A STUDY OF NMVCCS TO IDENTIFY CRITICAL PRECRASH FACTORS IN FATAL CRASHES

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ABSTRACT

A NHTSA paper published in 2009, "Fatalities in Frontal Crashes Despite Seat Belts and Air Bags" [1] found that around 40% of crashes in a study of National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) frontal fatal crashes with a belted occupant and frontal air bag were exceedingly severe. The paper concluded that once an occupant of a light vehicle is involved in a crash of this magnitude, chances for survival based on current crashworthiness practices are slim. Therefore, the most effective way to prevent fatalities of this type from occurring would be through avoiding or mitigating the severity of the crash.

To expand upon that analysis, the intent of this study is to identify and prioritize the factors involved in fatal crashes and assess the potential effectiveness of emerging or existing technologies that may have prevented or lessened the severity of the crash. The study was conducted by a multidisciplinary team of NHTSA crash investigators, engineers and a statistician who analyzed real-world fatal crashes found in the National Motor Vehicle Crash Causation Survey (NMVCCS).

NMVCCS was a nationally representative survey conducted by NHTSA from 2005-2007. Trained researchers conducted on-scene investigations on nearly 7,000 crashes during the project, focusing on the precrash phase of the crash. The ability to investigate the selected crashes on-scene, in most cases within minutes, allowed the researchers to make better assessments of the events that led up to the crash. The survey collected up to 300 data elements on the driver, vehicle, and environment. Important components of NMVCCS were based on a methodology originally outlined by Kenneth Perchonok [2], including coding of the critical event, critical reason, and the associated factors that were present at the time of the crash.

During this study the NHTSA team conducted in-depth clinical analysis of each of the fatal crashes collected in NMVCCS, assigning the critical and secondary factors that led to the crash. The team also identified potential crash prevention measures at the driver, vehicle, and environmental levels. The results indicate that crash avoidance technologies including lane departure warning/lane keeping, ESC, alcohol detection, and auto/assisted braking could have been beneficial in preventing many of the fatalities.

INTRODUCTION

There have been considerable crashworthiness improvements in the light vehicle fleet over the past decade as evidenced by the 2009 fatality rates dropping to the lowest levels since 1950 [3]. With a high percentage of vehicles performing very well in NHTSA's New Car Assessment Program (NCAP) and the Insurance Institute for Highway Safety consumer information crash test programs along with seat belt usage estimates at 84% [4] a logical next step in addressing fatalities on the nation's roads appears to be in the area of crash avoidance. Technologies such as lane departure warning, auto/assisted braking (e.g., forward collision warning), and electronic stability control (ESC), are making their way into the current fleet, and being encouraged through NHTSA's 2011 NCAP. Assessing crashes that might be candidates for these technologies are important in their evaluation.

After examining the available data sources for a study focusing on causal factors in fatal crashes, the team selected NMVCCS as the best source for an in-depth clinical analysis. NMVCCS used trained researchers at 24 nationally-representative locations across the country and initiated cases based on a series of notification criteria, with the key components including at least one towed light vehicle, EMS dispatch, and the ability of the researcher to perform an on-scene investigation.

NMVCCS was based on a methodology similar to the Large Truck Crash Causation Study (LTCCS) which was conducted by the Federal Motor Carrier Safety Administration (FMCSA) and NHTSA from 2001-2003. An evaluation of crash avoidance countermeasures for medium/heavy trucks using LTCCS was conducted in 2009 [5] and yielded findings comparable to those found in this study.

In NMVCCS, due to the researcher's unique on-scene perspective, the precrash variables including pre-event movement, critical event, avoidance maneuver, and crash type were able to be coded with a high degree of accuracy. Additionally, NMVCCS collected a multitude of information on the associated factors in the crash including the driver's condition, recognition, decision, performance, and emotional factors. Factors associated with the vehicle, highway, and environment were collected as well.

The critical precrash 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. NMVCCS coding of the critical reason, which is the immediate reason and the failure that led to the critical event [6], also proved to be a valuable tool in this analysis. Although the critical event and critical reason are important parts of the description of the crash, they do not imply the cause of the crash or assignment of fault. The primary purpose of the variables is to enhance the description of events and allow analysts to better analyze similar events [7]. The critical reason for the critical event, which is typically assigned to one party in a crash, was attributed to driver related factors in 94% of the crashes in the case study as shown in Figure 1.

