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Comparison of Rear Impact Crash Reconstructions to Event Data Recorders in the Crash Investigation Sampling System Database

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Abstract

This article compares the results of automotive accident reconstructions to event data recorder (EDR) data from vehicles involved in rear-end collisions. Accident reconstructions in the Crash Investigation Sampling System (CISS) database calculate crash severity expressed as the impact-related change in velocity (delta-V) experienced by a vehicle. The accuracy of the CISS-reconstructed delta-V in rear impacts was assessed by comparison to the delta-V recorded during the crash by the EDR on board the rear-ended vehicles. The CISS database was searched for single rear impact cases with a CISS-reconstructed delta-V as well as an EDR download. A total of 256 cases met these criteria. On average, the CISS-reconstructed delta-V was 4.0% lower than the delta-V recorded by the EDR. The accuracy of the CISS reconstructions varied with crash configuration, vehicle type, collision partner, and crash severity. Crash severity had the largest effect on accuracy, with low-speed reconstructions overestimating the EDR delta-V by 36% on average.

Keywords

EDR, CISS, NASS, Rear impact, Accident reconstruction

Introduction

This article aims to compare rear impact accident reconstruction data, specifically delta-V, in the National Highway Traffic Safety Administration (NHTSA)'s Crash Investigation Sampling System (CISS) database with event data recorder (EDR) data contained in the same database.

The NHTSA conducts multiple data collection programs in support of its traffic safety mission. The CISS is a nationally representative probability-based crash sampling system designed by NHTSA's National Center for Statistics and Analysis as a replacement for the National Automotive Sampling System Crash Data System (NASS-CDS). The NASS was originally developed in the 1970s and its design was updated in 1988. Data collection through NASS-CDS ended in 2015. In 2016, the NHTSA completed a pilot year to further develop the CISS. Currently, the CISS database includes four full years of data from 2017 to 2020. The CISS is part of a modernization effort directed at all of NHTSA's data programs and has been upgraded in comparison to NASS-CDS.

Like its predecessors, the CISS is a sample of police-reported crashes that undergo further investigation by NHTSA crash analysts. Where NASS-CDS cases required one vehicle to be towed due to damage, CISS has loosened this requirement to one vehicle towed for any reason. Each investigation includes data regarding the crash scene, the vehicles involved, and the occupants of each vehicle. CISS scene and vehicle data collection is upgraded from NASS-CDS. CISS measurements are taken electronically rather than by hand, and crush measurement is done within a computer environment. EDRs are downloaded at a higher rate in CISS cases. This process generates a large amount of data for each crash, vehicle, and occupant. CISS-investigated crashes are chosen to represent the full spectrum of crash severity [1, 2, 3].

A fundamental aspect of the CISS database is the quantification of the crash severity using the crash-related change in velocity, or delta-V. CISS crashes are reconstructed to calculate delta-V using the collected vehicle deformation measurements along with NHTSA's WinSmash accident reconstruction software. WinSmash is based on the CRASH (Calspan Reconstruction of Accident Speeds on the Highway) methodology developed for the NHTSA wherein delta-V is calculated using vehicle crush measurements and stiffness coefficients [4, 5]. Collinear crashes in CISS use the WinSmash damage-based methods only. Scene data is not used in these reconstructions. CISS reconstructions use updated techniques for quantifying vehicle damage compared to the predecessor NASS-CDS database. The accuracy of CISS reconstructions compared to the delta-V recorded on the subject vehicle EDR is reported to be slightly better than the NASS-CDS due to the use of electronic measuring devices and an upgraded vehicle measurement procedure [2]. Previous researchers have reported the accuracy of EDR longitudinal delta-V in instrumented crash tests [6, 7]. Compared to laboratory instrumentation, EDRs report delta-V within 6-7%.

The accuracy of NASS-CDS reconstructions in comparison to EDR data for frontal collisions has been explored by previous authors. In 2004 Gabler reported on a comparison of WinSmash reconstructed delta-V plotted against EDR delta-V for 65 NASS-CDS cases from 2000 to 2002. Analysis in this study showed that the NASS reconstructed delta-V underestimated the EDR delta-V by 23% with an R^2 value of 0.739 [8]. At the time of the 2004 Gabler study, most NASS-CDS cases involved EDR data from General Motors (GM) vehicles.

