective when short time frames and limited funding for data collection and analysis are required. However, reviewing the police material and images it's clear law enforcement and agency research-related goals are somewhat different. Police reconstruction reports sometimes delve into driver factors, but in most cases information in this important area was limited. None of the material in these cases had any information on the status of the avoidance equipment, if it was on or off, or if the equipment activated during the crash. For more in-depth details, additional data collection efforts would be required.

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Appendix A: More Estimates of Coded Variables

Table 12. Vehicle Level Coded Variable: Vehicle Type by Critical Reason for Critical Event

Table of truck_domain by CRReason						
truck_ domain	**CRReason**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	Critical event not coded to this vehicle	124	715.8535	50.6263	27.6173	1.9512
	Sleep, that is, actually asleep	1	5.4907	5.0013	0.2118	0.1930
	Heart attack or other physical impairment of the ability to act	0	.	.	.	.
	Other critical non-performance (specify)	2	12.8875	8.3820	0.4972	0.3232
	Unknown critical non-performance	2	13.0038	8.4672	0.5017	0.3265
	Internal distraction	7	38.3783	13.2986	1.4806	0.5134
	External distraction	0	.	.	.	.
	Inadequate surveillance (e.g., failed to look, looked but did not see)	1	5.4907	5.0013	0.2118	0.1930
	Unknown recognition error	9	55.5962	17.0634	2.1449	0.6571
	Too fast for conditions to be able to respond to unexpected actions of other roadway users (specify condition)	13	69.5789	17.5235	2.6843	0.6775
	Misjudgment of gap or other`s speed	4	29.9364	13.5886	1.1549	0.5229
	Following too closely to respond to unexpected actions	1	5.4907	5.0013	0.2118	0.1930
	Illegal maneuver	7	36.4720	12.5176	1.4071	0.4838
	Inadequate evasive action (e.g., braking only, not braking and steering)	0	.	.	.	.
	Aggressive driving behavior	5	26.6411	10.8367	1.0278	0.4185

Table of truck_domain by CRReason						
truck_ domain	CRReason	Frequency	Weighted Frequency	Std Err of Wgt Freq	Percent	Std Err of Percent
	Other decision error (specify)	0	.	.	.	.
	Unknown decision error	1	7.5132	6.8436	0.2899	0.2639
	Overcompensation	4	20.0001	9.1221	0.7716	0.3524
	Unknown performance error	1	7.3969	6.7377	0.2854	0.2598
	Type of driver error unknown	48	277.4113	35.0811	10.7024	1.3517
	Tires/wheels failed	1	4.5094	4.1075	0.1740	0.1585
	Other vehicle failure (specify)	0	.	.	.	.
	View obstructed by roadway design/furniture	1	7.5132	6.8436	0.2899	0.2639
	Slick roadways (low friction road surface due to ice, loose debris, any other cause)	0	.	.	.	.
	Other weather-related condition (specify)	0	.	.	.	.
	Glare	2	14.9101	9.5929	0.5752	0.3696
	Unknown reason for critical event	1	5.4907	5.0013	0.2118	0.1930
	Total	235	1360.0000	57.3054	52.4514	2.1889
Medium Truck	Critical event not coded to this vehicle	118	692.4082	51.1664	26.7128	1.9501
	Sleep, that is, actually asleep	4	25.0131	11.5845	0.9650	0.4465
	Heart attack or other physical impairment of the ability to act	2	10.9813	7.0650	0.4237	0.2726
	Other critical non-performance (specify)	1	5.4907	5.0013	0.2118	0.1930
	Unknown critical non-performance	1	7.5132	6.8436	0.2899	0.2639
	Internal distraction	8	48.8952	15.8782	1.8864	0.6118

Table of truck_domain by CRReason						
truck_ domain	**CRReason**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	External distraction	4	21.0843	9.6041	0.8134	0.3709
	Inadequate surveillance (e.g., failed to look, looked but did not see)	6	40.1055	15.0622	1.5473	0.5798
	Unknown recognition error	10	56.2199	16.1568	2.1689	0.6238
	Too fast for conditions to be able to respond to unexpected actions of other roadway users (specify condition)	10	54.9665	15.8311	2.1206	0.6114
	Misjudgment of gap or other`s speed	0	.	.	.	.
	Following too closely to respond to unexpected actions	3	15.6598	8.2559	0.6041	0.3187
	Illegal maneuver	3	16.4720	8.6431	0.6355	0.3336
	Inadequate evasive action (e.g., braking only, not braking and steering)	1	5.4907	5.0013	0.2118	0.1930
	Aggressive driving behavior	2	10.0000	6.4647	0.3858	0.2496
	Other decision error (specify)	1	5.4907	5.0013	0.2118	0.1930
	Unknown decision error	1	7.5132	6.8436	0.2899	0.2639
	Overcompensation	10	54.9066	15.6552	2.1183	0.6049
	Unknown performance error	1	4.5094	4.1075	0.1740	0.1585
	Type of driver error unknown	19	102.7580	21.1906	3.9644	0.8200
	Tires/wheels failed	2	12.8875	8.3820	0.4972	0.3232
	Other vehicle failure (specify)	1	4.5094	4.1075	0.1740	0.1585

Table of truck_domain by CRReason						
truck_ domain	**CRReason**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	View obstructed by roadway design/furniture	1	7.5132	6.8436	0.2899	0.2639
	Slick roadways (low friction road surface due to ice, loose debris, any other cause)	1	11.1136	10.1231	0.4288	0.3898
	Other weather-related condition (specify)	1	5.4907	5.0013	0.2118	0.1930
	Glare	0	.	.	.	.
	Unknown reason for critical event	1	5.4907	5.0013	0.2118	0.1930
	Total	212	1232.0000	57.8847	47.5486	2.1889
Total	Critical event not coded to this vehicle	242	1408.0000	57.7655	54.3301	2.1820
	Sleep, that is, actually asleep	5	30.5037	12.5978	1.1768	0.4856
	Heart attack or other physical impairment of the ability to act	2	10.9813	7.0650	0.4237	0.2726
	Other critical non-performance (specify)	3	18.3782	9.7472	0.7090	0.3759
	Unknown critical non-performance	3	20.5170	10.8704	0.7915	0.4189
	Internal distraction	15	87.2735	20.5423	3.3670	0.7920
	External distraction	4	21.0843	9.6041	0.8134	0.3709
	Inadequate surveillance (e.g., failed to look, looked but did not see)	7	45.5962	15.8450	1.7591	0.6099
	Unknown recognition error	19	111.8160	23.2502	4.3138	0.8958
	Too fast for conditions to be able to respond to unexpected actions of other roadway users (specify condition)	23	124.5454	23.3124	4.8049	0.9024

