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Influence of Skidded Distance on the Initial Velocity of Vehicle in Chain Accidents at Intersections

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ABSTRACT : *The objective of this study is to determine the influence of skidded distance on the initial velocity of the first vehicle in a chain accident at intersections involving three vehicles. Regression analysis on the results of these variables was conducted. Excellent correlation coefficient was found for the relationship at $\alpha = 0.05$ significance level. The influence of Skidded Distance on the Initial Velocity is shown by a quadratic equation (Initial velocity = -0.0003 Skidded distance ^{2} +0.185 Skidded Distance + 51.83) with R = 1.*

Keywords: *Accident Reconstruction, Chain Accident, Initial Velocity, Skidded Distance, Regression Analysis.*

I. INTRODUCTION

Accident reconstructing engineering is the planning, surveying, measuring, investigating, analyzing, and report making process on the intricate engineering details of how accidents occurred. The analysis and conclusions are based on the extensive application of fundamental principles of physics and engineering including Newton's Laws of Motion [1] and First Law of Thermodynamics [2]. The first law of thermodynamics when applied to accidents states that the total energy before and after the accident will be the same. The input variables include roadway, vehicle, driver and environmental conditions. Accident reconstruction engineering studies can be utilized by the industry, city and state governments for modifying the structural facilities such as roads. The modifications may include obtaining improved friction factors, increased number of lanes and lane widths and better site distances. Vehicle manufacturers use the results of the studies for developing better designs of vehicles. Some of the recent vehicles may use event data recorder containing information on the speed of the vehicle before and at the time of the accident. Some manufacturers, such as GM and Ford, allow downloading the information from these boxes after an accident [3]. The results of the accident reconstruction studies are also used for producing better navigations aids to assist the drivers.

In this study the guidelines of Accreditation Commission for Traffic Accident Reconstruction (ACTAR) [4] are used. There are many research studies on the application of accident reconstruction engineering principles. One of the most important one is that of Hurt's [5]. Hurt found that motorcyclists needed to develop their capabilities on controlling skids and proper use of helmets significantly reduced head injuries. Hurt further found that out of all the turning movements, the left turners were the most involved ones in the accidents while turning in front of the oncoming motorcycles.

II. SCOPE OF THE STUDY

The study is limited to the accidents caused by negligent drivers of cars hitting the parked cars [6,7,8]. All the accidents caused elastic deformations only [9]. There are no significant plastic deformations [10].

III. METHODOLOGY

C3 was a parked car by the side of the road. The speed limit of the road is 15 mph. C2 was parked behind C3. C1 was driven by a negligent driver. The friction coefficients of the shoulder and pavement were measured. C1 saw C2 too late and hit the brakes. C1 skidded and hit C2. C2 skidded and hit C3. C3 skidded on to the shoulder and stopped. In most of the cases C3 was damaged and its driver was injured. As the plaintiff, C3's driver sued the negligent driver of C1. In most of the cases C1 driver underestimated his or her speed at the time of the accident.

3.1. Parked vehicle Car 3

The following steps were followed.

1. Deceleration = Friction factor * acceleration due to gravity
2. Final velocity of C3 = 0
3. Initial velocity of C3 is shown in the following equation.

$$u = \sqrt{2 \cdot a \cdot s} \quad (1)$$

Where, u= initial velocity of the vehicle, ft/sec
a= deceleration of the vehicle, ft/sec^2
s= skidded distance, feet

4. The total product of mass and velocity of Car2 is equal to that of Car 3 as shown in the following equation.

$$M_2 u_2 = m_3 u_3 \quad (2)$$

Where, m_2= mass of vehicle C2 and u_2 is the velocity of C2. M_3= mass of C3 and u_3 = velocity of C3.

