Case Study 1

Scenario: A 1991 Buick Century sedan (Buick) was westbound and stopped at a stop sign at an intersection with a four lane divided highway. The female driver of the Buick intended to make a left turn on US-1. She pulled across the northbound lanes and stopped partially in the median to wait for traffic to clear in the southbound lanes so that she could complete her turn. Concurrently, a 1997 Kawasaki Vulcan 750 motorcycle (Kawasaki), operated by a male, was traveling in the left northbound lane of the highway. An impact occurred between the front of the Kawasaki and the left rear of the Buick. The Buick rotated counter clockwise heading east at final rest. The police report diagram (Figure 5-8) showed the final rest position to the south of its position at impact, which clearly violates the laws of conservation of linear momentum; however, the angle of final rest was confirmed by all parties to be accurate. The speed limit for the northbound traffic on US-1 was 60 miles per hour.

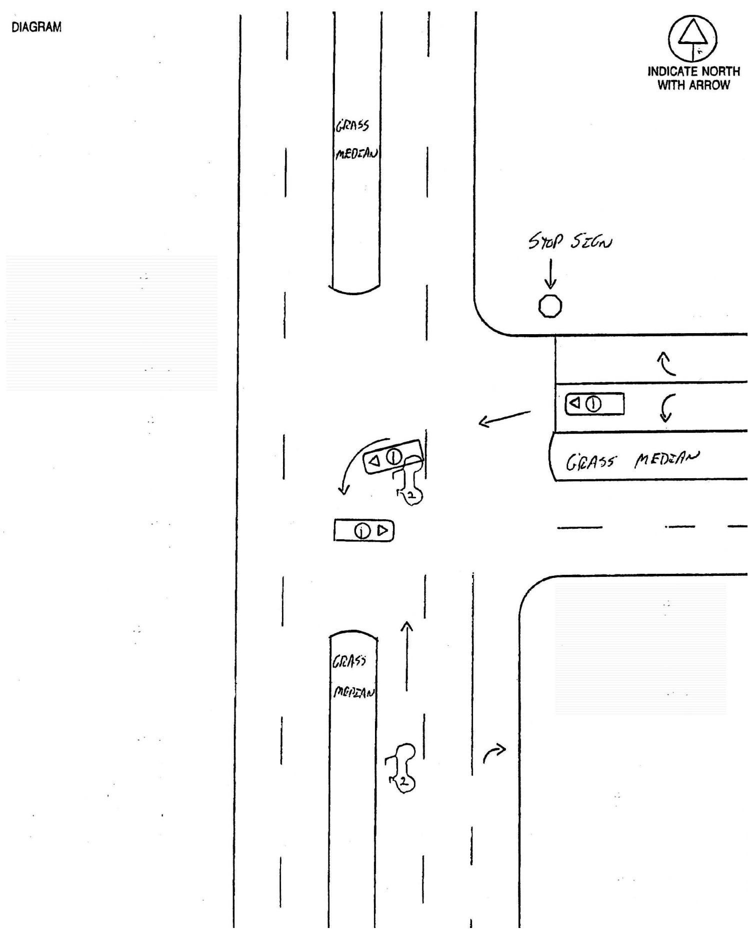

Figure 5-8

The damage to the Buick shows a distinct tire print on the rear edge of the left rear door, forward of the left rear wheel well. Additional damage is noted to the left ‘C’ pillar area. The left rear wheel is missing, with damage to the front portion of the wheel well. The unibody is bowed and concaved at the point of impact, Figures 5-9 and 5-10.

