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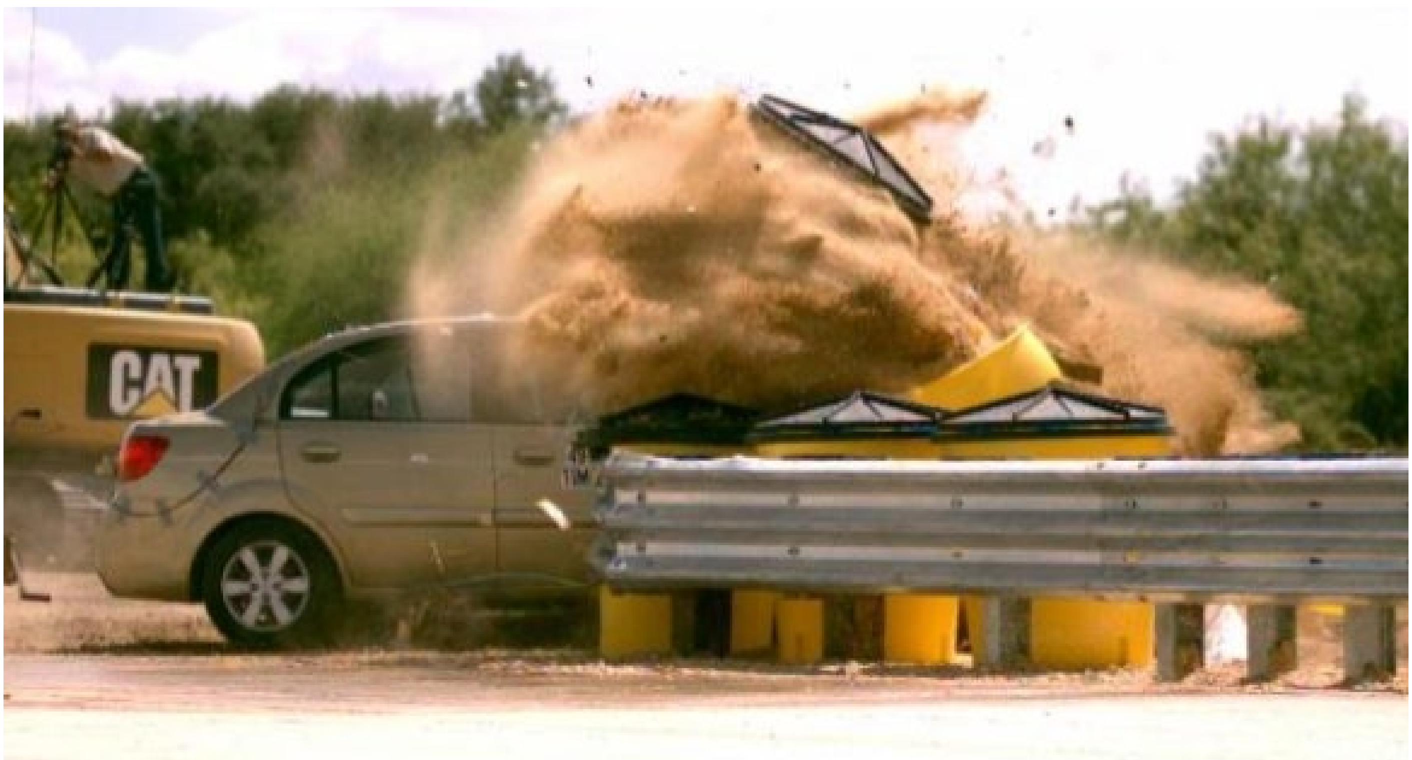

ACCIDENT RECONSTRUCTION JOURNAL

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FEDERAL SHUTDOWN SLOWS PROBES OF TRANSPORTATION DEATHS

Because of the partial federal government shutdown, 10 new crashes in which 22 people died have not been investigated by the National Transportation Safety Board.

The nation's top transportation oversight investigative agency has been unable to study the circumstances of seven plane crashes in which 13 people were killed, two fatal railroad crashes, a highway crash in which seven people died and an incident in which a school bus collided with a tractor-trailer, injuring 15.

The NTSB also was unable to gather enough information to determine whether to send investigators to three other crashes — two on roadways and one on rails — that killed eight people.

"The National Transportation Safety Board's mission to promote safety in transportation has come to almost a complete halt because of this absurd government shutdown," said Rep. Peter A. DeFazio (D-Ore.), the new chairman of the House Transportation Committee. "This means dozens of ongoing investigations are sitting idle, and that numerous accidents that have occurred since the shutdown are not getting investigated.

"When NTSB employees cannot determine what caused an accident, we can't establish how to prevent similar accidents from happening," DeFazio said. "For the safety of all those who travel within our country, we must reopen the government."

Dolline Hatchett, acting director of the NTSB's Office of Safety Recommendations and Communications, said the agency's investigators have been furloughed and it is unable to go to "major accidents, as well as other accidents where specific risks to transportation safety exist."

NTSB investigators routinely are sent when planes and trains are involved in fatal crashes, and they often are dispatched to look at vehicle crashes such as the October limousine crash in Upstate New York that killed the driver, his 17 passengers — including four sisters and three of their husbands — plus two pedestrians.

Since the shutdown began, the agency has been unable to send teams to fatal small-plane crashes in Georgia, Florida, South Dakota, Tennessee and California. Two fatal rail crashes in New York have not been scrutinized by the agency. Neither has a Jan. 3 highway collision involving two tractor-trailers in a crash with a 15-passenger van that resulted in seven deaths. *- Washington Post*

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CRUSH FACTOR: A VALIDITY ANALYSIS - PART I (FRONTAL)

by Daniel W. Vomhof III and Daniel W. Vomhof, PhD

Background

4N6XPRT Systems began selling the Expert AutoStats® program in December 1991. As part of that program a set of "Crush Factor" values was published. These values were the summary of data analysis performed by the authors independently and jointly. None of the in-depth background analysis used to arrive at the Crush Factor values was published at that time or subsequently. However, a brief discussion of the authors' efforts was presented at the "Crash 98" conference.

The approach of calculating speed from crush using the speed from skid formula:

$$S = \sqrt{30*d*f}$$

Where: S = Speed in miles per hour,
f = drag factor
d = distance in feet

was originally 'suggested' to the authors in the "Traffic Accident Investigation Manual" by J. Stannard Baker. [Ref. 1] One of the tables on page 245 in that First Edition was titled "Typical Values of Acceleration and Deceleration for Motor Vehicles on Level Surfaces". Two lines were found at the bottom of that table are presented here in Table 1.