A study by Funk et al. compared the delta-V in 228 frontal crashes reconstructed by the NASS to the delta-V recorded by EDRs in those crashes. All vehicles in the dataset were GM models. This dataset showed the NASS reconstructions underestimated EDR delta-V by 19% on average, with an R^2 value of 0.49, and a standard deviation of 8.5 kph [9].

WinSmash was updated in 2008 resulting in an improvement in the accuracy of the WinSmash reconstructions in the NASS-CDS. Hampton and Gabler reported that the updated WinSmash underestimated the frontal EDR delta-V by 13.2% on average with an R^2 value of 0.8845, and a root mean square error (RMSE) of 9.8 kph. [10]. This study used data from 1,265 vehicles, all GM products. Interestingly, their study reported that vehicle type was found to influence reconstructed delta-V accuracy in earlier versions of WinSmash. The updates reported to WinSmash included the ability to use vehicle-specific stiffness as well as an upgrade to the categorical vehicle stiffnesses. The difference in reconstruction accuracy due to body type remained; however, no difference in average delta-V was observed using either vehicle-specific stiffness values or updated categorical stiffness values. The improved WinSmash underestimated the EDR delta-V for cars by 16%, vans by 11.2%, pickup trucks by 4.2%, and utility vehicles by 2.3%. This study reported an average underestimate of 11.7% for vehicles with more than 50% overlap and an underestimate of 24.1% for vehicles with less than 50% overlap.

In 2017 Gabler compared WinSmash to EDR data for rear impacts in the NASS database [11]. This study searched for rear impacts with EDR data from the years 2000-2015. The study found no EDRs that recorded rear crashes before the model year 2004 and no NASS cases with rear impact EDR data earlier than 2006. A total of 140 cases were analyzed. The dataset was made up of Chrysler, Ford, GM, and Toyota vehicles. On average, WinSmash delta-V underestimated the EDR delta-V by 4.5%. In small overlap crashes, WinSmash underestimated the delta-V by 22%. The study found that cars had higher delta-V than light transport vehicles (LTVs) and that WinSmash showed a smaller underestimate of delta-V (3-4%) for LTVs versus a 10% delta-V underestimate for cars. The type of WinSmash algorithm used was evaluated and showed an average of 1.6% delta-V overestimate for the missing vehicle algorithm and an underestimate of 10% when the algorithm used damage measurements for both vehicles to calculate the delta-V.

In recent years the prevalence of data collected from vehicle-based EDRs through both NASS-CDS and CISS has improved understanding of the errors associated with accident reconstruction methods adopted by the NHTSA. The focus of this study is to characterize the reconstruction error in rear impact collisions within the updated CISS database.

Methods

CISS data files for the years 2017-2020 were available at the time of this writing. A total of 19,984 vehicles and 7,255 EDR images were present in this data. These data were queried and sorted using Microsoft Access and Microsoft Excel. Rear impacts were defined by the CISS-reported principal direction of force (PDOF) between 150 and 210 degrees with CDCPLANE of B. Using the CISS variable DVRANK, vehicles that experienced more than one impact were excluded. Vehicles that experienced rollover were also excluded using the CISS variable ROLLTYPE. Only EDR files with event recording marked complete were used. Cases that did not have a CISS-reconstructed delta-V were excluded. The EDR data files were checked manually to ensure the reported event was consistent with the subject crash. The resulting dataset contained 256 rear-impacted vehicles with a CISS reconstruction and EDR report.

The dataset was analyzed as a whole and in different subsets using linear regression. CISS-reported longitudinal delta-V was compared to EDR-reported longitudinal delta-V for each vehicle in the dataset. The regression analyses were performed using the XLStat software package in Microsoft Excel. The regressions were fit to the data with the intercept set to zero. The slope of the regression line was compared to a 1:1 line representing a perfect agreement between the CISS-reconstructed delta-V and EDR delta-V. Values of R^2 and RMSE were computed for each subset of the data. This methodology allowed comparison with previous studies comparing WinSmash delta-V to EDR delta-V [8, 9, 10, 11].

Crash overlap was evaluated for full engagement impacts, moderate overlap impacts, and small overlap impacts and sorted using the CISS variable CDCLONGLAT. Override/underride impacts were evaluated and sorted with the CISS variable OVERUNDER. Override/underride crashes were evaluated independent of overlap; the override/underride dataset included all three overlap conditions. Separate analyses were performed for cars and LTVs, as well as the four permutations of crash partners: Car-Car, Car-LTV, LTV-Car, and LTV-LTV.