Table of truck_domain by CRReason						
truck_ domain	**CRReason**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Misjudgment of gap or other`s speed	4	29.9364	13.5886	1.1549	0.5229
	Following too closely to respond to unexpected actions	4	21.1505	9.6360	0.8160	0.3721
	Illegal maneuver	10	52.9440	15.1380	2.0426	0.5853
	Inadequate evasive action (e.g., braking only, not braking and steering)	1	5.4907	5.0013	0.2118	0.1930
	Aggressive driving behavior	7	36.6411	12.5792	1.4136	0.4861
	Other decision error (specify)	1	5.4907	5.0013	0.2118	0.1930
	Unknown decision error	2	15.0263	9.6674	0.5797	0.3725
	Overcompensation	14	74.9066	18.0059	2.8899	0.6967
	Unknown performance error	2	11.9063	7.8831	0.4593	0.3040
	Type of driver error unknown	67	380.1694	39.6694	14.6668	1.5333
	Tires/wheels failed	3	17.3969	9.3227	0.6712	0.3596
	Other vehicle failure (specify)	1	4.5094	4.1075	0.1740	0.1585
	View obstructed by roadway design/furniture	2	15.0263	9.6674	0.5797	0.3725
	Slick roadways (low friction road surface due to ice, loose debris, any other cause)	1	11.1136	10.1231	0.4288	0.3898
	Other weather-related condition (specify)	1	5.4907	5.0013	0.2118	0.1930
	Glare	2	14.9101	9.5929	0.5752	0.3696
	Unknown reason for critical event	2	10.9813	7.0650	0.4237	0.2726
	Total	447	2592.0000	20.0029	100	
Frequency Missing = 24						

Table 13. Vehicle Level Coded Variable: Vehicle Type by Crash Type

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No Impact	0	.	.	.	.
	Single Driver-Right Roadside Departure-Drive Off Road	2	12.8875	8.3820	0.4972	0.3232
	Single Driver-Right Roadside Departure-Control/Traction Loss	2	10.9813	7.0650	0.4237	0.2726
	Single Driver-Right Roadside Departure-Avoid Collision With Veh., Ped., Anim.	1	7.3969	6.7377	0.2854	0.2598
	Single Driver-Right Roadside Departure-Specifics Unknown	1	7.5132	6.8436	0.2899	0.2639
	Single Driver-Left Roadside Departure-Drive Off Road	2	14.7938	9.5178	0.5707	0.3668
	Single Driver-Left Roadside Departure-Control/Traction Loss	0	.	.	.	.
	Single Driver-Left Roadside Departure-Avoid Collision With Veh., Ped., Anim.	0	.	.	.	.
	Single Driver-Left Roadside Departure-Specifics Unknown	1	7.5132	6.8436	0.2899	0.2639
	Single Driver-Forward Impact-Parked Veh.	5	27.3970	11.3163	1.0570	0.4367
	Single Driver-Forward Impact-Sta. Object	1	5.5936	5.0951	0.2158	0.1966
	Single Driver-Forward Impact-Pedestrian/ Animal	4	29.8983	13.5732	1.1535	0.5224

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Single Driver-Forward Impact-End Departure	0	.	.	.	.
	Single Driver-Forward Impact-Specifics Other	1	7.3969	6.7377	0.2854	0.2598
	Same Trafficway, Same Direction-Rear End-Stopped	7	38.4945	13.3521	1.4851	0.5154
	Same Trafficway, Same Direction-Rear End-Stopped, Straight	15	79.5851	18.4755	3.0704	0.7151
	Same Trafficway, Same Direction-Rear End-Stopped, Left	1	7.5132	6.8436	0.2899	0.2639
	Same Trafficway, Same Direction-Rear End-Stopped, Right	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Rear End-Slower	5	24.5094	9.9875	0.9456	0.3860
	Same Trafficway, Same Direction-Rear End-Slower, Going Straight	9	51.4384	15.5747	1.9845	0.6011
	Same Trafficway, Same Direction-Rear End-Decelerating (Slowing)	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Rear End-Decelerating (Slowing), Going Straight	4	20.9813	9.5550	0.8095	0.3690
	Same Trafficway, Same Direction-Rear End-Specifics Other	1	4.5094	4.1075	0.1740	0.1585
	Same Trafficway, Same Direction-Angle, Sideswipe-	1	4.5094	4.1075	0.1740	0.1585

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Straight Ahead on Left					
	Same Trafficway, Same Direction-Angle, Sideswipe-Straight Ahead on Left/Right	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Angle, Sideswipe-Changing Lanes to the Left	2	10.9813	7.0650	0.4237	0.2726
	Same Trafficway, Same Direction-Angle, Sideswipe-Specifics Other	2	10.0000	6.4647	0.3858	0.2496
	Same Trafficway, Same Direction-Angle, Sideswipe-Specifics Unknown	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Opposite Direction-Head-On-Lateral Move (Left/Right)	27	140.5666	24.0084	5.4230	0.9328
	Same Trafficway, Opposite Direction-Head-On-Lateral Move (Going Straight)	9	48.4346	14.5979	1.8686	0.5642
	Same Trafficway, Opposite Direction-Head-On-Specifics Other	2	9.0188	5.8024	0.3479	0.2241
	Same Trafficway, Opposite Direction-Forward Impact-Avoid Collision With Vehicle	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Opposite Direction-	1	5.4907	5.0013	0.2118	0.1930

