

**ANALYSES USING EXISTING
DATA
SHRP2 S01(A)**

Gary A. Davis

John Hourdos

**Minnesota Traffic Observatory
Center for Transportation Studies
University of Minnesota**

July 23, 2009

Project Focus

- (1) “...statistical relationship of surrogate measures of collisions (conflicts, critical incidents, near collisions, or roadside encroachments) with actual collisions...” ?
- (2) Can data from SHRP2 field studies support microscopic crash modeling (& future editions of HSM)?

Phase I Identified Three Research Problems:

1. Structural Modeling of Crash/Near Crash Events
2. Counterfactual Screening of Non-Crash Events
3. Modeling Driver Selection of Evasive Actions

Crashes and Surrogates in the Literature

ICSTCT: conflict= “risk of collision if their movements remain unchanged”

Svenson & Hyden: Conflict severity= $f(\text{TTC}/\text{CS})$

100-Car Study: “circumstance that requires a rapid, evasive maneuver...that approaches the limit of vehicle capabilities”

Volpe Team: Crash-Near Crash Boundary:
 $R = \frac{RR^2}{2(.65)g}$

Summary

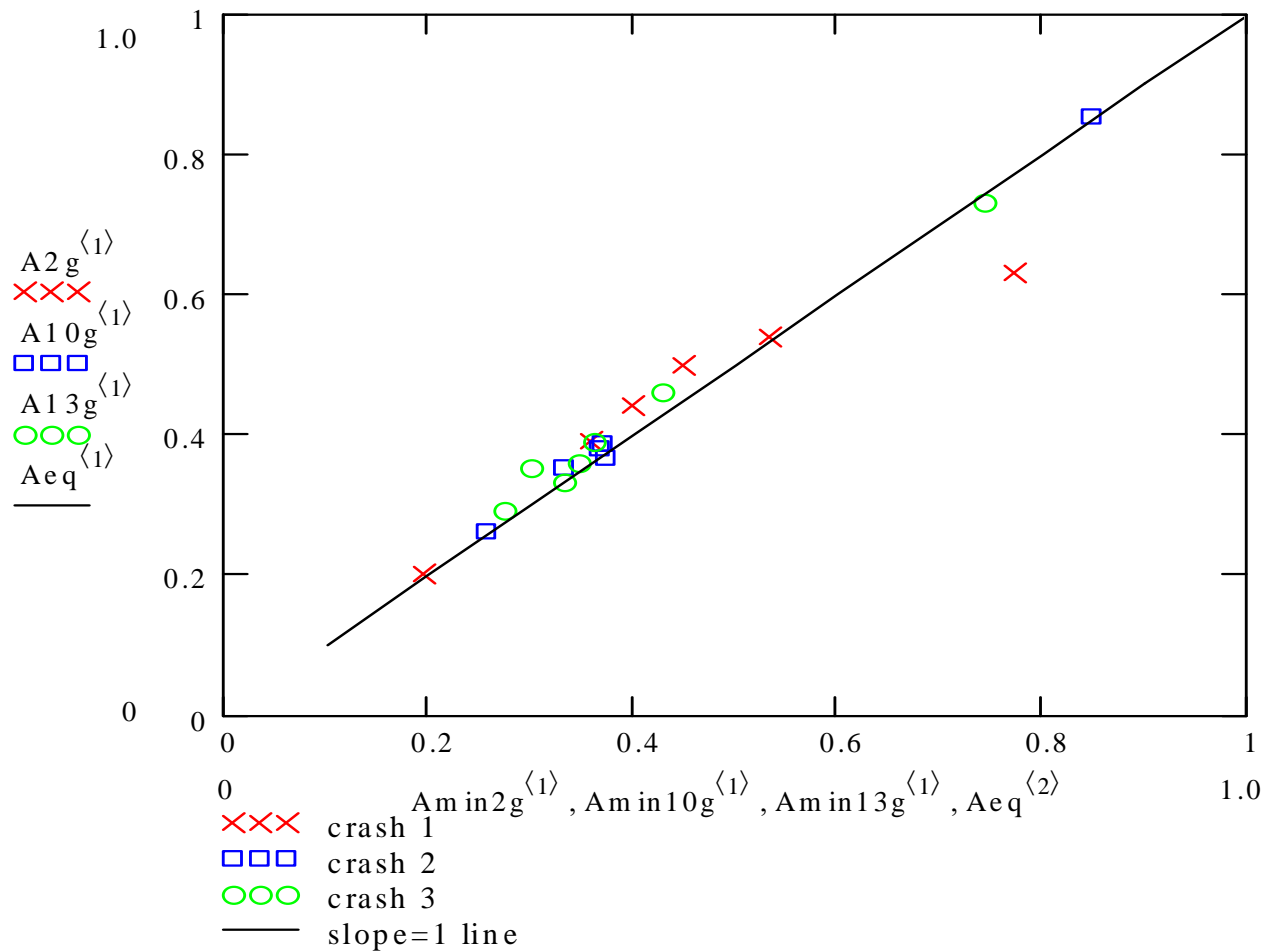
Near-crash definitions have 2 features:

(1) Counterfactual component:

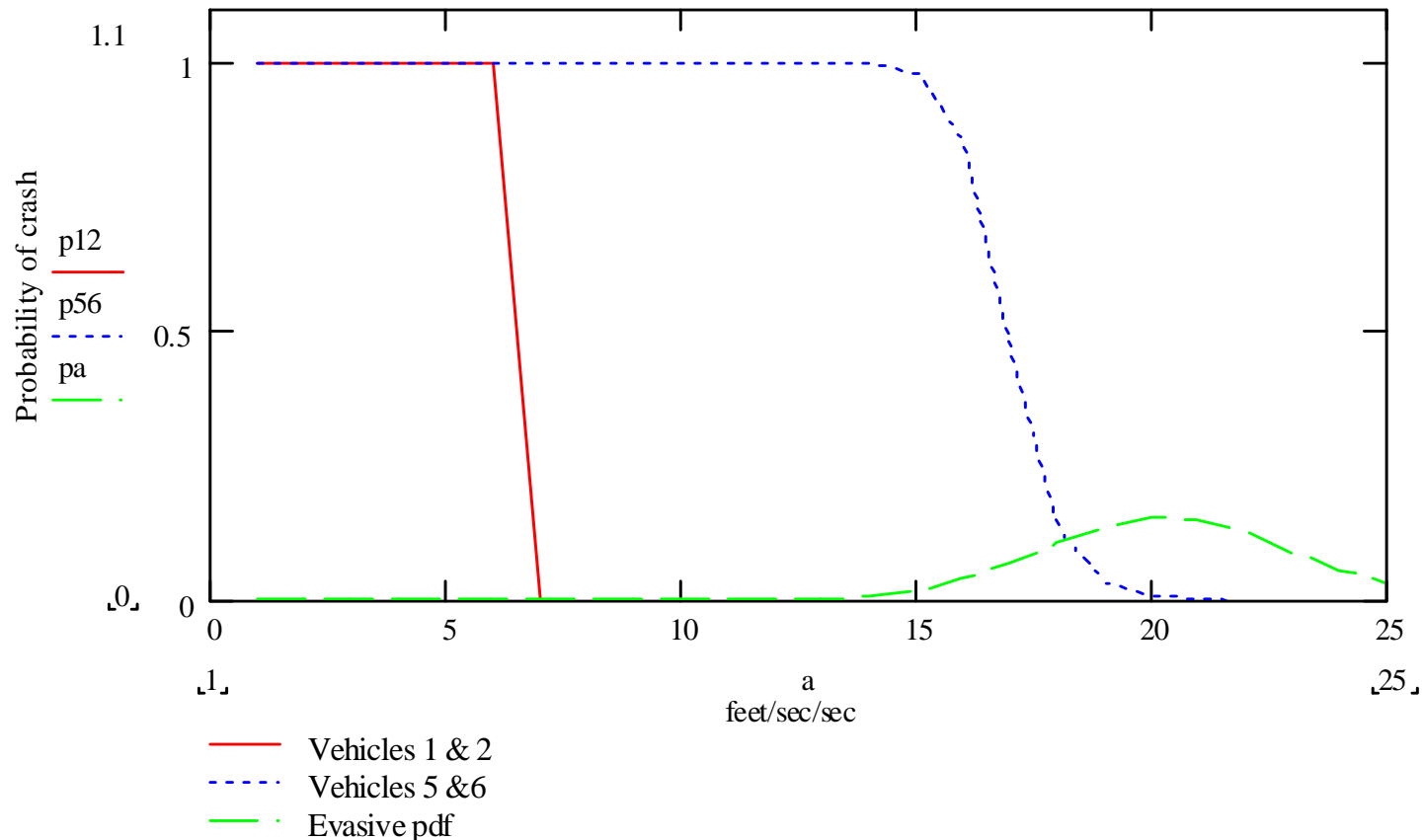
Non-Crash which would have been a crash, absent evasive action

(2) Extremity component: Minimal successful evasive action was “extreme”