Collisions with a PDOF between 150 and 210 degrees were used. To check the effect of PDOF and any attendant error due to rotation due to impact, the error in cases with the PDOF between 150 and 170 degrees and cases with the PDOF between 190 and 210 degrees were compared to the error in cases with the PDOF of 180 degrees with a t-test.

The WinSmash methodology used in the CISS reconstruction was evaluated. WinSmash methods in the dataset included Damage only, Missing vehicle, and Damage with Collision Deformation Classification (CDC) only. Regression was performed for the Damage only and Missing vehicle cases; there were only five CDC-only cases.

CISS data includes confidence in the reconstruction variable, DVCONF. The dataset included cases with codes 1—results appear reasonable, 2-results appear high, 3-results appear low, and 4-borderline reconstruction. Regression was performed for codes 1 and 4, which made up 97% of the total dataset. There were only eight cases coded with 2-results appear high or 3-results appear low. The assessments in these eight cases agreed with the discrepancy with respect to the corresponding EDR delta-V.

Acceleration time history data was extracted for EDRs that recorded this information. Characteristics of the acceleration time history data were analyzed using linear regression and parametric tests for significance.

TABLE 1 Number of vehicles by manufacturer.

Make	Count
Jeep	13
Chrysler	2
Dodge	8
Ford	25
Buick	4
Cadillac	1
Chevrolet	35
Pontiac	1
GMC	7
VW	3
BMW	2
Nissan	28
Fiat	1
Honda	23
Mazda	3
Mercedes-Benz	2
Subaru	1
Toyota	81
Volvo	1
Acura	3
Lexus	10
Scion	2

Results

This methodology resulted in a dataset containing 256 CISS-reconstructed rear impact cases with EDR data for the rear-impacted vehicle. Toyota and its divisions had the highest number of vehicles in the study with 93. There were 48 GM vehicles, 28 Nissan, 26 Honda, 25 Ford, 24 Chrysler, 3 Volkswagen (VW), 3 Mazda, and 2 each of Mercedes-Benz and BMW. One Volvo was present (Table 1). The average model year in the study was 2014, with a range from 2002 to 2020 (Table 2). For the complete rear impact with the EDR dataset, the CISS reconstructions underestimated the EDR delta-V by 4.0% on average, with an R^2 value of 0.894 (Table 3). RMSE was 7.4 kph. The complete rear impact dataset had an average EDR-reported delta-V of 20.3 kph and an average CISS-reconstructed delta-V of 20.0 kph. The majority of cases had an EDR delta-V less than 19.3 kph (Figure 1).

The CISS-reconstructed delta-V in our dataset overestimated the EDR delta-V by an average of 36% in low-speed cases with EDR-recorded delta-V up to 16.1 kph (Figure 2). For cases with delta-V above 16.1 kph and below 40.2 kph, the CISS reconstructions underestimated EDR delta-V by 11%. The changeover point from low-speed CISS overestimate to moderate-speed CISS underestimate was between 16.1 and 24.1 kph as reported by the EDR. At the highest delta-V, CISS reconstructions overestimated the EDR. Cases with EDR delta-V over 40.2 kph were overestimated by an average of 10% by the CISS reconstruction. The difference in error between the 111 cases with EDR delta-V below 16.1 kph and the 145 cases with EDR delta-V above 16.1 kph was statistically significant ($P < 0.0001$) based on a two-tailed t-test.

Reconstructions of collisions with full engagement underestimated delta-V compared to the full dataset (4.6% vs 4.0%, with R^2 of 0.91). Reconstructions of moderate and small overlap collisions had a larger underestimate of 10.1% and 5.5%, respectively. The moderate overlap R^2 was 0.899 and the small overlap R^2 was 0.945. The override/underride reconstructions overestimated delta-V by 2.9% with an R^2 of 0.911 (Table 4). Compared to distributed collision reconstruction error only a narrow overlap error was statistically significant

TABLE 2 Number of vehicles by model year.

Model year	Count
2002	1
2004	1
2005	7
2006	4
2007	6
2008	2
2009	2
2010	12
2011	15
2012	12
2013	29
2014	28
2015	35
2016	34
2017	29
2018	27
2019	10
2020	2

TABLE 3 Regression results for the complete dataset.

