THE USE OF EDR DATA IN VEHICLE ACCIDENT RECONSTRUCTIONS

RAYMOND M. BRACH, PHD, PE
UNIVERSITY OF NOTRE DAME
BRACH ENGINEERING, LLC

Abstract

This article describes two example crash reconstructions intended to be representative of vehicle accident reconstructions combining Event Data Recorder (EDR) data with other quantitative physical evidence. Underreporting of the speed values in EDR data is known to occur. Its cause is examined and a way to correct the speeds for heavy braking is presented. Analysis of EDR speed versus time data to estimate vehicle acceleration and position is also examined. The first example is a vehicle-pedestrian collision for which the vehicle EDR data includes precrash speeds. The second example is a reconstruction of a head-on crash of two vehicles where EDR data include both precrash speeds and delta-V values. In this example, a single comprehensive reconstruction of the initial vehicle speeds is carried out combining the EDR data with a crush energy analysis. The reconstruction is formulated in a manner such that the results satisfy the principle of impulse and momentum.

Accident Reconstruction

Vehicle accident reconstruction is a process carried out with the specific purpose of estimating, in both a qualitative and quantitative manner, how an accident occurred. This process is accomplished using engineering, scientific and mathematical principles/laws and is based on physical evidence obtained through an accident investigation. The collection of facts, data and physical evidence associated with the circumstances of an accident is referred to as *accident investigation*. Determining what happened in an accident and how it happened is referred to as *accident reconstruction*.

Using EDR[1] Data in a Vehicle Accident Reconstruction: In a recent article [2], the author presents a detailed discussion of meanings, interpretations and content of the term accident reconstruction, such as above. The terms "complete reconstruction" and "situational complete reconstruction" are introduced and explored. In particular, the question of whether or not Event Data Recorder (EDR) data is accurate and reliable and if and how it should be used in an accident reconstruction is addressed. Assuming that in a particular crash the data imaged from a EDR is determined to be reasonably accurate and reliable, the answer is, of course such data should be used. When other reliable quantitative data (such as skid mark lengths, crush energy calculations, etc.) for a particular crash are available, all should be collectively used in the reconstruction process. Methods outlining the direct use of EDR data in the reconstruction of collisions have been discussed, documented and used for years, especially ΔV values [3, 4, 5, 6, 7]. As used in the examples in References 5, 6 and 7, the longitudinal component of a vehicle's ΔV in a crash can be incorporated into a reconstruction using appropriate impact models such as the planar impact equations (impact equations that take vehicle rotational velocities into account). More vehicles are now equipped with multi-axis accelerometers and so longitudinal, lateral and rotational ΔV values are becoming available for inclusion in reconstructions. EDR data can and should be used to carry out reconstructions.

DATA IMAGED FROM AN EDR OTHER THAN THE VALUE OF A VEHICLE'S DELTA-V IS VERY USEFUL.

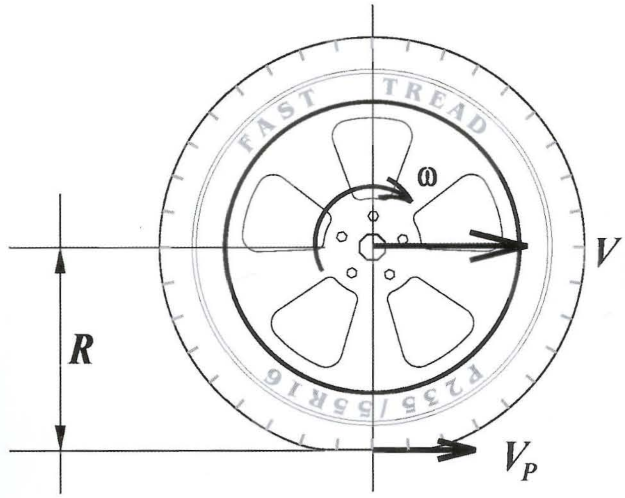


Figure 1: Velocities of a rotating wheel with slip.

Data imaged from an EDR other than the value of a vehicle's ΔV is very useful. Moreover, additional processing of the EDR data can often provide vital reconstruction information. For example, preimpact vehicle speeds are often recorded by a EDR. Through the use of numerical integration, speed-time data can reveal the preimpact displacement of the vehicle as a function of time (relative to the vehicle position at Algorithm Enable, AE). Estimates of levels of deceleration can be obtained from changes in preimpact speed over time. Examples are presented here of two reconstructions that use EDR data in combination with other accident data and physical evidence in such a way.

The first is a vehicle-pedestrian collision and the second is a head-on crash of two vehicles. Both are hypothetical, but the second is based on a staged collision with actual data [2], from known, measured results. In general, each accident and its reconstruction are unique. The two examples presented here are just that, examples. However the approach of using all available quantitative data, traditional and from EDRs, in a scientific and mathematical manner is illustrative of what is happening in the field of accident reconstruction.

