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The Use of EDSMAC To Simulate Bicycle and Motor Vehicle Collisions

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Introduction

The purpose of this paper is to enable licensed users of the EDSMAC[1] program to understand how to simulate motor vehicle and bicycle collisions. EDSMAC is the Engineering Dynamics Corporation simulation model of automobile collisions. The model basically simulates vehicle dynamics at impact and velocity change as a result of impact.

The use of this collision model will not be explained in this paper since that is a function of obtaining the license and taking the necessary classes. This program is the model that is commonly accepted in court and by forensic engineers as being authoritative. Therefore, rewriting the input language to include collisions with bicycles would be helpful in reconstructing these types of accidents.

Field verification of these input values has been accomplished. These data are provided and the limitations of the use of EDSMAC in these types of collisions are given. Also, an actual EDSMAC computer run is provided as the forensic engineer can visualize the actual inputs needed for these types of reconstructions.

It must be emphasized that in order to run the EDSMAC program for a bicycle, error codes and default values are deliberately introduced. In our analysis we are interested in the kinetics up until the point of impact (POI). It is possible to verify the motor vehicle speeds and cycling speeds in the field. This has been done for this paper. However, of more difficulty is the determination of the physics of the two entities after impact. Several post-accident scenarios have been observed that correspond to the position of the bicycle in EDSMAC. It appears that EDSMAC will give a very good approximation of the position of the bicycle past impact. The initial investigations that I have conducted in the field reveal that EDSMAC probably can be used for post impact dynamics of the bicycle for at least 0.5 seconds after the impact, if the bicycle stays on the ground. Further work needs to be done in this area. However, enough field verification has been done to state that EDSMAC will give very accurate results up to the point of impact and can be used, with the changes noted in this paper.

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Input Changes to EDSMAC

The key inputs to EDSMAC, for a bicycle, are noted under Vehicle Dimensional and Inertial Properties. Vehicle 1 was chosen to be the bicycle. Wheelbase is noted as 48.0 inches for an exemplar bicycle. The wheelbase is measured from the point of contact of the front and rear wheels with the ground. It should be measured from the actual bicycle instead of an exemplar. Center of gravity (Cg) for the EDSMAC application is defined as the center of gravity of the combined mass of the bicycle, its rider, and any attached gear normally carried (such as panniers, handlebar bags, carriers, etc.). For this application, the weight of the bicycle at the center of gravity (Cg) is assumed to be 15 pounds; the location of the Cg in relation to the front and rear axle is 0.5 times the wheelbase, or 24 inches in this example. The overall length of the bicycle is the distance from plumb lines tangential to the front and rear wheels. The overall length in this example is 70 inches. Therefore, the distance of the Cg to both the front and rear ends is 0.5 times the overall length or 35 inches. The vehicle 2 parameters under Vehicle Dimensional and Inertial Properties is an exemplar motor vehicle chosen from the EDSMAC data bank. The moment of inertia is a default value that will have no influence on this EDSMAC simulation. All values noted are with the rider in the seated position on level ground. Example calculations are shown as follows:

Example Calculations for Vehicle Dimensional and Inertial Properties for Simulating a Bicycle

Parameter	Calculation or Measurement	Input Value
Vehicle Class Category	Use 1 to run program	1
Wheelbase	Measured value from bicycle	48.0 inches
Distance of Cg to Front Axle	0.5 x 48 inches	24.0 inches
Distance of Cg to Rear Axle	0.5 x 48 inches	24.0 inches
Truck Width	Width of tire on ground	1.0 inches
Overall Length	Measured value from bicycle	70.0 inches
Distance of Cg to Front End	0.5 x 70 inches	35.0 inches
Distance of Cg to Rear End	0.5 x 70 inches	35.0 inches
Overall Width	Measured width of tire & rim	2.0 inches
Weight	Total weight of rider/bicycle system	150 pounds
YAW Moment of Inertia	Default value – must be input to run	11,432 $lbs\text{-}sec^2\text{-}inch$

These are example calculations and are not from an actual reconstruction.

For this example simulation, Vehicle 1 was assumed to be the bicycle. The settings given were:

	Vehicle 1	Vehicle 2
X-Coordinate	47.0 ft.	00.00 ft.
Y-Coordinate	-1.00 ft.	37.0 ft
PSI - Coordinate (heading)	180 degrees	270 degrees
U-Velocity	10.0 mph	10.0 mph
V-Velocity	0.0 mph	0.0 mph
YAW Moment of Inertia	0.0 mph	0.0 mph

The motor vehicle was given a surprise reaction steer angle of 8 degrees to be applied 2 seconds into the simulation.

The input for this exemplar vehicle becomes:

Wheel Force and Steer Angle – Vehicle No. 2 (Motor Vehicle)

Wheel Force – Pounds				Time (sec)	Steer Angle (deg.)	
R/F	L/F	R/R	L/R		R/F	L/F
-0.01	-0.01	0.01	0.01	0.000	0.00	0.00
			2.000	8.00	8.00	

The bicycle was chosen to proceed in a straight path. The steer angles can be applied to the bicycle as well. It would be best to define the steer angle of the bicycle in the field, using the accident bicycle or an exemplar bicycle.