All cases	
Count	256
% of total	100%
Slope	0.96
Error	−4.0%
R^2	0.894
RMSE (kph)	7.4
Avg CISS DV (kph)	19.9
Avg EDR DV (kph)	20.2
CISS min DV (kph)	6.0
EDR min DV (kph)	5.0
CISS max DV (kph)	70.0
EDR max DV (kph)	62.1

(P = 0.019). Figure 3 shows distributed, moderate, and narrow overlap datapoints with ±5%, 10%, and 20% error bounds.

The dataset consisted of collinear single-impact rear-end collisions. The error in cases with the PDOF between 150 and 170 degrees and cases with the PDOF between 190 and 210 degrees were compared to the error in cases with the PDOF of 180 degrees with a t-test. There was no statistically significant difference in error between these datasets. This is an indication that the moment arm between the location of the EDR and point of impact and any attendant impact rotation imposed by PDOF in this range is not a significant factor for error in the delta-V calculation for these collisions.

Reconstructions where the rear-impacted vehicle was a car underestimated EDR delta-V by an average of 3.1%. Reconstructions of rear-impacted LTVs underestimated delta-V by an average of 5.2%. The dataset showed an average of 20.4 kph for EDR-reported delta-V in cars and 19.8 kph for EDR delta-V in LTVs (Table 4). The difference in error was not statistically significant.

Car-Car reconstructions underestimated the struck vehicle delta-V by 5.0%. Car-LTV reconstructions underestimated the struck vehicle delta-V by 4.4% For cars struck by an LTV, the CISS reconstructions underestimated delta-V by 1.0% on average. LTVs struck by another LTV were underestimated by an average of 1.5% (Table 4).

Analysis of the WinSmash algorithm used showed that reconstructions using the WinSmash missing vehicle algorithm had an underestimate of 6.5% compared to the WinSmash algorithm using damage data for both vehicles, which had an average underestimate of 3.1%. R^2 was 0.855 for the missing vehicle algorithm and 0.915 for cases with damage data for both vehicles (Table 4). The difference in error between the two methods was not statistically significant.

The investigator's confidence in the reconstruction variable DVCONF contains the codes "results appear reasonable" and "borderline reconstruction." Error for cases where the analyst entered "results appear reasonable" was −4.0%. Error in the

FIGURE 1 EDR delta-V versus CISS delta-V for the complete rear impact dataset. Points above the 1:1 diagonal are overestimates, and points below the line are underestimates. The orange-dotted line is the regression line. Black-dotted lines show ±5%, 10%, and 20% error bounds.