No discussion as to how these factors were arrived at was presented in the manual. The authors found that the value of -5 for a vehicle-to-vehicle impact was much lower than was practical based on vehicle reconstructions when they used this approach. However, in many of the reconstructions where they had other independent ways of calculating vehicle speeds other than using the crush, such as momentum, the values obtained using the -20 value seemed to be in reasonable agreement with the other methods. The authors found that depending upon both the physical evidence and the "fact" situation, a Crush Factor of between 15-22 to calculate a speed from crush matched well with other speed estimates in nearly every situation.

The Crush Factor is obtained/calculated in the same manner as a drag factor:

$$CF = \frac{S * S}{MID*30}$$

Where: S = Speed in miles per hour,
CF = Crush Factor,
MID = Maximum Indentation Depth (in feet)

The NHTSA Crash tests, as published in the *Accident Reconstruction Journal* [Ref. 2-6] as well as crash test data published by Engineering Dynamics Corp, [Ref. 7] were analyzed to find an independent Crush Factor Value based on crash tests as opposed to a value which was to a certain extent "force fit" into a crash reconstruction. Much of the data published by Engineering Dynamics was for vehicles older than the vehicles contained in the NHTSA crash test database, [Ref. 8] which is important for reconstructionists who work in areas outside of the snow/rust belt of the United States where vehicles are on the road for 10, 20, 30, and more (sometimes MANY more) years after they were originally sold.

Since the value in question was being used to evaluate Speed from Crush, the authors retitled the value "Crush Factor" in order to separate it from a speed from skid (and because it avoided the question of what was dragging across what).

The analysis of the various crash test data previouslyreferred to found that the tests tended to group about a Crush Factor of 21. Using a Crush Factor value of 21 in a back calculation of speed in each of the tests resulted in a calculated speed within +/- 5 mph of the recorded test closing speeds for the vast majority of the tests. The round number of CF=21 for frontal damage was used, in part, because:

- it was based upon known crash tests,
- it could be easily checked by others in the accident reconstruction community,
- it was usable in a commonly recognized formula,
- it was EASY to use...ESPECIALLY while on the witness stand or in a deposition,
- a whole number, as opposed to a number with decimals attached, was easy to remember,
- it was felt it would be of benefit to others in the accident reconstruction community, and
- it was independent of make, model, year, or body style of vehicle where the GVWR was under 10,000 pounds

TABLE 1. Typical Values of Deceleration for Motor Vehicles on Level Surfaces [Ref. 1]			
Deceleration Type	**Drag Factor**	**Meters/sec/sec**	**Feet/sec/sec**
Car Crash into Standing Car	5.00	49.01	161.0
Car Crash into Solid Fixed Object	20.00	196.0	644.0

Since originallypublishing the Crush Factor values there has been some resistance in certain quarters to using the approach, for one or more of the following reasons:

- it's too simple,
- one stiffness value cannot possibly be valid for all vehicles,
- the approach becomes erratic when minimal crush is present.

Thus, it was felt that it was time to re-evaluate the Crush Factor value both to give more background to the value AND to see if it had changed significantly since the original work was completed 33 years ago.

Analysis Process and Assumptions

In order to generate the initial data groups the 4N6XPRT StifCalcs® program was used to search the NHTSA Crash Test database (as downloaded on May 12, 2017) for all frontal crash tests in the database. One data set was developed based on the calculated AVERAGE crush, the other based on the MAXIMUM crush. Figure 1 and Figure 2 show the Average Crush data summaries.

It can be seen that the total number of frontal impact tests available where average crush can be calculated is 3045 tests.

The speed used for the stiffness calculation is the Kinetic Energy Equivalent Speed (KEES) rather than the Closing Speed. In the event that the vehicle is moving and strikes a fixed barrier, KEES = Closing Speed. However, when a barrier is moving and impacts the vehicle, the KEES needs to be used instead of the Closing Speed, as the Closing Speed will be erroneously high. The authors define the Kinetic Energy Equivalent Speed as the Kinetic Energy required to create the damage expressed as a speed.

The data was then imported into an Excel spreadsheet for further analysis and filtering.

The 4N6XPRT StifCalcs® program provides test summaries with the statistical measurements of the data set of: Number of tests, Average, Minimum, Maximum, and Standard Deviation (Sample). The Average value output by the program is the Arithmetic Mean value of the data. By using the Excel program the analysis can add the additional AVERAGE measurement methods of MEDIAN - the central value of the data set, MODE

- the most commonly occurring value in the data set, and QUARTILE 2 - the 50% value of the data set, which is also the MEAN. Further use of the Excel spreadsheet allows display of Quartiles 0-4 from which we can quickly see the values within the data set of various data points at the minimum (Q0), 1/4 point (Q1), ½ point (Q2), 3/4 point (Q3) and the maximum (Q4). Finallywe can easily displaythe Standard Deviation value spread from the AVERAGE (Mean) value rather than having the reader do the calculations in their head. In each case the Standard Deviation value used for this display is the SAMPLE Standard Deviation. Where the "A" stiffness value was negative, the A-B-G stiffness values were deleted but the test as a whole was retained as the data for a Crush Factor was still available. Where the Kv stiffness values were negative those values were also deleted.

When the analysis of the Crush Factor is broken down by body style, an additional filter of an upper threshold value for the "A" stiffness value is applied. The values applied are based on the calculation of A-B-G stiffness values and application of those values to vehicles involved in crash tests for hundreds of vehicles.

The A value is commonly defined as ***"A = Maximum force per inch of damage without permanent damage"***. This can be confirmed through unit analysis. Restated, when the Force per inch of crush length exceeds that shown in the A value, you will have permanent crush, when the Force is less than that shown in the A value, you will see no damage post impact. Values above the filter thresholds applied are usually indicative of measurement errors and/or "air gap" issues within the data.

Additional discussion of the A value filter and why the particular values were chosen is present in the discussion of each body type data set.

To help the reader quickly see various items, the Crash III "A" value column and the Crush Factor column have been highlighted with color. Additionally, selected values have been boxed as they are important and will be discussed in the analysis.

Part of the maximum crush Crush Factor analysis also includes a "back calculation" of the KEES speed based on the reported maximum crush and an evaluation of the calculated speed as compared to the reported speed.

