

# NASS/CDS Delta-V Estimates: The Influence of Enhancements to the WinSmash Crash Reconstruction Code

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**ABSTRACT** – The change in velocity (delta-V) crash severity metric in the NASS/CDS (National Automotive Sampling System / Crashworthiness Data System) is computed using the WinSmash crash reconstruction code. Beginning in 2008, NASS/CDS investigators have started to use an enhanced version of WinSmash, WinSmash 2008, which features a comprehensive vehicle specific library for over 5000 vehicle make-model-year combinations and updated categorical stiffness values. The use of WinSmash 2008 is expected to greatly improve delta-V estimates. However, there is concern that this may result in a step change in the NASS/CDS delta-V estimates, making it difficult to compare NASS/CDS 2008 with earlier years. A total of 1,808 collisions were recomputed using data from NASS/CDS 2007. The new version of WinSmash shows improved accuracy, but still underpredicts delta-V. The use of WinSmash 2008 increased the delta-V by 7.9% or 1.9 kph on average. The changes in delta-V were not evenly distributed. Delta-V increases were larger for side impacts (8.3%) than for back impacts (5.3%). The calculation type had little effect on the delta-V changes. For vehicles, pickup trucks showed a small increase (3.3%) and utility vehicles increased the most (9.6%). This jump in delta-V may prevent the data from NASS/CDS 2008 and later from being readily aggregated with previous years.

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## INTRODUCTION

The NASS/CDS is a National Highway Traffic and Safety Administration (NHTSA) database containing records of crashes of sufficient severity to require towing of one or more vehicles. One of the most crucial components of the database is the estimated change in velocity (delta-V) for each vehicle. These delta-V values are generated with the WinSmash crash reconstruction software and are used by NHTSA to analyze trends in injury risks and vehicle safety performance.

WinSmash estimates delta-V values based on post-crash vehicle deformation and stiffness values [Prasad, 1990; 1991a; 1991b; NHTSA, 1986; Sharma, et. al., 2007]. While the crush values can be easily measured by investigators, the vehicle stiffness is more difficult to determine. In earlier versions of WinSmash the vehicle fleet was divided into categories by vehicle wheelbase and body style. For each category, WinSmash provided average stiffness values intended to represent the entire group of vehicles. These stiffness values were referred to as categorical stiffnesses. The stiffness values vary by the side of the vehicle struck, leading to different stiffnesses for the front, back, and sides of the vehicle. The crush and stiffness values were used to calculate the energy absorbed by the vehicle. The distribution of energy between two vehicles (or a

vehicle and fixed barrier) was used to estimate the delta-V of each vehicle.

One criticism of this approach is that the stiffness values used for each category, which were based on crash tests for vehicle models dating from 1974 to 1995, may not accurately represent the diverse vehicle fleet of today. Previous research has also shown that WinSmash underpredicts the delta-V by approximately 20% [Niehoff and Gabler, 2006]. WinSmash 2008, which was integrated into the NASS data entry system in January 2008, offered an improved stiffness library with vehicle specific stiffness values and updated stiffness categories with the intent of improving the accuracy of delta-V predictions. This raised an important question: to what extent would the WinSmash delta-V predictions change?

## Description of WinSmash 2008

The WinSmash 2008 release included a new library of more than 5,000 vehicle specific stiffness values for passenger vehicles of model years 1974-2008. There were also new categorical stiffness coefficients to better reflect the current vehicle fleet. These new stiffness values resulted in changes to some of the WinSmash delta-V predictions.

In addition to the changes made to the stiffness values, the stiffness selection process of WinSmash

2008 was reformulated. The previous method of stiffness assignment used by WinSmash 2007 required the assignment of a numerical stiffness category to each vehicle based on the vehicle body style and wheelbase. One of the difficulties associated with this method was that it relied on the user's knowledge of the exact range of wheelbases and body styles for each category.

A new, automated stiffness selection process was added in WinSmash 2008 to reduce some of the difficulties associated with WinSmash 2007. Rather than rely on the assignment of a numerical stiffness number by the crash investigator, WinSmash 2008 automatically assigns stiffness values based on the vehicle damage side, wheelbase, and body style. WinSmash 2008 first attempts to retrieve vehicle specific stiffness values from the new library of vehicle stiffness values. If this is not successful, WinSmash 2008 will then automatically select the appropriate stiffness category.

The changes made to WinSmash 2008 may have a significant effect on the NASS delta-V distributions. This change could have important policy repercussions, as the delta-V predictions made by WinSmash and published in the NASS/CDS database are widely used by NHTSA and other crash safety groups to define crash safety problems and evaluate countermeasure effectiveness. If the delta-V distributions predicted by the new WinSmash do not agree with the previous versions, the validity of research conducted using the previous versions of NASS/CDS based on older versions of WinSmash may need to be re-examined.

## **Objective**

The objective of this study was to determine how the WinSmash 2008 enhancements will affect the distributions of delta-V in NASS/CDS. Because the delta-V estimates for the 2007 case year were computed using WinSmash 2007, this study is effectively a comparison of WinSmash 2007 and WinSmash 2008.

## **METHODS**

The approach was to select one NASS/CDS case year and recompute all delta-Vs for that case year with WinSmash 2008. The WinSmash 2008 results would then be compared to the results stored in NASS/CDS. The NASS/CDS 2007 case year was selected as a reasonably sized pool of cases upon which to run the WinSmash comparison. Results for this case year were computed using WinSmash 2007. The raw data for 2,762 collisions, involving 4,859 vehicles, were

collected from the NHTSA Electronic Data System (EDS). The EDS is an internal, non-public database maintained by NHTSA which contains information used to generate the publically available NASS/CDS SAS tables. The EDS database contained all of the WinSmash input parameters needed to compute delta-V for each NASS/CDS case.

To facilitate comparison of the two versions, each collision in NASS EDS that was ranked as the most severe impact and for which WinSmash results were available was computed in both WinSmash 2007 and WinSmash 2008. The WinSmash versions used for this study were WinSmash 2007 (v2008.1.10) and WinSmash 2008 (v2008.11.24.0). The WinSmash 2008 stiffness library release date was 5-15-2009.