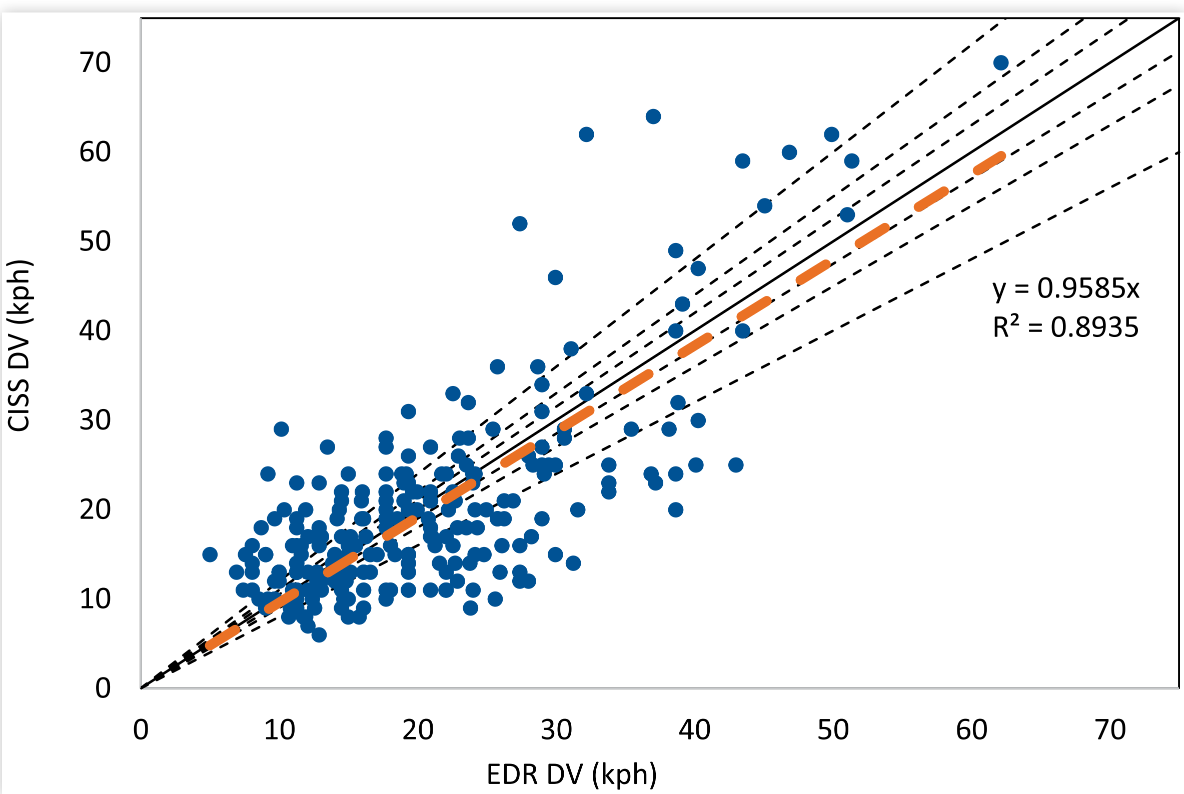
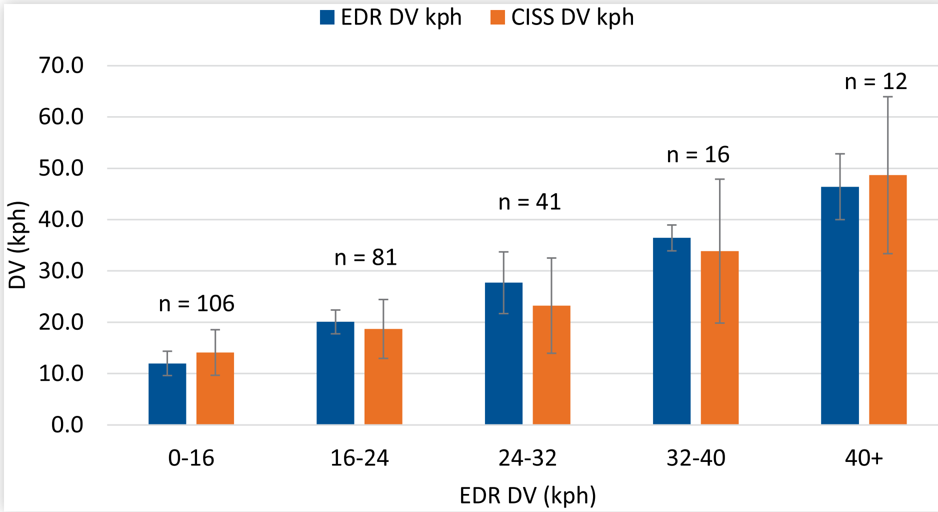


FIGURE 2 EDR delta-V compared to CISS delta-V. Though CISS underestimates EDR overall, overestimate or underestimate is a function of EDR delta-V.



case where the analyst entered "borderline reconstruction" was the same, −4.0% (Table 4). Delta-V error in cases where the investigator entered "results appear reasonable" or "borderline reconstructions" did not have a statistically significant difference.

Eighty-five of the EDRs contained acceleration time history data. Average and peak acceleration was strongly correlated with EDR delta-V (Figure 4). Pearson product-moment correlation coefficients of 0.85 and 0.77 were calculated for average and peak acceleration, respectively ($P < 0.0001$). The average EDR delta-V in this subset of data was 20.4 kph, with a range of 5.0-51.0 kph. The average CISS delta-V in this subset was 20.8 kph with a range of 9.0-64.1 kph. On average, peak acceleration was 2.4 times higher than average acceleration. The average crash pulse duration was 129 ms, with a standard deviation of 34 ms, minimum of 80 ms, and maximum of 240 ms.

Discussion

Overall, the CISS reconstructions underestimated the EDR delta-V by 4% on average with an RMSE of 7.4 kph and a standard deviation of 4.8 kph. These results show improvement over results reported for the NASS-CDS database which used a reconstruction methodology similar to CISS. Gabler's study of rear-end collisions in the NASS-CDS database reported an overall NASS reconstruction underestimate of 4.5% below EDR delta-V [11]. Hampton and Gabler reported a 13.2% average underestimate for frontals in their 2010 study, which was an improvement over the underestimates of 20% to 23% in previous studies. Hampton and Gabler reported an RMSE of 9.8 kph [10]. Funk's 2008 study showed a 19% underestimate for frontals with a standard deviation of 8.5 kph [9]. Compared to NASS-CDS, the present study showed improvement in absolute error, RMSE, and standard deviation.