For the purposes of this analysis, it is assumed that:

- the data contained in the NHTSA database is correct, which based on our analysis of the database, for the majority of the data is a valid assumption,
- the data is assumed to have a normal distribution

Maximum Crush vs. Average Crush

It should be noted that the calculation of the Crush Factor as published in the Expert AutoStats® program, and thus the speed from crush in a subject accident, was based on the "maximum crush", not the average crush as was, and is today, more common. This was intentionally done for several reasons, including:

- ease of calculation using one point instead of multiple points,
- reduced measurement, and calculation time,
- relative ease of spotting the measurement point in the field, and
- in general represents the point of maximum work/energy exchange

Since the original work was completed, it has been found that using the maximum crush has the added benefit of having a "data normalization" effect which is important for offset and pole tests. Additionally, a review of the statistical summary of the data shows increased "scatter" in the results when the average crush is used for the crush depth. (See Figures 1 & 2) Figure 1 is a summary of the entire NHTSA database as of May 12, 2017 with calculations based on the Average Crush Depth, and Figure 2 is the same database filtered with the following restrictions: the Crush Factor Value is in the range of 0<CF<100 and the Average Crush Depth, in inches, is within the range of 0<Crush<60. A quick review of these tables will begin to indicate to the reader why the original analysis was based on the maximum crush. No further work beyond these two tables will be shown in this discussion.

Maximum Crush - All Tests - No Filter

Figure 3 shows the data summary for all Frontal Tests where stiffness can be calculated based upon MAXIMUM crush. It should be noted that there are a total of 3056 tests available for use using maximum crush where as noted previously there are only3045 tests with the availability of AVERAGE crush.

The first thing to note in this table

Year	Make	Model	Body Style	No Damage Speed (mph)	Average Crush (inch)	KEES	A	B	G	Kv	Crush Factor	b_sub_1	Crush Length	Vehicle Weight (pounds)
Number of Tests (n)				3045	3045	3045	3045	3045	3045	3045	3045	3045	3045	3045
Average (AVG)				5	13.2	32.3	13088.4	28423375.0	223.1	46947549.1	883.1	1166.2	69.6	3811.6
Minimum (MIN)				5	0.0	4.7	-96379.3	-42739.8	-123367.6	-61951.7	5.2	-8.8	-0.4	1829.5
Maximum (MAX)				5	69.5	61.6	6764107.2	44862276416.6	6455.8	75593115214.7	374924.0	583651.4	229.7	17756.8
Standard Deviation (STDev-sample)				0	6.8	6.3	170957.8	880045294.6	5690.1	1477205730.8	10018.1	14581.8	7.4	954.7
Standard Deviation (STDev-population)				0	6.8	6.3	170929.7	879900776.1	5689.1	1476963148.3	10016.4	14579.4	7.4	954.5
Median				5	14.2	34.9	433.3	163.2	531.3	231.7	29.2	33.5	70.0	3709.6
Mode				5	0.1	35.0	301.0	114.2	566.7	91.3	25.1	34.1	66.5	2999.9
Quartile 0				5	0.0	4.7	-96379.3	-42739.8	-123367.6	-61951.7	5.2	-8.8	-0.4	1829.5
Quartile 1 - 25%				5	8.9	29.5	333.9	107.8	469.1	151.8	24.2	28.1	66.7	3152.0
Quartile 2 - 50%				5	14.2	34.9	433.3	163.2	531.3	231.7	29.2	33.5	70.0	3709.6
Quartile 3 - 75%				5	17.7	35.1	625.9	324.5	603.6	477.1	41.1	47.7	72.9	4366.5
Quartile 4				5	69.5	61.6	6764107.2	44862276416.6	6455.8	75593115214.7	374924.0	583651.4	229.7	17756.8
	-2 Std Dev						-328827.2	-1731667214.2	-11157.1	-2907463912.4	-19153.1			
	-1 Std Dev						-157869.4	-851621919.6	-5467.0	-1430258181.7	-9135.0			
	Average						**13088.4**	**28423375.0**	**223.1**	**46947549.1**	**883.1**			
	+1 Std Dev						184046.2	908468669.6	5913.1	1524153279.9	10901.1			
	+2 Std Dev						355004.1	1788513964.2	11603.2	3001359010.6	20919.2			

5 - 2017 Front AVG Summary | 0<CF<100 Cr<60 | CAR 0<A<500 | Pickup 0<A<650 | VAN 0<A<700 | Utility C

Figure 1

is that while the average Crush Factor value is 24.9, the Median/Q2 value (the central value) is 21.3. It can also be seen that the back calculation of speed based on the Max Crush depth and a CF=21 value calculates the speed from crush for at least 75% of the tests within a +/- 5 mph range.

The lack of filtering of the data set leads to some very wide data scatter as can be seen from the Standard Deviation values for the various calculated stiffness values (A-B-G-Kv-CF).

Maximum Crush - All Tests - Filters = 0<CF<100 and 0<Crush<60

Figure 4 is the summary of the data after the most extreme outliers are eliminated. The tests where the Crush Factor was not positive (equal or less than 0) or greater than 100 were deleted, as were the tests where the reported maximum crush was not positive or was greater than 60 inches. This filtering resulted in the elimination of 57 tests, bringing the total number of tests evaluated down to 2999. The Average (MEAN) CF value of all the tests has dropped to 22.1 and the Median/Q2 value (the central value) is still at 21.3.

The Standard Deviation values for the A-B-G stiffness values are still running more than 100, which is a good indication that this data set still has some significant scatter. However, even with this scatter more than 75% of the tests are within +/- 5 mph of the KEES.

At this point, it has been shown that, based on the current NHTSA Crash Test database, speed from crush for frontal impacts accurate to within +/- 5 mph can be obtained 75+% of the time using a Crush Factor of 21 for all vehicles.