Wheel Slip and Underreporting of Precrash Speeds by EDRs

Before proceeding to Example 1, it is helpful to discuss the concept of wheel slip that occurs during braking. Braking affects the rotational speed of a vehicle's wheels through application of a resistive torque to each wheel. This torque causes the wheel to have a rotational speed (angular velocity) slower than a freely rolling wheel, to the extent that a locked wheel has zero rotational speed even as a vehicle is still moving forward (skidding). That is, the vehicle has a forward speed, but a speedometer connected to a vehicle speed sensor monitoring the mechanical powertrain output would read zero. The presence of wheel slip during braking can cause the speed indicating device on a vehicle to provide a speed value lower than that of the speed of the vehicle relative to the ground, that is, underreport the speed. Although the speed measuring device can vary from vehicle to vehicle (transmission shaft output, wheel sprocket speed, etc.), EDRs report the speed indicated by the vehicle's speed measuring device, or sensor(s).

Figure 1 shows a rolling wheel with a center velocity, V (the speed of the vehicle), a wheel rotational angular velocity, ω, the tire/wheel velocity at the contact point with the pavement, V_p, and a rolling radius, R. Braking wheel slip, s, typically is defined as [3]:

$$s = \frac{V_P}{V} = \frac{V - R\omega}{V} \tag{1}$$

Note that for a locked wheel, $\omega = 0$, and the slip $s = 1$; for pure, or free, rolling, $V = R\omega$ and the slip $s = 0$. All conditions of braking are controlled by the brake pedal force which controls slip to range between $0 \le s \le 1$. Typically, antilock braking systems (ABS) control wheel slip to cycle over a region of maximum tire force [3, 8]. This means that the slip is cycled to remain typically in the range of $0.15 \le s \le 0.25$. Let the $R\omega$ term in Equation 1 represent an equivalent output of a speed sensor (speedometer signal) that is recorded and stored by the EDR as the vehicle speed such that $R\omega = V_{EDR}$. Solving for the speed of the vehicle indicated by the EDR, V_{EDR}, from Equation 1 gives:

$$V_{EDR} = (1 - s)V \tag{2}$$

It is clear from Equation 2 that when a brake is applied causing s to be greater than zero that the reported speed (as indicated by the EDR) is less than the vehicle speed. For example, if the vehicle speed at a given precrash time is $V = 30$ mph (44 ft/s, 48.2 kph) but is indicated as $V_{EDR} = 25$ mph (36.7 ft/s, 40.2 kph), this would imply a wheel slip (averaged over the vehicle's four wheels) of $s = 0.17$, an underreporting of 5 mph (7.3 ft/s, 8.0 kph), or 17%. Reust and Morgan [15] found from their tests that speeds during braking can be underreported by Sensing and Diagnostic Modules (SDMs) by 8% to 18% and significantly more at low vehicle speeds. With an understanding of wheel slip, it is possible to estimate speed of the vehicle more accurately if the average slip of the vehicle's wheels is known or can be reasonably estimated. In the following example, the accelerations suggested by the EDR data are estimated using the information that the vehicle's ABS system is in operation.

Example 1 Vehicle-Pedestrian Collision: This is an example where a pedestrian, a young man weighing 150 lb, is hit by a 4000 lb pickup truck with a high vertical front profile. This is typically referred to as a forward projection pedestrian collision [3], where the pedestrian is propelled straight forward from the vehicle (as compared to being wrapped onto the hood and interacting with the windshield). Figure 2 shows some of the conditions of the accident including the rest positions of the vehicle and pedestrian. It was not possible to determine the point of impact from the scene evidence but it was determined from the rest positions that the pickup truck came to a stop 4 feet closer to the point of impact than the pedestrian. In this case, the impact severity did not reach a level sufficient to actuate the driver's airbag, but the event was recorded by the EDR as a Non-Deployment event. The road conditions were dry and it is known that the vehicle had an ABS which was actuated continuously over a distance of at least 60 feet before coming to rest.