The error in the CISS reconstructions was not constant across delta-V. Low-speed events showed the highest percent error with the reconstructed delta-V overestimating the EDR delta-V by over 80% for crashes with EDR delta-V 8 kph or less. The high percent error in low-speed reconstructions is partially due to the low speeds involved; an 80% error for an 8 kph delta-V is an absolute error of 6.4 kph. The low-speed overestimates decreased with increasing delta-V until crossing between 16.1 and 24.1 kph. Between 16.1 and 40.2 kph, the reconstructions underestimated the EDR by 11%. The difference in error between reconstructions with EDR delta-V below 16.1 kph, and those with EDR delta-V above 16.1 kph was statistically significant. There were 136 cases with EDR delta-V between 16.1 and 40.2 kph, making up 53% of the total database. Above 40.2 kph the CISS reconstructions began to overestimate the EDR by 10% on average.

Crash configuration showed an effect on the comparison of reconstructed delta-V to EDR delta-V. Collisions with full engagement had a slightly greater underestimate of delta-V compared to the full dataset (4.6% vs 4%). This result showed a higher error compared to the 2% underestimate full engagement rear impact result reported in Gabler's 2017 NASS study. Moderate and small overlap collisions had underestimates of 10.1% and 5.5%, respectively. The error in narrow overlap crashes showed a statistically significant difference from the error in distributed crashes. Despite the difference in error, these results are substantially improved over Gabler's findings in the NASS-CDS database where moderate and small overlap rear-end reconstructions underestimated the EDR by 18.5% and 22%, respectively.

In our dataset, reconstructions with rear-struck cars underestimated EDR delta-V by 3.1%. Rear-struck LTV reconstructions underestimated delta-V by 5.2%. These underestimates straddle the overall dataset underestimate of 4%. The difference in error between cars and LTVs was not statistically significant in our dataset. These findings are different from Gabler's results based on rear impacts in the NASS-CDS database where reconstructions involving rear-struck LTVs overestimated delta-V by 3.7% and reconstructions involving rear-struck cars underestimated delta-V by 8.5%. The 140-vehicle dataset evaluated by

TABLE 4 Regression results by overlap configuration, vehicle type, collision partner, WinSmash algorithm, and analyst rating.

Crash type	Count	% of total	Slope	Error (%)	R^2	RMSE (kph)	Avg CISS DV (kph)	Avg EDR DV (kph)	CISS min DV (kph)	EDR min DV (kph)	CISS max DV (kph)	EDR max DV (kph)
Wide	145	57%	0.954	−4.6	0.909	7.8	22.7	22.3	9.0	6.9	70.0	62.1
Moderate	71	28%	0.899	−10.1	0.862	7.4	18.0	18.8	6.0	5.0	64.0	43.0
Narrow	35	14%	0.945	−5.5	0.894	4.3	12.4	15.2	7.0	7.4	29.0	35.4
Override	66	26%	1.029	2.9	0.911	7.4	21.6	20.5	9.0	7.6	70.0	62.1
Struck vehicle	**Count**	**% of total**	**Slope**	**Error (%)**	**R^2**	**RMSE (kph)**	**Avg CISS DV (kph)**	**Avg EDR DV (kph)**	**CISS min DV (kph)**	**EDR min DV (kph)**	**CISS max DV (kph)**	**EDR max DV (kph)**
Car	146	57%	0.969	−3.1	0.888	7.8	20.4	20.5	6.0	5.0	62.0	51.4
LTV	110	43%	0.948	−5.2	0.904	6.9	19.2	19.8	8.0	8.0	70.0	62.1
Collision partner	**Count**	**% of total**	**Slope**	**Error (%)**	**R^2**	**RMSE (kph)**	**Avg CISS DV (kph)**	**Avg EDR DV (kph)**	**CISS min DV (kph)**	**EDR min DV (kph)**	**CISS max DV (kph)**	**EDR max DV (kph)**
Car-Car	91	36%	0.95	−5.0	0.889	7.0	18.7	19.2	6.0	5.0	59.0	43.5
Car-LTV	62	24%	0.956	−4.4	0.914	6.1	18.0	19.1	8.0	8.0	70.0	62.1
LTV-Car	55	21%	0.99	−1.0	0.888	8.9	23.4	22.7	8.0	7.6	62.0	51.4
LTV-LTV	48	19%	0.985	−1.5	0.896	7.7	20.7	20.7	10.0	9.7	64.0	46.9
WinSmash algorithm	**Count**	**% of total**	**Slope**	**Error (%)**	**R^2**	**RMSE (kph)**	**Avg CISS DV (kph)**	**Avg EDR DV (kph)**	**CISS min DV (kph)**	**EDR min DV (kph)**	**CISS max DV (kph)**	**EDR max DV (kph)**
Damage data	139	54%	0.969	−3.1	0.915	6.9	20.8	21.0	8.0	5.0	70.0	62.1
Missing vehicle	112	44%	0.935	−6.5	0.855	7.9	18.3	18.9	6.0	6.9	64.0	43.5
Analyst rating	**Count**	**% of total**	**Slope**	**Error (%)**	**R^2**	**RMSE (kph)**	**Avg CISS DV (kph)**	**Avg EDR DV (kph)**	**CISS min DV (kph)**	**EDR min DV (kph)**	**CISS max DV (kph)**	**EDR max DV (kph)**
Reasonable	71	28%	0.96	−4.0	0.92	6.7	21.3	21.4	8.0	5.0	62.0	51.0
Borderline	177	69%	0.96	−4.0	0.885	7.6	19.4	19.7	6.0	6.9	70.0	62.1

