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Results of Event Data Recorders Pre-Crash Duration Study

Required Under

The Fixing America's Surface Transportation Act (FAST Act)

Report to the House Committee on Energy and Commerce and the Senate Committee on Commerce, Science, and Transportation

Report to Congress

National Highway Traffic Safety Administration
U.S. Department of Transportation
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1. Introduction

The 2015 Fixing America's Surface Transportation Act (FAST Act), Pub. L. No. 119-14, SEC. 24303, Vehicle Event Data Recorder (EDR) Study, requires the Administrator of the National Highway Traffic Safety Administration (NHTSA) to submit "to Congress a report that contains the results of a study conducted by the Administrator to determine the amount of time event data recorders installed in passenger motor vehicles should capture and record for retrieval of vehicle-related data in conjunction with an event in order to provide sufficient information to investigate the cause of motor vehicle crashes." This summary document and the attached report fulfill the FAST Act EDR research requirement.

NHTSA has promulgated an EDR regulation (49 CFR Part 563), which became effective September 1, 2012. Under Part 563, voluntarily provided EDRs must meet requirements for the accuracy, collection, storage, survivability, and retrievability of onboard motor vehicle crash event data in passenger cars and other light vehicles.

Widespread deployment of EDRs, which record data elements such as brake application time, accelerator position and vehicle speed, offers a unique opportunity to determine crash causation and better understand driver pre-crash behavior. The latest generation of EDRs in a vehicle can provide a snapshot of the vehicle kinematics and driver inputs in the seconds prior to a crash. However, a limitation of current EDRs is that they are only required to record a minimum of 5 seconds of pre-crash data at a frequency of 2 Hertz (a total of 10 data points). It was hypothesized that, in many cases, this recording duration may be insufficient to determine the factors which led to the crash or the pre-crash actions taken by the driver to avoid the collision. The study summarized below attempted to answer the question of whether extending the pre-crash recording duration would enable EDRs to more fully capture the history of driver pre-crash behavior. It is anticipated that a better understanding of driver pre-crash behavior may also assist in the evaluation of emerging active safety systems. However, this was not a goal of the current research activity.

The EDR duration study was initiated in August 2016 and conducted by researchers at Virginia Tech over a 9-month period. The research examined existing NHTSA crash investigation programs and naturalistic driving studies to provide bounds on the recording durations necessary to capture available driver inputs preceding a crash. The attached report titled, "Event Data Recorders (EDR) Duration Study," provides the detailed results from that effort.

The research project was conducted in two phases. The first phase provided an estimate of the frequency with which the current 5-second EDR duration requirement may be insufficient to capture pre-crash initiation of driver maneuvers in rear-end, intersection, and road departure crashes. The second phase sought to determine the complete duration of the same driver actions based on normal and pre-crash driver actions extracted from two previous naturalistic driving studies.

2. Phase 1

In the first phase, the project examined the frequency with which EDRs may not have captured the complete sequence of the driver's pre-crash actions that may be necessary to fully understand the causation of the crash. Required duration was expected to vary by crash mode, so the analysis was conducted for each of three crash modes, i.e., rear-end crashes, intersection crashes, and road/lane departure crashes. The data used in the analysis were EDR records from the National Automotive Sampling System Crashworthiness Data System (NASS/CDS) (2000 - 2015). Each year NASS/CDS conducts in-depth investigations of approximately 5,000 cases selected from police reported crashes across the United States. EDR data is available for a subset of approximately 10,000 NASS/CDS cases. Selection criteria applied to the dataset resulted in inclusion of data downloads from 1,616 EDRs in 329 rear-end crashes, 839 intersection crashes, and 415 road departure crashes.

The NASS/CDS EDR data elements evaluated in this study - to determine driver pre-crash maneuvers - were brake on/off, non-zero steering angle, and accelerator input. Currently, Part 563 requires a minimum of 5 seconds of pre-crash data for brake on/off and engine throttle as a percentage of full accelerator pedal depression. Steering angle is an optional data element. A subset of data was available with 8 seconds of pre-crash data. This data was truncated at 5 seconds to normalize the analysis.
As noted above, since Part 563 did not go into effect until 2012 and this dataset spans calendar years 2000 – 2015 (model years 1999 – 2015), the EDRs from the earlier models in the study were less likely to contain all three data elements.

2.1 Results

Phase 1: High level Summary - Analysis of EDR capture of pre-crash maneuvers in rear-end, intersection, and road/lane departure follows:

2.1.1 Rear-end crashes:

Approximately 96 percent of the EDRs in the NASS/CDS sample included braking information, 14 percent included steering and 39 percent included accelerator input.

The distributions of onset of pre-crash driver maneuvers in the cases analyzed show that 5-seconds of EDR recording did not capture the initiation time for nearly 35 percent of brake applications, 80 percent of steering maneuvers, and 9 percent of accelerator pedal releases. The availability of steering angle data, an optional data element, was very limited, reducing its significance in this study. The failure to capture the onset of brake application was the most notable research finding in this crash mode.