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Forward Impact-Avoid Collision With Vehicle					
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Lateral Move (Left/Right)	13	68.4347	17.1087	2.6402	0.6621
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Lateral Move (Going Straight)	6	32.9439	12.1818	1.2710	0.4704
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Specifics Other	3	16.4720	8.6431	0.6355	0.3336
	Trafficway Vehicle Turning-Turn Across Path-Initial Opposite Directions (Left/Right)	6	44.9627	16.6263	1.7346	0.6390
	Trafficway Vehicle Turning-Turn Across Path-Initial Opposite Directions (Going Straight)	5	37.5658	15.2339	1.4493	0.5859
	Trafficway Vehicle Turning-Turn Across Path-Initial Same Directions (Turning Left)	0	.	.	.	.
	Trafficway Vehicle Turning-Turn Across Path-Initial Same Directions (Going Straight)	1	4.5094	4.1075	0.1740	0.1585
	Trafficway Vehicle Turning-Turn Into Path-Turn Into	8	57.1015	18.4234	2.2029	0.7077

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Opposite Directions (Turning Left)					
	Trafficway Vehicle Turning-Turn Into Path-Turn Into Opposite Directions (Going Straight)	2	13.0038	8.4672	0.5017	0.3265
	Intersecting Paths-Straight Paths-Striking from the Right	6	41.3722	15.4223	1.5961	0.5935
	Intersecting Paths-Straight Paths-Struck on the Right	2	13.1729	8.5589	0.5082	0.3300
	Intersecting Paths-Straight Paths-Striking From the Left	2	13.1729	8.5589	0.5082	0.3300
	Intersecting Paths-Straight Paths-Struck on the left	6	37.6654	14.0638	1.4531	0.5419
	Other Crash Type	64	364.3298	38.8630	14.0557	1.5032
	Total	235	1360.0000	57.3054	52.4514	2.1889
Medium Truck	No Impact	2	10.9813	7.0650	0.4237	0.2726
	Single Driver-Right Roadside Departure-Drive Off Road	11	59.4196	16.4528	2.2924	0.6355
	Single Driver-Right Roadside Departure-Control/Traction Loss	3	16.4720	8.6431	0.6355	0.3336
	Single Driver-Right Roadside Departure-Avoid Collision With Veh., Ped., Anim.	0	.	.	.	.
	Single Driver-Right Roadside Departure-Specifics Unknown	0	.	.	.	.

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Single Driver-Left Roadside Departure-Drive Off Road	5	27.4533	11.1330	1.0591	0.4298
	Single Driver-Left Roadside Departure-Control/Traction Loss	2	10.9813	7.0650	0.4237	0.2726
	Single Driver-Left Roadside Departure-Avoid Collision With Veh., Ped., Anim.	1	4.5094	4.1075	0.1740	0.1585
	Single Driver-Left Roadside Departure-Specifics Unknown	0	.	.	.	.
	Single Driver-Forward Impact-Parked Veh.	3	20.3874	10.7815	0.7865	0.4155
	Single Driver-Forward Impact-Sta. Object	0	.	.	.	.
	Single Driver-Forward Impact-Pedestrian/ Animal	16	117.3888	26.9659	4.5288	1.0288
	Single Driver-Forward Impact-End Departure	1	5.6598	5.1554	0.2184	0.1989
	Single Driver-Forward Impact-Specifics Other	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Rear End-Stopped	13	71.6076	17.9856	2.7626	0.6949
	Same Trafficway, Same Direction-Rear End-Stopped, Straight	3	17.5132	9.3993	0.6757	0.3625
	Same Trafficway, Same Direction-Rear End-Stopped, Left	0	.	.	.	.
	Same Trafficway, Same Direction-Rear End-Stopped, Right	0	.	.	.	.

Table of truck_domain by ACC_TYPE						
truck_ domain	ACC_TYPE	Frequency	Weighted Frequency	Std Err of Wgt Freq	Percent	Std Err of Percent
	Same Trafficway, Same Direction-Rear End-Slower	9	50.4571	15.3166	1.9466	0.5913
	Same Trafficway, Same Direction-Rear End-Slower, Going Straight	5	23.5282	9.5748	0.9077	0.3702
	Same Trafficway, Same Direction-Rear End-Decelerating (Slowing)	4	20.9813	9.5550	0.8095	0.3690
	Same Trafficway, Same Direction-Rear End-Decelerating (Slowing), Going Straight	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Rear End-Specifics Other	1	4.5094	4.1075	0.1740	0.1585
	Same Trafficway, Same Direction-Angle, Sideswipe-Straight Ahead on Left	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Angle, Sideswipe-Straight Ahead on Left/Right	3	15.4907	8.1610	0.5976	0.3151
	Same Trafficway, Same Direction-Angle, Sideswipe-Changing Lanes to the Left	0	.	.	.	.
	Same Trafficway, Same Direction-Angle, Sideswipe-Specifics Other	2	10.0000	6.4647	0.3858	0.2496
	Same Trafficway, Same Direction-	1	5.4907	5.0013	0.2118	0.1930

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Angle, Sideswipe-Specifics Unknown					
	Same Trafficway, Opposite Direction-Head-On-Lateral Move (Left/Right)	7	37.4533	12.8342	1.4449	0.4958
	Same Trafficway, Opposite Direction-Head-On-Lateral Move (Going Straight)	25	129.5853	23.0604	4.9993	0.8956
	Same Trafficway, Opposite Direction-Head-On-Specifics Other	2	9.0188	5.8024	0.3479	0.2241
	Same Trafficway, Opposite Direction-Forward Impact-Avoid Collision With Vehicle	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Opposite Direction-Forward Impact-Avoid Collision With Vehicle	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Lateral Move (Left/Right)	5	27.4533	11.1330	1.0591	0.4298
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Lateral Move (Going Straight)	12	62.9440	16.4007	2.4284	0.6346
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Specifics Other	1	5.4907	5.0013	0.2118	0.1930