It will now be explored whether this holds true when specific body types are ex-

Test Number	Year	Make	Model	Body Style	No Damage Speed (mph)	Average Crush (inch)	KEES	A	B	G	Kv	Crush Factor	b_sub_1	Crush Length	Vehicle Weight (pounds)
	Number of Tests (n)				2695	2695	2695	2695	2695	2695	2695	2695	2695	2695	2695
	Average (AVG)				5	14.7	31.9	299.6	180.2	304.4	286.3	31.9	37.1	69.9	3859.9
	Minimum (MIN)				5	0.2	4.7	-78725.7	-25164.3	-123367.6	-36538.8	3.7	-8.8	-0.4	1829.5
	Maximum (MAX)				5	48.0	60.0	4507.8	3348.7	6455.8	28195.7	99.1	156.8	229.7	17756.8
	Standard Deviation (STDev-sample)				0	5.5	5.7	3209.4	1094.2	4917.9	1761.4	14.9	17.4	7.3	961.7
	Standard Deviation (STDev-population)				0	5.5	5.7	3208.8	1094.0	4917.0	1761.1	14.9	17.4	7.3	961.6
	Median				5	15.1	34.9	408.2	146.8	535.8	208.2	28.0	32.0	70.1	3755.9
	Mode				5	15.3	35.0	294.3	92.4	566.7	91.3	25.1	34.1	66.5	2999.9
	Quartile 0				5	0.2	4.7	-78725.7	-25164.3	-123367.6	-36538.8	3.7	-8.8	-0.4	1829.5
	Quartile 1 - 25%				5	11.4	29.5	321.8	103.0	473.1	145.3	23.6	27.4	66.8	3177.3
	Quartile 2 - 50%				5	15.1	34.9	408.2	146.8	535.8	208.2	28.0	32.0	70.1	3755.9
	Quartile 3 - 75%				5	18.2	35.1	527.4	233.6	610.7	335.4	34.8	40.1	73.1	4432.6
	Quartile 4				5	48.0	60.0	4507.8	3348.7	6455.8	28195.7	99.1	156.8	229.7	17756.8
		-2 Std Dev						-6119.2	-2008.2	-9531.5	-3236.6	2.0			
		-1 Std Dev						-2909.8	-914.0	-4613.6	-1475.2	17.0			
		Average						299.6	180.2	304.4	286.3	31.9			
		+1 Std Dev						3509.0	1274.3	5222.3	2047.7	46.9			
		+2 Std Dev						6718.4	2368.5	10140.2	3809.1	61.8			

0<CF<100 Cr<60 / CAR 0<A<500 / Pickup 0<A<650 / VAN 0<A<700 / Utility 0<A<650

Figure 2

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
3071																
3072			Number of Tests (n)		3056	3056	3056	3056	3056	3056	3056	3056	3056	1438	1618	Number of Tests (n)
3073			Average (AVG)		5	20.2	32.3	164.3	172.7	223.8	275.4	24.9	32.0	4.2	-4.2	Average (AVG)
3074			Minimum (MIN)		5	0.3	0.0	-66172.7	-20658.8	-123367.6	-30049.2	0.0	4.0	0.0	-47.0	Minimum (MIN)
3075			Maximum (MAX)		5	133.8	61.6	7937.4	56030.3	6455.8	80670.5	508.4	83.8	50.2	0.0	Maximum (MAX)
3076			Standard Deviation (STDev-sample)		0	7.7	6.4	3163.6	1930.0	5679.9	3127.1	28.2	6.0	5.2	5.9	Standard Deviation (STDev-sample)
3077			Standard Deviation (STDev-population)		0	7.7	6.4	3163.1	1929.7	5678.9	3126.6	28.2	6.0	5.2	5.9	Standard Deviation (STDev-populatic
3078																
3079	2006		Median		5	20.1	34.9	296.0	80.7	531.2	113.6	21.3	32.5	2.6	-2.6	Median
3080	2013		Mode		5	21.5	35.0	269.7	79.4	566.7	105.9	20.9	33.6	1.2	-1.4	Mode
3081																
3082														1079	1214	75% of Speed Sample
3083																
3084	1976		Quartile 0		5	0.3	0.0	-66172.7	-20658.8	-123367.6	-30049.2	0.0	4.0	0.0	-47.0	Quartile 0
3085	1995		Quartile 1 - 25%		5	16.5	29.5	240.4	59.2	469.1	83.5	18.1	29.4	1.1	-4.7	Quartile 1 - 25%
3086	2006		Quartile 2 - 50%		5	20.1	34.9	296.0	80.7	531.2	113.6	21.3	32.5	2.6	-2.6	Quartile 2 - 50%
3087	2012		Quartile 3 - 75%		5	23.4	35.1	364.7	112.6	603.3	158.8	24.9	35.0	4.9	-1.2	Quartile 3 - 75%
3088	2017		Quartile 4		5	133.8	61.6	7937.4	56030.3	6455.8	80670.5	508.4	83.8	50.2	0.0	Quartile 4
3089																
3090			-2 Std Dev			//	---------------	-6162.9	-3687.4	-11135.9	-5978.7	-31.4				
3091			-1 Std Dev			/////	//---	-2999.3	-1757.3	-5456.1	-2851.7	-3.3				
3092			Average			95%	68%	164.3	172.7	223.8	275.4	24.9				
3093			+1 Std Dev			\\\\\	\\---	3327.8	2102.7	5903.6	3402.5	53.1				
3094			+2 Std Dev			\\	---------------	6491.4	4032.7	11583.5	6529.5	81.3				
3095																

1965 - 2017 Front MAX Summary / 0<CF<100 Cr<60 / CARS A<500 / Pickups A<800 / VANS A<700 / Utility A

Figure 3

amined, or do the large amount of CAR front ends "swamp out" differences in the smaller number of samples PICKUP, VAN, and UTILITY vehicle types.

Maximum Crush - All Tests -
Filters = CAR and "A"<500

Figure 5 shows the CAR type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 500. The CAR data set has a total of 1918 tests after this filtering is completed. The benefit of the additional filter based on the "A" stiffness value can be seen in that the Standard Deviation for the "A" value has dropped to ~77, and the "B" and "G" Standard Deviations have dropped to even lower values, which indicates a "tighter" data set.

The Average (MEAN) CF value of all the tests has dropped to 21.1 and the Median/Q2 value (the central value) is at 20.9. Looking at the Quartile analysis, the 75% point in overestimating the speed is just above 5 mph higher (5.1 mph) than the KEES. On the underestimate side, the speed is only 4 mph less than the KEES. The authors are confident that an in-depth evaluation would show that a CF=21 value would still estimate more than 75% of the tests within +/- 5 mph. That analysis will be discussed in a subsequent paper.

Maximum Crush - All Tests -
Filters = PICKUP and "A"<800

Figure 6 shows the PICKUP type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 800. The PICKUP data set has a total of 287 tests after this filtering is completed. The filtering based on the "A" stiffness value of less than 800 only dropped the Standard Deviation for the "A" value to ~101. However, experience with the NHTSA database has shown that because some Heavy Duty Pickups with their sturdier frames are included in the database, a higher top threshold "A" value is appropriate.