Table 1 shows the critical event for vehicles in the fatal study that were assigned the critical reason by the NMVCCS researcher; many appear to be prime candidates for crash avoidance technologies.

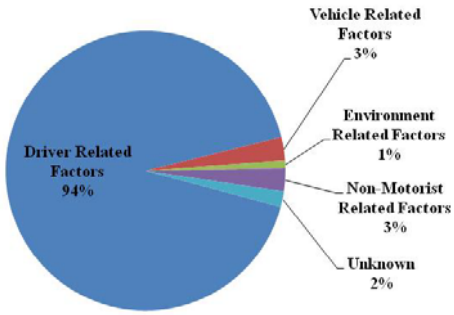

Figure 1
Critical Reason Coded in NMVCCS
(Percentages rounded)

Table 1
Critical Event for Vehicles Assigned the Critical Reason in NMVCCS
(Percentages rounded)

Critical Event Category	Critical Event	%
This Vehicle Traveling	Off the edge of the road on the right side	20%
This Vehicle Traveling	Off the edge of the road on the left side	18%
This Vehicle Traveling	Over the lane line on left side of travel lane	17%
This Vehicle Traveling	Turning left at intersection	9%
This Vehicle Control Loss Due to	Traveling too fast for conditions	8%
This Vehicle Traveling	Crossing over (passing through) intersection	7%
Other Vehicle in Lane	Traveling in same direction with lower steady speed	3%
This Vehicle Control Loss Due to	Unknown cause of control loss	3%
Pedestrian, Pedacyclist	Pedestrian in roadway	3%
This Vehicle Control Loss Due to	Blow out/flat tire, (specify) :	2%
This Vehicle Traveling	End departure	2%
Other Vehicle Encroachment	From crossing street, across path	2%
This Vehicle Control Loss Due to	Poor road conditions (puddle, pot hole, ice, etc.)	2%
Other Vehicle Encroachment	From adjacent lane (same direction) - over left lane line	1%
Other Vehicle Encroachment	From adjacent lane (same direction) - over right lane line	1%
This Vehicle Control Loss Due to	Non-disabling vehicle problem (e.g., hood flew up)	1%
Other Vehicle in Lane	Traveling in opposite direction	1%
This Vehicle Traveling	Turning right at intersection	1%
Other Vehicle in Lane	Traveling in same direction while decelerating	1%
Other	Other (specify) :	1%

METHOD

This study analyzed the 119 fatal crashes collected by NMVCCS during its three-year duration and was not limited to crash type. The cases were examined by a team consisting of engineers (crashworthiness, crash avoidance, human factors), crash investigators, and a statistician. The majority of the team members also participated in a previous clinical study of real-world crashes published in 2009. The previous study reviewed the factors affecting fatalities of air bag and restrained occupants in frontal crashes [8], and the group elected to use a similar case analysis strategy that was effective in that study. Since the objective of the study required more detailed information than could be extracted from the coded NMVCCS variables alone, the team developed a case review template to capture important information found in the scene diagram, scene and vehicle photographs, coded data, and narrative crash summary. The team also cross-referenced the NMVCCS data with alcohol/drug testing results, and driver license/history information from the corresponding case in the Fatal Analysis Reporting System (FARS). Each team member individually reviewed a subset of the cases and prepared a summary, using the review template as a guide. The team then met and reviewed each case in-depth, reaching a consensus on the critical and secondary factors that led to the crash. In addition, the group identified crash prevention measures that may have been applicable to the vehicle, driver, and environment.

Factors related to the fatal crashes were deemed critical or secondary, depending on the nature of their causative effects. Only one critical factor was assigned to each case, but in most cases there were multiple secondary factors cited. A factor was assessed to be critical if the absence of the factor would have prevented the fatal event. The ability to relegate a factor to secondary status allowed the team to capture the essentials of the case without diluting the importance of the factor considered most significant to the initiation of the fatal crash. However, in some cases determining which of the factors present would be assigned the critical factor proved difficult. For example, several cases involved drivers with very high Blood Alcohol Concentrations (BAC's) that were also speeding at the time of the crash. The team considered these on a case-by-case basis, but in most situations the team selected alcohol as the critical factor and speeding a secondary factor.