Figure 5-9

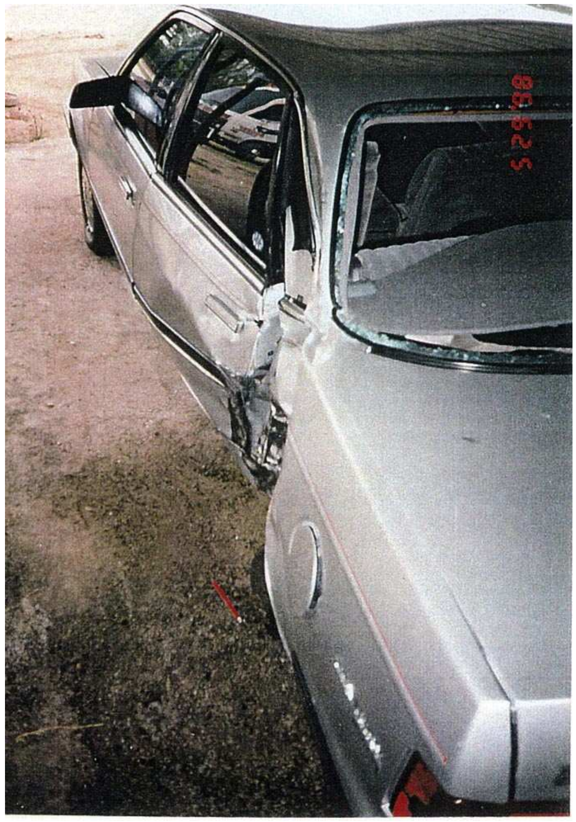

Figure 5-10

The photographs of the Kawasaki illustrate an impact from the front (Figures 5-11 and 5-12). The front fork tubes are bent rearward approximately 20° on the left and approximately 15° on the right. The handlebars were broken off the top of the fork tubes. The gas tank was dented on the top rear and demonstrated adjacent side damage that appeared to have been caused by compression from the sides due to the thighs of the driver. The front alloy wheel, which appears to have seven spokes, shows some deformation of the rim, consistent with an impact adjacent to one of the spokes. The tire and rim are pushed into the radiator/engine area of the motorcycle. The front tire appears to still be inflated.

Figure 5-11

Figure 5-12

The roadway was inspected and documented. A scale diagram of the scene was drawn, as shown in Figure 5-13. The approximate point of impact was based on the geometry of the intersection and statements of the Buick's driver. The post impact position of the Buick was based on testimony of the two drivers and a witness that arrived on the scene before the Buick was moved. The final rest of the Kawasaki based on a fluid mark on the roadway. The final rest of the Kawasaki driver was based on his testimony.