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
3014																
3015			Number of Tests (n)		2999	2999	2999	2986	2986	2986	2989	2999	2999	1424	1575	Number of Tests (n)
3016			Average (AVG)		5	20.2	32.1	313.6	101.5	546.6	151.8	22.1	32.2	4.0	-3.5	Average (AVG)
3017			Minimum (MIN)		5	0.3	4.7	44.1	2.6	255.3	5.1	2.1	4.0	0.0	-31.5	Minimum (MIN)
3018			Maximum (MAX)		5	58.3	61.6	2334.7	3700.9	6455.8	12142.9	97.9	55.3	34.3	0.0	Maximum (MAX)
3019			Standard Deviation (STDev-sample)		0	6.2	5.8	132.5	132.1	153.5	322.8	8.8	5.1	4.4	3.8	Standard Deviation (STDev-sample)
3020			Standard Deviation (STDev-population)		0	6.1	5.8	132.4	132.1	153.5	322.8	8.8	5.1	4.4	3.8	Standard Deviation (STDev-population)
3021																
3022	1999		Median		5	20.2	34.8	295.6	80.6	532.4	113.2	21.3	32.6	2.6	-2.5	Median
3023	2001		Mode		5	21.5	35.0	269.7	79.4	566.7	105.9	20.9	33.6	1.2	-1.4	Mode
3024																
3025														1068	1181	75% of Speed Sample
3026																
3027	1972		Quartile 0		5	0.3	4.7	44.1	2.6	255.3	5.1	2.1	4.0	0.0	-31.5	Quartile 0
3028	1990		Quartile 1 - 25%		5	16.7	29.5	241.3	59.5	471.1	83.7	18.1	29.6	1.1	-4.4	Quartile 1 - 25%
3029	1999		Quartile 2 - 50%		5	20.2	34.8	295.6	80.6	532.4	113.2	21.3	32.6	2.6	-2.5	Quartile 2 - 50%
3030	2007		Quartile 3 - 75%		5	23.4	35.1	361.7	111.2	604.4	156.9	24.7	35.0	4.8	-1.2	Quartile 3 - 75%
3031	2017		Quartile 4		5	58.3	61.6	2334.7	3700.9	6455.8	12142.9	97.9	55.3	34.3	0.0	Quartile 4
3032																
3033			-2 Std Dev			//	-------------	48.7	-162.7	239.6	-493.9	4.6				
3034			-1 Std Dev			/////	//---	181.1	-30.6	393.1	-171.0	13.4				
3035			**Average**			95%	68%	**313.6**	**101.5**	**546.6**	**151.8**	**22.1**				
3036			+1 Std Dev			\\\\\	\\---	446.0	233.6	700.1	474.7	30.9				
3037			+2 Std Dev			\\	-------------	578.5	365.7	853.6	797.5	39.6				
3038																

0<CF<100 Cr<60 / CARS A<500 / Pickups A<800 / VANS A<700 / Utility A<800 / PU+Uti A<800

Figure 4

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
1933																
1934			Number of Tests (n)		1918	1918	1918	1909	1909	1909	1911	1918	1918	975	943	Number of Tests (n)
1935			Average (AVG)		5	20.7	32.0	270.6	78.6	495.7	121.4	21.1	32.6	4.3	-3.1	Average (AVG)
1936			Minimum (MIN)		5	0.3	4.7	44.1	2.6	287.3	5.1	2.1	4.0	0.0	-31.5	Minimum (MIN)
1937			Maximum (MAX)		5	58.3	61.6	498.5	311.5	857.9	12142.9	92.9	55.3	34.3	0.0	Maximum (MAX)
1938			Standard Deviation (STDev-sample)		0	6.2	6.0	77.0	40.2	74.1	305.9	7.0	5.0	4.7	3.3	Standard Deviation (STDev-sample)
1939			Standard Deviation (STDev-population)		0	6.2	6.0	77.0	40.2	74.1	305.8	7.0	5.0	4.7	3.3	Standard Deviation (STDev-population)
1940																
1941	1996		Median		5	20.5	34.8	266.1	72.2	497.8	101.2	20.9	32.8	2.7	-2.2	Median
1942	2001		Mode		5	20.9	35.0	269.7	79.4	441.4	91.5	20.7	33.1	1.0	-1.4	Mode
1943																
1944														731	707	75% of Speed Sample
1945																
1946	1972		Quartile 0		5	0.3	4.7	44.1	2.6	287.3	5.1	2.1	4.0	0.0	-31.5	Quartile 0
1947	1987		Quartile 1 - 25%		5	17.0	29.5	223.9	54.0	445.1	76.1	17.6	29.9	1.1	-4.0	Quartile 1 - 25%
1948	1996		Quartile 2 - 50%		5	20.5	34.8	266.1	72.2	497.8	101.2	20.9	32.8	2.7	-2.2	Quartile 2 - 50%
1949	2005		Quartile 3 - 75%		5	23.7	35.0	314.2	94.7	542.9	134.1	24.0	35.3	5.1	-1.1	Quartile 3 - 75%
1950	2017		Quartile 4		5	58.3	61.6	498.5	311.5	857.9	12142.9	92.9	55.3	34.3	0.0	Quartile 4
1951																
1952			-2 Std Dev			//	-------------	116.6	-1.8	347.4	-490.3	7.1				
1953			-1 Std Dev			/////	//---	193.6	38.4	421.6	-184.5	14.1				
1954			**Average**			95%	68%	**270.6**	**78.6**	**495.7**	**121.4**	**21.1**				
1955			+1 Std Dev			\\\\\	\\---	347.5	118.8	569.8	427.3	28.0				
1956			+2 Std Dev			\\	-------------	424.5	159.0	644.0	733.2	35.0				
1957																

0<CF<100 Cr<60 / CARS A<500 / Pickups A<800 / VANS A<700 / Utility A<800 / PU+Uti A<800

Figure 5

The Average (MEAN) CF value of all tests has dropped to 20.2 and the Median/Q2 value (the central value) is at 19.9. This is surprising as it is an indication that PICKUPs are actually somewhat softer than CAR front ends. Looking at the Quartile analysis, the 75% point in overestimating the speed is again just above 5 mph higher (5.1 mph) than the KEES. On the underestimate side, the speed is only~4 mph less than (3.9 mph) the KEES. The authors are again confident that an in depth evaluation would show that a CF=21 value would still estimate more than 75% of the tests within +/- 5 mph. That analysis will also be discussed in a subsequent paper.

Maximum Crush - All Tests - Filters = VAN and "A"<700

Figure 7 shows the VAN type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 700. The VAN data set has a total of 208 tests after this filtering is completed. The "A" stiffness value top threshold of 700 is based on the short front end of a number of the full size vans. It can be seen in that the Standard Deviation for the" A" value has dropped to ~81, and the "B" and "G" Standard Deviations have dropped to even lower values, which indicates a "tighter" data set.

