U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

www.nhtsa.gov

DOT HS 810 935 **April 2008**

Analysis of Event Data Recorder Data for Vehicle Safety Improvement

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 2008	3. REPORT TYPE AND DATES COVERED Final Report April 2006 – November 2007

4. TITLE AND SUBTITLE Analysis of Event Data Recorder Data for Vehicle Safety Improvement	5. FUNDING NUMBERS HS50/EG048
6. AUTHOR(S) Marco P. daSilva	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Research and Innovative Technology Administration John A. Volpe National Transportation Systems Center Cambridge, MA 02142	8. PERFORMING ORGANIZATION REPORT NUMBER DOT-VNTSC-NHTSA-08-01
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation National Highway Traffic Safety Administration 1200 New Jersey Avenue SE. Washington, DC 20590	10. SPONSORING/MONITORING AGENCY REPORT NUMBER DOT HS 810 935
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Volpe Center performed a comprehensive engineering analysis of *Event Data Recorder* (EDR) data supplied by NHTSA to assess its accuracy and usefulness in crash reconstruction and improvement of vehicle safety systems. The Volpe Center gathered and analyzed 2,541 EDR files downloaded from the National Automotive Sampling System (NASS), Special Crash Investigations (SCI), and Crash Injury Research & Engineering Network (CIREN) databases supplied by NHTSA. The analyses focused on EDR file format and potential improvements, assessment of crash types where EDR data exists, review of EDR data for accuracy and completeness, EDR data comparisons with existing crash data, review of pre-crash, crash, and post-crash data for usefulness in better understanding the crash reconstruction, identification of error sources, and determination of methods by which researchers could use the EDR data to improve their crash case information. The results of the engineering analysis show that EDR data can objectively report real-world crash data and therefore be a powerful investigative and research tool, by providing very useful information to crash reconstructionists and vehicle safety researchers. Due to significant limitations however, EDR data should always be used in conjunction with other data sources.

14. SUBJECT TERMS Event data recorder, crash data recorder, vehicle safety	15. NUMBER OF PAGES 133
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

PREFACE

The National Highway Traffic Safety Administration, in conjunction with the Research and Innovative Technology Administration's Volpe National Transportation Systems Center (Volpe Center), conducts vehicle safety research in crash avoidance and crashworthiness. In particular, extensive analyses have been performed to define the crash and injury problems, identify intervention opportunities, assess the state-of-the-art technology for crash avoidance and injury mitigation systems, and estimate potential safety benefits of promising systems. This research supports NHTSA's mission to save lives, prevent injuries, and reduce health care and other economic costs associated with motor vehicle crashes.

Under sponsorship from the NHTSA Office of Vehicle Safety Research, the Volpe Center conducted research into the use of event data recorder data for vehicle safety improvement. The author of this report is Marco P. daSilva.

The author wishes to thank John Hinch, director, NHTSA's Human Vehicle Performance Research for his guidance and support. Appreciation is due to John Brophy and his team at NHTSA Special Crash Investigations, and Mark Scarboro at NHTSA Applied Vehicle Safety Research, for their expertise and ideas.

Special thanks is also given to Clay Gabler and his team at Virginia Tech for EDR data acquisition and validation work performed for this study.

ACRONYMS

ACCTYPE	Accident Type
ACM	Air Bag Control Module
Ax	Longitudinal Acceleration Change (g)
Ay	Lateral Acceleration Change (g)
BAGDEPLY	Air Bag System Deployment
CDR	Crash Data Retrieval
CDC	Collision Deformation Classification
CDS	Crashworthiness Data System
CIREN	Crash Injury Research and Engineering Network
D	Deployment (event)
D/DL	Deployment and Deployment-Level (event)
D/N	Deployment and Non-Deployment (event)
Delta V	Change in velocity (mph)
DL	Deployment-Level (event)
DLC	Diagnostic Link Connector
DVLAT	Lateral component of delta V
DVLONG	Longitudinal component of delta V
EDR	Event Data Recorder
EDS	Electronic Data System
GM	General Motors
kph	kilometers per hour
mph	miles per hour
ms	milliseconds
MANEUVER	Attempted Avoidance Maneuver
MANUSE	Manual (Active) Belt System Use
MY	Model year
NASS	National Automotive Sampling System
N	Non-Deployment (event)
NCSA	National Center for Statistics and Analysis
NHTSA	National Highway Traffic Safety Administration
No	Number
OEM	Original Equipment Manufacturer
PDOF	Principal Direction of Force (1st)
PDOF1	Clock Direction for PDOF in Degrees (Highest CDC)
RCM	Restraint Control Module
RF	Right-Front
RPM	revolutions per minute
SCI	Special Crash Investigations
SDM	Sensing and Diagnostic Module
sec	seconds
t	time (seconds)
US DOT	United States Department of Transportation
VIN	Vehicle Identification Number
Vx	Longitudinal delta V (mph)
Vy	Lateral delta V (mph)

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EXECUTIVE SUMMARY

The Volpe Center performed a comprehensive engineering analysis of *Event Data Recorder* (EDR) data supplied by NHTSA to assess its accuracy and usefulness in crash reconstruction and improvement of vehicle safety systems. EDRs have been used in vehicles for many years to capture certain data pertaining to the events just prior to, and during a crash. Although EDRs provide very limited recording capabilities, they can provide objective real-world crash information for vehicle safety research purposes.

The Volpe Center gathered and analyzed over 2,500 EDR files that have been downloaded from the *National Automotive Sampling System*'s (NASS) *Crashworthiness Data System* (CDS), *Special Crash Investigations* (SCI), and *Crash Injury Research & Engineering Network* (CIREN) databases supplied by NHTSA. The analyses focused on EDR file format and potential improvements, assessment of crash types where EDR data exist, review of EDR data for accuracy and completeness, EDR data comparisons with existing crash data, review of pre-crash, crash, and post-crash data for usefulness in better understanding the crash reconstruction, identification of error sources, and determination of methods by which researchers could use the EDR data to improve their crash case information.

The ultimate objective is to determine if EDR data should be used by motor vehicle safety researchers to aid in the development and evaluation of vehicle safety concepts. The use of EDR data might enable a more accurate assessment of safety benefits for various crash countermeasures, intelligent vehicle crash avoidance technologies, and current crash test procedures by creating objective data to better model pre-crash and crash events.

1. INTRODUCTION

The Volpe National Transportation Systems Center (Volpe Center) has been providing technical support to NHTSA in crash avoidance and crashworthiness research. This research has been conducted in support of NHTSA's mission to save lives, prevent injuries, and reduce health care and other economic costs associated with motor vehicle crashes. In particular, the Volpe Center has performed extensive analyses to define the crash problem, identify intervention opportunities, and assess the state-of-the-art technology for crash avoidance and injury prevention systems. Moreover, the Volpe Center has developed and applied novel methodologies to estimate the safety benefits of these systems based on driver-vehicle-system performance data. In addition, the Volpe Center has played a supporting role to NHTSA in the development of performance specifications and objective test procedures for crash warning systems.

Currently, there is an abundance of EDR technology being developed and supplied by the *Original Equipment Manufacturers* (OEMs) and aftermarket suppliers. Various versions of EDRs, more commonly referred to in the media as "crash data recorders," exist today on many vehicle models. These types of recorders are very limited in terms of the number of recorded parameters and storage capacity, but this stored information could prove to be very useful to crash reconstructionists and vehicle safety researchers. Also, the capability of these recorders is increasing with the introduction of newer models in the vehicle fleets that incorporate more and more sensors for a variety of vehicle operating functions such as stability and rollover control. These EDR-type devices provide an independent measurement of many crash-related parameters, which have traditionally been estimated using crash reconstruction techniques.

As documented in previous reports and publications documenting research in this area, EDR data could provide great benefits to existing coding in national databases.[1] Some NASS variables are less reliable than others due to the large number of unknowns present in the databases or miscoded information. EDR measurements have the potential to provide better accuracy, more reliability, and quantification to many NASS codes that describe the pre-crash situation. Moreover, some variables do not contain specific enough information that might add more insight into the understanding of the pre-crash situation.

This project involved a comprehensive engineering analysis of EDR data collected by NHTSA as part of three national crash programs (CDS, SCI, and CIREN) since 1999. A Microsoft Excel-based database was developed to store the parameter data from these EDR file downloads and then the crash data was analyzed and compared to the associated crash database values. The analyses focused on EDR file format and potential improvements; assessment of crash types where EDR data exists; review of EDR data for accuracy and completeness; EDR data comparisons with existing crash data; review of pre-crash, crash, and post-crash data for usefulness in better understanding the crash reconstruction; identification of error sources; and determination of methods by which researchers could use the EDR data to improve their crash case information.

It should be noted that the results presented in this report were based on analyses of a limited set of vehicle crash data that contained EDR-acquired information, which was used for the analytical purpose defined above. As such, the results presented are not nationally representative and therefore no generalized conclusions about these results should be made.

2. PREVIOUS WORK

Event data recorders have been installed in vehicles for over 30 years, with *General Motors* (GM) being at the forefront of the use of this technology by introducing it in select vehicle models starting in 1974. The EDRs in these vehicles were primarily used to control and record air bag deployments. Although various names exist, these systems are commonly known as *sensing and diagnostic modules* (SDMs), *restraint control modules* (RCMs), or *air bag control modules* (ACMs). Their primary function is to run an algorithm that analyzes sensor data and then activate the vehicle's air bag and restraint systems when a key parameter reaches a specific threshold. These modules also have limited storage capability, which has been used by OEMs to store event data information for research purposes. Until recently, only the OEMs had the capability to download and analyze the information stored in these modules. However, a crash data retrieval toolkit was made publicly available starting in the year 2000. This toolkit allowed police, crash reconstructionists, researchers, and the general public to connect an EDR via the vehicles's *diagnostic link connector* (DLC) or directly to the air bag module.[2] This crash data retrieval package can retrieve EDR data from a select number of GM vehicles of *model year* (MY) 1996 and newer and a select number of Ford vehicles from 2003 and on. The system generates a *crash data retrieval* (CDR) file that stores and visualizes the information downloaded from the EDR. A sample CDR file taken from a NHTSA vehicle crash test is shown in Appendix A.[3]

Previous research conducted by the Volpe Center entailed understanding EDR technology and studying its potential to add qualitative and quantitative insight in the pre-crash event sequence.[4] That study identified various NASS crash data elements that could be enhanced by objectively captured EDR data.

Various government and industry initiatives have also spurred advancements in data standardization and validity as well as addressing many other technical and societal issues relating to the use of this technology. Much of the research and EDR history is well documented in the NHTSA Event Data Recorder Research Web Site.[5] Another source, a Transportation Research Board report entitled **Use of Event Data Recorder (EDR) Technology for Highway Crash Data Analysis,**[1] provides a comprehensive overview of EDR technology, national accident databases, and technical and legal issues surrounding the use of the data.

3. EDR DATA ACQUISITION

3.1. Acquire EDR Data

NHTSA has collected and stored EDR data from GM and Ford vehicles in three of their national crash databases within the *Electronic Data System* (EDS). NHTSA collects this data to help the scientific community analyze motor vehicle crashes. These databases are briefly detailed below:

- CDS: This database is a nationwide crash data collection program that collects detailed crash information on a random sample of about 5,000 police reported vehicle crashes per year.[6]
- SCI: This database is a project within the *National Center for Statistics and Analysis* (NCSA) at NHTSA that "examines the safety impact of new, emerging, and rapidly changing technology (such as air bags and alternative fuel systems) and for exploring alleged or potential vehicle defects."[6]
- CIREN: This multi-center research program gathers detailed vehicle and occupant injury data (long-term) from severe vehicle crashes. The program enlists clinicians and engineers in academia, industry, and government to "improve the prevention, treatment, and rehabilitation of motor vehicle crash injuries to reduce deaths, disabilities, and human and economic costs."[7]

The data within these databases is gathered by NHTSA crash investigators and data collection teams throughout the United States using the CDR System.[2] These files are then electronically stored as CDR files. The CDR files gathered by the NHTSA field teams from 2000 to 2005 were obtained by the Volpe Center and the Virginia Tech-Wake Forest School of Biomedical Engineering and Sciences for this study. These files are electronically available through the NHTSA NCSA and downloaded through ftp://ftp.nhtsa.dot.gov/NASS/EDR_Reports/ for cases dating from 2000-2003, and via its online case viewer[8] for cases dating from 2004 and on.

3.2. Data collection Issues

Currently, EDR data can only be accessed and downloaded from a subset of GM and Ford vehicles.[2] Furthermore, it has been estimated that NASS field data collection teams achieve a 60-percent successful EDR data download rate of applicable vehicles.[9] Some issues affecting the success of data download from crashed vehicles are damaged DLCs, inoperative EDR modules, and unavailability of correct hardware cables for specific vehicle models.

Although the analyses conducted in this study used data from a total of 2,541 EDR downloads, the original EDR file count was 3,459. The original count was not based on counting the actual number of CDR files downloaded by the field collection teams but rather a count of a specific crash database variable that indicated whether or not the EDR was downloaded. The actual number of EDR files used for this study was substantially lower for a variety of reasons as detailed below:

- A substantial number of EDR files acquired and validated in this study either
  - did not contain any information, possibly due to a read failure during the field data collection, or
  - their key identifier information did not match the data in the associated vehicle file in the crash databases. The key identifier used in this study was the *Vehicle Identification Number* (VIN).
- Some EDR files that were thought to have been stored in the EDS simply did not exist, or could not otherwise be found.
- Prior to 2001, most EDR data was scanned into the EDS and the actual EDR files were discarded. This presented a problem affecting data validity and therefore those cases were not analyzed.

A total of 918 EDR files, comprising about 26 percent of the overall EDR file count, were not included in the subset analyzed in this study as a result of the issues mentioned above. The data acquisition and validation process by the Volpe Center and Virginia Tech determined the final count of 2,541 EDR file downloads for analysis.

3.3. EDR Database

The data analysis scheme developed for this study built on existing software processes and tools designed and maintained by Virginia Tech. Virginia Tech has been conducting research in this field for numerous years and has developed a database of EDR data collected in years 2000-2004 as well as an automated tool for coding new cases from EDR files. The Volpe Center used the existing Virginia Tech research tools and updated the database to include EDR data from the year 2005. Again, these files are electronically available through the NHTSA NCSA Web site, as previously described.

The associated vehicle data from the CDS, SCI, and CIREN crash databases was then downloaded and incorporated into to a Microsoft Excel based spreadsheet workbook for analysis.

4. EDR DATA SET CHARACTERIZATION

A total of 2,541 EDR files gathered were selected for analysis. These files were gathered from three national crash databases (CDS, SCI, and CIREN) ranging from the year 2000 to the year 2005, as shown in Figure 1. These files belonged to a wide range of GM and Ford vehicle models ranging from MY 1994 through MY 2005, as shown in Figure 2. About two-thirds of the EDR files originated from vehicles of MY 2000 or newer. Also, the vast majority of the 2,541 EDR files originated from GM vehicle models, about 97 percent. The rest were extracted from Ford vehicles. As reflected in Figure 3, about 93 percent of the EDR files are associated with the CDS program. Table 1 shows the distribution of EDR files per vehicle make and associated NHTSA vehicle crash program.

Each crash database (CDS, SCI, and CIREN) contained unique characteristics both at the program level (crash cases collected for different purposes across each database) and case level (different variables and reporting schemes). Each crash database was therefore independently analyzed, as reflected in this report.

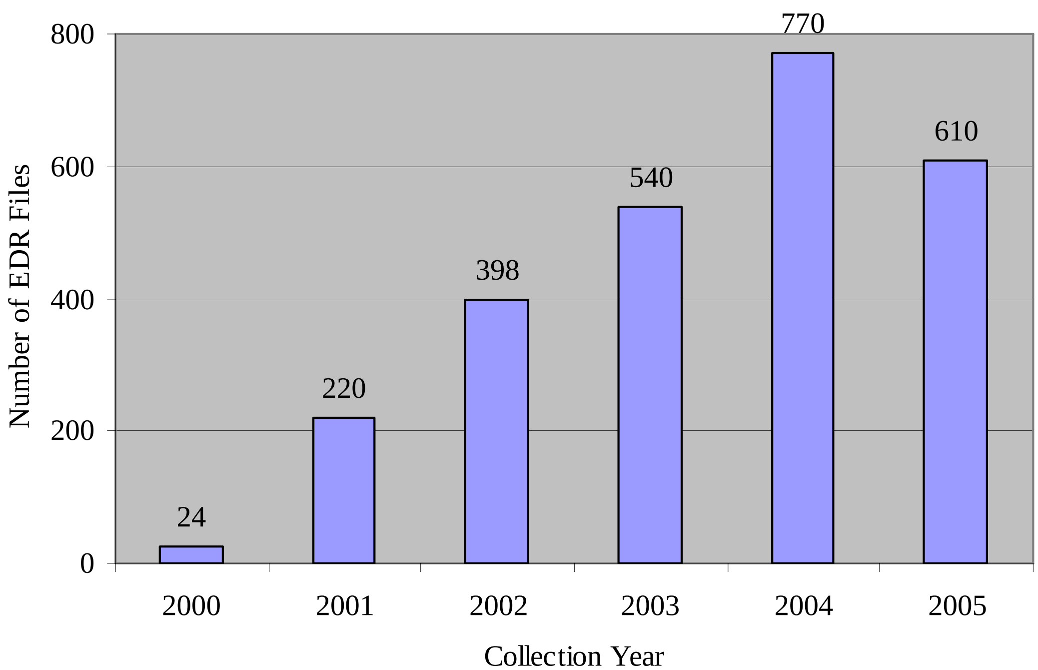


Figure 1. EDR File Distribution per Data Collection Year

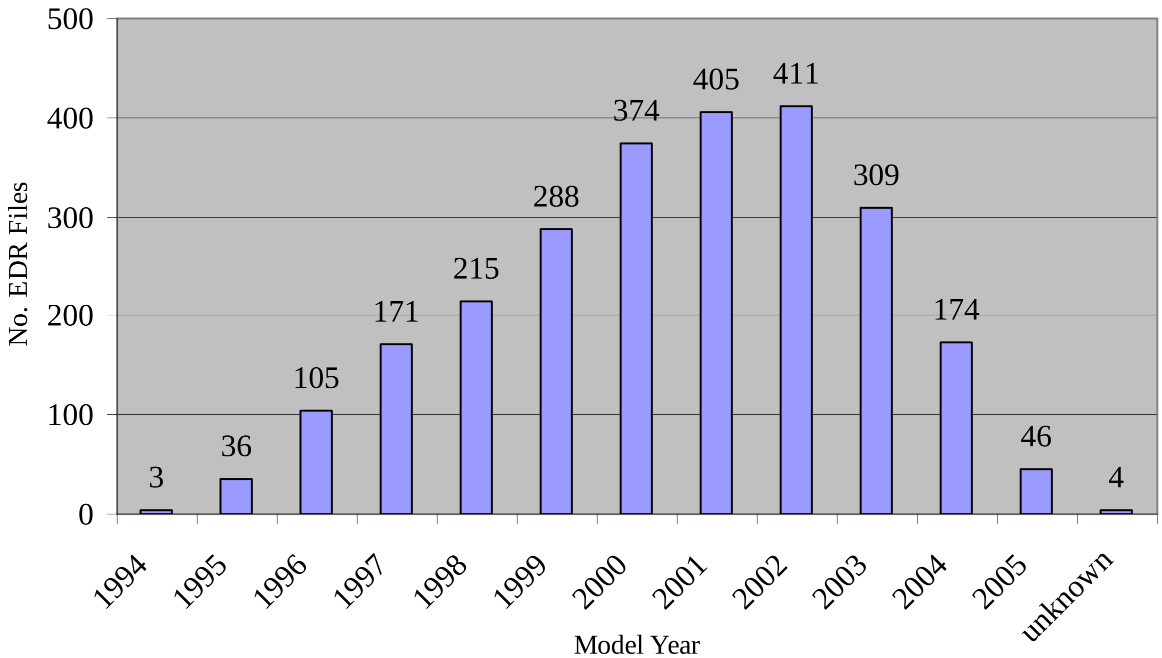


Figure 2. EDR File Distribution per Vehicle Model Year

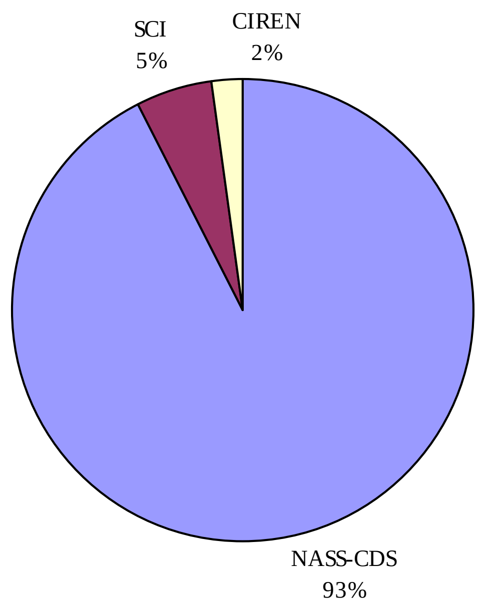


Figure 3. EDR File Distribution per NHTSA Vehicle Crash Program

Table 1. EDR File Distribution per NHTSA Vehicle Crash Program and Vehicle Make

Program	No. EDR Files/vehicle make		Total
	GM	Ford	
NASS-CDS	2,283	69	2,352
SCI	123	8	131
CIREN	56	2	58
Total	2,462	79	2,541

The CDS program contains a probability sample of all police reported crashes. From 2000 to 2005, the CDS collected data in a yearly average of about 4,600 crashes representing a average of about 2.5 million yearly crashes in the United States. The CDS-related EDR data presented in this report originated from 2,352 vehicle files over the same six-year period. This means that EDR data was obtained from at least one vehicle in about 8.5 percent of the overall CDS crash data population. In terms of nationally representative estimates ("weighted"[10]), EDR data was collected in at least one vehicle in the crash in about 7.8 percent of all police-reported crashes, since the 2,352 EDR cases were associated with a nationally representative estimate of about 192 thousand yearly crashes. The yearly relative frequency of the "weighted" crash population with downloaded EDR data is shown in Figure 4. The relative frequency of CDS cases in which EDR data was collected reached a peak of about 13 percent (14.5 percent of weighted estimates) in 2005.

As shown in Figure 4, the relative frequency of actual case counts and associated representative estimates were very similar. However, the results presented in this report are not necessarily nationally representative since the analysis was performed on actual case counts and not the associated nationally representative estimates.

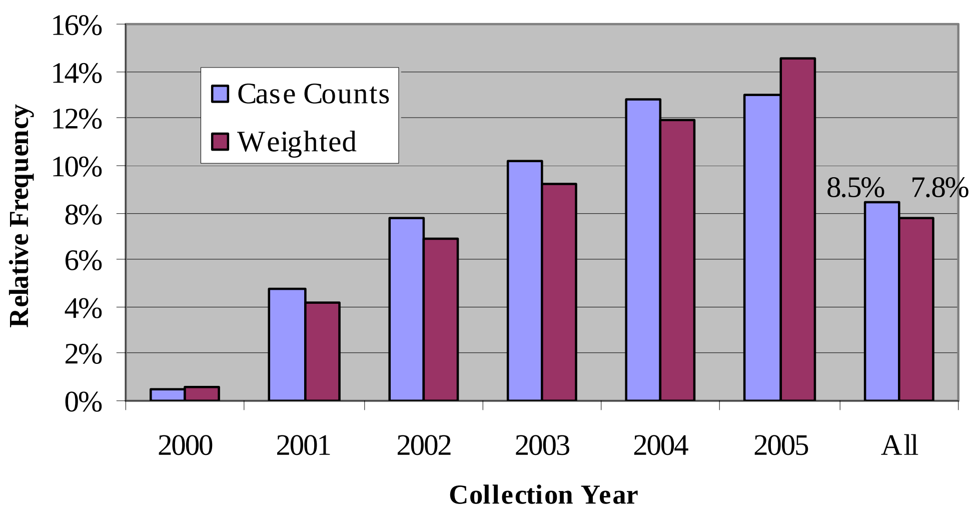


Figure 4. Relative Frequency of CDS Cases With Downloaded EDR Data

4.1. Event Type

Typically, vehicle EDRs are capable of recording two types of events. One type, called a *non-deployment* (N) event, is defined as an event that is "severe enough to 'wake up' the sensing algorithm but not severe enough to deploy the air bag(s)."[3] The other type, called a *deployment* (D) event, is one that is severe enough to cause deployment of the air bags. Most EDRs can record up to two air bag deployment events, and the second one will be labeled as a *deployment-level* (DL) event since one *deployment* event has already been recorded and the air bag deployed. It should be noted that GM EDR *non-deployment* event data is typically cleared after 250 ignition cycles (or 250 times turning the engine on/off) that represent approximately 60 days of driving.[3]

Table 2 shows the distribution of event types for the EDR files collected under the three vehicle crash programs. About 65 percent of the EDR files contain only one event, whether a *non-deployment* or a *deployment* event type. The remaining files contain multiple event data, 774 files contain one *deployment* event and one *non-deployment* each and 66 files contain data on two *Deployment* events where the second event is labeled as a *deployment-level* event. Overall, 49 percent of all EDR files contained *non-deployment* crash event data only, as is shown in Figure 5. EDR files containing a *deployment* event, including files with multiple events, constitute another 49 percent of the overall files. The remaining two percent include one file with a *deployment-level* only event and 42 files with no identified event type and therefore categorized as "Unknown." The event type breakdown per vehicle make is shown in Table 3.

Table 2. EDR Event Type Distribution per Vehicle Crash Program

	No. EDR Files per Crash Program			
Type of Event	**NASS-CDS**	**SCI**	**CIREN**	**Total**
Non Deployment, "N"	1,193	45	15	1,253
Deployment, "D"	364	27	14	405
Dep. + Non Dep, "D/N"	691	56	27	774
Dep. + Dep. Level, "D/DL"	61	3	2	66
Deployment Level, "DL"	1	-	-	1
Unknown	42	-	-	42
Total	2,352	131	58	2,541

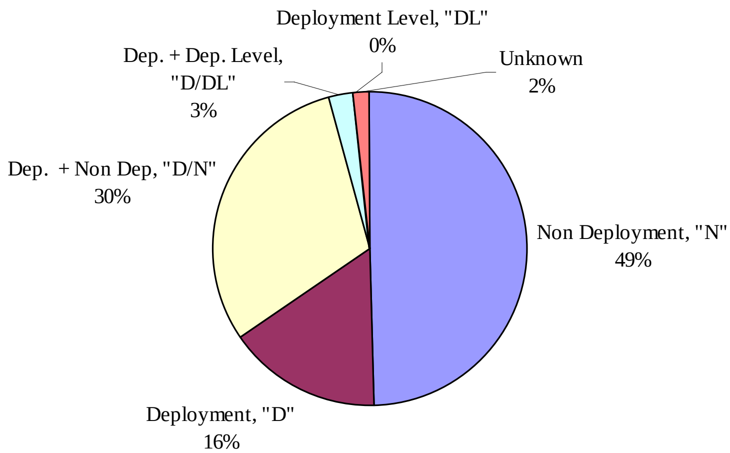


Figure 5. EDR Event Type Distribution

Table 3. EDR Event Type Distribution per Crash Program and Vehicle Make

Type of Event	No. EDR Files per Crash Program			Total
	NASS-CDS	SCI	CIREN	
GM				
Non Deployment, "N"	1,162	43	15	1,220
Deployment, "D"	326	21	12	359
Dep. + Non Dep, "D/N"	691	56	27	774
Dep. + Dep. Level, "D/DL"	61	3	2	66
Deployment Level, "DL"	1	-	-	1
Unknown	42	-	-	42
GM Total	2,283	123	56	2,462
Ford				
Non Deployment, "N"	31	2	-	33
Deployment, "D"	38	6	2	46
Ford Total	69	8	2	79

4.2. EDR Module Types

Many versions of EDRs exist on today's vehicle models, each with its own data collection, operating, and data downloading characteristics. However, EDRs generally consist of four major components as shown by the block diagram in Figure 6.[1] The basic system consists of a sensory package, associated processors, storage of generated data, and a retrieval mechanism. It should be noted that not all EDRs contain the storage and retrieval components.

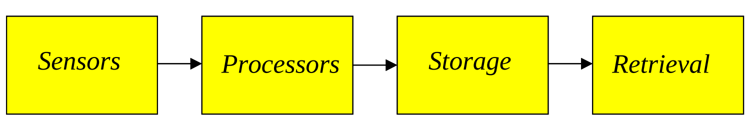


Figure 6. Block Diagram of a Typical EDR[1]

The EDR data set used in this study contains data collected from 26 different types of EDR modules, 24 of them from GM and 2 from Ford. EDR modules, like most other vehicle components, are continually redesigned. The vehicle MYs represented in this EDR data set range from 1996 through 2005, encompassing 10 years of EDR technology.

4.2.1. GM EDR Modules

As indicated above, a total of 24 variants of the GM EDR modules are present in the data set, and they are shown in Table 4. The *[blank]* category in Table 4 indicates the GM EDR files in which the module name was not reported. Even though GM has used many different modules through the years, about two-thirds of the EDR files in the database originate from only three module types: SDMRSDD, SDMG2001, and SDMG2000.

Table 4. GM EDR Module Types

GM EDR Module Name	No. EDR Files per Crash Program			Total	% Total
	NASS-CDS	SCI	CIREN		
SDMRSDD	562	6	13	581	24%
SDMG2001	527	14	12	553	22%
SDMG2000	503	13	11	527	21%
SDMGF2002	130	62	1	193	8%
SDMGT2001	125	4	5	134	5%
SDMG1999	75	2	5	82	3%
SDMR	77	3	1	81	3%
SDMGT2002	66	5	2	73	3%
SDMDW2003	35	6	-	41	2%
SDMA	33	2	1	36	1%
SDMD2002	21	3	2	26	1%
SDMG2000S	24	1	-	25	1%
SDMCL21999	22	-	1	23	1%
SDMB	17	2	1	20	1%
SDMDG2002	11	-	1	12	0%
SDMU	11	-	-	11	0%
SDMGS	5	-	-	5	0%
SDMI	5	-	-	5	0%
SDMCL21997	4	-	-	4	0%
SDME	4	-	-	4	0%
SDMDG2001	3	-	-	3	0%
SDMS	2	-	-	2	0%
SDMG1999N	1	-	-	1	0%
SDMG2002	1	-	-	1	0%
[blank]	19	-	-	19	1%
Total	2,283	123	56	2,462	100%

These modules can be separated into two main categories that reflect the major difference between them. Many earlier GM EDRs do not record any pre-crash information such as vehicle speed, engine speed, percent throttle, and brake status. These modules do, however, record longitudinal delta V information for up to 300 *milliseconds* (ms) at a rate of 100 Hz (every 10 ms). Later modules record the pre-crash information but in turn are only capable of recording 150 ms of longitudinal *change in velocity* (delta V), because the pre-crash information takes up some storage on the module but overall capacity remains the same. Roughly 31 percent of the GM EDR modules in the data set have no pre-crash recording capabilities but have the capability to record up to 300 ms of delta V, as shown in Figure 7. EDR module SDMG2000S is the one exception since it was designed to record up to 10 seconds of pre-crash data as well as up to 300 ms of delta V. A more detailed breakdown of the parameters reported per GM module is shown in Table 5, along with the range of vehicle MYs.

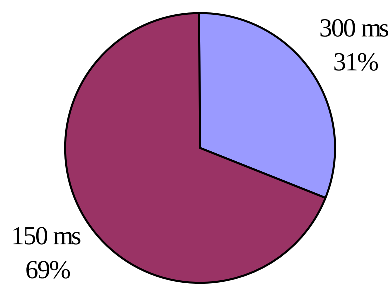


Figure 7. GM EDR Delta V Recording Capability

Table 5. Reported Parameters per GM EDR Module

Reported Parameters	CDR Module Name												
	SDMA	**SDMB**	**SDMCL21997**	**SDMCL21999**	**SDMD2002**	**SDMDG2001**	**SDMDG2002**	**SDMDW2003**	**SDME**	**SDMG1999**	**SDMG1999N**	**SDMG2000**	**SDMG2000S**
System													
CDR Module	X	X	X	X	X	X	X	X	X	X	X	X	X
VIN*	X	X	X	X	X	X	X	X	X	X	X	X	X
NonDep/Dep event	X	X	X	X	X	X	X	X	X	X	X	X	X
Warning Lamp Status	X	X	X	X	X	X	X	X	X	X	X	X	X
Seat Belt Status (Driver)	X	X	X	X	X	X	X	X	X	X	X	X	X
Seat Belt Status (RF Pass)													
Passenger Air Bag Suppression										X	X	X	
Pre-Crash													
Vehicle Speed (mph) - 5 sec at 1 Hz				X	X	X	X	X		X		X	X*
Engine Speed (RPM) - 5 sec at 1 Hz				X	X	X	X	X		X		X	X*
Percent Throttle - 5 sec at 1 Hz				X	X	X	X	X		X		X	X*
Brake Status - 5 sec at 1 Hz				X	X	X	X	X		X		X	
Crash													
Ignition Cycles @ Nondeployment/Deployment Level	X	X	X	X	X	X	X	X	X	X	X	X	X
Ignition Cycles at Investigation	X	X	X	X	X		X	X	X				
Time to 1st Stage Deployment (ms)	X	X	X	X					X				X
EDR Maximum Recorded Delta V (mph)	X	X	X	X	X		X	X	X	X		X	
Time from Algorithm Enable to Maximum Delta V (ms)	X	X	X	X				X	X				X
DeltaV (longitudinal, mph) - up to 150 ms at 100 Hz	X	X	X	X	X	X	X	X	X	X	X	X	X
DeltaV (longitudinal, mph) - up to 300 ms at 100 Hz	X	X	X	X					X				
Number of EDR Files	**36**	**20**	**4**	**23**	**26**	**3**	**12**	**41**	**4**	**82**	**1**	**527**	**25**
Vehicle Model Years	**1995-1996**	**1995-1997**	**1997**	**1997-2002**	**2002-2003**	**2001**	**2002-2003**	**2003-2005**	**1995-1996**	**1999-2004**	**1999**	**2000-2002**	**2000-2003**

Reported Parameters	CDR Module Name											
	SDMG2001	**SDMG2002**	**SDMGF2002**	**SDMGS**	**SDMGT2001**	**SDMGT2002**	**SDMI**	**SDMR**	**SDMRSDD**	**SDMS**	**SDMU**	**[BLANK]**
System												
CDR Module	X	X	X	X	X	X	X	X	X	X	X	X
VIN*	X	X	X	X	X	X	X	X	X	X	X	X
NonDep/Dep event	X	X	X	X	X	X	X	X	X	X	X	
Warning Lamp Status	X	X	X	X	X	X	X	X	X	X	X	
Seat Belt Status (Driver)	X	X	X	X	X	X	X	X	X	X	X	
Seat Belt Status (RF Pass)			X									
Passenger Air Bag Suppression	X	X							X			
Pre-Crash												
Vehicle Speed (mph) - 5 sec at 1 Hz	X		X		X	X						
Engine Speed (RPM) - 5 sec at 1 Hz	X		X		X	X						
Percent Throttle - 5 sec at 1 Hz	X		X		X	X						
Brake Status - 5 sec at 1 Hz	X		X		X	X						
Crash												
Ignition Cycles @ Nondeployment/Deployment Level	X		X	X	X	X	X	X	X	X	X	
Ignition Cycles at Investigation	X	X	X		X	X	X	X	X	X	X	
Time to 1st Stage Deployment (ms)	X						X	X	X	X	X	
EDR Maximum Recorded Delta V (mph)	X	X	X	X	X	X	X	X	X	X	X	
Time from Algorithm Enable to Maximum Delta V (ms)	X	X	X		X	X	X	X	X	X	X	
DeltaV (longitudinal, mph) - up to 150 ms at 100 Hz	X	X	X	X	X	X	X	X	X	X	X	X
DeltaV (longitudinal, mph) - up to 300 ms at 100 Hz							X	X	X	X	X	
Number of EDR Files	**553**	**1**	**193**	**5**	**134**	**73**	**5**	**81**	**581**	**2**	**11**	**19**
Vehicle Model Years	**2001-2005**	**2001**	**2002-2005**	**2000-2002**	**2001-2005**	**1999-2004**	**1996-2001**	**1996-1997**	**1996-2003**	**1995**	**1998-1999**	**1997-2004**

* VIN was entered by the NASS field data collection investigator

4.2.2. Ford

There are two types of Ford EDR modules represented in the database, as shown in Table 6. The ARM100 module is the older of the two Ford modules and is associated with vehicle model years 2000-2001, while the Takata module dates from vehicle model year 2001 and on. Perhaps the major difference between these two modules is that the newer modules, the Takata, record crash information for longitudinal change in velocity (*delta V*) and longitudinal acceleration for a period of up to 142 ms at a rate of 100 Hz, while the older module, the ARM100, record only up to 80 ms at 50Hz. However, the older model records lateral delta V and lateral acceleration as well. It should be noted that the recording time for both Ford and GM EDR modules does not necessarily start at the time of crash. For the ARM100 modules, the delta V and acceleration information is stored beginning at t = 0, which is when the time at which the air bag firing algorithm "wakes up," For the Takata EDR module, the system can store delta V and acceleration information up to time (t) = -142 ms, which is well before the air bag algorithm wakes up. The list of parameters reported by each Ford EDR module type is shown in Table 7. The parameters labeled Vx and Vy refer to longitudinal delta V and lateral delta V, respectively. Similarly, Ax denotes change in longitudinal acceleration and Ay denotes change in lateral acceleration. The Ford EDR modules in the data set did not store travel speed or impact speed information.

Table 6. Ford EDR Module Types

Ford EDR Module Name	No. EDR Files per Crash Program			Total	% Total
	NASS-CDS	SCI	CIREN		
ARM100	30	1	-	31	39%
Takata	39	7	2	48	61%
Total	69	8	2	79	100%

Table 7. Reported Parameters per Ford EDR Module

Reported Parameters	Ford EDR Module Name	
	ARM100	Takata
CDR Module	X	X
VIN	X	X
Events Recorded	X	X
Driver Belt Buckle	X	X
Passenger Belt Buckle	X	X
EDR Version	X	
Time To Left Side Bag Dep (ms)	X	
Time To Right Side Bag Dep (ms)	X	
Diagnostic Codes	X	
Time Wakeup To Pretensioner (ms)	X	
Time Wakeup To Stage1 Unbelted (ms)	X	
Time Wakeup To Stage1 Belted (ms)	X	
Time Wakeup To Stage2 (ms)	X	
Driver Seat Foward	X	
Algorithm Runtime (ms)	X	
Invalid Times	X	
Ford Part Number		X
Number of Active Faults		X
Driver Seat Foward		X
Occupant Class Status		X
Unbelted Stage1		X
Unbelted Stage2		X
Belted Stage1		X
Belted Stage2		X
Driver Pretensioner		X
Passenger Pretensioner		X
Vx (mph)	X	X
Vy (mph)	X	
Ax (g)	X	X
Ay (g)	X	

4.3. EDR Parameters

Table 8 displays the number of files with reported values per parameter recorded by the GM EDR modules. The relative low frequency of reported pre-crash data was mostly related to the inability of many EDR modules to record that information, as previously stated and reflected in Table 5. The relative pre-crash variable reporting frequency for the modules where these parameters were recorded was about 81 percent (772 EDR files originated from modules where those parameters were not recorded). Similarly, the *Seat Belt Status (RF passenger)* parameter was only available in the SDMGF2002 EDR module, which was present in only 194 EDR files. Of those, 58 files contained data on *Seat Belt Status (RF Pass)* and therefore that parameter was coded in about 30 percent of applicable files, as compared to only 2 percent of the total number of GM EDR files.

Table 8. Count of Reported Values per GM EDR Parameter

GM EDR Parameters	No. Files with reported values			Total Reported	% Reported
	NASS-CDS	SCI	CIREN		
System					
CDR Module	2,264	123	56	2,443	99%
VIN	2,283	123	56	2,462	100%
Non Deployment / Deployment event	2,241	123	56	2,420	98%
Warning lamp status	2,240	123	56	2,419	98%
Seat belt switch circuit status (Driver)	2,240	123	56	2,419	98%
Seat belt switch circuit status (RF passenger)	38	19	-	57	2%
Passenger air bag suppression	1,654	35	41	1,730	70%
Pre-Crash					
Vehicle speed (mph)	1,252	90	28	1,370	56%
Engine speed (RPM)	1,252	90	28	1,370	56%
Percent throttle	1,252	90	28	1,370	56%
Brake switch status	1,231	89	28	1,348	55%
Crash					
Ignition cycles @ Non Deployment/Deployment Level	1,162	102	56	1,320	54%
Ignition cycles at investigation	1,630	88	40	1,758	71%
Time to 1st Stage deployment (ms)	667	18	19	704	29%
EDR maximum recorded Delta V (mph)	1,520	100	43	1,663	67%
Time from algorithm enable to maximum Delta V (ms)	1,192	85	15	1,292	52%
DeltaV (longitudinal, mph)	1,889	86	33	2,008	81%

Table 9 displays the number of files with reported values per parameter recorded by the two Ford EDR modules. Certain parameters were coded in 100 per cent of the files, such as “Driver Belt Buckle” and “Vx”, which is also noted as longitudinal delta V. Other parameters were specific to each module and only recorded for that module type as listed in Table 7.

Table 9. Count of Reported Values per Ford EDR Parameter

Ford EDR Parameters	No. Files with reported values			Total Reported	% Reported
	NASS-CDS	SCI	CIREN		
CDR Module	69	8	2	79	100%
VIN	69	8	2	79	100%
Events Recorded	69	8	2	79	100%
Driver Belt Buckle	69	8	2	79	100%
Passenger Belt Buckle	69	8	2	79	100%
EDR Version	30	1	-	31	39%
Time To Left Side Bag Dep (ms)	30	1	-	31	39%
Time To Right Side Bag Dep (ms)	30	1	-	31	39%
Diagnostic Codes	30	1	-	31	39%
Time Wakeup To Pretensioner (ms)	30	1	-	31	39%
Time Wakeup To Stage1 Unbelted (ms)	30	1	-	31	39%
Time Wakeup To Stage1 Belted (ms)	30	1	-	31	39%
Time Wakeup To Stage2 (ms)	30	1	-	31	39%
Driver Seat Foward	30	1	-	31	39%
Algorithm Runtime (ms)	30	1	-	31	39%
Invalid Times	30	1	-	31	39%
Ford Part Number	39	7	2	48	61%
Number of Active Faults	39	7	2	48	61%
Driver Seat Foward	39	7	2	48	61%
Occupant Class Status	39	7	2	48	61%
Unbelted Stage1	39	7	2	48	61%
Unbelted Stage2	39	7	2	48	61%
Belted Stage1	39	7	2	48	61%
Belted Stage2	39	7	2	48	61%
Driver Pretensioner	39	7	2	48	61%
Passenger Pretensioner	39	7	2	48	61%
Vx (mph)	69	8	2	79	100%
Vy (mph)	30	1	-	31	39%
Ax (g)	69	8	2	79	100%
Ay (g)	30	1	-	31	39%

4.4. Sources of Error

The CDR system used to download the EDR files from crashed vehicles generates a CDR file containing the EDR data as well as a section detailing known data limitations associated with the specific EDR module type being downloaded. An example of a CDR file download is shown in Appendix A. These limitations, ranging from seat belt status reporting inaccuracies to timing issues, vary across the EDR modules. Various papers and studies have also been published on the subject of EDR data validation. One analysis conducted by Niehoff et al., studied the accuracy of EDR data measured during crash tests. Four types of errors, mostly affecting delta V estimations (isolated acceleration point errors, calibration point errors, rotation-induced acceleration errors, and incomplete pulses errors), were explored in that study.[11] Other research has also focused on comparing EDR measurements to estimates from accident reconstructions.[12] Yet another study presented the results of analyses into the asynchronous nature of pre-crash timing which affects the accuracy of reported pre-crash data such as speed and brake status.[13]

5. CDS EDR DATA ANALYSIS

The CDS is a national, statistically sampled, vehicle crash database consisting of about 5,000 yearly crashes. This database is used by vehicle researchers to assess crash performance and overall safety of vehicles. The use of EDR data to augment the CDS vehicle data may provide very useful information to researchers. The EDR measurements may provide better accuracy, more reliability, and quantification to many CDS codes that describe the pre-crash situations as well as the crash pulse. Some CDS variables are less reliable than others due to the large number of "unknowns" present in the database or miscoded information. Moreover, some variables do not contain specific enough information that might add more insight into the understanding of the pre-crash situation.

It should be noted that the data presented in this report are not nationally representative and therefore no generalized conclusions about these results should be made. The results were based on analyses of a limited set of vehicle crash data that contained EDR-acquired information.

Appendix C contains GM EDR data analysis results aggregated over the three crash databases (CDS, SCI, and CIREN).

5.1. Analysis of CDS EDR Data - GM Vehicles

A total of 2,283 EDR files were obtained from GM vehicles as part of vehicle crash data collection under the CDS program. The recorded parameter analysis presented herein focuses on this subset of files, which constitute 90 percent of all EDR files in this study. These files were matched to the associated CDS case and vehicle files for comparison. The comparison of similar parameters in these files, especially travel speed, brake application, restraint use, air bag deployment, as well as other relevant variables, should provide useful insight into the potential added value of using EDR data in crash reconstruction and other vehicle safety research initiatives. A comprehensive list of yearly CDS user's manuals can be found NHTSA NCSA web documentation page.[10]

5.1.1. Accident Type

The parameter comparison between the EDR and CDS data is broken down into the different categories of accident type, as reported in the CDS vehicle file under the *Accident Type* (ACCTYPE) variable name.[10] The ACCTYPE variable, a diagram of which is attached in Appendix B,[14] denotes the type of crash the subject vehicle was involved in. Table 10 shows the distribution of EDR files per ACCTYPE variable. The ACCTYPE with the highest frequency (7.9%) was the one involving the subject vehicle turning across the path of another vehicle from the opposite direction (*ACCTYPE = 68*). About one quarter of the EDR vehicle files were associated with single-vehicle crashes (*ACCTYPE = 1-15*). It should be noted that the *Accident Type* variable is based on the first harmful event in the crash sequence, which may or may not be the source of the highest delta V in the crash.

Table 10. Distribution of EDR Files per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. Files	%
Single Driver	Right Roadside Departure	1	148	6.5%
		2	124	5.4%
		3	25	1.1%
		4	2	0.1%
	Left Roadside Departure	6	83	3.6%
		7	124	5.4%
		8	20	0.9%
		9	4	0.2%
	Forward Impact	11	13	0.6%
		12	3	0.1%
		13	15	0.7%
		14	10	0.4%
		15	3	0.1%
Same Trafficway - Same Direction	Rear-End	20	123	5.4%
		21	72	3.2%
		22	23	1.0%
		23	1	0.0%
		24	44	1.9%
		25	16	0.7%
		27	1	0.0%
		28	23	1.0%
		29	21	0.9%
		30	6	0.3%
		31	1	0.0%
		32	9	0.4%
	Forward Impact	42	3	0.1%
	Sideswipe Angle	44	2	0.1%
		45	22	1.0%
		46	8	0.4%
		47	12	0.5%
		48	12	0.5%
Same Trafficway - Opposite Direction	Head-On	50	55	2.4%
		51	45	2.0%
		52	5	0.2%
	Forward Impact	55	1	0.0%
		58	1	0.0%
	Sideswipe Angle	64	22	1.0%
		65	21	0.9%
		66	22	1.0%
Change Trafficway - Vehicle Turning	Turn Across Path	68	180	7.9%
		69	165	7.2%
		70	2	0.1%
		71	3	0.1%
		72	12	0.5%
		73	6	0.3%
		74	4	0.2%
	Turn Into Path	76	11	0.5%
		77	6	0.3%
		78	6	0.3%
		79	8	0.4%
		80	4	0.2%
		81	4	0.2%
		82	116	5.1%
		83	104	4.6%
		84	1	0.0%
Intersecting Paths	Straight Paths	86	87	3.8%
		87	76	3.3%
		88	73	3.2%
		89	87	3.8%
		90	5	0.2%
Miscellaneous	Backing, Etc.	92	3	0.1%
		93	6	0.3%
		98	169	7.4%
		Total	**2,283**	**100.0%**

5.1.2. Travel Speed Comparison

Accurate travel speed information is very important for crash researchers especially for development and evaluation of crash avoidance and injury mitigation technologies. The CDS database reports the vehicle's pre-crash travel speed under the variable named *Police Reported Travel Speed*.[10] The value in this CDS field is not an estimate based on crash reconstruction but rather the value taken directly from the crash police report. Initial comparisons of the reporting frequency of travel speed indicated that, out of the 2,283 vehicles selected for comparison, only about 29 percent of the associated CDS vehicle files contained travel speed information. The associated EDR vehicle files contained travel speed information on 54 percent of the total number of vehicles. However, excluding the EDR modules that did not store pre-crash data, the travel speed reported frequency was about 80 percent. Table 11 shows the distribution of reported and not reported travel speed crossed between EDR and CDS vehicle information.

Table 11. EDR & CDS Police Reported Travel Speed Frequency

		CDS			% of	
		Reported	Not Reported	Total	All EDRs	Applicable EDRs
EDR	Reported	369	871	1,240	54%	80%
	Not Reported	301	742	1,043	46%	20%
	Total	670	1,613	2,283	100%	100%
	% of Total	29%	71%			

As shown in the Table 11 above, a total of 369 vehicle cases contained travel speed information from both the EDR and CDS vehicle files. However, 8 of these cases were excluded from the comparison analysis because:

1. The CDS travel speed information for 8 of these vehicles was listed as "160," which is not a specific speed but rather a value corresponding to any speed 159.5 *kilometers per hour* (kph) and above, and
2. The EDR travel speed information for the other 8 cases was reported at ½ Hz, which makes it difficult to analyze along with the other 361 cases that reported travel speed information at 1 Hz.

Figure 8 displays the reported values of travel speed as data pairs (EDR Reported Travel Speed versus CDS Police Reported Travel Speed) for the 361 cases in which travel speed information was reported both in the EDR and CDS files. The blue line denotes the space where EDR and CDS equal (slope = 1). Table 12 shows the pertinent information on the comparison between EDR and CDS Police Reported Travel Speed per *Accident Type* category. The EDR Reported Travel Speed information was determined from analysis of the EDR *Brake Switch Status* (*Brake Status*) variable information. The following criteria were used to determine which EDR Travel Speed value to compare to the CDS Travel Speed value:

Striking vehicle - if braking was reported then the travel speed value reported at last *Brake Status = OFF* was used, or value at -5 seconds if *Brake Status = ON* for all five seconds of pre-crash information

Struck vehicle – Travel speed value at -1 second

Overall, the average EDR travel speed for those 361 cases was 37.3 mph while the average CDS travel speed was 34.7 mph, about 7 percent lower. But, as is shown in Figure 8 and Table 12, the majority of travel speed data does not compare well. In fact, the CDS Police Reported Travel Speed falls within ±20 percent of the reported EDR Travel Speed value in only 160 out of the 361 files (44%), and within ±10 percent in only one in every five files. The case-by-case comparison analysis indicates an average absolute difference of 12.7 mph, which translates to about 37 percent variance from the reported EDR values.

Figure 9 shows the EDR/CDS Police Reported Travel Speed comparison for the vehicles involved in frontal impacts, which amounted to 91 out of the 361 vehicle files. For the purposes of this study, frontal impact conditions are defined by the variable *ACCTYPE = 11, 12, 13, 14, 15, 16, 20, 24, 28, 34, 36, 38, 40, 42, 43, 50, 51, 54, 56, 58, 60, 62, 63, 80, 81, 83, 86, 88*. The average EDR reported travel speed for this subset was 45.1 mph while the associated CDS Police Reported Travel Speed was 40.0 mph, which is over 11 percent lower. The comparison of the absolute value difference between the two variables yields an average of 11.8 mph, which is about a 30 percent deviation from the reported EDR values. The CDS Police Reported Travel Speed falls within ±20 percent of the reported EDR Travel Speed value in only 41 out of the 91 applicable files in this subset (45%).

Another subset of *Accident Type* categories (*ACCTYPE = 20, 24, 28*) denote the striking vehicles in rear end crashes. A travel speed comparison of these cases is displayed in Figure 10. In this group, the reported EDR and CDS travel speed values were within ±20 percent of each other in 16 out of the 34 vehicle files (47%). The absolute difference between EDR and CDS Police Reported Travel Speed values averages 12.8 mph, which is about a 29 percent deviation from the reported EDR values.

It should be noted some of the outlier points in these Figures, namely the ones plotted along the EDR Reported Travel Speed = 0 vertical axis, could have been caused by crash-related factors such as the disabling of the vehicle's electrical system early in the crash sequence, which may not have allowed the onboard EDR enough time or power to capture the crash event.

Appendix E contains Figures for all ACCTYPE categories.

