

INFLUENCE OF THE MISSING VEHICLE AND CDC ONLY DELTA-V RECONSTRUCTION ALGORITHMS FOR PREDICTION OF OCCUPANT INJURY RISK

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ABSTRACT

Delta-V, the change in velocity of a vehicle, is a widely used predictor of occupant injury in vehicle collisions. In real world crashes, delta-V is commonly estimated from measurements of vehicle deformation using absorbed energy based methods. The accuracy of these estimates is highly dependent on the availability of deformation measurements for both vehicles involved in a crash. Specialized algorithms have been developed for those cases in which complete information is not available from a crash (e.g. the missing vehicle algorithm) or has been estimated (e.g. the collision deformation classification, or CDC only algorithm). The objectives of this study are to evaluate (1) the accuracy of the missing vehicle and CDC only algorithms and (2) the influence of these algorithms upon estimates of occupant injury risk. The approach is to develop and critically evaluate occupant injury risk curves using the standard, missing, and CDC only reconstruction algorithms for 1899 real vehicles extracted from the National Automotive Sampling System / Crash Data System for 2006.

Keywords: Crash reconstruction delta-V occupant injury risk

INTRODUCTION

In the U.S., over six million police-reported crashes occur each year. To better understand the trends in vehicle and roadside safety, the National Highway Traffic and Safety Administration (NHTSA) maintains the National Automotive Sampling System / Crash Data System (NASS/CDS) to collect in-depth information on these crashes. One element of these investigations is a reconstruction of the crash to determine the delta-V. Delta-V, or the change in velocity, is widely used as a predictor of the risk of occupant injury. Reconstruction tools such as CRASH3 [1] use an absorbed energy method to estimate delta-V using vehicle properties and crush measurements.

Error in these delta-V estimations can occur in a number of ways, but one of the most prevalent sources of error is the inability to perform a post-crash vehicle inspection. For this reason, there are three different reconstruction algorithms (standard [2], CDC only, and missing vehicle [3]), each respectively requiring less information to compute delta-V. Because these alternative algorithms do not require certain measurements considered key to the reconstruction, the accuracy of the delta-V predictions, and by extension the prediction of injury, has been questioned.

Objective

The goals of this project are:

1. To determine the accuracy of the missing vehicle and CDC only algorithms for delta-V reconstruction.
2. To determine the influence of each of these algorithms on the prediction of occupant injury risk.

METHODS

This study was designed to assemble a set of well documented crashes for which the standard reconstruction algorithm could be used, and then apply the standard, missing vehicle, and collision deformation classification (CDC) only algorithms. The injury risk curves generated from these delta-Vs can be validated against existing risk curves. This study can be broken down into the following steps: (1) assembly of the dataset, (2) computation of the standard, missing vehicle, and CDC only results, and (3) generation and validation of injury risk curves using the predicted delta-Vs.

Data Sources

Information needed to perform a reconstruction was extracted from year 2006 of the NASS/CDS system. The NASS/CDS system is a publicly available database containing detailed accident, vehicle, and occupant information on tow-away crashes across the U.S. The basic set of information required by the standard algorithm can be found within this database and included the following: vehicle make and model, basic vehicle dimensions, orientations of the vehicles, and damage profiles. Crashes for which this information was not known were removed from the data set.

Information on the occupant injury was restricted to only the drivers of the vehicles. Injury severity was measured using the Abbreviated Injury Scale (AIS) [4]. For each driver, only the highest recorded injury (called MAIS) was used, and only if the MAIS score was in the range of 0 to 6 (No injury to maximum injury). Drivers using full 3-point belts, lap belts, and shoulder belts were considered “belted” whereas drivers not using any form of manual restraint were considered “unbelted.” Vehicles for which the belt status was not known were excluded. Vehicles for which the national weight factor (used to quantify how often similar crashes occurred across the country) was unknown were excluded as well. The use of airbags was not considered.

The final set of data consisted of 1086 crashes, all of which had sufficient information to compute the delta-V using all three reconstruction algorithms. In these crashes, there were 1899 vehicles meeting the occupant injury requirements that were used for this study.

Computation of Delta-V Results

The next step was to compute the delta-V for the vehicles in each crash using the absorbed energy reconstruction method. The delta-V for each case was computed three times, once with each of the three available algorithms. The algorithms all required that the vehicle dimensions and stiffness be known, but the information available on the vehicle damage varied according to the following criteria.

The standard algorithm required crush measurements precisely determined by a field investigator. This generated an accurate measure of the volume of deformation, which was combined with the vehicle stiffness to calculate the delta-V. In such situations where the crush can not be measured, but the location and extent of damage can be determined by other means, the CDC only algorithm can be used to generate an approximate crush profile. For the worst case situations, in which nothing was known about the vehicle damage, the missing vehicle algorithm was employed [3]. The damage was loosely

associated with an entire vehicle plane (front, rear, left, or right) and the results for the missing vehicle were derived from the information available on the known vehicle.