The Average (MEAN) CF value of all tests has dropped to 21.2 and the Median/Q2 value (the central value) is at 21.3. The Quartile analysis indicates that a CF=21 value will quite comfortably estimate the speed of more than 75% of the tests within +/- 5 mph of the KEES.

Maximum Crush - All Tests - Filters = UTILITY and "A"<800

Figure 8 shows the UTILITY type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 800. The UTILITY data set has a total of 446 tests after this filtering is completed. The "A" stiffness value top threshold of 800 is based on the Utility Vehicles often being considered interchangeable with the pickups in regard to front end shape and

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
302																
303			Number of Tests (n)		287	287	287	287	287	287	287	287	287	170	117	Number of Tests (n)
304			Average (AVG)		5	21.3	32.0	337.8	93.9	641.0	132.4	20.2	33.1	3.9	-2.8	Average (AVG)
305			Minimum (MIN)		5	7.9	9.9	81.8	6.4	255.3	14.4	3.5	20.4	0.0	-9.4	Minimum (MIN)
306			Maximum (MAX)		5	50.1	40.2	784.0	382.6	979.0	598.0	39.5	51.3	21.7	0.0	Maximum (MAX)
307			Standard Deviation (STDev-sample)		0	5.8	5.1	101.1	49.5	118.0	68.7	5.5	4.5	3.8	2.1	Standard Deviation (STDev-sample)
308			Standard Deviation (STDev-population)		0	5.8	5.1	101.0	49.4	117.8	68.5	5.5	4.5	3.8	2.1	Standard Deviation (STDev-population)
309																
310	2001		Median		5	20.8	34.9	330.1	88.2	635.9	121.9	19.9	33.0	2.6	-2.4	Median
311	1999		Mode		5	18.5	35.0	287.9	51.8	524.5	108.0	18.3	31.2	4.5	-4.0	Mode
312																
313														128	88	75% of Speed Sample
314																
315	1978		Quartile 0		5	7.9	9.9	81.8	6.4	255.3	14.4	3.5	20.4	0.0	-9.4	Quartile 0
316	1992		Quartile 1 - 25%		5	17.6	29.6	275.6	64.3	547.3	89.4	17.0	30.4	1.4	-3.9	Quartile 1 - 25%
317	2001		Quartile 2 - 50%		5	20.8	34.9	330.1	88.2	635.9	121.9	19.9	33.0	2.6	-2.4	Quartile 2 - 50%
318	2008		Quartile 3 - 75%		5	24.6	35.1	386.9	109.9	716.1	153.6	23.3	35.9	5.1	-1.3	Quartile 3 - 75%
319	2017		Quartile 4		5	50.1	40.2	784.0	382.6	979.0	598.0	39.5	51.3	21.7	0.0	Quartile 4
320																
321			-2 Std Dev			//	-------------	135.5	-5.1	405.0	-4.9	9.1				
322			-1 Std Dev			/////	//---	236.6	44.4	523.0	63.8	14.6				
323			**Average**			**95%**	**68%**	**337.8**	**93.9**	**641.0**	**132.4**	**20.2**				
324			+1 Std Dev			\\\\\	\\---	438.9	143.4	759.0	201.1	25.7				
325			+2 Std Dev			\\	-------------	540.0	192.9	877.0	269.7	31.3				
326																

0<CF<100 Cr<60 | CARS A<500 | **Pickups A<800** | VANS A<700 | Utility A<800 | PU+Uti A<800

Figure 6

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
223																
224			Number of Tests (n)		208	208	208	206	206	206	207	208	208	94	114	Number of Tests (n)
225			Average (AVG)		5	19.7	31.6	351.7	103.0	629.4	152.1	21.2	31.9	3.3	-2.3	Average (AVG)
226			Minimum (MIN)		5	1.0	4.8	104.9	9.1	456.4	25.6	3.5	7.2	0.0	-8.8	Minimum (MIN)
227			Maximum (MAX)		5	41.8	40.7	675.3	347.3	1085.3	1142.1	42.3	46.8	17.6	0.0	Maximum (MAX)
228			Standard Deviation (STDev-sample)		0	5.4	5.4	82.1	45.9	77.3	97.2	5.2	4.7	3.7	1.9	Standard Deviation (STDev-sample)
229			Standard Deviation (STDev-population)		0	5.3	5.4	81.9	45.8	77.1	97.0	5.2	4.7	3.7	1.8	Standard Deviation (STDev-population)
230																
231	1998		Median		5	20.2	34.8	352.8	98.7	616.4	136.0	21.3	32.6	2.1	-1.9	Median
232	2005		Mode		5	19.6	35.0	266.3	63.4	604.1	114.9	22.4	32.1	1.4	-1.9	Mode
233																
234														71	86	75% of Speed Sample
235																
236	1978		Quartile 0		5	1.0	4.8	104.9	9.1	456.4	25.6	3.5	7.2	0.0	-8.8	Quartile 0
237	1992		Quartile 1 - 25%		5	16.5	29.4	299.1	75.3	591.4	104.1	18.9	29.4	0.8	-3.3	Quartile 1 - 25%
238	1998		Quartile 2 - 50%		5	20.2	34.8	352.8	98.7	616.4	136.0	21.3	32.6	2.1	-1.9	Quartile 2 - 50%
239	2004		Quartile 3 - 75%		5	23.1	35.0	396.5	122.7	654.2	174.9	23.9	34.8	3.9	-0.9	Quartile 3 - 75%
240	2017		Quartile 4		5	41.8	40.7	675.3	347.3	1085.3	1142.1	42.3	46.8	17.6	0.0	Quartile 4
241																
242			-2 Std Dev			//	-------------	187.4	11.2	474.8	-42.3	10.8				
243			-1 Std Dev			/////	//---	269.6	57.1	552.1	54.9	16.0				
244			**Average**			**95%**	**68%**	**351.7**	**103.0**	**629.4**	**152.1**	**21.2**				
245			+1 Std Dev			\\\\\	\\---	433.8	148.9	706.7	249.3	26.4				
246			+2 Std Dev			\\	-------------	516.0	194.7	784.0	346.5	31.6				
247																

0<CF<100 Cr<60 | CARS A<500 | Pickups A<800 | **VANS A<700** | Utility A<800 | PU+Uti A<800

Figure 7

stiffness. Therefore the same top end threshold was used for the UTILITY vehicles as was used for the Pickups. This can be seen in that the Standard Deviation for the "A" value has dropped to ~81, and the "B" and "G" Standard Deviations have dropped below 100 as well, which indicates a "tighter" data set than was present in the Figure 4 data set.