3.2. Car 2

Deceleration was calculated by using Equation1.
Final velocity was calculated by the following equation.

$$u \quad \sqrt{v^2 \quad 2 * a * s} \qquad (3)$$

Where, u= initial velocity of the vehicle, ft/sec
v=final velocity, ft/sec
a= deceleration of the vehicle, ft/sec^2
s= skidded distance, feet

3.3 Car 1

Deceleration was calculated by using Equation1.
Final velocity was calculated by Equation 3.

IV. RESULTS AND DISCUSSION

The following assumptions were made in this study

1. The energy lost in sound produced by the accident is negligible.
2. The energy lost in causing the slight angular movement of the vehicle is negligible.

Professional engineering principles allow the application of the above two assumptions in the appropriate engineering calculations.

Table I shows the Engineering Calculations for Mixed Variables for Case 1 through Case 5 for Determininig the Initial Velocity while Table II gives the Engineering Calculations for Mixed Variables for Case 6 thorugh 7 for Determininig the Initial Velocity.
Engineering Calculations for Case 1 through Case 5; Case 6 through Case 10; and Case 11 through Case 15 for Determininig the influence of Skidded Distance on the Initial Velocity are given in Tables III, IV, and V respectively.
The following regression relationship was found with statistically significant correlation coefficient for predicting the performance of the engineering variables. The relationship was significant at $\alpha = 0.05$ significance level [11,12,13,14].

Fig. 1 shows the influence of Skidded Distance on the Initial Velocity. This relationship is described by a quadratic equation (Initial velocity = -0.0003 Skidded distance ^{2} +0.185 Skidded Distance + 51.83) with R = 1.

Table I. Engineering Calculations for Mixed Variables for Case 1 through Case 5 for Determininig the Initial Velocity.

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Car3					
Final Velocity, ft/sec	**0**	**0**	**0**	**0**	**0**
Subgrade Friction	**0.38**	**0.38**	**0.38**	**0.38**	**0.38**
Skidded Distance, ft	**48**	**29**	**33**	**39**	**46**
Deceleration, ft/sec^2	**12.24**	**12.24**	**12.24**	**12.24**	**12.24**
Initial Velocity, ft/sec	**34.27**	**26.64**	**28.42**	**30.89**	**33.55**
Weight, pounds	**1800**	**2100**	**2400**	**2600**	**2500**
Car2					
Weight, Pounds	**3300**	**3100**	**3600**	**3900**	**4200**
Weight Ratio, C2/C1	**0.55**	**0.68**	**0.67**	**0.67**	**0.60**
Final Velocity, ft/sec	**18.69**	**18.05**	**18.95**	**20.60**	**19.97**
Skidded Distance, ft	**8.00**	**12.00**	**14.00**	**13.00**	**11.00**
Pavement Friction	**0.12**	**0.10**	**0.15**	**0.20**	**0.25**
Deceleration, ft/sec^2	**3.86**	**3.22**	**4.83**	**6.44**	**8.05**
Initial Velocity, ft/sec	**20.28**	**20.07**	**22.23**	**24.32**	**24.00**
Car1					
Weight, pounds	**3400**	**3700**	**4000**	**4150**	**4450**
Weight Ratio, C2/C1	**0.97**	**0.84**	**0.90**	**0.94**	**0.94**
Final Velocity, ft/sec	**19.68**	**16.82**	**20.01**	**22.86**	**22.65**
Skidded Distance, ft	**5.00**	**7.00**	**9.00**	**11.00**	**10.00**
Pavement Friction	**0.3**	**0.15**	**0.12**	**0.21**	**0.18**
Deceleration, ft/sec^2	**9.66**	**4.83**	**3.86**	**6.76**	**5.80**
Initial Velocity, ft/sec	**22.00**	**18.72**	**21.68**	**25.91**	**25.08**

Table II. Engineering Calculations for Mixed Variables for Case 6 through Case 7 for Determininig the Initial Velocity.