FIGURE 3 Datapoints differentiated by collision overlap.

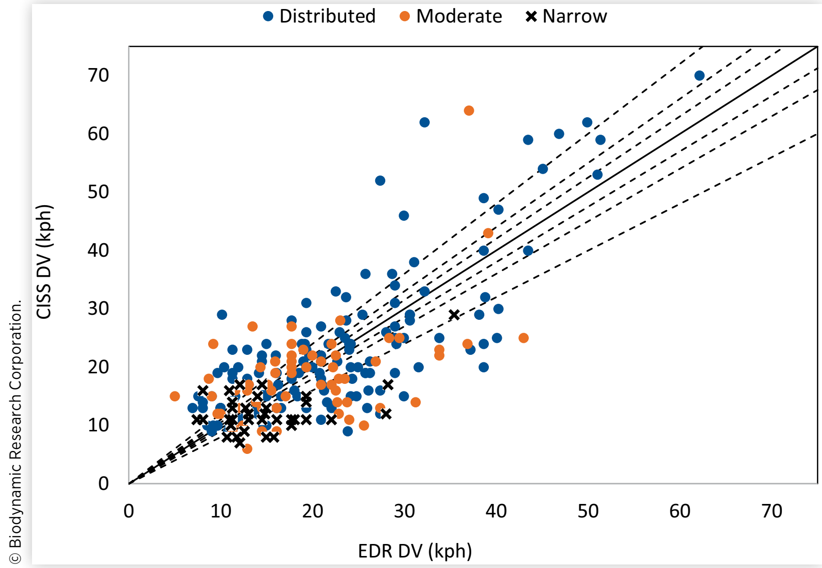
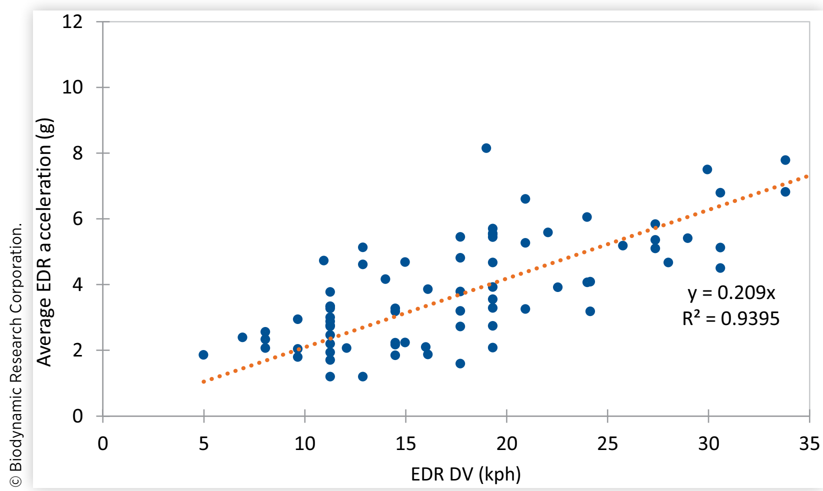


FIGURE 4 Average EDR acceleration plotted against EDR delta-V.