The input for the example bicycle becomes:

Wheel Force and Steer Angle – Vehicle No. 1 (Bicycle)

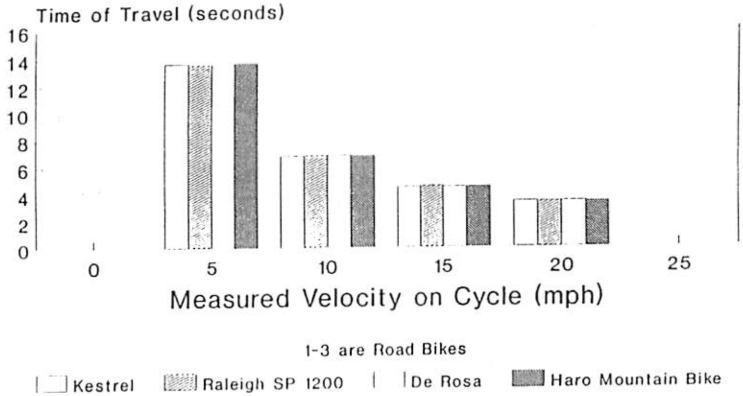
Wheel Force – Pounds				Time (sec.)
R/F	L/F	R/R	L/R	
-0.01	-0.01	0.01	0.01	0.000

No steer angle was utilized.

Output of EDSMAC Trajectory Simulation

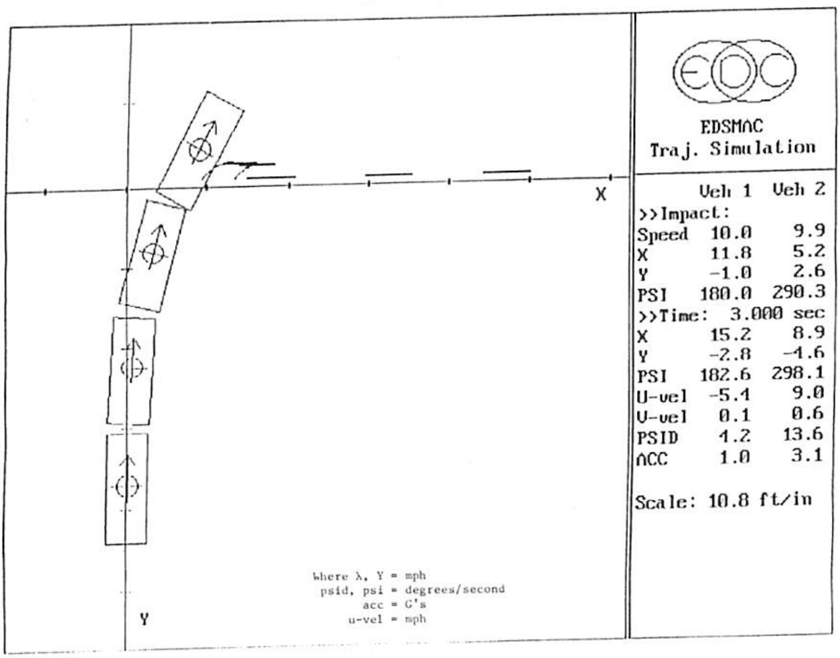
The output of the example EDSMAC simulation is shown in Figure 1. The bicycle approaches along the X-axis at 10 mph. (Figure 2). The motor vehicle, on the Y-axis, approaches at an 8 degree steer angle which is executed 2 seconds

Figure 1
Predicted Time of Travel from EDSMAC
Compared to Field Measured Values



EDSMAC Results are; 5mph = 13.61,
10mph = 6.80, 15mph = 4.54,
20mph = 3.40 (Results in Seconds)

Figure 2
Example Trajectory



into the scenario. The point of impact on the motor vehicle occurs approximately one-third of the way back from the front of the motor vehicle. The bicycle is moved laterally in the direction of the path of travel of the car. This movement causes skid marks to be left on the pavement. A coefficient of friction of 0.700 is assumed as an input value. This is noted as nominal road friction. The EDSMAC program actually is capable of showing skid marks from the bicycle, even though the mass is reduced from that of a motor vehicle to that of a bicycle/rider system.

Conclusion of the Analysis Using EDSMAC to Simulate Bicycle and Motor Vehicle Collisions

Field tests were conducted to validate EDSMAC's ability to simulate the travel time of a bicycle. Four different cycles were used in the tests. Each cycle's Time of Travel (TOT) over a calibrated course was compared to the TOT (Time of Travel) or Velocity predicted in EDSMAC. The results of the field tests are noted in Table 1.