	Case 6	Case 7
Car3		
Final Velocity, ft/sec	**0**	**0**
Subgrade Friction	**0.38**	**0.38**
Skidded Distance, ft	**44**	**48**
Deceleration, ft/sec^2	**12.24**	**12.24**
Initial Velocity, ft/sec	**32.81**	**34.27**
Weight, pounds	**2700**	**4500**
Car2		
Weight, Pounds	**4350**	**3750**
Weight Ratio, C2/C1	**0.62**	**1.20**
Final Velocity, ft/sec	**20.37**	**41.13**
Skidded Distance, ft	**15.00**	**20.00**
Pavement Friction	**0.30**	**0.35**
Deceleration, ft/sec^2	**9.66**	**11.27**
Initial Velocity, ft/sec	**26.54**	**46.29**
Car1		
Weight, pounds	**2450**	**2750**
Weight Ratio, C2/C1	**1.78**	**1.36**
Final Velocity, ft/sec	**47.13**	**63.12**
Skidded Distance, ft	**13.00**	**19.00**
Pavement Friction	**0.1**	**0.23**
Deceleration, ft/sec^2	**3.22**	**7.41**
Initial Velocity, ft/sec	**48.01**	**65.31**

Table III. Engineering Calculations for Case 1 through Case 5 for Determininig the Relationship between Skided Distance and Initial Velocity.

	Case 1	Case 2	Case 3	Case 4	Case 5
Car3					
Final Velocity, ft/sec	**0**	**0**	**0**	**0**	**0**
Subgrade Friction	**0.38**	**0.38**	**0.38**	**0.38**	**0.38**
Skidded Distance, ft	**55**	**55**	**55**	**55**	**55**
Deceleration, ft/sec^2	**12.24**	**12.24**	**12.24**	**12.24**	**12.24**
Initial Velocity, ft/sec	**36.69**	**36.69**	**36.69**	**36.69**	**36.69**
Weight, pounds	**1800**	**1800**	**1800**	**1800**	**1800**
Car2					
Weight, Pounds	**3300**	**3300**	**3300**	**3300**	**3300**
Weight Ratio, C2/C1	**0.55**	**0.55**	**0.55**	**0.55**	**0.55**
Final Velocity, ft/sec	**20.01**	**20.01**	**20.01**	**20.01**	**20.01**
Skidded Distance, ft	**8.00**	**8.00**	**8.00**	**8.00**	**8.00**
Pavement Friction	**0.30**	**0.30**	**0.30**	**0.30**	**0.30**
Deceleration, ft/sec^2	**9.66**	**9.66**	**9.66**	**9.66**	**9.66**
Initial Velocity, ft/sec	**23.56**	**23.56**	**23.56**	**23.56**	**23.56**
Car1					
Weight, pounds	**1500**	**1500**	**1500**	**1500**	**1500**
Weight Ratio, C2/C1	**2.20**	**2.20**	**2.20**	**2.20**	**2.20**
Final Velocity, ft/sec	**51.83**	**51.83**	**51.83**	**51.83**	**51.83**
Skidded Distance, ft	**2.00**	**4.00**	**6.00**	**10.00**	**13.00**
Pavement Friction	**0.30**	**0.30**	**0.30**	**0.30**	**0.30**
Deceleration, ft/sec^2	**9.66**	**9.66**	**9.66**	**9.66**	**9.66**
Initial Velocity, ft/sec	**52.20**	**52.57**	**52.94**	**53.66**	**54.20**

Table IV. Engineering Calculations for Case 6 through Case 10 for Determininig the Relationship between Skidded Distance and Initial Velocity.