Table of truck_domain by ACC_TYPE						
truck_ domain	ACC_TYPE	Frequency	Weighted Frequency	Std Err of Wgt Freq	Percent	Std Err of Percent
	Trafficway Vehicle Turning-Turn Across Path-Initial Opposite Directions (Left/Right)	4	30.0526	13.6410	1.1594	0.5249
	Trafficway Vehicle Turning-Turn Across Path-Initial Opposite Directions (Going Straight)	5	37.4495	15.1871	1.4448	0.5841
	Trafficway Vehicle Turning-Turn Across Path-Initial Same Directions (Turning Left)	1	4.5094	4.1075	0.1740	0.1585
	Trafficway Vehicle Turning-Turn Across Path-Initial Same Directions (Going Straight)	0	.	.	.	.
	Trafficway Vehicle Turning-Turn Into Path-Turn Into Opposite Directions (Turning Left)	2	13.0038	8.4672	0.5017	0.3265
	Trafficway Vehicle Turning-Turn Into Path-Turn Into Opposite Directions (Going Straight)	8	57.1015	18.4234	2.2029	0.7077
	Intersecting Paths-Straight Paths-Striking From the Right	2	13.1729	8.5589	0.5082	0.3300
	Intersecting Paths-Straight Paths-Struck on the Right	6	41.3722	15.4223	1.5961	0.5935
	Intersecting Paths-Straight Paths-	6	37.6654	14.0638	1.4531	0.5419

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Striking From the Left					
	Intersecting Paths-Straight Paths-Struck on the left	2	13.1729	8.5589	0.5082	0.3300
	Other Crash Type	34	192.7534	29.3003	7.4363	1.1320
	Total	212	1232.0000	57.8847	47.5486	2.1889
Total	No Impact	2	10.9813	7.0650	0.4237	0.2726
	Single Driver-Right Roadside Departure-Drive Off Road	13	72.3071	18.3876	2.7896	0.7098
	Single Driver-Right Roadside Departure-Control/Traction Loss	5	27.4533	11.1330	1.0591	0.4298
	Single Driver-Right Roadside Departure-Avoid Collision With Veh., Ped., Anim.	1	7.3969	6.7377	0.2854	0.2598
	Single Driver-Right Roadside Departure-Specifics Unknown	1	7.5132	6.8436	0.2899	0.2639
	Single Driver-Left Roadside Departure-Drive Off Road	7	42.2471	14.5953	1.6299	0.5627
	Single Driver-Left Roadside Departure-Control/Traction Loss	2	10.9813	7.0650	0.4237	0.2726
	Single Driver-Left Roadside Departure-Avoid Collision With Veh., Ped., Anim.	1	4.5094	4.1075	0.1740	0.1585
	Single Driver-Left Roadside Departure-Specifics Unknown	1	7.5132	6.8436	0.2899	0.2639
	Single Driver-Forward Impact-Parked Veh.	8	47.7844	15.5635	1.8435	0.5999

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Single Driver-Forward Impact-Sta. Object	1	5.5936	5.0951	0.2158	0.1966
	Single Driver-Forward Impact-Pedestrian/ Animal	20	147.2871	29.9722	5.6823	1.1403
	Single Driver-Forward Impact-End Departure	1	5.6598	5.1554	0.2184	0.1989
	Single Driver-Forward Impact-Specifics Other	2	12.8875	8.3820	0.4972	0.3232
	Same Trafficway, Same Direction-Rear End-Stopped	20	110.1021	22.1699	4.2477	0.8572
	Same Trafficway, Same Direction-Rear End-Stopped, Straight	18	97.0983	20.6036	3.7460	0.7972
	Same Trafficway, Same Direction-Rear End-Stopped, Left	1	7.5132	6.8436	0.2899	0.2639
	Same Trafficway, Same Direction-Rear End-Stopped, Right	1	5.4907	5.0013	0.2118	0.1930
	Same Trafficway, Same Direction-Rear End-Slower	14	74.9666	18.1589	2.8922	0.7022
	Same Trafficway, Same Direction-Rear End-Slower, Going Straight	14	74.9666	18.1589	2.8922	0.7022
	Same Trafficway, Same Direction-Rear End-Decelerating (Slowing)	5	26.4720	10.7649	1.0213	0.4158
	Same Trafficway, Same Direction-Rear End-Decelerating (Slowing), Going Straight	5	26.4720	10.7649	1.0213	0.4158

Table of truck_domain by ACC_TYPE						
truck_domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Same Trafficway, Same Direction-Rear End-Specifics Other	2	9.0188	5.8024	0.3479	0.2241
	Same Trafficway, Same Direction-Angle, Sideswipe-Straight Ahead on Left	2	10.0000	6.4647	0.3858	0.2496
	Same Trafficway, Same Direction-Angle, Sideswipe-Straight Ahead on Left/Right	4	20.9813	9.5550	0.8095	0.3690
	Same Trafficway, Same Direction-Angle, Sideswipe-Changing Lanes to the Left	2	10.9813	7.0650	0.4237	0.2726
	Same Trafficway, Same Direction-Angle, Sideswipe-Specifics Other	4	20.0001	9.1221	0.7716	0.3524
	Same Trafficway, Same Direction-Angle, Sideswipe-Specifics Unknown	2	10.9813	7.0650	0.4237	0.2726
	Same Trafficway, Opposite Direction-Head-On-Lateral Move (Left/Right)	34	178.0199	26.8613	6.8679	1.0453
	Same Trafficway, Opposite Direction-Head-On-Lateral Move (Going Straight)	34	178.0199	26.8613	6.8679	1.0453
	Same Trafficway, Opposite Direction-Head-On-Specifics Other	4	18.0375	8.1873	0.6959	0.3165

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Same Trafficway, Opposite Direction-Forward Impact-Avoid Collision With Vehicle	2	10.9813	7.0650	0.4237	0.2726
	Same Trafficway, Opposite Direction-Forward Impact-Avoid Collision With Vehicle	2	10.9813	7.0650	0.4237	0.2726
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Lateral Move (Left/Right)	18	95.8880	20.2401	3.6993	0.7839
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Lateral Move (Going Straight)	18	95.8880	20.2401	3.6993	0.7839
	Same Trafficway, Opposite Direction-Angle, Sideswipe-Specifics Other	4	21.9626	9.9689	0.8473	0.3848
	Trafficway Vehicle Turning-Turn Across Path-Initial Opposite Directions (Left/Right)	10	75.0153	21.3889	2.8941	0.8199
	Trafficway Vehicle Turning-Turn Across Path-Initial Opposite Directions (Going Straight)	10	75.0153	21.3889	2.8941	0.8199
	Trafficway Vehicle Turning-Turn Across Path-Initial Same Directions (Turning Left)	1	4.5094	4.1075	0.1740	0.1585
	Trafficway Vehicle Turning-Turn Across	1	4.5094	4.1075	0.1740	0.1585

