

Characterization of Lane Departure Crashes Using Event Data Recorders Extracted from Real-World Collisions

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ABSTRACT

Lane Departure Warning (LDW) is a production active safety system that can warn drivers of an unintended departure. Critical in the design of LDW and other departure countermeasures is understanding pre-crash driver behavior in crashes. The objective of this study was to gain insight into pre-crash driver behavior in departure crashes using Event Data Recorders (EDRs). EDRs are units equipped on many passenger vehicles that are able to store vehicle data, including pre-crash data in many cases.

This study used 256 EDRs that were downloaded from GM vehicles involved in real-world lane departure collisions. The crashes were investigated as part of the NHTSA's NASS/CDS database years 2000 to 2011.

Nearly half of drivers (47%) made little or no change to their vehicle speed prior to the collision and slightly fewer decreased their speed (43%). Drivers who did not change speed were older (median age 41) compared to those who decreased speed (median age 27). Drivers in lane departure crashes were traveling above the posted speed limit in 65% of cases. Almost half (49%) of drivers did not apply the brakes during the pre-crash record, suggesting that drivers may be steering more often than braking to avoid crashes.

The newest advanced EDRs record steering wheel angle in addition to the data collected by older EDRs most common in the current fleet. We also present a case study using advanced EDR data to simulate the vehicle's trajectory. This method could be invaluable in benefits estimates of safety systems.

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INTRODUCTION

Lane departure crashes can be extremely dangerous crashes that occur when a vehicle leaves its travel lane and strikes either a vehicle or object. These types of crashes can include striking a vehicle traveling in the same or opposite direction but also includes impacts with fixed objects off the road, i.e. road departure crashes. Although only 16% of all crashes were road departures into fixed objects, these crashes accounted for 34% of all fatal crashes in 2009 [1]. Opposite direction crashes only comprised approximately 9% of crashes yet accounted for 17% of all seriously injured occupants [2].

Lane Departure Warning (LDW) and Lane Departure Prevention (LDP) are production safety systems offered on vehicles worldwide. The objective of LDW is to warn the driver if the vehicle is likely to inadvertently leave its lane. LDP can actively assist the driver in keeping his or her lane.

The effectiveness of both of these systems depends on the behavior of the driver. Examples of these behaviors include distraction, reaction times to warnings, steering wheel input,

vehicle speed, and brake application. Event Data Recorders (EDRs) may provide insight into some of these factors, specifically those related to the vehicle.

Event Data Recorders (EDRs) are devices that are associated with the airbag control modules of many passenger vehicles. In the event of a crash, the EDR can store data pertaining to the vehicle before and during the crash to be later retrieved by an investigator. Because some EDRs record pre-crash vehicle parameters, e.g. speed, brake application, they offer a unique opportunity to study driver behavior that leads to a crash. The data recovered from EDRs is naturalistic in nature but unlike long-term instrumented naturalistic studies, all of the data pertains to drivers that were in crashes. EDRs have been used in the past to study driver behavior in crash imminent situations, e.g. brake reaction time in rear-end collisions [3].

This study utilized crash data from the National Automotive Sample System, Crashworthiness Data System (NASS/CDS) years 2000 to 2011. NASS/CDS is a nationally representative sample of crashes collected by NHTSA. In

order to be included in the database, a crash must have involved at least one passenger vehicle towed from the scene due to damage. Investigation teams throughout the U.S. perform in-depth field investigations of approximately 5,000 crashes per year. Investigators photograph and diagram the crash scene, measure vehicle damage, and retrieve injury information from occupants involved.

When available, the investigators also recover data from the vehicle's EDR using a publicly available download tool, the Bosch Crash Data Retrieval Tool. Since case year 2000, investigators have been able to download General Motors EDRs. Because of the early availability of GM EDRs, GM is the most frequent make in the NASS/CDS collection of EDRs. More recently NASS/CDS has collected Ford, Chrysler, and Toyota EDR data once these makes were supported by later versions of the Bosch tool. There are fewer Chrysler and Ford EDRs collected from NASS/CDS cases compared to GM EDRs. The focus of this study will be on GM EDRs.

The objective of this study was to examine the pre-crash data recovered from EDRs in vehicles involved in lane departure crashes in order to gain insight into driver behavior in these crashes.

METHODOLOGY

Crashes were extracted from NASS/CDS years 2000 to 2011 that involved: 1) a lane departure crash with the driver drifting out of the lane and 2) a GM vehicle with EDR data recovered that contained pre-crash data. Drift out of lane departure crashes, as opposed to those caused by control loss or vehicle failure, are the crashes that LDW and other active safety systems will likely be most effective in mitigating and preventing. Applicable lane departure crashes were selected using pre-crash variables from NASS/CDS that described the critical pre-crash event that led to the collision, the vehicle's pre-crash maneuvers, and the accident type.