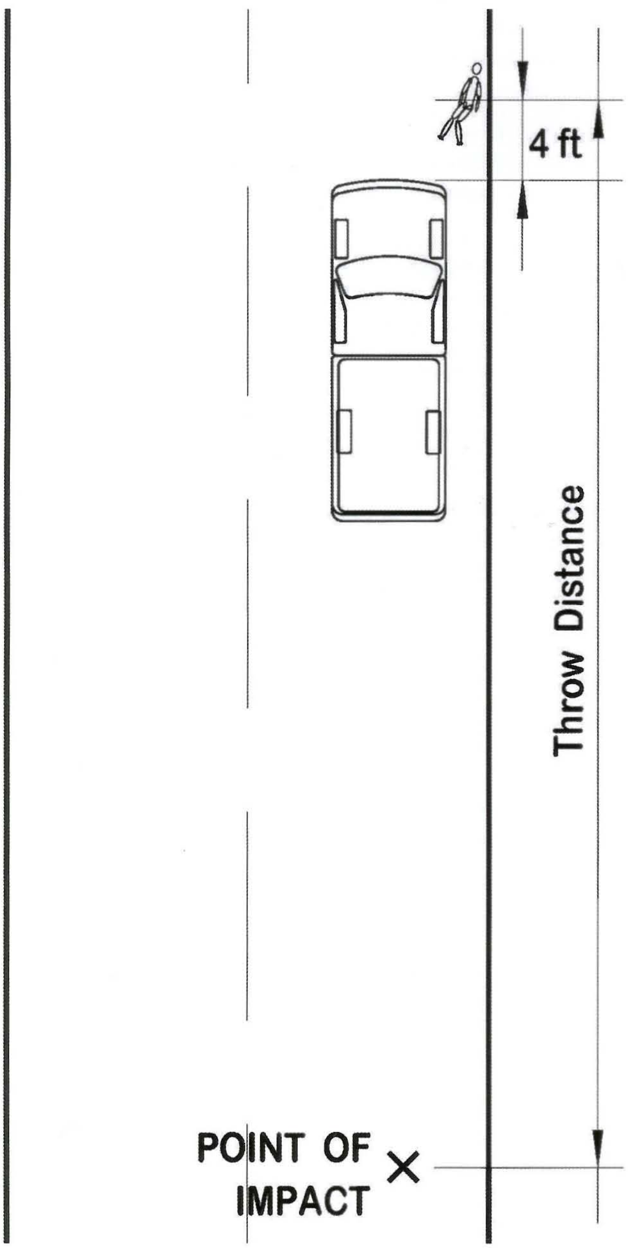


Figure 2: Vehicle-pedestrian accident diagram.

Table 1 shows the precrash data imaged from the EDR. The data have been examined and found to be reliable with no limitations indicated. Table 2 shows the values of the vehicle's average acceleration calculated from the changes in the speed values shown in Table 1. The acceleration value of -1.23 g's at t = -1 seconds before Algorithm Enable (AE) indicates a high level of braking consistent with the observation of ABS activation. However, with ABS activation, wheel slip would cause the speed of 42 mph (61.6 ft/s, 67.5 kph) at t = -1 s before AE to be underreported. Using an average wheel slip of s = 0.2, this means that the vehicle speed at t = -1 s before AE is 42/0.8 = 52 mph, truncated (76.3 ft/s, 83.6 kph). In turn, this implies that the actual acceleration from 69 mph (101.2 ft/s, 110.9 kph) to 52 mph (76.3 ft/s, 83.6 kph) is -0.77 g's, not -1.23 g's. If it is assumed that braking in the last second before AE remains at this level, the speed at AE can be estimated and is 35 mph (51.3 ft/s, 56.3 kph). These corrected and extrapolated data are shown in Tables 3 and 4. If AE occurred at the time of impact with the pedestrian, then the vehicle speed at impact was 35 mph. This information can be evaluated using a vehicle-pedestrian impact model.

Seconds before AE	Vehicle Speed (mph)	Engine Speed (rpm)	Percent Throttle	Brake Switch
-5	69	3048	85	Off
-4	71	3048	85	Off
-3	71	2056	71	On
-2	69	1208	6	On
-1	42	980	0	On

Table 1: Data from the CDR Report for the Vehicle Striking the Pedestrian in Example 1

Average Acceleration g's
.09
.00
-.09
-1.23

Table 2: Average Accelerations, Computed from Speed in Column 2 of Table 1

Seconds Before AE	Vehicle Speed (mph)	Engine Speed (rpm)	Percent Throttle	Brake Switch
-5	69	3048	85	Off
-4	71	3048	85	Off
-3	71	2056	71	On
-2	69	1208	6	On
-1	52	980	0	On
0	35			On

Table 3: Data from the CDR Report for the Vehicle Striking the Pedestrian in Example 1, Corrected for Underreporting of Vehicle Speed, s = 0.20