## **Computing the WinSmash results**

After the collection and assembly of all the data elements needed to run WinSmash, the next step was to calculate the WinSmash 2007 and WinSmash 2008 results for each run. A program was developed with the ability to read a database containing the raw WinSmash data collected from the EDS. Then the program would run both WinSmash 2007 and 2008 on the data and assemble the results. Each result set contained the total, longitudinal, and lateral delta-V, as well as the absorbed energy. For each run, this program would report three sets of results: the original results as saved in NASS/CDS, the WinSmash 2007 results as recalculated by the program, and the WinSmash 2008 results.

Both WinSmash 2007 and WinSmash 2008 possessed several options for calculating delta-V, referred to as calculation types, which allowed a greater degree of flexibility in situations where some vehicle information was missing. The available calculation types (also called runs, which is analogous to collisions) were:

- Standard Run – Two fully defined vehicles
- Barrier Run – One fully defined vehicle and one fixed, non-deforming object
- CDC (Collision Deformation Code) Only Run – One fully defined vehicle and one CDC only vehicle
- Missing Run – One fully defined vehicle and one missing vehicle

Fully defined vehicles are characterized by a CDC and a crush profile. A CDC only vehicle is similar, but lacks the crush profile, which WinSmash approximates from the CDC. Missing vehicles have the least information available as both the CDC and crush profile are unknown. The amount of vehicle

information available usually decides which calculation type will be used, i.e. if one vehicle is missing then only a missing run can be calculated.

The WinSmash calculation type used to compute the delta-V for each run was not recorded in the NASS EDS. Thus, it was necessary to find a way to determine which calculation type (Standard, Missing, Barrier, or CDC Only) was used to generate the results. Our approach was to try all possible calculation types until the correct type was found (the matching process is further discussed in the validation section below).

**Validation**

Before any comparisons between the WinSmash 2007 and 2008 were made, the recomputed WinSmash 2007 results were validated against the results saved in the NASS/CDS tables. This step verified that the WinSmash 2007 input data was correctly reassembled to reproduce the same results as were stored in NASS/CDS.

The first part of the validation was a comparison of the absorbed energies of both vehicles in the collision. If even one vehicle energy value differed by more than two joules, then the reconstructed WinSmash run was considered invalid. All runs for which the energies could not be matched were separated from the analysis. In total, 89 runs were rejected due to the inability to reproduce the recorded energy values.

Due to flexibility in the assignment of stiffness categories by the investigators, the energies of the vehicles as stored in the NASS/CDS did not always match with the recalculated energy for 109 runs. This had the greatest effect on utility vehicles and a smaller effect on vans. Utility vehicles in particular were overrepresented in the group of runs for which energies could not be matched, due mostly to deviances in stiffness category assignment. Energy mismatches were biased toward both front and back impacts. Utility vehicle side impacts were the least affected, most likely due to the simpler stiffness category selection process. A small number of car impacts also made this list, but the reasons could not be determined.

In addition to matching by energy, the NASS/CDS results were also verified by total delta-V. Any run for which the recomputed WinSmash 2007 total delta-V did not exactly match the NASS/CDS delta-V for all vehicles was removed from the analysis. A total of 423 runs were removed due to unmatched

delta-V values, leaving 1,808 runs involving 3,201 vehicles with validated energies and delta-Vs.

With the NASS/CDS results validated, the final comparison between the NASS/CDS and WinSmash 2008 delta-Vs could be made. For groups of vehicles, the percent difference between the WinSmash 2008 total delta-V values and the WinSmash 2007 total delta-V values was computed using a least squares fit to the data. All trendlines were linear and forced to pass through the point (0, 0). The trendline equation takes the form of

$$y = mx$$

Where the value of (m – 1) represents the average percent change in delta-V values between NASS/CDS 2007 and WinSmash 2008.

**RESULTS**

The make-up of the successfully matched WinSmash runs is summarized in Table 1 and Table 2. The most common run type was standard runs at 41%. The majority of the vehicles were cars (62.2%) and the most common general area of damage (GAD) was the front. For slightly more than half of the vehicles (60.4%), the vehicle specific stiffness values were used.

With the WinSmash 2007 and WinSmash 2008 results computed for all 1,808 runs, the differences in the delta-V distribution were calculated. The resulting distribution is shown in Figure 1 and Figure 2. As shown in Figure 2, the delta-V predicted by WinSmash 2008 was found to be about 7.9% higher on average. This corresponded to a 1.9 kph (or 1.2 mph) increase on average for each vehicle.

Table 1 – Composition of the dataset by WinSmash run type

	<b>Total</b>	<b>%</b>
<b>WinSmash Run Type</b>		
Barrier	415	23.0%
CDC Only	10	0.5%
Missing Vehicle	643	35.6%
Standard	740	40.9%
<b>Total</b>	<b>1808</b>	<b>100.0%</b>

Table 2 – Composition of the dataset by vehicles

	Total	%
<b>Total # of Vehicles</b>	3201	
<b>General Area of Damage</b>		
Back (B)	393	12.3%
Front (F)	1930	60.3%
Side (R, L)	878	27.4%
<b>Body style</b>		
Cars	1990	62.2%
Pickup Trucks	403	12.6%
Utility Vehicles	594	18.5%
Vans	214	6.7%
<b>Stiffness Source</b>		
Categorical	1268	39.6%
Vehicle Specific	1933	60.4%

The spread was very large for individual runs. Decreases of -50% and increases of +100% were the largest observed. The more extreme values were typically associated with the use of the WinSmash missing vehicle calculation type.

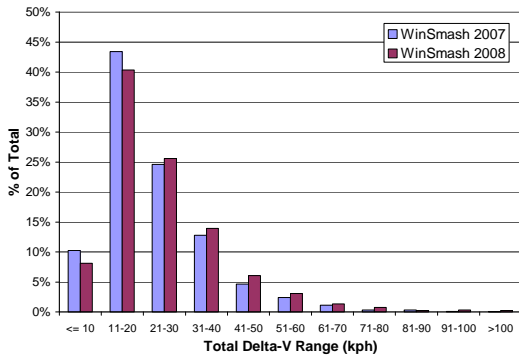


Figure 1 - Delta-V distributions for WinSmash 2007 and WinSmash 2008

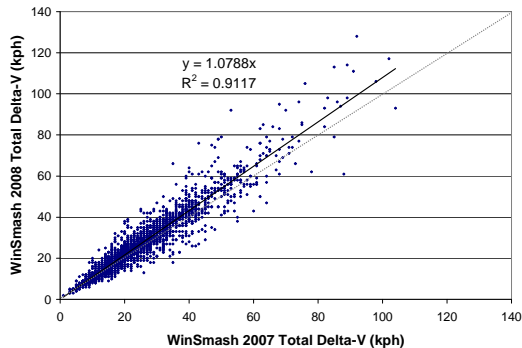


Figure 2 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V

Previous research [Niehoff and Gabler, 2006] indicated that the accuracy of WinSmash was

dependent on vehicle type. Table 3 and Figure 3 show the breakdown for all vehicle delta-Vs by vehicle type. Pickup trucks showed the smallest increase (3.3%) while utility vehicles increased the most (9.6%). In previous versions of WinSmash, utility vehicles and vans were always lumped together into the same category, so it was not surprising that both groups of vehicles showed similar increases.