Although typically not considered when assessing crash avoidance, the team elected to include not wearing a seat belt/not using a child restraint, and no valid drivers license as secondary factors in the crashes. The team's crashworthiness background crept into the study when reviewing the cases, theorizing that some of the cases would not have been fatal, thus not qualifying for the study, had the fatal occupant been restrained. Similarly, drivers without a valid license should in theory not be on the road in the first place.

Crash prevention measures were assigned for each case using the basic mindset of, "How could this crash have been avoided?" Technological features on the vehicle, driver's behavior or actions, and environmental modifications were all considered, and in most crashes multiple prevention measures were chosen. A conservative approach was applied when assigning crash avoidance features limiting them to technologies that are already available, or slated to deploy in the near-term.

Results

During the reviews, it became apparent that a small number of the cases did not fit the study criteria and were thus excluded from the study. Examples include crashes that involved law enforcement intervention and drivers that were fatal due to heart attacks immediately prior to a minor crash. Eight cases were deleted from the original set leaving 111 for analysis. In the 111 fatal cases analyzed in the study there were 125 total persons killed, 112 light vehicle occupants, 9 motorcycle occupants, and 4 nonmotorists. A histogram of the age of the driver or nonmotorist assigned the critical reason by the NMVCCS researcher is shown in Figure 2.

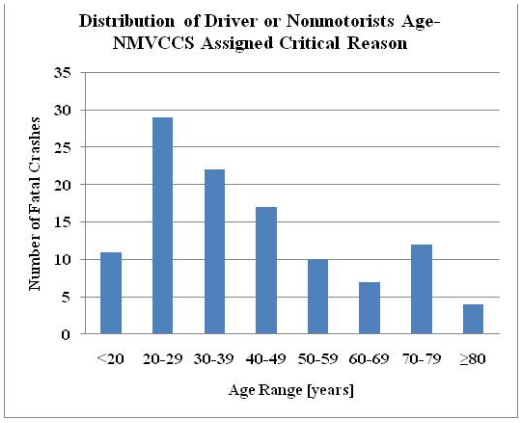

Figure 2
Distribution of Driver or Nonmotorist Age
NMVCCS Assigned Critical Reason

Figure 3 shows the rounded percentage distribution of the critical factor assigned to each of the 111 crashes by the review team.