Fitting the Injury Risk Curves

Binary logistic regression curves employing the delta-V estimates as predictors of occupant injury were developed. All statistical analyses were performed with the SAS[®] v9.2 software, and all data was weighted by the national weight factor for each vehicle. The maximum injury to the driver was split into two different categories of significant injuries. Two different, but overlapping, threshold values for significant injury were used: A MAIS score of 2 or greater and a MAIS score of 3 or greater. The data set was also further split into belted and unbelted groups, creating four distinct groups for analysis: belted MAIS 2+, belted MAIS 3+, unbelted MAIS 2+, and unbelted MAIS 3+. Injury risk curves were generated for each group and compared.

RESULTS

Before generating the injury risk curves, the effect of the reconstruction algorithms on the distribution of delta-Vs was examined. For this initial analysis, the standard algorithm was assumed to be correct (which may or may not be true) and was used as the basis of comparison. Figure 1 and Figure 2 below show the distribution of delta-V between the standard algorithm and the missing vehicle and CDC only algorithm. In each figure the dashed line $y=x$ is provided for reference along with a linear fit to the data.

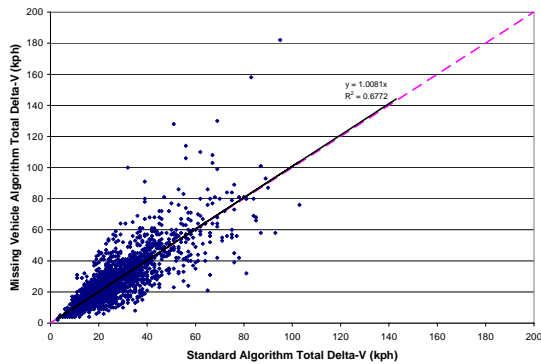


Figure 1: Comparison of standard and missing vehicle delta-V predictions

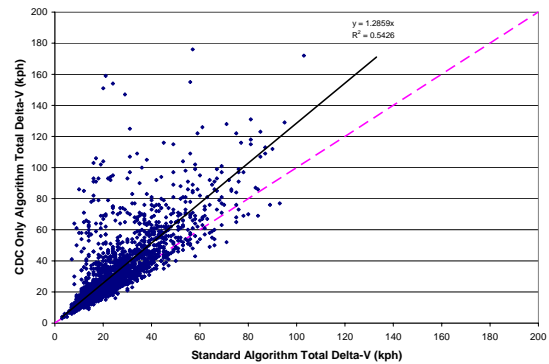


Figure 2: Comparison of standard and CDC only delta-V predictions

On average, the missing vehicle algorithm delta-V predictions matched well with those of the standard algorithm (1% increase). However, for any given vehicle, the missing vehicle algorithm had the potential to both greatly over- or under-estimate the vehicle delta-V. Unlike the missing vehicle algorithm, the CDC only algorithm overestimated the delta-V by 28.6% on average. The CDC algorithm delta-V values showed a similar variance on a single vehicle basis.

A previous study conducted by Gabauer and Gabler [5] provided risk curves to validate the delta-V predictions. In the study, a small pool of cases for which the true maximum change in velocity was

recorded by EDR was used to generate a binary logistic curve relating the delta-V to the maximum injury recorded in NASS/CDS. These risk curves are shown in Figure 3 - Figure 6. The risk curves were separated into four groups based on occupant seat belt use and injury level. Since the data sets were broken down in the same manner, the reconstructed and EDR delta-V predictions could be easily compared to determine the accuracy of the reconstruction algorithms. Each risk curve also shows the 95% confidence interval associated with the data.

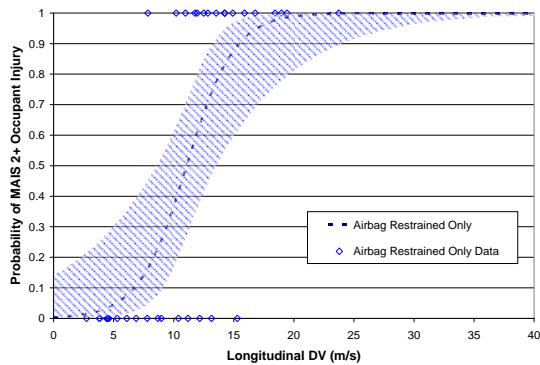


Figure 3: Probability of MAIS 2+ injury for unbelted occupants [5]