The Average (MEAN) CF value of all tests has dropped to 23.1 and the Median/Q2 value (the central value) is at 23.0. This is more along the lines of what was expected from the Pickups, a stiffer front end than is found in the CAR body style front end. However, the Quartile analysis indicates that a CF=21 value will quite comfortably estimate the speed of more than 75% of the tests within +/- 5 mph of the KEES. The author would not argue with someone who wishes to use a slightly stiffer CF value for Utility vehicles based on this analysis. At the same time, the author feels that the Quartile analysis indicates that the potential benefits in possible accuracy are outweighed by the loss of uniformity of using a "default" CF value other than 21.

Maximum Crush - All Tests - Filters = PICKUP+UTILITY and "A"<800

Figure 9 shows the PICKUP + UTILITY type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 800. The PICKUP + UTILITY data set has a total of 739 tests after this filtering is completed. This combining of the PICKUPS with the UTILITY vehicles was done to see if the front ends really are "interchangeable". It can be seen that the Standard Deviation for the "A" value has dropped to ~81, and the "B" and "G" Standard Deviations have dropped below 100 as well, which indicates a "tighter" data set than was present in the Figure 4 data set.

The Average (MEAN) CF value of all tests is at 22.0 and the Median/Q2 value (the central value) is at 21.9. The Quartile analysis indicates that a CF=21 value will quite comfortably estimate the speed of more than 75% of the tests within +/- 5 mph of the KEES. The effect of the UTILITY body type tests can be seen in the reduction of the A-B-G Standard Deviation values as well as the Q3 speed over-

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
461																
462			Number of Tests (n)		446	446	446	444	444	444	444	446	446	149	297	Number of Tests (n)
463			Average (AVG)		5	20.2	33.5	372.2	112.3	643.2	155.7	23.1	32.4	3.1	-3.3	Average (AVG)
464			Minimum (MIN)		5	6.7	15.0	143.1	21.7	411.2	34.0	6.2	18.8	0.1	-12.0	Minimum (MIN)
465			Maximum (MAX)		5	40.9	42.9	679.5	358.7	1081.0	516.9	43.3	46.3	14.8	0.0	Maximum (MAX)
466			Standard Deviation (STDev-sample)		0	4.4	4.0	80.9	47.3	90.8	65.5	5.5	3.6	2.9	2.3	Standard Deviation (STDev-sample)
467			Standard Deviation (STDev-population)		0	4.4	4.0	80.8	47.2	90.7	65.5	5.5	3.6	2.9	2.3	Standard Deviation (STDev-population)
468																
469	2005		Median		5	20.2	35.0	361.7	103.6	642.5	144.0	23.0	32.5	2.2	-3.0	Median
470	2002		Mode		5	21.3	35.0	376.2	97.1	566.7	117.8	22.8	33.4	1.0	-1.4	Mode
471																
472														112	223	75% of Speed Sample
473																
474	1978		Quartile 0		5	6.7	15.0	143.1	21.7	411.2	34.0	6.2	18.8	0.1	-12.0	Quartile 0
475	2001		Quartile 1 - 25%		5	17.5	34.7	318.0	82.3	574.4	114.9	19.8	30.3	1.0	-4.6	Quartile 1 - 25%
476	2005		Quartile 2 - 50%		5	20.2	35.0	361.7	103.6	642.5	144.0	23.0	32.5	2.2	-3.0	Quartile 2 - 50%
477	2011		Quartile 3 - 75%		5	22.6	35.1	412.4	129.7	696.2	179.6	26.3	34.4	4.1	-1.5	Quartile 3 - 75%
478	2017		Quartile 4		5	40.9	42.9	679.5	358.7	1081.0	516.9	43.3	46.3	14.8	0.0	Quartile 4
479																
480			-2 Std Dev			//	------------	210.4	17.8	461.6	24.6	12.1				
481			-1 Std Dev			/////	//---	291.3	65.0	552.4	90.1	17.6				
482			**Average**			**95%**	**68%**	**372.2**	**112.3**	**643.2**	**155.7**	**23.1**				
483			+1 Std Dev			\\\\\	\\---	453.1	159.6	733.9	221.2	28.6				
484			+2 Std Dev			\\	------------	534.0	206.8	824.7	286.8	34.1				
485																

0<CF<100 Cr<60 / CARS A<500 / Pickups A<800 / VANS A<700 / Utility A<800 / PU+Uti A<800

Figure 8

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
748																
749			Number of Tests (n)		733	733	733	731	731	731	731	733	733	319	414	Number of Tests (n)
750			Average (AVG)		5	20.6	32.9	358.7	105.1	642.3	146.5	22.0	32.7	3.5	-3.1	Average (AVG)
751			Minimum (MIN)		5	6.7	9.9	81.8	6.4	255.3	14.4	3.5	18.8	0.0	-12.0	Minimum (MIN)
752			Maximum (MAX)		5	50.1	42.9	784.0	382.6	1081.0	598.0	43.3	51.3	21.7	0.0	Maximum (MAX)
753			Standard Deviation (STDev-sample)		0	5.0	4.5	90.9	49.0	102.3	67.7	5.7	3.9	3.4	2.2	Standard Deviation (STDev-sample)
754			Standard Deviation (STDev-population)		0	5.0	4.5	90.8	48.9	102.2	67.6	5.7	3.9	3.4	2.2	Standard Deviation (STDev-populat
755																
756	2004		Median		5	20.5	35.0	351.8	96.9	640.6	134.2	21.9	32.8	2.5	-2.8	Median
757	2011		Mode		5	18.5	35.0	376.2	117.0	524.5	108.0	21.2	31.2	0.7	-1.4	Mode
758																
759														239	311	75% of Speed Sample
760																
761	1978		Quartile 0		5	6.7	9.9	81.8	6.4	255.3	14.4	3.5	18.8	0.0	-12.0	Quartile 0
762	1998		Quartile 1 - 25%		5	17.6	30.1	304.8	75.0	565.4	105.8	18.6	30.4	1.1	-4.4	Quartile 1 - 25%
763	2004		Quartile 2 - 50%		5	20.5	35.0	351.8	96.9	640.6	134.2	21.9	32.8	2.5	-2.8	Quartile 2 - 50%
764	2011		Quartile 3 - 75%		5	23.4	35.1	403.3	122.8	699.3	170.7	25.5	35.0	4.5	-1.4	Quartile 3 - 75%
765	2017		Quartile 4		5	50.1	42.9	784.0	382.6	1081.0	598.0	43.3	51.3	21.7	0.0	Quartile 4
766																
767			-2 Std Dev			//	------------	176.9	7.1	437.8	11.2	10.6				
768			-1 Std Dev			/////	//---	267.8	56.1	540.1	78.9	16.3				
769			**Average**			**95%**	**68%**	**358.7**	**105.1**	**642.3**	**146.5**	**22.0**				
770			+1 Std Dev			\\\\\	\\---	449.6	154.0	744.6	214.2	27.7				
771			+2 Std Dev			\\	------------	540.5	203.0	846.8	281.9	33.3				
772																

0<CF<100 Cr<60 / CARS A<500 / Pickups A<800 / VANS A<700 / Utility A<800 / PU+Util A<800

Figure 9

estimation speed error reduction, and the effect of PICKUP tests can be seen in the slight reduction of the CF average values from what we saw in Figure 8.