Table of truck_domain by ACC_TYPE						
truck_ domain	**ACC_TYPE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Path-Initial Same Directions (Going Straight)					
	Trafficway Vehicle Turning-Turn Into Path-Turn Into Opposite Directions (Turning Left)	10	70.1053	20.2077	2.7046	0.7758
	Trafficway Vehicle Turning-Turn Into Path-Turn Into Opposite Directions (Going Straight)	10	70.1053	20.2077	2.7046	0.7758
	Intersecting Paths-Straight Paths-Striking From the Right	8	54.5451	17.5805	2.1043	0.6761
	Intersecting Paths-Straight Paths-Struck on the Right	8	54.5451	17.5805	2.1043	0.6761
	Intersecting Paths-Straight Paths-Striking From the Left	8	50.8383	16.4072	1.9613	0.6318
	Intersecting Paths-Straight Paths-Struck on the left	8	50.8383	16.4072	1.9613	0.6318
	Other Crash Type	98	557.0831	45.9081	21.4920	1.7791
	Total	447	2592	20.00292	100	
Frequency Missing = 24						

Table 14. Vehicle Level Coded Variable: Underride/Override

Table of truck_domain by UNDER_OVERRIDE						
truck_ domain	**UNDER_OVERRIDE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No Underride or Override Noted	223	1,306.000	59.497	47.525	2.132
	Underriding a Motor Vehicle In-Transport, Underride, Compartment Intrusion	12	64.094	16.697	2.332	0.609
	Underriding a Motor Vehicle In-Transport, Underride, No Compartment Intrusion	1	5.491	5.001	0.200	0.182
	Underriding a Motor Vehicle In-Transport, Underride, Compartment Intrusion Unknown	2	10.981	7.065	0.400	0.257
	Underriding a Motor Vehicle Not In-Transport, Underride, Compartment Intrusion	1	5.491	5.001	0.200	0.182
	Overriding a Motor Vehicle In-Transport	4	21.963	9.971	0.799	0.363
	Total	243	1,414.000	59.227	51.456	2.134
Medium Truck	No Underride or Override Noted	211	1,242.000	59.865	45.181	2.127
	Underriding a Motor Vehicle In-Transport, Underride, Compartment Intrusion	5	29.476	12.069	1.073	0.439
	Underriding a Motor Vehicle In-Transport, Underride, No Compartment Intrusion	0	.	.	.	.
	Underriding a Motor Vehicle In-Transport, Underride, Compartment Intrusion Unknown	0	.	.	.	.

Table of truck_domain by UNDER_OVERRIDE						
truck_ domain	**UNDER_OVERRIDE**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
	Underriding a Motor Vehicle Not In-Transport, Underride, Compartment Intrusion	0	.	.	.	.
	Overriding a Motor Vehicle In-Transport	12	62.944	16.411	2.291	0.599
	Total	228	1,334.000	59.893	48.544	2.134
Total	No Underride or Override Noted	434	2,548.000	37.397	92.706	1.061
	Underriding a Motor Vehicle In-Transport, Underride, Compartment Intrusion	17	93.570	20.440	3.405	0.746
	Underriding a Motor Vehicle In-Transport, Underride, No Compartment Intrusion	1	5.491	5.001	0.200	0.182
	Underriding a Motor Vehicle In-Transport, Underride, Compartment Intrusion Unknown	2	10.981	7.065	0.400	0.257
	Underriding a Motor Vehicle Not In-Transport, Underride, Compartment Intrusion	1	5.491	5.001	0.200	0.182
	Overriding a Motor Vehicle In-Transport	16	84.907	19.075	3.090	0.697
	Total	471	2,748.000	20.852	100.000	

Table 15. Vehicle Level Coded Variable: Vehicle Type

Table of Medium Truck by Vehicle Type						
Medium Truck	**Vehicle Type**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	Buses	1	5.49065	5.00132	0.1998	0.182
	Large Trucks	24	139.5769	25.61053	5.0791	0.9318
	Light Trucks	90	533.862	47.03109	19.4267	1.6989
	Motorcycles	22	129.0643	25.0235	4.6965	0.9093
	Other Vehicles	1	7.39689	6.73767	0.2692	0.245
	Passenger Cars	104	593.1673	47.53919	21.5848	1.7371
	Unknown Body Type	1	5.49065	5.00132	0.1998	0.182
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	Single-unit straight truck or Cab-Chassis (GVWR range 10,001 to 19,500 lbs.)	98	572.1634	47.93325	20.8205	1.7356
	Single-unit straight truck or Cab-Chassis (GVWR range 19,501 to 26,000 lbs.)	35	202.3814	30.39371	7.3645	1.1061
	Medium/heavy Pickup (GVWR greater than 10,000 lbs.)	95	559.4896	48.00624	20.3593	1.7316
	Total	228	1334	59.89274	48.5442	2.1343

Table 16. Vehicle Level Coded Variable: *Vehicle Type by Rollover*

Table of Medium Truck by ROLLOVER						
truck_ domain	**ROLLOVER**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No Rollover	222	1293	59.04351	47.0391	2.1303
	Rollover, Tripped by Object/Vehicle	18	102.8804	22.04324	3.7437	0.8023
	Rollover, Untripped	2	13.00381	8.46771	0.4732	0.308
	Rollover, Unknown Type	1	5.49065	5.00132	0.1998	0.182
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	No Rollover	194	1147	59.45541	41.7321	2.1112
	Rollover, Tripped by Object/Vehicle	30	165.2377	26.89941	6.0128	0.9823
	Rollover, Untripped	4	21.96262	9.97067	0.7992	0.3631
	Rollover, Unknown Type	0	.	.	.	.
	Total	228	1334	59.89274	48.5442	2.1343
Total	No Rollover	416	2440	42.2726	88.7713	1.3202
	Rollover, Tripped by Object/Vehicle	48	268.1181	33.90373	9.7566	1.2385
	Rollover, Untripped	6	34.96643	13.04254	1.2724	0.4746
	Rollover, Unknown Type	1	5.49065	5.00132	0.1998	0.182
	Total	471	2748	20.85225	100	