Some GM EDRs can record pre-crash data. *Figure 1* shows an example of pre-crash data recovered from a 2009 Pontiac G6 involved in a frontal collision with another vehicle. The vehicle was traveling at a constant speed of 44 mph until the driver started braking 1 second prior to the crash which slowed the vehicle slightly. Most GM EDRs record pre-crash data for five seconds prior to the crash at a frequency of 1 sample per second. Some GM EDRs record pre-crash data for 2.5 seconds prior to the crash at 2 samples per second.

Events that deploy the vehicle's airbags, i.e. deployment events, are locked in the memory of the EDR. GM EDRs can also store non-deployment events if there was no airbag deployment event. These non-deployment events are not locked in the memory of the EDR, however. As such, we excluded EDRs that did not have an airbag deployment.

The vehicle speeds in the EDR are recorded from the power control module of the vehicle, which is based off of a transmission speed sensor. When there is excessive wheel

slip, such as in emergency braking or wheel lockup, the recorded vehicle speed can be much lower than the actual vehicle speed. We excluded EDRs where the investigator reported wheel lockup or when there was greater than a 1 g deceleration between consecutive pre-crash vehicle speeds to remove cases with excessive wheel slip.

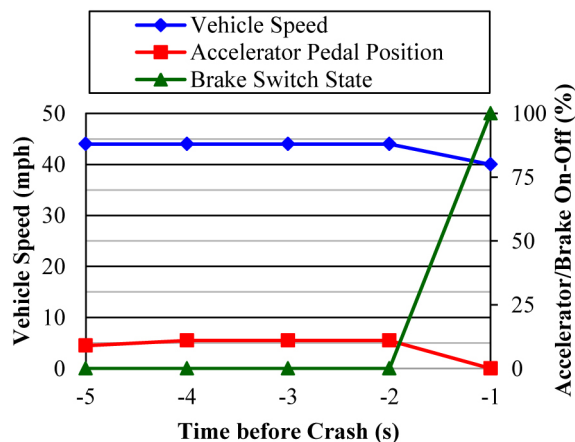


Figure 1. Example Pre-Crash Data from a 2009 Pontiac G6 (NASS/CDS Case 2010-12-154).

In some GM EDRs with pre-crash data, the brake switch circuit status is recorded from 8 seconds prior to the collision at a frequency of 1 second. *Figure 2* shows brake timing variables that can be derived from EDR data. Note that *Figure 2* is only a schematic that shows 5 seconds of pre-crash braking, while most EDRs had 8 seconds of braking prior to the crash. The first brake time is first brake application prior to the crash. The pre-crash brake time is the time before the collision that the brake is consecutively applied. The total time ON is the sum of the brake ON time. The maximum consecutive ON time is the longest time the brake was consecutively held ON.

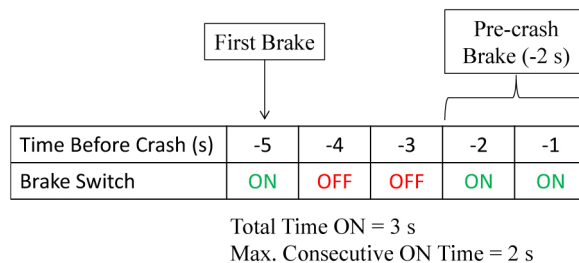


Figure 2. Example of Brake Timing Variables for EDR Pre-Crash Record

Finally, in order to make the sample of collisions nationally representative, NASS/CDS assigns each case a sample weight. This weight statistically corrects for the stratified and clustered sample design of NASS/CDS and represents the number of similar collisions that occurred nationally during the sample period. For the remainder of the paper, frequencies and percentages reflect weighted numbers

while italic “*n*=” represents the raw count of cases. All confidence intervals were performed at the 95% level and variance was estimated using the survey procedures in the statistical package SAS (SAS Institute, Cary, N.C. version 9.3).

RESULTS

Selected Cases

Table 1 summarizes the number and frequency of selected lane departure cases with EDR pre-crash data used in this study. In total, there were 5447 GM EDRs downloaded from NASS/CDS cases. Of those, approximately 9% were crashes in which the driver drifted out of the lane. For the EDRs in these departures, 28% had a locked airbag deployment event and had pre-crash data available. Finally, 38 modules, or 13% of weighted cases, were discarded because there was deceleration greater than 1 g recorded on the pre-crash vehicle speed leaving a total of 256 EDRs for analysis. Of selected collisions, 239 modules recorded 5 seconds of pre-crash data at 1 samples per second and 17 recorded 2.5 seconds of pre-crash data at 2 samples per second. The distribution of crashes in the resulting dataset include single vehicle departures into fixed objects (68%), striking another vehicle in the opposite direction (20%), striking parked cars (9%), and same direction (3%) crashes.