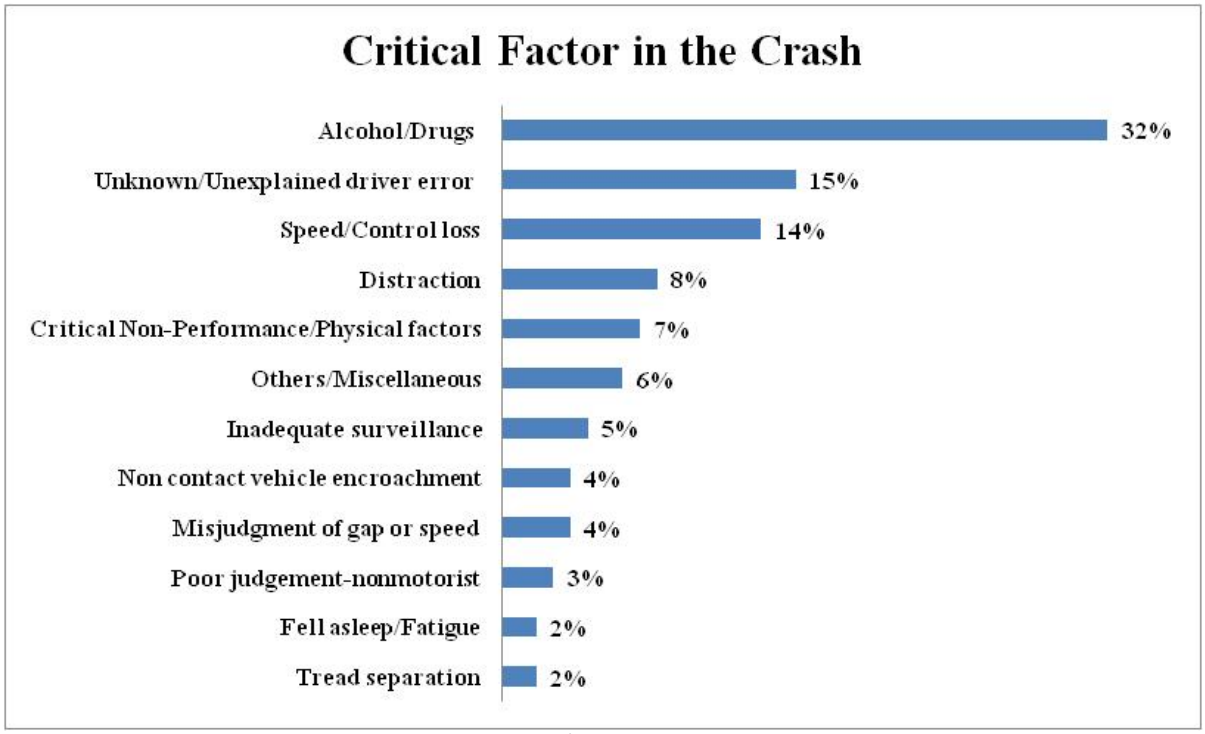

Figure 3
Assigned Critical Factor

A total of 168 secondary factors were also listed in the crashes. Multiple secondary factors were coded in some cases. Table 3 displays the frequency of all 279 factors selected by the team.

Findings from the NMVCCS analysis show that in 80% of the crashes, countermeasures on the vehicle may have helped prevent the crash. The five most common vehicle crash prevention technologies and the percentage of cases they could have been effective in are listed in Table 2. Multiple technologies were beneficial in many crashes.

Table 2
Common Vehicle Crash Prevention Technologies
Percentage of cases

Vehicle Crash Prevention Technology	%
Electronic Stability Control	32%
Lane Departure Warning/Lane Keeping	32%
Alcohol Detection	27%
Auto/Assisted Braking	23%
Distracted/Drowsy Driver Technology	7%

Table 3
All Factors

Speed/Control loss	46
Alcohol/Drugs	45
No Seat belt/Child restraint usage	32
No valid license	29
Unknown/Unexplained driver error	19
Vehicle factor	17
Illegal maneuver/Aggressive	14
Critical non-performance/Physical factors/Medical conditions	13
Environmental factor	11
Distraction	9
Driver performance/Overcompensation	9
Inadequate surveillance	7
Feel Asleep/Fatigue	7
Non contact vehicle encroachment	6
Misjudgment of Gap or speed	4
Decision error/Poor judgement	3
Poor judgement-nonmotorist	3
Inexperience	2
No helmet use	1
Occupant not in seat	1
Unfamiliar roadway	1
Total factors	279

Discussion

Critical Factors

Alcohol/Drugs (32%) was by far the most common critical factor cited by the team during the case review process (See Figure 3). Alcohol accounted for 22 critical factors, drugs 4, and a combination of alcohol and drugs in 9 of the cases. It is important to note that the team did not arbitrarily assign alcohol/drugs as the critical factor merely due to its presence in the crash. In addition to the 35 cases where alcohol/drugs were assigned the critical factor, there were 10 cases where it was a secondary factor, making alcohol/drugs a factor in 41% of the cases. In the cases with alcohol/drugs as the critical factor and the BAC was known, the average BAC was 0.20. Almost three-quarters (72%) of the drivers were more than double the .08 legal-limit.

Another critical factor listed which has received significant attention in recent years is distraction. Distraction was deemed the critical factor in 8% of the reviewed fatal NMVCCS cases. While this figure seems comparatively low to the 16% distraction-reported fatality numbers in recent statistics released by NHTSA [9] it should be noted that the team selected unknown/unexplained driver error as the critical factor in an additional 15% of the cases. Many of these cases showed characteristics of distraction crashes, however, it could not be determined definitively based on the available information, therefore the team decided to err on the conservative side. Determining distraction, particularly when a driver is deceased, is difficult to assess even by trained investigators on-scene.