Table 3 - Delta-V changes by vehicle type

	% Change	Correlation (R <sup>2</sup> )
Cars	8.3%	0.918
Pickup Trucks	3.3%	0.889
Utility Vehicles	9.6%	0.899
Vans	8.5%	0.916

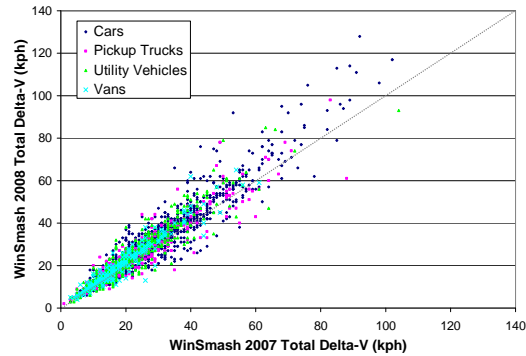


Figure 3 – Results by vehicle type

The data were next broken down by calculation type in Table 4 and Figures 4 - 7. There was little variation in average delta-V change by run type. Barrier and standard runs showed increases between 8.3% and 8.7%. Missing vehicle runs increased by 6.4%. CDC only runs were the exception with a 13.1% increase, but there were very few CDC only runs.

Table 4 - Results by WinSmash Run Type

	# of Runs	% Increase
Barrier	415	8.3%
Standard	740	8.7%
Missing Vehicle	643	6.4%
CDC Only	10	13.1%

Most of the run types showed strong correlation between the WinSmash 2007 and WinSmash 2008 delta-V (R<sup>2</sup> above 0.93). The exception was the missing vehicle runs, which showed a larger degree of variability, dropping the R<sup>2</sup> score for these runs to 0.83. From Figure 6, it can be seen that most of the greatest changes in delta-V were associated with the missing vehicle run type.