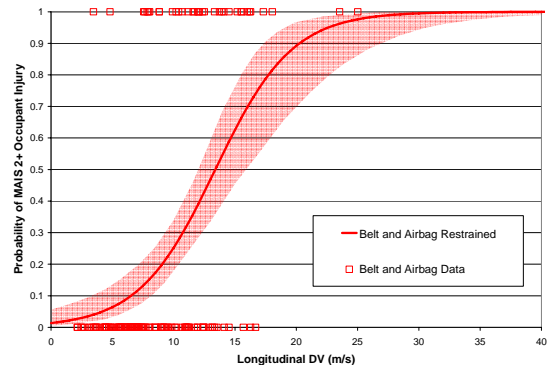


Figure 4: Probability of MAIS 2+ injury for belted occupants [5]

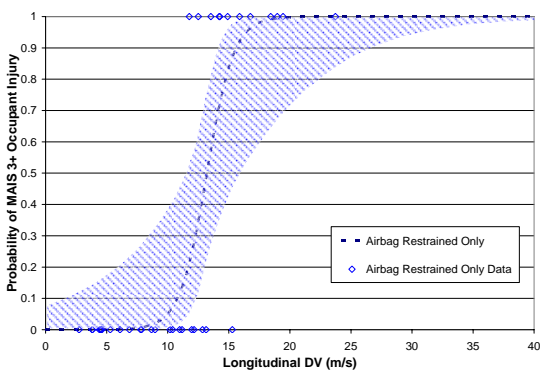


Figure 5: Probability of MAIS 3+ injury for unbelted occupants [5]

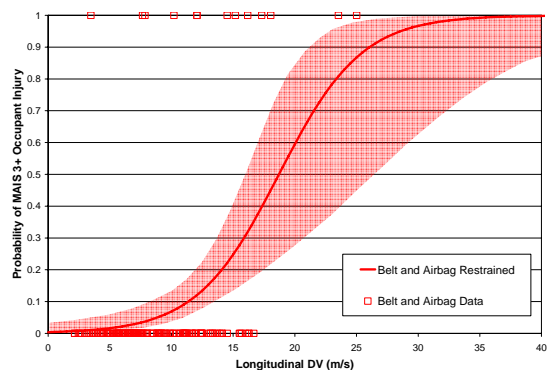


Figure 6: Probability of MAIS 3+ injury for belted occupants [5]

Binary logistic regression analysis was used to generate the injury risk curves shown in Figure 7 - Figure 10. In each figure, the injury risk curve generated by the EDR data (without the confidence interval) was shown along with each of the injury risk curves to facilitate comparison.

The injury risk curves generated from the reconstruction algorithms overestimated the delta-V, leading to an underestimated risk of injury. As expected, the standard algorithm risk curve was the closest to the EDR generated risk curve. This was not unexpected since the requirements to perform standard analyses were higher. Surprisingly, the missing vehicle algorithm was able to more accurately predict occupant injury than the CDC only approach, in spite of the less stringent requirements. Although all of the algorithms underestimated the occupant risk at high delta-Vs, the CDC only algorithm in particular greatly underestimated the risk of injury at extremely high delta-Vs. As might be expected, the use of proper driver restraints (seat belts) reduced the risk of injury at a given delta-V.