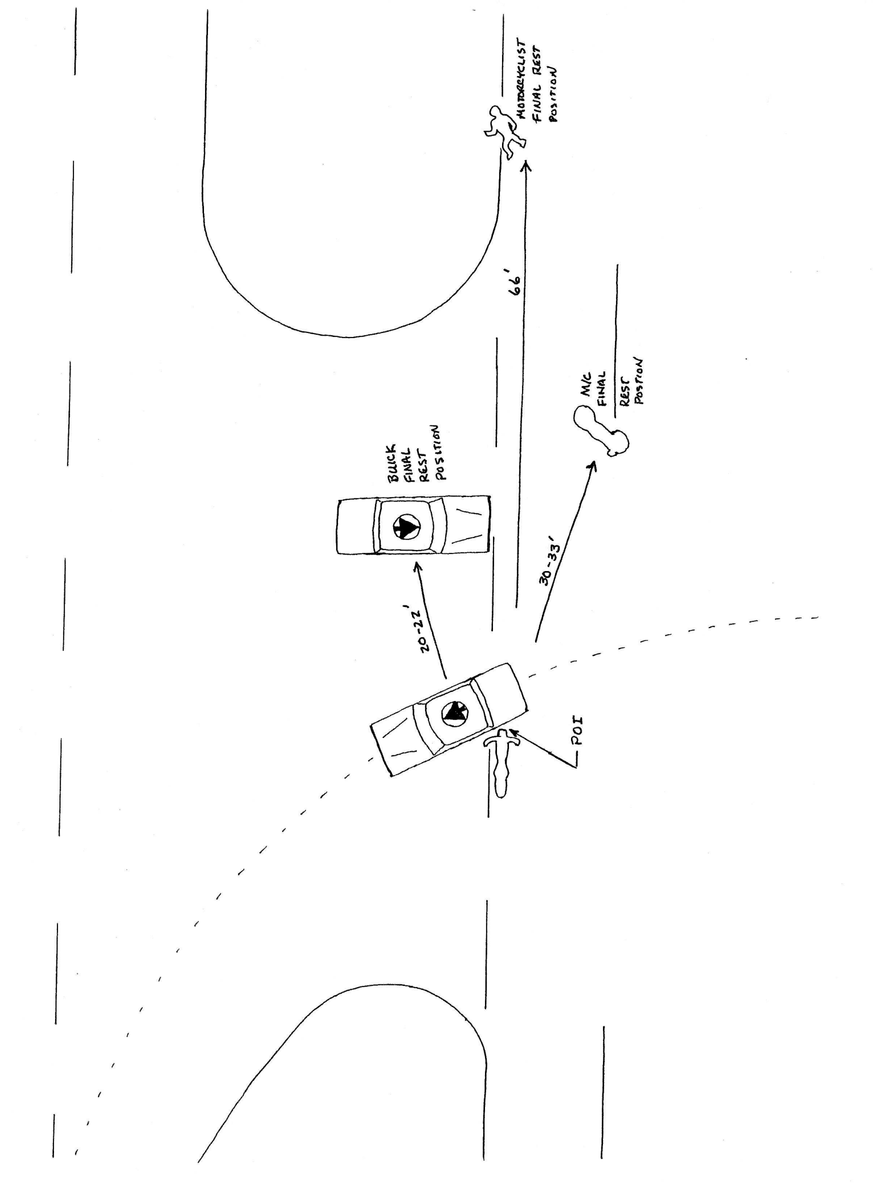

Figure 5-13

The driver of the Kawasaki indicated that he had locked up his brakes at least 15 feet prior to impact.

The driver of the Buick indicated that she had a trunk full of items, which she listed in detail. The estimated weight of the items in the trunk was 105 pounds. The driver was estimated to weigh 139 pounds, the weight of a 50 percentile adult female (Woodson, 1992).

The driver of the motorcycle weighed approximately 220 pounds. While only a portion of the weight of the driver would be involved in the change in momentum during the collision, the damage to the Buick 'C' pillar suggests that a substantial portion of the passenger weight should be included. Based on the Kawasaki driver's own estimate of his final rest position, the distance that his body traveled suggests that he retained a substantial portion of his initial kinetic energy. For the purposes of this analysis and to under-estimate the Kawasaki's speed, all of the driver's weight will be included for the rotational calculations.

Data for the calculations are as follows:

Buick		**Kawasaki**	
Overall Length (L_V)	15.75 ft		
Overall Width (W_V)	5.75 ft		
Wheel Base (L_{wb})	8.75 ft		
A (CG to front axle)	3.15 ft		
B (CG to rear axle)	5.60 ft		
Curb weight	2710 lbs_f	Dry Weight	483 lbs_f
Driver	139 lbs_f	Driver	220 lbs_f
Trunk cargo	105 lbs_f	Liquid weight	40 lbs_f
Total	2954 lbs_f	Total	743 lbs_f

The moment of inertia for the Buick is calculated using Equation 1-35 (K_G = 13.8 and K_M = 0.769 for automobiles).

$$m_{curb} = \frac{W_{curb}}{32.2} = \frac{2710}{32.2} = 84.16 \quad \text{and} \quad m_{loaded} = \frac{W_{loaded}}{32.2} = \frac{2954}{32.2} = 91.74$$

$$I = \frac{m_{curb}}{K_G}\left(L_V^2 + W_V^2\right)\left(1 + K_M\left(\frac{m_{loaded} - m_{curb}}{m_{loaded}}\right)\right)$$

$$I = \frac{84.16}{13.8}\left((15.75)^2 + (5.75)^2\right)\left(1 + 0.769\left(\frac{91.74 - 84.16}{91.74}\right)\right)$$