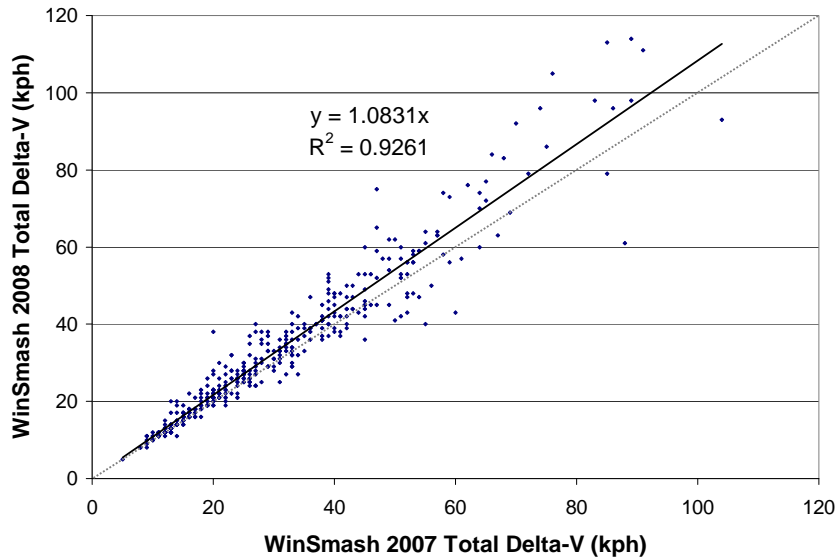


Figure 4 – WinSmash 2008 vs. WinSmash 2007 delta-V for all barrier runs

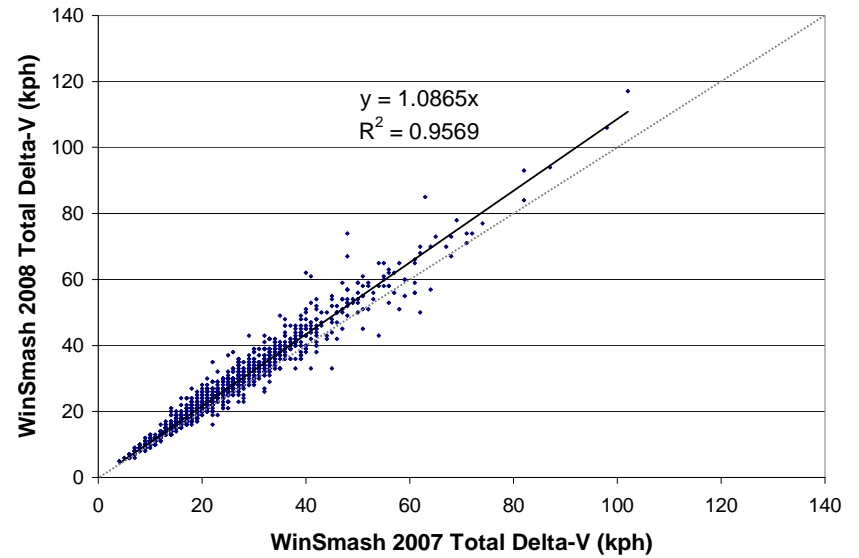


Figure 5 - WinSmash 2008 vs. WinSmash 2007 delta-V for all standard runs

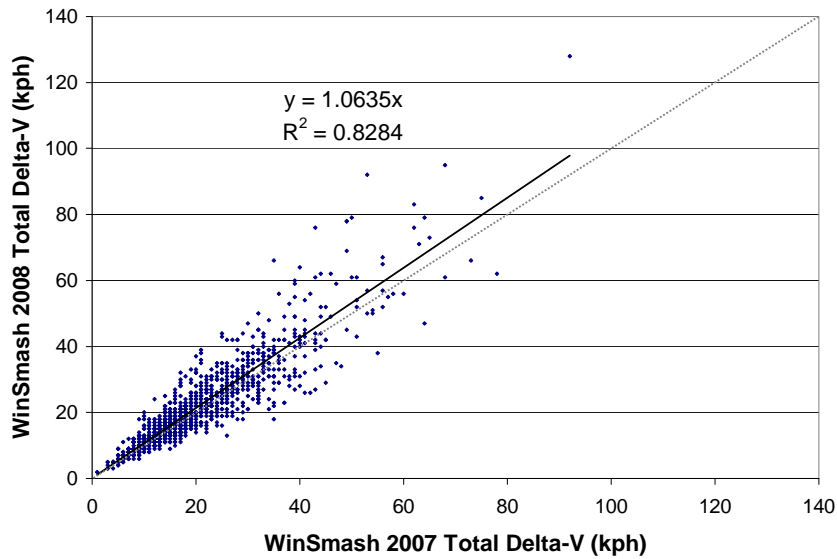


Figure 6 - WinSmash 2008 vs. WinSmash 2007 delta-V for missing vehicle runs

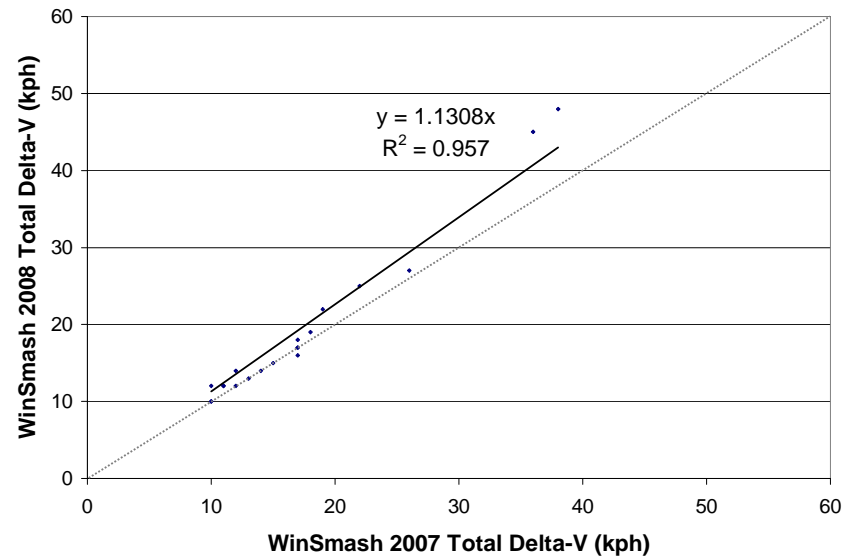


Figure 7 – WinSmash 2008 vs. WinSmash 2007 delta-V for all CDC only runs

### Delta-V Changes by General Area of Damage

Vehicle stiffness values vary by the side on which the damage occurs (front, side, back), called General Area of Damage (GAD) in NASS/CDS and damage side in WinSmash. Therefore, any difference in delta-V between the two versions of WinSmash could also vary by GAD. WinSmash runs using the barrier calculation type were useful because these crashes involve only one vehicle and thus there was no secondary vehicle to influence the delta-V results of the first vehicle. The results for all 415 barrier runs are shown in Table 5 and Figure 8. The delta-V results were found to vary greatly by the GAD. Back impacts showed a small change (3.0%) while side impacts showed a larger increase (11.5%) that was higher than the 8.0% average increase for frontal impact barrier runs.

Table 5 - Average delta-V increase by GAD and run type

	Front	Side	Back	# of Runs
All Runs	8.1%	8.3%	5.3%	1808
Barrier	8.0%	11.5%	3.0%	415
Standard	8.6%	10.7%	4.6%	740
Missing Vehicle	7.4%	3.9%	6.6%	643
CDC Only	16.4%	7.8%	2.3%	10

All of the WinSmash runs as a whole showed delta-V trends that were similar to those for barrier runs, although less pronounced. All side impacts increased by 8.3% on average and back impacts increased only 5.3% on average. Front impacts increased by 8.1%. Standard runs, also shown in Figure 9, showed similar increases.

CDC only runs showed the largest increases in delta-V for frontal impacts. Delta-V increases for missing vehicle runs were the most consistent across all GADs. Missing vehicle runs were the largest contributors to delta-V increases in back impacts with a 6.6% increase. The largest increase in delta-V was from CDC only vehicles struck in the front at 16.4%, but the results for CDC only vehicles were unreliable due to the small sample size.

One limitation of analyzing the delta-V results by the GAD of one vehicle was that most delta-V results were affected by the other vehicle in the crash. This was especially true for missing vehicle runs, which rely heavily on the fully defined partner vehicle's energy and relative stiffness to generate the missing vehicle results. Table 6 was created to observe the changes in delta-V by GAD pairings rather than by looking at individual GADs.

For standard runs, the data trends in Table 6 matched up with the trends shown in Table 5, i.e. the greatest increases were observed for side impacts and the smallest increases for back impacts. The data points for this analysis are shown in Figures 12 - 15. For standard runs, the increase in delta-V for all front-to-side crashes was 11.1%, less than side-to-side which increased by 15.2%, but higher than front-to-front which increased by 7.3%. Side-to-back impact was the only crash configuration to result in a delta-V decrease, although this may have been due to the small sample size.

The delta-V breakdown for missing vehicles was not as clear. The results from Table 5 suggested that the delta-V increases would be fairly consistent for all of the damage pairs. However, in Table 6 the changes in delta-V varied widely. The average increases for front-front and side-side pairs were large (13.4% and 15.5% respectively). However, the change in front-side pairs was well below that of any other run type. The missing vehicle results might be explained by examining which vehicle a GAD is associated with. To determine whether this was the case, the missing vehicle data was more closely examined.

Table 6 - Average delta-V change for WinSmash runs (excluding barrier runs) by damaged side pairs

	All Types	Standard	Missing Vehicle	CDC	Total Runs
F - F	9.0%	7.3%	13.4%	21.5%	256
F - S	7.6%	11.1%	3.0%	11.2%	734
F - B	6.2%	4.9%	7.4%	1.4%	363
S - S	15.2%	15.2%	15.5%	14.0%	32
S - B	-3.7%	-3.8%	-3.7%	0.0%	8
Total Runs	1393	740	643	10	1393

Unlike standard runs, missing vehicle runs were asymmetric. In Table 7 and Figures 16 - 18, the results by missing vehicle GAD and the partner vehicle GAD are presented. The delta-V increases varied by a large amount. For example, a missing vehicle struck in the side by the front of a fully defined vehicle resulted in a 0.9% decrease in delta-V whereas a fully defined vehicle struck in the side by the front of a missing vehicle resulted in a 10% increase in delta-V. The same pattern was observed for side-to-back and front-to-back impacts as well. Thus, the missing vehicle runs were very asymmetric in that the results were strongly dependent on which vehicles the GADs were associated with.