Summary

The analysis of the NHTSA Crash Test Database frontal tests using MAXIMUM crush has shown that:

1) It IS appropriate to use a Crush Factor value of 21 for CARs, PICKUPs, VANs, and UTILITY vehicle front ends and that a speed estimate within +/- 5 mph can be obtained 75% or more of the time.

2) This approach is less accurate when dealing with minimal crush. However, the author believes this to be true to most approaches to minimal crush. Additionally, while erratic from a statistical view point, the speed estimates still fall within the +/- 5 mph bracket in most cases, and when they don't, it is usually only slightly outside of that bracket.

It is stressed, however, that caution must still be used when applying any method to calculating speed from crush. Just because one has a formula, a stiffness value and some crush depths, it does not mean one should blindly apply the formula. Some thought still needs to be exercised.

This is the first of what is intended to be a series of articles. Future articles will deal with the side and rear tests and values derived there from.

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# # #

UTAH TO IMPLEMENT THE NATION'S STRICTEST DUI LIMIT, FIRST STATE TO GO TO .05

On New Year's Eve, as people across the country raise a glass or two to toast the end of one year and the beginning of another, residents of Utah probably will have to decline that last drink if they want to drive home afterward.

The state plans to impose the country's strictest limit for alcohol consumption before driving, making the new blood alcohol limit .05, down from the .08 standard nationwide. The measure — slated to take effect Dec. 30 — has prompted some criticism and spurred new training for law enforcement officials, but if it helps reduce drunken-driving deaths, other states could take notice.

"I don't anticipate other states immediately following," said Jonathan Adkins, executive director of the Governors Highway Safety Association. But, he said, "if it turns out this has been successful and is having an impact on drunk driving, it's certainly possible that other states will follow."

The shift in Utah — the first state to lower its limit below .08 — comes as deaths from drunken driving remain a serious danger nationwide. While down significantly during the past three decades amid aggressive enforcement of drunken-driving laws, alcohol-impaired drivers were involved in nearly one-third of all motor vehicle fatalities in 1997.

More than 37,000 people were killed in crashes in 2017, and more than 10,000 of them — about 29 percent — died in crashes involving drivers impaired by alcohol, defined as those with blood alcohol concentrations of .08 or higher, according to the National Highway Traffic Safety Administration. In Utah, about 19 percent of traffic deaths involved alcohol-impaired drivers, the lowest figure of any state.

Utah has long had restrictions on alcohol, including limits on how strong beer can be and prohibitions against bringing alcohol in from other states, but officials say drinking and driving remains an ongoing problem there.

"Despite decades of public campaigns and other efforts to discourage driving after drinking, survey and observational data show that many people continue to do so," the Utah Department of Public Safety said in a statement addressing the new law. "Over the last five years, there were 54,402 arrests for DUI in Utah, which represents an average of 29.8 per day."

The public safety department said that law enforcement agencies in the state had to undergo refresher training on field sobriety tests. The law taking effect this month states that a person cannot operate or be in physical control of a vehicle if a test shows that they have "a blood or breath alcohol concentration" of .05 or greater. It also states that a person who has that alcohol amount and "operates a motor vehicle in a negligent manner causing the death of another" will have committed an automobile homicide, a felony.

Utah Gov. Gary R. Herbert (R) signed the new law last year, noting that while he had some issues with the measure, it would "save lives, therefore it is good public policy."

The .08 standard nationwide was set in a bill signed by President Bill Clinton in 2000, though the exact laws and penalties often vary, according to the Governors Highway Safety Association. Most states and the District also have harsher penalties for drivers with particularly high blood alcohol measurements, although again, the specifics depend on the state. Federal authorities have long pushed for tougher drunken-driving laws than the .08 standard. The National Transportation Safety Board argued in 2013 for dropping that figure to .05, saying that research showed drivers above that level "are impaired and at a significantly greater risk of being involved in a crash where someone is killed or injured."

The American Beverage Institute — a restaurant trade association that lobbies for the industry and has opposed lowering the blood alcohol level — once called that 2013 proposal "terrible." It also decried the new Utah measure.

"I have no doubt that proponents of .05 laws are well-intentioned, but good intentions don't necessarily yield good public policy," Jackson Shedelbower, spokesman for the institute, said in a statement this week.

Shedelbower described the new measure as "targeting moderate and responsible drinkers" rather than people with much higher blood alcohol levels "and repeat drunk driving offenders responsible for the vast majority of alcohol-related traffic fatalities."

Federal statistics link deadly accidents with greater alcohol consumption. NHTSA has said that while .08 is considered impaired, "the large majority of drivers in fatal crashes with any measurable alcohol had levels far higher." Adkins, who said his group is monitoring the Utah law to see what impact it has, said that to combat drunken driving, "we need to reduce the high alcohol offenders."

The Centers for Disease Control and Prevention says a 160-pound man would reach a .05 blood alcohol concentration level — and have a reduced ability to track moving objects or steer — after having about three drinks in an hour. The CDC describes a standard drink as 12 ounces of beer, five ounces of wine or a shot of liquor, though it notes that a person's specific reaction to alcohol can vary depending on their age, physical condition, weight and other factors.

- Washington Post

The tables in the article are .... small .... through no fault of the Journal. The authors (primarily Daniel Vomhof III) assumes that responsibility as he could not figure out how to break them up into smaller chunks without losing meaning. In an effort to help lessen that effect, the tables are available on our web site in jpg format for easier viewing and printing in a larger size.

If you go to

http://www.4n6xprt.com/papers.htm

and start scrolling down, you will quickly see where the figures are for this article.