Table 17. Vehicle Level Coded Variable: Vehicle Type by Forward Collision Warning

Table of Medium Truck by FwdCollisionWarning						
truck_ domain	**FwdCollision Warning**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No	119	699.6404	51.45169	25.4592	1.8611
	Possible	102	594.3933	48.34752	21.6294	1.7543
	Probable	22	120.0149	23.23043	4.3672	0.8472
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	No	86	507.7037	46.08487	18.4748	1.6659
	Possible	106	624.3264	49.99472	22.7186	1.8011
	Probable	36	202.0043	29.83855	7.3507	1.0888
	Total	228	1334	59.89274	48.5442	2.1343
Total	No	205	1207	59.30407	43.934	2.1206
	Possible	208	1219	59.38645	44.348	2.1226
	Probable	58	322.0192	36.66602	11.718	1.3412
	Total	471	2748	20.85225	100	

Table 18. Vehicle Level Coded Variable: Vehicle Type by Automatic Emergency Braking

Table of Medium Truck by AutomaticBraking						
truck_ domain	**Automatic Braking**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No	119	699.6404	51.45169	25.4592	1.8611
	Possible	102	594.3933	48.34752	21.6294	1.7543
	Probable	22	120.0149	23.23043	4.3672	0.8472
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	No	86	507.7037	46.08487	18.4748	1.6659
	Possible	106	624.3264	49.99472	22.7186	1.8011
	Probable	36	202.0043	29.83855	7.3507	1.0888
	Total	228	1334	59.89274	48.5442	2.1343
Total	No	205	1207	59.30407	43.934	2.1206
	Possible	208	1219	59.38645	44.348	2.1226
	Probable	58	322.0192	36.66602	11.718	1.3412
	Total	471	2748	20.85225	100	

Table 19. Vehicle Level Coded Variable: Vehicle Type by Lane Departure Warning

Table of Medium Truck by LaneDepartureWarning						
truck_ domain	**LaneDeparture Warning**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No	187	1107	58.68086	40.2647	2.0977
	Possible	20	108.9517	21.9844	3.9646	0.8021
	Probable	36	198.5887	29.30754	7.2264	1.071
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	No	194	1146	59.43874	41.7092	2.111
	Possible	7	37.4533	12.8386	1.3629	0.4679
	Probable	27	150.3768	25.87178	5.4721	0.9439
	Total	228	1334	59.89274	48.5442	2.1343
Total	No	381	2253	49.98552	81.974	1.5962
	Possible	27	146.405	25.17412	5.3275	0.9199
	Probable	63	348.9654	37.72061	12.6985	1.3827
	Total	471	2748	20.85225	100	

Table 20. Vehicle Level Coded Variable: Vehicle Type by Lane Keeping Support

Table of Medium Truck by LaneKeeping						
truck_ domain	**LaneKeeping**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No	187	1107	58.68086	40.2647	2.0977
	Possible	20	108.9517	21.9844	3.9646	0.8021
	Probable	36	198.5887	29.30754	7.2264	1.071
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	No	194	1146	59.43874	41.7092	2.111
	Possible	7	37.4533	12.8386	1.3629	0.4679
	Probable	27	150.3768	25.87178	5.4721	0.9439
	Total	228	1334	59.89274	48.5442	2.1343
Total	No	381	2253	49.98552	81.974	1.5962
	Possible	27	146.405	25.17412	5.3275	0.9199
	Probable	63	348.9654	37.72061	12.6985	1.3827
	Total	471	2748	20.85225	100	

Table 21. Vehicle Level Coded Variable: Vehicle Type by Blind Spot

Table of Medium Truck by BlindSpot						
truck_domain	**BlindSpot**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Others	No	242	1409	59.24633	51.256	2.1344
	Possible	1	5.49065	5.00132	0.1998	0.182
	Total	243	1414	59.22698	51.4558	2.1343
Medium Truck	No	225	1319	59.93862	47.9805	2.1337
	Possible	3	15.49069	8.1619	0.5637	0.2972
	Total	228	1334	59.89274	48.5442	2.1343
Total	No	467	2727	23.35602	99.2365	0.3481
	Possible	4	20.98134	9.55665	0.7635	0.3481
	Total	471	2748	20.85225	100	

Table 22. Person Level Coded Variable: Vehicle Driver Type by Alcohol Use

Table of MT_DRIVER by alcohol						
MT_DRIVER	**alcohol**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Medium Truck Driver	BAC= .00	62	370.94224	41.88601	8.4685	0.9531
	BAC= .01-.07	1	5.49065	5.00132	0.1253	0.1142
	BAC= .08+	25	137.95353	25.02620	3.1494	0.5724
	Unknown	122	709.07776	54.74455	16.1880	1.2472
	Total	210	1223	66.85885	27.9313	1.5199
Other Vehicle Driver	BAC= .00	86	498.24058	46.72672	11.3747	1.0674
	BAC= .01-.07	6	39.34965	14.73911	0.8983	0.3362
	BAC= .08+	29	164.67895	27.77519	3.7596	0.6346
	Unknown	113	651.80446	52.32421	14.8805	1.1960
	Total	234	1354	68.18714	30.9131	1.5594
Non-driver	BAC= .00	36	218.48731	33.17316	4.9880	0.7549
	BAC= .01-.07	1	4.50938	4.10750	0.1029	0.0938
	BAC= .08+	17	107.32756	23.82853	2.4503	0.5429
	Unknown	248	1472	71.42186	33.6144	1.6078
	Total	302	1803	75.14902	41.1556	1.6748
Total	BAC= .00	184	1088	64.83540	24.8312	1.4692
	BAC= .01-.07	8	49.34968	16.06843	1.1266	0.3666
	BAC= .08+	71	409.96004	42.92577	9.3593	0.9802
	Unknown	483	2833	73.09768	64.6829	1.6223
	Total	746	4380	26.96692	100.0000	