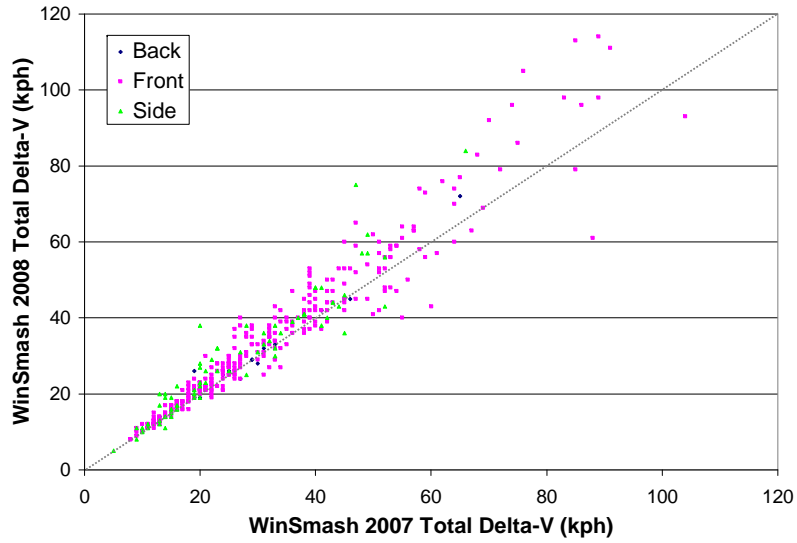


Figure 8 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for barrier runs by GAD

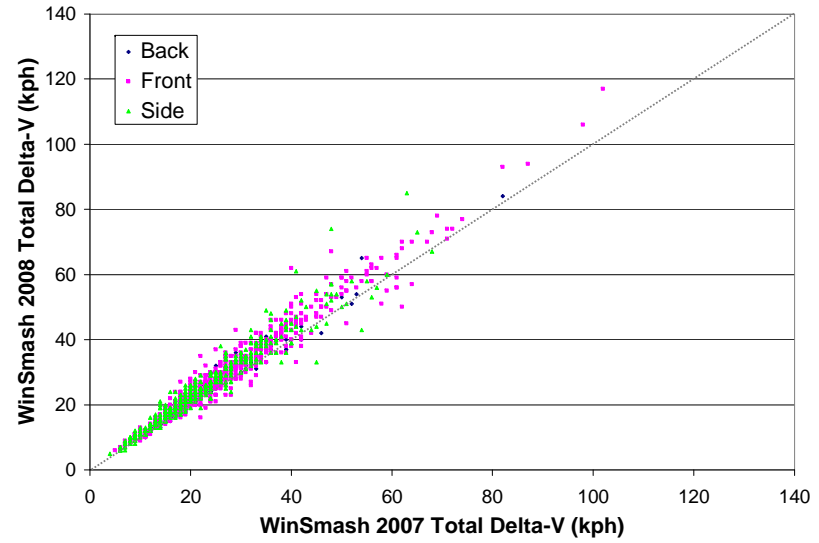


Figure 9 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for standard runs by GAD

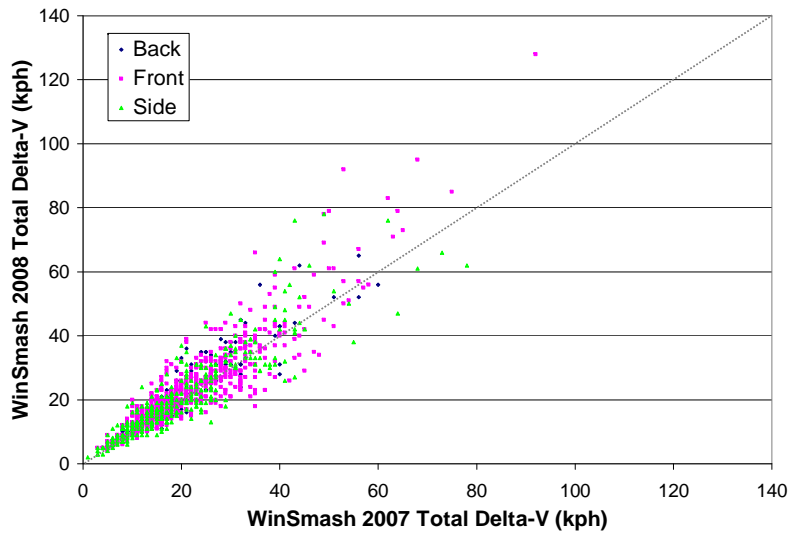


Figure 10 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for missing vehicle runs by GAD

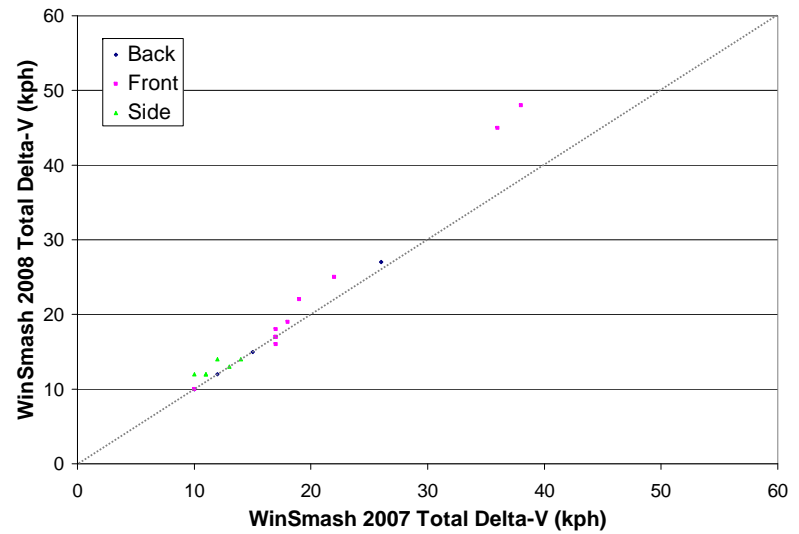


Figure 11 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for CDC only runs by GAD