2.1.2 Intersection crashes:

Intersection collisions can be divided into four phases: the approach, the traversal, any evasive action, and impact. For almost all intersection crashes, the driver action leading to the crash, for example running a red light, occurred in the approach phase. Once in the intersection the error has already been committed. Intersection crashes in the NASS/CDS dataset were categorized into five different crash configurations depending on whether

the vehicle was turning right, left, or straight into the path of the oncoming striking vehicle. About 52 percent of the struck vehicles were turning left across the path of the striking vehicle traveling in the opposite direction, 23 percent were proceeding straight across the path of the striking vehicle traveling from either left or right, and 22 percent were turning left into the path of the striking vehicle traveling left to right. The remaining approximately 3 percent of vehicles were turning left or right into the path of a vehicle traveling in the same direction.

The distribution of pre-crash driver maneuvers show that 5 seconds of EDR recording duration did not capture initiation time for nearly 35 percent of drivers who applied brakes, 64 percent who initiated a change in steering angle, and 4 percent of drivers who released the accelerator pedal. 13 percent of the EDRs did not have sufficient recording duration to capture the time of intersection boundary crossing.

2.1.3 Road departure crashes:
Approximately 96 percent of the EDRs in road departure collisions contained braking information, with 14 percent and 38 percent containing pre-crash steering and accelerator pedal information, respectively.

The analysis showed that 5 seconds of EDR recording duration did not capture all driver pre-crash maneuvers. Approximately 35 percent of drivers who applied brakes did so outside of the 5-second period prior to impact. There were few cases with steering data, but 88 percent of those exhibited some steering angle more than 5 seconds prior to impact. Approximately 8 percent of the drivers released the accelerator pedal outside of the 5 seconds recorded. The median time duration off road, between road departure and initial impact or final rest was, 1.5 seconds, with the maximum time between road departure and final rest of 6 seconds.

Table 1. Percentage of Events for which 5 Seconds of EDR Recording Duration was Insufficient from NASS/CDS

Driver Pre-crash Maneuver		EDR Failed to Record Maneuver Initiation (%)
Rear-End	**Braking Input**	35%
	Steering Input	80%
	Accelerator Release	9%
Intersection	**Braking Input**	35%
	Steering Input	64%
	Accelerator Release	5%
Road Departure	**Braking Input**	35%
	Steering Input	88%
	Accelerator Release	8%

3. Phase 2

The EDR dataset analysis conducted in the first phase provided an estimate of the frequency with which EDRs did not record a sufficient duration of pre-crash data. However, the EDR analysis cannot provide insight into what duration beyond 5 seconds of pre-crash data is needed to capture the initiation of pre-crash maneuvers.
The emphasis in the second phase of the project was on driver actions in normal driving. In the second phase, the project examined data from two Naturalistic Driving Studies (NDSs) to understand the complete duration of drivers' actions in car following, intersection traversal, and lane departure. To capture time to rear-end crashes, time to closest approach to a stopped or slower moving lead vehicle is needed, for intersection crashes, time to approach and traversal duration is needed, and for road departure crashes, time to drift out of lane through recovery is needed.

The term "naturalistic driving" refers to a research method of unobtrusively observing driving during everyday trips by using specialized equipment to record data on the driver, vehicle, and the surrounding roadway and landscape. The data collected greatly enhances understanding of the circumstances and conditions of safe travel, near misses, and crashes.

The 100-Car NDS is a large-scale naturalistic driving study conducted by the Virginia Tech Transportation Institute (VTTI). Approximately 100 vehicles were instrumented with cameras and inertial measurement devices along with personal computers (PCs) to collect and store the data. Participants drove the vehicles normally for approximately one year per vehicle. The result was over 1.1 million miles traveled in over 139,000 trips.

Vehicle instrumentation included a yaw rate sensor, dual axis accelerometers, and a Global Positioning System (GPS) navigation unit. The vehicles were equipped with lane-tracking systems to detect proximity of lane markings. Five cameras offered continuous views in and around the vehicle.

The second Strategic Highway Research Program (SHRP-2) NDS is a recent study sponsored by the Transportation Research Board and the National Academy of Sciences. As in the 100-Car Study, SHRP-2 used unobtrusive retrofitted instrumentation to collect data on everyday driving situations. In all, 3,362 private vehicles equipped with cameras, radars, and other sensors collected a total of over 6.5 million trips, accounting for almost 50 million miles over three years. A large number of selection criteria were applied to both datasets to determine case selection for each of the studied crash modes.

The analysis of the NDS data from this phase of the study allows for a determination of the probability of capturing particular driver maneuvers within a specified time of data recording. This analysis helps to establish the basis for an EDR pre-crash recording duration that provides a greater certainty of obtaining sufficient information to investigate the cause of motor vehicle crashes.