An example of a distraction critical factor case was 2006-48-040 [1] involving a 1994 Nissan Maxima and a 1994 Peterbilt tractor trailer combination. Conditions at the time of the crash were dry and daylight on a weekday afternoon with a posted speed limit of 70 mph. The Maxima was traveling westbound on the divided interstate and crossed the center median striking the tractor trailer head-on. The crash resulted in the deaths of two female occupants. Figure 4 shows the vehicle at final rest.

Figure 4
Vehicle Final Rest
NMVVCS case 2006-48-040

A witness reported that the driver was talking on a cell phone and the front right passenger was reclined with her feet on the instrument panel. The witness stated it looked as if the driver dropped something and was trying to retrieve the object from the floor when the vehicle moved left into the median. The driver steered right, back into the travel lanes, and then abruptly left as she overcompensated. The vehicle entered the median and crossed into the oncoming lanes where it collided with the tractor trailer before catching on fire.

The driver's father indicated his daughter was on her way home across two states after finishing college semester finals and had only slept about three hours the night before. She drove the vehicle on a daily basis but only rarely on this roadway. Figure 5 is an overview of the impact area while rescue efforts were still ongoing.

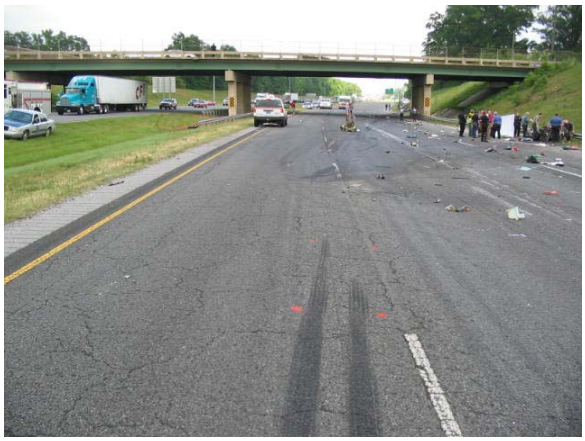

Figure 5
Impact area NMVVCS Case 2006-48-040
Critical Factor – Distraction

[1] References to specific cases are in the form 200x-YY-ZZZ, where 200x represents the NMVCCS case year, YY the primary sampling unit (PSU), and ZZZ the case number. Cases can be viewed using the on-line NMVCCS case viewer accessible via the NHTSA web site at http://www-nass.nhtsa.dot.gov/nmvccs_pub/SearchForm.aspx

The team selected distraction as the critical factor in the crash. Secondary factors were overcompensation and fatigue. Vehicle-related crash prevention measures that may have been beneficial were ESC, lane departure warning/lane keeping, and distracted driver technology. Figure 6 is a scaled diagram of the scene.