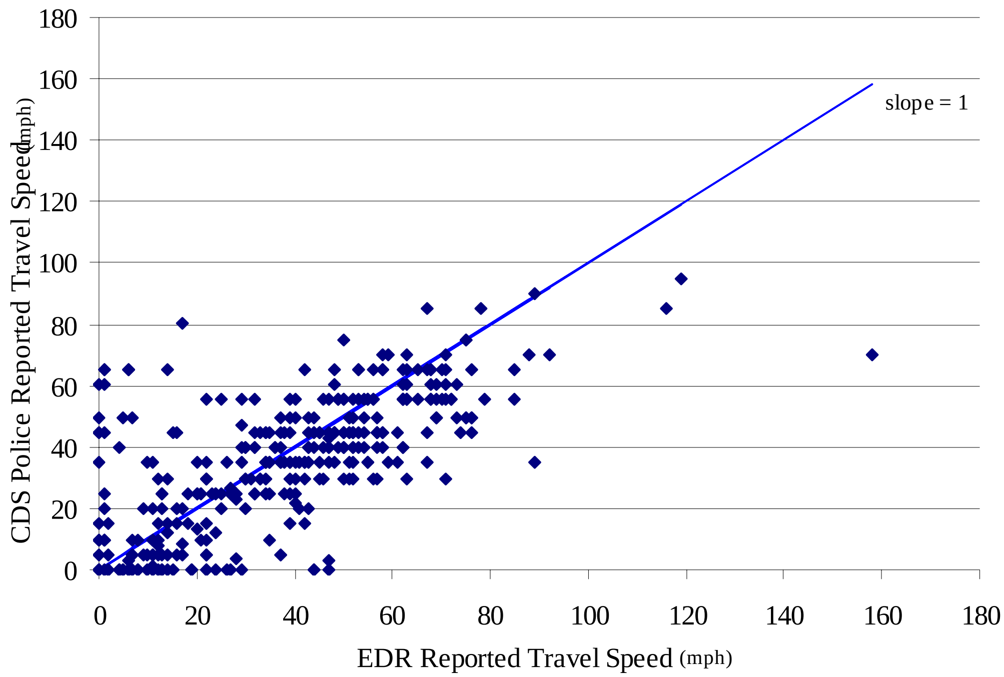


Figure 8. EDR/CDS Police-Reported Travel Speed Comparison (361 Files)

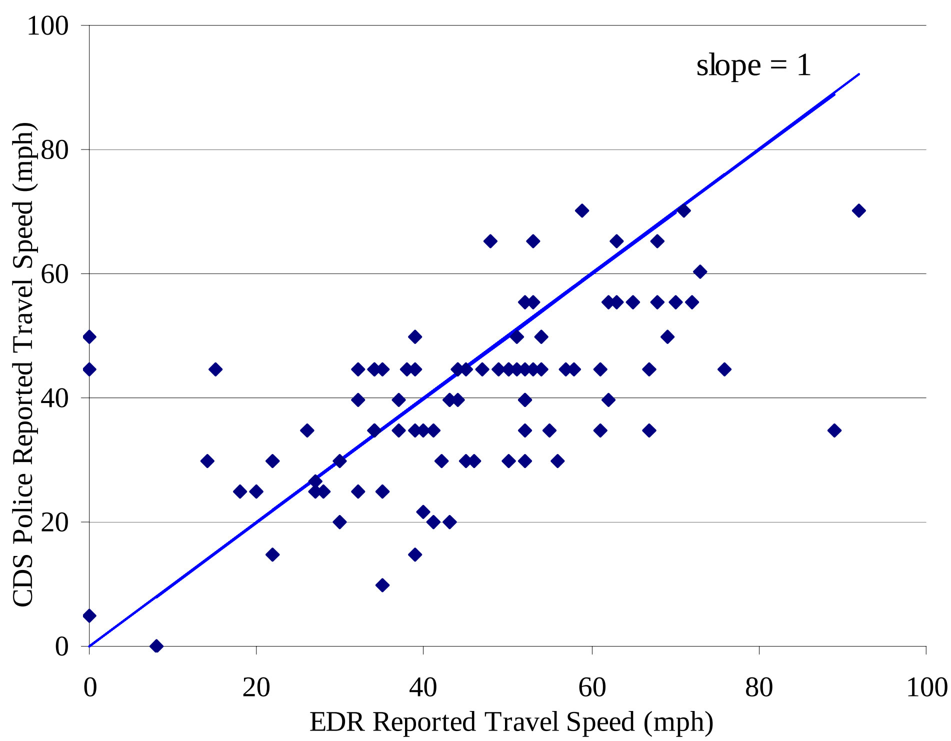


Figure 9. EDR/CDS Police-Reported Travel Speed Comparison – Frontal Impact (91 Files)

Table 12. EDR/CDS Police-Reported Travel Speed per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. of Files	Avg. Travel Speed (mph)		CDS values within 20%	
				CDS	EDR	No.	%
Single Driver	Right Roadside Departure	1	31	49.7	47.1	18	58%
		2	13	57.5	53.5	1	8%
		3	5	51.9	43.4	3	60%
	Left Roadside Departure	6	13	57.4	55.5	6	46%
		7	23	54.6	55.4	10	43%
		8	4	46.0	65.3	1	25%
	Forward Impact	11	2	32.3	35.5	-	0%
		12	1	29.8	46.0	-	0%
		13	2	37.3	56.5	-	0%
		14	1	44.7	54.0	1	100%
Same Trafficway - Same Direction	Rear-End	20	23	39.7	44.2	11	48%
		21	20	0.4	10.3	1	5%
		22	4	-	22.8	-	0%
		24	8	53.8	60.0	4	50%
		25	3	28.4	16.3	-	0%
		27	1	9.9	22.0	-	0%
		28	3	44.7	40.0	1	33%
		29	2	39.8	21.5	-	0%
		30	1	-	44.0	-	0%
		32	3	21.7	38.3	-	0%
	Sideswipe Angle	45	1	34.8	37.0	1	100%
		46	1	70.2	63.0	1	100%
		47	2	50.0	38.0	1	50%
		48	2	65.2	68.0	2	100%
Same Trafficway - Opposite Direction	Head-On	50	9	42.7	49.6	3	33%
		51	7	39.1	39.3	3	43%
	Sideswipe Angle	64	4	47.5	51.5	3	75%
		65	3	9.9	16.0	1	33%
		66	4	38.7	40.5	3	75%
Change Trafficway - Vehicle Turning	Turn Across Path	68	26	39.2	40.0	15	57.7%
		69	25	38.1	46.2	10	40%
	Turn Into Path	76	4	23.6	18.0	2	50%
		77	2	43.8	52.5	1	50%
		78	3	10.4	14.3	1	33%
		79	2	27.3	35.5	-	0%
		82	15	6.9	10.9	2	13%
		83	13	35.5	38.9	8	62%
Intersecting Paths	Straight Paths	86	13	30.6	35.8	5	38%
		87	11	28.8	29.4	7	64%
		88	8	48.1	58.0	4	50%
		89	8	33.6	32.5	4	50%
		90	1	14.9	11.0	-	0%
		98	34	26.3	28.9	26	76%
		Total:	361		Total:	160	

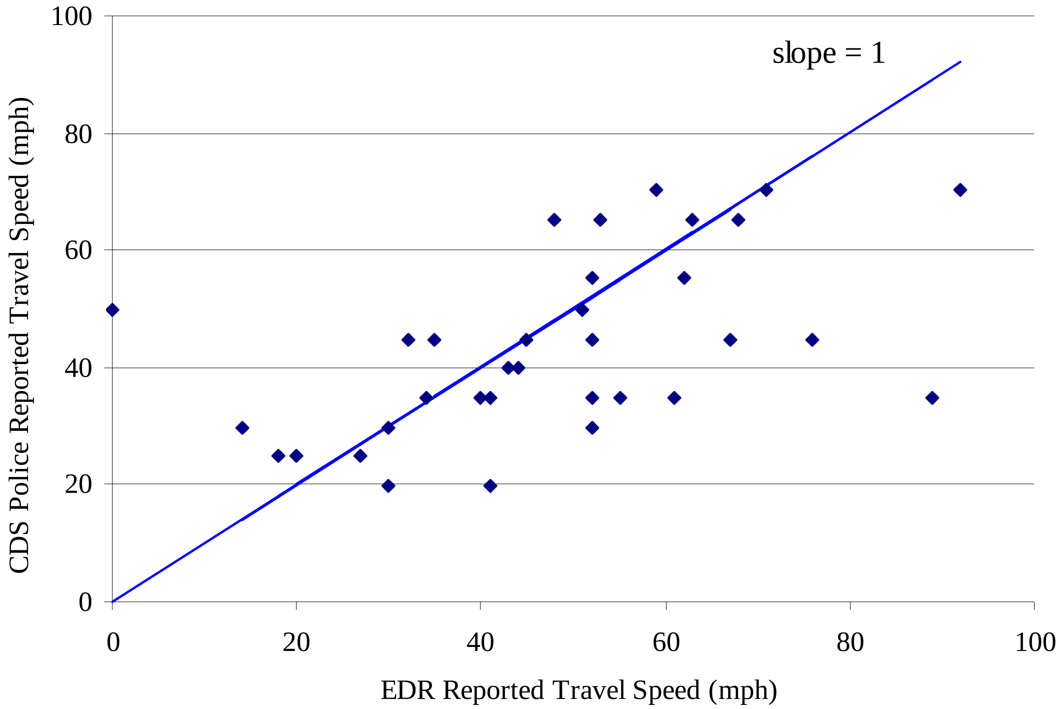


Figure 10. EDR/CDS Police-Reported Travel Speed Comparison – Rear End Striking Vehicle (ACCTYPE = 20, 24, 28; 34 Files)

5.1.3. Avoidance Maneuver (Brake Status)

Accurate information on the attempted avoidance maneuver is another key parameter for crash researchers developing and evaluating crash avoidance and injury mitigation technologies. Real-world data on driver actions are a very important component in the overall dynamics of a crash event. The CDS database reports the vehicle driver's avoidance actions, whether they pressed the brakes, steered, accelerated, or took no avoidance action at all, under the variable named *Attempted Avoidance Maneuver (MANEUVER).*[10] It is important to understand that this CDS variable "assesses what the vehicle did rather than what the driver stated he/she tried to do"[10,] and is derived from post-crash driver interviews and/or scene evidence. Most GM EDRs report *Brake Status* information at 1 Hz for the 5 seconds preceding a crash. If the *brake switch status* indicator was turned on during this time (not a physical measure of vehicle deceleration but rather an electronic indication of brake activation), then the EDR-stored variable would report this action as *Brake Status = ON*. This study compared the frequency of reported braking as denoted by the applicable CDS variable (*MANEUVER = 2, 3, 4, 8, 9*) to the EDR data.

The breakdown of the MANEUVER type variable codes is shown in Table 13 over all *Accident Type* categories as well as for the subset of vehicle files associated with striking vehicles involved in frontal impact and rear end crashes. As previously discussed, some EDR modules do not record pre-crash information. Therefore, part of Table 13 shows the distribution of CDS *Attempted Avoidance Maneuver* for only those cases where the associated EDR module was capable of reporting pre-crash information (1,518 total vehicle cases).

Table 13. CDS *Attempted Avoidance Maneuver* (MANEUVER)

Attempted Avoidance Maneuver (CDS *MANEUVER*)	All Accident Types		Vehicle Cases with Precrash Reporting Capable EDR Modules					
			All Accident Types		Frontal Impact		Rear-End	
	No. Cases	Freq.	No. Cases	Freq.	No. Cases	Freq.	No. Cases	Freq.
No impact	-	0%	-	0%	-	0%	-	0%
No avoidance action	897	39%	589	39%	117	29%	32	24%
Braking (no lockup)	228	10%	150	10%	83	21%	32	24%
Braking (lockup)	64	3%	46	3%	17	4%	5	4%
Braking (lockup unknown)	35	2%	25	2%	11	3%	7	5%
Releasing brakes	1	0%	1	0%	-	0%	-	0%
Steering left	110	5%	69	5%	18	5%	3	2%
Steering right	115	5%	73	5%	13	3%	2	2%
Braking & steering left	85	4%	58	4%	14	4%	2	2%
Braking & steering right	116	5%	72	5%	18	5%	8	6%
Accelerating	21	1%	18	1%	-	0%	-	0%
Accelerating & steering left	5	0%	1	0%	-	0%	-	0%
Accelerating & steering right	2	0%	2	0%	-	0%	-	0%
Other action	19	1%	13	1%	2	1%	-	0%
Unknown	583	26%	400	26%	106	27%	40	31%
No driver present	2	0%	1	0%	-	0%	-	0%
Total	2,283	100%	1,518	100%	399	100%	131	100%
Includes Braking	528	23%	351	23%	143	36%	54	41%

Overall, an *Attempted Avoidance Maneuver* that included braking (*MANEUVER = 2, 3, 4, 8, 9*) was reported in 528 cases, accounting for about 23 percent of the total. Of those 528 cases, 327 cases reported just braking while 201 cases reported a combination of braking and steering. Table 13 also shows the comparative braking data results for only those vehicles that were involved in frontal impacts (i.e., those that were the striking vehicles) and were equipped with EDR modules capable of reporting pre-crash information. For the purposes of this study, frontal impact conditions are defined by the variable *ACCTYPE = 11, 12, 13, 14, 15, 16, 20, 24, 28, 34, 36, 38, 40, 42, 43, 50, 51, 54, 56, 58, 60, 62, 63, 80, 81, 83, 86, 88*. These subset criteria narrowed the target population to 399 vehicle cases. For this subset, the CDS files denoted an *Attempted Avoidance Maneuver* that included braking in 143 vehicle files, or in about 36 percent of the 399 vehicles. Yet another subset analyzed targeted striking vehicles involved in rear end crashes, as denoted by the variable *ACCTYPE = 20, 24, 28*. In this group, braking was denoted in a total of 54 out of 131 vehicles, or a frequency of 41 percent.

Table 14 lists the number of cases with EDR *Brake Status* information per value reported at each pre-crash time interval. As previously discussed and shown in Table 5, many GM EDR modules do not report any pre-crash information. So, Table 14 provides *Brake Status* information for only the 1,518 EDR files that reported this parameter, as well as for the subsets involved in frontal impact and rear end crashes as denoted by the CDS-reported *Accident Type* parameter. Overall, the analysis of the EDR data reveals a decrease in *Brake Status = OFF*, indicating application of the brakes, throughout the five seconds leading to the crash. For vehicles experiencing frontal impacts, a total of 231 out of 399 EDR modules reported braking at the -1 second time interval, which indicates that roughly 58 percent of frontal impact vehicle drivers applied the brakes before the crash. A similar percentage of EDR modules recorded braking at the -1 second time interval for the rear end crash vehicle target population. However, excluding the vehicle cases with no *Brake Status* information, denoted as *[blank]*,or *Invalid*, the EDR *Brake Status* data indicated 68 percent of frontal impact vehicle drivers applied the brakes before the crash (231 out of 338). The braking frequency of the EDR-equipped vehicles (*Brake Status = ON*), excluding *Invalid* or *[blank]* EDR *Brake Status* values, is plotted in Figure 11 for these three sets of *Accident Type* groupings.

Table 14. EDR *Brake Status*

BRAKE STATUS	Time				
	-5 sec	-4 sec	-3 sec	-2 sec	-1 sec
All Accident Types					
OFF	905	918	882	752	508
ON	315	302	338	467	711
INVALID	11	11	11	12	12
[blank]	287	287	287	287	287
Total	1,518	1,518	1,518	1,518	1,518
% ON	20.8%	19.9%	22.3%	30.8%	46.8%
Frontal Impact					
OFF	295	290	275	219	107
ON	43	48	63	119	231
[blank]	61	61	61	61	61
Total	399	399	399	399	399
% ON	10.8%	12.0%	15.8%	29.8%	57.9%
Rear-End					
OFF	97	94	86	70	41
ON	16	19	27	43	72
[blank]	18	18	18	18	18
Total	131	131	131	131	131
% ON	12.2%	14.5%	20.6%	32.8%	55.0%

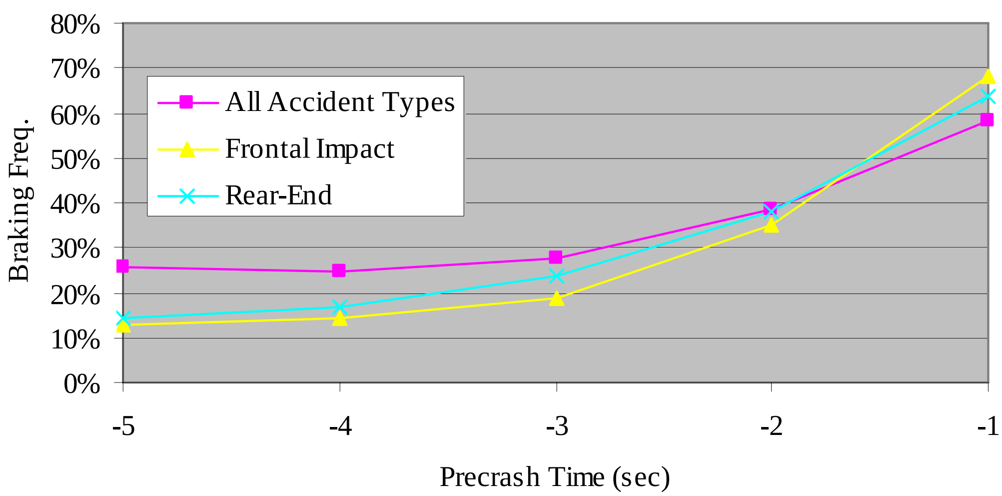


Figure 11. EDR-Reported Braking Frequency

The comparison of the driver braking action as reported by the EDR to the CDS reported *Attempted Avoidance Maneuver* could only be done for the cases in which the EDR modules recorded pre-crash information. Table 15 through
Table 17 contain the comparative results for the three subsets of vehicle cases.

As shown in Table 15, only 209 cases out of the 1,518 contained braking-related indicators from both the associated EDR and CDS files. A further 235 cases reported braking from the EDR module but the associated CDS vehicle file denoted *No Avoidance Action*. Overall, about 47 percent of the EDR files denoted braking at the -1 second pre-crash time interval while only about 23 percent of the CDS files reported an attempted avoidance action that included braking. For the frontal impact subset as shown in Table 16, only 93 cases out of the 399 contained braking-related indicators from both the associated EDR and CDS files. A further 59 cases reported braking from the EDR module but the associated CDS vehicle file denoted *No Avoidance Action*. About 58 percent of the EDR files denoted braking at the -1-second pre-crash time interval while only about 36 percent of the CDS files reported an attempted avoidance action that included braking. The comparative results for rear end striking vehicles are shown in Table 17. Thirty out of a total of 131 vehicle cases contained braking-related indicators from both the associated EDR and CDS files, and about 55 percent of the EDR files denoted braking at the -1-second pre-crash time interval while only about 41 percent of the CDS files reported an attempted avoidance action that included braking. Appendix F contains more braking-related information.

Table 15. Comparison of Braking Reported by EDR (at -1 sec) vs. CDS – All *Accident Types*

	CDS				
EDR (-1 sec)	**Includes Braking***	**No Avoid. Action**	**All Other**	**Total**	**% of Total**
Brake=OFF	77	229	202	508	33%
Brake=ON	209	235	267	711	47%
Brake=Invalid	4	4	4	12	1%
Brake=[blank]	62	121	104	287	19%
Total	352	589	577	1,518	
% of Total	23%	39%	38%		

*Includes Braking: CDS MANEUVER = 2, 3, 4, 8, and 9

Table 16. Comparison of Braking Reported by EDR (at -1 sec) vs. CDS in Frontal Impact Vehicles

	CDS				
EDR (-1 sec)	**Includes Braking***	**No Avoid. Action**	**All Other**	**Total**	**% of Total**
Brake=OFF	28	43	36	107	27%
Brake=ON	93	59	79	231	58%
Brake=[blank]	22	15	24	61	15%
Total	143	117	139	399	
% of Total	36%	29%	35%		

*Includes Braking: CDS MANEUVER = 2, 3, 4, 8, and 9

Table 17. Comparison of Braking Reported by EDR (at -1 sec) vs. CDS in Rear-End-Striking Vehicles

	CDS				
EDR (-1 sec)	**Includes Braking***	**No Avoid. Action**	**All Other**	**Total**	**% of Total**
Brake=OFF	16	14	11	41	31%
Brake=ON	30	15	27	72	55%
Brake=[blank]	8	3	7	18	14%
Total	54	32	45	131	
% of Total	41%	24%	34%		

*Includes Braking: CDS MANEUVER = 2, 3, 4, 8, and 9

5.1.4. Seat Belt Usage

All of the GM EDR modules in this study were capable of recording the operational status of the driver seat belt via the S*eat Belt Circuit Switch status* (*Seat Belt Status*) variable, whether it was buckled or unbuckled, at the time of the crash. The driver seat belt was reported by the EDR as being buckled in about 61 percent out of the 2,283 NASS-CDS GM vehicle files, as shown in Table 18. The associated CDS vehicle cases had occupant information in 2,073 of the 2,283 total cases. The CDS variable *Manual (Active) Belt System Use* (MANUSE)[10] found in the Occupant Form of the CDS case files was used for comparative purposes. The distribution of CDS cases per MANUSE code description is shown in Table 19. The CDS-reported driver seat belt usage (buckled) was about 80 percent, as compared to 61 percent reported by the EDRs. Figure 12 displays the relative frequency of seat belt usage reported by the EDR and the CDS vehicle driver files.

Table 18. EDR-Reported Driver *Seat Belt Status* Indicator

EDR - Driver Seatbelt Status	No. Cases	Frequency
BUCKLED	1,383	61%
UNBUCKLED	857	38%
[blank]	43	2%
Total	2,283	100%

Table 19. CDS-Reported Driver *Manual (Active) Belt System Use* (MANUSE)

CDS Driver File MANUSE		No. Cases	Frequency
Code	**Description**		
00	None used, not available or destroyed	409	20%
04	Lap and shoulder belt	1,649	80%
05	Belt used - type unknown	1	0%
99	Unknown if belt used	14	1%
	Total	2,073	100%

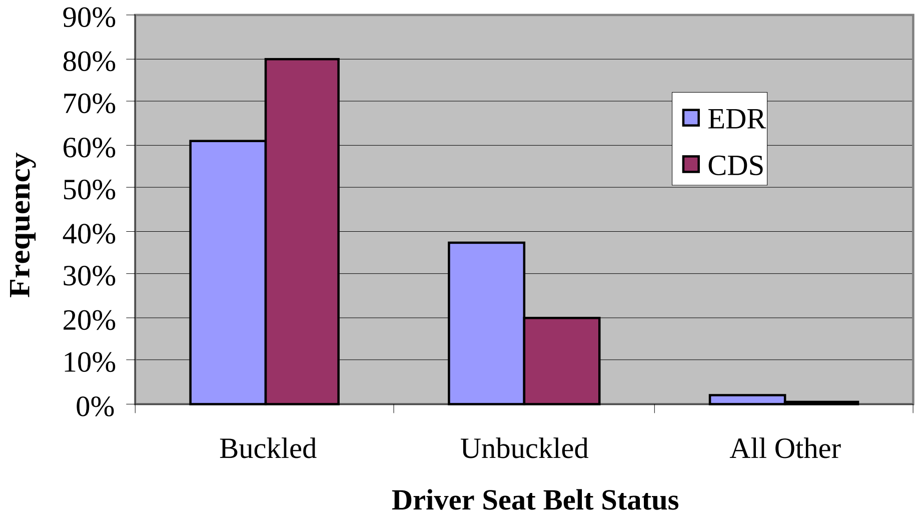


Figure 12. Driver Seat Belt Status Frequency as Reported by EDR and CDS

A cases-by-case comparative analysis was conducted for the 2,073 vehicle cases in which there was a person file in the CDS for the driver and the results are summarized in Table 20. The driver was reported as buckled in the CDS data in about 80 percent of the vehicle cases but only in about 60 percent of the associated EDR files. About 25 percent of drivers were listed in the CDS person file as being buckled while the EDR file listed their seat belt as unbuckled. Figure 13 shows the distribution of EDR-reported driver seat belt status for the cases where the CDS file reported the driver as buckled (left) and for cases where the CDS file reported the driver as unbuckled (right). A full 26 percent of vehicle cases in which the CDS data reported a buckled driver contained EDR driver seat belt status information that indicated otherwise.

Figure 14 shows the distribution of CDS-reported driver injuries by seat belt status as reported by the EDRs and Figure 15 shows the same analysis of the driver injury data as reported in the CDS.

Table 20. Comparison of Driver Seat Belt Use Reported by EDR vs. CDS

EDR \ CDS	Buckled	Unbuckled	All Other	Total	% of Total
Buckled	1,214	28	6	1,248	60%
Unbuckled	412	377	8	797	38%
All Other	24	4	-	28	1%
Total	1,650	409	14	2,073	
% of Total	80%	20%	1%		

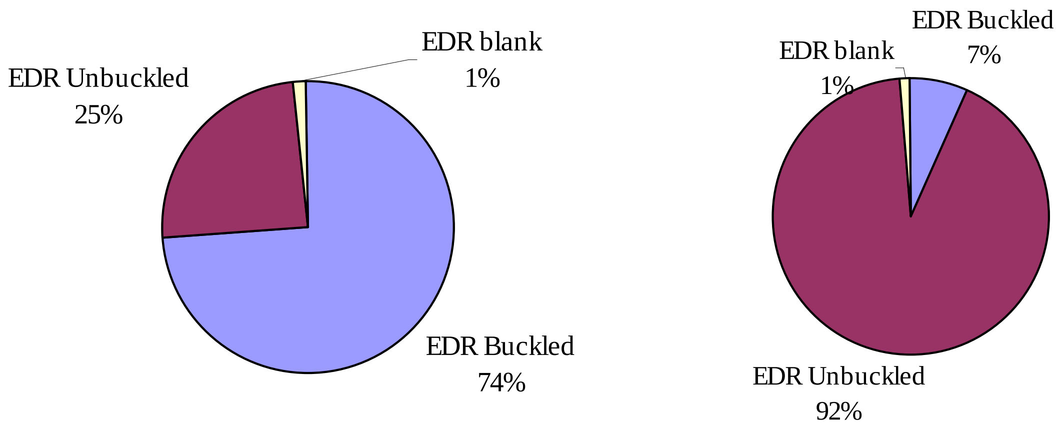


Figure 13. Distribution of EDR-Reported Driver Seat Belt Status per CDS Reported Seat Belt Status (Left: CDS Buckled, Right: CDS Unbuckled)

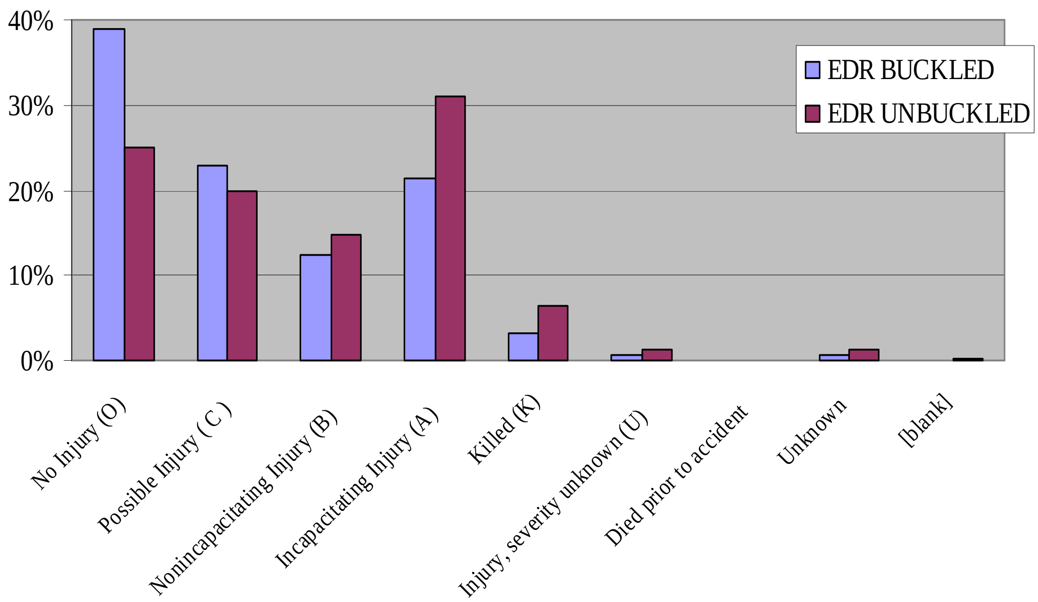


Figure 14. Driver Injuries by Seat Belt Status as Reported by EDR

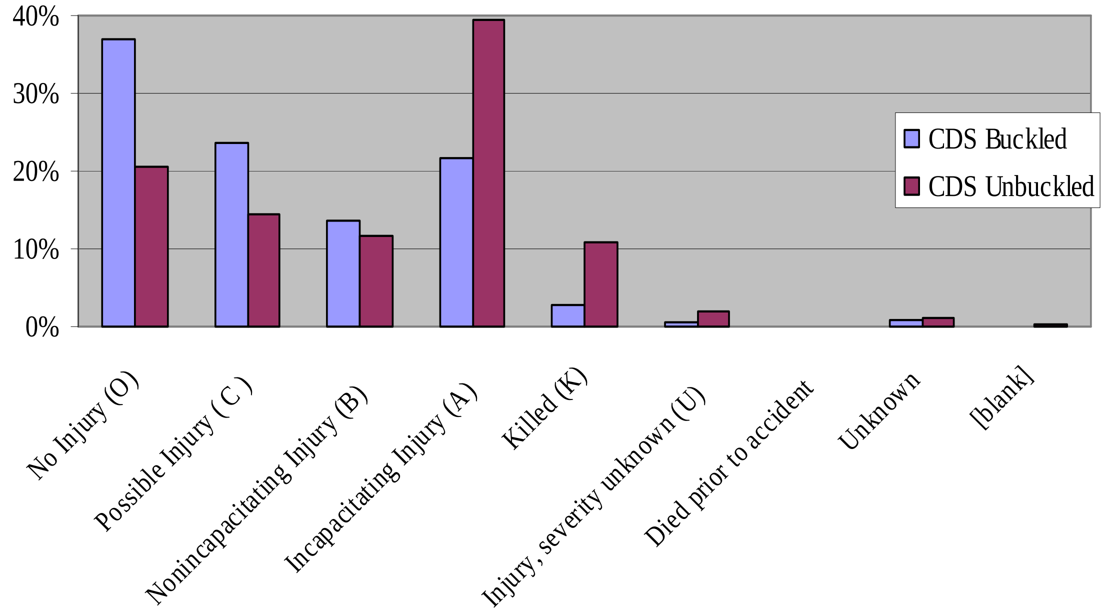


Figure 15. Driver Injuries by Seat Belt Status as Reported by CDS

5.1.5. Air Bag Deployment

As with seat belt status, all of the GM EDR modules in this study were capable of reporting on the status of the steering-wheel air bag, whether it was deployed or not, during the crash. The EDRs used air bag status data to classify the events into the categories shown in Table 21. As previously discussed, GM EDRs can store up to two types of events. This is reflected in the event types in Table 21, where EDR files classified under the event type D/N contained one *Deployment* event and one *Non-Deployment* event, and those classified under D/DL contained two deployment events the second of which was categorized as a *Deployment-Level* event since the first event had already triggered the air bag firing algorithm.

Table 21. EDR Event Type Distribution

Type of Event	No. EDR Cases	Frequency
Deployment Only, "D"	326	14%
Non Deployment, "N"	1,162	51%
Dep. + Non Dep, "D/N"	691	30%
Dep. + Dep. Level, "D/DL"	61	3%
Dep. Level, "DL"	1	0%
[blank]	42	2%
Total	2,283	100%

The EDR event type was compared to the CDS-reported *Frontal Air Bag System Deployment* (BAGDEPLY)[10] variable in the driver file for each vehicle case. The CDS-reported driver air bag deployment status distribution is shown in Table 22. It should be noted that there were three cases in which the driver file indicated a non-deployed air bag but the occupant file for the right-front passenger indicated a deployment. These cases were classified as air bag deployment cases as reported by the CDS files even though the driver air bag was reported as not deployed in its occupant file.

Table 22. Distribution of CDS Driver *Frontal Air Bag System Deployment* (BAGDEPLY)

CDS Driver File BAGDPLY		No. CDS Cases	Frequency
Code	Description		
0	Not equipped/not available	6	0%
1	Air bag deployed during crash	1,036	45%
2	Air bag deployed prior to crash	-	0%
3	Deployed, sequence unknown	6	0%
4	Deployed-noncollision event	-	0%
5	Unknown if deployed	6	0%
7	Nondeployed	1,019	45%
9	Unknown	1	0%
n.a.	[Blank]	209	9%
	Total	2,283	100%

The CDS-reported air bag deployment status was separated into three categories as determined from the following BAGDPLY codes:

- Non-Deployment: 0, 7
- Deployment: 1, 2, 3, 4
- Unknown: 5, 9

The comparison of frontal air bag deployment status as reported by the EDR and CDS for each vehicle case is shown in Table 23. A total of 87 percent of all vehicle cases contained EDR air bag deployment status data that matched that of the associated CDS files. Most of the remaining cases contained either a CDS BAGDPLY code of *unknown* or no data in the event type field of the EDR file. It should be noted that the frequency of vehicle files with no EDR air bag status information was just 2 percent while the frequency of vehicle files with no CDS air bag status information was about 9 percent of the total number of vehicle cases.

Although most frontal air bag status data matched between EDR and CDS, a significant number of cases contained contradicting information. There were 23 cases in which the EDR file indicated air bag deployment where the CDS file denoted a non-deployment event. Conversely, 15 cases contained EDR data indicating air bag non-deployment where the CDS file denoted a deployment event. Figure 16 displays the distribution of CDS-reported frontal *Air Bag System Deployment* (BAGDEPLY) per EDR reported event type, with the left graphic displaying the CDS frontal *Air Bag System Deployment* distribution for EDR air bag deployment events, and the graphic on the right displaying the CDS frontal *Air Bag System Deployment* distribution for EDR air bag non-deployment events. As reflected in Figure 16, about 3 percent of EDR deployment vehicle cases were coded in the CDS as being a non-deployment event. This means that, upon the physical inspection of the vehicle, the NASS field data collection investigator determined that the air bag did not deploy even thought the EDR reported a *Deployment* event. This subset of cases, 23 in all, was further analyzed to determine the nature of the discrepancy between the reported air bag status between the EDR and CDS files.

Table 23. EDR vs. CDS Frontal Air Bag Deployment Status

EDR \ CDS	Deployed	Nondeployed	Unknown	Total	% of Total
Deployed	1,030	23	21	1,074	47%
Nondeployed	15	972	180	1,167	51%
[blank]	-	27	15	42	2%
Total	1,045	1,022	216	2,283	
% of Total	46%	45%	9%		

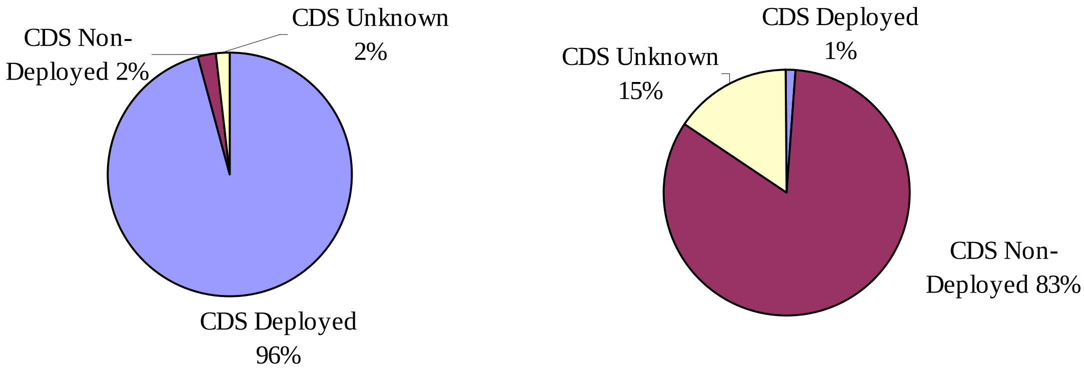


Figure 16. Distribution of CDS Reported Driver *Air Bag System Deployment* per EDR Reported Event Type (Left: EDR *Deployment*, Right: EDR *Non-Deployment*)

Air Bag Deployment Status Discrepancies - EDR *Deployment*/CDS Nondeployment

A total of 23 vehicle cases contained contradictory EDR versus CDS frontal air bag deployment status information, specifically denoted by the EDR files as *Deployment* while reported by the CDS files as non-deployment. These cases, along with the CDS *Accident Type* category and longitudinal delta V as reported by the CDS and EDR, are listed in Table 24. The EDR files in 6 of these cases reported only a single *Deployment* event. The associated CDS files denoted frontal air bag deployment status of "Not equipped/not available" in three of these cases while indicating "Nondeployed" in the remainder. The EDRs from the other 17 cases contained two recorded events, one a *Deployment* type and one a *Non-Deployment* type. However, analysis of the ignition cycle data reported by the EDR indicated that the EDR data was obtained by the NASS researcher after the crash for which a *Deployment* event was reported by the EDR. The *Non-Deployment* events stored on the EDRs were either from then same crash or from another prior vehicle incident.

As shown in Table 24 and displayed in Figure 17, a significant number of these cases contained longitudinal delta V data from both the CDS (*DVLONG*)[10] and EDR files that indicated a severe crash where, under normal circumstances, the air bag should have deployed. A case by case analysis of the CDS data files noted an indication by the NASS investigator of the air bag not being reinstalled correctly or at all, possibly during repairs following previous crash, in at least four of the 23 cases (Case Nos. 200349207, 200349176, 200108175, 200550060). An example of an empty steering wheel air bag cavity is shown in Figure 18. The NASS investigator also coded the attribute *bag failure* in two other high delta V cases (Case No. 200112116 and Case No. 200548231) as a note for further review. An example of a *bag failure* vehicle case with high delta V is shown in Figure 19. In this case (CDS Case No. 200112116) the vehicle's EDR reported a longitudinal delta V value of -26.4 mph while the CDS vehicle file reported a value of -40.4 mph. The driver was belted but died as a result of the crash. A total of 13 out of the 23 vehicles, or about 56 percent, were from vehicle MY 1994 through MY 1999. This is highly disproportionate when compared to the overall ratio of the 1994-1999 MY vehicle set, which contained 781 out of the total 2,283 vehicle cases (34%). It should also be noted that the EDR reported the W*arning Lamp Status* as "ON" in three cases (Case Nos. 200445246, 200548231, and 200512176), which is a fault code associated with the air bag module.

Table 24. List of Vehicle Cases With Air Bag Deployment Status Information: CDS Non-Deployment/ EDR Deployment

CDS					EDR	
Case No.	**Vehicle No.**	**ACCTYPE**	**BAGDEPLY**	**DVLONG (mph)**	**Dep./Non-Dep.**	**DeltaV (mph)**
200108175	1	69	Nondeployed	[redacted]	D/N	-20.6
200112116	2	0	Nondeployed	-40.4	D/N	-26.4
200202124	1	0	Nondeployed	[redacted]	D/N	-6.4
200212006	2	0	Nondeployed	-3.1	D/N	-3.7
200212150	1	6	Nondeployed	-6.8	D/N	-11.8
200343168	2	0	Nondeployed	-8.7	D/N	-3.3
200349176	1	78	Not equipped/not available	[redacted]	D/N	-3.1
200349207	1	0	Not equipped/not available	[redacted]	D	-17.8
200376107	1	20	Nondeployed	[redacted]	D/N	-2.6
200402003	1	1	Nondeployed	-1.9	D	-6.2
200411115	1	20	Nondeployed	-2.5	D	-4.1
200445246	2	0	Not equipped/not available	-10.6	D	-17.4
200450044	1	6	Not equipped/not available	-23.0	D	-9.6
200481052	1	1	Nondeployed	[redacted]	D/N	-2.2
200512112	1	98	Nondeployed	[redacted]	D/N	-3.1
200512176	2	2	Nondeployed	20.5	D/N	-28.0
200513101	1	21	Nondeployed	[redacted]	D/N	-7.0
200513137	1	7	Nondeployed	-1.2	D/N	-4.6
200543047	2	82	Nondeployed	[redacted]	D/N	-19.4
200548231	2	2	Nondeployed	-24.9	D	-35.3
200550060	1	68	Nondeployed	[redacted]	D/N	-18.8
200573123	1	6	Nondeployed	[redacted]	D/N	-4.0
200575056	1	7	Nondeployed	[redacted]	D/N	-12.1

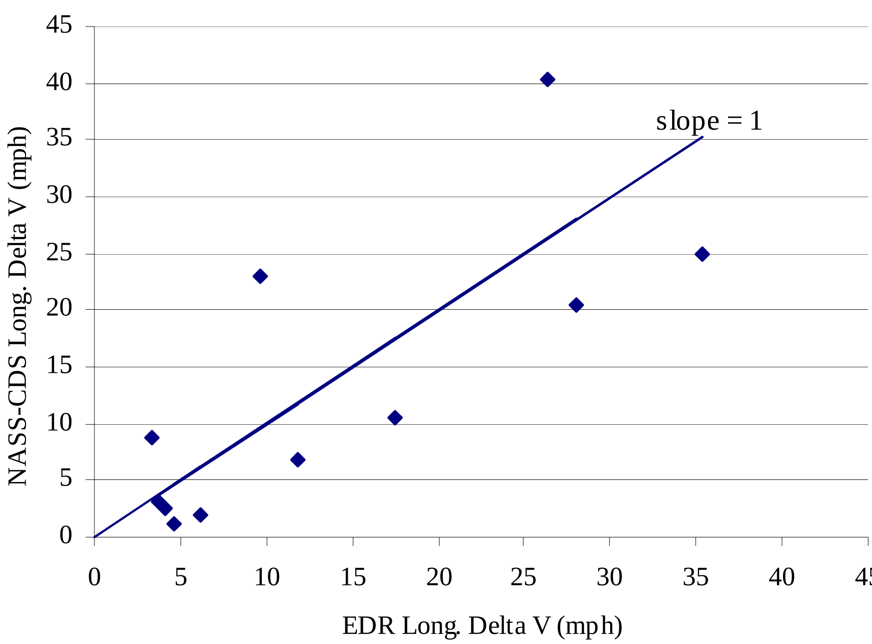


Figure 17. Longitudinal Delta V Comparison

Figure 18. Empty Steering Wheel Air Bag Cavity (CDS Case No. 200349207)[15]

Figure 19. *Non-Deployment* for Crash With High Delta V (CDS Case No. 200112116)[15]

Air Bag Deployment Status Discrepancies - EDR *Non-Deployment*/CDS Deployment

A total of 15 cases contained EDR data indicating air bag *non-deployment* where the CDS file denoted a deployment event. These cases, along with the CDS *Accident Type* category and longitudinal delta V as reported by the CDS and EDR, are listed in Table 25. Most of the cases in this subset contained longitudinal delta V data from both the CDS and EDR files that indicated a low delta V crash where the air bag most likely would have not deployed. A total of 12 out of the 15 vehicles, or about 80 percent, were from vehicle MY 1994 through MY 1999. This is highly disproportionate to the size of the 1994-1999 MY subset (34%). Also, 5 out of these 12 cases involved vehicles from the 1999 MY alone even though the 1999 MY only constitutes about 12 percent of the overall GM CDS vehicle case total. Furthermore, EDR data from two cases (Case nos. 200408040 and 200547002) revealed a large ignition cycle difference between event and EDR download. The gap ignition cycle gap between the event and EDR download was 42 cycles for case 200408040 and 71 cycles for case 200547002. This raises the possibility that the EDR downloaded might not have been the one present in the crash event, but rather the replacement installed during repairs. It should also be noted that the EDR reported *Warning Lamp Status* as *ON* in case number 200548215, which is indicative of an issue present within the air bag system.

There exist situations where the air bags fire automatically if the car is on fire and the temperature of the EDR module reaches a certain threshold. In these situations, the NASS investigator might note that the air bag was deployed even though in reality it was not deployed during the crash. Also, the vehicle's electrical system can be disabled early in the crash sequence and the onboard EDR might not have enough time or power to capture the crash event. In extreme situations, the electrical system can become disabled at the exact instant where the air bag firing algorithm sends the air bag firing signal and the signal never reaches the air bag firing mechanisms, but might be recorded by the EDR as a *deployment* event.

Table 25. List of Vehicle Cases With Air Bag Deployment Status Information: CDS Deployment/ EDR *Non-Deployment*

CDS					EDR	
Case No.	**Vehicle No.**	**ACCTYPE**	**BAGDEPLY**	**DVLONG (mph)**	**Dep./Non-Dep.**	**DeltaV (mph)**
200073209	1	6	Air bag deployed during crash	-5.6	N	-0.66
200212146	2	29	Air bag deployed during crash	-3.7	N	-1.73
200312138	1	1	Air bag deployed during crash	-6.8	N	0
200349211	1	8	Air bag deployed during crash	-11.8	N	-3.29
200349268	1	6	Air bag deployed during crash	[redacted]	N	-0.22
200379199	5	98	Deployed, sequence unknown	[redacted]	N	-0.37
200408040	2	82	Air bag deployed during crash	[redacted]	N	0
200448121	1	88	Air bag deployed during crash	-15.5	N	-0.44
200449032	1	64	Air bag deployed during crash	-7.5	N	-0.88
200473013	1	64	Air bag deployed during crash	[redacted]	N	0
200476084	2	89	Air bag deployed during crash	-3.7	N	-0.44
200512117	1	1	Air bag deployed during crash	-24.9	N	-0.44
200543036	1	83	Air bag deployed during crash	-15.5	N	-2.06
200547002	1	1	Air bag deployed during crash	[redacted]	N	-3.61
200548215	2	21	Air bag deployed during crash	34.2	N	0

5.1.6. Delta V

Perhaps the most valuable data element stored by EDRs, the delta V versus time history of a vehicle during a crash can be extremely useful in crash and injury research. The GM EDRs analyzed in this study were capable of recording longitudinal delta V information at a sampling rate of 100 Hz for either 150ms or 300ms during a crash, depending on module type. However, only about three-quarters of the EDR files in this study contained EDR-reported delta V information, as shown in Table 26. The associated CDS vehicle files contained longitudinal delta V information, coded under the variable *DVLONG,*[10] on about two-thirds of the cases. Only half of all cases (1,148) contained longitudinal delta V information from both the CDS and associated EDR files.

Table 26. Longitudinal Delta V Reporting Comparison – GM EDR vs. CDS

		CDS			
		Reported	**Not Reported**	**Total**	**% of Total**
EDR	**Reported**	1,148	533	1,681	74%
	Not Reported	354	248	602	26%
	Total	1,502	781	2,283	
	% of Total	66%	34%		

A comparison of delta V values was carried out only those cases in which the vehicle sustained frontal impact damage, since the GM EDRs only reported longitudinal delta V. These cases were identified by selecting vehicle cases in which the CDS *PDOF1*[10] variable was equal to 0, 10, or 350 degrees. Out of the 1,148 cases with longitudinal delta V information from both the CDS and EDR, only 466 met this criterion. Out of the 466 case subset that sustained frontal impact damage as defined above, the EDRs were judged to have captured the full delta V crash pulse in 427 cases. Due to the limited storage capacity of EDRs, many did not record complete delta V profiles where the maximum delta V could be identified. The EDR data set was therefore submitted through a down-select process to isolate those cases with full recorded delta V pulses based on the following selection criteria:

1. Maximum delta V value captured before end of the recorded pulse, or
2. Delta V pulse reached a constant value by the end of the recorded pulse (at least two consecutive data points).

As a result, a total of 427 vehicle cases judged to have contained the full longitudinal delta V pulse were selected for comparison. It should be noted that the CDS delta V information is estimated from models based on full frontal fixed-barrier crash data. As reflected in Table 27, the average EDR and CDS longitudinal delta V was -16.9 mph and -16.3 mph, respectively. Although the overall comparison seems to indicate a very close match between the EDR and CDS data, a more thorough analysis proves otherwise.

Table 27. Longitudinal Delta V Reporting Comparison – Frontal Impact Cases (*PDOF1* = 0, 10, 350 degrees)

CDS Coded *PDOF1* (deg.)	No. Cases	EDR		CDS Avg *DVLONG* (mph)
		Avg time to max Delta V (ms)	Avg Delta V (mph)	
0	184	130.5	-17.1	-17.1
10	115	125.1	-16.7	-15.7
350	128	122.5	-16.8	-15.6
0, 10, 350	427	126.7	-16.9	-16.3

The CDS reported delta V values were within ±20 percent of the reported EDR delta V values in only 185 cases out of the 427 vehicle cases in this subset. The biggest variance, as can be seen in Figure 20, occurred in the vehicle cases with EDR reported longitudinal delta V under 10 mph. The average CDS-reported difference in longitudinal delta V from the EDR-reported values for those cases was about 350 percent, and only 28 percent contained CDS longitudinal delta V values that fell within ±20 percent of the reported EDR longitudinal delta V values. For the cases in which the EDR-reported value was greater that 10 mph, the average CDS-reported difference from the EDR-reported values was only about 25 percent, and about half contained CDS longitudinal delta V data that was within ±20 percent of the reported EDR values.

Table 28 lists the longitudinal delta V comparative analysis per *Accident Type* category for those frontal impact damage vehicle cases (*PDOF1* = 0, 10, 350) where the value was reported for both the CDS and EDR (427 cases). Appendix G contains Figures displaying the distribution of EDR versus CDS longitudinal delta V information for the cases where this information was reported in both the CDS (cases in which *PDOF1* = 0, 10, 350) and EDR (excluding truncated delta V pulses) separately for each *Accident Type* Category.

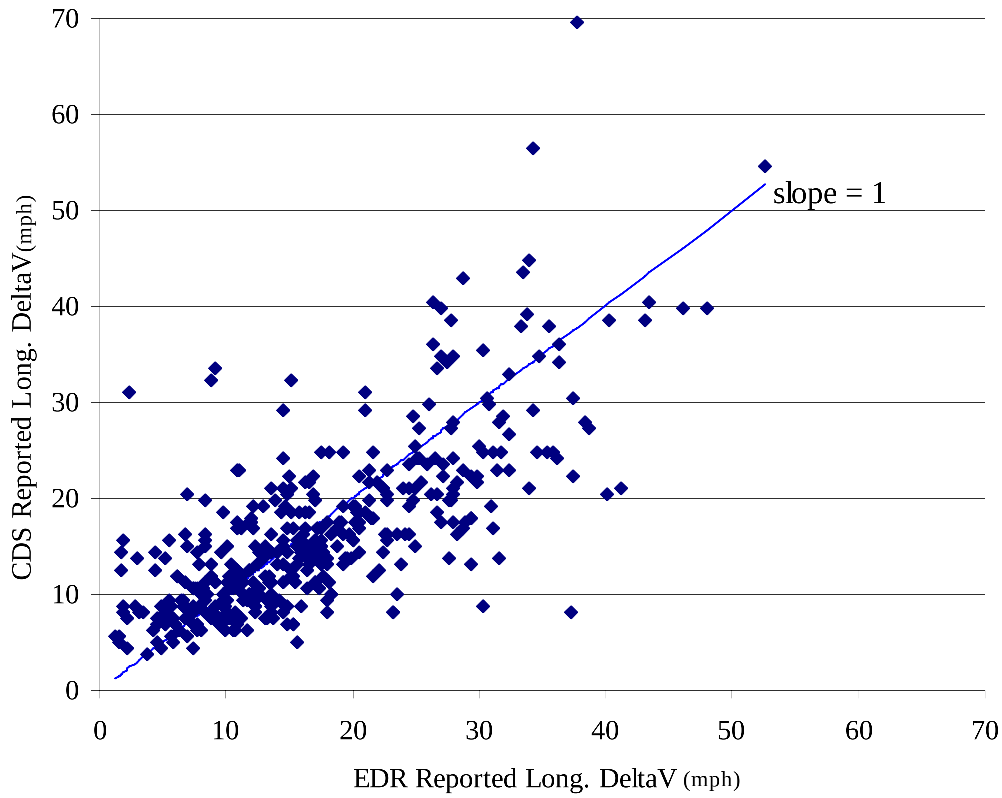


Figure 20. Comparison of Longitudinal Delta V for Cases Where Reported for Both NASS-CDS (*PDOF1*=0, 1, 350) and EDR Delta V (427 Cases)

Table 28. EDR/CDS Longitudinal Delta V per *Accident Type* (ACCTYPE) for Cases Where Reported for Both CDS (*PDOF1*=0, 1, 350) and EDR Delta V (427 Cases)

Category	Configuration	ACCTYPE	No. of Files	Avg. Long. DeltaV (mph)		CDS values within 20%	
				CDS	EDR	No.	%
Single Driver	Right Roadside Departure	1	31	-20.9	-21.2	12	38.7%
		2	6	-18.2	-15.7	1	17%
		3	3	-20.9	-19.6	1	33%
	Left Roadside Departure	6	21	-18.9	-20.7	7	33%
		7	9	-16.8	-17.5	2	22%
		8	5	-21.4	-26.9	3	60%
	Forward Impact	11	3	-14.5	-15.9	-	0%
		12	2	-15.2	-9.5	1	50%
		14	1	-16.8	-31.1	-	0%
Same Trafficway - Same Direction	Rear-End	20	62	-14.5	-14.7	25	40%
		21	6	-5.1	-8.2	3	50%
		24	20	-14.7	-13.4	8	40%
		25	1	-19.9	-14.0	-	0%
		28	12	-13.7	-13.2	8	67%
		32	3	-9.9	-8.4	2	67%
	Sideswipe Angle	45	1	-9.3	-11.4	1	100%
Same Trafficway - Opposite Direction	Head-On	50	31	-25.7	-28.0	13	42%
		51	27	-21.7	-23.0	13	48%
		52	4	-19.9	-22.9	2	50%
	Sideswipe Angle	64	6	-10.1	-7.3	1	17%
		65	2	-17.7	-21.3	1	50.0%
		66	4	-24.2	-26.3	3	75.0%
Change Trafficway - Vehicle Turning	Turn Across Path	68	16	-16.2	-17.5	9	56%
		69	51	-13.8	-15.6	22	43%
		73	1	-21.1	-25.0	1	100%
	Turn Into Path	77	2	-8.7	-7.5	-	0%
		79	1	-18.6	-20.6	1	100%
		80	1	-13.0	-18.0	-	0%
		81	1	-8.1	-37.3	-	0%
		82	1	-4.3	-7.5	-	0%
		83	29	-13.0	-13.2	14	48%
Intersecting Paths	Straight Paths	86	11	-11.3	-10.7	6	55%
		88	19	-15.3	-13.5	11	58%
		89	1	-11.2	-9.2	-	0%
Miscellaneous	Backing, Etc.	93	1	-5.0	-4.6	1	100%
		98	32	-13.7	-12.2	13	41%
		Total:	427		Total:	185	

5.2. Analysis of CDS EDR Data - Ford Vehicles

A total of 69 EDR files were collected from Ford vehicles as part of the CDS program. A total of 38 EDR files were identified as *deployment* events, where the air bag was deployed, and the remaining 31 EDR files were *non-deployment* events. A comparative analysis similar in nature to the one for the GM vehicle EDRs was conducted for the Ford EDR versus CDS files.