	Case 6	Case 7	Case 8	Case 9	Case 10
Car3					
Final Velocity, ft/sec	0	0	0	0	0
Subgrade Friction	0.38	0.38	0.38	0.38	0.38
Skidded Distance, ft	55	55	55	55	55
Deceleration, ft/sec^2	12.24	12.24	12.24	12.24	12.24
Initial Velocity, ft/sec	36.69	36.69	36.69	36.69	36.69
Weight, pounds	1800	1800	1800	1800	1800
Car2					
Weight, Pounds	3300	3300	3300	3300	3300
Weight Ratio, C2/C1	0.55	0.55	0.55	0.55	0.55
Final Velocity, ft/sec	20.01	20.01	20.01	20.01	20.01
Skidded Distance, ft	8.00	8.00	8.00	8.00	8.00
Pavement Friction	0.30	0.30	0.30	0.30	0.30
Deceleration, ft/sec^2	9.66	9.66	9.66	9.66	9.66
Initial Velocity, ft/sec	23.56	23.56	23.56	23.56	23.56
Car1					
Weight, pounds	1500	1500	1500	1500	1500
Weight Ratio, C2/C1	2.20	2.20	2.20	2.20	2.20
Final Velocity, ft/sec	51.83	51.83	51.83	51.83	51.83
Skidded Distance, ft	16.00	18.00	20.00	22.00	24.00
Pavement Friction	0.30	0.30	0.30	0.30	0.30
Deceleration, ft/sec^2	9.66	9.66	9.66	9.66	9.66
Initial Velocity, ft/sec	54.73	55.08	55.43	55.78	56.12

Table V. Engineering Calculations for Case 11 through Case 15 for Determininig the Relationship between Skidded Distance and Initial Velocity.

	Case 11	Case 12	Case 13	Case 14	Case 15
Car3					
Final Velocity, ft/sec	0	0	0	0	0
Subgrade Friction	0.38	0.38	0.38	0.38	0.38
Skidded Distance, ft	55	55	55	55	55
Deceleration, ft/sec^2	12.24	12.24	12.24	12.24	12.24
Initial Velocity, ft/sec	36.69	36.69	36.69	36.69	36.69
Weight, pounds	1800	1800	1800	1800	1800
Car2					
Weight, Pounds	3300	3300	3300	3300	3300
Weight Ratio, C2/C1	0.55	0.55	0.55	0.55	0.55
Final Velocity, ft/sec	20.01	20.01	20.01	20.01	20.01
Skidded Distance, ft	8.00	8.00	8.00	8.00	8.00
Pavement Friction	0.30	0.30	0.30	0.30	0.30
Deceleration, ft/sec^2	9.66	9.66	9.66	9.66	9.66
Initial Velocity, ft/sec	23.56	23.56	23.56	23.56	23.56
Car1					
Weight, pounds	1500	1500	1500	1500	1500
Weight Ratio, C2/C1	2.20	2.20	2.20	2.20	2.20
Final Velocity, ft/sec	51.83	51.83	51.83	51.83	51.83
Skidded Distance, ft	26.00	28.00	30.00	32.00	34.00
Pavement Friction	0.30	0.30	0.30	0.30	0.30
Deceleration, ft/sec^2	9.66	9.66	9.66	9.66	9.66
Initial Velocity, ft/sec	56.47	56.81	57.15	57.48	57.82