Average Accelerations g's
0.09
0.00
-0.09
-0.77
-0.77

Table 4: Average Accelerations, Computed from Speeds in Column 2 of Table 3

An appropriate vehicle-pedestrian impact model [3, 14] exists that relates the rest positions of the vehicle and the pedestrian and allows a full analysis of the collision using the available information. In summary, the impact speed was 35 mph (51.3 ft/s, 56.3 kph), the difference between the rest positions is known to be 4 feet and the deceleration of the vehicle from impact to rest was 0.77 g's. Other collision parameters are also known. For example, the vehicle and pedestrian weights (and masses) are known. For a forward projection collision, the pedestrian launch angle is zero (the center of mass of the pedestrian is propelled forward horizontally) and the wrap distance is zero. One of the unknowns however is the value of the equivalent drag factor of the pedestrian along the ground. It is known generally to lie in the range $0.7 \le f_p \le 0.8$ [3]. The approach taken here is to put all of the known information (including the EDR speed of 35 mph) into the vehicle-pedestrian model and determine the corresponding value of f_p. That is, for a vehicle impact velocity of 35 mph and a rest position separation distance of 4 feet, the value of f_p is found and compared to the feasible region.

Figure 3 (on the next page) is a copy of the vehicle-pedestrian impact spreadsheet from the *VCRware* software package [9]. Using the spreadsheet's *Goal Seek* feature, it is found that a value of $f_p = 0.74$ is required for agreement with all of the other collision conditions. (Note that the separation distance is negative 4 feet because of the definition of positive displacement in the model.) Since f_p lies in the feasible range, the reconstruction satisfies all conditions of the scene observations and the speed values from the corrected EDR data. Overall the reconstruction has not only determined the speed of the vehicle at impact but (from Fig 3) the pedestrian throw distance, s_p, is now known to be 53.4 feet — locating the unknown point of impact. In addition, the impact of the pedestrian with the ground was approximately 20.5 feet from the point of initial contact, and so on.

A reconstruction as carried out above, but using the uncorrected deceleration of the vehicle at AE (-1.23 g's) and the uncorrected speed at AE (15 mph) yields a frictional drag value of the pedestrian of $f_p = 1.0$, which is contrary to experimental data.

A check can be made on the above vehicle-pedestrian collision results by making a comparison with other models. For a throw distance of s_p = 53.4 ft (16.3 m), the experimental forward-projection model of Happer, et al. [10], gives a vehicle speed at impact, v_{c0}, in the range of 22 mph (32.3 ft/s, 35.3 kph) to 35 mph (51.3 ft/s, 56.3 kph). For a throw distance of s_p = 53.4 ft (16.3 m), the forward projection model of Wood [11], gives a vehicle speed, v_{c0} in the range of 18 mph (26.4 ft/s, 28.9 kph) to 35 mph (51.3 ft/s, 56.3 kph). The above reconstructed speed of 35 mph lies within the ranges of both models, although at the high end. Note that this reconstruction process may not apply to all vehicle-pedestrian collisions and can vary with different conditions and data.

One additional part of the reconstruction from the EDR data remains to be done. Since velocity is the mathematical derivative of the position, the position (or displacement) is the mathematical integral of the velocity. Figure 4 shows the displacement of the pickup truck as a function of time before AE found by numerical integration of the (corrected) speed data in Table 3. It shows, for example, that in the last two seconds before the impact, the truck traveled approximately 150 feet.

Finally, the above model of vehicle-pedestrian collisions has been validated [3, 14] and is one of the few models that can be used to reconstruct a vehicle-pedestrian collision using the difference in rest positions of the vehicle and pedestrian [13, 16]

Example 2: Head-On Crash of Two Cars: In the article on the use of EDR data and complete reconstructions [2], conditions are presented corresponding to a head-on collision.[3] A reconstruction of this crash is done here. The crash is based on a staged head-on crash of a 2009 Chevrolet Impala (Vehicle A) and a 2008 Ford Focus (Vehicle B). Because the crash is a head-on central collision (i.e., preimpact and postimpact rotational velocities of the vehicles are negligible), point mass, impulse and momentum theory [3] can be used. Among the data available for the reconstruction of the collision are those imaged from the EDR of both vehicles. These contain the speed of the Focus in the five seconds up to t = 0 s before impact and the speed of the Impala including t = -0.5 s before AE. In summary:

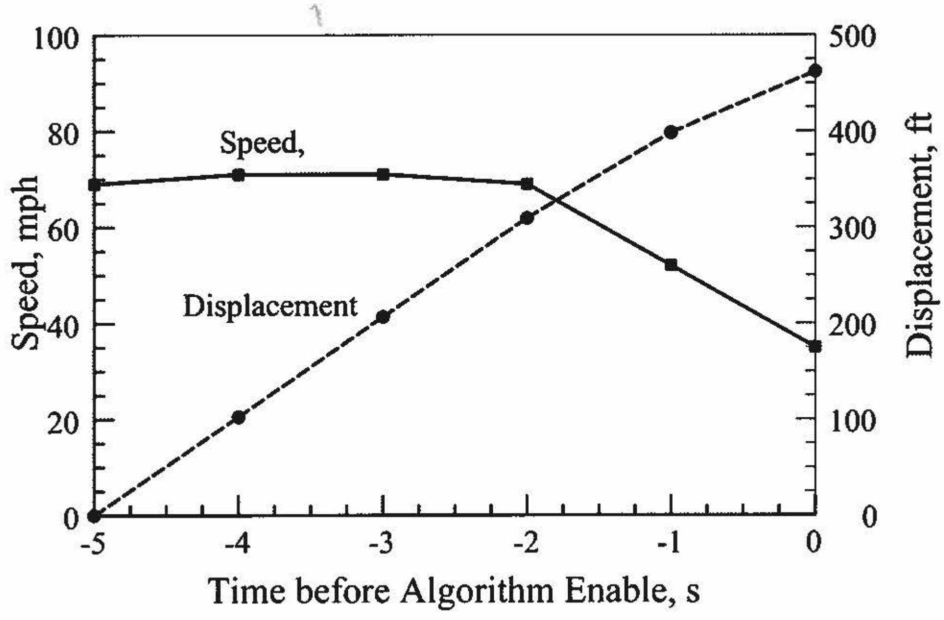


Figure 4: Vehicle speed and displacement using corrected EDR data (Table 3).

ped example 01.xls

8/29/2011

Analysis of Pedestrian Throw Distance from Initial Conditions

Brach Engineering
VCRware™
Vehicle Crash Reconstruction Software
www.brachengineering.com

NOTATION, COORDINATES, UNITS & VARIABLES:

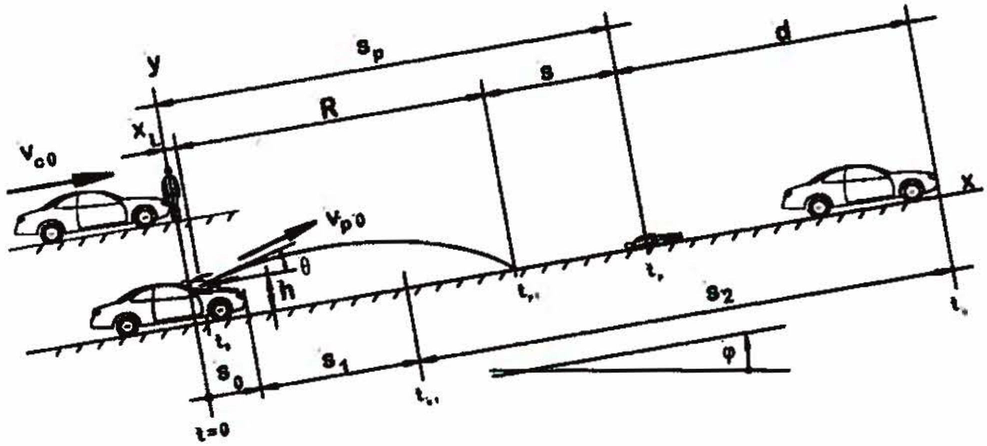
x	-		coordinate parallel to ground
y	-		coordinate perpendicular to ground

INPUT INFORMATION (KNOWNS):

a_2	0.77		deceleration of vehicle over distance s_2, g's
f_p	0.74		drag resistance coefficient of pedestrian over distance s
g	32.17	ft/s²	acceleration of gravity
h	2.75	ft	height of pedestrian center of gravity at launch, t_0
s_1	0.00	ft	distance of travel of vehicle at uniform speed
v_{c0}	51.33	ft/s	initial speed of vehicle
	35.0	mph	initial speed of vehicle
x_L	0.00	ft	x-distance of pedestrian from initial contact to launch
α	1.00		ratio of pedestrian speed to vehicle speed at time of launch
θ	0.00	deg	angle of launch of pedestrian relative to x axis
φ	0.00	deg	road grade angle
μ	0.74		impulse ratio for pedestrian-ground impact
m_c	124.32	lb-s²/ft	mass of vehicle, weight / g
m_p	4.67	lb-s²/ft	mass of pedestrian, weight / g

OUTPUT INFORMATION (UNKNOWNS):

v'_{c0}	49.48	ft/s	velocity of vehicle after impact with pedestrian
v_{p0}	49.48	ft/s	initial speed of pedestrian
R	20.46	ft	range of pedestrian throw, launch to ground impact
t_{p1}	0.41	s	time from impact to pedestrian initial contact with ground
s	32.95	ft	pedestrian ground contact distance, impact to rest
s_p	53.40	ft	throw distance; total distance from initial contact to pedestrian rest
t_p	2.08	s	total time of travel of pedestrian, initial contact to rest
t_{c1}	0.07	s	time of travel of vehicle to travel from initial contact to $s_0 + s_1$
s_0	0.00	ft	distance of travel of vehicle with pedestrian contact
s_2	49.40	ft	distance of travel of vehicle with uniform deceleration, a_2
$s_0+s_1+s_2$	49.40	ft	total distance of travel of vehicle
t_c	2.07	s	vehicle travel time, initial contact to rest
d	-4.00	ft	distance between rest positions of vehicle and pedestrian



igure 3: Spreadsheet showing the reconstruction of the vehicle-pedestrian impact, Example 1. Shaded cells are input values for an lysis but unknown input values can be found using the 'What If' feature of the spreadsheet for a reconstruction when output information is known.