Table 1

Predicted Time of Travel from EDSMAC Compared to Field Measured Time of Travel on a 100 ft. Calibrated Course

Bicycle	5 mph	10 mph	15 mph	20 mph
Kestrel 10-speed	13.61	6.79	4.49	3.42
Raleigh SP 1200	13.53	6.80	4.56	3.41
De Rosa 10-speed	13.58	6.83	4.48	3.42
Haro 24-speed	13.63	6.79	4.50	3.39
EDSMAC	13.61	6.80	4.54	3.40

The above data reveals the following:

(1) All bicycles were ridden by human subjects at rpm's sufficient to maintain the required velocity on a calibrated velometer. TOT was then measured using a Robic SC-600 chronometer with 1/100th precision. The results also are plotted in Figure 1.

(2) EDSMAC is a highly accurate program for plotting the approach speed of a bicycle up to POI (Point of Impact). The data plotted in Figure 1 and tabulated in Table 1 reveal no significant difference between field values and EDSMAC values for a cycle's TOT.

(3) Figure 2 shows the Trajectory Plot of the exemplar collision. It should be noted that EDSMAC produces reasonably accurate estimates

of bicycle dynamics if it is assumed that the exemplar bicycle stays on the ground.

(4) The modified EDSMAC program discussed in this paper accurately simulates motor vehicle/bicycle collisions up to POI. The program also is a good means for developing an index for immediate post-impact collisions, if the bicycle stays on the ground. Unfortunately, the modified program cannot be used for computing the trajectory of the bicyclist after impact.

Reference

1. EDSMAC is a licensed program that is available from Engineering Dynamics Corporation.

Appendix

Summary of EDSMAC Results
Example Reconstruction -- Bicycle at 10 mph

At the time execution was halted, both vehicles were still moving with the

following velocities:

Vehicle No.	Linear Velocity in ft/sec	Angular Velocity in deg/sec
1	8.0	4.2
2	13.2	13.6

Accident History

		POSITION			VELOCITY		
	time (sec)	X (ft)	Y (ft)	psi (deg)	U (mph)	V (mph)	angular (deg/sec)
Begining of Simulation							
Veh #1	0.00	47.0	-1.0	180.0	10.0	0.0	0.0
Veh #2		0.0	37.0	270.0	10.0	0.0	0.0
Impact							
Veh #1	2.40	11.8	-1.0	180.0	10.0	0.0	0.0
Veh #2		5.2	2.6	290.3	9.9	0.6	14.9
Separation							
Veh #1	2.60	12.0	-1.8	180.5	-5.6	4.5	5.3
Veh #2		6.4	0.1	292.6	9.0	.05	13.5
End of Simulation							
Veh #1	3.00	15.2	-2.8	182.6	-5.4	0.1	4.2
Veh #2	3.00	8.9	-4.6	298.1	9.0	0.6	13.6

Program Control Data

Initial Simulation Time	0.000 sec **
Maximum Simulation Time	3.000 sec
Collision Phase Integration Time Interval	0.010 sec
Separation Phase Integration Time Interval	0.010 sec **
Trajectory Phase Integration Time Interval	0.050 sec **
Output Print Interval	0.050 sec **
Minimum Linear Velocity for Stopping Test	2.000 mph **
Minimum Angular Velocity for Stopping Test	5.000 deg/sec **

Initial Conditions

	Vehicle #1	Vehicle #2
X-Coordinate	47.00 ft	0.00 ft
Y-Coordinate	-1.00 ft	37.00 ft
PSI-Coordinate (heading)	180.00 deg	270.00 deg
U-Velocity	10.00 mph	10.00 mph
V-Velocity	0.00 mph	0.00 mph
Yaw as Velocity	0.00 deg/sec	0.00 deg/sec

Vehicle Dimensional and Inertial Properties

	Vehicle #1	Vehicle #2
Vehicle Class Category	1	1
Wheelbase	48.00 in	93.20 in **
CG to Front Axle	24.00 in	45.10 in
CG to Rear Axle	24.00 in	48.10 in **
Track Width	1.00 in	51.10 in **
Overall Length	70.00 in	159.80 in **
CG to Front End	35.00 in	83.80 in **
CG to Rear End	35.00 in	60.80 in **
Overall Width	2.00 in	60.80 in **
Rear Axle Steer Angle	0.00 deg **	0.00 deg **
Weight	150.00 lb	2202.00 lb **
YAW as Moment of Inertia	11432.00 lb-sec^2-in **	11432.00 lb-sec^2-in **

** indicates default value

Wheel Force and Steer Angle Tables
Vehicle No. 1

Time	Wheel Force (lb)				Time	Steer Angle (deg)	
(sec)	R/F	L/F	R/R	L/R	(sec)	R/F	L/G
0.000	-0.01	-0.01	0.01	0.01			

Wheel Force and Steer Angle Tables
Vehicle No. 2

Time	Wheel Force (lb)				Time	Steer Angle (deg)	
(sec)	R/F	L/F	R/R	L/R	(sec)	R/F	L/G
0.000	-0.01	-0.01	0.01	0.01	0.000	0.000	0.000
					2.000	8.00	8.00