Gabler consisted of 65% cars and 35% LTVs. Gabler's data showed higher delta-V for cars, with 20% of the car cases over 30.6 kph delta-V and only 2% of the LTV cases over 30.6 kph. In contrast, our 256-vehicle dataset was distributed as 51% cars and 49% LTVs. Our dataset showed an average of 20.3 kph for EDR-reported delta-V in cars and 18.5 kph for EDR delta-V in LTVs. The uneven skew toward higher delta-V in Gabler's data for cars was not present in our dataset, with 8.7% of the car delta-V over 30.6 kph and 9.3% of the LTV delta-V over 30.6 kph.

Reconstructions in NASS-CDS and CISS frequently calculate delta-V using damage measurements from only one of the involved vehicles. This type of reconstruction uses the WinSmash missing vehicle algorithm, which estimates the energy absorbed by the missing vehicle based on the damage to the known vehicle. In the present study, 44% of the reconstructions used the missing vehicle algorithm compared to 42% of the vehicles in Gabler's 2017 NASS-CDS study. The CISS reconstructions using the WinSmash missing vehicle algorithm underestimated the EDR delta-V by 6.5% while the reconstructions based on damage to both vehicles underestimated the EDR by 3.1%. The difference in error was not statistically significant. Gabler's 2017 study of the NASS-CDS database showed a 1.6% overestimate of the EDR when using the missing vehicle algorithm with a wider spread between the two methods, with damage analysis with both vehicles underestimating the EDR by 10%.

Delta-V as a crash severity metric is a surrogate for acceleration. Average acceleration during the crash pulse can be expressed as delta-V divided by delta-t. In crash reconstruction, delta-t is often unknown and commonly assumed to range from approximately 80 ms up to 300 ms based on the characteristics of the crash [12, 13, 14]. A subset of the EDRs in this study recorded acceleration time history and showed average acceleration strongly correlated with delta-V. The same EDR data showed an average delta-t of 129 ms with a standard deviation of 34 ms.

A limitation of this study is the sparseness of single-impact collisions. By CDC code, rear impacts made up 2,067, or 8.7%, of the collisions in CISS. The final EDR dataset included 256, or 12.3%, of the rear impacts. A large portion of potential rear impacts with EDR data were removed as they involved multiple impacts. For this study, only collinear rear impacts were considered.

Previous authors have suggested that applying restitution to WinSmash reconstructions in the NASS improved the accuracy compared to EDR data [15]. In the Niehoff (2006) study, the authors found that WinSmash underestimated the EDR by 23% on average and that the inclusion of restitution reduced the error to within 1% of EDR delta-V. These findings were limited to WinSmash versions 2.42 and earlier. WinSmash was updated in 2008, reducing the average underestimate compared to EDR data to 13.2% in frontals and 4.5% in rear impacts [10, 11]. The present study shows an overall delta-V underestimate of 4% in rear impacts with overestimates of delta-V at the low end of severity. Application of restitution to the CISS reconstructions in this dataset would result in an overestimate of delta-V, particularly for the 41% of cases with delta-V below 16 kph, which already overestimate the EDR. This is exacerbated further by the observation that restitution has an inverse relationship with closing speed, which would tend to increase the overestimate at low delta-V [16, 17]. A review of CISS cases with the largest errors showed areas where future work is applicable. Identification of the sources of error and re-reconstruction of the highest error cases with the available CISS data and photos presents the opportunity to improve future CISS reconstructions.

Conclusions

The accuracy of rear-impact reconstructed delta-V in the CISS database in comparison to EDR delta-V of the actual events was assessed. The dataset was composed of 256 vehicles: 146 cars and 110 LTVs. Overall, the CISS reconstructions underestimated the delta-V by 4.0%. The CISS reconstructions overestimated delta-V in low severity collisions, underestimated delta-V in moderate to high severity collisions, and overestimated delta-V in the highest severity collisions. This effect was statistically significant. The transition from low-speed overestimates to underestimates occurred at delta-V between 16.1 and 24.1 kph. The accuracy of the CISS-reconstructed delta-V was improved compared to previous studies of the NASS-CDS database. Acceleration was strongly correlated with the delta-V crash severity metric.

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