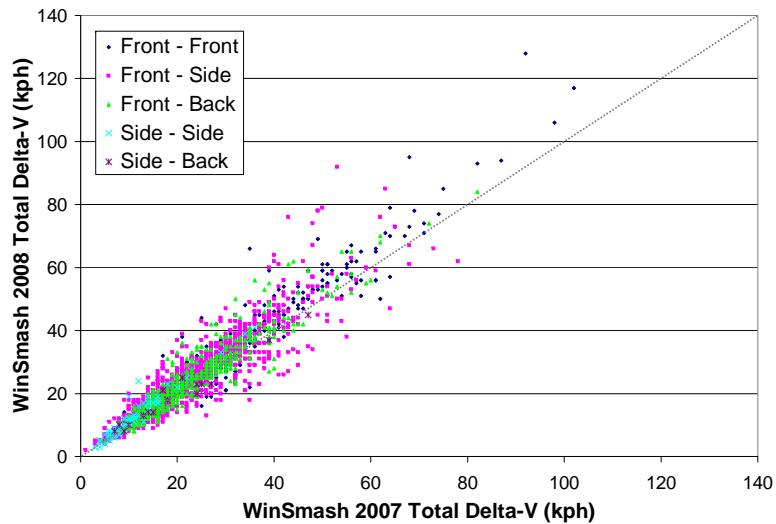


Figure 12 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for all runs by GADs

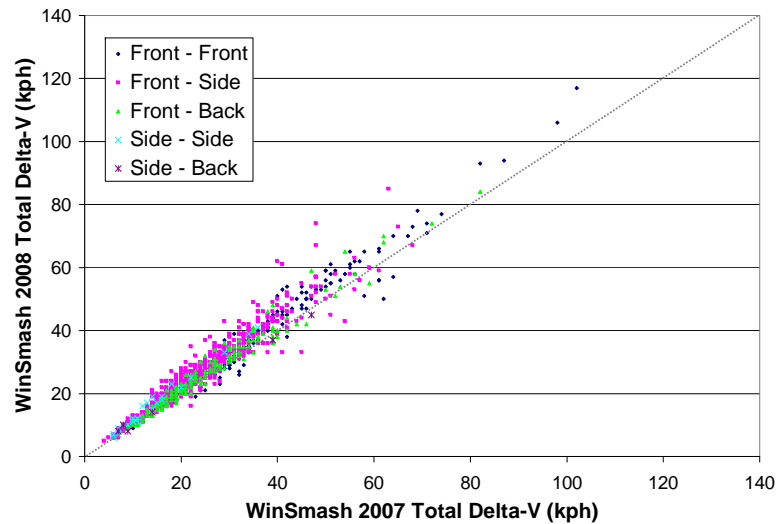


Figure 13 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for standard runs by GADs

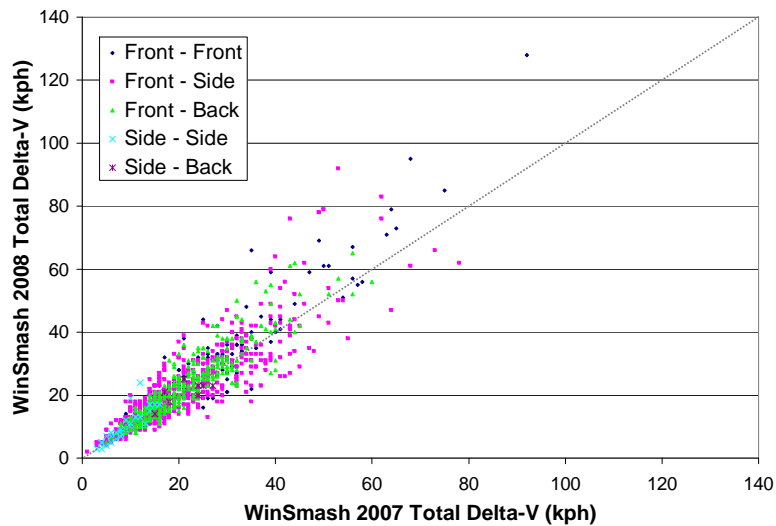


Figure 14 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for missing runs by GADs

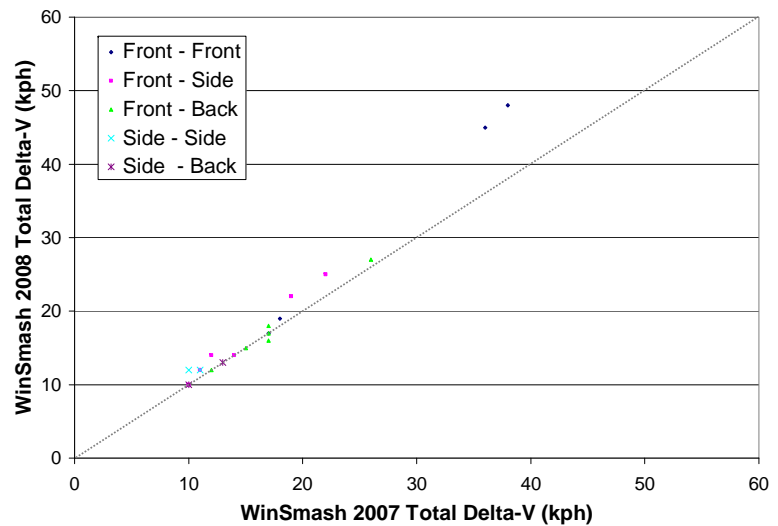


Figure 15 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for CDC only runs by GADs

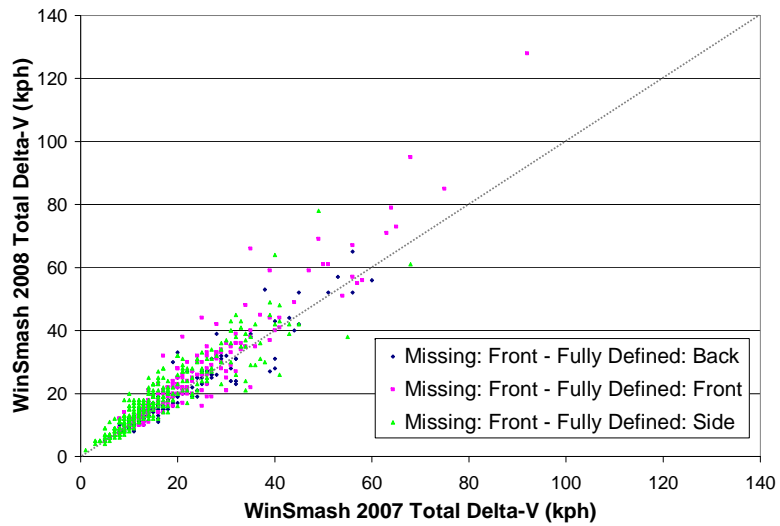


Figure 16 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for missing vehicle runs (GAD = F)