Appendix D contains Ford EDR data analysis results aggregated over the three crash databases (CDS, SCI, and CIREN).

5.2.1. Accident Type

The distribution of Ford EDR files per CDS ACCTYPE variable is shown in Table 29. The 69 Ford EDR files are associated with 31 different CDS ACCTYPE variables. Similarly to the GM CDS data, about one-quarter of the Ford EDR vehicle files were associated with single-vehicle crashes (*ACCTYPE = 1-15*).

Table 29. Distribution of CDS Ford EDR Files per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. Files	%
Single Driver	Right Roadside Departure	1	6	9%
		2	2	3%
		3	1	1%
		4	1	1%
	Left Roadside Departure	6	2	3%
		9	1	1%
	Forward Impact	11	1	1%
		12	2	3%
		13	2	3%
		14	1	1%
Same Trafficway - Same Direction	Rear-End	20	2	3%
		21	2	3%
		24	2	3%
		25	1	1%
		27	1	1%
		28	1	1%
		31	1	1%
	Sideswipe Angle	44	1	1%
		45	2	3%
		47	1	1%
Same Trafficway - Opposite Direction	Head-On	51	1	1%
Change Trafficway - Vehicle Turning	Turn Across Path	68	3	4%
		69	5	7%
	Turn Into Path	82	6	9%
		83	3	4%
Intersecting Paths	Straight Paths	86	5	7%
		87	3	4%
		88	2	3%
		89	4	6%
Miscellaneous	Backing, Etc.	93	1	1%
		98	3	4%
		Total	69	100%

5.2.2 Travel Speed Comparison
A total of 25 CDS Ford vehicle files (36%) contained police reported travel speed information. However, no comparison to EDR data was performed since the Ford EDRs in this study were not capable of reporting travel speed information.

5.2.3. Avoidance Maneuver (Brake Status)
The Ford EDRs analyzed in this study did not report information on brake usage. The CDS database reports the vehicle driver's avoidance actions, whether they pressed the brakes, steered, accelerated, or took no avoidance action at all, under the variable named *Attempted Avoidance Maneuver (MANEUVER).*[10] The breakdown of the MANEUVER type variable codes is shown in Table 30 over all *Accident Type* categories. Overall, an *Attempted Avoidance Maneuver* that included braking (*MANEUVER = 2, 3, 4, 8, 9*) was reported in 8 cases, accounting for about 12 percent of the total Ford EDR population in the CDS.

Table 30. CDS *Attempted Avoidance Maneuver* (MANEUVER)

Attempted Avoidance Maneuver (CDS *MANEUVER*)	**All Accident Types**	
	No. Cases	**Freq.**
No impact	1	1%
No avoidance action	28	41%
Braking (no lockup)	3	4%
Braking (lockup)	1	1%
Braking (lockup unknown)	-	0%
Releasing brakes	-	0%
Steering left	7	10%
Steering right	1	1%
Braking & steering left	2	3%
Braking & steering right	2	3%
Accelerating	1	1%
Accelerating & steering left	-	0%
Accelerating & steering right	1	1%
Other action	1	1%
Unknown	21	30%
No driver present	-	0%
Total	69	100%
Includes Braking	8	12%

5.2.4. Seat Belt Usage
The two Ford EDR module types in this study were capable of recording the operational status seat belt for the driver as well as for the passenger-side front seat, whether it was buckled or unbuckled, at the time of the crash. The driver seat belt was reported by the EDR as being buckled in almost 70 percent of the 69 CDS Ford vehicle files, as shown in Table 31, while the right-front passenger seat belt was reported as buckled in 44 percent of the cases. It should be noted that there were 5 vehicle cases in which the CDS did not

list an occupant in the right-front position but the associated EDR file listed that position's seat belt as being buckled.

The associated CDS vehicle cases had occupant information for the driver in 61 of the 69 total cases and listed a passenger seated in the right-front seat in 16 cases. The variable *Manual (Active) Belt System Use* (MANUSE)[10] was used for comparative purposes. The distribution of CDS cases per MANUSE code description is shown in Table 32. The CDS-reported driver seat belt usage rate was about 82 percent, as compared to 68 percent reported by the EDRs. Figure 21 and Figure 22 display the relative frequency of seat belt usage reported by the EDR and the CDS occupant files for the driver and right-front passenger, respectively.

Table 31. EDR-Reported Driver and Right-Front Passenger Seat Belt Status

EDR - Driver Seatbelt Status	Driver		Right Front Passenger	
	No. Cases	Frequency	No. Cases	Frequency
BUCKLED	47	68%	7	44%
UNBUCKLED	22	32%	9	56%
Total	69	100%	16	100%

Table 32. CDS-Reported Driver and Right-Front Passenger *Manual (Active) Belt System Use* (MANUSE)

CDS Occupant File MANUSE		Driver		Right Front Passenger	
Code	Description	No. Cases	Frequency	No. Cases	Frequency
00	None used, not available or destroyed	11	18%	5	31%
04	Lap and shoulder belt	50	82%	10	63%
14	Lap and shoulder w/child safety seat	-	0%	1	6%
	Total	61	100%	16	100%

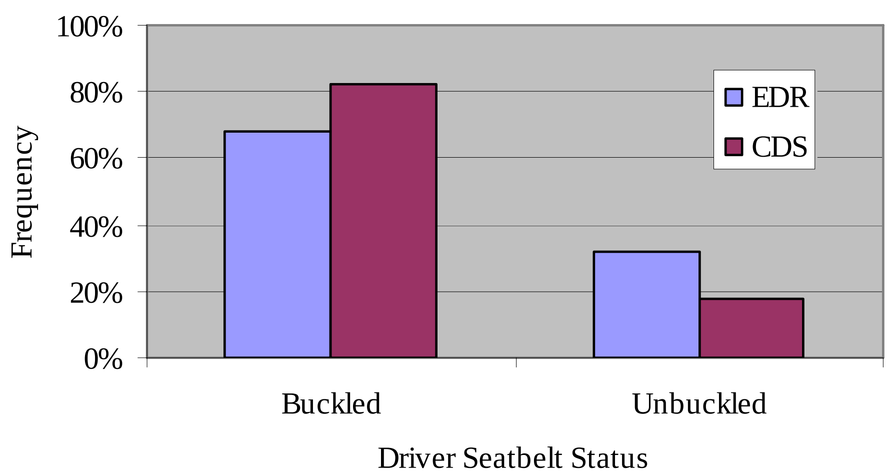


Figure 21. Driver Seat Belt Status Frequency as Reported by EDR and CDS

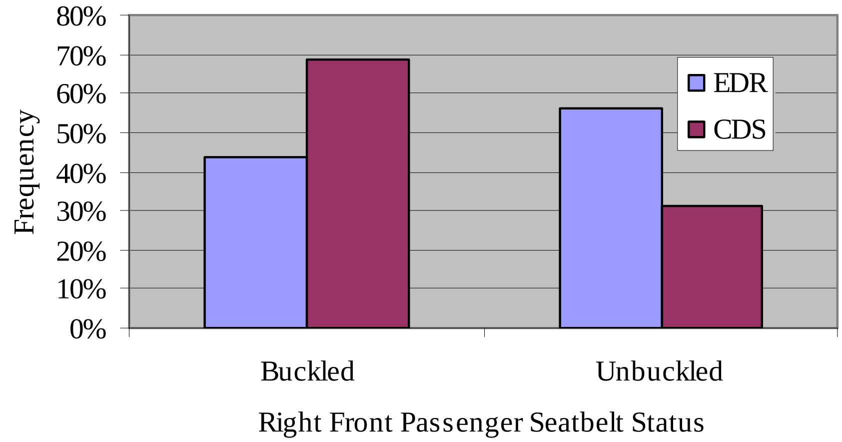


Figure 22. Right Front Passenger Seat Belt Status Frequency as Reported by EDR and CDS

A case-by-case comparative analysis was conducted for the 61 vehicle cases in which there was a person file in the CDS for the driver and the results are summarized in Table 33. The driver was reported as buckled in the CDS data in about 82 percent of the vehicle cases but only in about 69 percent of the associated EDR files. A total of 8 vehicle cases contained CDS data that reported a buckled driver and EDR driver seat belt status information that indicated otherwise.

Figure 23 shows the distribution of driver injuries by seat belt status as reported by the EDRs and Figure 24 shows the same analysis of the driver injury data as reported in the CDS. It should be noted that this analysis is based on a very limited set of data points and therefore no generalized conclusions about seat belt usage and injury should be made.

Table 33. Comparison of Driver Seat Belt Use Reported by EDR vs. CDS

EDR \ CDS	Buckled	Unbuckled	Total	% of Total
Buckled	42	-	42	69%
Unbuckled	8	11	19	31%
Total	50	11	61	
% of Total	82%	18%		

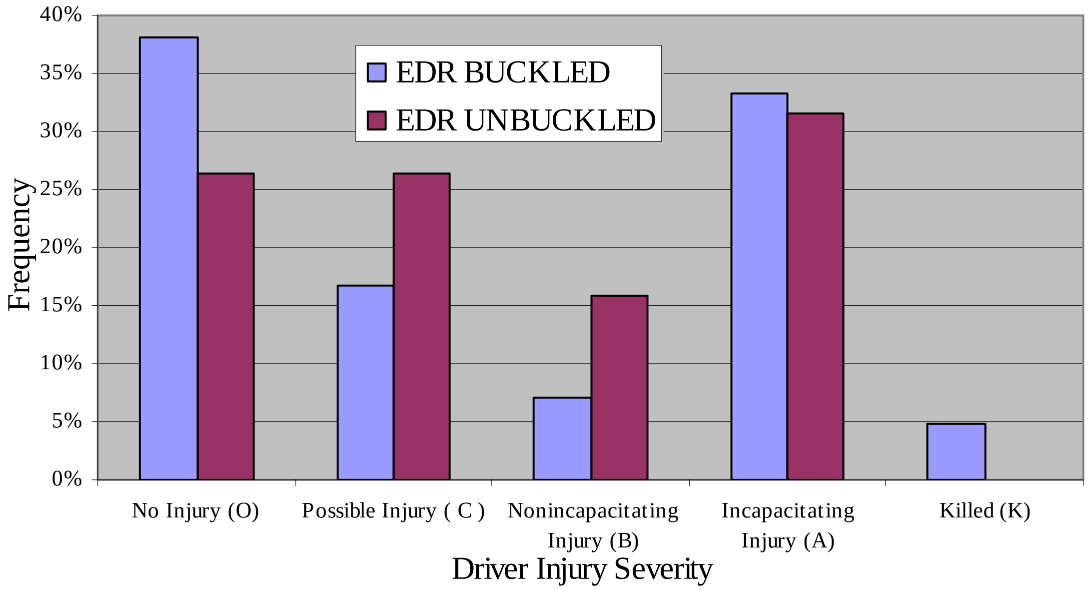


Figure 23. Driver Injuries by Seat Belt Status as Reported by EDR

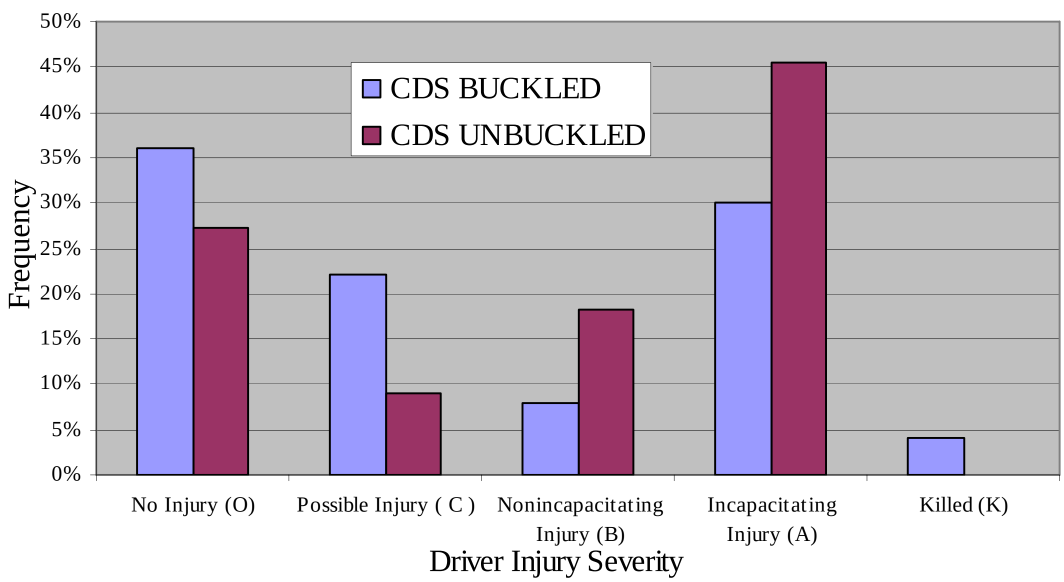


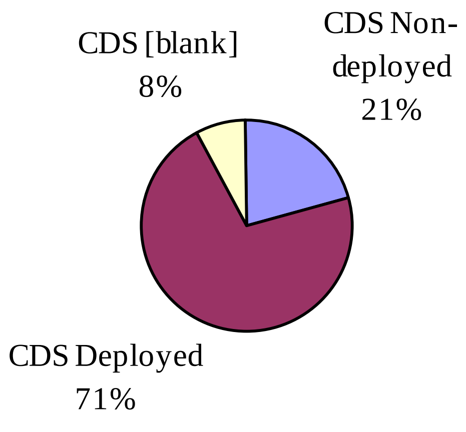
Figure 24. Driver Injuries by Seat Belt Status as Reported by CDS

5.2.5. Air Bag Deployment

All the Ford EDR modules in this study were capable of reporting on the status of the steering-wheel air bag, whether it was deployed or not, during the crash. This data was compared to the associated BAGDEPLY variable in the driver file of the CDS and the results are shown in Table 34. *Deployment* events, meaning a command to deploy the air bags was reported by the EDR, were identified in 38 EDR files. The associated CDS data showed that the driver air bag deployed in only 28 cases, as denoted by the BAGDEPLY variable in the driver file and shown in Table 34. A total of 9 vehicle cases contained contradictory EDR versus CDS frontal air bag deployment status information. Of those identified as *deployment* by the EDR files, 8 had driver BAGDEPLY information in the CDS that indicated the driver air bag was not deployed. It should be noted that the EDRs in 4 of those cases (Case Nos. 200309040, 200347056, 200543087, and 200573149) indicated deployment of the right-front passenger air bag even though indicating a non-deployed driver air bag. The distribution of CDS Reported Driver *Air Bag System Deployment* per EDR Reported Event Type is displayed in Figure 25.

Table 34. EDR Event Type vs. CDS Driver *Air Bag System Deployment* (BAGDEPLY)

	CDS Driver BAGDEPLY Variable			
EDR Type of Event	**Air bag deployed during crash**	**Nondeployed**	**[blank]**	**Total**
Deployment, "D"	27	8	3	**38**
Non Deployment, "N"	1	25	5	**31**
Total	**28**	**33**	**8**	**69**



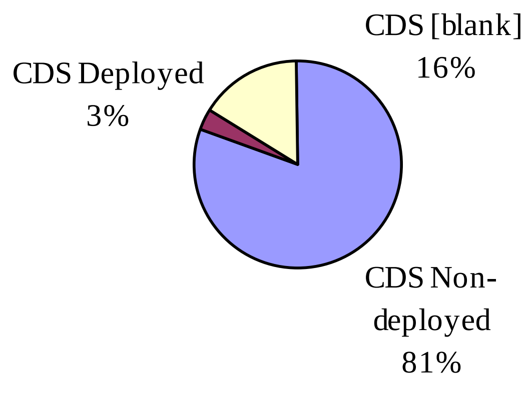


Figure 25. Distribution of CDS-Reported Driver *Air Bag System Deployment* per EDR Reported Event Type (Left: EDR *Deployment*, Right: EDR Non-Deployment)

Air Bag Deployment Status Discrepancies - EDR *Deployment*/CDS Nondeployment

A total of 4 vehicle cases contained EDR information indicating *Deployment* type events while reported by the CDS files as non-deployment events. These cases, along with the CDS *Accident Ty*pe category and longitudinal delta V as reported by the CDS and EDR, are listed in Table 35. Although the EDR and CDS data for most of these cases showed relatively low longitudinal delta V, at least one (Case No. 200211063, Vehicle No. 1) contained a relatively large longitudinal delta V value.

Conversely, 1 vehicle case contained EDR data indicating air bag *non-deployment* but where the CDS file denoted a deployment event. This case, along with the CDS *Accident Type* category and longitudinal delta V as reported by the CDS and EDR, is listed in Table 36. Longitudinal delta V information was not reported by the EDR or coded in the CDS vehicle file in this case.

Table 35. List of Vehicle Cases With Air Bag Deployment Status Information: CDS Non-Deployment/EDR *Deployment*

CDS					EDR	
Case No.	**Vehicle No.**	**ACCTYPE**	**BAGDEPLY**	**DVLONG (mph)**	**Dep./Non-Dep.**	**DeltaV (mph)**
200211063	1	1	Nondeployed	-21	Deployment	-16.82
200312101	1	20	Nondeployed	-14	Deployment	-11.86
200349139	1	2	Nondeployed		Deployment	-5.77
200472077	2	21	Nondeployed		Deployment	-10.5

Table 36. List of Vehicle Cases With Air Bag Deployment Status Information: CDS Deployment/EDR *Non-Deployment*

CDS					EDR	
Case No.	**Vehicle No.**	**ACCTYPE**	**BAGDEPLY**	**DVLONG (mph)**	**Dep./Non-Dep.**	**DeltaV (mph)**
200311145	1	13	Air bag deployed during crash		No Deployment	

5.2.6. Delta V (Longitudinal and Lateral)

The two Ford EDR modules analyzed in this study had very different capabilities with respect to crash pulse recording capabilities. As previously stated, one major difference between these two modules is that the newer modules, the Takata, recorded crash information for longitudinal change in velocity (delta V) and longitudinal acceleration for a period of up to 142 ms at a rate of 100 Hz, while the older module, the ARM100, recorded only up to 80 ms at 50Hz. However, the older model recorded lateral delta V and lateral acceleration as well.

Although the Ford EDR modules reported longitudinal delta V in all 69 cases, the full longitudinal delta V crash pulse was only captured in 11 of those files. The longitudinal delta V was reported in 46 of the CDS vehicle files and in 7 of the subset that included the full EDR-reported longitudinal crash pulse. A comparison of longitudinal delta V values was carried out only those cases in which the vehicle sustained frontal impact damage. These cases were identified by selecting vehicle cases in which the CDS variable *PDOF1* was equal to 0, 10, or 350 degrees. Out of the 7 cases with longitudinal delta V information from both the CDS and EDR, only 5 met this criterion. Figure 26 displays the distribution of EDR versus CDS longitudinal delta V information for these cases.

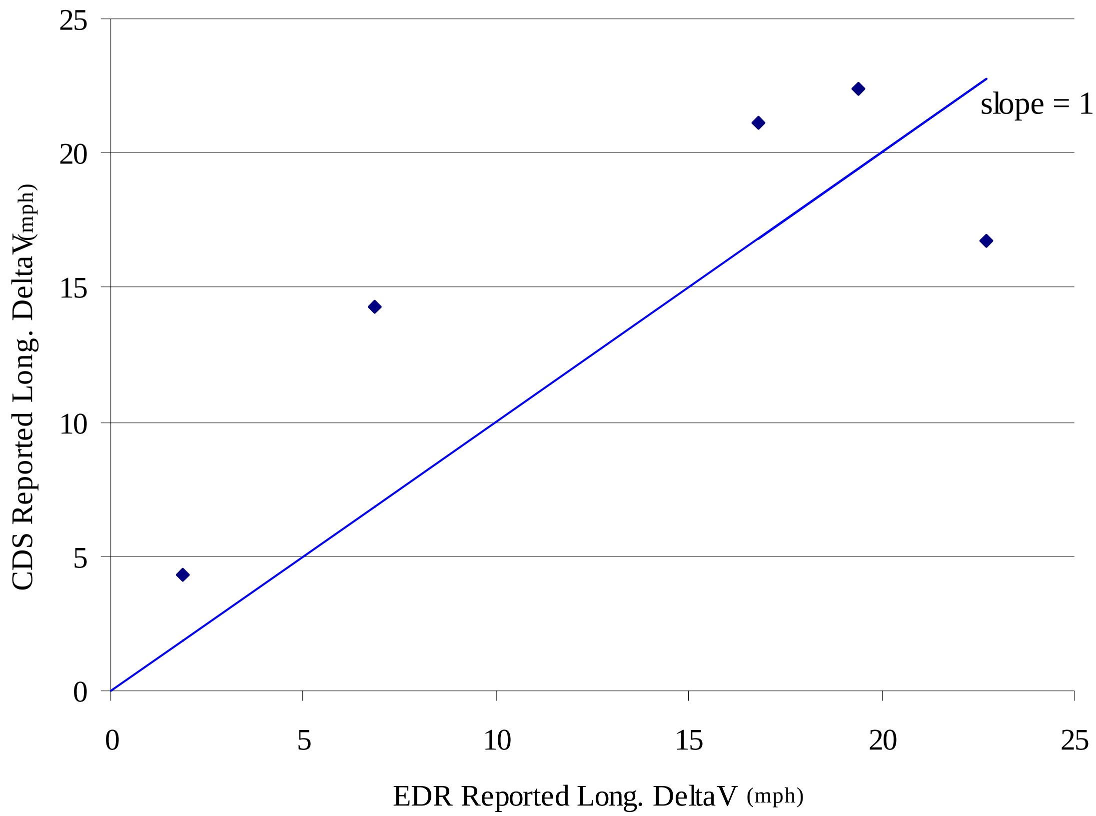


Figure 26. Comparison of Longitudinal Delta V for Cases Where Reported for Both CDS and EDR (5 Vehicle Cases)

The Ford ARM100 EDR modules analyzed in this study also stored lateral delta V information. A detailed analysis of the information contained in the 30 ARM100 EDR files associated with CDS vehicle files was performed. The analysis revealed only a total of 3 vehicle cases in which the EDR was judged to have reported the complete lateral delta V pulse, when the same down-select procedure as performed for the GM CDS data was applied. The lateral delta V pulse for each of those 3 cases is plotted in Figure 27. Of those, only 2 also contained CDS lateral delta V (*DVLAT*) [10] information. These are listed in Table 37.

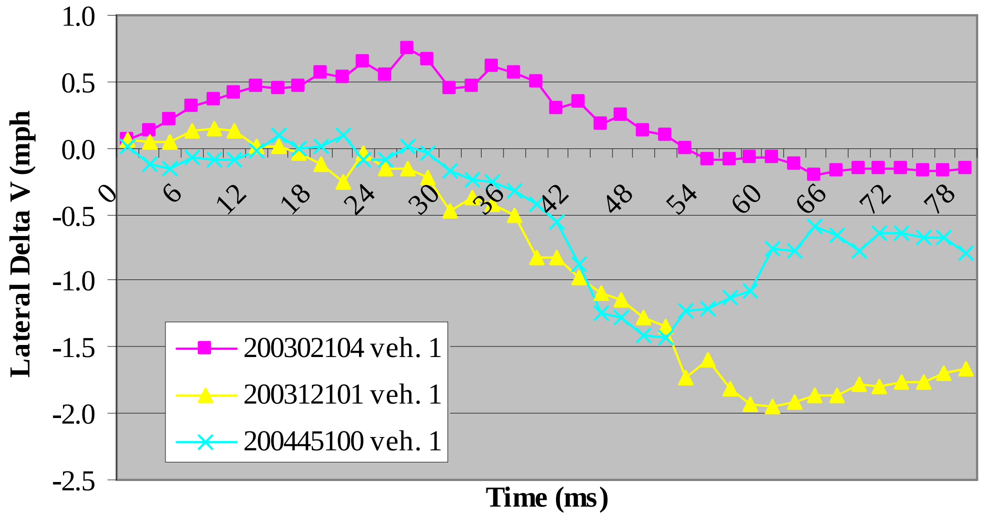


Figure 27. Lateral delta V for Cases Where Full Pulse Reported by the EDR (3 Vehicle Cases)

Table 37. Lateral Delta V Comparison

CDS			EDR
Case No.	**Vehicle No.**	**DVLAT (mph)**	**Delta V (mph)**
200312101	1	0.0	-1.95
200445100	1	-2.5	-1.43

6. SCI EDR DATA ANALYSIS

The SCI is a much smaller repository of vehicle crash information gathered by NHTSA within the NASS program for the purpose of analyzing emerging safety issues. Detailed information can be found at the NHTSA NCSA web portal.[6] This study analyzed a total of 131 EDR files associated with vehicles in the SCI program. The SCI data elements used in this study were defined in the same way as the CDS data elements detailed in Section 5.

Appendix C contains GM EDR data analysis results aggregated over the three crash databases (CDS, SCI, and CIREN).

6.1. Analysis of SCI EDR Data – GM Vehicles

A total of 123 EDR files were obtained from GM vehicles as part of vehicle crash data collection under the SCI program. The recorded parameter analysis presented herein focuses on this subset of files, which constituted about 5 percent of all EDR files in this study. These files were matched to the associated SCI case and vehicle files for comparison similarly to the analysis presented in Section 5.1.

6.1.1. Accident Type

The parameter comparison between the EDR and SCI data was broken down into the different *Accident Type* categories, as reported in the SCI vehicle file under the ACCTYPE variable name. The ACCTYPE variable denotes the type of crash the subject vehicle was involved in. Table 38 shows the distribution of EDR files per ACCTYPE variable. About one-third of all cases fell into the roadside departure *Accident Type* categories (*ACCTYPE = 1-10*).

Table 38. Distribution of EDR Files per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. Files	%
Single Driver	Right Roadside Departure	1	10	8.1%
		2	11	8.9%
		3	2	1.6%
	Left Roadside Departure	6	4	3.3%
		7	12	9.8%
		8	1	0.8%
	Forward Impact	11	1	0.8%
		13	1	0.8%
		14	2	1.6%
Same Trafficway - Same Direction	Rear-End	20	4	3.3%
		24	4	3.3%
		28	1	0.8%
		29	1	0.8%
	Sideswipe Angle	45	6	4.9%
		48	1	0.8%
Same Trafficway - Opposite Direction	Head-On	50	2	1.6%
		51	6	4.9%
	Forward Impact	59	1	0.8%
	Sideswipe Angle	64	3	2.4%
		65	3	2.4%
		66	2	1.6%
Change Trafficway - Vehicle Turning	Turn Across Path	68	4	3.3%
		69	9	7.3%
		73	1	0.8%
	Turn Into Path	81	1	0.8%
		82	1	0.8%
Intersecting Paths	Straight Paths	86	6	4.9%
		87	3	2.4%
		88	4	3.3%
		89	4	3.3%
		90	2	1.6%
Miscellaneous	Backing, Etc.	98	4	3.3%
		00	1	0.8%
Blank			5	4.1%
		Total	**123**	**100.0%**

6.1.2. Travel Speed Comparison

Out of the 123 GM vehicle files selected from the SCI crash data collection program, only about 24 percent contained police-reported travel speed information. The associated EDR vehicle files contained travel speed information on 54 percent of the total number of vehicles. However, excluding the EDR modules that did not have pre-crash data storage capabilities, the EDR-reported travel speed frequency was 60 percent. Table 39 shows the distribution of reported and not reported travel speed for both the EDR and SCI vehicle files.

Like previously done for the CDS data set, a comparison between the reported EDR travel speed values and associated reported values in the SCI files was conducted. Out of the 123 GM vehicle cases in the SCI database with EDR data, only 12 contained travel speed information reported in both the EDR and SCI. These are summarized by *Accident Type* category in Table 40 and the EDR versus SCI values graphically compared in Figure 28. The SCI Reported Travel Speed falls within ±20 percent of the reported EDR Travel Speed value taken at the -1-second time interval in 10 out of the 12 files (83 percent), and within ±10 percent in 7 cases (58 percent). The case-by-case comparison analysis indicates an average absolute difference of 7.7 mph, which translates to about 13 percent variance from the reported EDR values.

Table 39. EDR/SCI Police-Reported Travel Speed

		SCI			% of	
		Reported	Not Reported	Total	All EDRs	Applicable EDRs
EDR	Reported	12	54	66	54%	60%
EDR	Not Reported	18	39	57	46%	40%
	Total	30	93	123	100%	100%
	% of Total	24%	76%			

Table 40. EDR/SCI Police Reported Travel Speed per Accident Type (ACCTYPE)

Category	Configuration	ACCTYPE	No. of Files	Avg. Travel Speed (mph) SCI	Avg. Travel Speed (mph) EDR	SCI values within 20% No.	SCI values within 20% %
Single Driver	Right Roadside Departure	1	3	48	39.0	2	66.7%
		2	1	99	86.0	1	100.0%
	Left Roadside Dep.	7	2	80	73.5	2	100.0%
Same Trafficway - Same Direction	Rear-End	24	1	60	61.0	1	100.0%
Same Trafficway - Opposite Direction	Head-On	51	1	40	55.0	-	0.0%
Change Trafficway - Vehicle Turning	Turn Across Path	69	1	37	41.0	1	100.0%
Intersecting Paths	Straight Paths	86	1	56	60.0	1	100.0%
		88	1	76	75.0	1	100.0%
Blank			1	55	65.0	1	100.0%
		Total:	12		Total:	10	

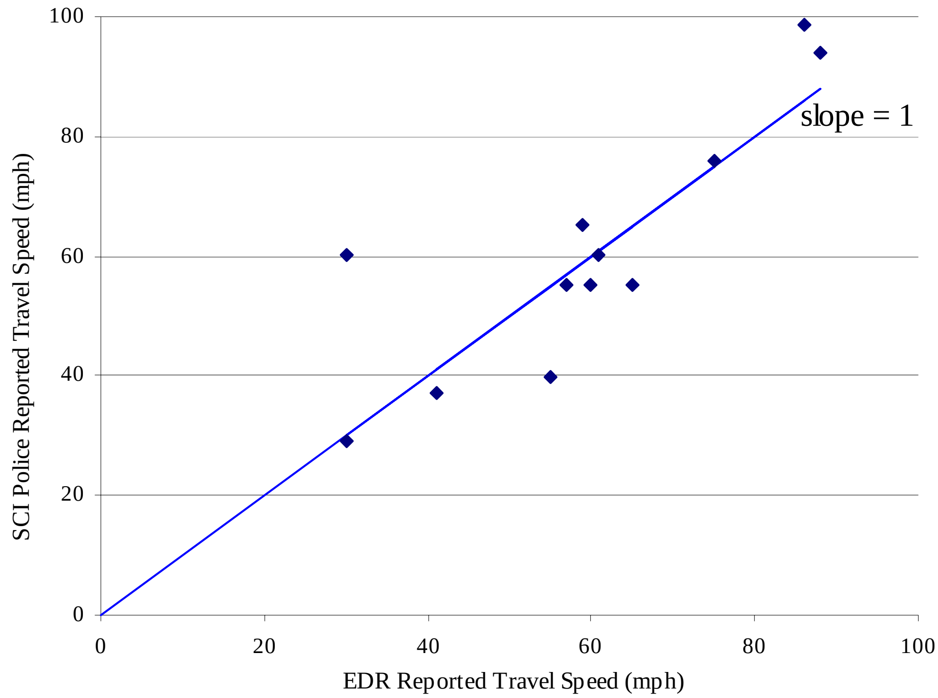


Figure 28. EDR/SCI Police-Reported Travel Speed Comparison (12 Files)

6.1.3. Avoidance Maneuver (Brake Status)

The breakdown of the MANEUVER type variable codes as reported in the SCI, as well as the associated *Brake Switch Status* data gathered from the EDR at -1 second, is shown in Table 41. Overall, an attempted avoidance maneuver that included braking was reported in 52 cases, accounting for about 42 percent of the total. Of those 52 cases, 32 cases reported just braking while 20 cases reported a combination of braking and steering. The associated EDR *Brake Status* data showed that the brakes were not applied in 5 of the 52 cases which the SCI data indicated as having an avoidance maneuver involving braking.

Table 42 lists the number of cases with EDR *Brake Status* information per value reported at each pre-crash time interval for those EDR modules that were capable of reporting pre-crash information (110 out of the 123). The EDR *Brake Status* information is listed for all *Accident Type* categories as well as for the frontal impact subset (*ACCTYPE = 11, 12, 13, 14, 15, 16, 20, 24, 28, 34, 36, 38, 40, 42, 43, 50, 51, 54, 56, 58, 60, 62, 63, 80, 81, 83, 86, 88*) and rear-end subset (*ACCTYPE = 20, 24, 28*) defined in this study. Overall, the analysis of the EDR data revealed a decrease in *Brake Status = OFF*, indicating application of the brakes, throughout the 5 seconds leading to the crash. For frontal impact vehicles cases, a total of 15 out of 28 EDR modules reported braking at the -1-second time interval, which indicates that 53 percent of frontal-impact vehicle drivers applied the brakes before the crash. However, excluding the vehicle cases with no *Brake Status* information, denoted as *[blank]*, or *Invalid*, the EDR *Brake Status* data indicated 75 percent of frontal-impact vehicle drivers applied the brakes before the crash (15 out of

20). The braking frequency of the EDR-equipped vehicles (*BRAKE* = *ON*), excluding *Invalid* and *[blank]* EDR *Brake Status* values, is plotted in Figure 29 for 3 three sets of *Accident Type* groupings.

Table 41. SCI *Attempted Avoidance Maneuver* (MANEUVER)

Attempted Avoidance Maneuver (SCI)	No. Cases	EDR BRAKE STATUS at -1 sec			
		OFF	ON	INVALID	[blank]
Braking (lockup unknown)	18	4	8	-	6
Braking (lockup)	2	-	1	-	1
Braking (no lockup)	12	-	9	-	3
Braking and steering left	7	-	5	-	2
Braking and steering right	13	1	7	-	5
ERROR - N/A	8	-	2	-	6
No avoidance maneuver	28	9	2	1	16
Other action (specify)	3	-	-	-	3
Steering left	6	2	1	-	3
Steering right	7	4	2	-	1
Unknown	15	1	6	-	8
[blank]	4	-	2	-	2
Total	123	21	45	1	56

Table 42. EDR *Brake Status*

BRAKE STATUS	Time				
	-5 sec	-4 sec	-3 sec	-2 sec	-1 sec
All Accident Types					
OFF	56	50	49	43	21
ON	10	16	17	23	45
INVALID	1	1	1	1	1
[blank]	43	43	43	43	43
Total	110	110	110	110	110
% ON	9.1%	14.5%	15.5%	20.9%	40.9%
Frontal Impact					
OFF	19	17	16	12	5
ON	1	3	4	8	15
INVALID	1	1	1	1	1
[blank]	7	7	7	7	7
Total	28	28	28	28	28
% ON	3.6%	10.7%	14.3%	28.6%	53.6%
Rear-End					
OFF	4	4	4	3	1
ON	-	-	-	1	3
[blank]	4	4	4	4	4
Total	8	8	8	8	8
% ON	0.0%	0.0%	0.0%	12.5%	37.5%

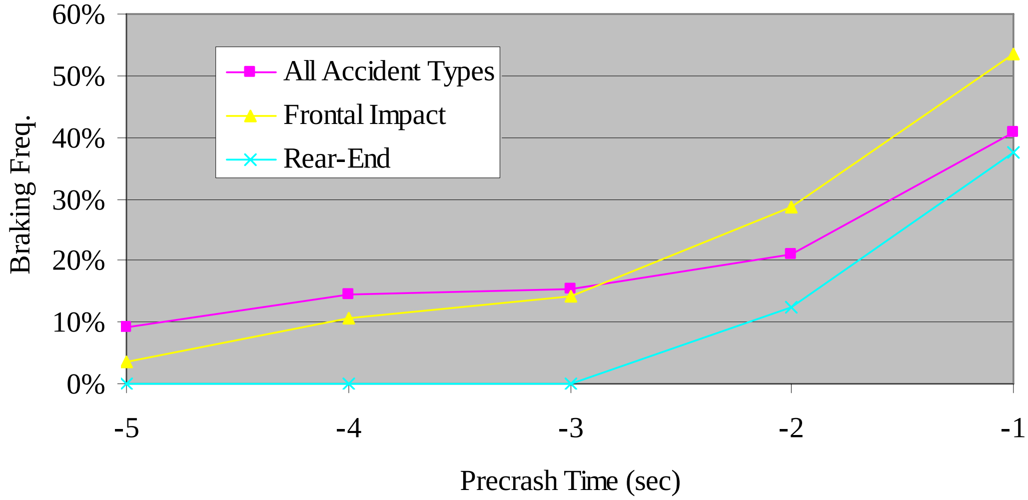


Figure 29. EDR-Reported Braking Frequency

Table 43 through Table 45 contain the results of the comparison of the driver braking action as reported by the brake switch status parameter in the EDR to the SCI reported *Attempted Avoidance Maneuver* for the cases in which the EDR modules recorded pre-crash information.

Table 43. Comparison of Braking Reported by EDR (at -1 sec) vs. SCI – All *Accident Types*

		SCI					
		Includes Braking	**No Avoid. Action**	**Other**	**Unknown**	**Total**	**% of Total**
EDR	**Brake=OFF**	5	9	6	1	21	19%
	Brake=On	30	3	3	10	46	42%
	Brake=Invalid	-	1	-	-	1	1%
	Brake=[blank]	14	11	6	11	42	38%
	Total	49	24	15	22	110	
	% of Total	45%	22%	14%	20%		

Table 44. Comparison of Braking Reported by EDR (at -1 sec) vs. SCI in Frontal-Impact Vehicles

		SCI					
		Includes Braking	**No Avoid. Action**	**Other**	**Unknown**	**Total**	**% of Total**
EDR	**Brake=OFF**	-	3	2	-	5	18%
	Brake=On	11	-	1	3	15	54%
	Brake=Invalid	-	1	-	-	1	4%
	Brake=[blank]	3	2	-	2	7	25%
	Total	14	6	3	5	28	
	% of Total	50%	21%	11%	18%		

Table 45. Comparison of Braking Reported by EDR (at -1 sec) vs. SCI in Rear-End-Striking Vehicles

		SCI					
		Includes Braking	No Avoid. Action	Other	Unknown	Total	% of Total
EDR	Brake=OFF	-	-	1	-	1	13%
	Brake=On	3	-	-	-	3	38%
	Brake=Invalid	-	-	-	-	-	0%
	Brake=[blank]	2	1	-	1	4	50%
	Total	5	1	1	1	8	
	% of Total	63%	13%	13%	13%		

6.1.4. Seat Belt Usage

The driver seat belt, as indicated by the EDR parameter *seat belt switch circuit status*, was reported as buckled in about 44 percent out of the 123 SCI GM vehicle files, as shown in Table 46. The associated SCI vehicle cases had driver occupant information in 107 of the 123 case set. The SCI-reported seat belt status was identified by *[blank]* in Table 46 for the remaining 16 cases. The overall SCI-reported driver seat belt usage (buckled) was about 53 percent, but about 62 percent when the cases without driver information were excluded. Figure 30 displays the relative frequency of seat belt usage reported by the EDR and the SCI vehicle driver files.

Table 46. Comparison of Driver Seat Belt Use Reported by EDR vs. SCI

EDR \ SCI	Buckled	Unbuckled	[blank]	Total	% of Total
Buckled	45	-	9	54	44%
Unbuckled	1	33	4	38	31%
[blank]	20	8	3	31	25%
Total	66	41	16	123	
% of Total	54%	33%	13%		

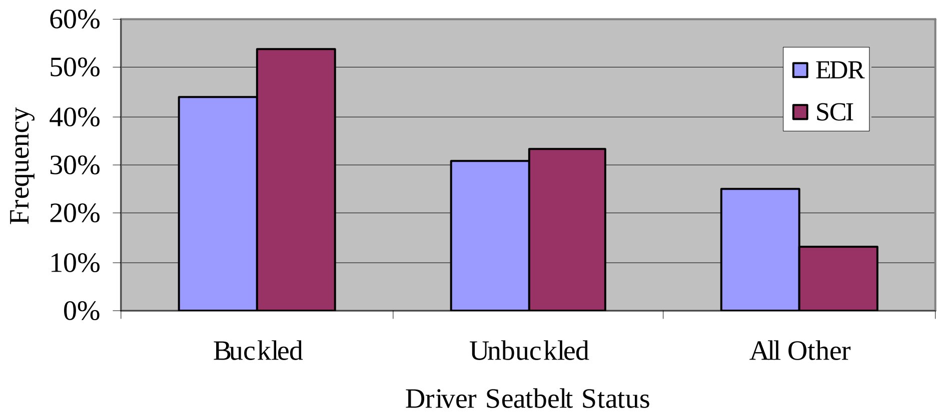


Figure 30. Driver Seat Belt Status Frequency as Reported by EDR and SCI

6.1.5. Air Bag Deployment

As previously stated in this report, all of the GM EDR modules in this study were capable of reporting on the status of the steering-wheel air bag, whether it was deployed or not, during the crash. These EDR modules could also store up to two types of events. The EDR event type was compared to the *Frontal Air Bag System Deployment* (BAGDEPLY) variable reported in the SCI for each vehicle case. There were 2 cases in which the driver air bag was reported in the SCI file as not being deployed but the front passenger's reported as deployed, and the associated EDR files for those 2 cases reported *Deployment*. The EDR-reported air bag status distribution is shown in Table 47 and the SCI-reported *Air Bag System Deployment* distribution is shown in Table 48. The comparison of frontal air bag deployment status as reported by the EDR and SCI for each vehicle case is shown in Table 49. The EDR and SCI air bag deployment data did not match in only 3 of the 107 vehicle cases where both sources reported air bag status information. These cases are listed in Table 50.

Table 47. EDR Event Type Distribution

Type of Event	No. EDR Cases	Frequency
Deployment Only, "D"	21	17%
Non Deployment, "N"	43	35%
Dep. + Non Dep, "D/N"	56	46%
Dep. + Dep. Level, "D/DL"	3	2%
Total	123	100%

Table 48. SCI Frontal *Air Bag System Deployment* Distribution

SCI Driver Air Bag	No. SCI	
Description	Cases	Frequency
Deployed during crash (as a result of impact)	64	52%
Non-collision Deployment	1	1%
Not deployed	42	34%
[Blank]	16	13%
Total	123	100%

Table 49. EDR vs. SCI Frontal Air Bag Deployment Status

EDR \ SCI	Deployed	Nondeployed	Total	% of Total
Deployed	63	1	64	60%
Nondeployed	2	41	43	40%
Total	65	42	107	
% of Total	61%	39%		

Table 50. List of Vehicle Cases With Contradicting Air Bag Deployment Status Information

SCI					EDR	
Case No.	**VIN**	**ACCTYPE**	**BAGDEPLY**	**DVLONG (mph)**	**Dep./Non-Dep.**	**DeltaV (mph)**
CA04-015	1GKEK13Z02	2	Deployed during crash (as a result of impact)		N	
IN02002	2G1WH55K9	66	Deployed during crash (as a result of impact)	-4.3	N	
CA02-037	1G2HX52KX	1	Not deployed	-19.9	D	

6.1.6. Delta V

Longitudinal delta V information was reported in 67 percent of the vehicle cases by both the EDR and SCI files, as shown in Table 51. However, only 58 cases contained longitudinal delta V information from both the SCI and associated EDR files. Out of these, the EDRs were judged to have captured the full delta V crash pulse in 19 cases (using the down-select process described in ***5.1.6***). A comparative analysis was done on this subset of cases and a case-by-case longitudinal delta V comparison is shown in Figure 31. The SCI reported longitudinal delta V values were within ±20 percent of the reported EDR longitudinal delta V values in only 7 cases out of the 19 in this subset. The biggest variance, as can be seen in Figure 31, occurred in the vehicle cases with EDR reported longitudinal delta V of less than 10 mph. For the cases in which the EDR-reported longitudinal delta V was greater that 10 mph, the average SCI-reported difference in longitudinal delta V from the EDR-reported values was only about 23 percent, as compared to about 70 percent for all 19 cases.

Table 51. Longitudinal Delta V Reporting Comparison – GM EDR vs. SCI

		SCI			
		Reported	**Not Reported**	**Total**	**% of Total**
EDR	**Reported**	58	24	82	67%
	Not Reported	25	16	41	33%
	Total	83	40	123	
	% of Total	67%	33%		

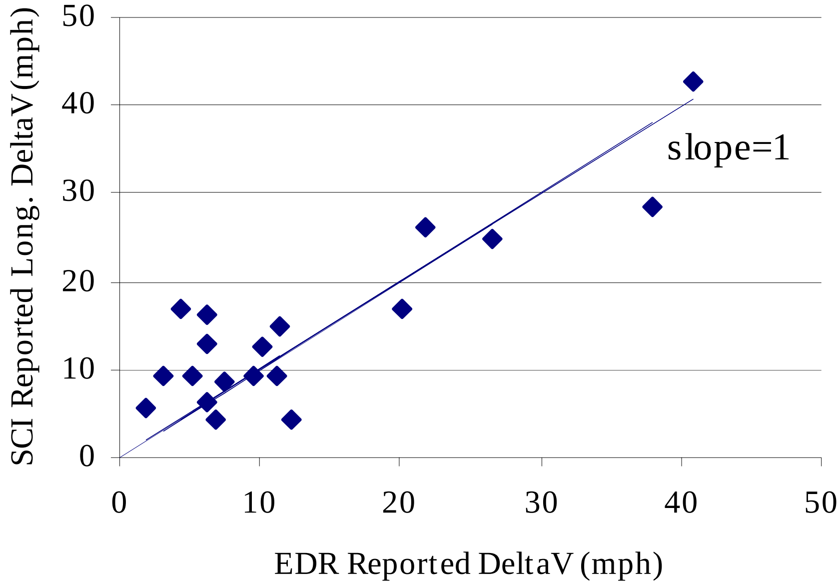


Figure 31. Comparison of Longitudinal Delta V for Cases Where Reported in Both SCI and EDR Vehicle Files

6.2. Analysis of SCI EDR Data – Ford Vehicles

A total of 8 EDR files were obtained from Ford vehicles as part of vehicle crash data collection under the SCI program. The recorded parameter analysis presented herein focuses on this subset of files, 6 of which were identified as *deployment* events indicating air bag deployment, and the remaining two EDR files identified as *non-deployment* events. These files were matched to the associated SCI case and vehicle files for comparison similarly to the analysis presented in Section 5.2.

Appendix D contains Ford EDR data analysis results aggregated over the three crash databases (CDS, SCI, and CIREN).

6.2.1. Accident Type

Table 52 shows the distribution of Ford EDR files per CDS ACCTYPE variable. The 8 Ford EDR files were associated with 7 different CDS ACCTYPE variables.

Table 52. Distribution of SCI Ford EDR Files per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. Files	%
Single Driver	Right Roadside Departure	2	1	13%
Same Trafficway - Same Direction	Rear-End	20	1	13%
Same Trafficway - Opposite Direction	Head-On	51	1	13%
Change Trafficway - Vehicle Turning	Turn Across Path	69	1	13%
	Turn Into Path	82	1	13%
Intersecting Paths	Straight Paths	86	2	25%
		88	1	13%
		Total	8	100%

6.2.2. Travel Speed Comparison

The Ford EDRs analyzed in this study did not report Travel Speed information. Furthermore, the Ford SCI vehicle files did not contain any Police-Reported Travel Speed information either.

6.2.3. Avoidance Maneuver (Brake Status)

The Ford EDRs analyzed in this study did not report information on brake usage. The SCI database reports the vehicle driver's avoidance actions (whether he/she pressed the brakes, steered, accelerated, or took no avoidance action at all) under the variable named *Attempted Avoidance Maneuver (MANEUVER)*. The breakdown of the MANEUVER type variable codes is shown in Table 53 over all *Accident Type* categories. Overall, an attempted avoidance maneuver that included braking (*MANEUVER = 2, 3, 4, 8, 9*) was reported in one case.

Table 53. CDS *Attempted Avoidance Maneuver* (MANEUVER)

Attempted Avoidance Maneuver (CDS *MANEUVER*)	All Accident Types	
	No. Cases	Freq.
No avoidance action	3	38%
Braking (lockup)	1	13%
Steering right	2	25%
Unknown	2	25%
Total	8	100%

6.2.4. Seat Belt Usage

As previously mentioned in this report, the two Ford EDR module types in this study were capable of recording the operational status seat belt for the driver as well as for the passenger-side front seat at the time of the crash. Table 54 summarizes the seat belt status conditions reported by the Ford EDRs. The driver seat belt was reported by the EDR as being buckled in 5 out of the 8 SCI Ford vehicle files. The EDR also reported 1 right front passenger seat belt as being buckled. The SCI reported driver seat belt as being buckled in 6 cases, as shown in Table 55. Figure 32 and Figure 33 display the relative frequency of seat belt usage reported by the EDR and the SCI files for the driver and right-front occupants, respectively. It should be noted that these frequencies are based on a very limited number of cases, as shown in Table 54 and Table 55.