$$I = 1823.4 \text{ (lb}_f\text{-ft-s}^2\text{)}$$

The Buick was stopped at impact and rotated at least 160°. Using the composite best fit line on Figure 4-1, $\xi \approx 0.72$. The median on which the Buick was stopped was asphalt with loose gravel and therefore, the roadway friction was estimated at 0.6. The rotational friction factor (f_r) is calculated as follows:

$$f_r = \xi f = (0.72)(0.6) \approx 0.43$$

The impact was approximately 14 inches forward of the rear axle, therefore the axial distance from the center of gravity to the impact is:

$$d = B - 14/12 = 5.60 - 1.17 = 4.43 \text{ ft}$$

The vehicle is at an approximate 20 degree angle with the roadway, therefore, the perpendicular distance to the line of force is calculated as follows (refer to Figure 5-13):

$$\theta_l = \tan^{-1}\left(\frac{W_v/2}{d}\right) = \tan^{-1}\left(\frac{5.75/2}{4.43}\right) = 33^o$$

$$r_l = \sqrt{\left(\frac{W_v}{2}\right)^2 + d^2} = \sqrt{\left(\frac{5.75}{2}\right)^2 + (4.43)^2} = 5.28 \text{ ft}$$

$$d_l = r_l \cos(\theta_l - 20) = 5.28 \cos(33 - 20) = 5.14 \text{ ft}$$

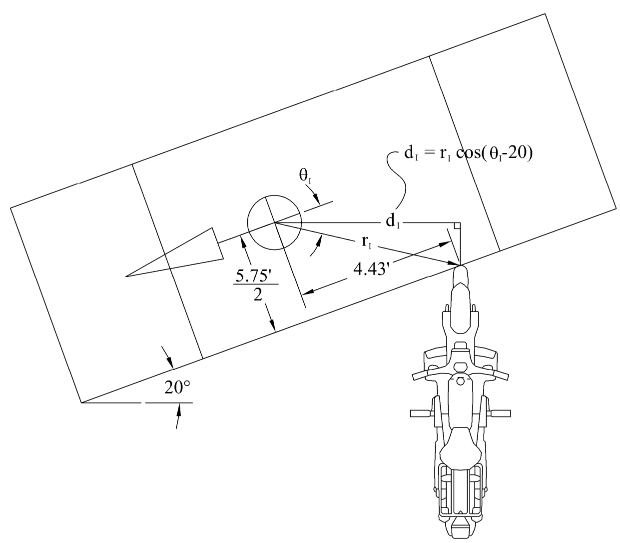

Figure 5-14

The post impact rotation of the motorcycle is unknown and involves a complex combination of rotation with the vehicle upright and on its side and angles in-between. From an energy standpoint, the post impact energy is minimal for the motorcycle and therefore is ignored. The impact is nearly perpendicular and therefore, Equation 2-71 is used, as follows:

$$S_A = \left(\frac{2.90}{W_A d_I} + \frac{2.90}{W_B d_I} + \frac{d_I}{11.10 I_B} \right) \sqrt{I_B \alpha_B f_r W_B L_{wbB}}$$

Where:

d_I = distance from point of impact to center of gravity (ft)

f_r = coefficient of rotational friction

I_B = yaw moment of inertia of Vehicle B (lb_f-ft-s^2)

L_{wb} = length of wheelbase (ft)

S_A = pre-impact speed of Vehicle A (mph)

W_A = weight of Vehicle A (lb_f)

W_B = weight of Vehicle B (lb_f)

α_B = angle of rotation of Vehicle B after impact (deg)

$$S_A = \left(\frac{2.90}{2965(5.14)} + \frac{2.90}{743(5.14)} + \frac{5.14}{11.10(1827.9)} \right) \sqrt{(1827.9)(160)(0.43)(2965)(9.75)}$$

$$S_A = 72.5 \text{ mph}$$

Assuming 15 feet of heavy braking as testified by the operator of the Kawasaki, his pre-braking speed is:

$$S = \sqrt{72.5^2 + 30(15)(0.7)} = 74.6 \text{ mph}$$