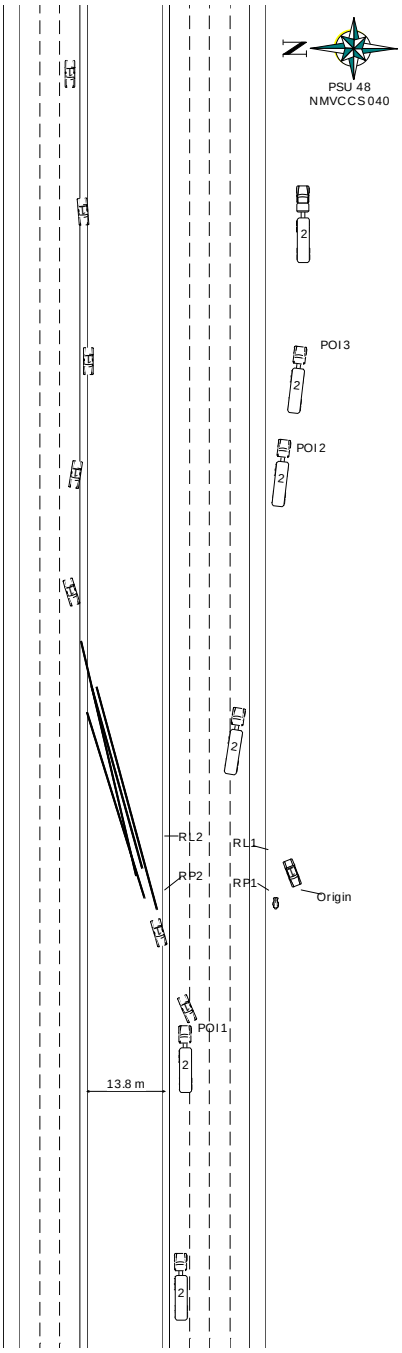

Figure 6
Scene Diagram
NMVCCS Case 2006-48-040

Secondary Factors

In addition to a critical factor for each case, the team added secondary factors where applicable, totaling 168 secondary factors in the 111 cases. As mentioned previously, some secondary factors included are non-causal. The most common secondary factors in the crashes were no seat belt or child restraint used (29%), speed/control loss (28%), and no valid drivers license (26%). Excessive speed and/or control loss was considered on a case by case basis using the available data and the group's expertise. As discussed earlier in the Method section of this paper, this factor often occurred in conjunction with alcohol/drugs and was more commonly assigned a secondary factor (31) than as the critical factor (15), making it a factor in 41% of all the fatal cases reviewed.

The team noted that in the alcohol/drug critical factor cases, multiple secondary factors were typically present. While reviewing the detailed information available in the crash narrative summaries and coded data a distinct pattern was apparent in these cases, pointing towards what many would consider general societal issues. The offending driver would not only have a high BAC, but be speeding, not wearing a seat belt, not have a valid drivers license, etc. Most of these drivers also had a lengthy list of prior citations and suspensions in the FARS database.

An example of such a case is 2006-43-073 which resulted in the fatality of a 35-year old male driving a 2004 Ford F-150. The crash occurred on a two lane road with a posted speed of 45 mph. The pickup truck departed the right side of the roadway, striking a mailbox, before reentering the roadway and departing the left side. The vehicle then returned to the roadway again, crossing the double yellow line, before departing the right side of the roadway for a second time. After this third roadway departure the pickup began a counterclockwise yaw. The vehicle contacted a speed limit sign while rolling eight-quarter turns, coming to rest on its wheels with the ejected driver underneath the vehicle. Figure 7 shows an image of the crash scene.

Figure 7
Rollover area
NMVCCS Case 2006-43-073
Critical Factor- Alcohol/Drugs

Figure 8
Vehicle Final Rest
NMVCCS Case 2006-43-073

The NMVCCS summary provided a multitude of background on the driver and the crash. The driver reportedly had a rare day off and was consuming alcohol while visiting relatives at a local lake. The parents stated that 17 years ago the driver was involved in a severe jet ski accident and suffered a head injury which required brain surgery and since then he had difficulty differentiating appropriate behavior. Eight months prior to the crash his parents reported he was arrested for exceeding 100 mph on a motorcycle. They claimed he "lived on the edge" and would often race cars at a local track. He'd also been recently treated for a stress-related ulcer and often times suffered from fatigue. NMVCCS data showed a suspended license, and FARS information indicated three prior suspensions and two previous speeding convictions. The police reported travel speed at the time of the crash was 65 mph in the 45 mph zone. During the vehicle inspection in clear view were several over-the-counter medications, including stimulants, stress tablets, mood stabilizers, and heartburn medications, along with several empty beer cans. Post mortem BAC was 0.25. Figure 8 is an image of the vehicle at final rest.

The team categorized the critical factor in this crash as alcohol/drugs. Secondary factors cited were speed/control loss, overcompensation, no valid license, and seat belt usage. Vehicle crash prevention measures listed were alcohol detection and ESC. The next section of this paper describes why lane departure warning/lane keeping was not selected as a crash prevention measure in this particular case.

Crash Prevention Measures

Crash preventions measures were identified at the vehicle, environment, and driver levels, with the team focusing on technological vehicle improvements available in the near future.

As seen in Table 2, the most common vehicle prevention technologies selected by the team were ESC, lane departure warning/lane keeping, alcohol detection, and auto/assisted braking. The implementation of ESC in the vehicle fleet as mandated in Federal Motor Vehicle Safety Standard (FMVSS) No. 126, "Electronic stability control systems," is currently being phased-in, and some of the other technologies identified are encouraged through the new NCAP program. Findings from the NMVCCS analysis show that in 80% of the crashes, countermeasures that could be installed on the vehicle may have helped prevent the crash or reduced the severity.