Table 54. EDR-Reported Driver and Right-Front Passenger Seat Belt **Status**

EDR - Driver Seatbelt Status	Driver		Right Front Passenger	
	No. Cases	Frequency	No. Cases	Frequency
BUCKLED	5	63%	1	50%
UNBUCKLED	3	38%	1	50%
Total	8	100%	2	100%

Table 55. SCI-Reported Driver and Right-Front Passenger *Manual (Active) Belt System Use* (MANUSE)

SCI Occupant File MANUSE		Driver		Right Front Passenger	
Code	Description	No. Cases	Frequency	No. Cases	Frequency
00	None used, not available or destroyed	2	25%	1	50%
04	Lap and shoulder belt	6	75%	1	50%
	Total	8	100%	2	100%

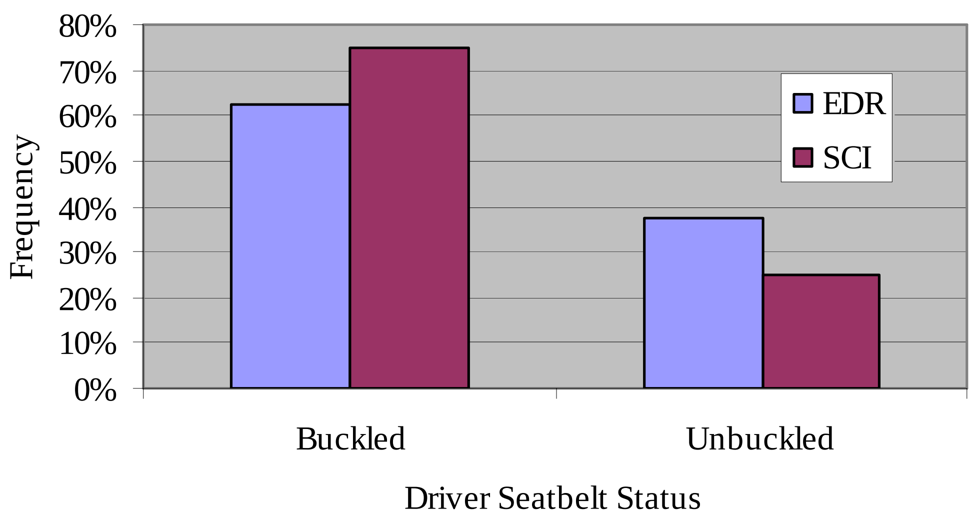


Figure 32. Driver Seat Belt Status Frequency as Reported by EDR and SCI

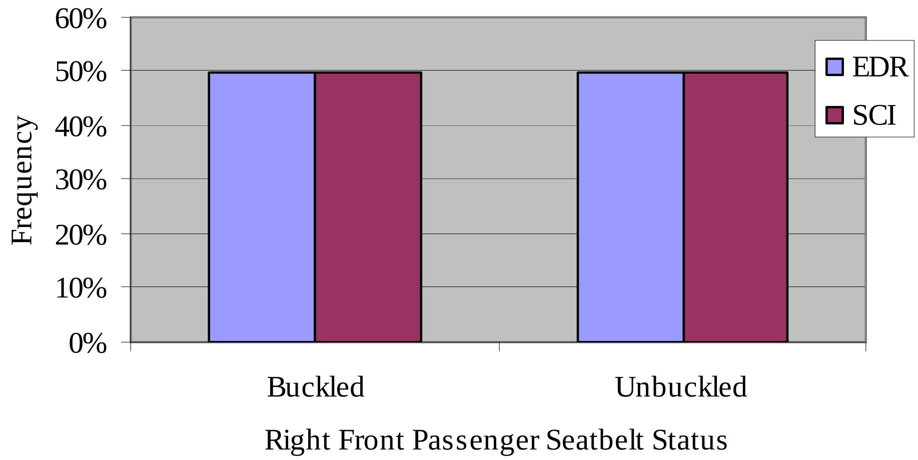


Figure 33. Right Front Passenger Seat Belt Status Frequency as Reported by EDR and SCI

A case-by-case comparative analysis between the EDR data and the 8 vehicle driver files vehicle cases is summarized in Table 56. Although most of the driver seat belt status data matched, there was one vehicle case in which the SCI data reported the driver as buckled but the associated EDR file denoted the seat belt as unbuckled (Case No. CA02-011).

Table 56. Comparison of Driver Seat Belt Use Reported by EDR vs. SCI

EDR \ SCI	Buckled	Unbuckled	Total	% of Total
Buckled	5	-	5	63%
Unbuckled	1	2	3	38%
Total	6	2	8	
% of Total	75%	25%		

6.2.5. Air Bag Deployment

The EDR event type was compared to the *Frontal Air Bag System Deployment* (BAGDEPLY) variable reported in the SCI for each vehicle case. The EDR-reported air bag status distribution is shown in Table 57 and the SCI-reported *Air Bag System Deployment* distribution is shown in Table 58. The comparison of frontal air bag deployment status as reported by the EDR and SCI for each vehicle case is shown in Table 59. The EDR and SCI air bag deployment data did not match in 2 of the 8 vehicle cases where both sources reported air bag status information. These cases are listed in Table 60.

Table 57. EDR Event Type Distribution

Type of Event	No. EDR Cases	Frequency
Deployment Only, "D"	6	75%
Non Deployment, "N"	2	25%
Total	8	100%

Table 58. SCI Frontal *Air Bag System Deployment* (BAGDEPLY) Distribution

SCI Driver Airbag	No. SCI	
Description	Cases	Frequency
Deployed during crash (as a result of impact)	6	75%
Not deployed	2	25%
Total	8	100%

Table 59. EDR vs. SCI Frontal Air Bag Deployment Status

SCI / EDR	Deployed	Nondeployed	Total	% of Total
Deployed	5	1	6	75%
Nondeployed	1	1	2	25%
Total	6	2	8	
% of Total	75%	25%		

Table 60. List of Vehicle Cases with Contradicting Air Bag Deployment Status Information

SCI					EDR	
Case No.	VIN	ACCTYPE	BAGDEPLY	DVLONG (mph)	Dep./Non-Dep.	DeltaV (mph)
CA02-011	1FAFP53U5Y	51	Deployed during crash (as a result of impact)		N	
CA02-007	2FAFP71W81	86	Not deployed	-10.6	D	

6.2.6. Delta V

The onboard EDR reported longitudinal delta V in all 8 applicable cases. However, the full longitudinal delta V pulse was only captured in 4 of those cases. The associated SCI vehicle files contained delta V information in all 4 cases. Even though none of those were classified as sustaining frontal-impact damage (*PDOF1* = 0, 10, or 350), the longitudinal delta V comparison is shown in Figure 34.

As previously discussed, the Ford ARM100 EDR module also stored lateral delta V information. However, only one such module associated with the SCI data was analyzed in this study. Additionally, this module did not contain the full lateral delta V pulse (stopped recording both longitudinal and lateral delta V at t = 30 ms). Similarly, the associated SCI vehicle file did not contain a value for lateral delta V.

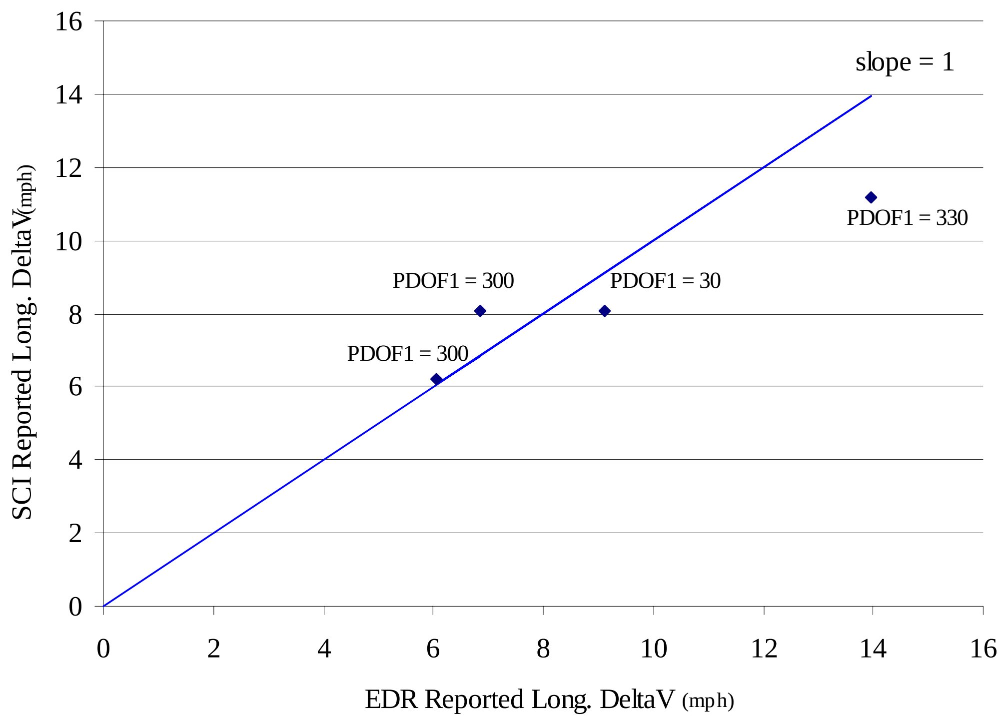


Figure 34. Comparison of Longitudinal Delta V for Cases Where Reported for Both SCI (*PDOF1=0, 1, 350*) and EDR (4 Cases)

7. EDR/CIREN DATA ANALYSIS

The CIREN data set consists of roughly 400 yearly cases with detailed crash and medical information gathered at eight Level 1 Trauma Centers spread throughout the country. Detailed information can be found at the NHTSA CIREN Web site.[7] It should be noted that CIREN contains information only for people who have agreed to release their information. Therefore, CIREN contains some cases in which there is no driver or passenger information even though there might have been such people involved in the crashes. This study analyzed a total of 58 EDR files associated with vehicles in the CIREN program. The CIREN data elements used in this study were defined in the same way as the CDS data elements detailed in Section 5.

Appendix C contains GM EDR data analysis results aggregated over the three crash databases (CDS, SCI, and CIREN).

7.1. Analysis of CIREN EDR Data – GM Vehicles

A total of 56 EDR files were obtained from GM vehicles as part of vehicle crash data collection under the CIREN program. The recorded parameter analysis presented herein focuses on this subset of files, which constituted about 2 percent of all EDR files in this study. These files were matched to the associated CIREN case and vehicle files for comparison similarly to the analysis presented in Section 5.1.

7.1.1 Accident Type

The parameter comparison between the EDR and CIREN data was broken down into the different categories of *Accident Type*, as reported in the CIREN vehicle file under the ACCTYPE variable name, and shown in Table 61. As in the preceding SCI case analysis, about one-third of all cases fell into the roadside departure *Accident Type* categories (*ACCTYPE = 1-10*).

7.1.2. Travel Speed Comparison

Out of the 56 GM vehicle files selected from the CIREN crash data collection program, only 12 of them contained travel speed information in the CIREN vehicle case data. The associated EDR vehicle files contained travel speed information on 35 vehicles. It should be noted that 16 vehicle cases were associated with EDR module types that did not record pre-crash information. Table 62 shows the travel speed reporting frequency for both the EDR and CIREN vehicle files.

Out of the 56 GM vehicle cases in the CIREN database with EDR data, only 5 contained travel speed information reported in both the EDR and CIREN. These are summarized by *Accident Type* category in Table 63 and the EDR versus CIREN values graphically compared in Figure 35. The CIREN Police-Reported Travel Speed fell within ±20 percent of the reported EDR Travel Speed value taken at the -1-second time interval in 4 out of the 5 files.

Table 61. Distribution of EDR Files per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. Files	%
Single Driver	Right Roadside Departure	1	3	5.4%
		2	6	10.7%
		3	1	1.8%
	Left Roadside Departure	6	3	5.4%
		7	4	7.1%
		8	2	3.6%
Same Trafficway - Same Direction	Rear-End	20	1	1.8%
		24	3	5.4%
		25	1	1.8%
	Forward Impact	42	1	1.8%
	Sideswipe Angle	46	1	1.8%
		48	1	1.8%
Same Trafficway - Opposite Direction	Head-On	50	3	5.4%
		51	3	5.4%
	Sideswipe Angle	64	2	3.6%
		65	1	1.8%
Change Trafficway - Vehicle Turning	Turn Across Path	68	2	3.6%
		69	2	3.6%
	Turn Into Path	80	1	1.8%
		82	3	5.4%
Intersecting Paths	Straight Paths	87	2	3.6%
		89	4	7.1%
Miscellaneous	Backing, Etc.	98	6	10.7%

Table 62. EDR/CIREN Reported Travel Speed

		CIREN			% of	
		Reported	Not Reported	Total	All EDRs	Applicable EDRs
EDR	Reported	5	30	35	63%	88%
	Not Reported	7	14	21	38%	13%
	Total	12	44	56	100%	100%
	% of Total	21%	79%			

Table 63. EDR/CIREN Reported Travel Speed per *Accident Type* (ACCTYPE)

Category	Configuration	ACCTYPE	No. of Files	Avg. Travel Speed (mph) CIREN	EDR	SCI values within 20% No.	%
Single Driver	Right Roadside Departure	1	1	55	60.0	1	100.0%
		2	1	70	48.0	-	0.0%
	Left Roadside Departure	8	1	50	47.0	1	100.0%
Same Trafficway - Opposite Direction	Head-On	51	1	65	67.0	1	100.0%
Miscellaneous	Backing, Etc.	98	1	45	45.0	1	100.0%
		Total:	5		Total:	4	

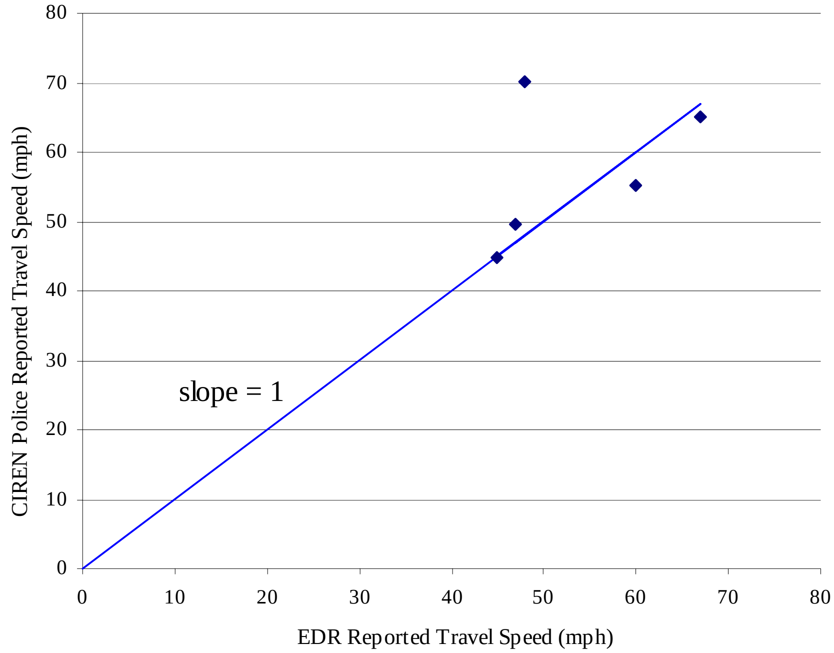


Figure 35. EDR/CIREN-Reported Travel Speed Comparison (5 Files)

7.1.3. Avoidance Maneuver (Brake Status)

The breakdown of the MANEUVER type variable codes as reported in the CIREN vehicle files, as well as the associated *Brake Status* data gathered from the EDR at -1 second, is shown in Table 64. Overall, an attempted avoidance maneuver that included braking was reported in 10 cases, accounting for about 18 percent of the total. The associated EDR *Brake Status* data indicated that the brake switch status was *OFF*, indicating no application of brakes, in one of those 10 cases in which the CIREN data indicated an avoidance maneuver involving braking.

Table 65 lists the number of cases with EDR *Brake Status* information per value reported at each pre-crash time interval for those EDR modules that were capable of reporting pre-crash information (40 out of 56). The EDR *Brake Status* information is reported for all Accident Type Categories as well as for the frontal impact (*ACCTYPE = 11, 12, 13, 14, 15, 16, 20, 24, 28, 34, 36, 38, 40, 42, 43, 50, 51, 54, 56, 58, 60, 62, 63, 80, 81, 83, 86, 88*) and rear end (*ACCTYPE = 20, 24, 28*) subsets defined in this study. Overall, the analysis of the EDR data revealed a decrease in *Brake Status = OFF*, indicating application of the brakes, throughout the 5 seconds leading to the crash. For vehicles involved in frontal impact crashes, a total of 7 out of 11 EDR modules reported braking at the -1-second time interval, which indicates that 64 percent of frontal impact vehicle drivers applied the brakes before the crash. However, excluding the vehicle cases with no *Brake Status* information, denoted as *[blank]*, the EDR *Brake Status* data indicated 78 percent of frontal-impact vehicle drivers applied the brakes before the crash (7 out of 9). The braking frequency of the EDR-equipped vehicles (*Brake Status = ON*), excluding *[blank]*

EDR *Brake Status* values, is plotted in Figure 36 for these three sets of *Accident Type* groupings.

Table 66 through Table 68 contain the results of the comparison of the driver braking action as reported by the *Brake Switch Status* parameter in the EDR to the CIREN reported *Attempted Avoidance Maneuver* for the cases in which the EDR modules recorded pre-crash information.

Table 64. CIREN *Attempted Avoidance Maneuver* (MANEUVER)

Attempted Avoidance Maneuver (CIREN)	No. Cases	EDR BRAKE STATUS at -1 sec		
		OFF	ON	[blank]
Braking (lockup unknown)	4	-	2	2
Braking (lockup)	1	-	1	-
Braking (no lockup)	2	-	2	-
Braking and steering left	1	1	-	-
Braking and steering right	2	-	1	1
No avoidance maneuver	27	10	6	11
Other action (specify)	4	-	2	2
Steering left	5	1	4	-
Steering right	3	1	1	1
Releasing Brakes	-	-	-	-
Accelerating	3	2	-	1
Accelerating and steering left	-	-	-	-
Accelerating and steering right	1	-	1	-
Unknown	3	-	-	3
No driver present	-	-	-	-
[blank]	-	-	-	-
Total	56	15	20	21

Table 65. EDR *Brake Status*

BRAKE STATUS	Time				
	-5 sec	-4 sec	-3 sec	-2 sec	-1 sec
All Accident Types					
OFF	27	26	25	22	15
ON	8	9	10	13	20
[blank]	5	5	5	5	5
Total	40	40	40	40	40
% ON	20.0%	22.5%	25.0%	32.5%	50.0%
Frontal Impact					
OFF	7	7	6	5	2
ON	2	2	3	4	7
[blank]	2	2	2	2	2
Total	11	11	11	11	11
% ON	18.2%	18.2%	27.3%	36.4%	63.6%
Rear-End					
OFF	1	1	1	1	-
ON	1	1	1	1	2
[blank]	1	1	1	1	1
Total	3	3	3	3	3
% ON	33.3%	33.3%	33.3%	33.3%	66.7%

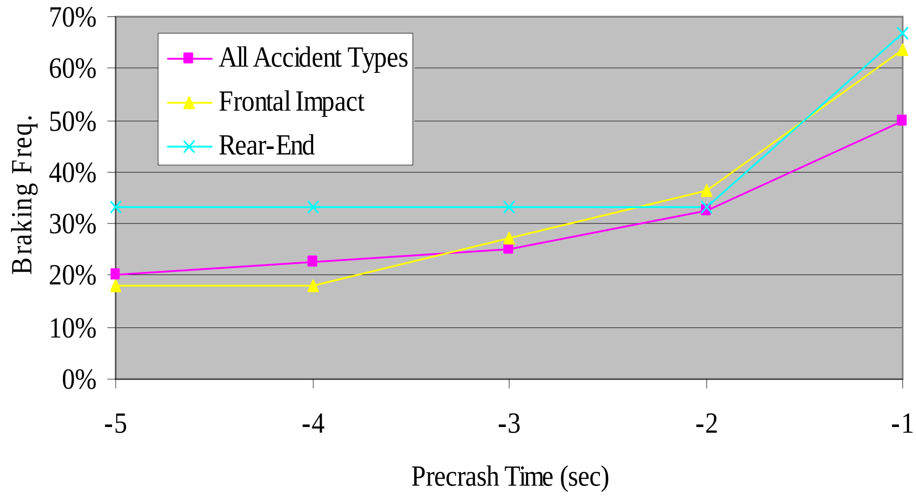


Figure 36. EDR-Reported Braking Frequency

Table 66. Comparison of Braking Reported by EDR (at -1 sec) vs. CIREN – All *Accident Types*

		CIREN					
		Includes Braking	**No Avoid. Action**	**Other**	**Unknown**	**Total**	**% of Total**
EDR	**Brake=OFF**	-	10	4	-	14	35%
	Brake=ON	6	6	8	-	20	50%
	Brake=[blank]	2	2	1	1	6	15%
	Total	8	18	13	1	40	
	% of Total	20%	45%	33%	3%		

Table 67. Comparison of Braking Reported by EDR (at -1 sec) vs. CIREN in Frontal-Impact Vehicles

		CIREN					
		Includes Braking	**No Avoid. Action**	**Other**	**Unknown**	**Total**	**% of Total**
EDR	**Brake=OFF**	1	1	-	-	2	18%
	Brake=ON	3	2	2	-	7	64%
	Brake=[blank]	1	-	-	1	2	18%
	Total	5	3	2	1	11	
	% of Total	45%	27%	18%	9%		

Table 68. Comparison of Braking Reported by EDR (at -1 sec) vs. CIREN in Rear-End-Striking Vehicles

		CIREN					
		Includes Braking	**No Avoid. Action**	**Other**	**Unknown**	**Total**	**% of Total**
EDR	**Brake=OFF**	-	-	-	-	-	0%
	Brake=ON	-	-	2	-	2	67%
	Brake=[blank]	1	-	-	-	1	33%
	Total	1	-	2	-	3	
	% of Total	33%	0%	67%	0%		

7.1.4. Seat Belt Usage

The EDR *Seat Belt Switch Circuit Status* parameter reported "buckled" in about 61 percent of the 56 CIREN GM vehicle files, as shown in Table 69. The CIREN data included driver occupant information in 43 cases and reported driver seat belt usage in 34 of those cases. The driver seat belt status information did not match in a total of 7 cases. In all 7 cases the CIREN data indicated *buckled* and the associated EDR indicated *unbuckled*. Figure 37 displays the relative frequency of seat belt usage reported by the EDR and the CIREN vehicle driver files.

Table 69. Comparison of Driver Seat Belt Use Reported by EDR vs. CIREN

EDR \ CIREN	Buckled	Unbuckled	[blank]	Total	% of Total
Buckled	27	-	7	34	61%
Unbuckled	7	9	6	22	39%
Total	34	9	13	56	
% of Total	61%	16%	23%		

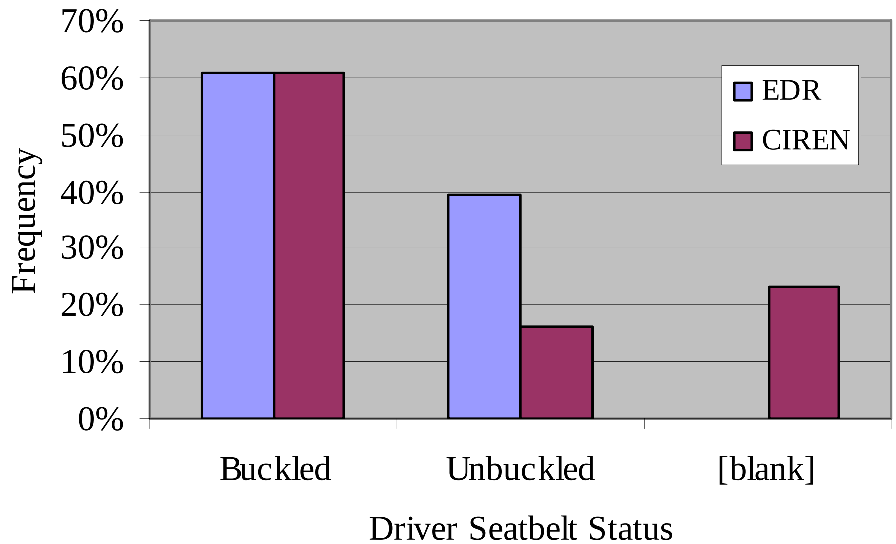


Figure 37. Driver Seat Belt Status Frequency as Reported by EDR and CIREN

7.1.5. Air Bag Deployment

As in the previous analyses, the EDR event type was compared to the *Frontal Air Bag System Deployment* (BAGDEPLY) variable reported in the CIREN file for each vehicle case. There was one case in which the driver air bag was reported in the CIREN file as not being deployed but the front passenger's reported as deployed, and the associated EDR file reported *deployment*. The EDR-reported air bag status distribution is shown in Table 70 and the CIREN-reported air bag deployment status distribution is shown in Table 71. The comparison of frontal air bag deployment status as reported by the EDR and SCI for each vehicle case is shown in Table 72. The EDR and CIREN air bag deployment data did not match in 3 of the 43 vehicle cases where both sources reported air bag status information. These cases are listed in Table 73.

Table 70. EDR Event Type Distribution

Type of Event	No. EDR Cases	Frequency
Deployment Only, "D"	12	21%
Non Deployment, "N"	15	27%
Dep. + Non Dep, "D/N"	27	48%
Dep. + Dep. Level, "D/DL"	2	4%
Total	56	100%

Table 71. CIREN Driver *Air Bag System Deployment* (BAGDEPLY) Distribution

CIREN Driver Airbag Description	No. CIREN Cases	Frequency
Deployed during crash (as a result of impact)	32	74%
Not deployed	11	26%
Total	43	100%

Table 72. EDR vs. CIREN Frontal Air Bag Deployment Status

EDR \ CIREN	Deployed	Nondeployed	Total	% of Total
Deployed	30	1	31	72%
Nondeployed	2	10	12	28%
Total	32	11	43	
% of Total	74%	26%		

Table 73. List of Vehicle Cases With Contradicting Air Bag Deployment Status Information

CIREN						EDR	
Case No.	**Vehicle ID**	**VIN**	**ACCTYPE**	**BAGDEPLY**	**DVLONG (mph)**	**Dep./Non-Dep.**	**DeltaV (mph)**
385003372	385077974	2G1WL52J1Y1	6	Deployed during crash (as a result of impact)	-52.2	N	[redacted]
555002865	555108318	2G1WF55E419	24		[redacted]	N	[redacted]
555003226	555113102	1GNDX03E91D	25	Not Deployed	32.9	D/N	-20.17

7.1.6. Delta V

A total of 34 cases (61%) contained longitudinal delta V information from both the CIREN and associated EDR files, as seen in Table 74. The crash pulse data was submitted through the down-select process previously discussed and the results showed that 18 of those cases contained crash pulse data that captured the full longitudinal delta V curve. A comparative analysis was done on this subset of cases and a case-by-case comparison of longitudinal delta V is shown in Figure 38. The CIREN-reported delta V values were within ±20 percent of the reported EDR longitudinal delta V values in only 7 cases out of the 18 cases in this subset. The biggest variance, as can be seen in Figure 38, occurred in the cases with EDR reported longitudinal delta V of less than 10 mph. For the 12 cases in which the EDR-reported longitudinal delta V was greater that 10 mph, the average CIREN-reported difference from the EDR-reported values was about 31 percent, as compared to about 45 percent for all 18 cases.

Table 74. Longitudinal Delta V Reporting Comparison – GM EDR vs. CIREN

		CIREN			
		Reported	**Not Reported**	**Total**	**% of Total**
EDR	**Reported**	34	10	44	79%
EDR	**Not Reported**	6	6	12	21%
	Total	40	16	56	
	% of Total	71%	29%		

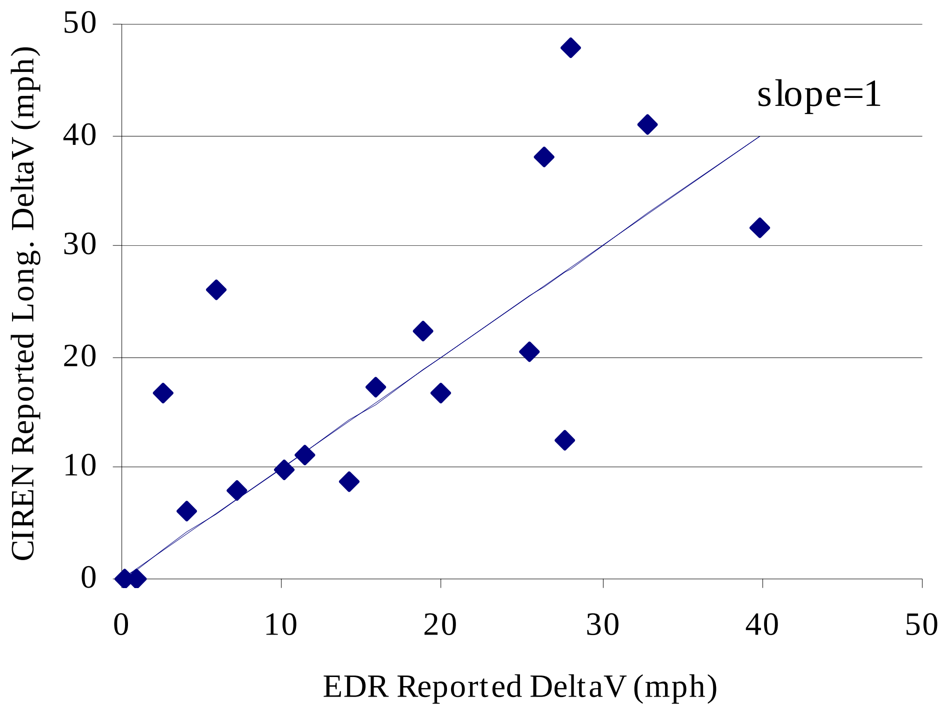


Figure 38. Comparison of Longitudinal Delta V for Cases Where Reported in Both CIREN and EDR Vehicle Files

7.2. Analysis of CIREN EDR Data – Ford Vehicles

A total of 2 EDR files, both identified as *deployment* events, were collected from Ford vehicles as part of the CIREN program. Due to the very low case count, a comparative analysis similar in nature to the one for the GM vehicle EDRs was not conducted for the Ford EDR versus CIREN files. Instead, the specific comparative values are summarized as follows:

- *Accident Type*: One vehicle case identified in CIREN as "Single Driver – Right Roadside Departure" (*ACCTYPE = 1*) and one vehicle case identified in CIREN as "Single Driver – Left Roadside Departure" (*ACCTYPE = 8*).
- *Attempted Avoidance Maneuver*: One vehicle case identified in CIREN as "steering left" (associated with *ACCTYPE = 8*) and one vehicle case identified in CIREN as "other action" (associated with *ACCTYPE = 1*).
- Seat Belt Usage: CIREN contained seat belt information within two-person files. The *seat belt switch circuit status* reported by the EDR in both cases agreed with the reported values in the associated CIREN person files. The driver in one case was reported as unbuckled and the right-front passenger in the other case was reported as buckled by both the CIREN and EDR data.
- Air Bag Deployment: The air bag was reported as deployed by the EDRs and CIREN data in both cases.
- Delta V: The CIREN data indicated values of "999" for both lateral and longitudinal delta V. The associated EDR data contained full-pulse longitudinal delta V information for both cases. The maximum EDR-reported longitudinal delta V for these two cases was -15.59 mph and -14.43 mph.

Appendix D contains Ford EDR data analysis results aggregated over the three crash databases (CDS, SCI, and CIREN).

8. CONCLUDING REMARKS

Current EDR technology can provide very useful information to crash reconstructionists and vehicle safety researchers by objectively reporting real-world crash data. Even though they are limited in the number of recorded parameters and storage capacity, their capabilities are increasing mainly due to emerging vehicle safety technologies such as electronic stability control. Present-day EDRs can provide useful information that can be used to support crash reconstruction research. This data also has the potential to augment data in crash databases, by providing information especially relating to system performance not traditionally collected nor estimated in these databases. Some examples are: air bag deployment times, second-stage deployments, and crash pulse acceleration. These are all important to vehicle safety researchers and not readily available from non-EDR real-world crash data.

The results presented in this report show the potential benefits of using EDR data for crash research. EDR data has the capability to increase the reporting frequency of several data elements reported in the crash databases. For the longitudinal delta V parameter analyzed in this study, EDR data was available in 591 vehicle files in which no crash files data was available. Substituting the unknown delta V values in the crash files with the known EDR data would increase the longitudinal delta V reporting frequency by 23 percent from about 66 percent to about 89 percent of those cases analyzed in this study. Similarly, the EDR data in this study showed a potential under-representation of attempted avoidance maneuvers involving braking in the crash databases. For the CDS data alone, about 47 percent of the EDR files denoted brake switch activation at the -1-second pre-crash time interval while only about 23 percent of the CDS files reported an attempted avoidance action that included braking. These observations enforce the potential for EDR data to add quantification to many codes in the crash files that describe the pre-crash situation. It is very important to understand the limitations of EDR data, however, and care should always be exercised when interpreting and using any EDR-reported parameter.

Other data elements not available in the various crash databases, but reported by EDRs, might add more insight into the understanding of the pre-crash situation. There are very significant vehicle and occupant protection system performance elements that cannot be determined by NASS investigators, such as air bag timing and deployment parameters.[9] Further research focusing on those EDR data elements, which might provide insight into system performance and aid in injury mitigation research, is recommended. This research could be conducted on the current compilation of 2,541 EDR data files collected through the end of 2005, or on an expanded set including the latest EDR data collected by NHTSA.

The author also recommends further analysis of the EDR lateral delta V and acceleration pulses when more data becomes available. At the time of this study, only three Ford EDR modules contained full lateral delta V crash pulses and no analysis of acceleration pulses was conducted. With the introduction of rollover stability technology and associated sensors, many more near-future EDR module types will have the capability to store information on these parameters.

It is very important to understand the limitations of EDR data and care should always be exercised when interpreting any EDR-reported parameter. A wide range of EDR module-specific limitations exist, and therefore importance should be placed on module type identification. Also, a clear understanding of what (and when) the EDR is measuring needs to be gained before any analysis. Awareness of the EDR limitations is needed for correct interpretation and use of the data. An example of a potentially misleading situation involves the GM EDR-reported "% throttle" pre-crash parameter. It can be measured at either the accelerator pedal or "under the hood," depending on the vehicle model. Each measurement location might report significantly different values for the same data element. There is also an uncertainty associated with pre-crash data timing due to the way in which the data is processed by the ACN. Similarly, crash pulse data does not necessarily start at the instant of the crash but most likely a short time thereafter.

Ultimately, present-day EDR data can be a powerful investigative and research tool by complementing existing crash evidence and estimates. It should always be used in conjunction with other data sources, including a complete reconstruction, since issues like the ones just described eventually limit the application of the EDR data.

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APPENDIX A

Sample CDR File Download[3]

CDR File Information

Vehicle Identification Number	2CNDL23F756002651
Investigator	
Case Number	
Investigation Date	
Crash Date	
Filename	NHTSA4985-2CNDL23F756002651.CDR
Saved on	Wednesday, July 28 2004 at 03:08:57 PM
Data check information	7CB06F85
Collected with CDR version	Crash Data Retrieval Tool 2.40
Collecting program verification number	32B7A917
Reported with CDR version	Crash Data Retrieval Tool 2.70
Reporting program verification number	70812808
Interface used to collected data	Block number: 00 Interface version: 3D Date: 06-18-04 Checksum: 5C00
Event(s) recovered	Deployment Non-Deployment

SDM Data Limitations

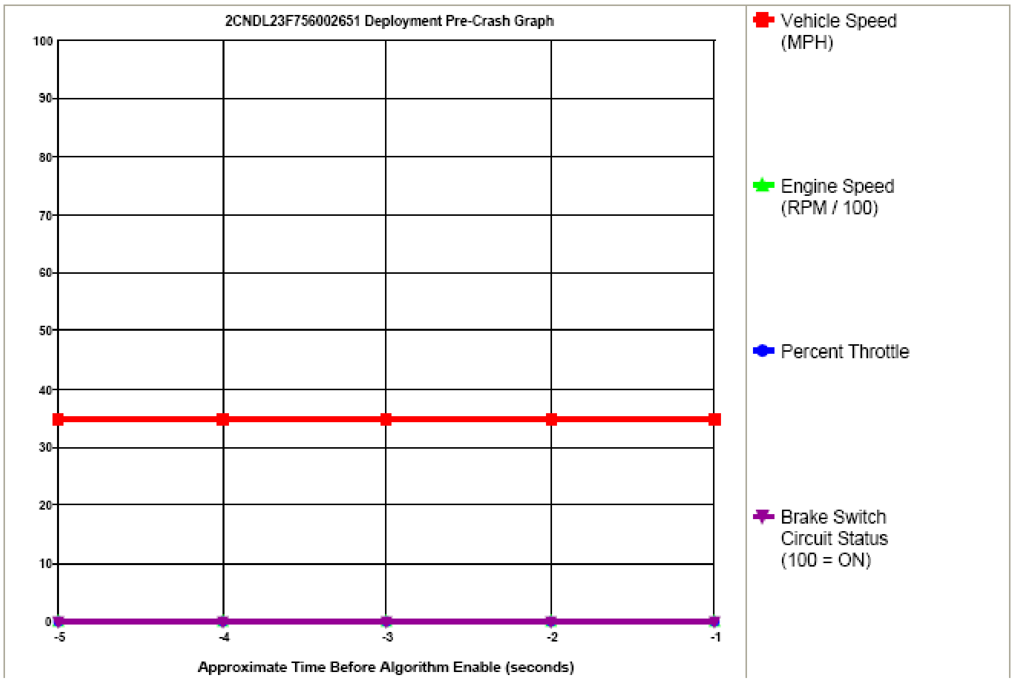
SDM Recorded Crash Events:
There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded forward velocity change. This event will be cleared by the SDM after the ignition has been cycled 250 times.
The second type of SDM recorded crash event is the Deployment Event. It also contains Pre-Crash and Crash data. The SDM can store up to two different Deployment Events, if they occur within five seconds of one another. Deployment events cannot be overwritten or cleared from the SDM. Once the SDM has deployed the air bag, the SDM must be replaced.
The data in the non-deployment file will be locked after a deployment, if the non-deployment occurred within 5 seconds before the deployment or a deployment level event occurs within 5 seconds after the deployment.

SDM Data Limitations:
-SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. SDM Recorded Vehicle Forward Velocity Change is the change in velocity during the recording time and is not the speed the vehicle was traveling before the event, and is also not the Barrier Equivalent Velocity. This data should be examined in conjunction with other available physical evidence from the vehicle and scene when assessing occupant or vehicle forward velocity change. For deployments and deployment level events, the SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. For non-deployments, the SDM will record the first 150 milliseconds of data after algorithm enable.
-Event Recording Complete will indicate if data from the recorded event has been fully written to the SDM memory or if it has been interrupted and not fully written.
-SDM Recorded Vehicle Speed accuracy can be affected if the vehicle has had the tire size or the final drive axle ratio changed from the factory build specifications.
-Brake Switch Circuit Status indicates the status of the brake switch circuit.
-Pre-Crash Electronic Data Validity Check Status indicates "Data Invalid" if the SDM does not receive a valid message.
-Driver's Belt Switch Circuit Status indicates the status of the driver's seat belt switch circuit.
-The Time between Non-Deployment and Deployment Events is displayed in seconds. If the time between the two events is greater than five seconds, "N/A" is displayed in place of the time.
-If power to the SDM is lost during a crash event, all or part of the crash record may not be recorded.

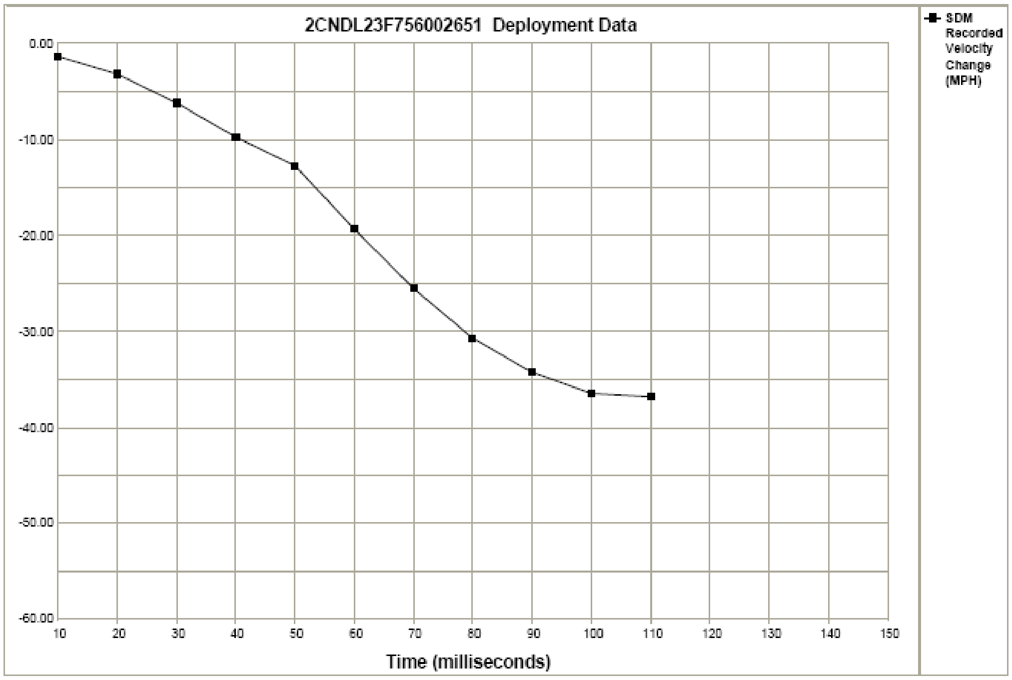
SDM Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the Class 2 data link, to the SDM.
-Brake Switch Circuit Status data is transmitted once a second by either the ABS module or the PCM, via the Class 2 data link, to the SDM. Depending on vehicle option content, the Brake Switch Circuit Status data may not be available.
-In most vehicles, the Driver's Belt Switch Circuit is wired directly to the SDM. In some vehicles, the Driver's Belt Switch Circuit Status data is transmitted from the Body Control Module (BCM), via the Class 2 data link, to the SDM.

System Status At Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Ignition Cycles At Deployment	49
Ignition Cycles At Investigation	50
Maximum SDM Algorithm Forward Velocity Change (MPH)	-37.04
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	107.5
Driver First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Driver Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	12.5
Passenger First Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	10
Passenger Second Stage Time Algorithm Enabled to Deployment Command Criteria Met (msec)	12.5
Time Between Non-Deployment And Deployment Events (sec)	N/A
Event Recording Complete	Yes



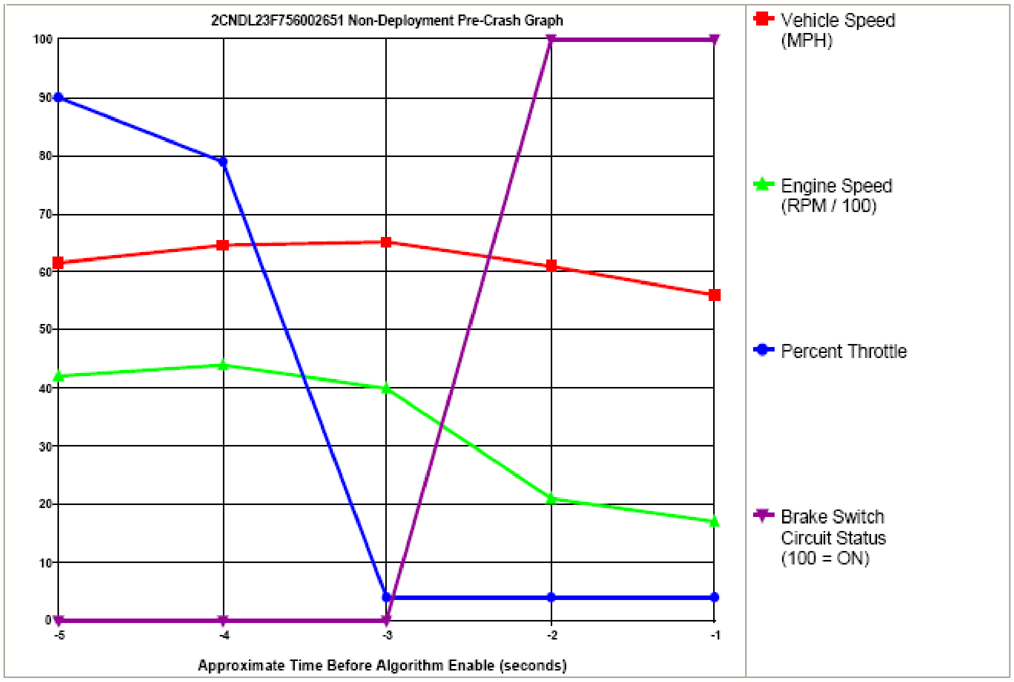
Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	35	0	0	OFF
-4	35	0	0	OFF
-3	35	0	0	OFF
-2	35	0	0	OFF
-1	35	0	0	OFF



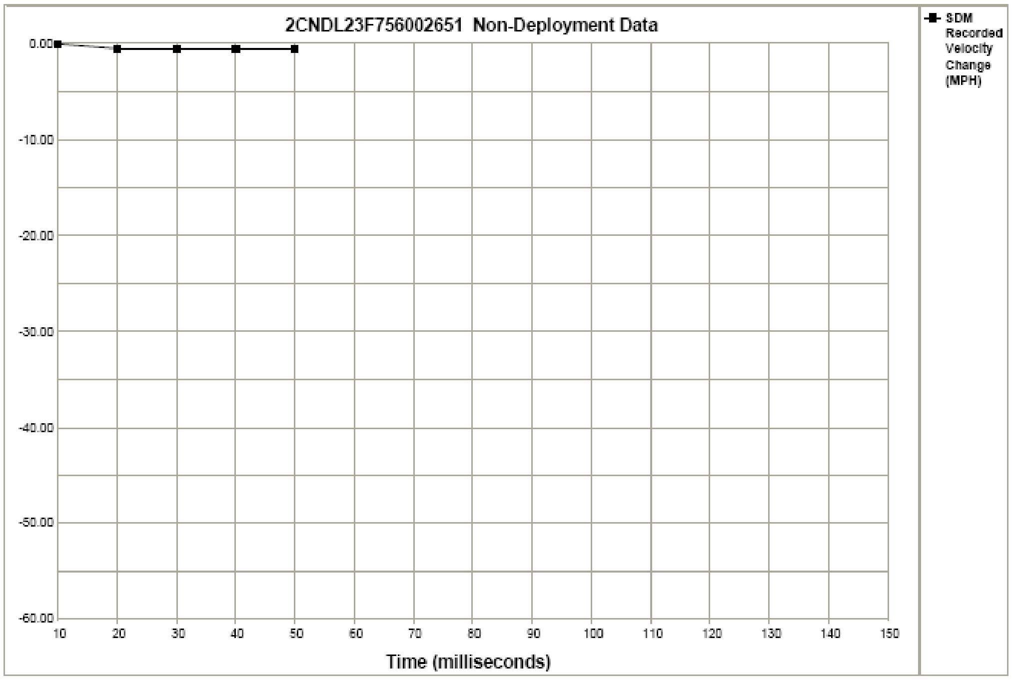
Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
SDM Recorded Velocity Change	-1.32	-3.07	-6.14	-9.65	-12.73	-19.31	-25.45	-30.72	-34.23	-36.42	-36.86	N/A	N/A	N/A	N/A

System Status At Non-Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	UNBUCKLED
Ignition Cycles At Non-Deployment	41
Ignition Cycles At Investigation	50
Maximum SDM Algorithm Forward Velocity Change (MPH)	-0.70
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	37.5
A Deployment was Commanded Prior to this Event	No



Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle	Brake Switch Circuit Status
-5	62	4160	90	OFF
-4	65	4352	79	OFF
-3	65	3968	4	OFF
-2	61	2112	4	ON
-1	56	1728	4	ON



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
SDM Recorded Velocity Change	0.00	-0.44	-0.44	-0.44	-0.44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Hexadecimal Data

This page displays all the data retrieved from the air bag module.
It contains data that is not converted by this program.

```
$01   A0 2C 00 00 00 00
$02   AC 91 00 00 00 00
$03   41 53 34 30 35 31
$04   4B 47 35 54 39 32
$05   02 41 32 00 00 00
$06   22 73 33 28 00 00
$10   FF F9 FC 00 00 00
$11   A9 00 9C 00 00 84
$12   00 00 00 00 00 00
$13   03 00 00 00 00 00
$14   F3 04 ED 80 51 00
$18   84 84 85 41 FF 00
$1C   FA FA FA FA FA FA
$1D   FA FA FA FA FA FA
$1E   FA FA 00 00 00 00
$1F   FF 02 00 00 00 00
$20   00 00 00 04 F0 00
$21   FF FF FF FF FF FF
$22   FF FF FF FF 00 00
$23   00 01 01 01 01 FF
$24   FF FF FF FF FF FF
$25   FF FF FF 05 00 00
$26   5A 62 69 68 63 C0
$27   0A 0A 0A CA E5 00
$28   1B 21 3E 44 41 00
$29   FF FA FE DB 00 00
$2A   00 00 00 00 00 00
$2B   00 00 00 00 00 00
$2C   00 00 FF 00 00 33
$2D   00 00 00 00 00 00
$2E   00 00 00 00 00 00
$30   40 00 00 05 F0 00
$31   FF FF FF FF FF FF
$32   FF FF FF FF 00 00
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$34   05 05 03 07 0E 16
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$36   54 FF FF FF FF 0B
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$38   00 00 00 00 00 00
$39   00 00 00 00 00 00
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$3B   00 00 22 22 00 00
$3C   4D 0A 90 00 00 AA
$3D   03 03 03 03 00 00
$3E   00 00 00 00 00 00
$40   FF FF FF FF FF 00
$41   FF FF FF FF FF FF
$42   FF FF FF FF 00 00
$43   FF FF FF 00 00 00
$44   FF 00 00 00 00 00
$50   00 00 00 00 0C 06
$51   0F AA 00 00 00 00
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$61   2B 00 00 00 00 00
```
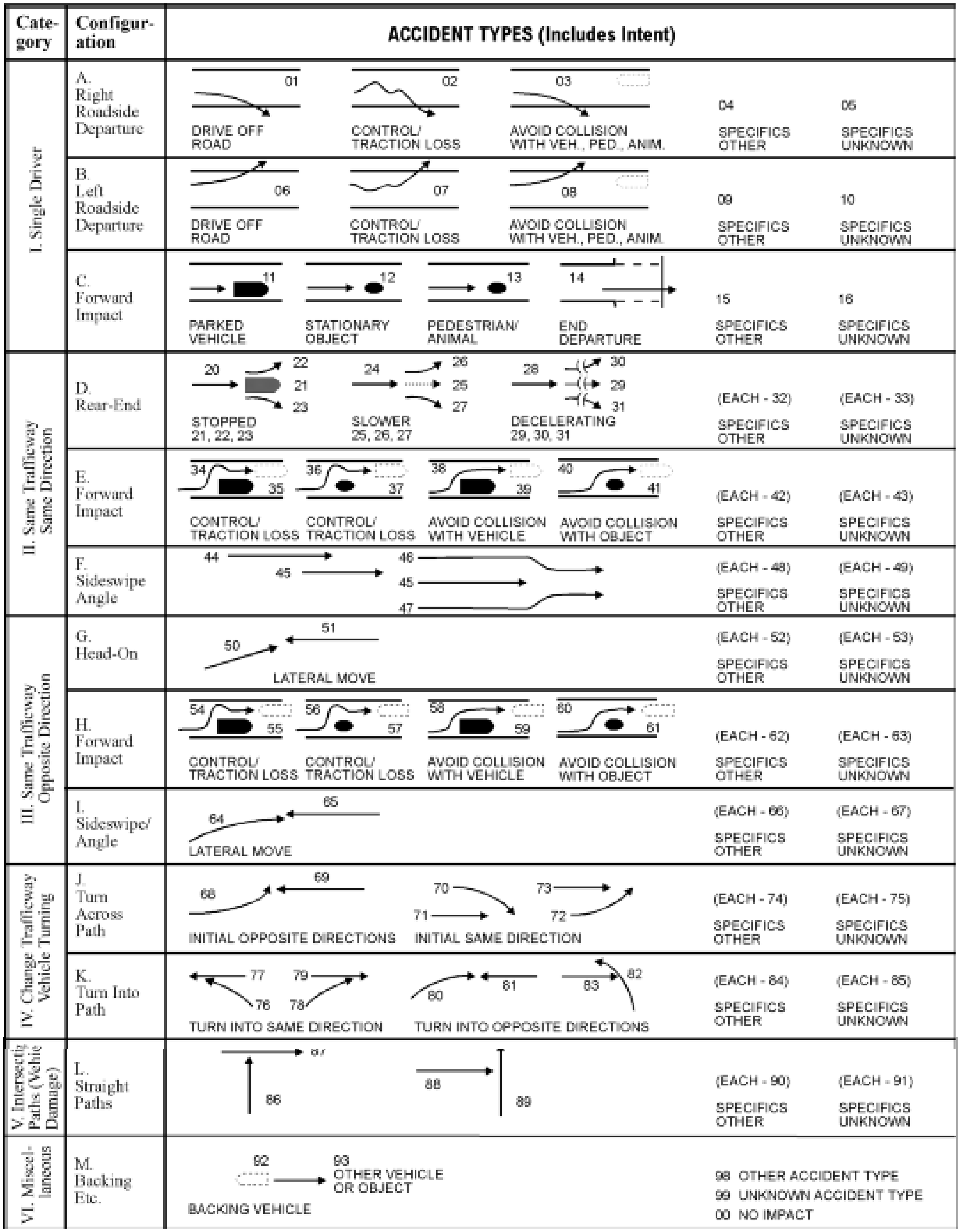

APPENDIX B

Accident Type Categories[14]



APPENDIX C

This appendix displays the overall distribution of GM EDR data versus the CDS, SCI, and CIREN data (grouped together and referred to as “Crash Files”) for each of the parameters previously compared separately.