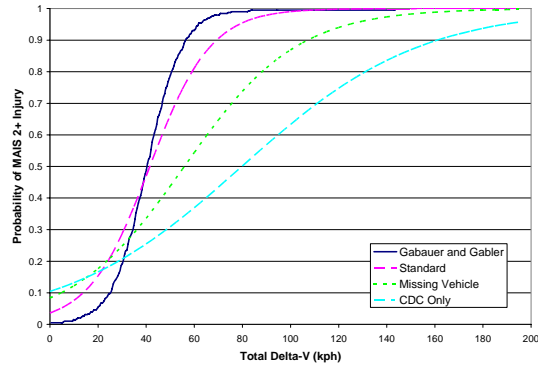


Figure 7: Risk of MAIS 2+ injury for unbelted drivers

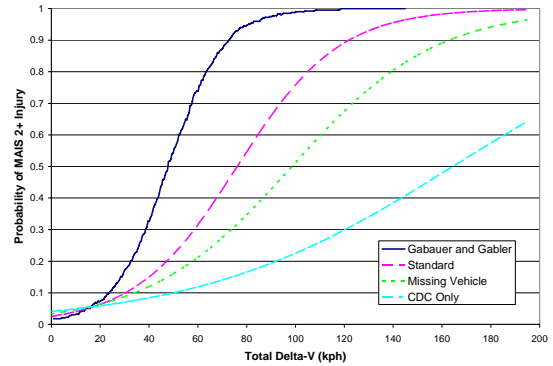


Figure 8: Risk of MAIS 2+ injury for belted drivers

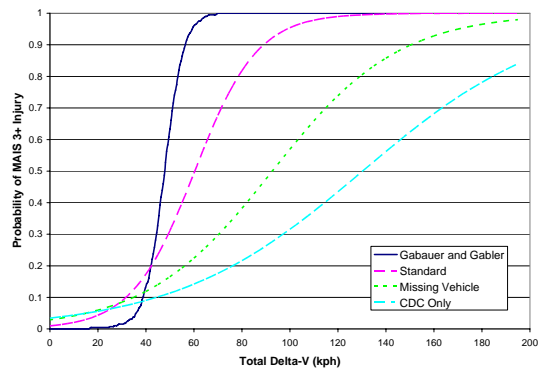


Figure 9: Risk of MAIS 3+ injury for unbelted drivers

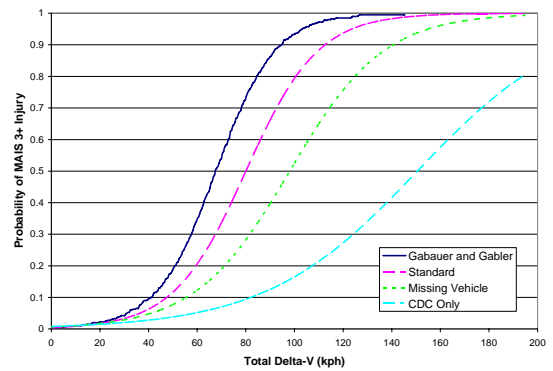


Figure 10: Risk of MAIS 3+ injury for belted drivers

The injury risk curves for unbelted drivers (MAIS 2+) and belted drivers (MAIS 3+) generated from the standard analysis fell within the 95% confidence interval for the EDR generated risk curve for all values of delta-V. For unbelted drivers (MAIS 3+) the predictions of the standard algorithm were on the border of the 95% confidence interval, except for extreme delta-V values where the standard curve moved within the confidence interval slightly. However, the standard algorithm was not within the confidence interval for belted drivers (MAIS 2+). The missing vehicle and CDC only algorithms were well outside of the confidence interval, except at very low delta-Vs.

DISCUSSION

Before any risk curves were generated, the CDC only and missing vehicle delta-Vs were cross-plotted against the standard delta-Vs to determine how algorithm affected the results. The CDC only algorithm was a poor predictor of the delta-V, being 28.6% high on average. The exact source of the error was not known. The error could be introduced by the assignment of an inappropriate CDC code or from poor estimation of crush values. The missing vehicle approach, which skipped the crush estimation process and simply estimated the missing vehicle absorbed energy, was better at matching the standard algorithm predictions. However, both the CDC only and missing vehicle algorithms sometimes

predicted drastically different delta-V values, implying that the approximations used by each was not always able to accurately reproduce the crash results.

The results of the delta-V comparisons were contingent upon the assumption that the standard algorithm was the most accurate of the three. To demonstrate that this was a reasonable assumption, injury risk curves were developed for four groups of drivers, divided according to maximum injury and belt usage. The risk curves were compared to existing curves from EDR data. Many of the curves predicted a non-zero chance of injury with no delta-V. This was an artifact of the binary logistic calculation. Factors such as age, gender, and airbag usage can influence the injury outcome of a crash but were not isolated in this study. Another contributing factor was the assumption of linear stiffness. The stiffness values were calibrated using crash tests performed in the range of 40 – 60 kph. The accuracy of the predictions would drop as the estimated crash speed deviated from this range.

Although the EDR and reconstructed risk curves did not match up exactly, the standard algorithm risk curve fell entirely within the 95% confidence interval for the unbelted MAIS2+ and belted MAIS3+ groups. The match was marginal for unbelted MAIS3+ occupants. Both the missing vehicle and CDC only algorithms were poor predictors of injury risk, most likely due to the assumptions that were needed to approximate the unknown vehicle damage.

CONCLUSIONS

The results of this study clearly indicate that the standard reconstruction algorithm with full crush profiles was the best predictor of maximum occupant injury (MAIS). The standard injury risk predictions for unbelted MAIS 2+ and belted MAIS 3+ groups were within the 95% confidence interval of the EDR predicted injury risk. Both the missing vehicle and CDC only algorithms failed to accurately predict the injury risk. While all of the algorithms tended to overestimate the delta-V, the CDC only algorithm in particular overestimated the vehicle delta-V by the largest amount, 28.6%. Ideally, all crash reconstructions should be performed with the standard algorithm. However, in situations where a standard analysis can not be performed the missing vehicle algorithm would be preferable. Use of the CDC only reconstruction should be avoided when possible.

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