3.1 Results

Phase 2: High level Summary - Analysis of naturalistic driving studies of maneuvers in car following (rear-end), intersection, and road/lane departure/recovery follows:

3.1.1 Rear-end crashes:

The overall objective was to characterize the time duration and time to collision in car-following braking events. The approach was to use normal braking events from the 100-car NDS to provide a threshold to fully capture driver braking behavior. The results were different depending on a stopped or travelling lead vehicle, but the study concluded that a time duration of about 12 seconds would capture 90 percent of the driver brake initiations.

Similarly, analysis of 111 rear-end crashes in the SHRP-2 NDS resulted in 90th percentile distributions of final accelerator release, brake initiation, and evasive steering durations of 12, 10, and 3 seconds, respectively.

3.1.2 Intersection crashes:

Cumulative distributions for the approach and traversal times were analyzed for each traffic control device type, approach action, traversal action, and lane size. There was no significant difference in total intersection timing between stop signs and signalized intersections. However, there was a significant reduction in both approach and traversal times for rolling stops versus complete stops. There was also a significant increase in traversal time for left turns over straight-through for small intersections, though not for larger intersections. There was a 50 percent increase in traversal times from two lane intersections to seven lane intersections.

From these results the 5-second EDR duration would capture less than 1 percent of total intersection event timing, 15 seconds would capture 50 percent, and 18.6 seconds would capture 90 percent.

3.1.3 Lane departure/road departure crashes:

Using the lane tracking information on-board in the 100-Car NDS, the median duration of lane excursion, from the moment a vehicle began to drift, depart the lane, and recover was about 3.2 seconds. The 90th percentile of the distribution was 6 seconds.
Analysis of 26 road-departure crashes in SHRP-2 showed that for those cases with valid data, median accelerator pedal release time to road departure was 23 seconds.
Median brake application was at 1.9 seconds after road departure, but as early as 21 seconds prior to road departure. Only one case provided evasive steering data, which initiated 4.8 seconds prior to road departure. Based on these observations, the 5-second EDR duration was insufficient to capture all driver inputs in road departure crashes.

Table 2. EDR Recording Duration Needed for Typical Driver Pre-Crash Maneuvers (100 Car NDS and SHRP-2)

Driver Pre-crash Event		Duration of Pre-Crash Action (seconds)
		90th Percentile
Rear-End	**Time to Closest Approach**	12.3
Intersection	**Approach + Traversal**	16.0-18.6
Road Departure	**Drift Out of Lane to Recovery**	6.0

4. Conclusions

This study determined that the duration of typical driver maneuver times exceeds the 5-second minimum recording time required in current EDRs. EDR files from NASS/CDS vehicle crashes indicated that 5 seconds of data recording was insufficient to capture more than one-third (35 percent) of brake initiation. 5 seconds was insufficient to capture pre-crash steering maneuvers in up to 88 percent of crashes, but this was based on much more limited data than for brake initiation.

In order to capture driver actions to investigate crash causation, the 90th percentile duration required for rear-end, intersection and road departure crashes are 12, 19, and 6 seconds respectively.

5. Final Statement

The results of the study on EDR recording duration concluded that the current 5-second minimum recording requirement of Part 563 did not capture the initiation of crash avoidance maneuvers. The analysis demonstrates that 20 seconds of pre-crash data would encompass the 90th percentile recording duration required for the three crash modes and the crash avoidance maneuvers analyzed.

6. Limitations

The bulk of the EDR data analyzed for this report came from vehicles manufactured prior to the enactment of Part 563, which requires a pre-crash sample rate of only 2 Hertz (hz), for a total of 10 data points over 5 seconds. Much of the data used in this analysis was collected at a sampling frequency of only 1 hz (5 data points). The study did not address different or higher resolution sampling.

The study did not assess the effects of inclement weather and road surface conditions on driver inputs and outcomes. Road conditions and visibility affect not only driver inputs but also vehicle capabilities.

The study did not analyze the possible effects of higher speed limits and their role in cases where brake initiation occurred earlier than 5 seconds pre-crash. Higher velocities would require greater braking distance and time.

The brake status data element is currently recorded as an on-and-off state, which provides only ordinal data. Drivers can "ride" brakes with little effect on deceleration, yet still create an "on"" condition. Beyond the scope of this study was the addition of interval data channels which could be used to quantify actual brake performance such as deceleration and distance traveled while braking.

The study was limited to the use of driver initiated inputs in both the EDR and naturalistic driving sections of the analysis to assess EDR pre-crash recording duration. As vehicles are increasingly equipped with crash avoidance and autonomous vehicle technologies, the pre-crash recording duration may need to be reassessed. Furthermore, the study did not assess the potential need to acquire additional data elements specific to these technologies.