Table 23. Person Level Coded Variable: Vehicle Occupant Type by Drug Use

Table of MT_DRIVER by DRUGS						
MT_DRIVER	**DRUGS**	**Frequency**	**Weighted Frequency**	**Std Err of Wgt Freq**	**Percent**	**Std Err of Percent**
Medium Truck Driver	No (drugs not involved)	128	762.22460	57.23659	17.4013	1.2968
	Yes (drugs involved)	13	77.83707	19.68939	1.7770	0.4493
	Not Reported	57	316.54305	37.28541	7.2266	0.8542
	Reported as Unknown	12	66.85946	17.68881	1.5264	0.4041
	Total	210	1223	66.85885	27.9313	1.5199
Other Vehicle Driver	No (drugs not involved)	139	816.37550	57.88359	18.6376	1.3183
	Yes (drugs involved)	13	75.42003	19.16262	1.7218	0.4375
	Not Reported	54	301.57298	36.58840	6.8848	0.8377
	Reported as Unknown	28	160.70513	27.50281	3.6688	0.6282
	Total	234	1354	68.18714	30.9131	1.5594
Non-driver	No (drugs not involved)	45	283.97190	38.33928	6.4830	0.8694
	Yes (drugs involved)	5	29.56546	12.10650	0.6750	0.2764
	Not Reported	238	1388	69.17752	31.6912	1.5746
	Reported as Unknown	14	101.03041	24.82865	2.3065	0.5641
	Total	302	1803	75.14902	41.1556	1.6748
Total	No (drugs not involved)	312	1863	75.57735	42.5219	1.6819
	Yes (drugs involved)	31	182.82256	29.63574	4.1738	0.6763
	Not Reported	349	2006	73.42088	45.8026	1.6876
	Reported as Unknown	54	328.59501	40.13251	7.5017	0.9119
	Total	746	4380	26.96692	100.0000	

Table 24. Line Types

		Frequency	Weighted Frequency	Std Err of Wgt Freq	Percent	Std Err of Percent
Line_Type_Right	No Driver Present	1	5	5	0.2	0.18
	None	44	278	37	10.1	1.35
	Solid White	300	1720	57	62.6	2.08
	Solid Yellow	2	9	6	0.3	0.21
	Dotted/Dashed White	88	503	45	18.3	1.63
	Dotted/Dashed Yellow	2	12	8	0.4	0.29
	Unknown or Missing	34	221	34	8.0	1.22
	Total	471	2748	21	100	
Line_Type_Left	No Driver Present	1	5	5	0.2	0.18
	None	22	147	29	5.3	1.03
	Solid White	20	121	25	4.4	0.89
	Solid Yellow	196	1133	58	41.2	2.10
	Dotted/Dashed White	129	738	51	26.9	1.88
	Dotted/Dashed Yellow	68	377	39	13.7	1.43
	Unknown or Missing	35	227	34	8.2	1.23
	Total	471	2748	21	100	

Appendix B: MTSS Variables

CRASH

Math Analysis Case Number
FARS Case Number
Number of Vehicle Forms
Number of Occupant Forms
Crash Date
Crash Time
Relation to Junction
Type of Intersection
Relation to Trafficway
Work Zone
Light Conditions
Atmospheric Conditions
FARS Crash Related Factors
First Harmful Event
Manner of Collision
Accident Event Sequence Number
Sequence Vehicle # (This Vehicle)
Sequence Areas of Impact (This Vehicle)
Sequence of Events (SOE)
Sequence Vehicle # (Other Vehicle)
Sequence Areas of Impact (Other Vehicle)
Trafficway Identifier
Route Signing
Land Use and Functional System
Ownership
National Highway System
Special Jurisdiction
Milepoint
Global Position
Crash Notes

TRUCK

Vehicle Number
Number of Occupants
Unit Type
Travel Speed
Underride/Override
Vehicle Removal
Sequence of Events
Most Harmful Event
Vehicle Model Year
Vehicle Identification Number
Vehicle Make
Vehicle Model
Vehicle Body Type

GVWR
Vehicle Empty Weight – Power Unit/Cargo Body
Motor Carrier Authority / ID number
Vehicle Configuration
Cargo Body Type
Cargo Type
Cargo Weight
Cargo Spillage
Hazardous Material Involvement / Placard
Vehicle Trailing
Jackknife
Bus Use
Special Use
Emergency Motor Vehicle Use
FARS Vehicle Related Factors
Vehicle Condition Factors
Fire
Trailer Identification Number
Empty Weight – Trailer
Rollover
Location of Rollover
Number of Quarter Turns
Interrupted Roll
Pre-Rollover Maneuver
Rollover Initiation Type
Rollover Initiation Object Contacted Class
Rollover Initiation Object Contacted
Direction of Initial Roll
Estimated Distance From Trip to Final Rest (in meters)
Plane in Contact with Ground at Final Rest
Exterior Mirror Locations
Field of View Restriction/Blind Spots Related
Was Truck Sight Line to the Other Vehicle Clear
Was Truck View of The Other Vehicle Obscured
Did Cab/Passenger Compartment Separate From Chassis
Area of Greatest Cab/Passenger Compartment Intrusion
Retroreflective Tape Power Unit/Cargo Body
Retroreflective Tape Trailer
Rear Underride Guard Power Unit/Cargo Body
Rear Underride Guard Trailer
Side Underride Guard Power Unit/Cargo Body
Side Underride Guard Trailer
FMCSA/MCSAP Truck Inspection Conducted
Brake Inspection Conducted
Presence Of ESC
Presence of RSC

EDR Equipped/Obtained
Avoidance Equipment Available
Avoidance Equipment Notes
Impact Speed
Source of Speed and Distance Estimates
Truck Notes