Table 1. Summary of Selected Cases for Lane Departure EDR Crashes

Category	n	Weighted
All GM EDRs	5447	2,370,194
EDRs in Drift Out of Lane Departures	759	218,975
Locked EDR with Pre-Crash	294	61,210
Locked EDR with Valid Accelerations	256	53,537

Pre-Crash Vehicle Speed

The maximum EDR recorded vehicle speed versus the posted speed on the roadway in lane departure collisions is shown in Figure 3. The area of each point is proportional to the weighted frequency of each case. If the maximum speed of all vehicles was equal to the posted speed limit, the points would fall on top of the dotted line. In total, 65% of drivers were speeding prior to these lane departure crashes. The solid line shows a linear regression line, which shows that drivers were speeding on low speed limit roads more often than on high speed limit roads. The mean travel speeds, 95% confidence intervals about the means, and regression coefficients are tabulated in the appendix. Of the 239 EDRs that recorded 5 seconds prior to the crash, over half (55%) of maximum speeds occurred five seconds prior to the crash, the first pre-crash record for vehicle speed. In the 17 EDRs that recorded 2.5 seconds prior to the crash approximately three quarters (74%) occurred during the first recorded vehicle speed.

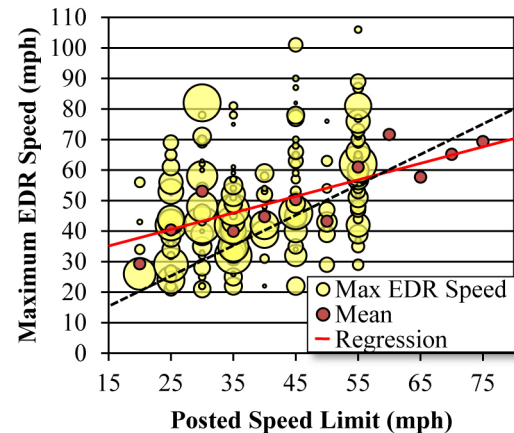


Figure 3. Posted Speed Limit and Maximum Recorded Speed on EDR (n=256).

Figure 4 shows the difference in speed from the beginning of the pre-crash record (i.e. 5 seconds before the crash) and the last pre-crash record (i.e. 1 second before the crash). Only the 239 cases with five seconds of pre-crash data are shown in Figure 4. Many drivers did not have large changes in speed prior to the crash. Of all drivers, approximately half (47%) had a speed change of ± 5 mph or less, 10% sped up more than 5 mph, and 43% slowed down more than 5 mph. Missing from this data is at what time during the pre-crash record the vehicle departed the lane. The data does, however, indicate that in general drivers either do not change speed much or slow down in lane departure crashes.

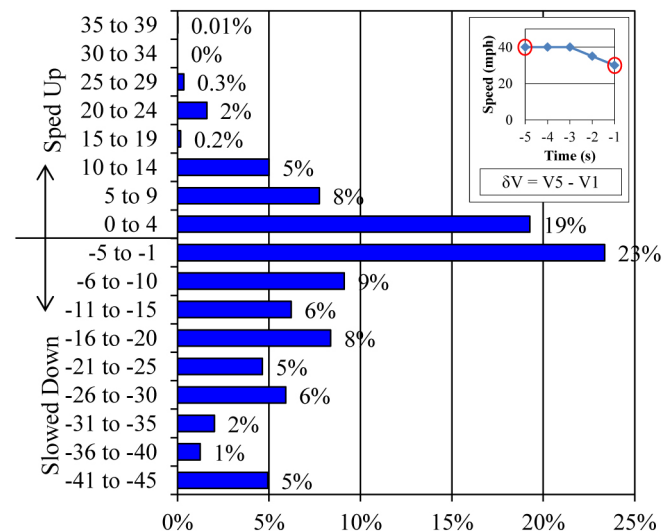


Figure 4. Speed Change during 5 Seconds of Pre-crash Records (n=239).

The cumulative distribution of driver age for the three categories of pre-crash speed change is shown in Figure 5. The median age for drivers who had little or no speed change was 41 while drivers who slowed down and sped up had a median age of 27 and 35 years, respectively. Although we are