- The Focus data show no preimpact brake lamp actuation with the speed at t = 0 s as 25.9 mph (37.99 ft/s, 41.7 kph).
- The Impala data show brake lamp actuation beginning at t = -0.5 s before AE and a speed at t = -0.5 s of 23 mph (33.73 ft/s, 37.0 kph).
- The EDR data include the longitudinal crash ΔV values, ΔV = 19.24 mph (28.2 ft/s, 30.9 kph) for the Impala and ΔV = 23.15 mph (34.0 ft/s, 37.2 kph) for the Focus.

The frontal residual crush of both vehicles was measured and crush energy analyses were carried out [2]. The results of these analyses are expressed as values of ΔV_C, computed from crush energy:

- ΔV_C^A = 18.2 mph (26.7 ft/s, 29.3 kph) for the Impala
- ΔV_C^A = 23.3 mph (34.2 ft/s, 37.5 kph) for the Focus.

The initial speeds of each vehicle cannot be reconstructed using the results of the crush energy analysis alone; only the closing speed can be determined. Moreover, EDR data is known to contain inaccuracies and that values sometimes are truncated. However, if the EDR data are available and are considered reliable, a reconstruction of the preimpact speeds of the vehicles can be carried out using combined data from the crush analysis and the EDR. This minimizes the effects of inaccuracies and truncation errors and allows a reconstruction rather than comparison of the individual values of ΔV from the EDR with their corresponding values from the crush analysis and separately using the speeds at AE from the EDR data.

Method of Least Squares: An analysis of a combination of the crush and EDR data can be carried out using the method of least squares, described as follows. The quantity Q is defined as the sum of squares of differences between each value of a variable obtained from physical evidence (e.g. the ΔV from the EDR data) and the value of that same variable that corresponds to the solution of an appropriate physical model (here the point mass central impact equations). Let:

$$Q = \sum_{i=1}^{n} w_i (u_i - u_i^{data})^2 \tag{3}$$

where n is the number of variables whose values are to be used from the data, w_i is a weighting factor, u_i^{data} is the value of variable i from physical evidence and u_i is the corresponding value of variable i that satisfies the physical model. The approach is to minimize Q in a way that determines the values of variables, v_i from the model of the physical system, that are needed from a reconstruction. This process satisfies the physical model AND matches the physical evidence in a "best, or optimal" way. It is not always necessary that the reconstructed/unknown variables, v_i be the same as the fitted variables, u_i, although they can be. In this example the values used from the data are the four values given in Table 5. The variables to be found (reconstructed) are the initial speeds, V_A and V_B. All values of the weighting factors, w_i, were chosen to be unity, that is, w_i = 1, i = 1, . . ., 4.

	Impala (Veh A)	Focus (Veh B)
ΔV from crush, mph	18.2	23.3
Initial Velocity, EDR, mph	23.0	25.9

Table 5: Physical Data used for Least-Squares Reconstruction

A convenient way to carry out such a reconstruction is to place the impulse-momentum model equations into a spreadsheet [3], set up the computation of Q and let the optimization routine of the spreadsheet carry out the minimization [12]. Figure 5 shows a spreadsheet from the *VCRware* software package [9] that is programmed to handle central impacts (including low speed impacts) using the impulse-momentum model. The equations in this spreadsheet allow the effects of braking-tire impulses to be taken into account because for low speed collisions such effects can be significant.

Figure 5 (on the following page) shows the results of the minimization process. Figure 6 shows the input to the spreadsheet's optimization routine (called "Solver"), including the "target" cell containing Q which is to be minimized, and the cell numbers of the quantities whose values are to be determined (reconstructed) through the minimization process. The reconstructed values of the initial speeds are: V_A = -20.52 mph (30.1 ft/s, 33.0 kph) and V_B = 23.42 mph (34.4 ft/s, 37.7 kph). Because the spreadsheet solves the general central impact problem many other reconstructed results are shown. Table 6 shows a summary of results of the speed reconstruction. Table 6 also contains the initial speeds measured from the crash test for comparison.