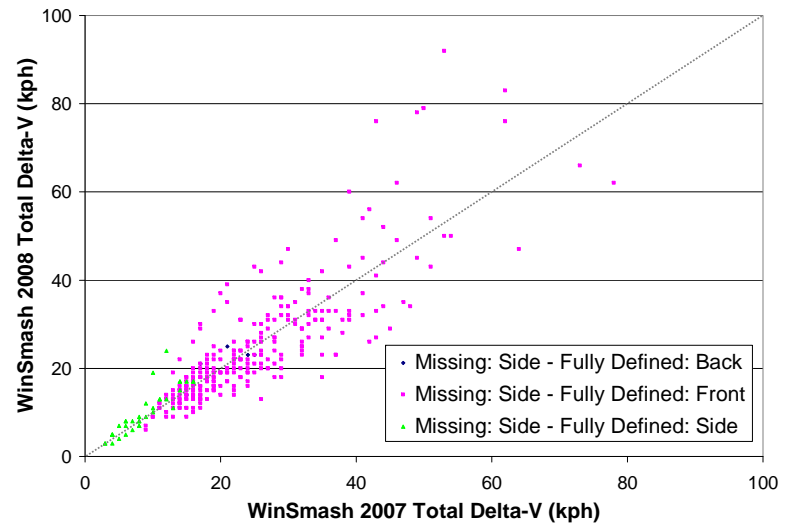


Figure 17 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for missing vehicle runs (GAD = S)

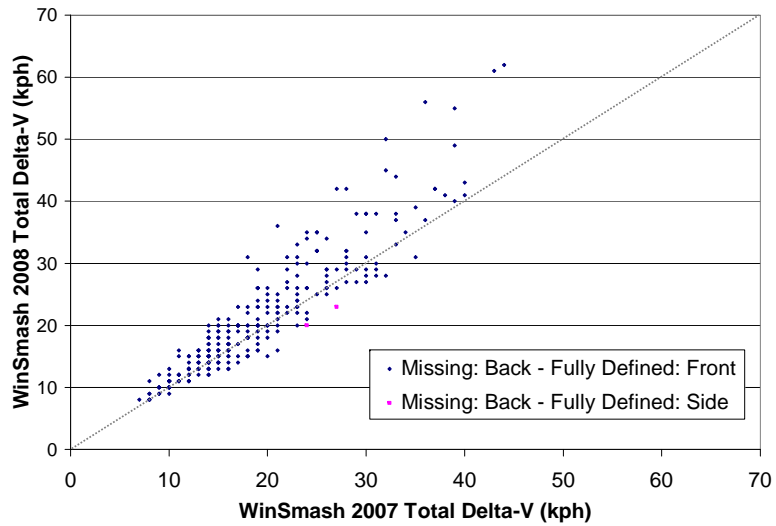


Figure 18 - WinSmash 2008 delta-V vs. WinSmash 2007 delta-V for missing vehicle runs (GAD = B)

Table 7 - Average delta-V change for missing vehicle runs by GADs

		Fully Defined Vehicle GAD			Total Runs
		Front	Side	Back	
Missing Vehicle GAD	Front	13.4% (n=82)	10.0% (n=179)	-0.4% (n=78)	8.9% (n=339)
	Side	-0.9% (n=145)	15.5% (n=18)	2.5% (n=3)	-0.6% (n=166)
	Back	12.6% (n=137)	-15.6% (n=1)	NA	12.3% (n=138)
Total Runs		6.6% (n=364)	9.9% (n=198)	-0.3% (n=81)	643

### Effect of Using Vehicle Specific Stiffness Values

Given that WinSmash 2008 used a different stiffness selection procedure than WinSmash 2007, it was possible that changes in the delta-V results could be biased toward vehicles for which vehicle specific stiffness values were available. A subset of the data was collected containing 774 runs including 1,265 vehicles. This group contained 675 unique vehicles or roughly 13% of the vehicles in the library. The vehicles in this dataset used vehicle specific stiffness values. All of these runs were recomputed in WinSmash 2008, this time forcing the use of categorical stiffness values. Both sets of results (vehicle specific and categorical) were compared against the original NASS/CDS results as recomputed with WinSmash 2007.

Table 8 - Delta-V changes using vehicle specific stiffness

	Average % Increase	# of Vehicles
All Vehicles	7.6%	1265
Standard Runs	7.2%	526
Barrier Runs	7.8%	283
CDC Only Runs	6.0%	4
Missing Runs	8.1%	452

Table 9 - Delta-V changes using categorical stiffness

	Average % Increase	# of Vehicles
All Vehicles	7.7%	1265
Standard Runs	9.0%	526
Barrier Runs	8.1%	283
CDC Only Runs	6.0%	4
Missing Runs	5.1%	452

The average delta-V changes (with respect to the NASS/CDS 2007 delta-Vs) were broken down by the stiffness source, as shown in Table 8 and Table 9. Table 8 shows the average delta-V increases for vehicles using vehicle specific stiffness values in WinSmash 2008. Table 9 shows the average delta-V changes for vehicles using categorical stiffness.