The team deduced that lane departure warning and lane keeping technology could have been useful in 32% of the cases. In many cases it was determined that lane departure warning would not be effective unless some form of lane keeping technology was also present, thus the two technologies were grouped together. The number of cases deemed candidates for these avoidance features by the team is significantly lower than the 55% of crashes in the study where the vehicle assigned the critical reason in NMVCCS had a critical event of 'this vehicle traveling off the edge of the road' or 'over the lane line' (see Table 1). Though these crashes appeared to be candidates for lane departure warning/lane keeping when viewed purely from a statistical standpoint, after clinically reviewing the cases, the team felt that the technology

would not be sufficient to prevent the crash. The case example used earlier, 2006-43-073, is a good example of why studies relying solely on police reported information cannot be reliably used for countermeasure evaluation and benefits estimates. Some cases involving very high BAC were excluded, because an ensuing crash of another configuration seemed highly likely. ESC was another vehicle prevention countermeasure that would have preceded the need for lane departure warning/lane keeping technology in certain instances. Furthermore, in many cases the lack of the shoulder on the roadway would have prevented a lane departure warning/lane keeping system from being effective.

Alcohol detection technology was listed as a potential countermeasure in 27% of the cases. The percentage closely resembles the 32% of the total alcohol-impaired traffic fatalities reported by NHTSA for 2009 [10]. In-vehicle technologies such as those being investigated in the Driver Alcohol Detection System for Safety (DADSS) program would be invaluable in addressing the alcohol-impaired driving problem that this study confirms. DADSS is a cooperative research agreement between The Automotive Coalition for Traffic Safety (ACTS), whose members represent a majority of the automotive companies, and NHTSA. Additional information on the project can be found at http://www.dadss.org.

For 23% of the cases auto/assisted braking was listed as a potential countermeasure to prevent or lessen the severity of the crash. For these crashes there appeared to be sufficient time for forward looking sensor to recognize an impending threat and reduce the speed of the subject vehicle. These cases included front-to-front, front-to-side and front-to-rear crash configurations. Although most forward looking crash avoidance systems available today are only currently designed for front-to-rear end crash mitigations, the team believed these systems will eventually mature to include other crash types.

Environmental crash prevention measures, such as the addition of guardrails, were identified in 15% of the cases, but generally not seen as a feasible solution. It seems impractical to install guardrails or barriers on every mile of roadway throughout the country to prevent road departure including median crossover crashes. Other environmental factors such as glare or poor road conditions were rarely seen in the study.

Crash prevention measures that could be geared toward drivers largely centered on long-standing behavioral issues such as speeding, drinking and driving, operating without a valid license and disregard of traffic controls. However, there were some driver issues that are relatively new problems including, cell phone/texting, and medical/physical issues primarily pertaining to the aging population. NHTSA continues to work closely with stakeholders at the local, state, and national levels to target these areas through enforcement and education.

Conclusions

Detailed clinical reviews of the fatal cases in the National Motor Vehicle Crash Causation Survey yielded valuable information on the critical and secondary factors that contributed to the crash and possible crash prevention measures. Alcohol/drug-impaired driving was selected as the critical factor in 32% of the crashes, by far the most frequent in the study. The most common secondary factor in the crashes was no seat belt or child restraint used (29%). Many of these crashes were not exceedingly severe crashes, or involved ejection and the occupant would have likely survived if properly restrained. Although seat belt usage did not initiate the crash, it certainly relates directly to the source and severity of the fatal injuries. The four most common crash avoidance technologies; ESC, lane departure warning/lane keeping, alcohol detection, and auto/assisted braking, account for 82% of the vehicle crash prevention measures identified by the team in the cases.

The factors identified in the study are issues which need to be addressed in future years to continue the reduction of fatalities. The findings suggest that implementation of crash avoidance technologies could be very effective in continuing the reduction of fatalities. In addition, the study highlights the need for additional detailed data on the precrash phase of the crash to refine target populations for benefits estimates.

References

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