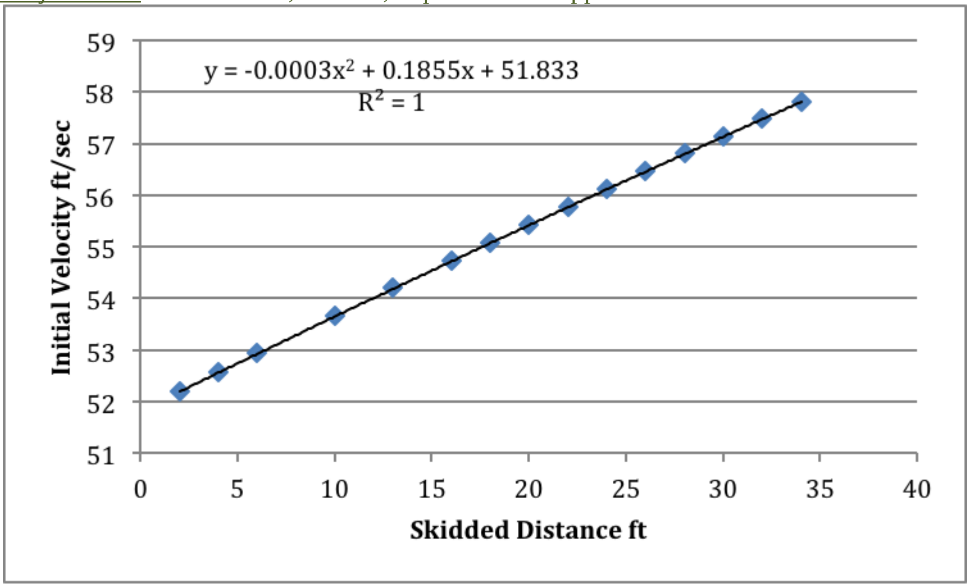

Figure 1 Influence of Skidded Distance on the Initial Velocity

V. CONCLUSIONS

The following regression relationship was found with statistically significant correlation coefficient for predicting the performance of the engineering variables.

The influence of Skidded Distance on the Initial Velocity is shown by a quadratic equation (Initial velocity = -0.0003 Skidded distance ^{2} +0.185 Skidded Distance + 51.83) with R = 1.

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REFERENCES

[1] Newton's Three Laws of Motion. http://csep10.phys.utk.edu/astr161/lect/history/newton3laws.html
[2] First Law of Thermodynamics. http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/firlaw.html
[3] Engber, D. The Ferrari That Split in Half. 2006. http://www.slate.com/articles/news_and_politics/explainer/2006/04/the_ferrari_that_split_in_half.html
[4] Accreditation Commission for Traffic Accident Reconstruction (ACTAR). http://www.actar.org/
[5] Hurt, H. Jr. AMA Motorcycle Hall of Fame. http://www.motorcyclemuseum.org/halloffame/detail.aspx?RacerID=398
[6] Brooks R. M.; Cetin M. Determination of the Influence of Vehicles Weight Ratio on the Initial Velocity Using the Accident Reconstruction Engineering Principles. International Journal of Emerging Technology and Advanced Engineering. Volume 3, Issue 3, ISSN: 2250-2459, S. No: 159, March 2013, pp. 927-931.
[7] Brooks R. M.; Cetin M. Determination of the Influence of Pavement Friction on the Initial Velocity Using the Accident Reconstruction Engineering Principles. International Journal of Engineering Inventions. Volume 2, Issue 6, e-ISSN: 2278-7461, p-ISBN: 2319-6491, S. No: 9, April 2013, pp. 63-68.
[8] Brooks R. M.; Cetin M. Determination of the Influence of Skidded Distance on the Initial Velocity Using the Accident Reconstruction Engineering Principles. International Journal of Research and Reviews in Applied Sciences. Volume 15, Issue 3, EISSN: 2076-7366, ISSN: 2076-734X, S. No: 3, June 2013, pp 225-229.
[9] Brooks R. M.; Cetin M. Influence of Pavement Friction on the Initial Velocity of Vehicle in Chain Accidents at Intersections. International Journal of Emerging Technology and Advanced Engineering. Volume 3, Issue 7, S. No: 2, ISSN 2250-2459, July, 2013, page 10-15.
[10] Brooks R. M.; Cetin M. Pavement Friction V. Initial Velocity of Vehicle in Chain Accidents on Highways. International Journal of Engineering Inventions. Volume 3, Issue 2, e-ISSN: 2278-7461, p-ISBN: 2319-6491, S. No: 5, September 2013, pp. 27-31.
[11] Mendenhall, W., and Sincich, T., (2007) "Statistics for Engineering and the Sciences", Prentice Hall. 5th Edition.
[12] Hogg, R. V., and Tanis, E. A., (2006) "Probability and Statistical Inference", Prentice Hall, 7th Edition.
[13] Field, A., (2009) "Discovering Statistics Using SPSS", Sage, 3rd Edition.
[14] Walpole, R.E., Myers, R. H., Myers, S. L., and Ye, K., (2007) "Probability and Statistics for Engineers and Scientists", Pearson Education International. 8th Edition.