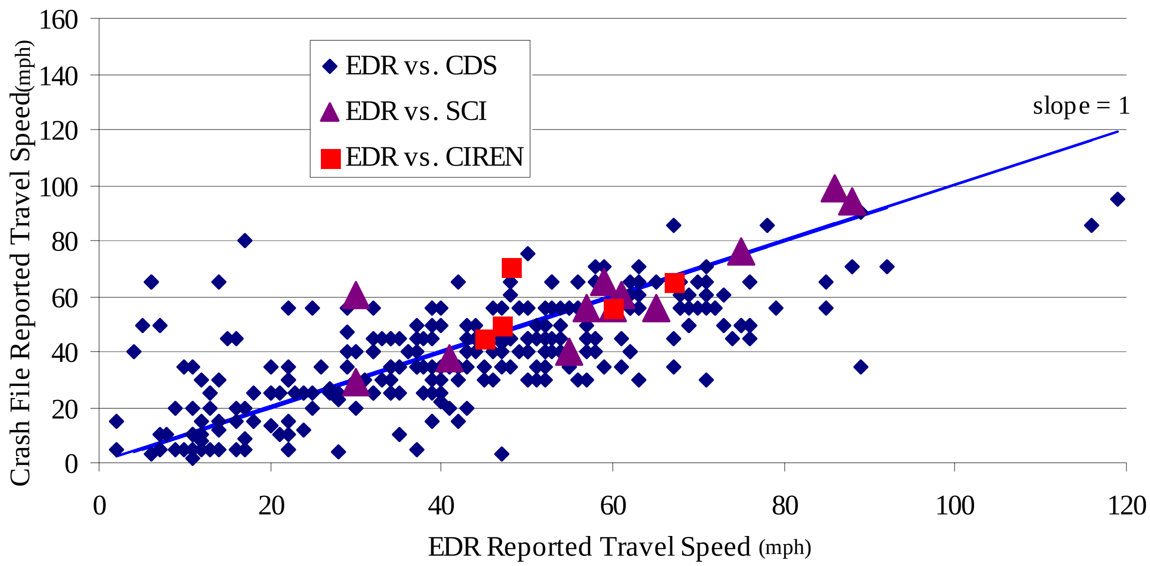


Figure C1. EDR/CDS Police-Reported Travel Speed Comparison (case selection: GM cases with reported Travel Speed (non-zero) in both EDR and crash files [299 CDS, 12 SCI, 5 CIREN - 316 Total])

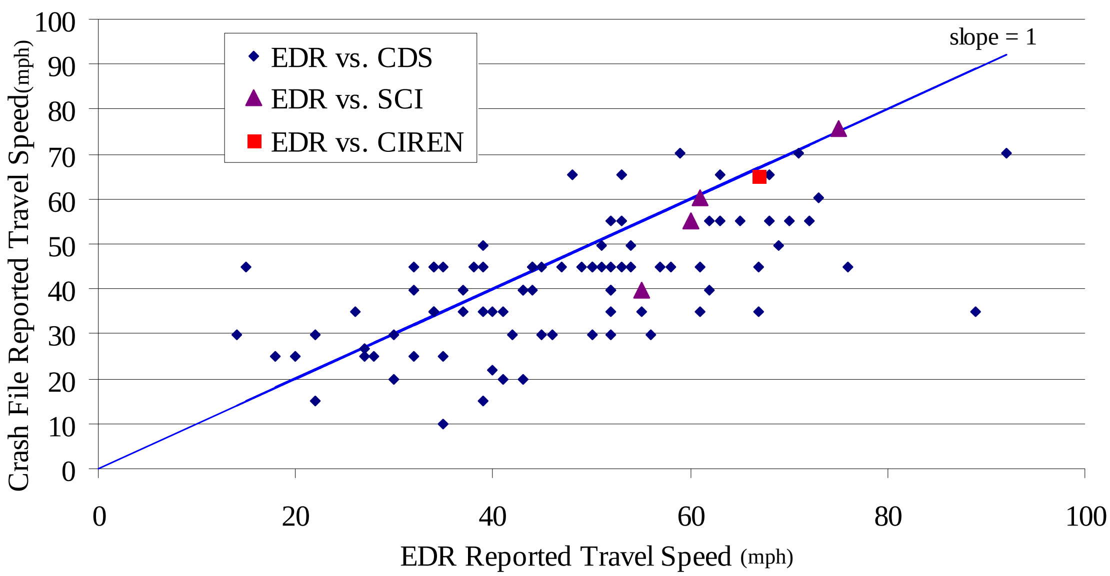


Figure C2. EDR/CDS Police-Reported Travel Speed Comparison for Frontal Impact Cases (case selection: Frontal impact GM vehicle cases with reported Travel Speed in both EDR and crash files [89 CDS, 4 SCI, 1 CIREN - 94 Total])

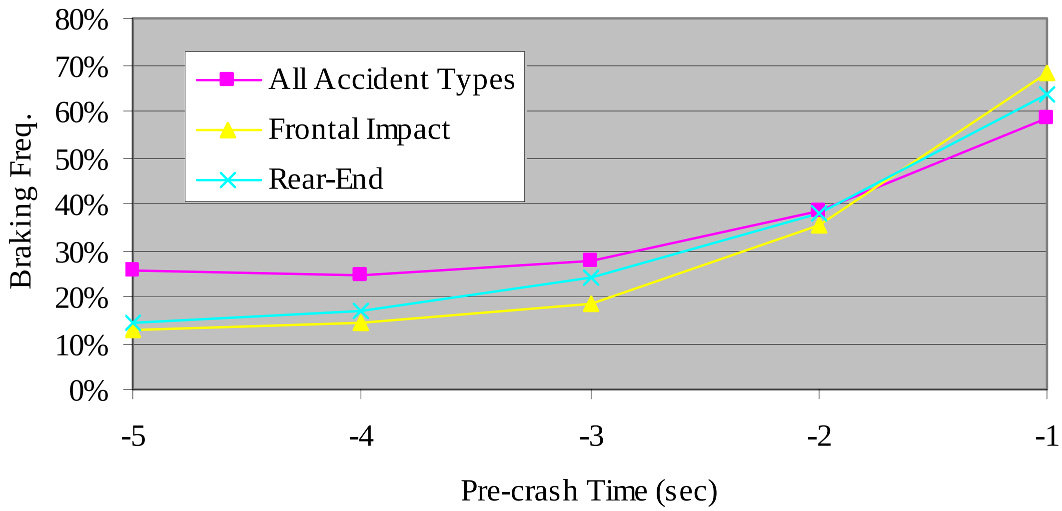


Figure C3. EDR-Reported Braking Frequency (case selection: GM vehicle cases with reported brake switch status information in EDR files [All *Accident Types*: 1,320 files, Frontal Impact: 367 files, Rear End: 119 files])

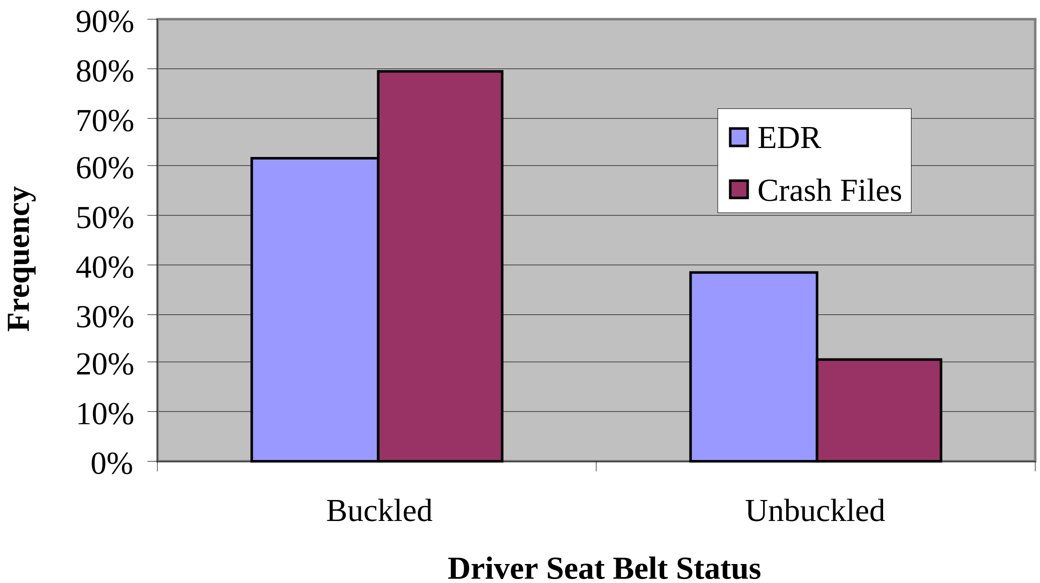


Figure C4. Driver Seat Belt Status Frequency as Reported by EDR and CDS (case selection: GM vehicle cases with reported driver seat belt status information in EDR files [2,462 files] and Crash files [2,252 files])

Table C1. Distribution of driver air bag deployment condition as reported by the EDRs and in Crash files (case selection: GM vehicle cases with reported driver air bag deployment information in both EDR files and Crash files [2,040 CDS, 107 SCI, 43 CIREN – 2,190 Total])

		Crash files			
		Deployed	**Nondeployed**	**Total**	**% of Total**
EDR	**Deployed**	1,123	25	1,148	52%
EDR	**Nondeployed**	19	1,023	1,042	48%
	Total	1,142	1,048	2,190	
	% of Total	52%	48%		

Table C2. Distribution of longitudinal delta V as reported by the EDRs and in Crash files (case selection: GM vehicle cases – 2,462 Total)

		Crash Files			
		Reported	**Not Reported**	**Total**	**% of Total**
EDR	**Reported**	1,240	567	1,807	73%
EDR	**Not Reported**	385	270	655	27%
	Total	1,625	837	2,462	
	% of Total	66%	34%		

APPENDIX D

This appendix displays the overall distribution of Ford EDR data versus the CDS, SCI, and CIREN data (grouped together and referred to as "Crash Files") for each of the parameters previously compared separately.

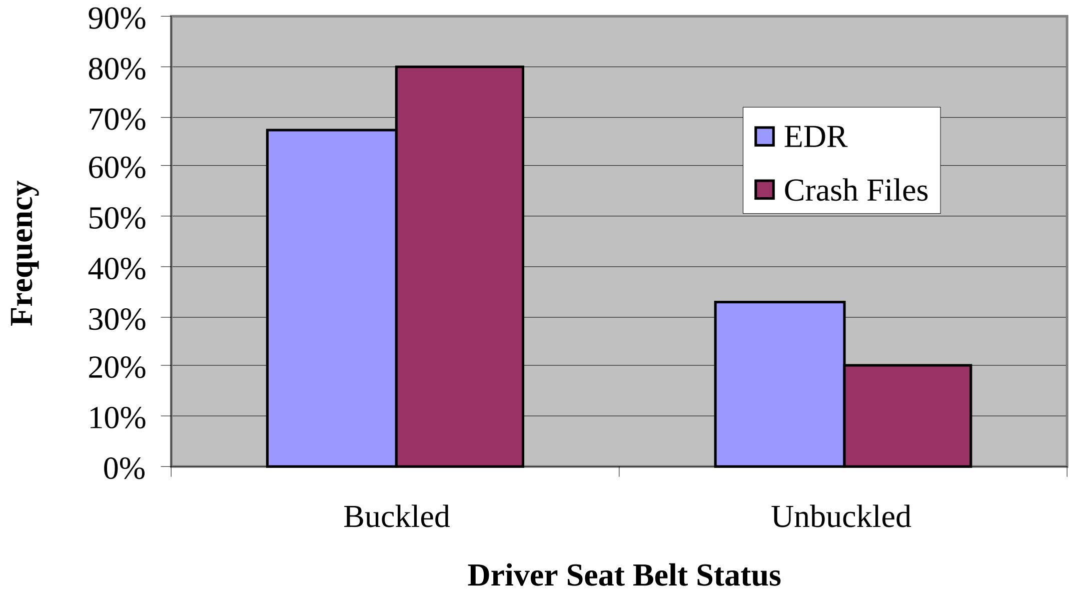


Figure D1. Driver Seat Belt Status Frequency as Reported by EDR and CDS (case selection: Ford vehicle cases with reported driver seat belt status information in EDR files [79 files] and Crash files [70 files])

Table D1. Distribution of driver air bag deployment condition as reported by the EDRs and in Crash files (case selection: Ford vehicle cases with reported driver air bag deployment information in both EDR files and Crash files [61 NASS-CDS, 8 SCI, 1 CIREN – 70 Total])

		Crash files			
		Deployed	**Nondeployed**	**Total**	**% of Total**
EDR	**Deployed**	33	9	42	60%
	Nondeployed	2	26	28	40%
	Total	35	35	70	
	% of Total	50%	50%		

Table D2. Distribution of longitudinal delta V as reported by the EDRs and in Crash files (case selection: Ford vehicle cases– 79 total)

		Crash File			
		Reported	**Not Reported**	**Total**	**% of Total**
EDR	**Reported**	45	24	69	87%
	Not Reported	6	4	10	13%
	Total	51	28	79	
	% of Total	65%	35%		

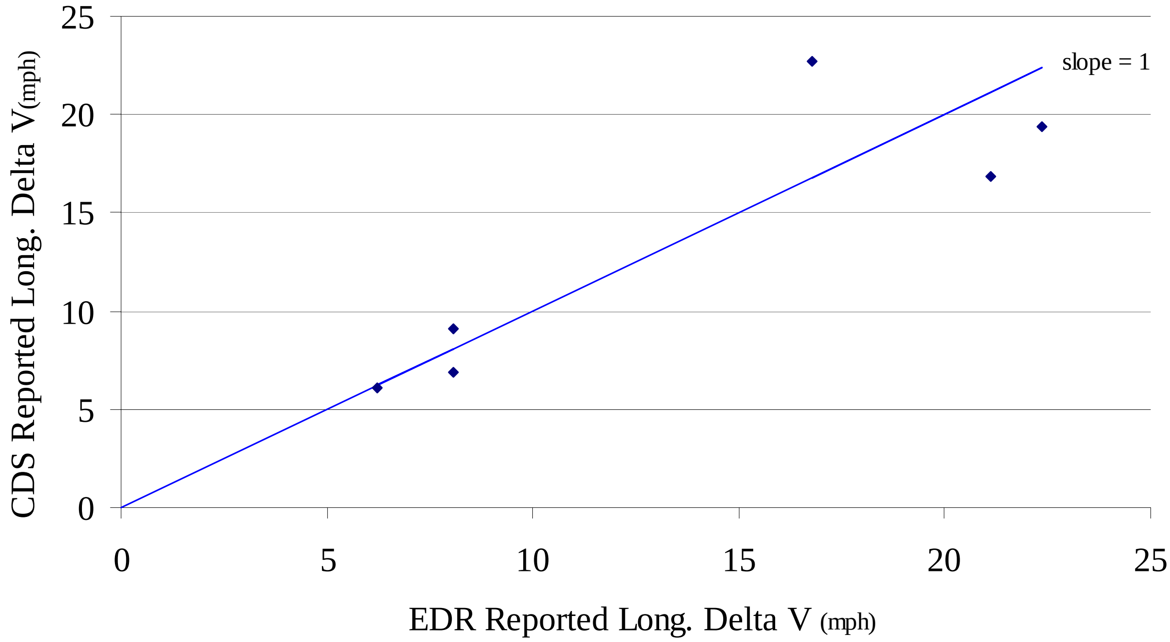


Figure D2. Longitudinal delta V comparative analysis of EDR vs. Crash File data (case selection: 6 frontal impact Ford vehicle cases in which delta V is known for both EDR [full pulse] and Crash file [3 NASS-CDS, 3 SCI – 6 Total] [frontal impact damage: *PDOF1* = 0, 10, 350])

APPENDIX E

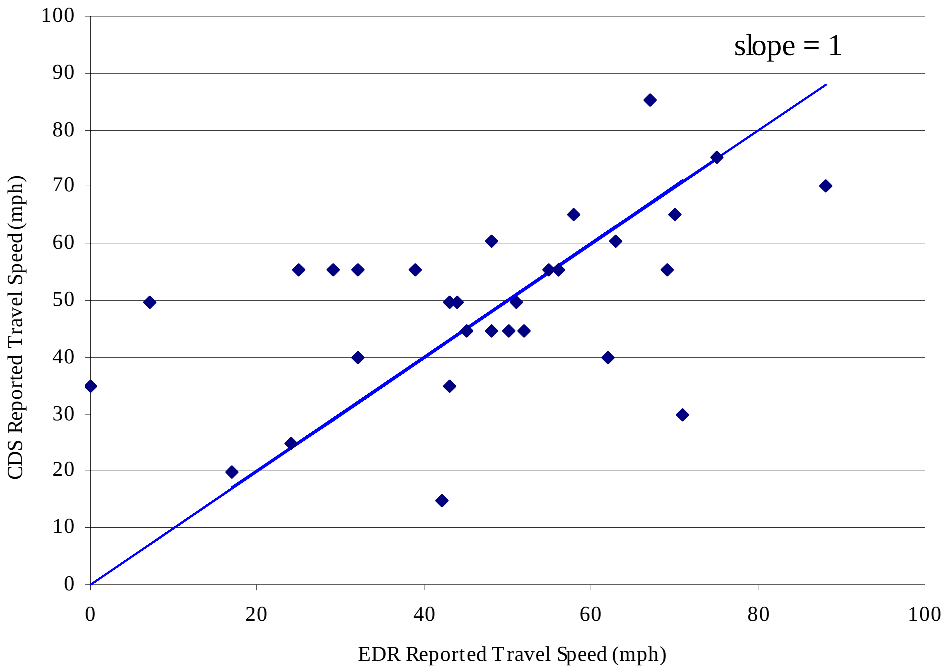


Figure E1. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 1*; 31 Files)

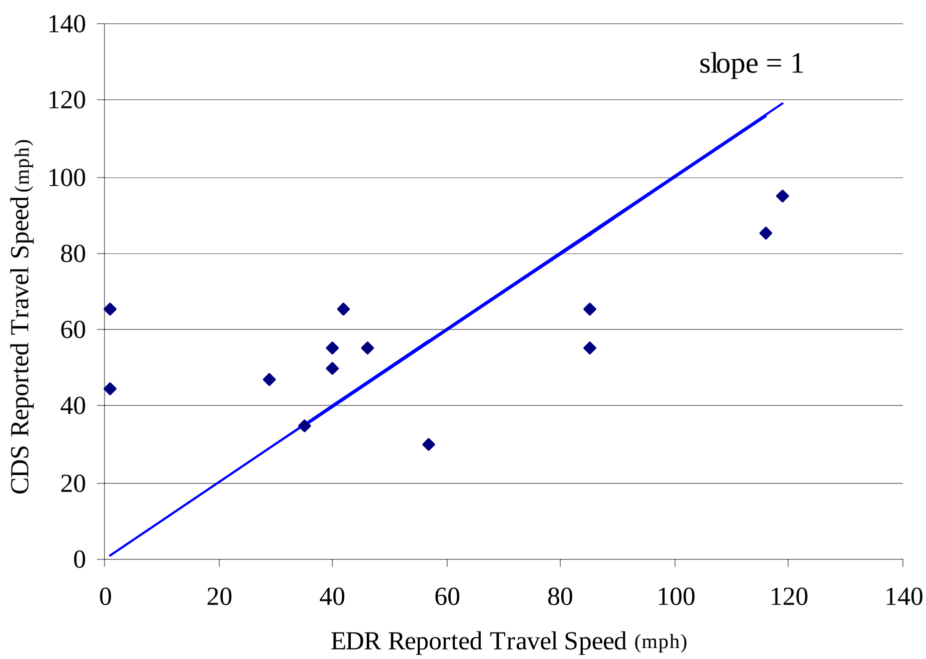


Figure E2. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 2*; 13 Files)

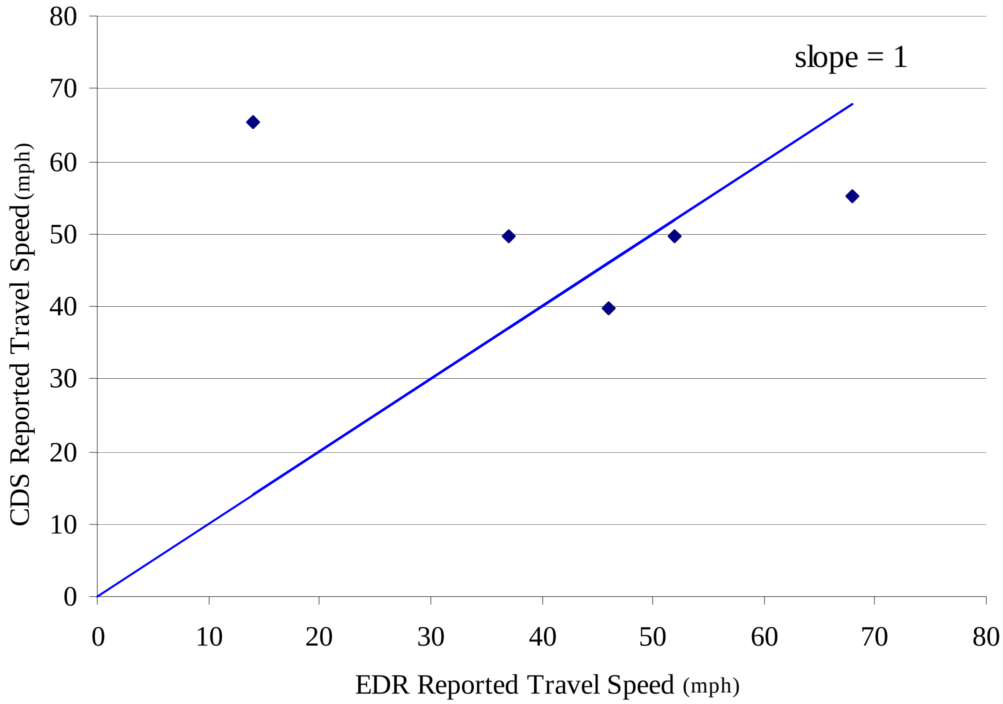


Figure E3. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 3*; 5 Files)

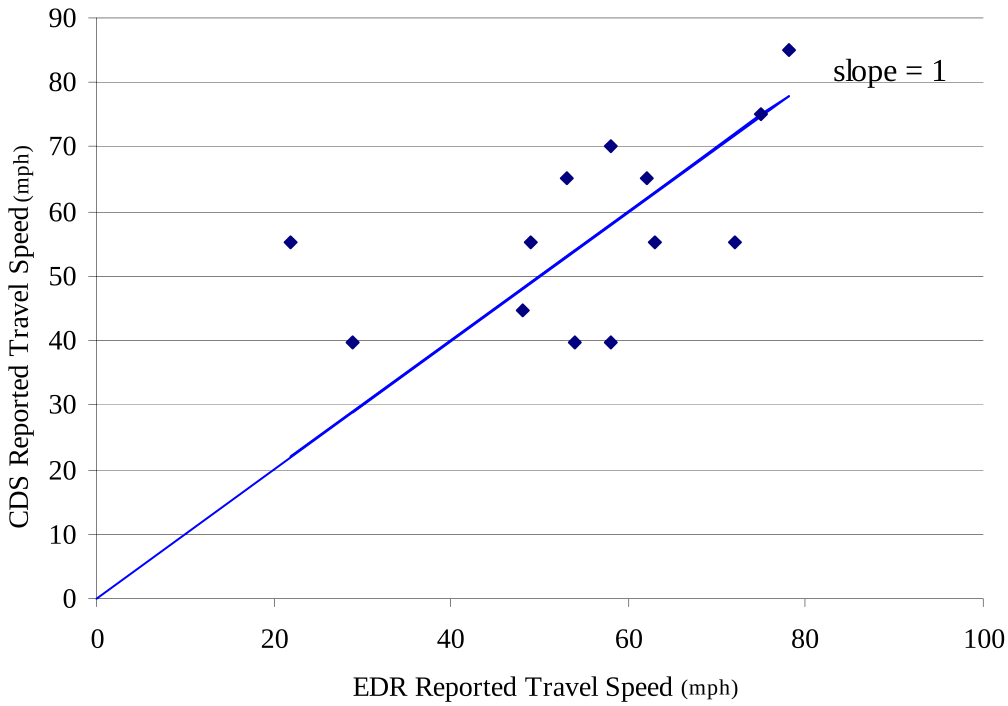


Figure E4. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 6*; 13 Files)

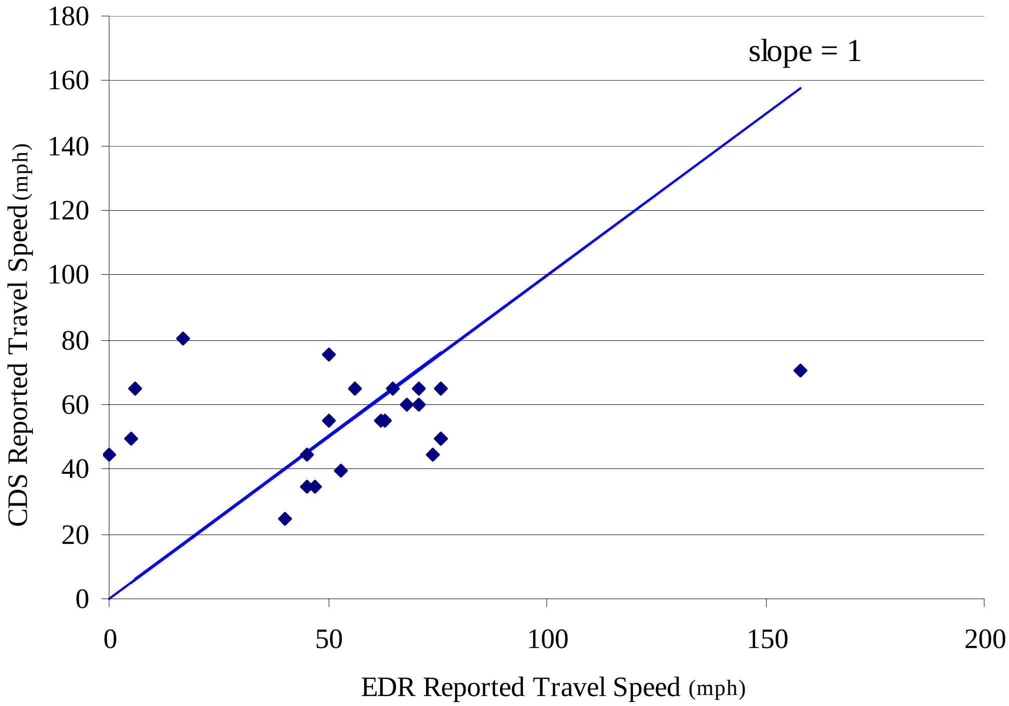


Figure E5. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 7*; 23 Files)

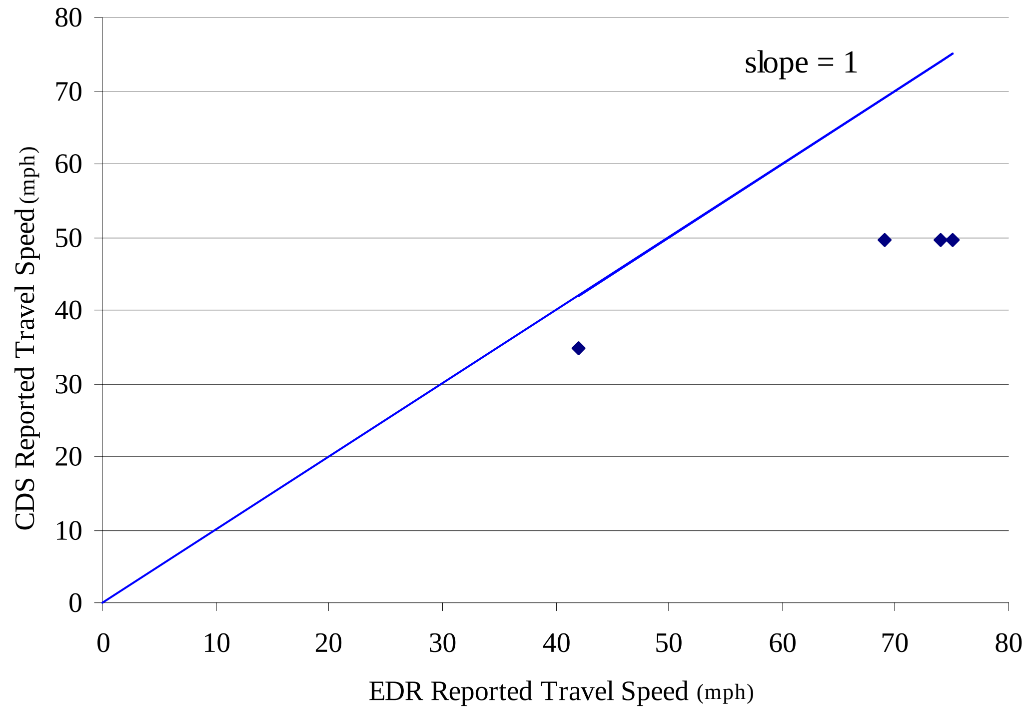


Figure E6. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 8*; 4 Files)

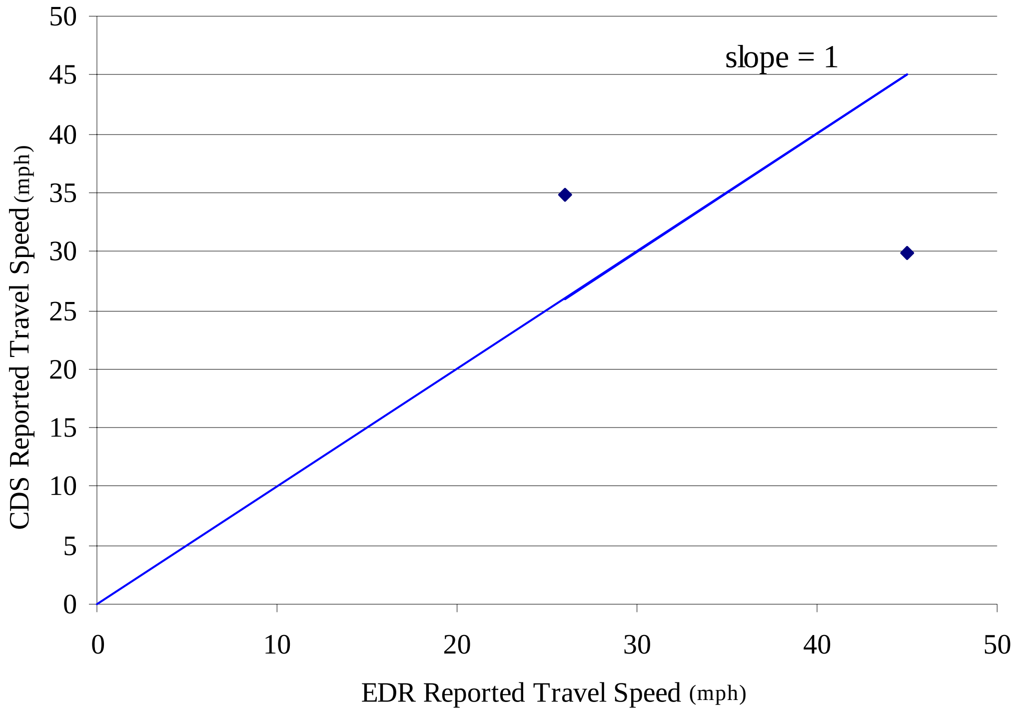


Figure E7. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 11*; 2 Files)

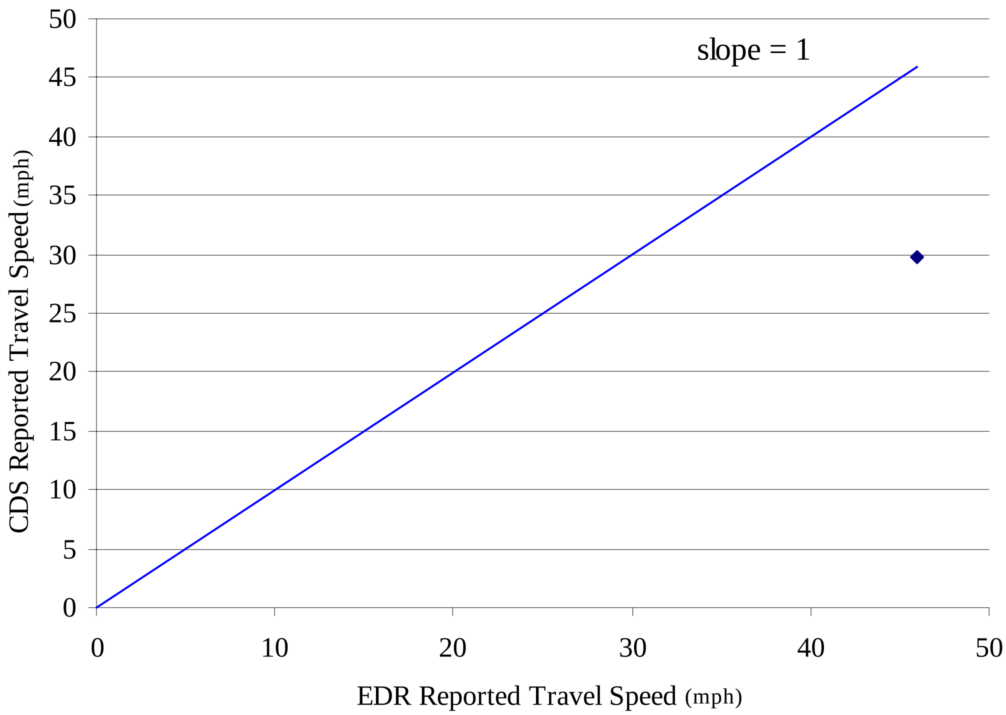


Figure E8. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 12*; 1 File)

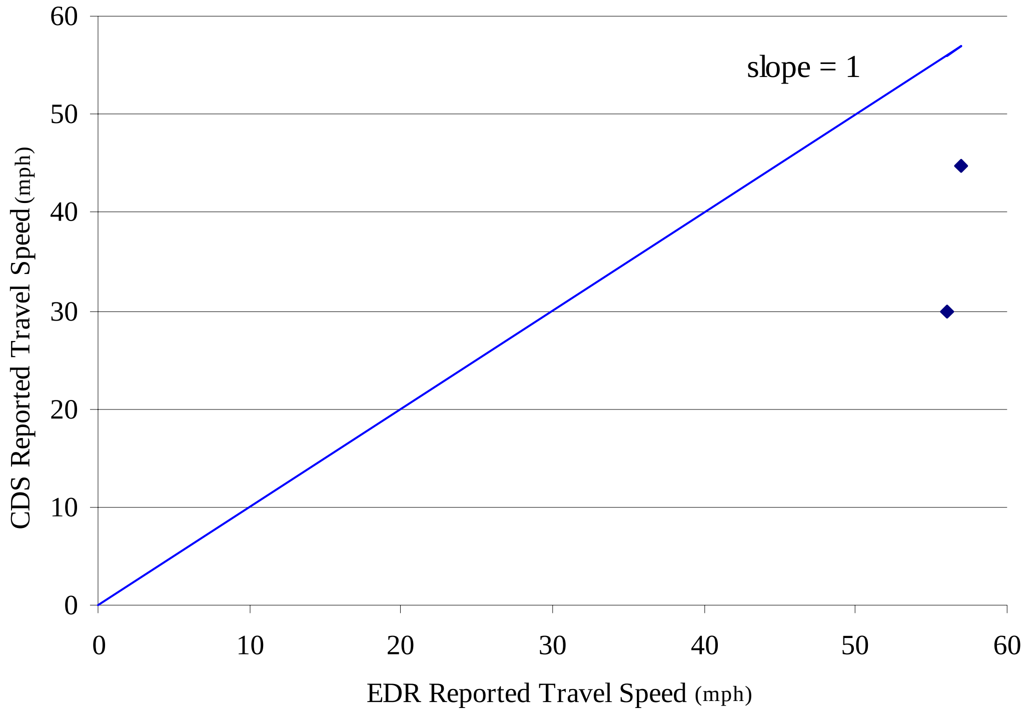


Figure E9. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 13*; 2 Files)

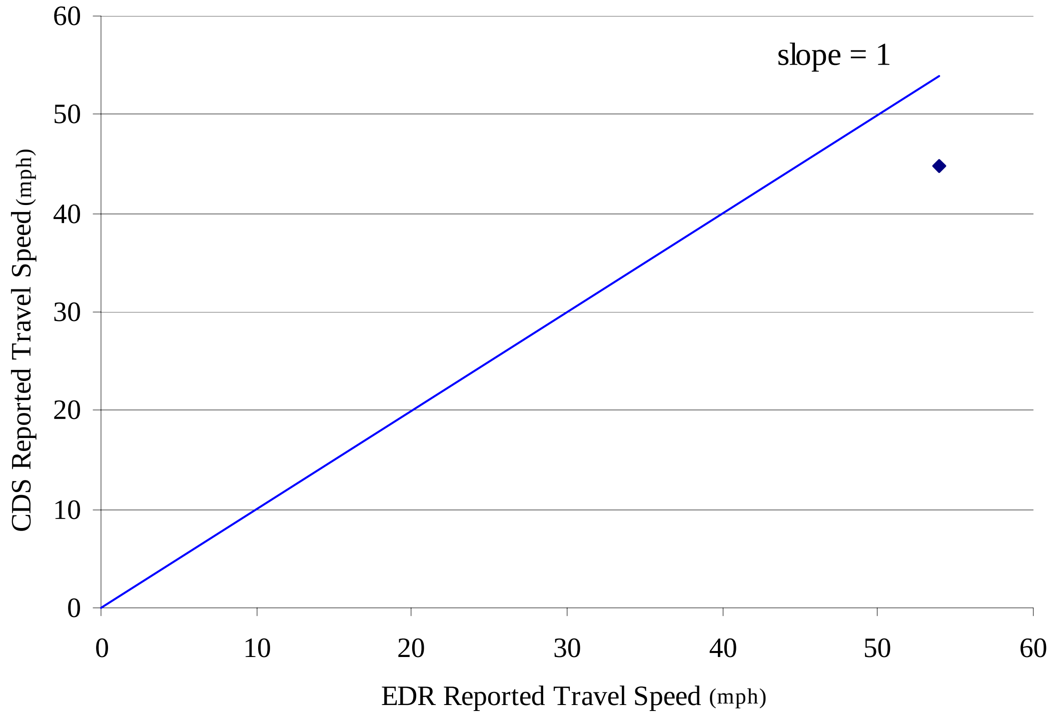


Figure E10. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 14*; 1 File)

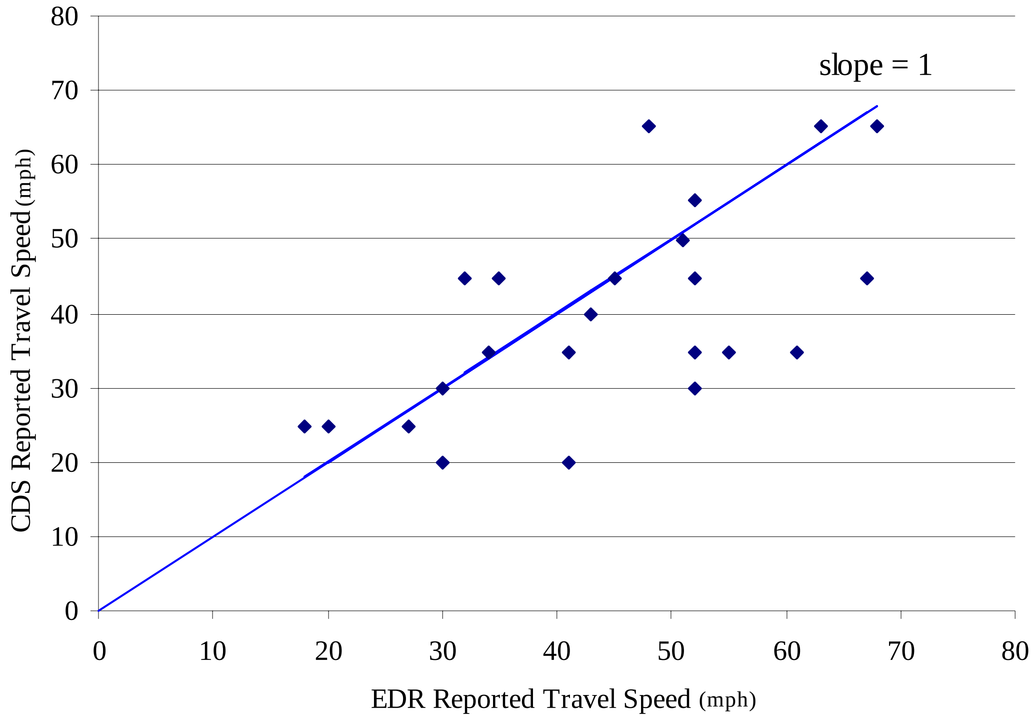


Figure E11. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 20*; 23 Files)

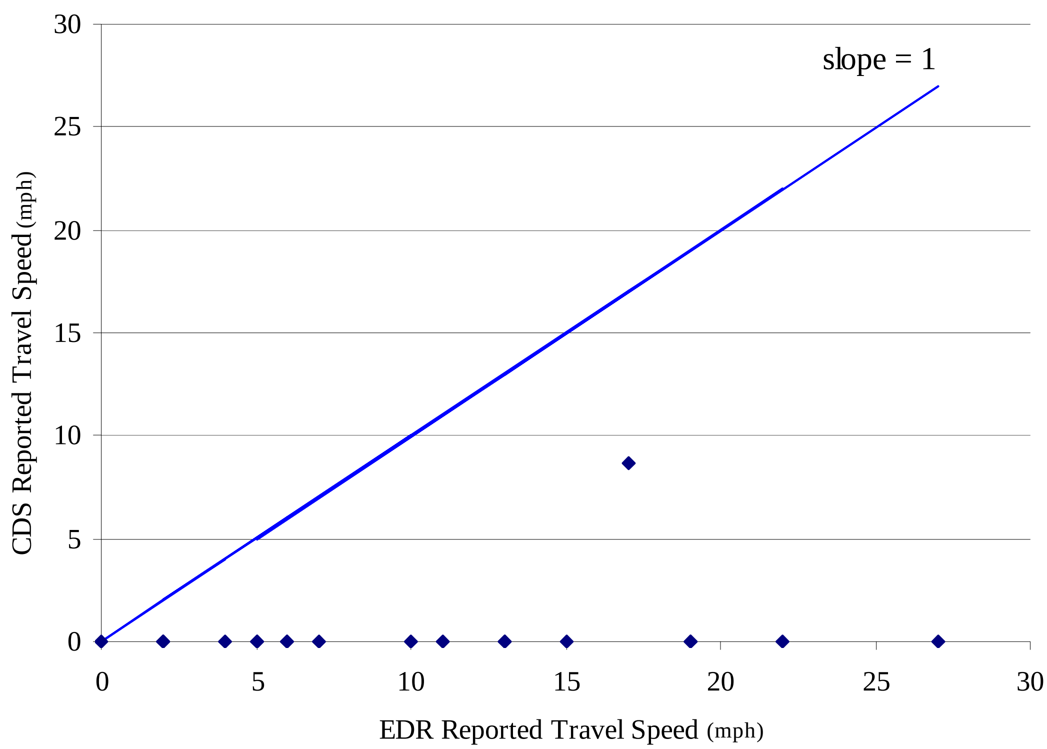


Figure E12. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 21*; 20 Files)

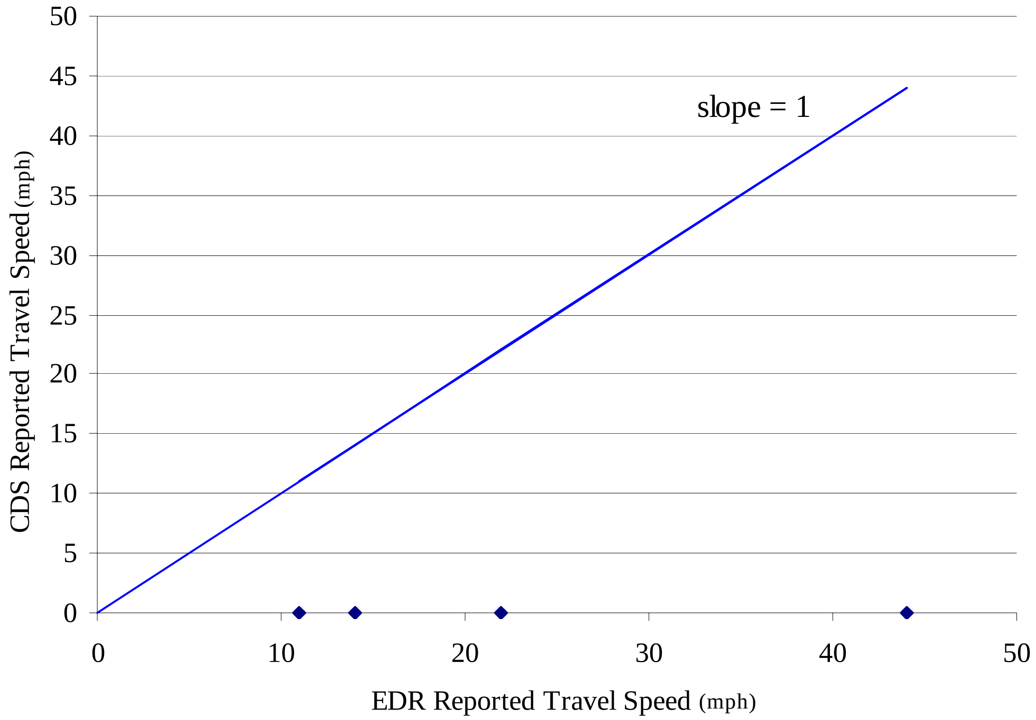


Figure E13. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE* = *22*; 4 Files)

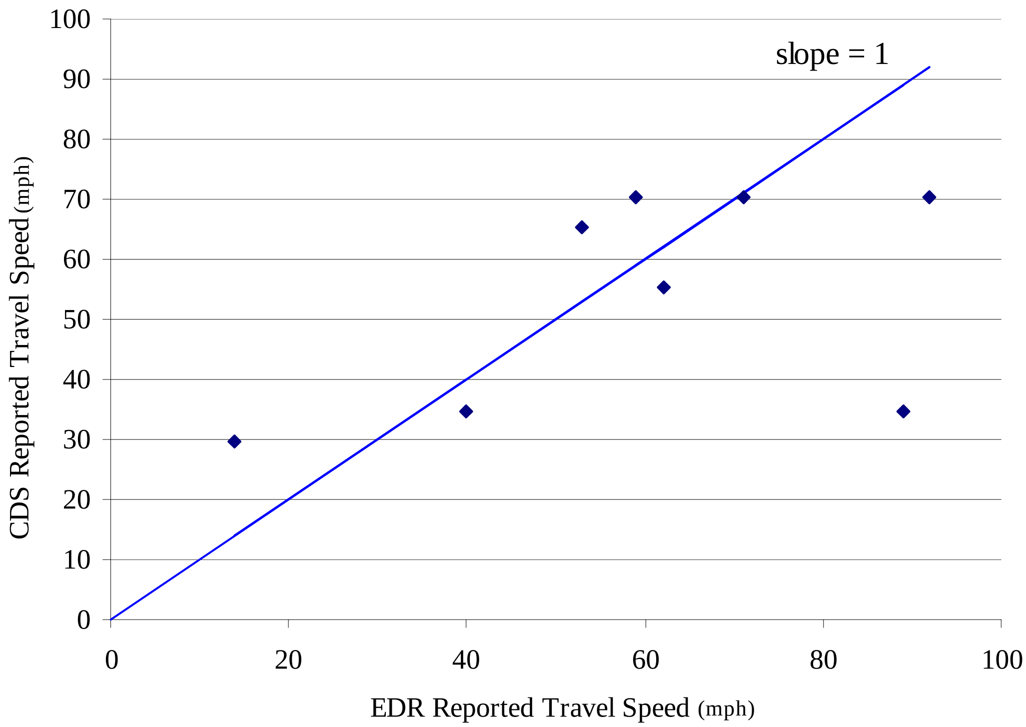


Figure E14. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE* = *24*; 8 Files)

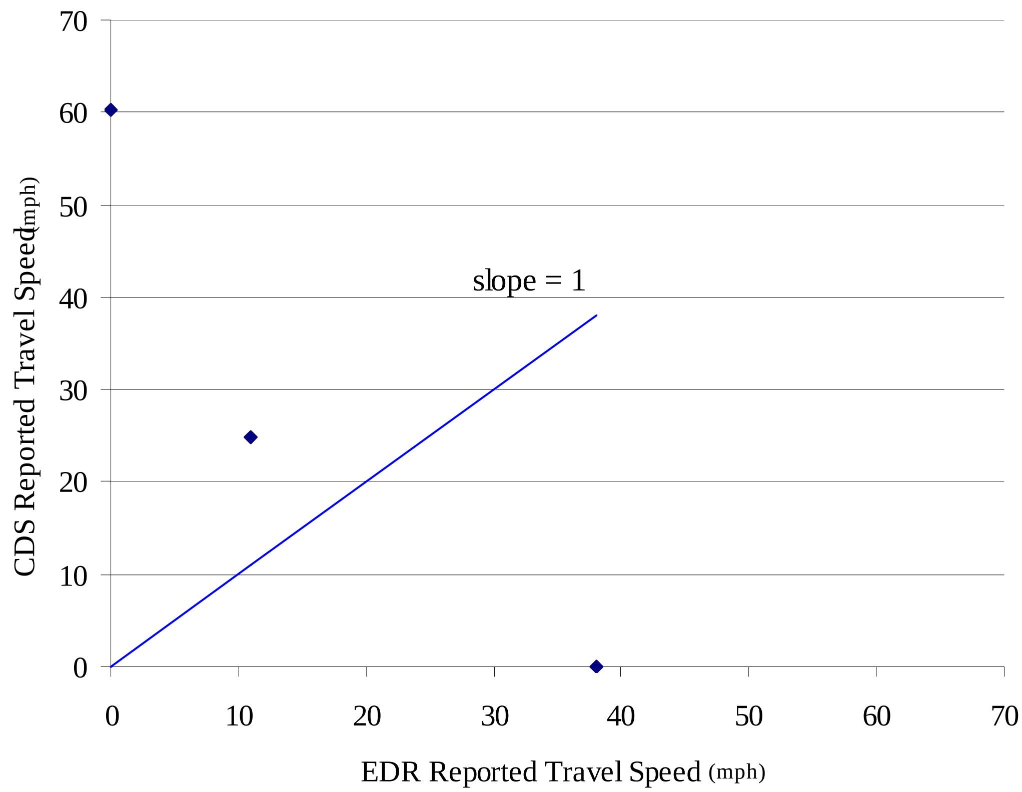


Figure E15. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 25*; 3 Files)

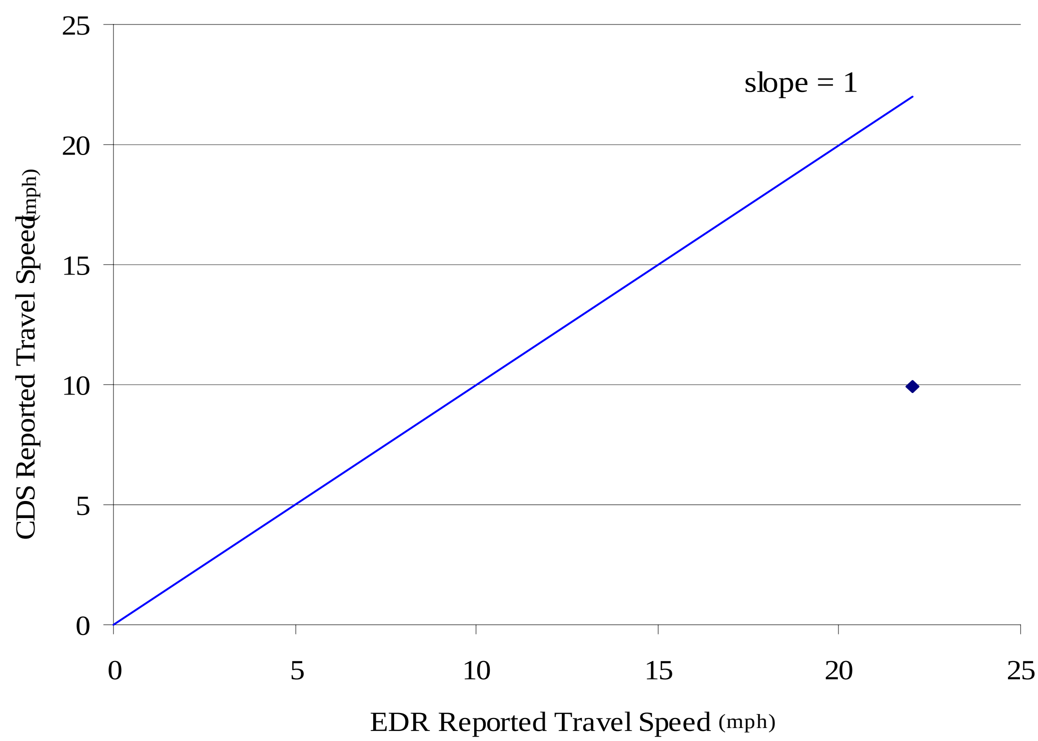


Figure E16. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 27*; 1 File)