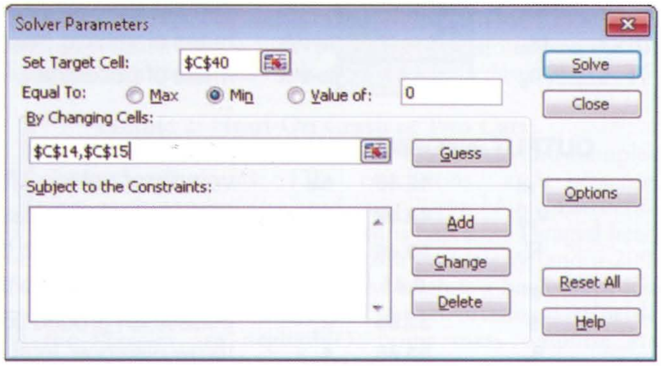


Figure 6: Input to Solver routine for minimization of Q (cell C40) in order to find the vehicle initial speeds (cells C14 and C15).

	Impala (Veh A)	Focus (Veh B)
Reconstructed Initial Speed, mph	20.5	23.4
Reconstructed Velocity Change, mph	20.43	23.52
Measured Initial Test Speed, mph	22	25

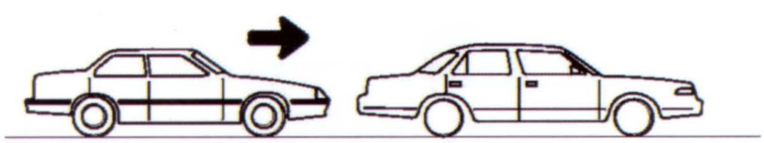
Table 6: Reconstruction and Test Results

Note that the reconstructed closing velocity that satisfies the impulse momentum equations is V_C = 43.9 mph (64.4 ft/s, 70.7 kph).

Some comments can be made concerning the reconstruction process (least-square minimization) and results.

- The Impala EDR showed a brake application in the last half-second before AE. Depending on the level of braking, this could have added an external frictional impulse to the collision. This impulse could have been taken into account in the least square minimization process by adding the friction coefficient, f_A (see Figure 5), of Veh A to the list of unknowns to be found. This was done initially, but the closing speed of the collision was high enough to be considered a high speed collision and the change in results due

	A	B	C	D	E	F	G	H
1	Head On Crash.xls		**Low Speed Front-to-Rear Impact of Vehicles**					
2	version 2.0				**(including tire friction effects)**			
3	7/24/2011							
4		weight	lb			friction coefficients		
5	**2009 Impala**	wt, W_A:	3,800.0			f_A	0.00	
6	**2008 Focus**	wt, W_B:	3,300.0			f_B	0.00	
7								
8		mass	lb-s^2/ft			contact duration, sec		
9		m_A:	118.11			Δt	0.105	
10		m_B:	102.57					
11		mbar:	54.90					
12								
13		initial speeds	mph			coefficient of restitution		
14	**2009 Impala**	Veh A	-20.52			low e (e_1)	0.00	
15	**2008 Focus**	Veh B	23.42			high e (e_2)	0.05	
16								
17								
18	range: velocity changes (e_1, e_2)		ft/s		**mph**			
19	**2009 Impala**	ΔV_A	29.96	31.45	**20.43**	**21.45**		
20	**2008 Focus**	ΔV_B	-34.50	-36.22	**-23.52**	**-24.70**		
21								
22		**average** acceleration, g's			**peak** accel, g's, (2 to 3 x a_{avg})			
23		a_A, avg:	8.87	9.31	a_A, peak:	**17.7**	**27.9**	
24		a_B, avg:	-10.21	-10.72	a_B, peak:	**-20.4**	**-32.2**	
25								
26	Energy Equivalent Barrier Speed		ft/s		**mph**			
27	**2009 Impala**	$EEBS_A$	30.10	30.07	**20.5**	**20.5**		
28	**2008 Focus**	$EEBS_B$	34.35	34.30	**23.4**	**23.4**		
29							tire-friction	
30							impulses,	lb-s
31		**B** 2008 Focus		**A**	2009 Impala		P_A	0.0
32							P_B	0.0



38	Sum of Squares		
39			
40		Q	23.03

Brach Engineering

VCRware™

Vehicle Crash Reconstruction Software

www.brachengineering.com

Figure 5: Spreadsheet showing the results of the least-square reconstruction, Example 2. Shaded cells are input values for an analysis but unknown values can be found using the 'What If' feature of the spreadsheet for a reconstruction when output information is known.

to the external friction impulse, if it existed, was negligible.

- The coefficient of restitution was chosen to be fixed at $e = 0$ for the least-square reconstruction. It too could have been found as part of the least-square process. Initially it was included in the least-square minimization, was found to be zero and was then simply fixed at $e = 0$.
- A question could be asked as to why the ΔV values from crush were used in the fitting process rather than the ΔV values from the EDR. This was done intentionally because the values generated from the crush energy analyses were considered to be independent from the EDR data. Because the impact speeds from the EDR were being used, the use of crush energy data gives a more balanced reconstruction.