OTHER VEHICLE

Vehicle Number
Number of Occupants
Unit Type
Travel Speed
Underride/Override
Vehicle Removal
Sequence of Events
Most Harmful Event
Rollover
Rollover Initiation Location
Vehicle Model Year
Vehicle Identification Number
Vehicle Make
Vehicle Model
Vehicle Body Type
FARS Vehicle Related Factors
Fire
EDR Equipped/Obtained
Avoidance Equipment Available
Avoidance Equipment Notes
Impact Speed
Source of Speed and Distance Estimates
Other Vehicle Notes

PRECRASH

Vehicle Number-Precrash Level
Contributing Circumstances, Motor Vehicle
Trafficway Description
Total Lanes in Roadway
Speed Limit
Roadway Alignment
Roadway Grade
Roadway Surface Type
Roadway Surface Condition
Traffic Control Device
Traffic Control Device Functioning
Initial Travel Lane
Driver’s Vision Obscured By
Driver Distracted

Pre-Event Movement
Critical Pre-Crash Category
Critical Pre-Crash Event
Attempted Avoidance Maneuver
Pre-Impact Stability
Pre-Impact Location
Crash Type
Critical Reason for Critical Event
Shoulder Surface Type
Shoulder Width
Rumble Strip Initial Travel Lane
Rumble Strip Road
Line Type Right
Line Type Left
Roadway Related Factors
Weather Related Factors
Other Environmental Factors
Traffic Flow Interruption Factors
Driver Fatigue
Driver Illness
Pre First Harmful Event Maneuver (PRE-FHE)
Precrash Notes

DRIVER
Vehicle Number - Driver Level
Driver Presence
Driver Zip Code
Violations Charged
Speeding Related (FARS definition)
Condition (Impairment) at Time of Crash
FARS Driver-Related Factors
Non-CDL License Type / Status
Commercial Motor Vehicle License Status
Compliance with CDL endorsements
License Compliance With Class of Vehicle
Compliance With License Restrictions
Driver Height
Driver Weight
Previous Recorded Crashes
Previous Recorded Suspensions, Revocations, and Withdrawals
Previous DWI Convictions
Previous Speeding Convictions
Previous Other Moving Violation Convictions
Date of First Crash, Suspension, Conviction
Date of Last Crash, Suspension, Conviction
Driver Notes

PERSON

Vehicle Number- Person Level
Person Number
Age
Sex
Person Type
Injury Severity
Seating Position
FARS Person Related Factors
Restraint Usage
Air Bag Deployed
Ejected
Ejection Path
Extrication
Police-Reported Alcohol Involvement
Alcohol Test Status / Type / Result
Police Reported Drug Involvement
Drug Toxicology Status / Specimen / Results
Person Notes

PERSON (Not a Motor Vehicle Occupant)

Vehicle Number- Person Level
Person Number
Age
Sex
Person Type
Injury Severity

AVOIDANCE

Critical Reason for Critical Event Assigned to Medium Truck
Forward Collision Warning Helpful- Medium Truck
Automatic Emergency Braking Helpful- Truck
Lane Departure Warning Helpful- Medium Truck
Lane Keeping Support Helpful- Medium Truck
Blind Spot Helpful- Medium Truck
Forward Collision Warning Helpful- Other Vehicles
Automatic Emergency Braking Helpful- Other Vehicles
Lane Departure Warning Helpful- Other Vehicles
Lane Keeping Support Helpful- Other Vehicles
Blind Spot Helpful- Other Vehicles
Avoidance Assessment Notes

Appendix C: Critical Reason for Critical Event Element

(000) Critical event not coded to this variable

DRIVER RELATED FACTOR:

Critical Non-Performance Errors

(100) Sleep, that is, actually asleep
(101) Heart attack or other physical impairment of the ability to act
(108) Other critical non-performance (specify): __________
(109) Unknown critical non-performance

Recognition Errors

(110) Inattention (i.e., daydreaming)
(111) Internal distraction
(112) External distraction
(113) Inadequate surveillance (e.g., failed to look, looked but did not see)
(118) Other recognition error (specify): __________
(119) Unknown recognition error

Decision Errors

(120) Too fast for conditions to be able to respond to unexpected actions of other roadway users (specify condition): __________
(121) Too slow for traffic stream
(122) Misjudgment of gap or other's speed
(123) Following too closely to respond to unexpected actions
(124) False assumption of other roadway user's actions
(125) Illegal maneuver
(126) Failure to turn on head lamps
(127) Inadequate evasive action (e.g., braking only, not braking and steering)
(128) Aggressive driving behavior
(138) Other decision error (specify): __________
(139) Unknown decision error

Performance Errors

(141) Panic/Freezing
(142) Overcompensation
(143) Poor directional control (e.g., failing to control vehicle with skill ordinarily expected
(148) Other performance error (specify): __________
(149) Unknown performance error
(199) Type of driver error unknown

VEHICLE RELATED FACTOR:

(200) Tires/wheels failed
(201) Brakes failed
(202) Steering failed
(203) Cargo shifted
(204) Trailer attachment failed
(205) Suspension failed

(206) Lights failed
(207) Vehicle related vision obstructions
(208) Body, doors, hood failed
(209) Jackknifed
(298) Other vehicle failure (specify): __________
(299) Unknown vehicle failure

ENVIRONMENT RELATED FACTOR:
Highway Related
(500) Signs/signals missing
(501) Signs/signals erroneous/defective
(502) Signs/signals inadequate
(503) View obstructed by roadway design/furniture
(504) View obstructed by other vehicles
(505) Roadway design – roadway geometry (e.g., ramp curvature)
(506) Roadway design – sight distance
(507) Roadway design – other
(508) Maintenance problems (potholes, deteriorated road edges, etc.)
(509) Slick roadways (low friction road surface due to ice, loose debris, any other cause)
(518) Other highway-related condition (specify): ___________

Weather Related
(521) Rain, snow
(522) Fog
(523) Wind gust
(528) Other weather-related condition (specify): ___________

Other
(530) Glare
(531) Blowing debris
(538) Other sudden change in ambience (specify): ___________
(999) Unknown reason for critical event

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