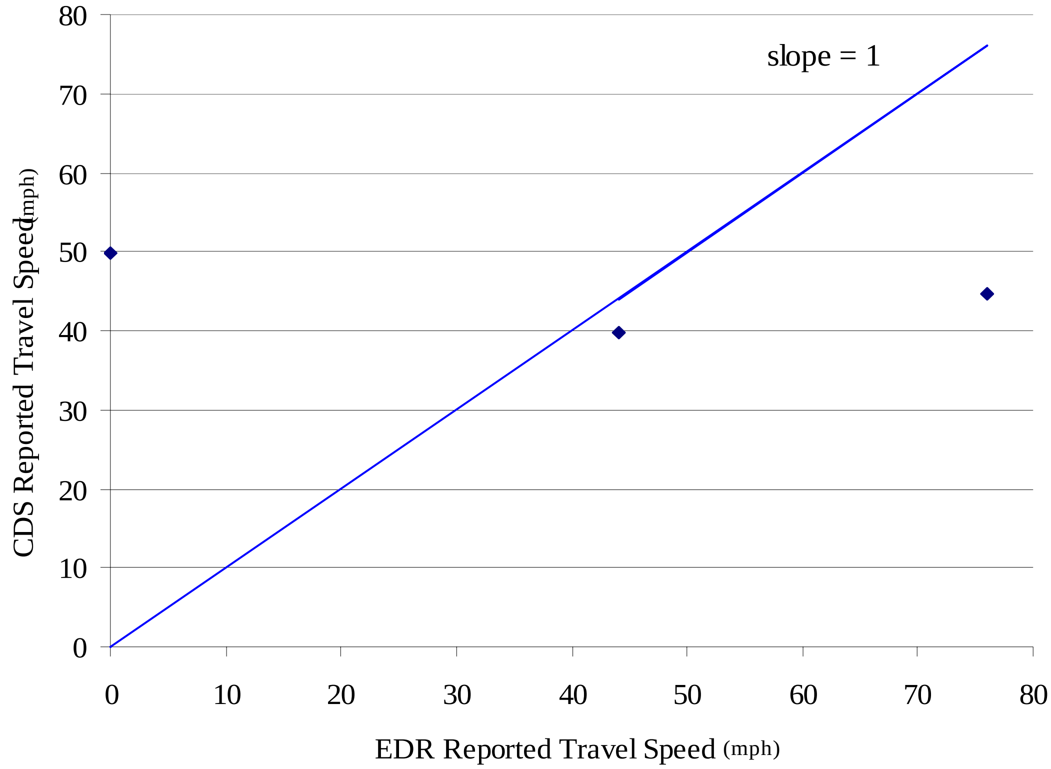


Figure E17. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 28*; 3 Files)

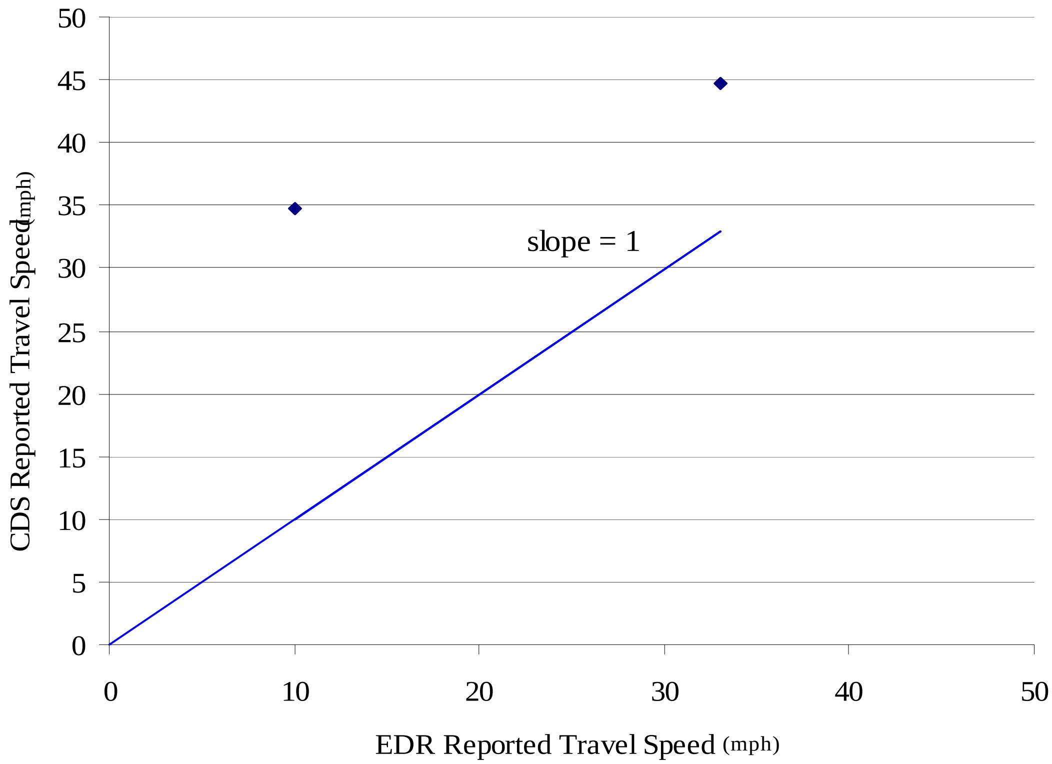


Figure E18. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 29*; 2 Files)

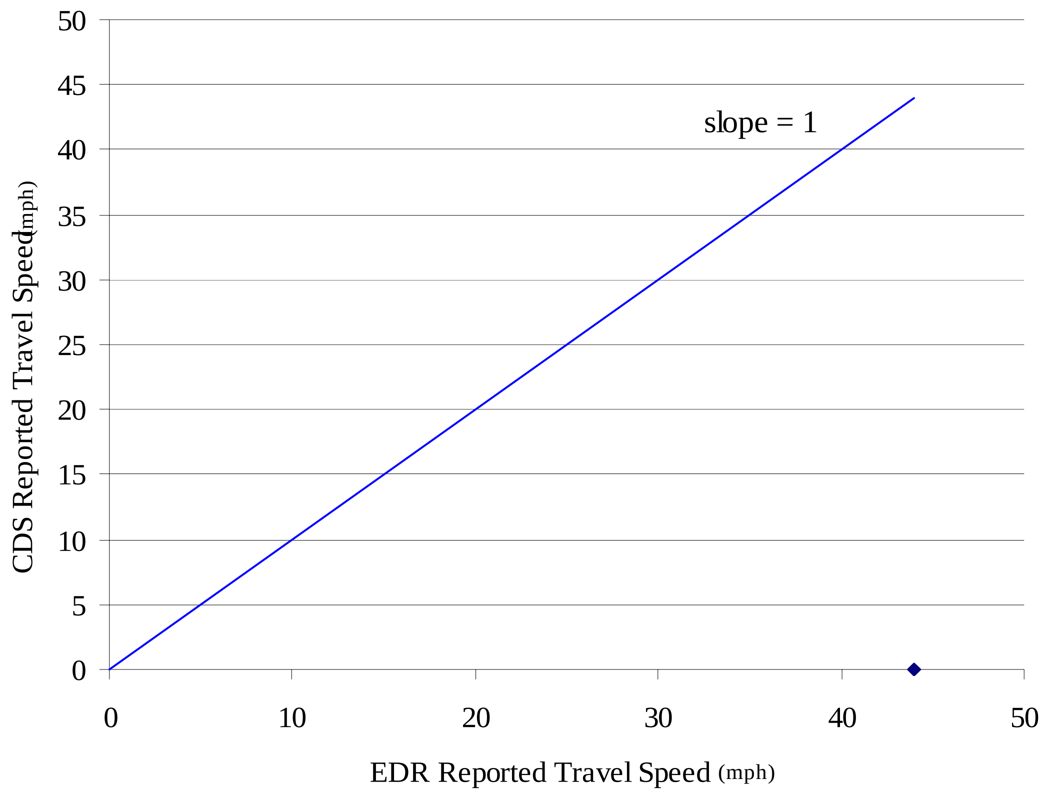


Figure E19. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 30*; 1 File)

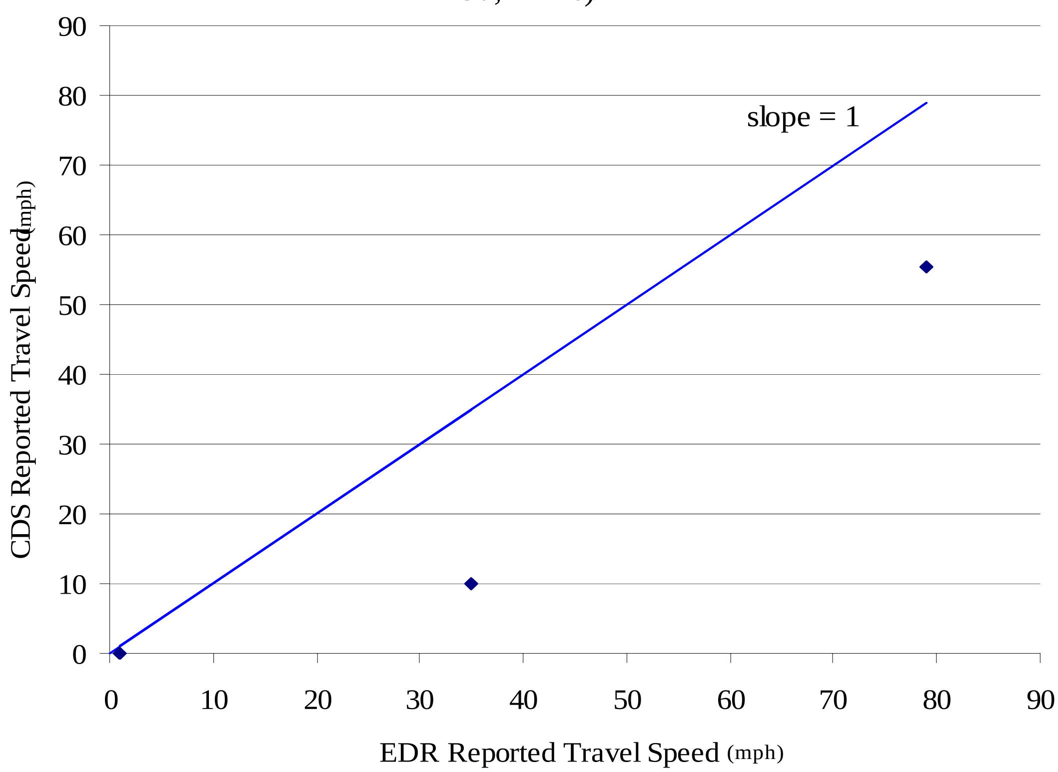


Figure E20. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 32*; 3 Files)

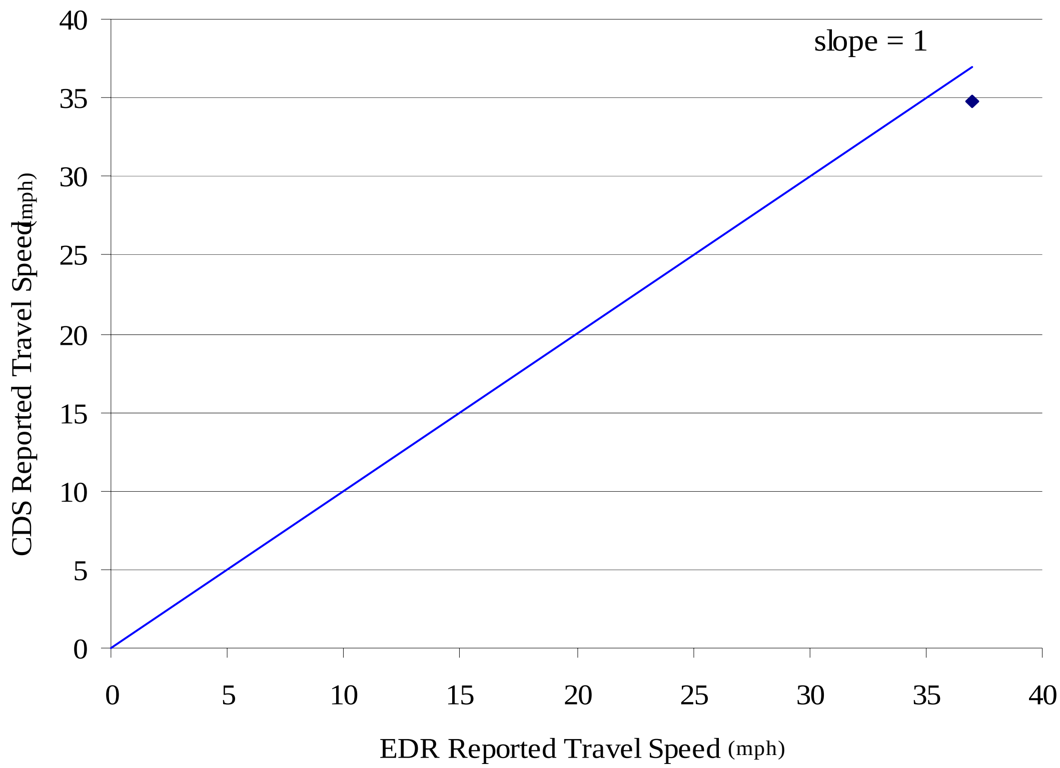


Figure E21. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 45*; 1 File)

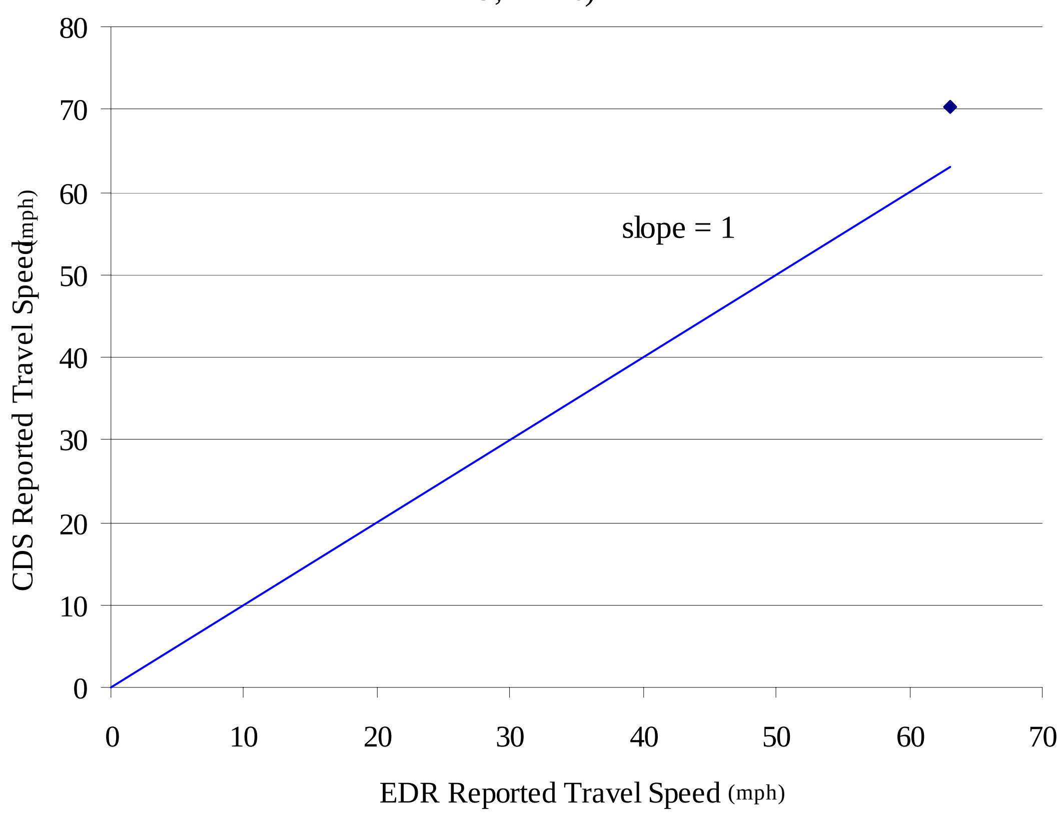


Figure E22. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 46*; 1 File)

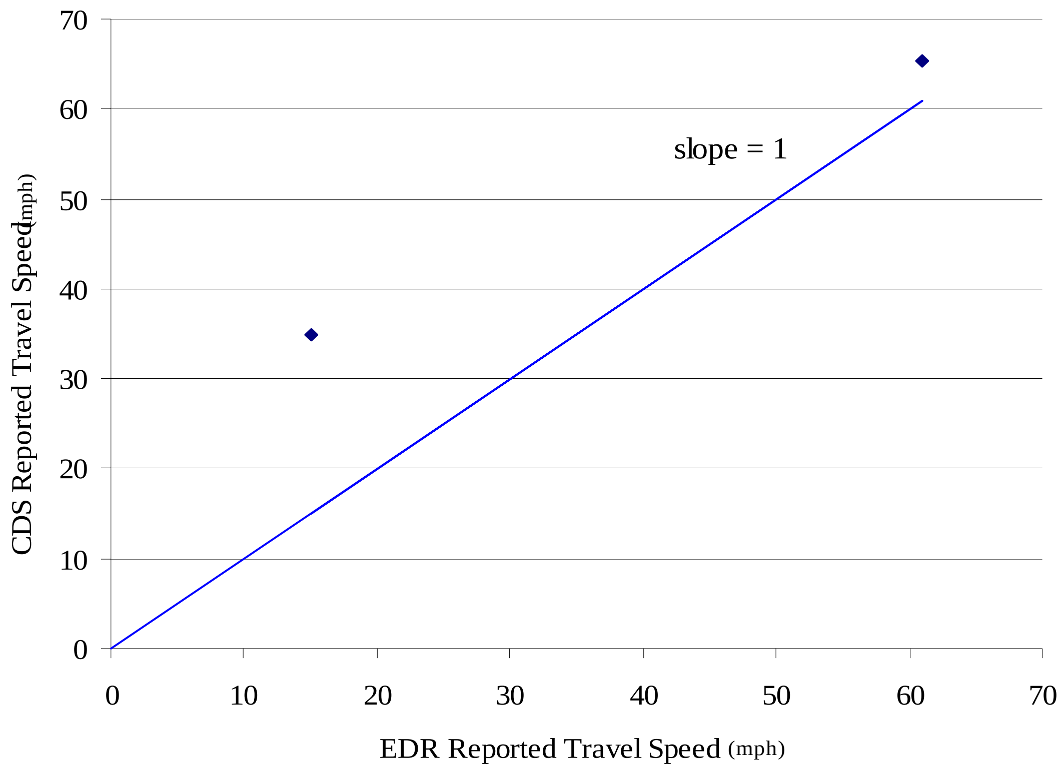


Figure E23. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 47*; 2 Files)

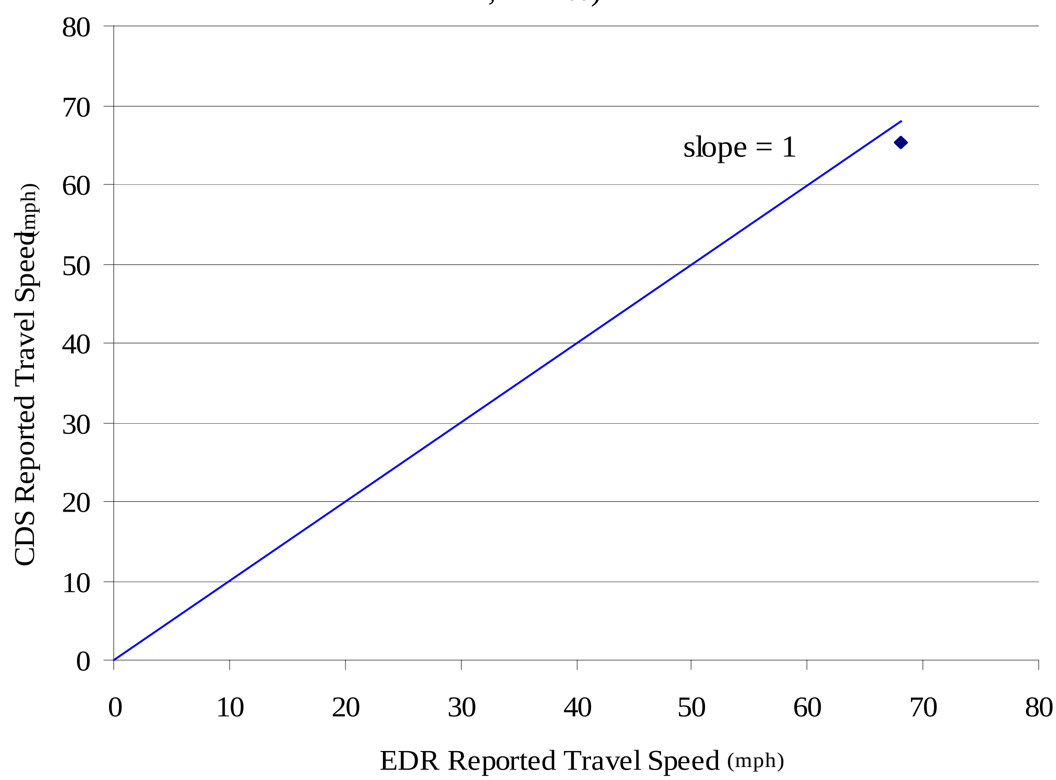


Figure E24. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 48*; 2 Files)

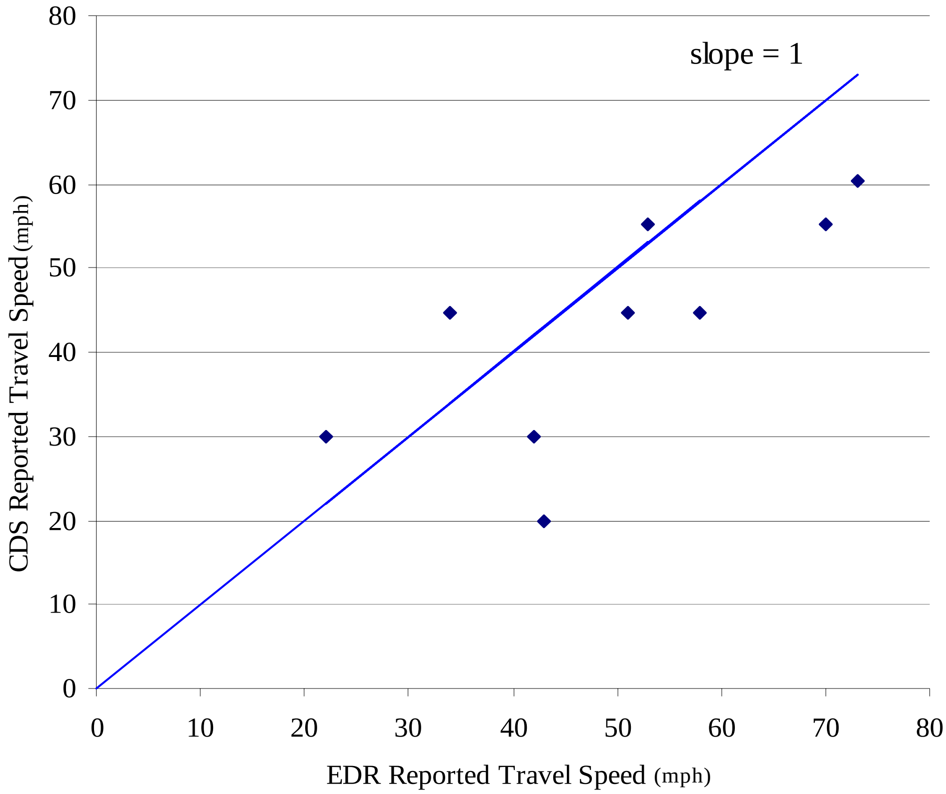


Figure E25. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 50*; 9 Files)

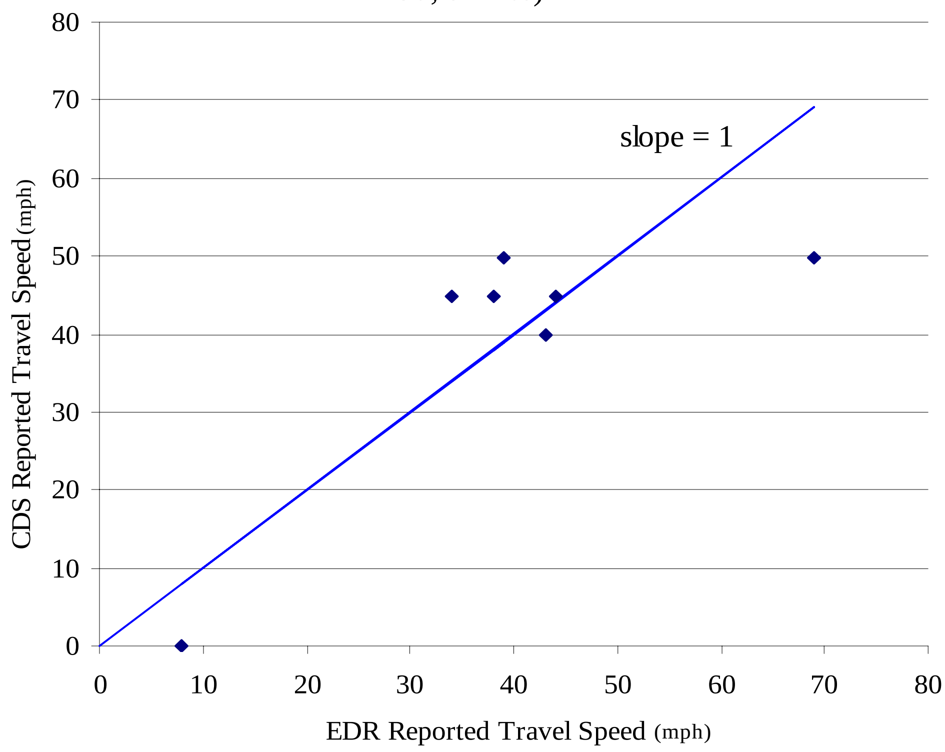


Figure E26. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 51*; 7 Files)

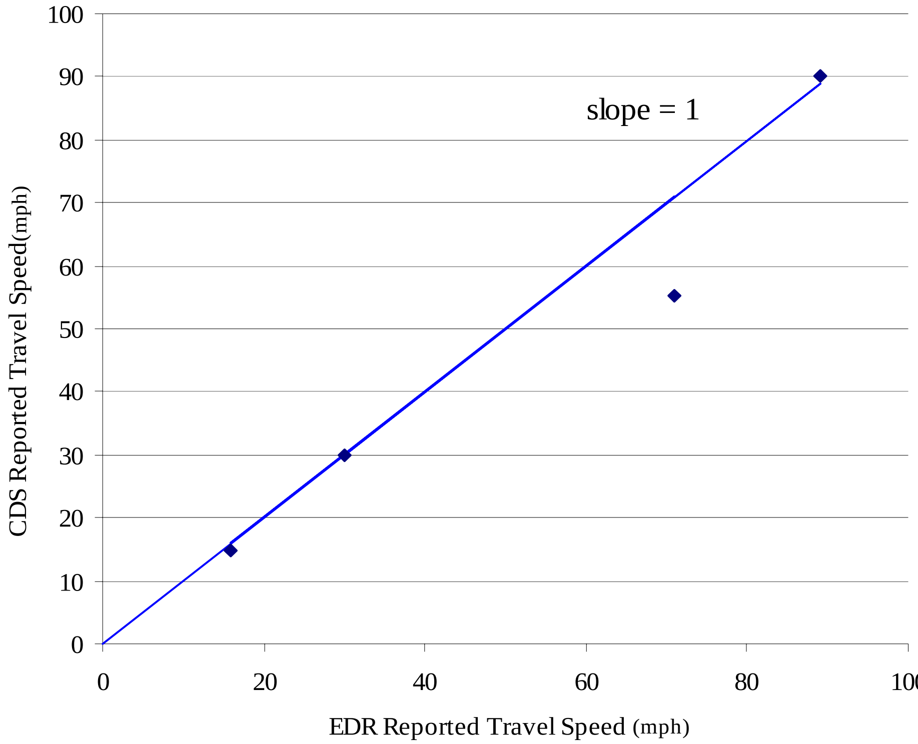


Figure E27. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 64*; 4 Files)

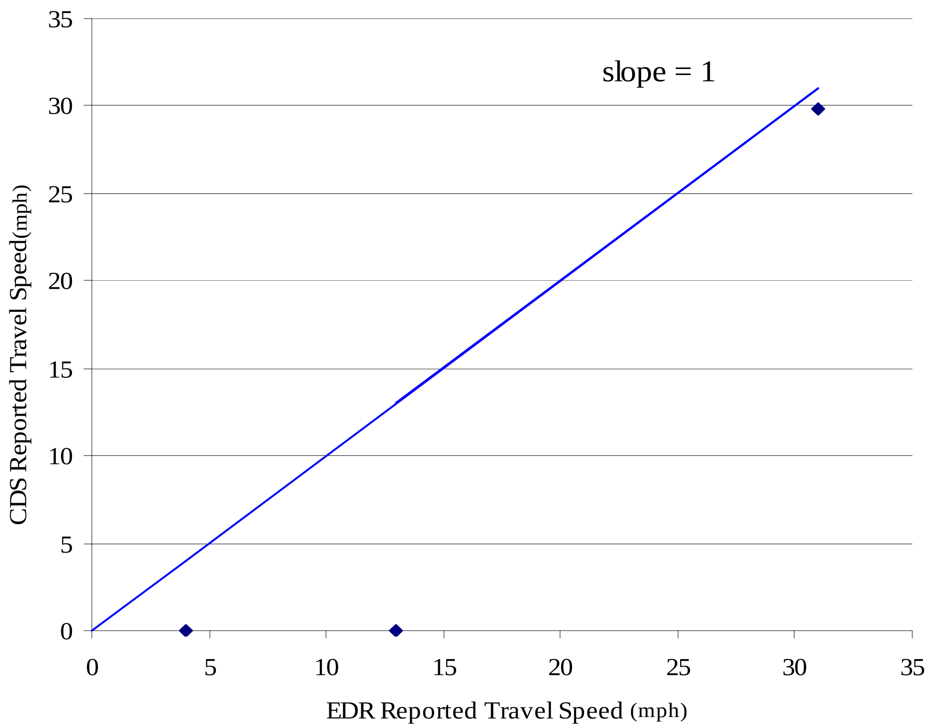


Figure E28. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 65*; 3 Files)

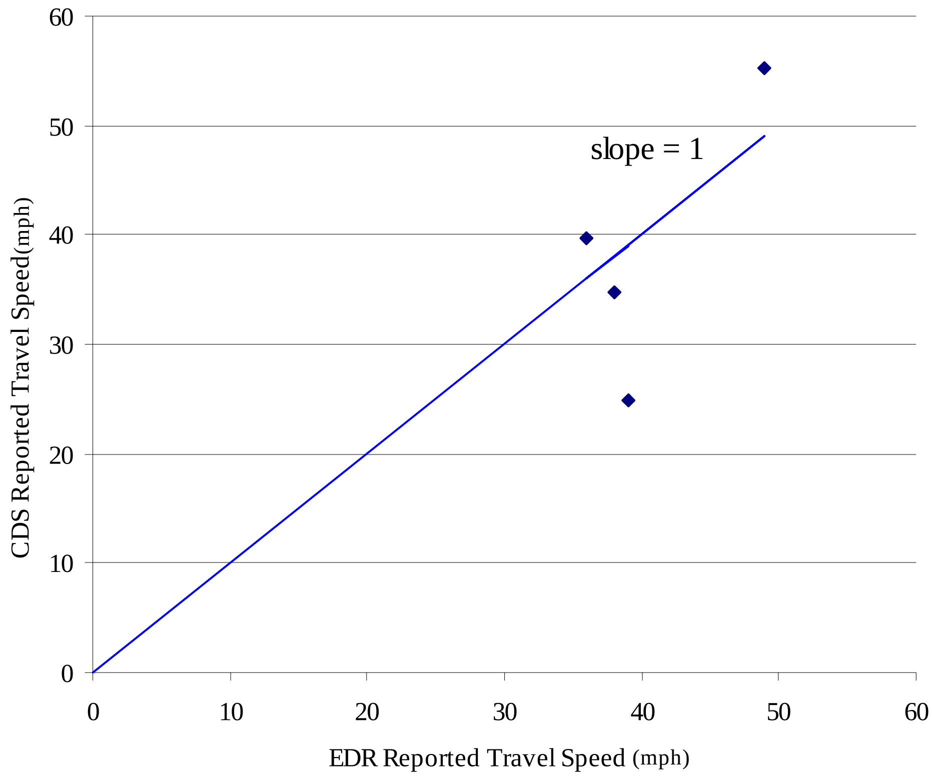


Figure E29. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 66*; 4 Files)

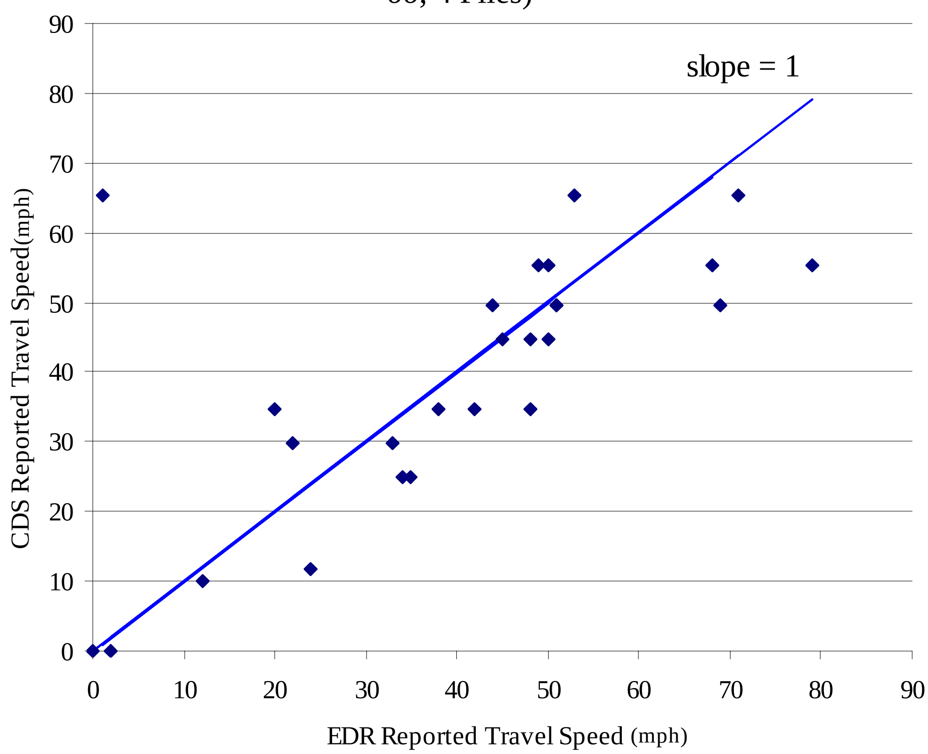


Figure E30. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 68*; 26 Files)

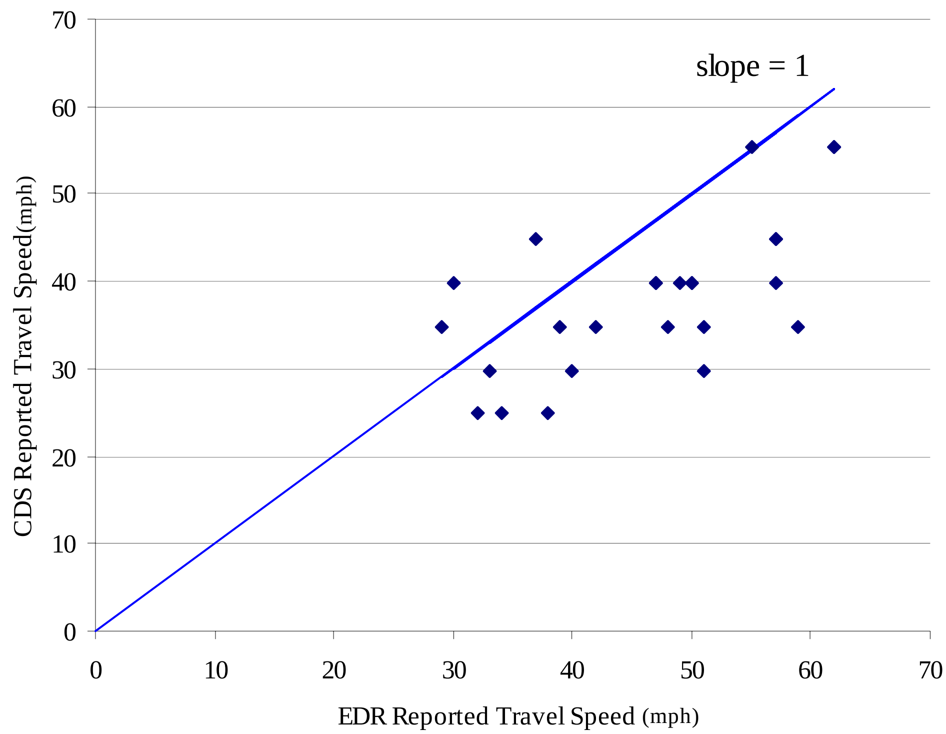


Figure E31. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 69*; 25 Files)

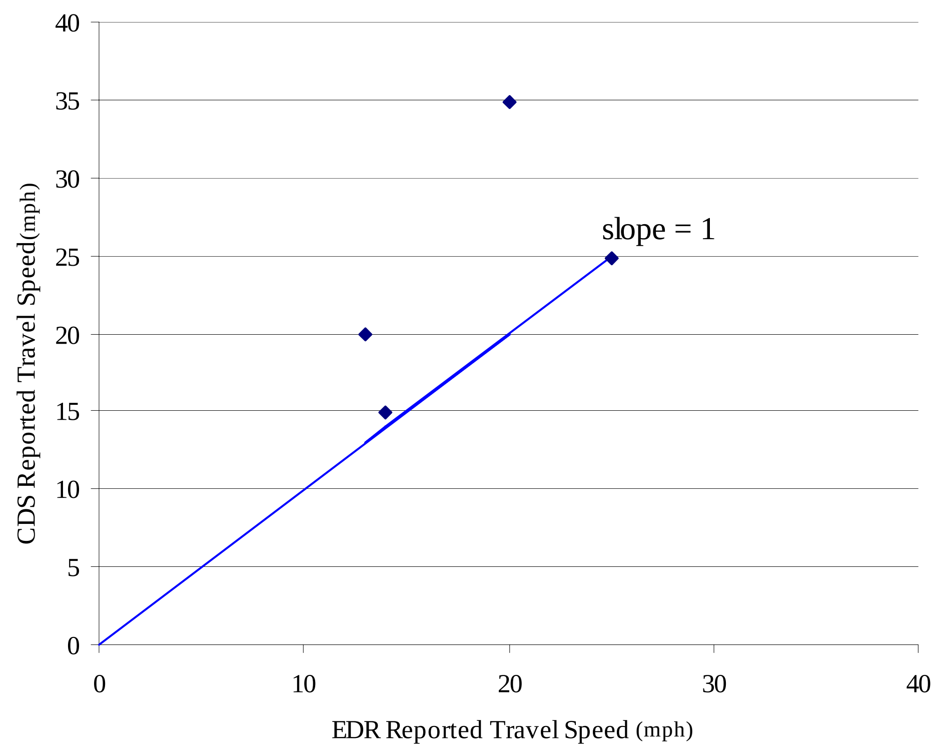


Figure E32. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 76*; 4 Files)

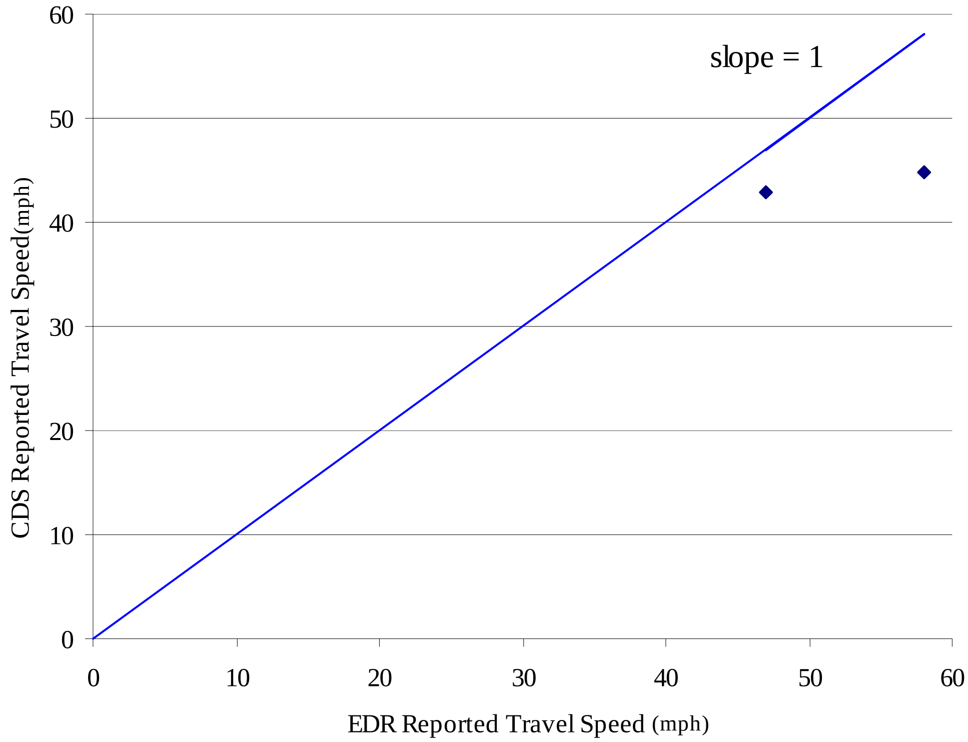


Figure E33. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 77*; 2 Files)

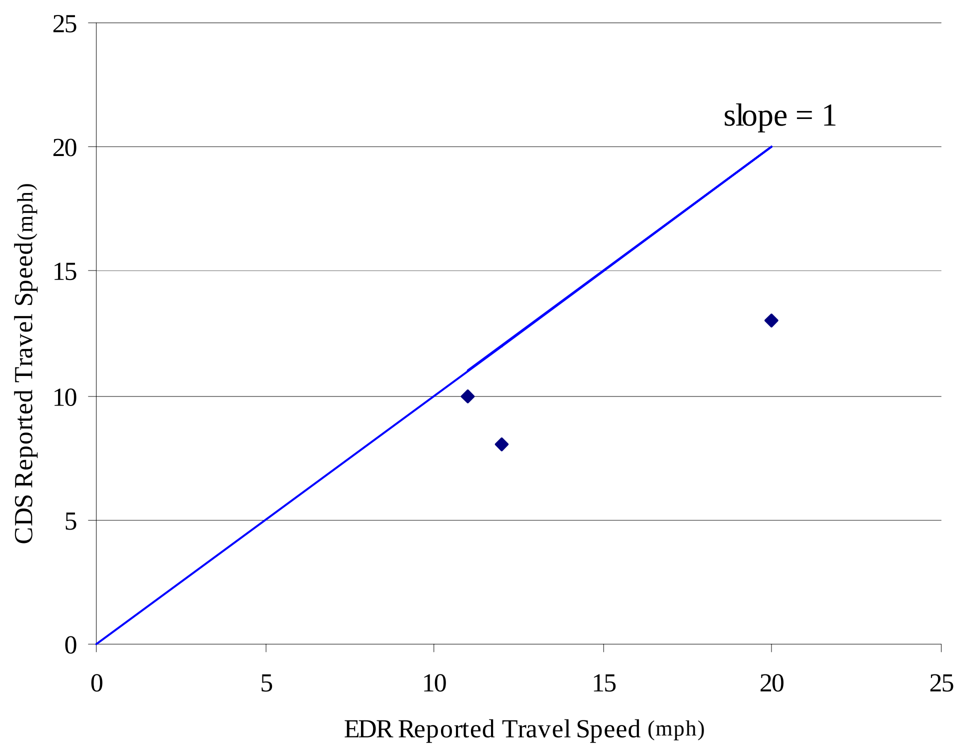


Figure E34. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 78*; 3 Files)

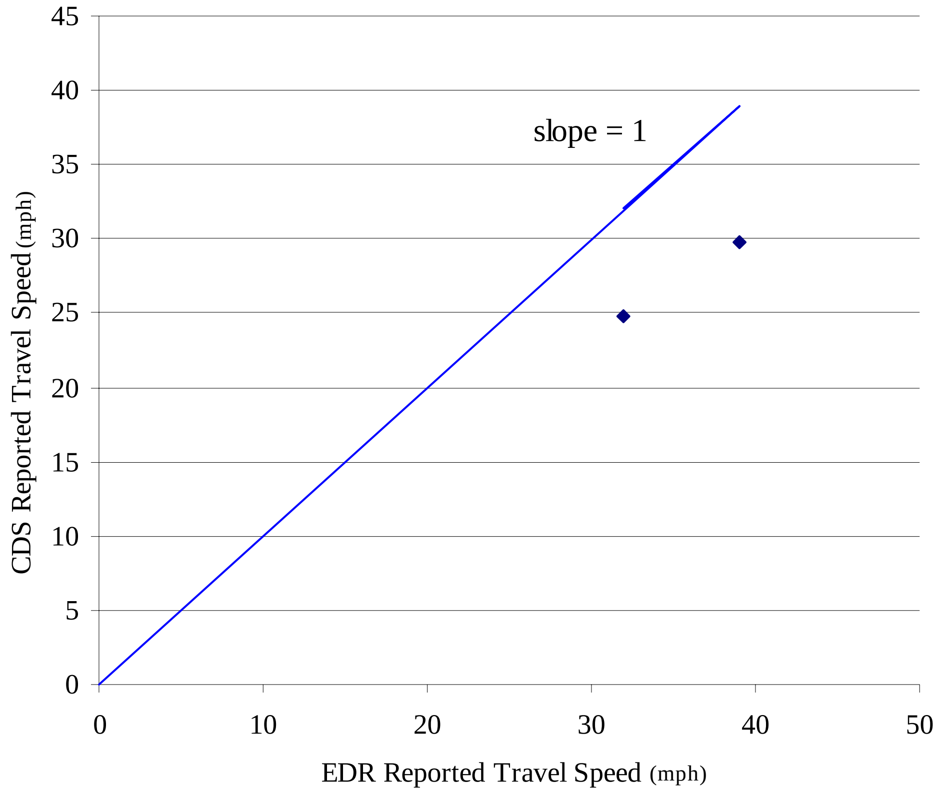


Figure E35. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 79*; 2 Files)

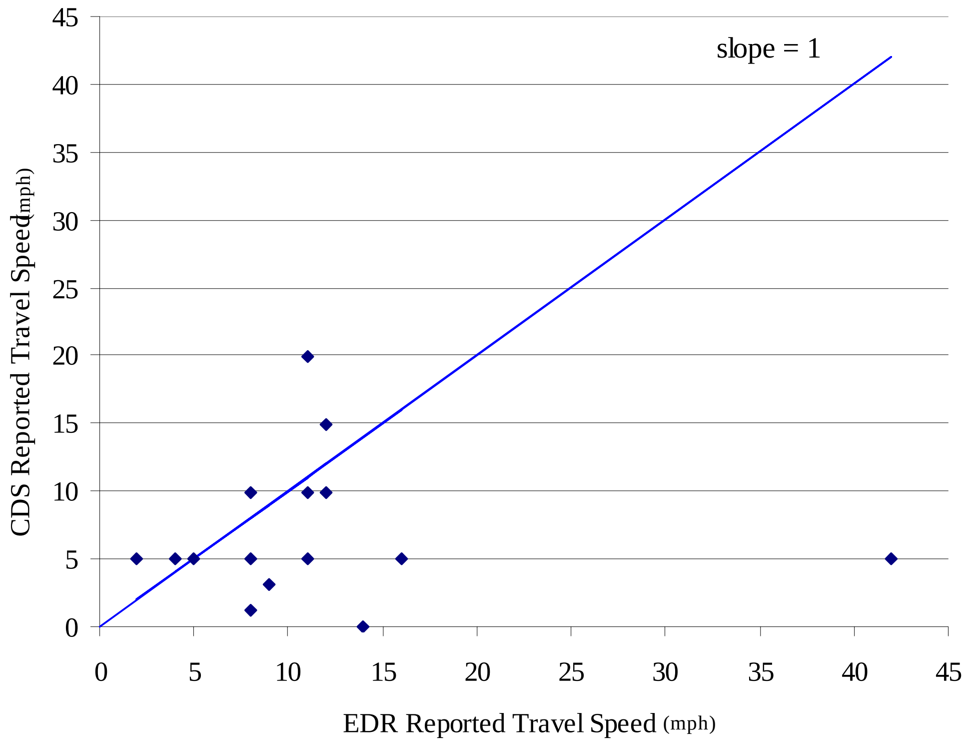


Figure E36. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 82*; 15 Files)

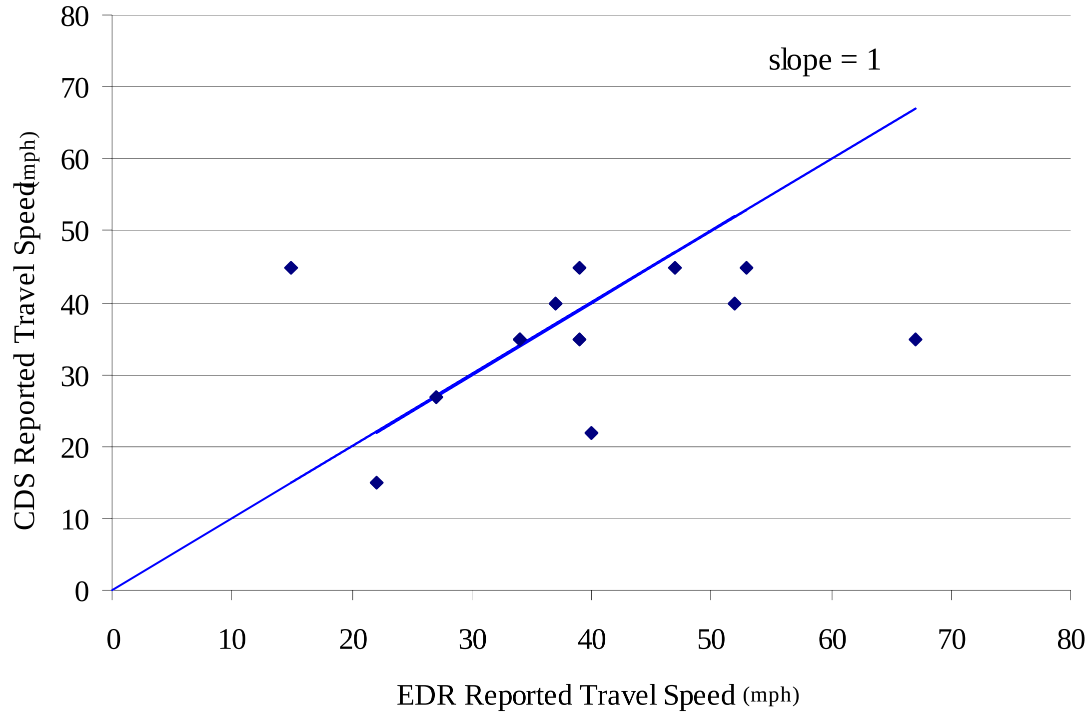


Figure E37. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 83*; 13 Files)

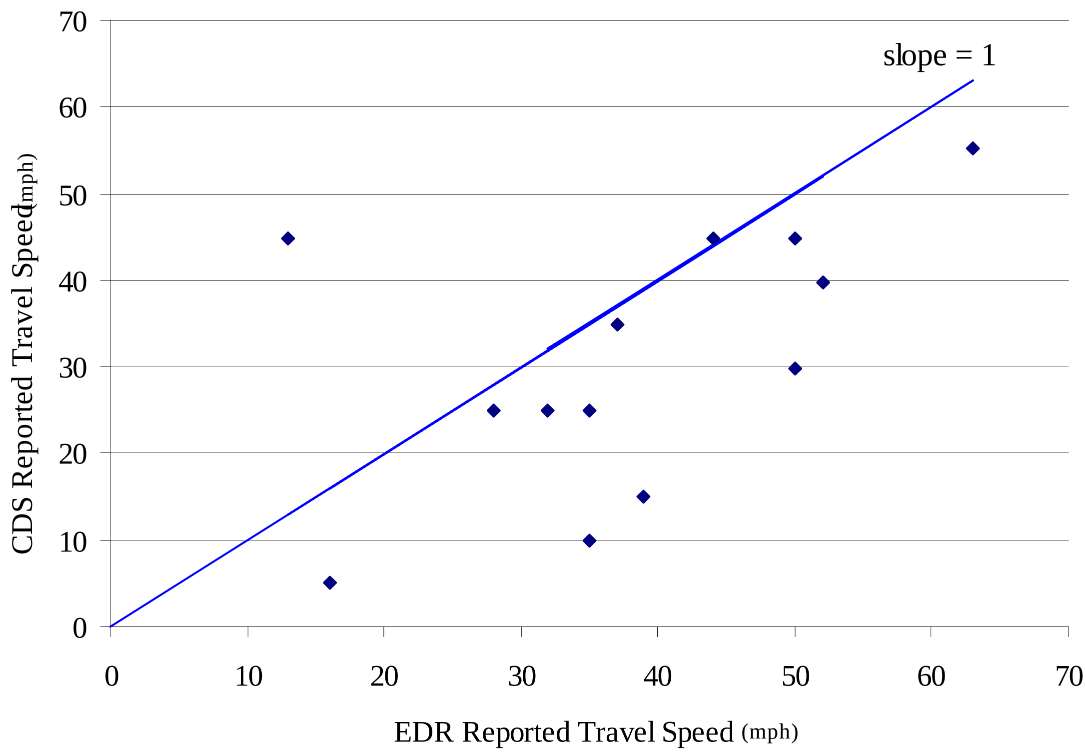


Figure E38. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 86*; 13 Files)