Summary and Conclusions

Example 1 shows that EDR data and other, traditional, quantitative accident data can be combined to provide a reasonably accurate reconstruction. It also shows how knowledge of wheel slip can be used to correct underreported EDR vehicle speeds during braking. It shows that the location of the vehicle-pedestrian impact (point of impact), or throw distance, is not always needed to reconstruct the vehicle speed. Note that few pedestrian throw models allow such reconstructions; a comprehensive study [16] mentions none.

THE METHOD OF LEAST SQUARES USED ABOVE RECONSTRUCTS THE INITIAL VEHICLE SPEEDS (AND CLOSING SPEED) USING COMBINED CRUSH DATA AND EDR DATA.

From Example 2 the method of least squares used above reconstructs the initial vehicle speeds (and closing speed) using combined crush data and EDR data. The results are reasonably accurate in that the reconstructed initial speeds of the vehicles are within approximately 1.5 mph (2.4 kph) of the measured test values and also that the reconstructed collision closing speed of 44 mph (64.5 ft/s, 70.7 kph) is within 3 mph (4.8 kph) of the measured value, 47 mph (68.9 ft/s, 75.5 kph). A significant feature of this procedure is that all of the reconstructed results satisfy the central impact equations of Newton's laws.

In general, both examples show that the use of appropriate, validated mathematical models used with conveniently formulated software allows an accurate reconstruction to be carried out using data from numerous sources.

References

1. NHTSA: 49 CFR Part 563 - *Event Data Recorders.*

2. Haight, W. R. "Rusty", *"Using CDR System Data in Crash Reconstruction or What does the Term 'Complete Reconstruction' Mean?"*, Collision, Volume 6, Issue 1.

3. Brach, Raymond and Matthew Brach, *Vehicle Accident Analysis and Reconstruction Methods*, SAE International, 1st Ed, 2005, 2nd Ed, 2011.

4. Schmidt, Bruno, *"Two-Dimensional Analysis of EDR Information"*, Collision, Volume 2, Issue 1, 2007.

5. Brach, Raymond M. and R. Matthew Brach, *"Vehicle Accident Reconstruction Methods"*, SAE Professional Development Seminar, 2004-2010, SAE International, Troy, MI.

6. Brach, Raymond M. and R. Matthew Brach, *"Analysis of Collisions, Point Mass Mechanics and Planar Impact Mechanics"*, Collision, Volume 2, Issue 1, 2007.

7. Brach, Raymond and Matthew Brach, *"Analysis of Collisions, Point Mass Mechanics and Planar Impact Mechanics"*, Collision, Volume 2, Issue 2, Page 15, 2007.

8. *Bosch Automotive Handbook*, 7th Ed., Robert Bosch GmbH, Stuttgart Germany, 2007.

9. *VCRware*, Brach Engineering, Granger, IN 46530, www.brachengineering.com.

10. Happer, A., Araszewski, M., Toor, A., Overgaard, R., and Johal, R., *"Comprehensive Analysis Method for Vehicle/Pedestrian Collision"*, Paper 2000-10-0846, SAE, Warrendale, PA, 2000.

11. Wood, D. P. and D. G. Walsh, *"Pedestrian Forward Projection Impact"* IJCrash, Vol 7, No 3, Woodhead Publishing, UK, 2002.

12. Hallberg, B., S. Kinkoph, B. Ray, et al., Special Edition *Using Microsoft Excel 97*, Que Corp, 1997.

13. Evans, A. K. and R. Smith, *"Vehicle speed calculation from pedestrian throw distance"*, IMechE, Proc Instn Mech Engrs, Vol 213, Prt D, 1999.

14. Davis, Gary, *"A Baysian Approach to Cross-Validation in Pedestrian Accident Reconstruction"*, Paper 2011-01-0290, SAE International, 2011.

15. Reust, T. J. and J. M. Morgan, *"Detailed Comparison of Vehicle Speed and the Speed Recorded by an SDM"*, Collision, Volume 2, Issue 2, Fall, 2007.

16. Bonnett, G. M., *"Pedestrian Vaults, Humans Going Ballistic"*, Institute of Police Technology and Management, FL, 2005.

Footnotes:

1. The terms Event Data Recorder (EDR) and Crash Data Recorder (CDR) are often used synonymously. EDR is used in this paper since it conforms to terminology of the NHTSA (National Highway Traffic Safety Administration), Ref 1 [1].

2. The reader is encouraged to refer to [2] for additional information of the crash conditions and limitations of the EDR data, particularly for Example 2.