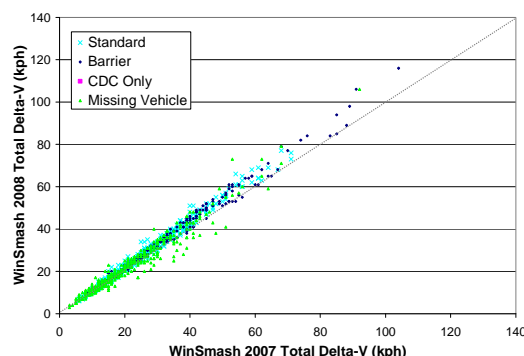


Figure 19 - Delta-V using categorical stiffness in WinSmash 2008

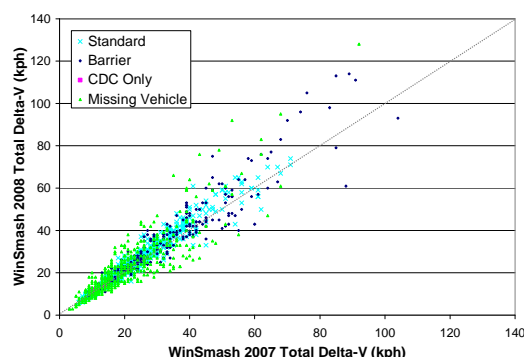


Figure 20 - Delta-V using vehicle specific stiffness in WinSmash 2008

Despite the potentially large differences in stiffness values between the vehicle specific and categorical sources, the changes in the overall delta-V were small (7.6% vs. 7.7%). The difference in average delta-V between the two groups was less than 0.3 kph. CDC only and barrier runs showed the least change in delta-Vs. When using different stiffness sources, the missing vehicle runs differed by 3%. When using categorical stiffness, the largest increases were observed in standard runs, while the largest increases for vehicle specific stiffness were associated with the missing vehicle runs.

One difference between the two sets of data that was not shown by the above table was the range by which an individual case would differ from the average. In Figure 19, all of the vehicle data used for the categorical analysis is shown. The correlation value,

$R^2$ , was 0.979 for this set of data, indicating that there delta-V predictions were consistent.

Figure 20 readily showed much more scatter with a 0.886  $R^2$ . The greater degree of variability was directly related to the greater variation in the vehicle specific stiffness values. The runs with the largest changes in delta-V tended to be missing vehicle runs. Missing vehicle runs were in general more susceptible to large changes in delta-V because the missing vehicle energy was calculated from the stiffness values of the two vehicles. However, the differences between the vehicle specific and categorical stiffness approaches tended to disappear as the number of runs became large.

## DISCUSSION

WinSmash 2008 was designed to have improved stiffness values and stiffness assignment procedures. Use of this new version had raised the question as to how the delta-V distributions of future NASS /CDS case years would differ from the previous years. To answer this question, the results for 1,808 runs from the NASS 2007 case year were recomputed using WinSmash 2007 and WinSmash 2008. The resulting data, shown in Figure 1 and Figure 2, indicated that WinSmash 2008 predicted delta-Vs 7.9% higher on average than WinSmash 2007, or 1.9 kph higher per case.

The spread was very large on an individual run basis, ranging between -50% and +100%. Many of the more extreme variations were due to the new stiffness selection process. Vehicle specific stiffness values, which pertain to only a single vehicle, can differ enormously from categorical stiffness values created by averaging many vehicles.

In a previous study by Niehoff (2006), it was reported that older versions of WinSmash underestimated the delta-V by 20% on average. When broken down by vehicle type, the study found that pickup trucks were underestimated by 3%, vans and utilities by 22%, and cars by 31%. With WinSmash 2008, the delta-V for all vehicle types has increased. Referring back to Table 3, the new accuracy of delta-V was computed. Pickup trucks, which experienced a 3.3% increase in delta-V, should now be within 1% of the true delta-V. On the other hand, predicted delta-Vs for vans and utilities were improved but were still underestimated by about 12% and cars were still greatly underestimating the delta-V by 23%.

GAD was found to have an important effect on the changes in delta-V for WinSmash 2008. An analysis

by individual vehicles, summarized in Table 5, revealed that side impacts tended to show the largest increases (8.3%) and back impacts generally showed the smallest increases (5.3%). A critical problem with this approach was that the other run types (standard, missing vehicle, and CDC only) all involve two vehicles, each of which can influence the other vehicle's results.

For runs involving more than one vehicle, the changes to the delta-V were broken down further by damage pairs in Table 6. For standard runs, the results were as expected. Delta-V in side-to-side impacts increased by 15.2%, while delta-V for front-to-front-impacts increased 7.3%, and any configuration that involved a back impact showed the lowest, or even a negative, change in delta-V. However, the results for missing vehicles did not follow this pattern due to the asymmetric nature of the missing vehicle runs.

Unlike standard runs, both missing vehicle and CDC only runs were asymmetric, in the sense that both types of runs involved a fully defined vehicle and another vehicle that was missing some amount of information. Thus, the delta-V changes will be different depending on which vehicle was struck in which side. It also depended on which vehicle was fully defined and which was a CDC or missing vehicle. Table 7 shows the results for missing vehicle, broken down by GAD permutations. It was assumed that the CDC only runs would have shown a similar asymmetric distribution. However, there were only 10 CDC only runs available, which was not enough to perform the analysis.

The use of the vehicle specific stiffness values had a minor effect on the overall change in delta-V, although results for individual runs could vary greatly. This was an expected result since the categorical stiffnesses were generated by averaging many vehicle specific stiffnesses. There was also little variation by run type. Missing vehicle runs were the most susceptible to extreme changes in delta-V. This was because the missing vehicle results depend on the ratio of vehicle stiffness values.

## CONCLUSION

The use of WinSmash 2008 resulted in an increase in the average delta-V when used to recompute the results of the NASS/CDS 2007 case year. All of the results in NASS/CDS 2007 were originally computed with WinSmash 2007. For the 1,808 runs in this study, the average increase in delta-V was 7.9% per vehicle. This was a 1.9 kph, or 1.2 mph, increase. Given that previously published literature indicated

that WinSmash underestimated delta-V by 20% on average, the changes in WinSmash 2008 represent an improvement in the delta-V estimates, although WinSmash still underestimates delta-V by roughly 11%.

- The increases in delta-V were relatively consistent across all vehicle types, except for pickup trucks. In order of magnitude, delta-V for utility vehicles increased 9.7%, vans 8.5%, cars 8.3%, and pickup trucks 3.3%.
- The results for barrier runs were broken down by general area of damage (GAD). The changes to delta-V were found to vary greatly by the side of damage. Delta-V for side impacts increased the most (8.3%), followed by frontal impacts (8.1%). Back impacts showed smaller increases in delta-V (5.4%). A similar pattern was observed in the standard runs, but not in the CDC or missing vehicle runs.
- The changes in delta-V varied widely by collision mode. Side-to-side impacts showed a large increase in delta-V (15.2%). Collision modes involving at least one front impact showed more moderate increases (6.2% to 9.0%). Side-to-back impacts were the only mode to show a decrease (-3.7%).
- The changes in WinSmash 2008 will result in a discontinuity between the average delta-V in NASS/CDS 2008 and the earlier years.

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