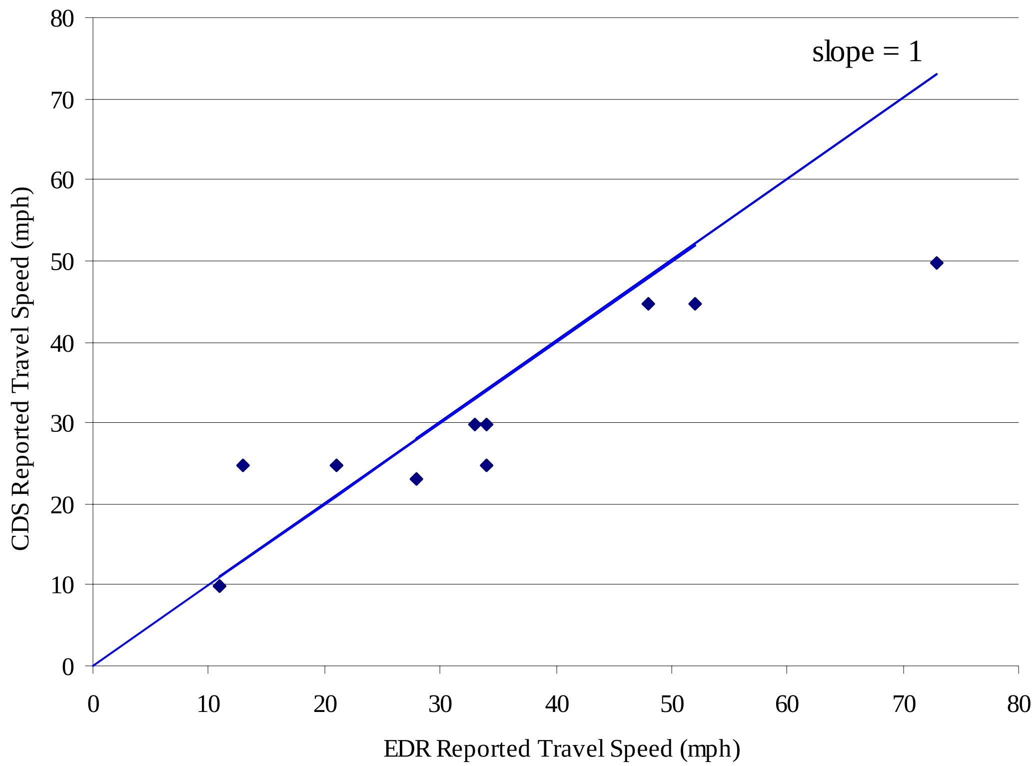


Figure E39. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 87*; 11 Files)

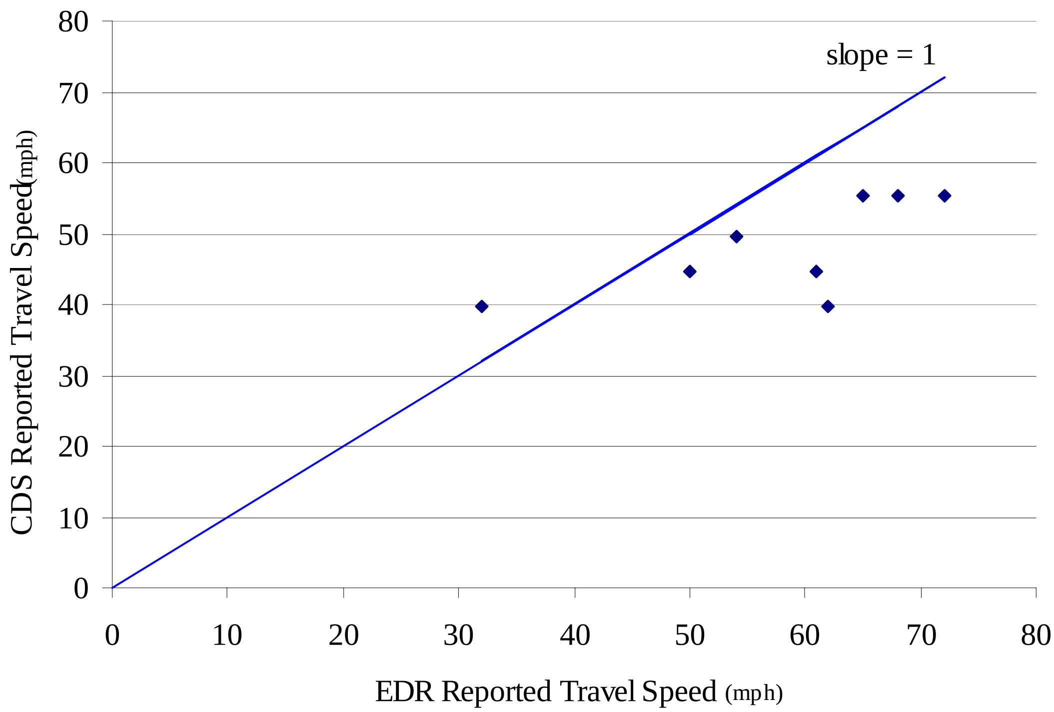


Figure E40. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 88*; 8 Files)

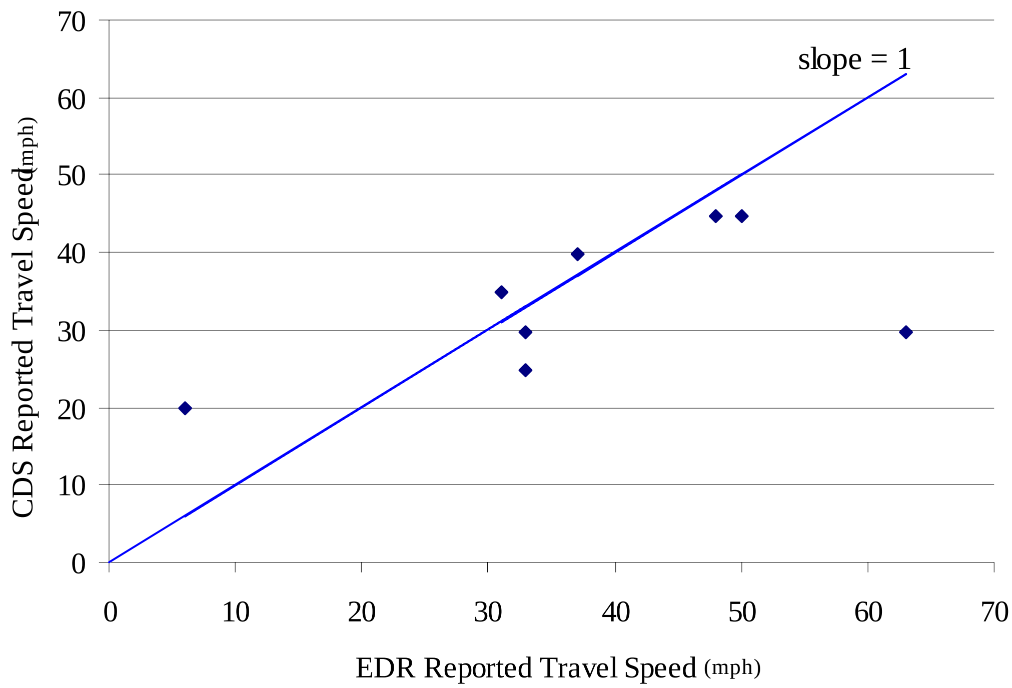


Figure E41. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 89*; 8 Files)

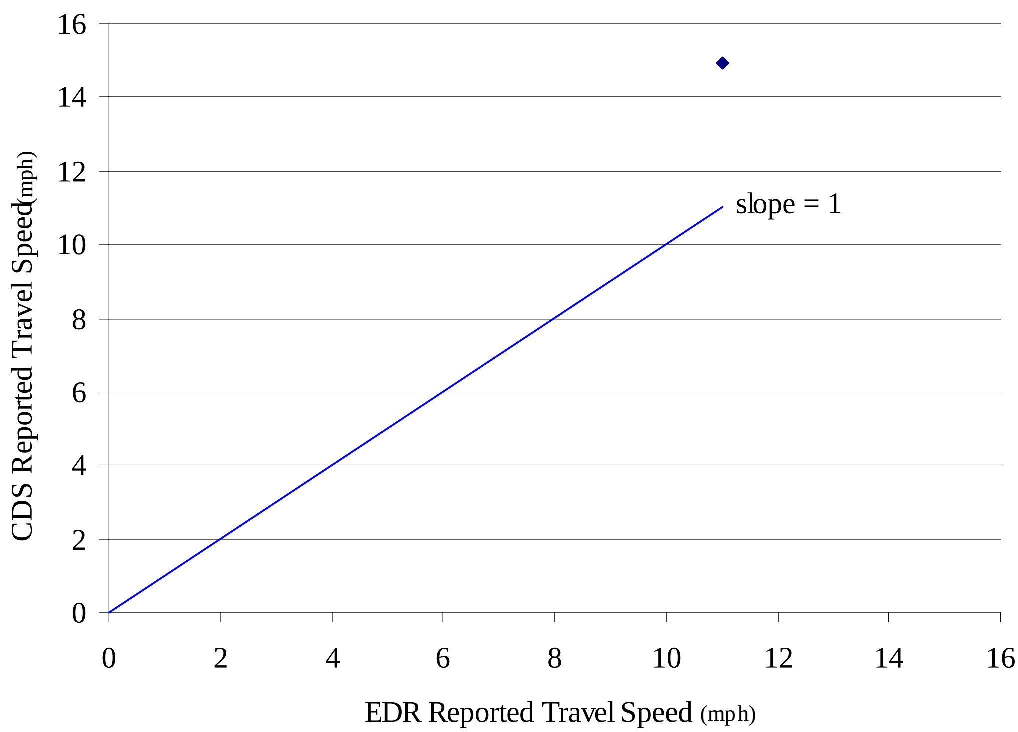


Figure E42. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 90*; 1 File)

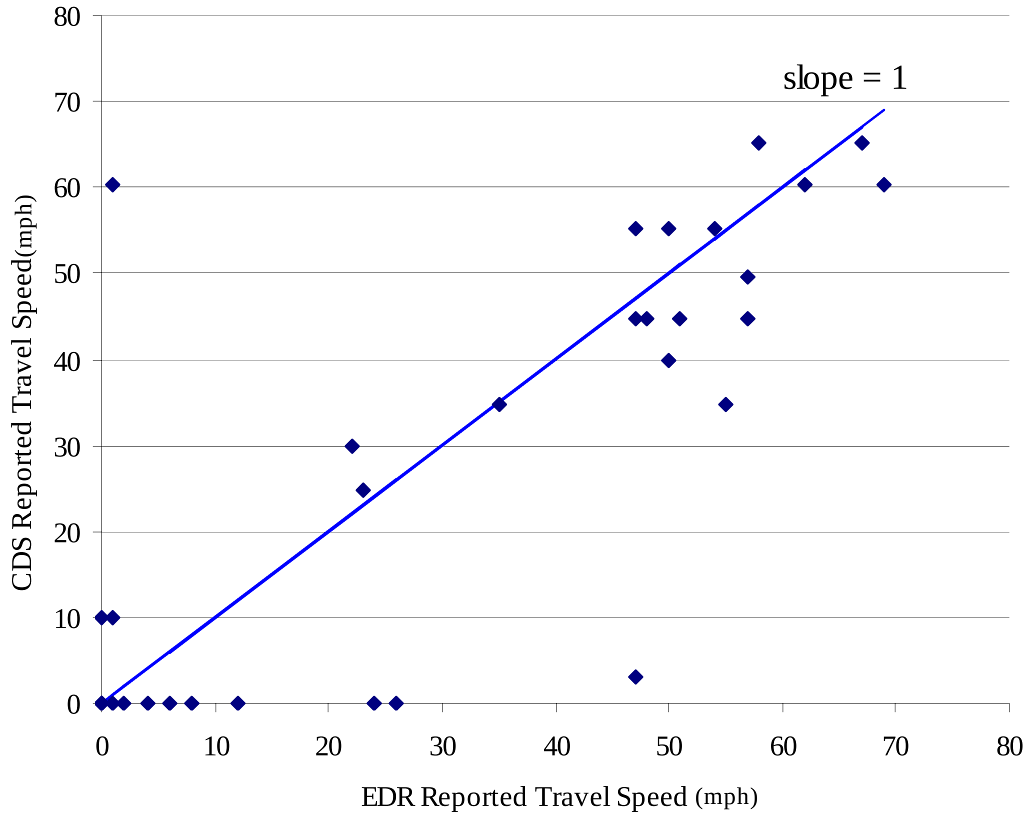


Figure E43. EDR/CDS Police-Reported Travel Speed Comparison (*ACCTYPE = 98*; 34 Files)

APPENDIX F

Table F1. *Brake Status* Information at -1 second per GM EDR Module

GM EDR Module	No. Cases	EDR BRAKE STATUS at -1 second			
		OFF	ON	INVALID	[blank]
SDMCL21999	22	1	9	-	12
SDMD2002	21	7	8	-	6
SDMDG2001	3	2	-	1	-
SDMDG2002	11	3	7	-	1
SDMDW2003	35	16	19	-	-
SDMG1999	75	11	14	-	50
SDMG2000	503	172	237	7	87
SDMG2001	527	163	265	4	95
SDMGF2002	130	53	63	-	14
SDMGT2001	125	55	56	-	14
SDMGT2002	66	25	33	-	8
Total	1,518	508	711	12	287

Table F2. CDS-Reported *Attempted Avoidance Maneuver* vs. EDR *Brake Status* Indicator at -1 second

Attempted Avoidance Maneuver (CDS)	No. Cases	EDR BRAKE STATUS at -1 sec			
		OFF	ON	INVALID	[blank]
No impact	-	-	-	-	-
No avoidance action	589	229	235	4	121
Braking (no lockup)	151	32	91	1	27
Braking (lockup)	46	6	32	1	7
Braking (lockup unknown)	25	7	14	1	3
Releasing brakes	1	-	1	-	-
Steering left	69	28	30	-	11
Steering right	73	27	32	1	13
Braking & steering left	58	19	30	-	9
Braking & steering right	72	13	42	1	16
Accelerating	18	8	7	-	3
Accelerating & steering left	1	-	-	-	1
Accelerating & steering right	2	1	1	-	-
Other action	13	3	5	-	5
Unknown	399	133	193	3	70
No driver present	1	-	-	-	1
Total	1,518	506	713	12	287

APPENDIX G

This appendix displays the distribution of cases where longitudinal delta V was reported for both CDS (*PDOF1*=0, 1, 350) and EDR (if attained before the EDR's maximum recording capability) for each *Accident Type* category.

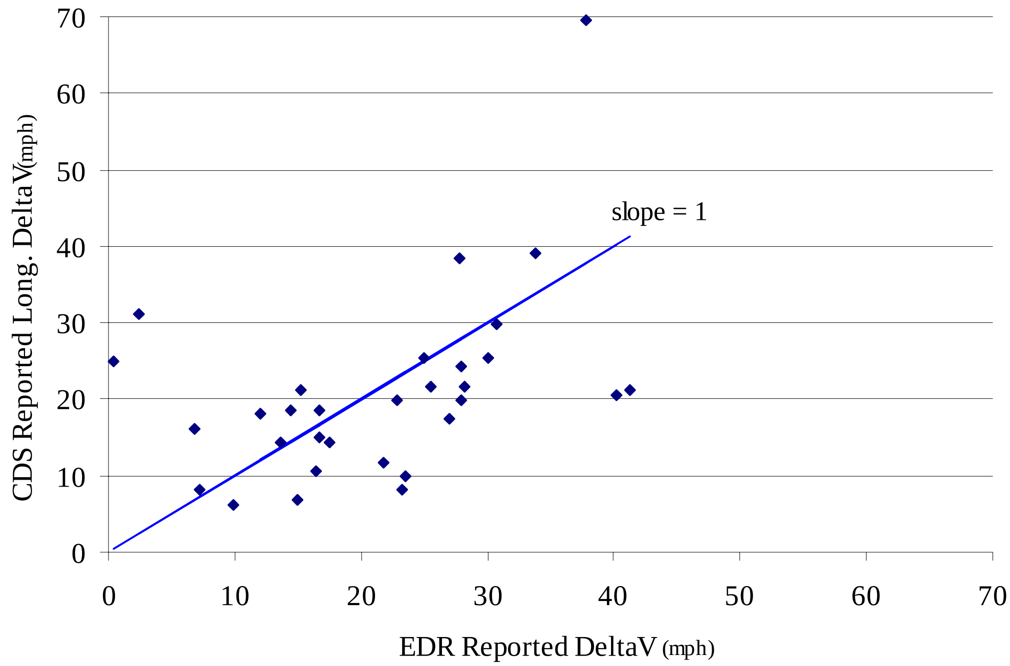


Figure G1. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE* = *1*; 31 Files)

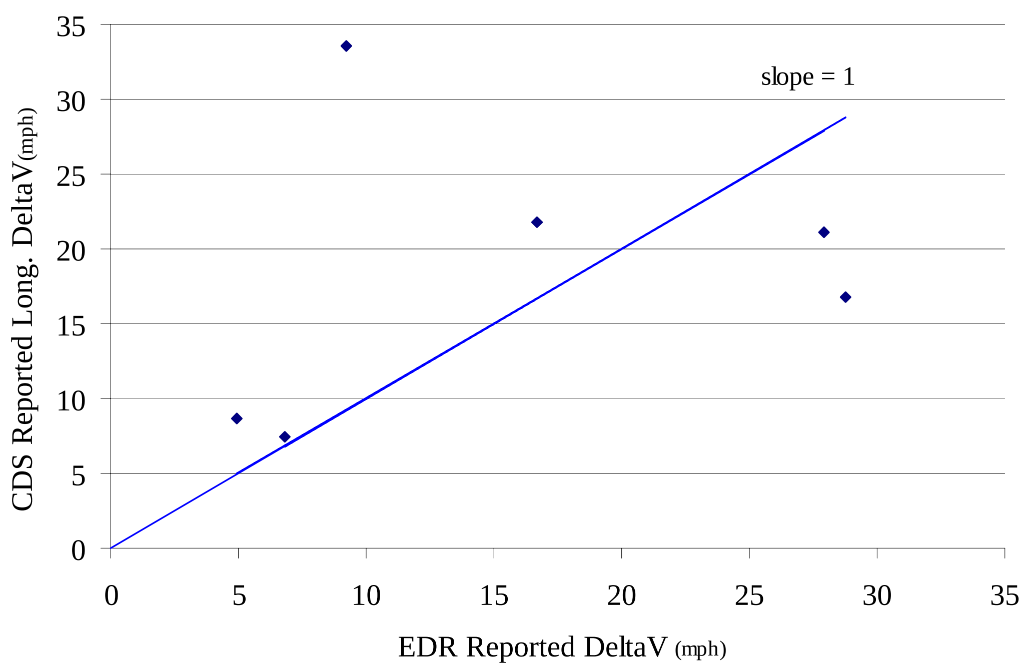


Figure G2. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE* = *2*; 6 Files)

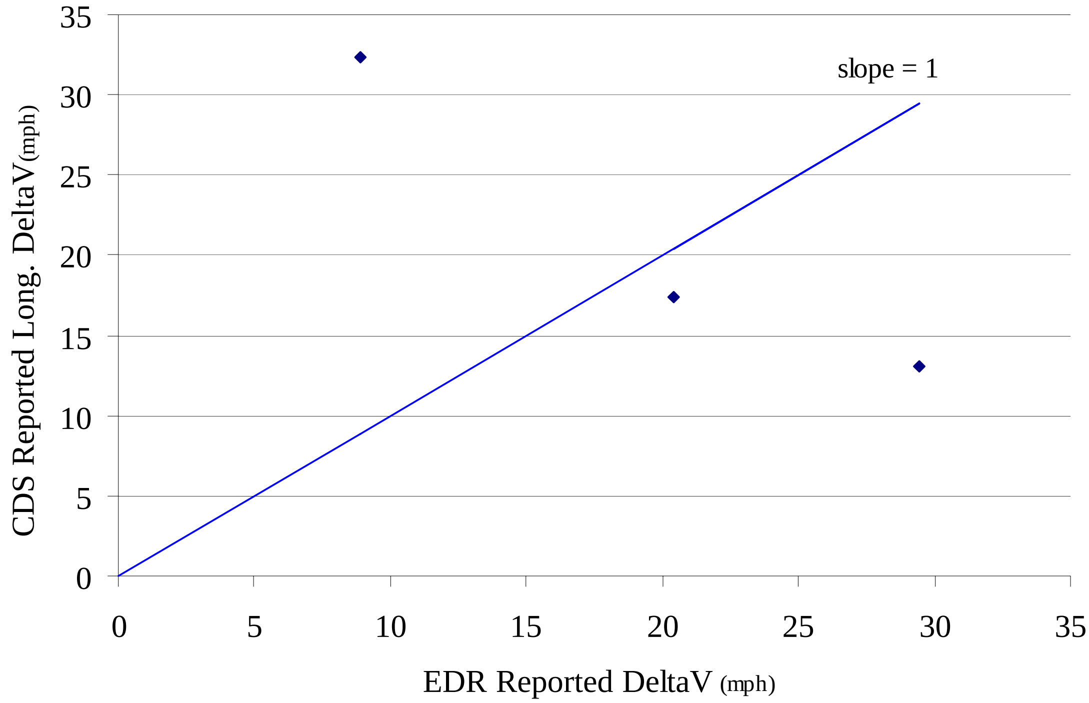


Figure G3. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE* = *3*; 3 Files)

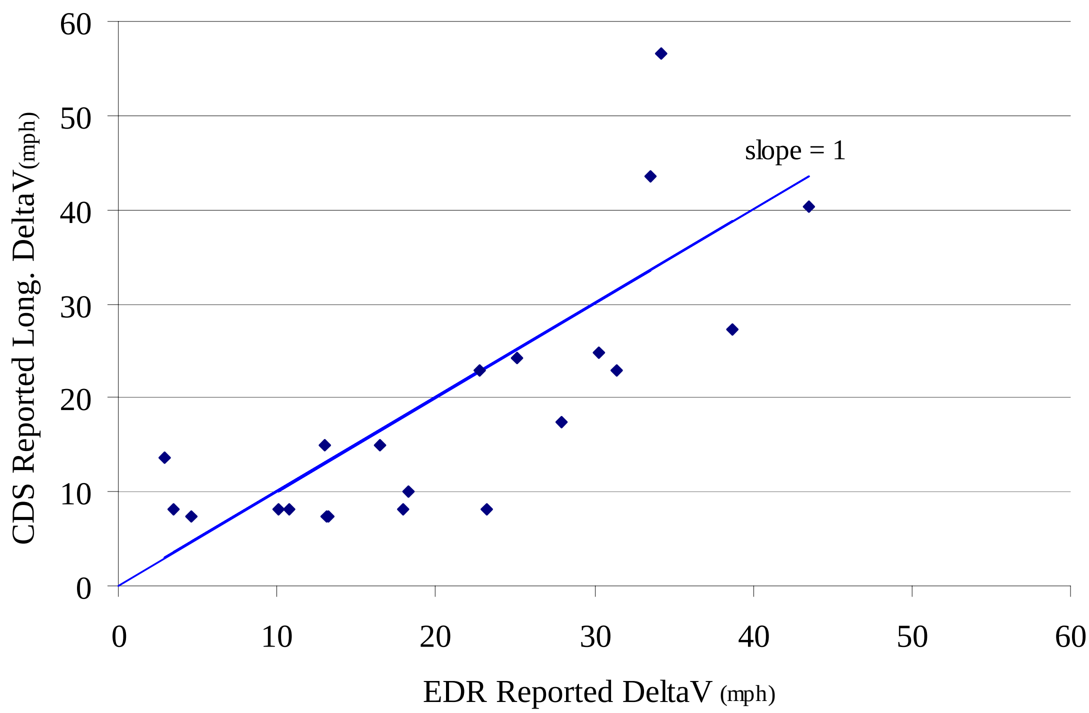


Figure G4. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE* = *6*; 21 Files)

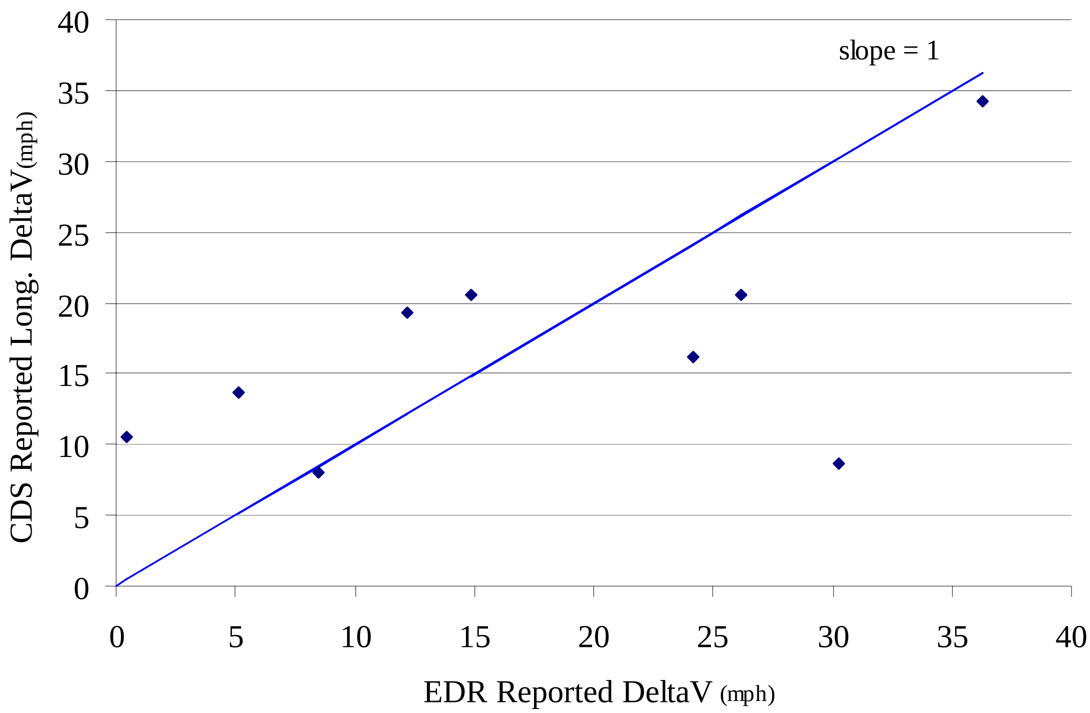


Figure G5. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 7*; 9 Files)

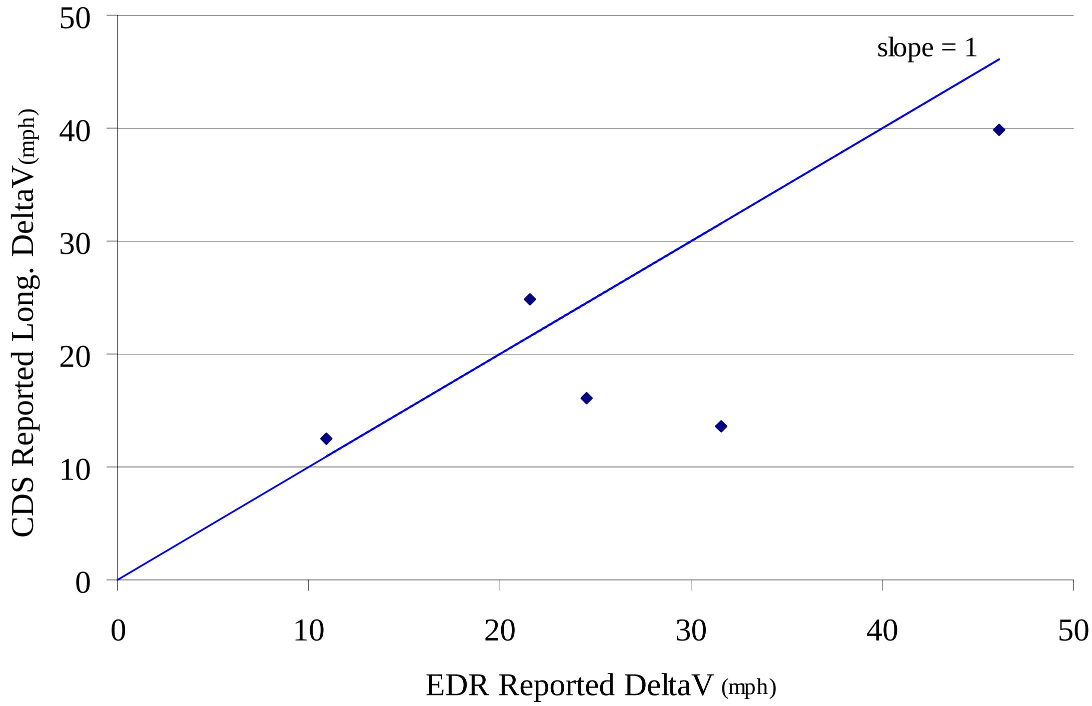


Figure G6. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 8*; 5 Files)

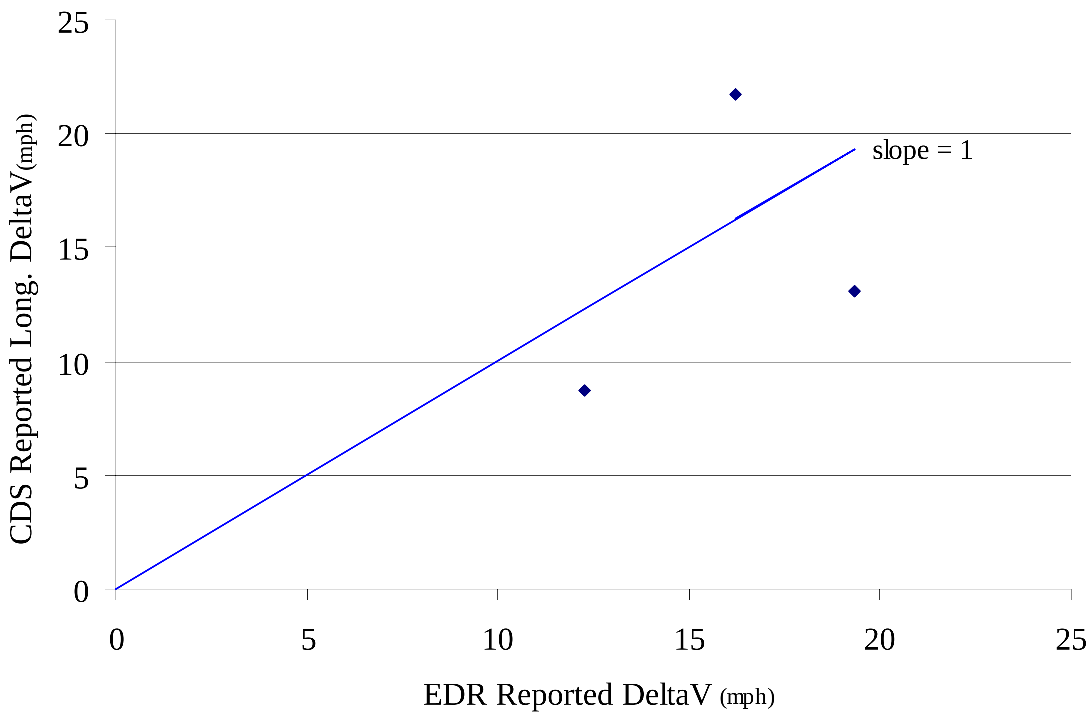


Figure G7. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 11*; 3 Files)

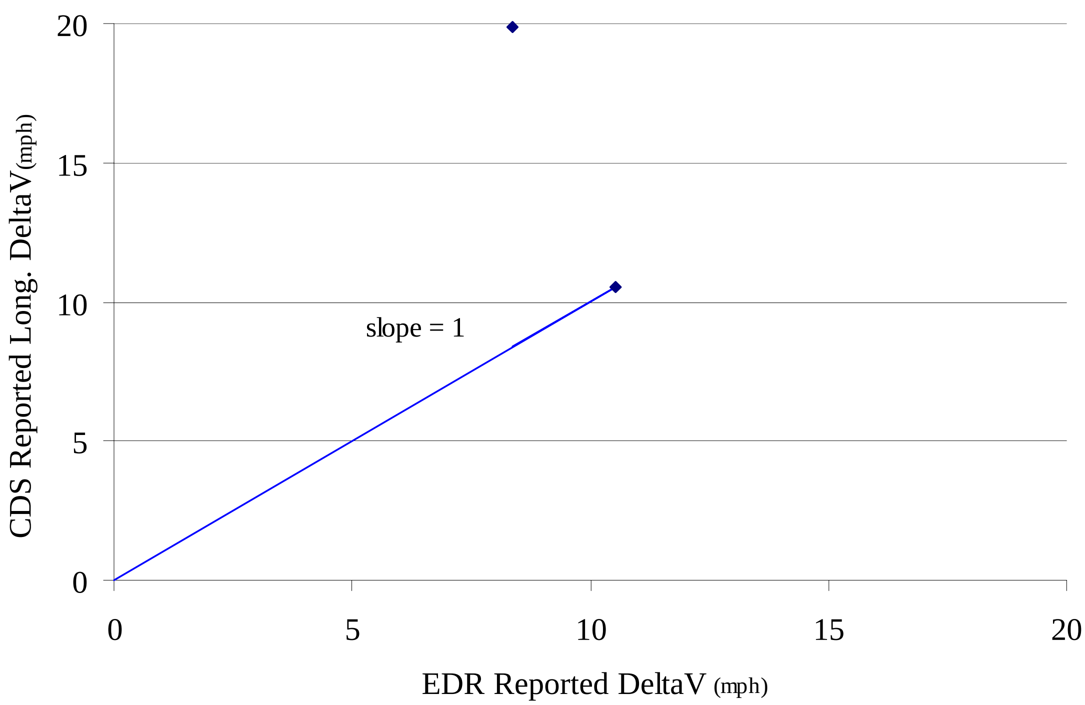


Figure G8. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 12*; 2 Files)

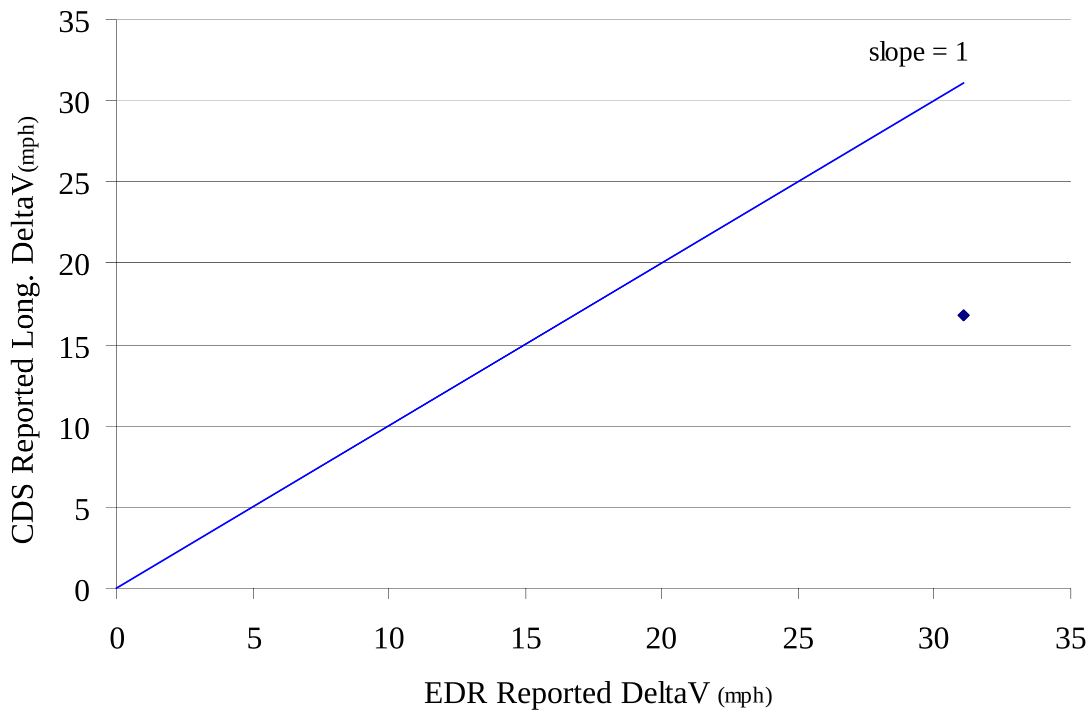


Figure G9. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 14*; 1 File)

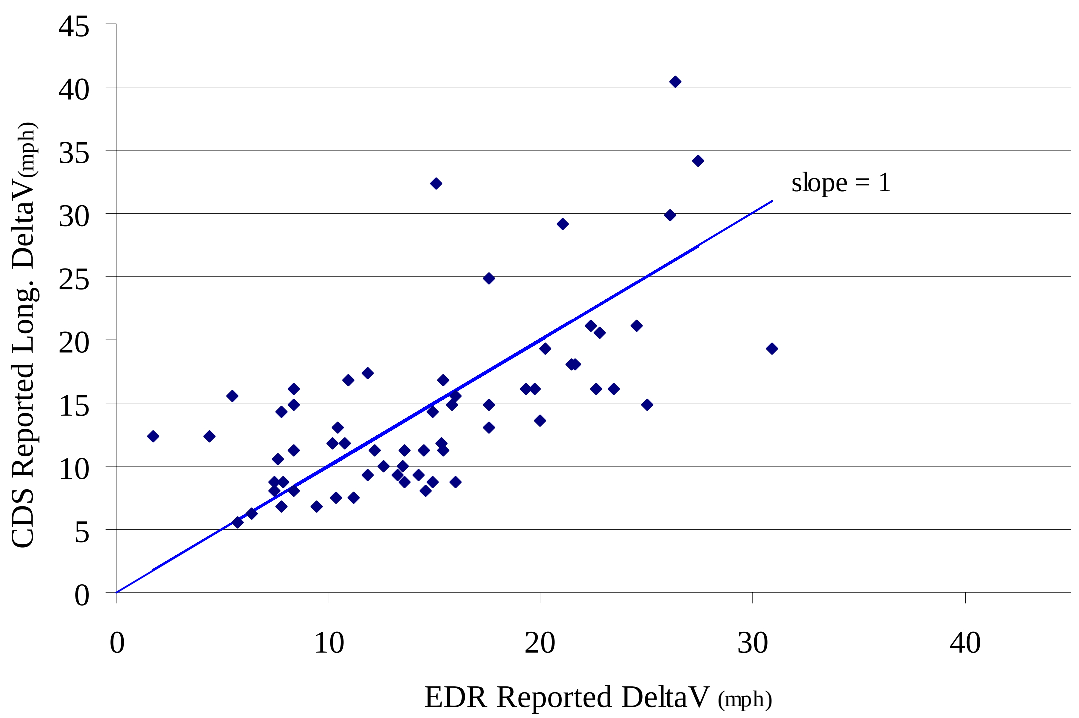


Figure G10. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 20*; 62 Files)

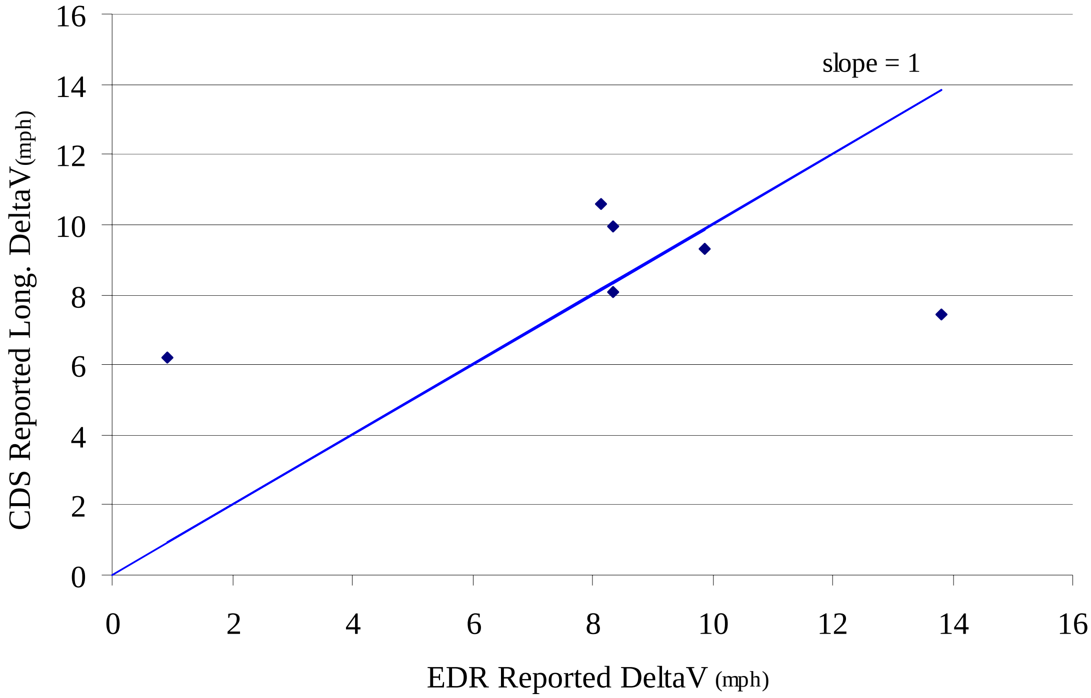


Figure G11. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 21*; 6 Files)

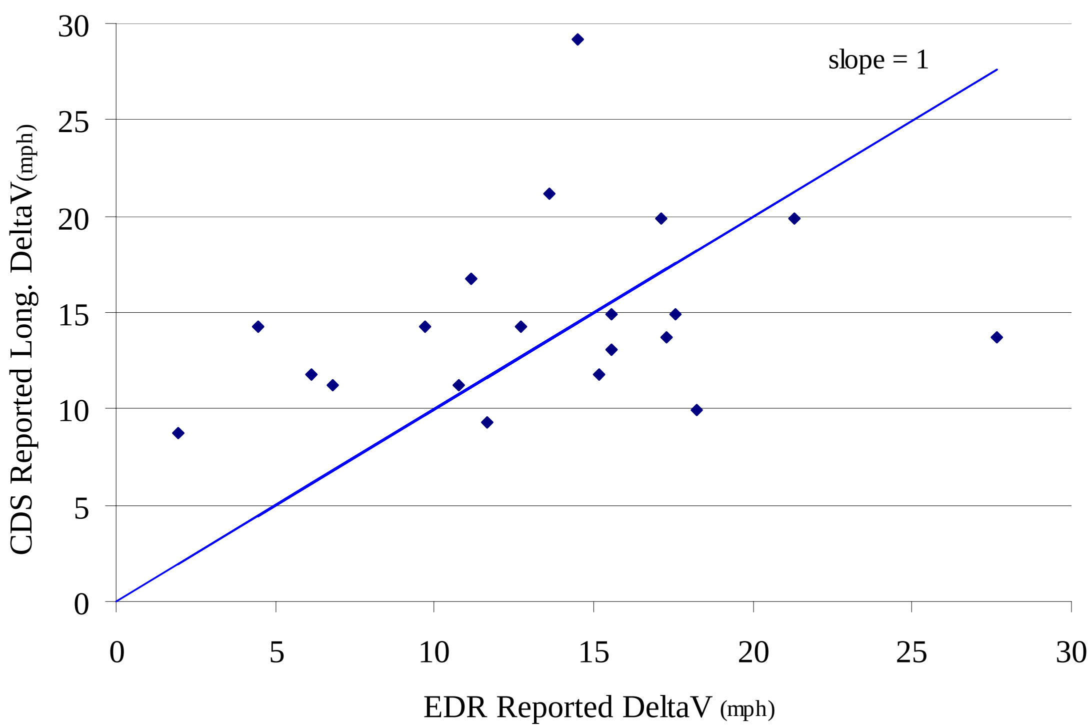


Figure G12. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 24*; 20 Files)

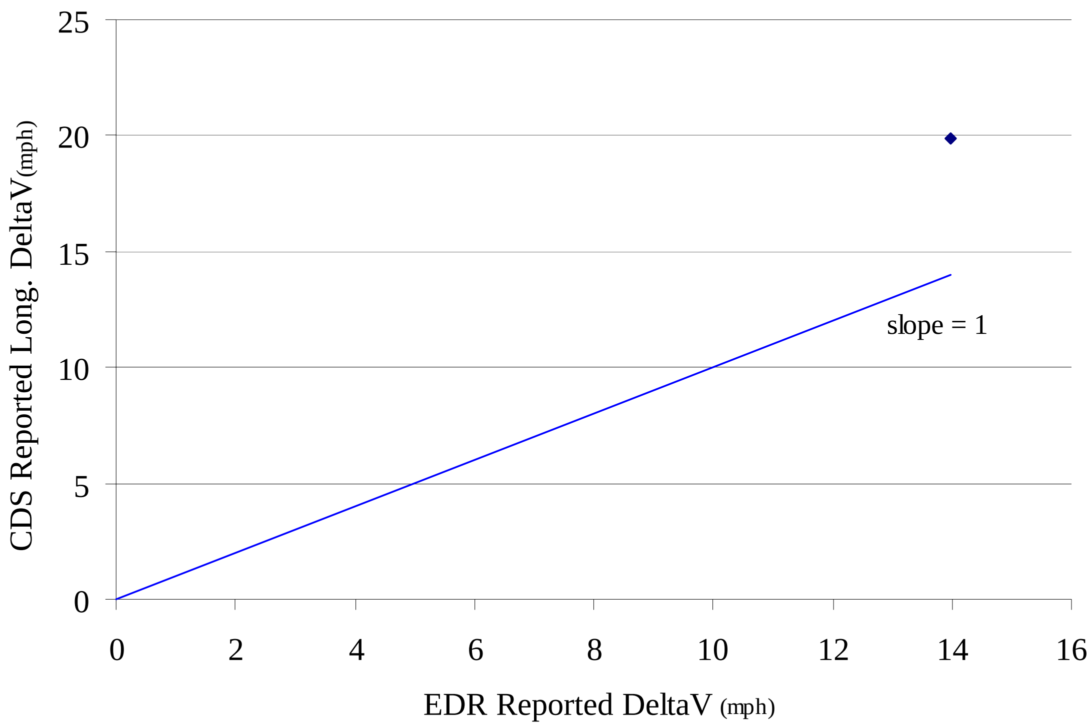


Figure G13. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 25*; 1 File)

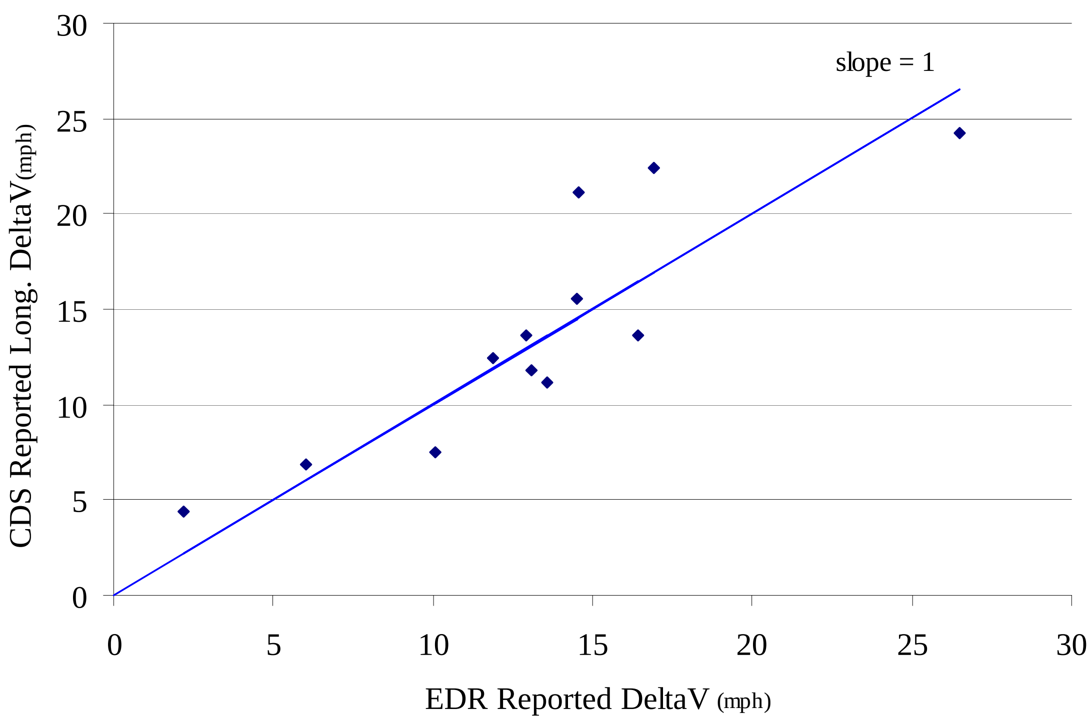


Figure G14. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 28*; 12 Files)

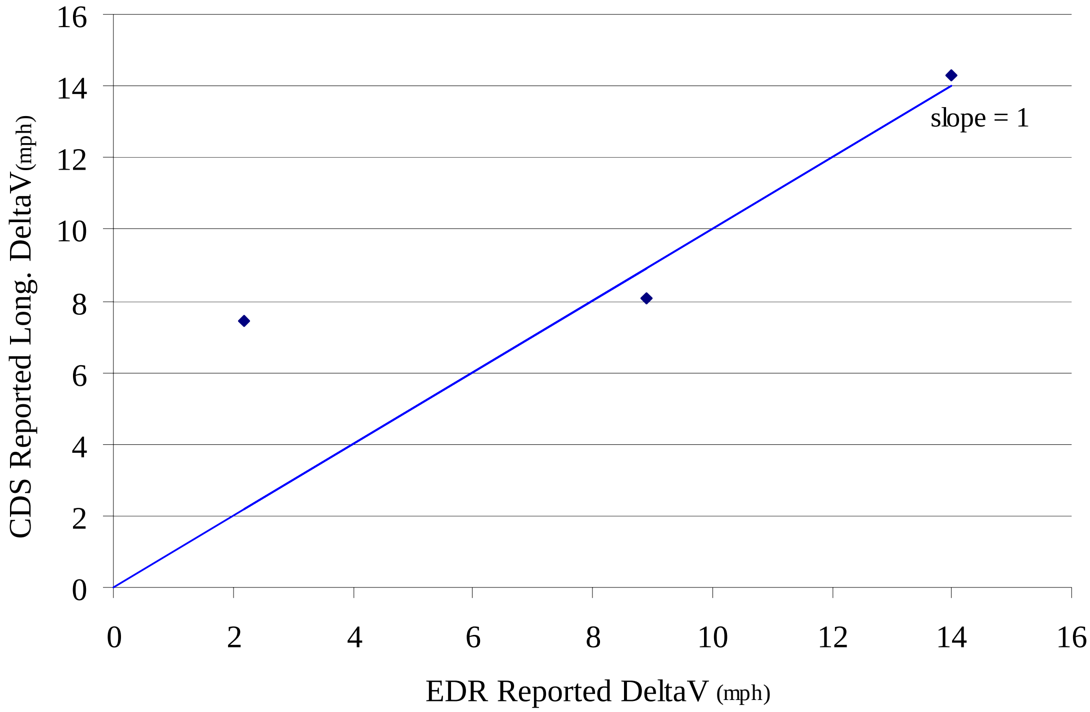


Figure G15. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 32*; 3 Files)

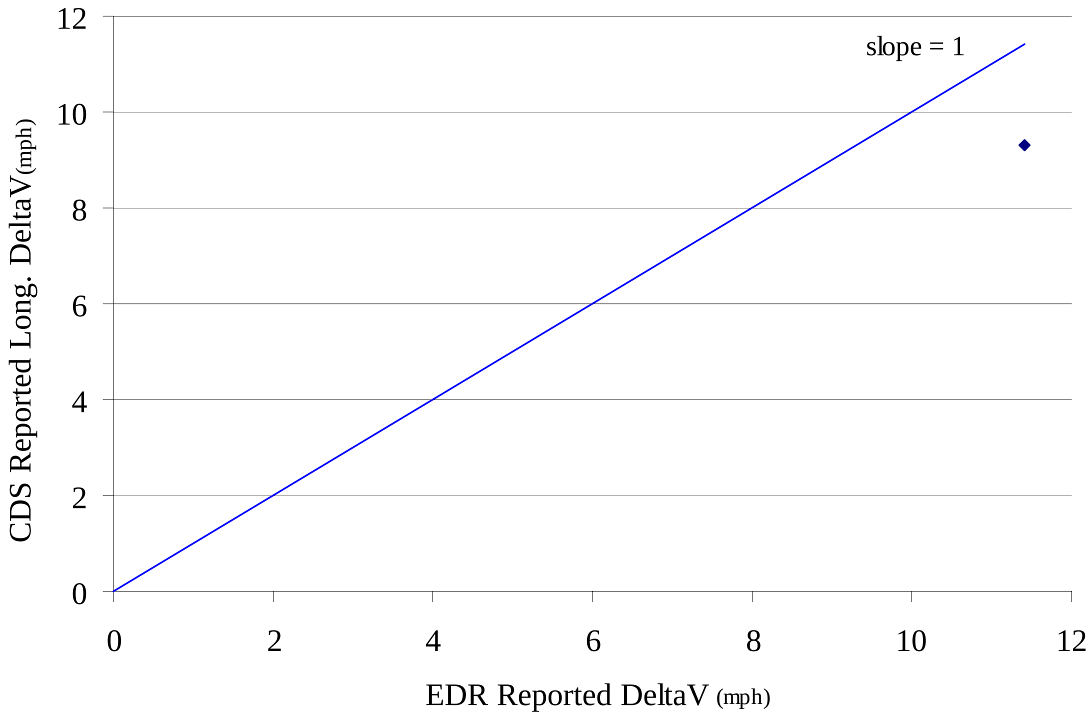


Figure G16. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 45*; 1 File)

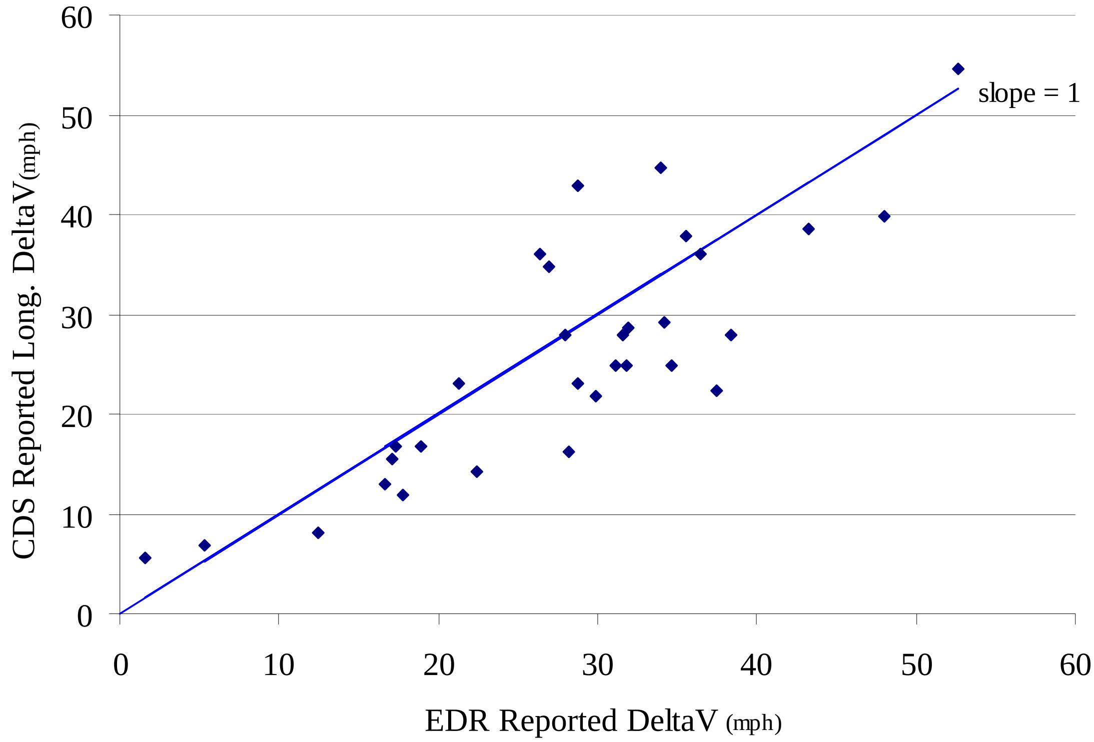


Figure G17. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 50*; 31 Files)

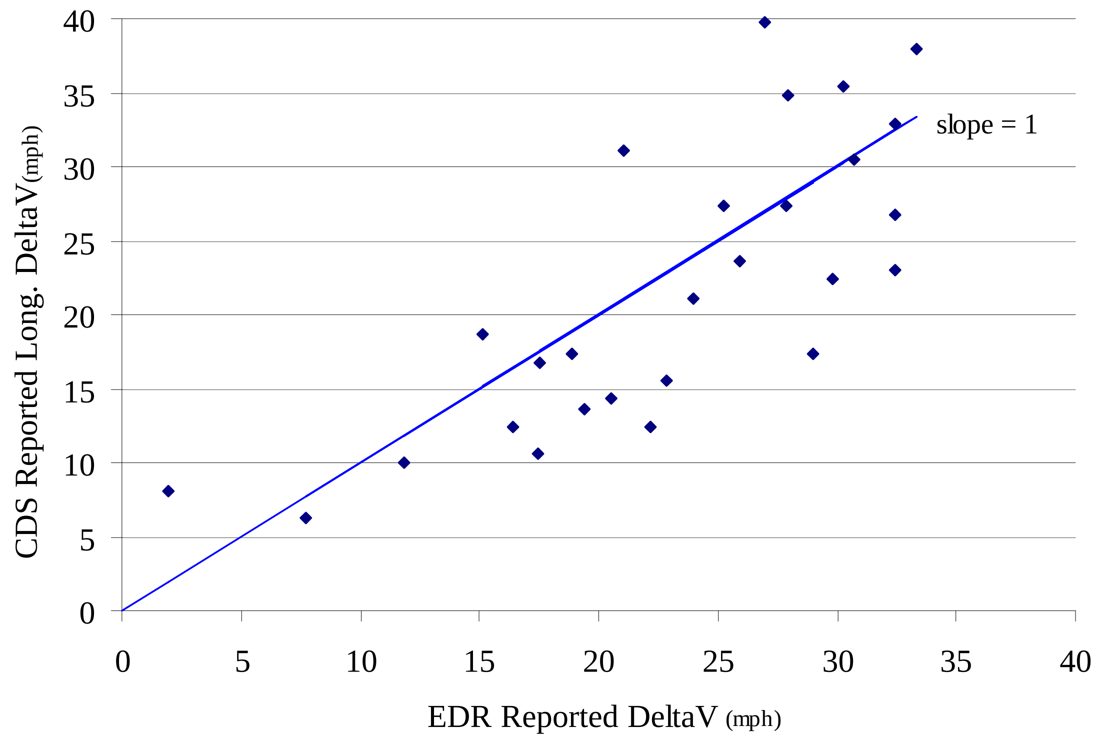


Figure G18. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 51*; 27 Files)

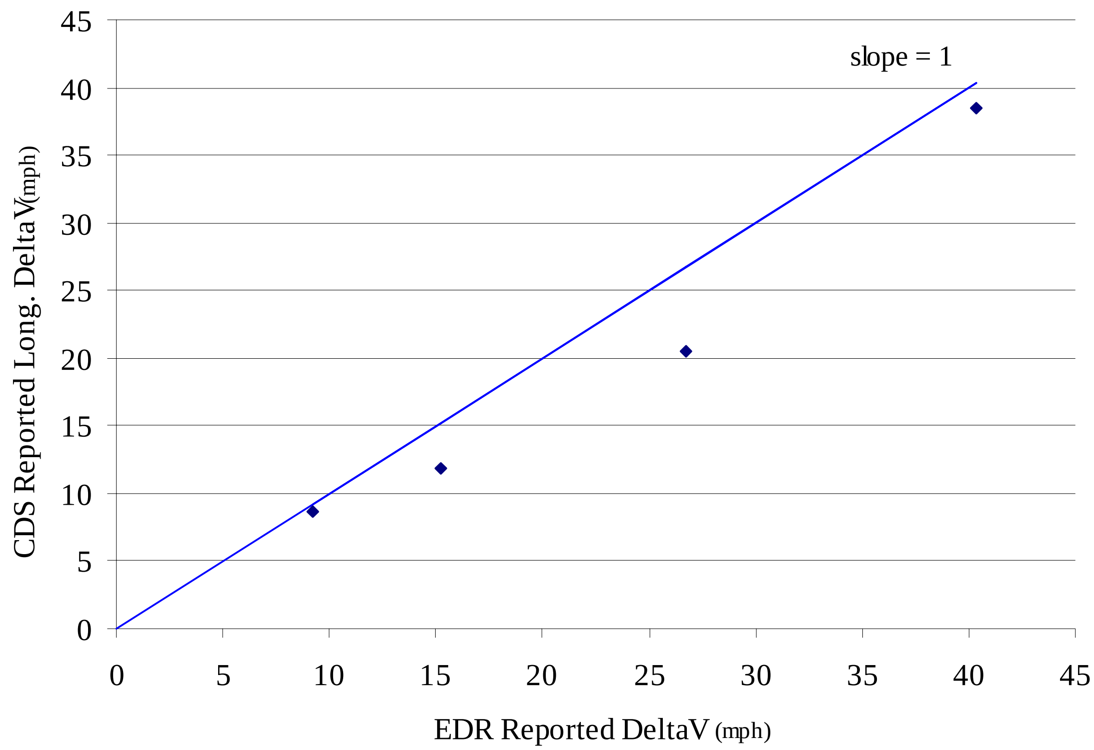


Figure G19. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 52*; 4 Files)

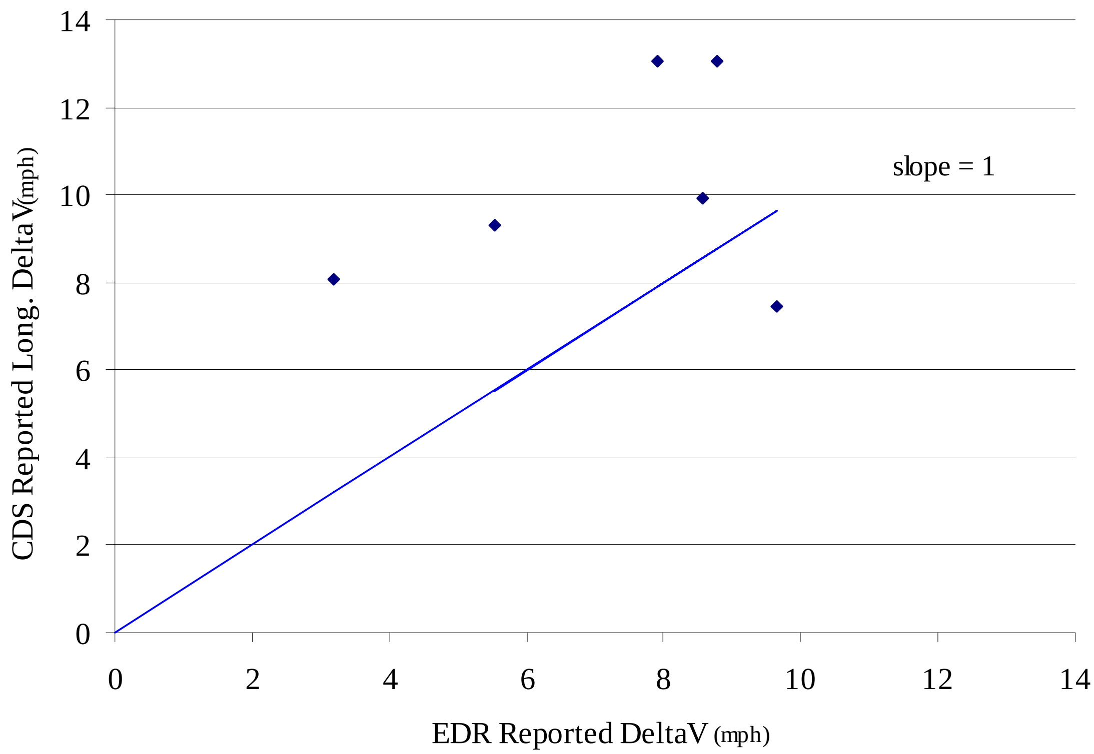


Figure G20. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 64*; 6 Files)

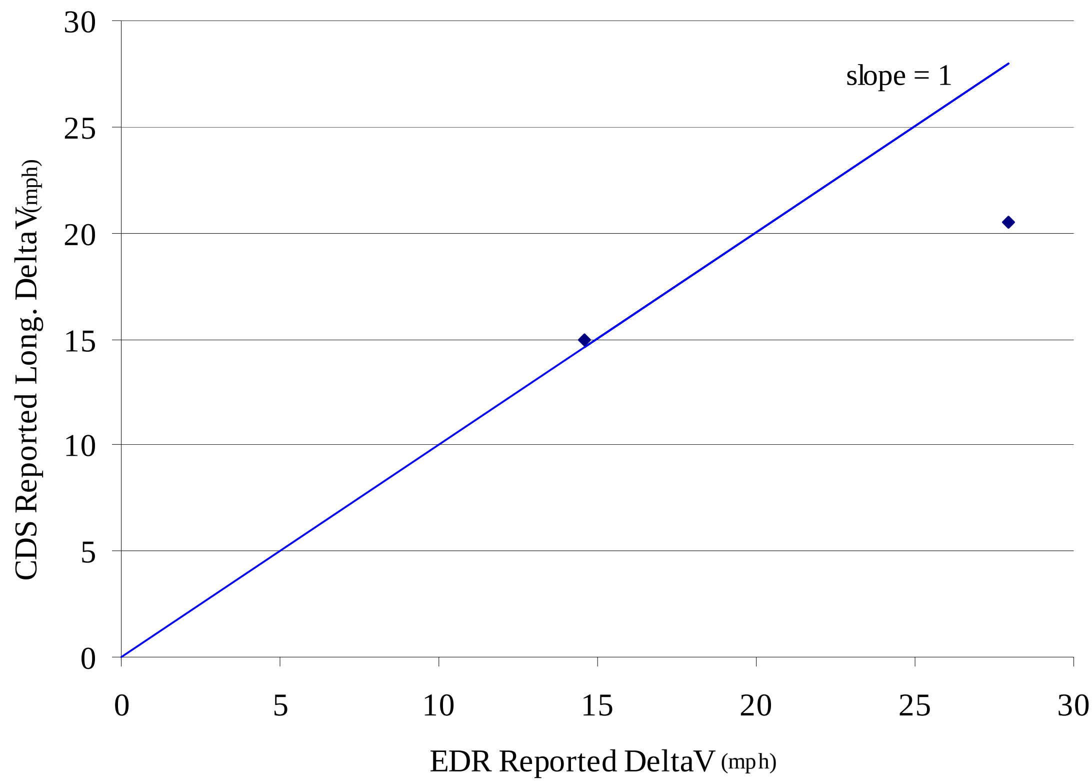


Figure G21. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE* = *65*; 2 Files)

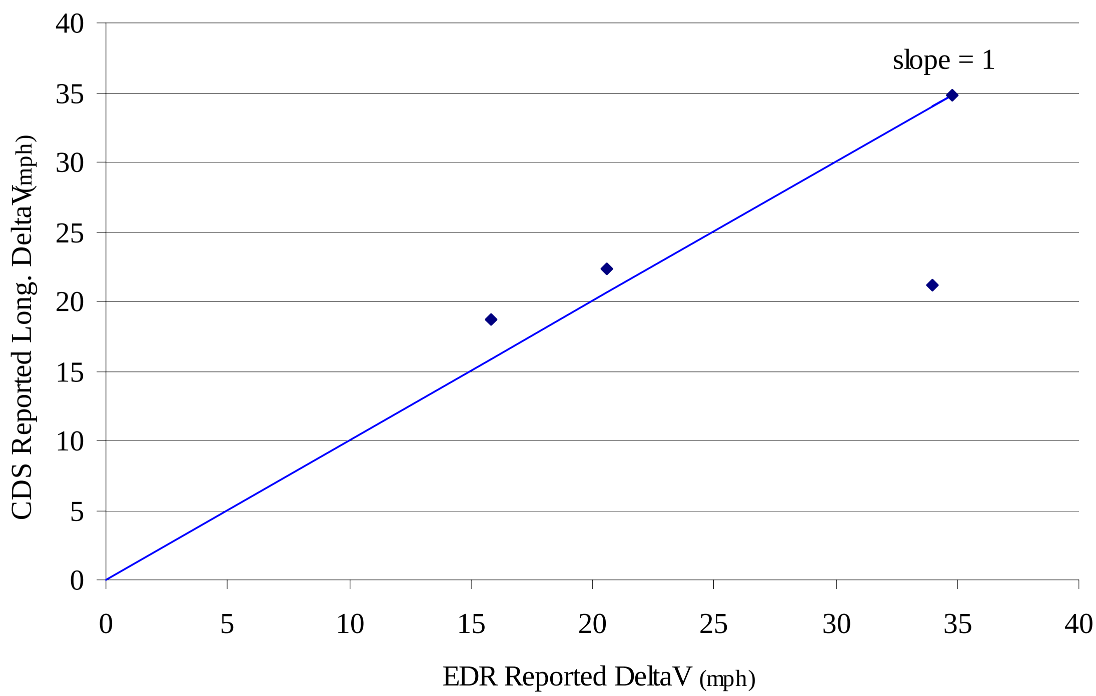


Figure G22. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE* = *66*; 4 Files)

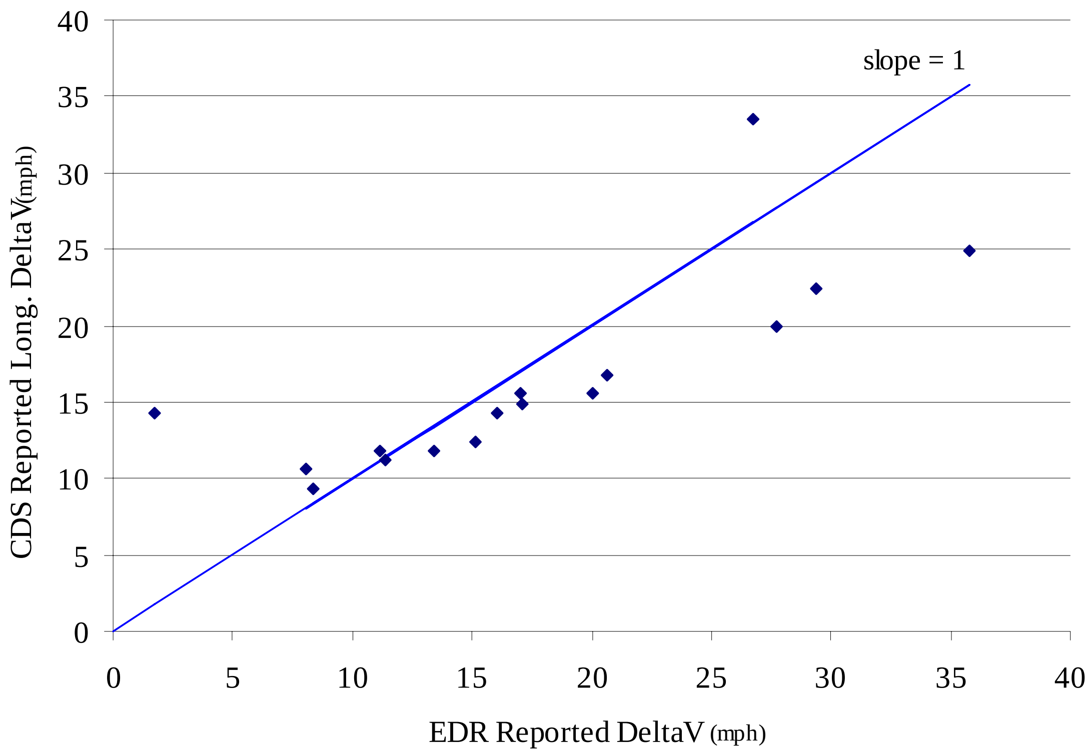


Figure G23. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 68*; 16 Files)

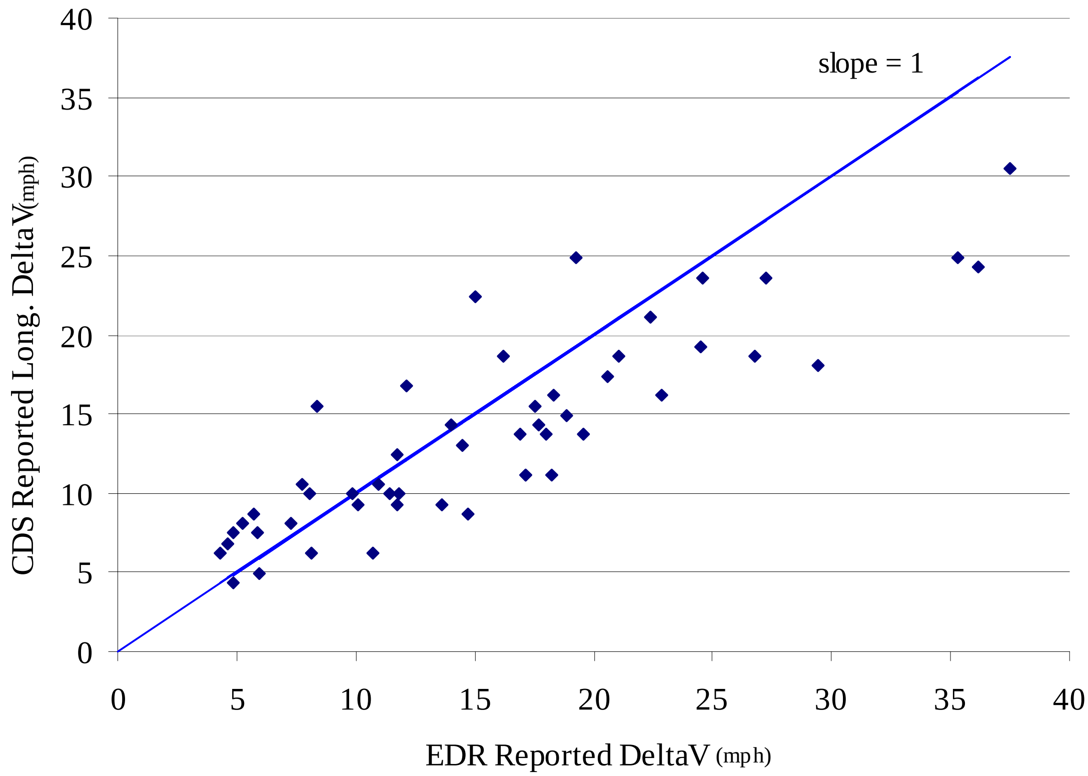


Figure G24. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 69*; 51 Files)

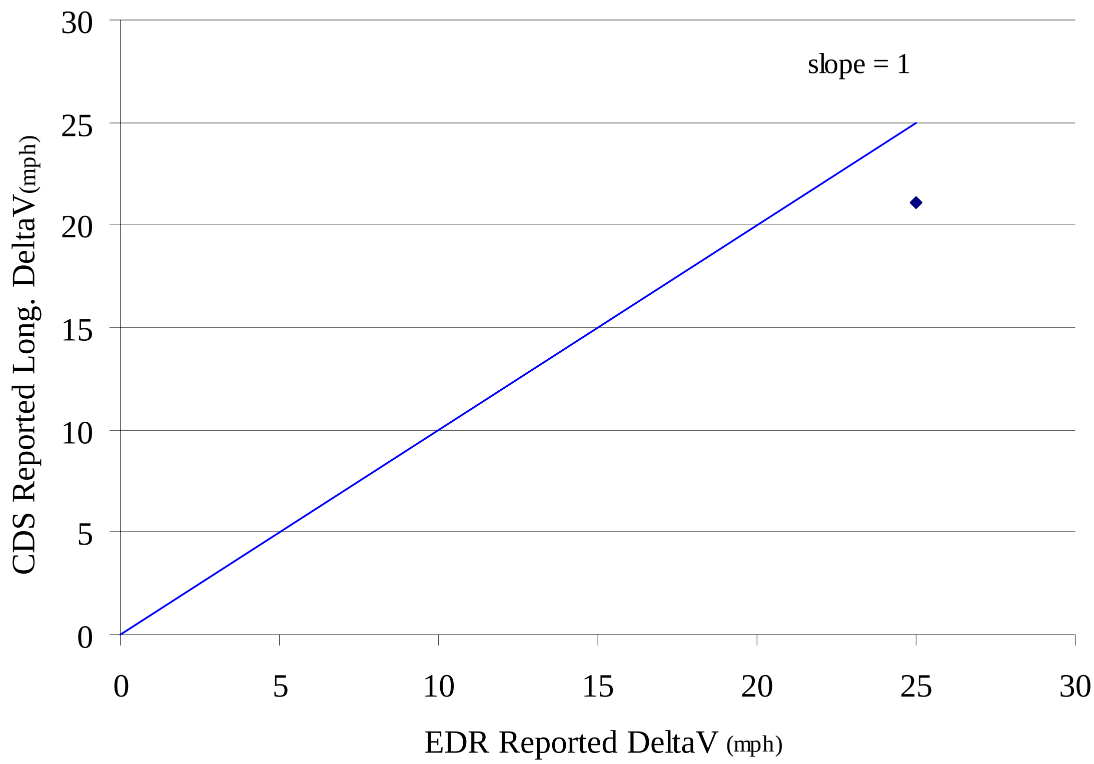


Figure G25. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 73*; 1 File)

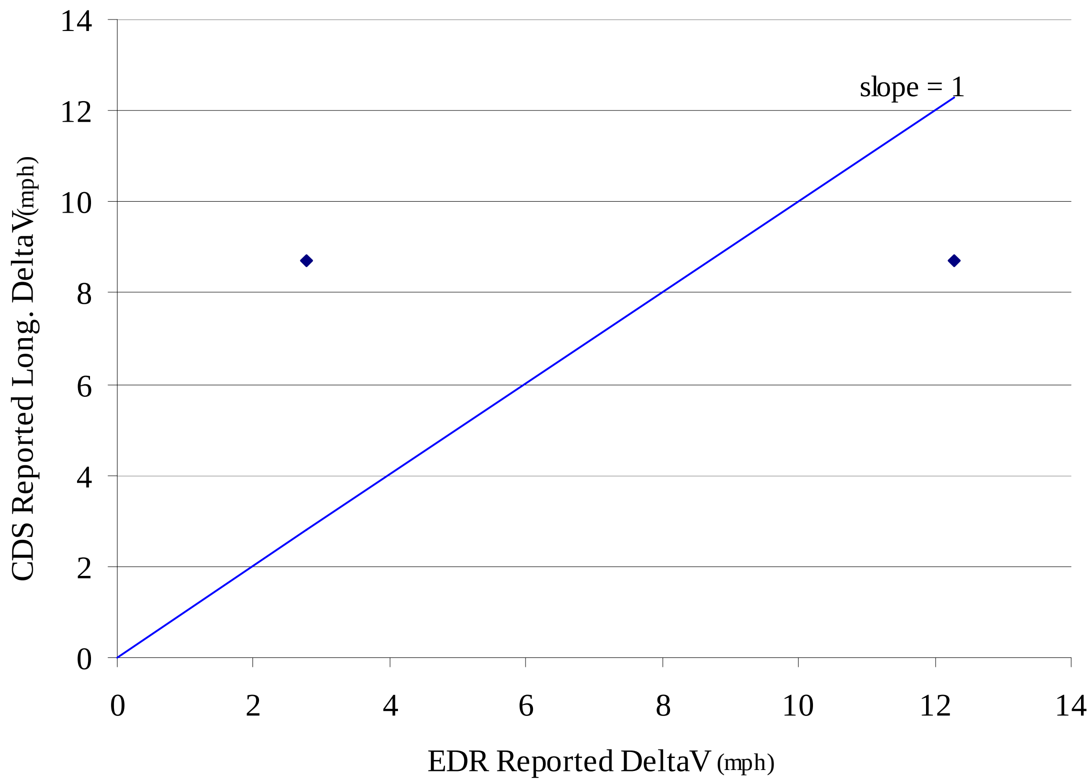


Figure G26. EDR/CDS-Reported Longitudinal Delta V Comparison (*ACCTYPE = 77*; 2 Files)

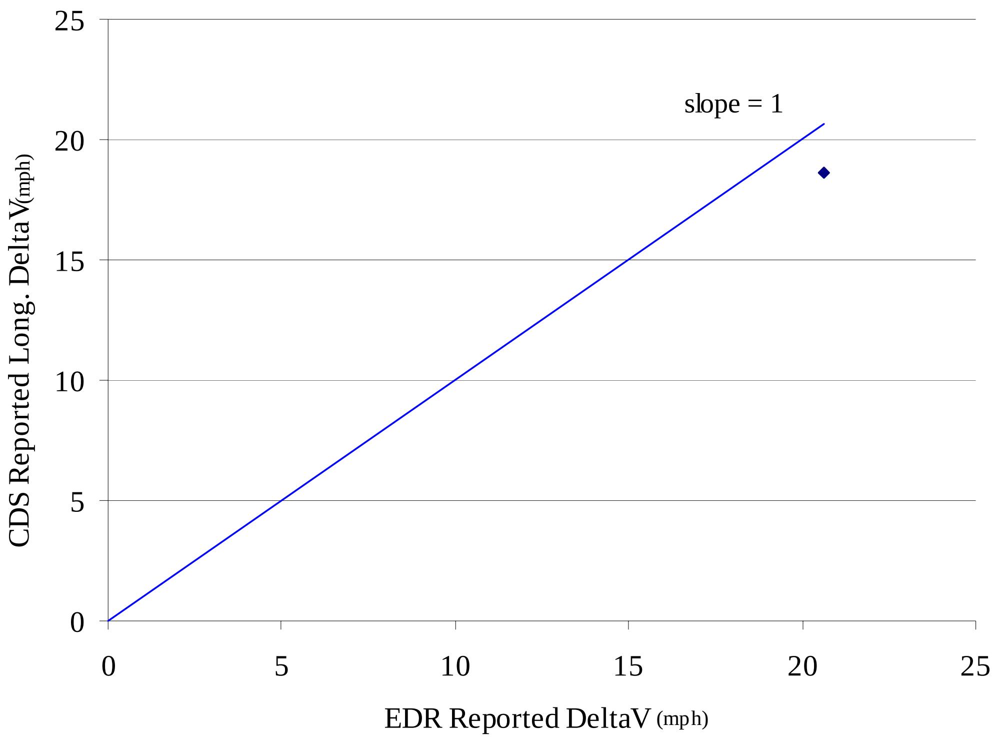


Figure G27. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE* = *79*; 1 File)

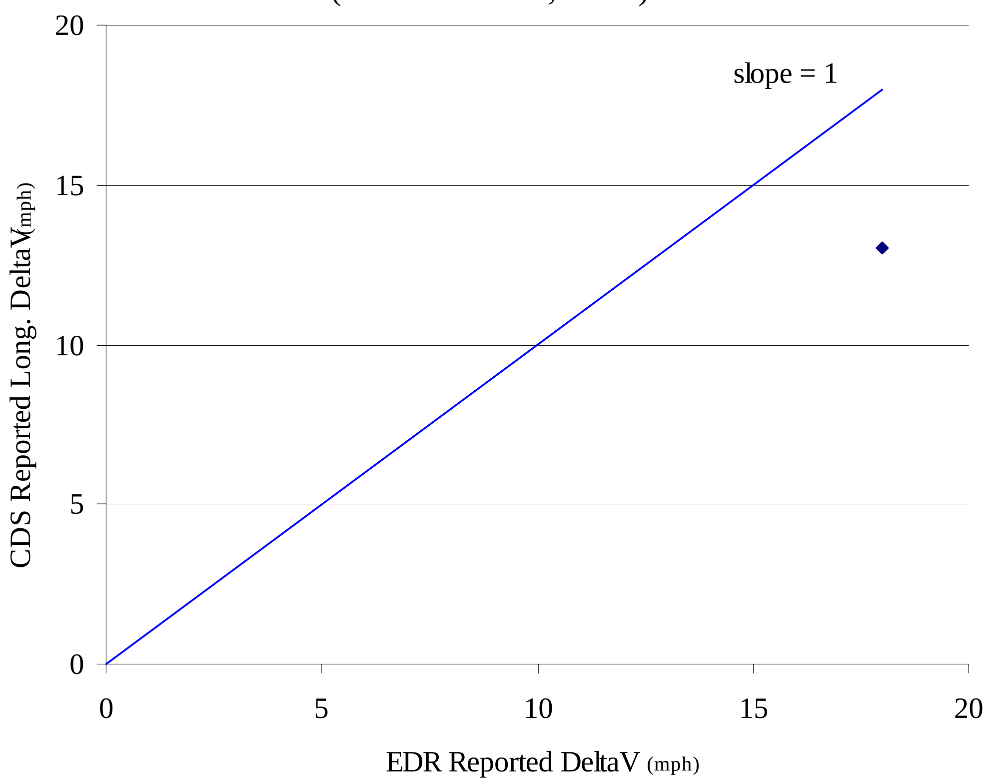


Figure G28. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE* = *80*; 1 File)

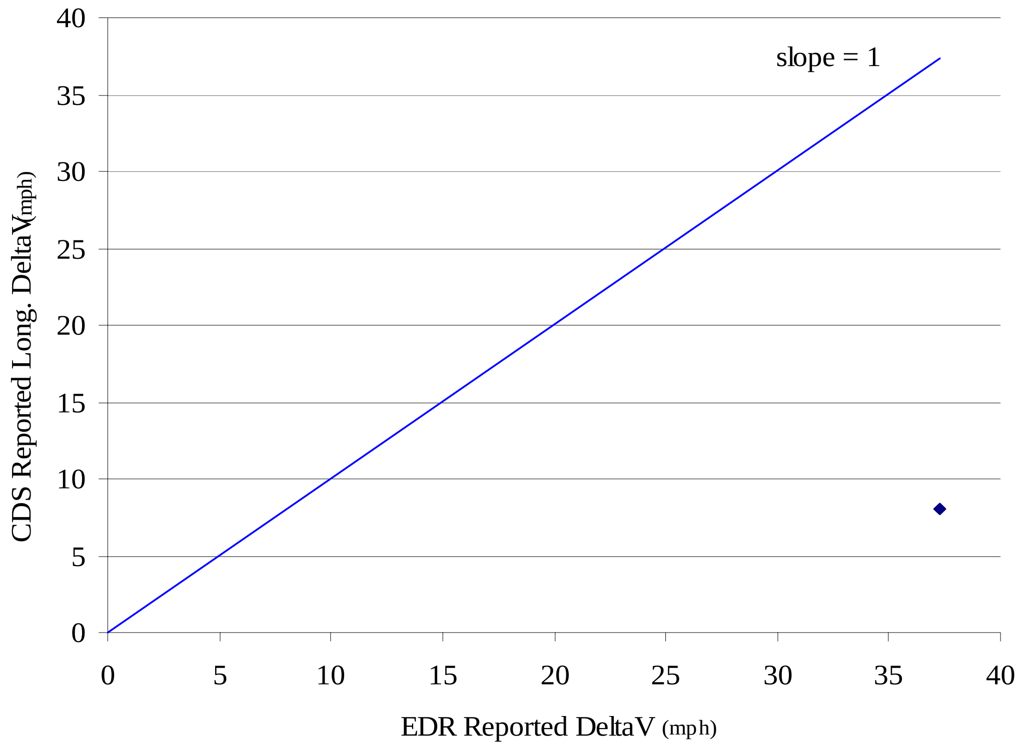


Figure G29. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 81*; 1 File)

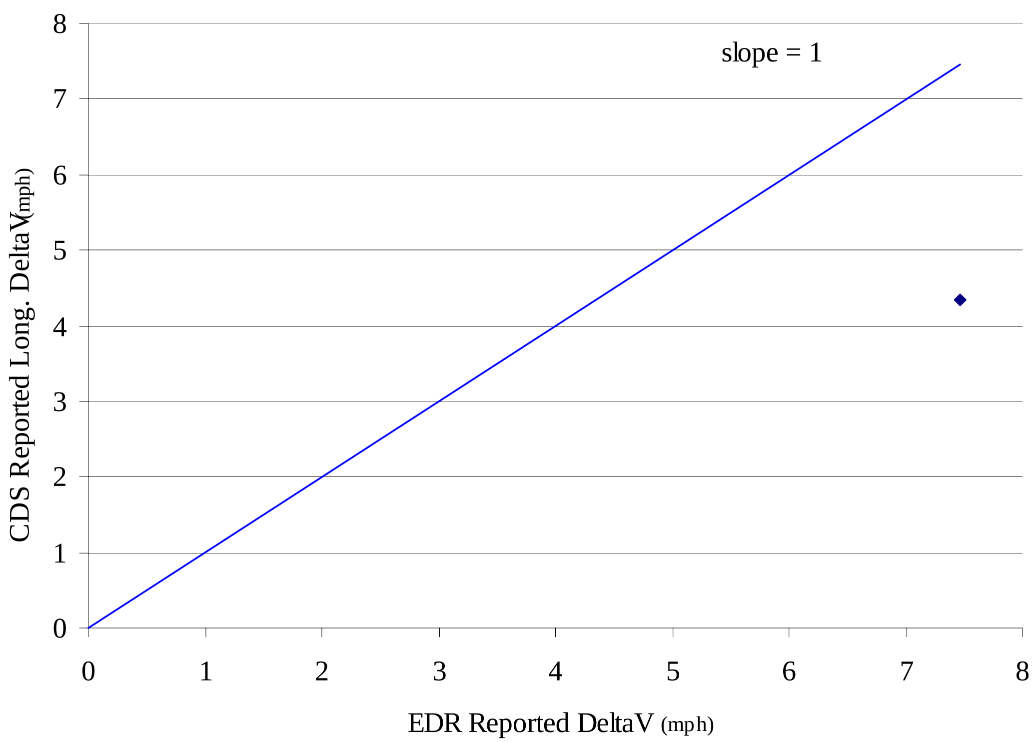


Figure G30. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 82*; 1 File)

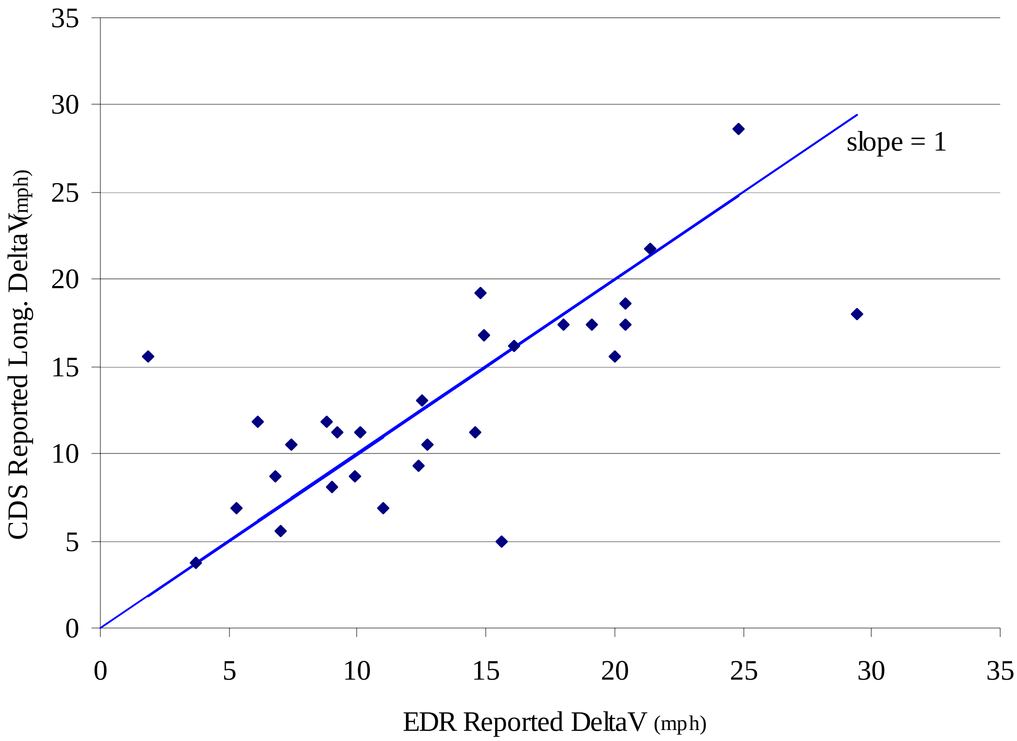


Figure G31. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 83*; 29 Files)

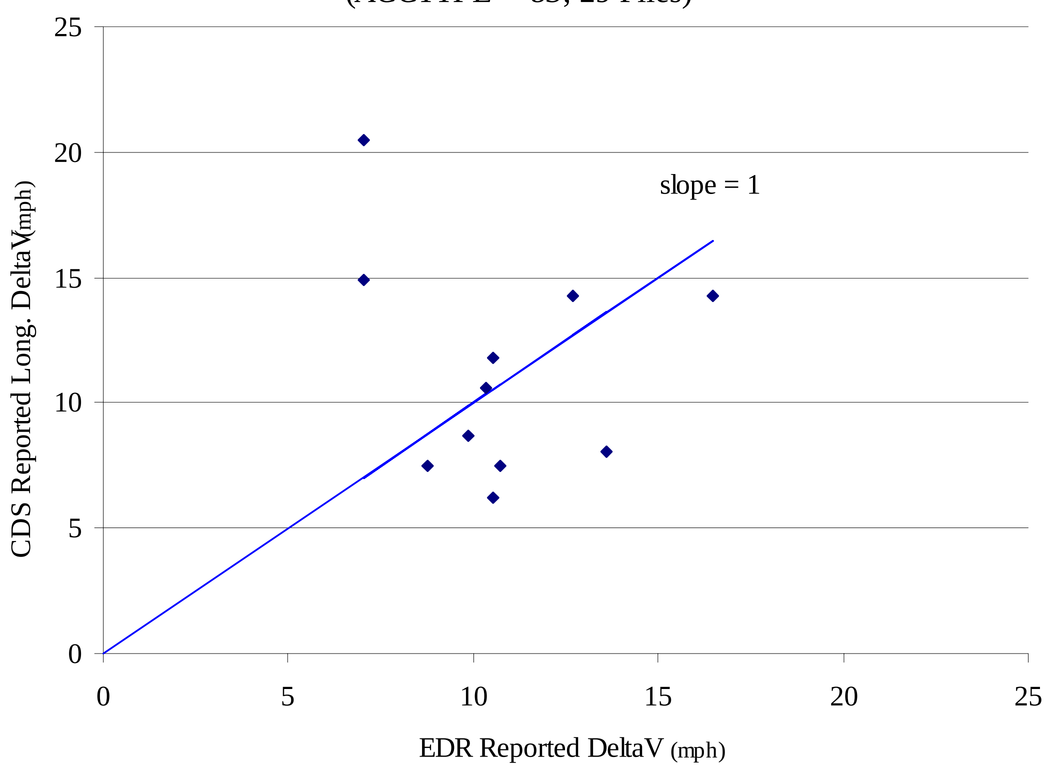


Figure G32. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 86*; 11 Files)

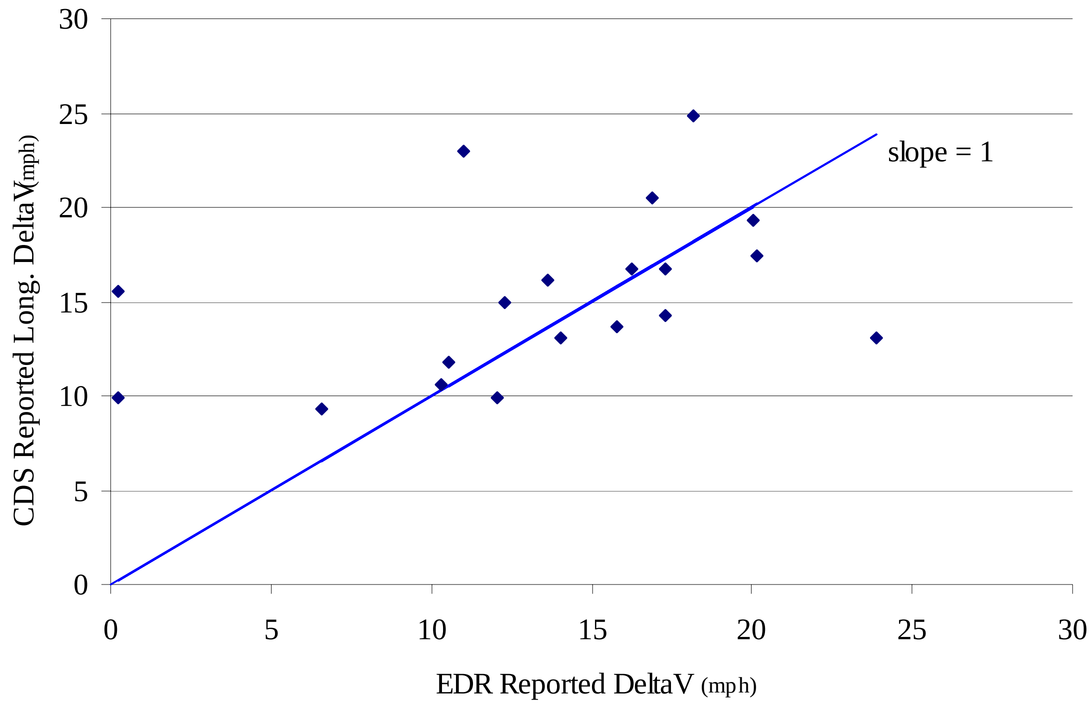


Figure G33. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 88*; 19 Files)

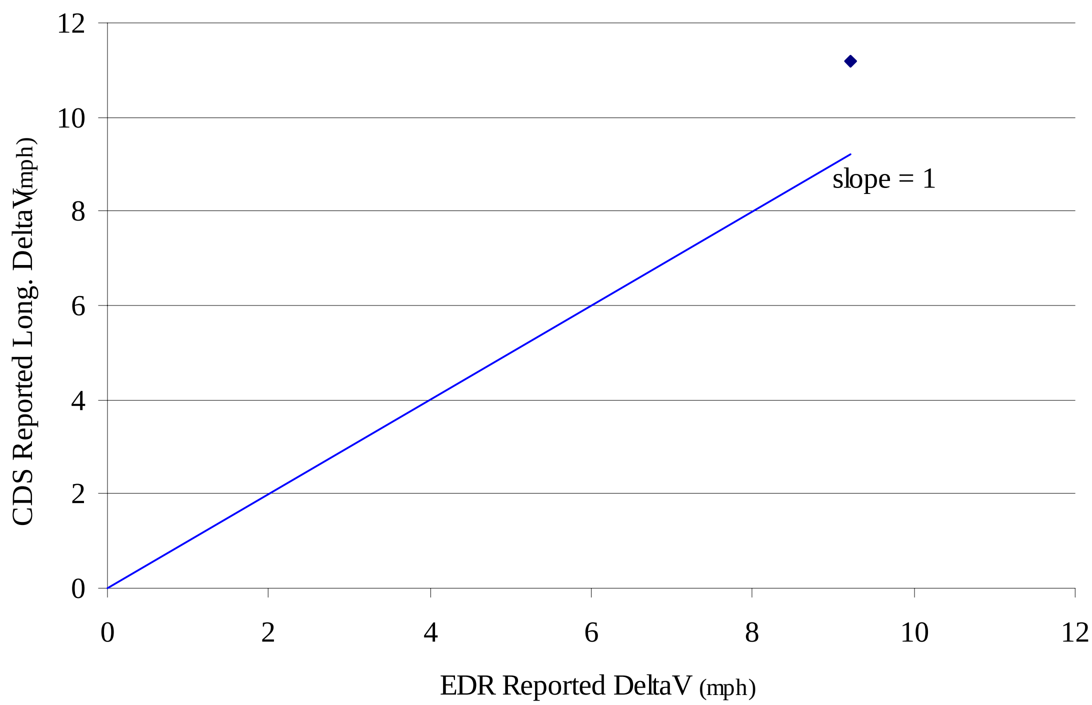


Figure G34. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 89*; 1 File)

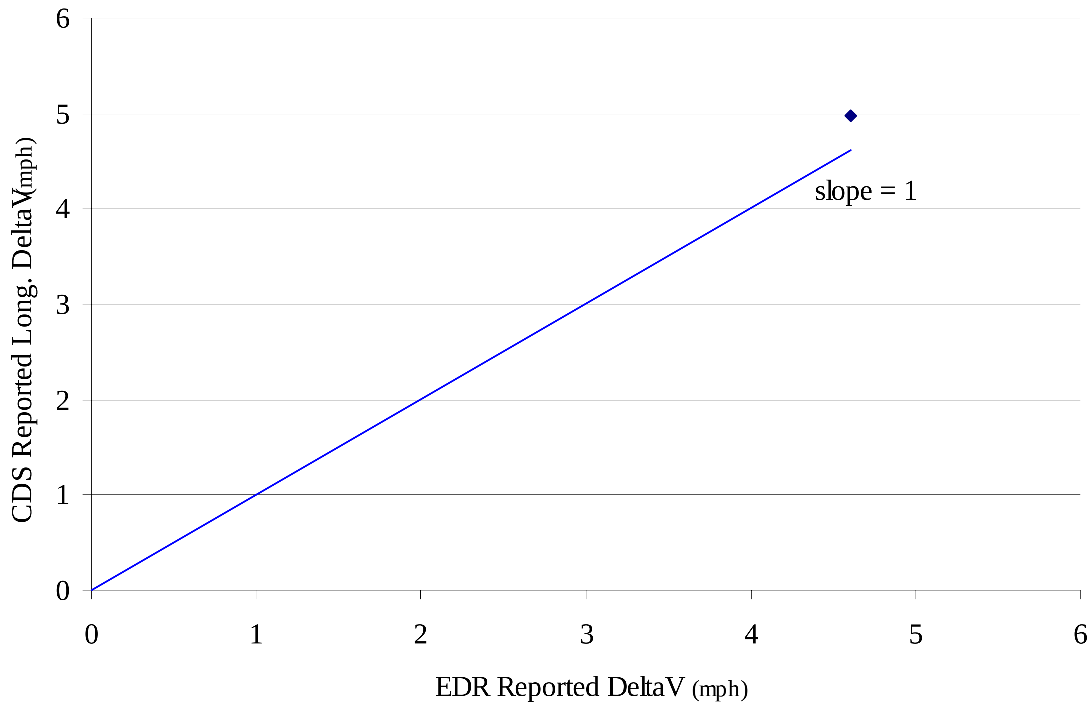


Figure G35. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 93*; 1 File)

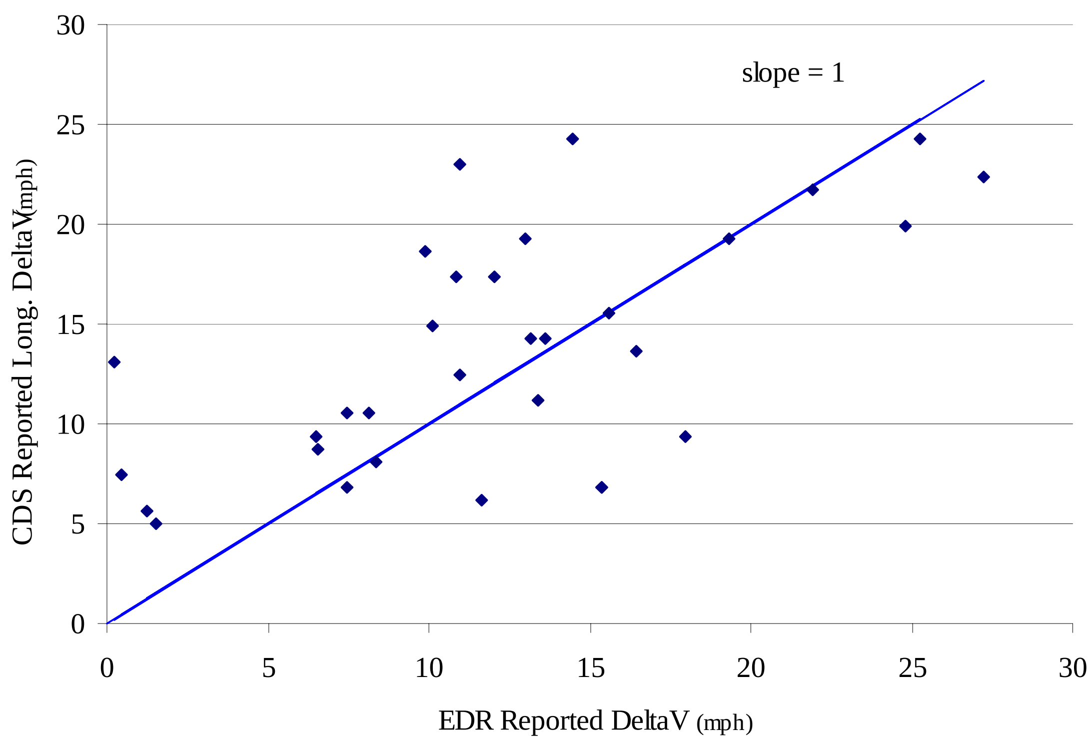


Figure G36. EDR/CDS-Reported Longitudinal Delta V Comparison
(*ACCTYPE = 98*; 32 Files)

DOT HS 810 935
April 2008

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