Observed vs Minimum Successful Braking: Rear-Ending Events on I94



Crash Probability vs Counterfactual Braking for 2 Events



Phase II Work

Focused on research problems 1 and 2

Structural Modeling

Counterfactual Screening

Method: Trajectory-based reconstruction of crashes and near-crashes

Emphasis on “intersection-related” events

Car-following behavior

Gap-selection behavior

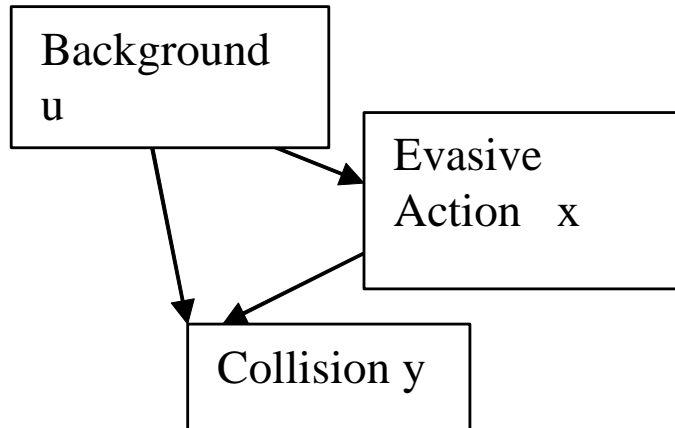
Data Sources:

(1) 100-Car vehicle-based data

(2) Video data from I-94 site

(3) Radar/Lidar data at intersection (limited)

Abstract Collision Model



$y(x,u)=1$, crash
0, no-crash

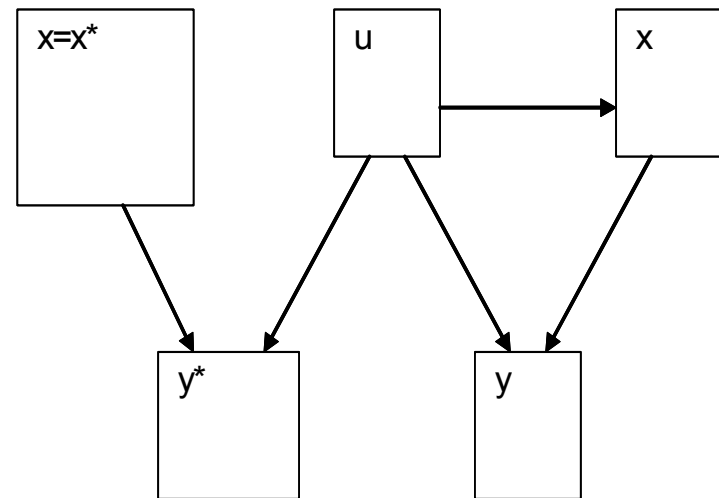
Joint distribution:

$P(y,x,u)=$

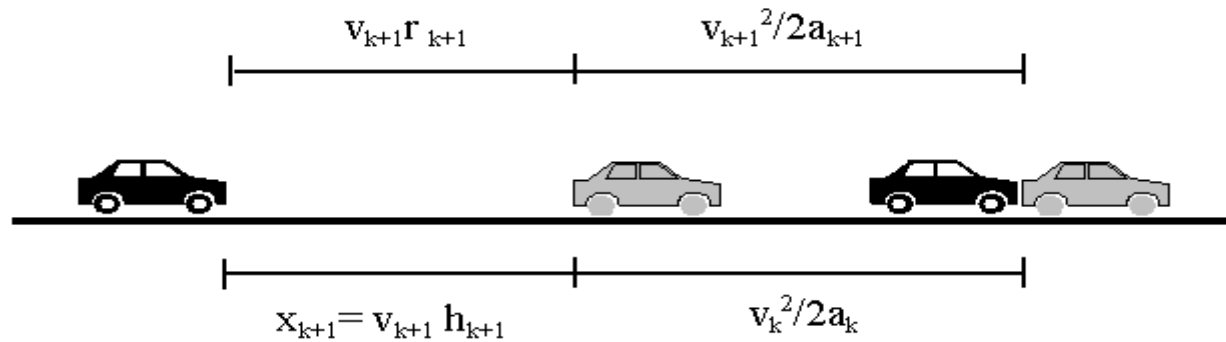
$P(y|x,u)P(x|u)P(u)$

Twin Network Method for Computing What-If Probabilities

1. Abduction: Compute posterior distribution for background variables $p(u|\text{data})$
2. Action: Set evasive action to $x=x^*$
3. Prediction: Compute $P(y^*=1)$ using $p(u|\text{data})$

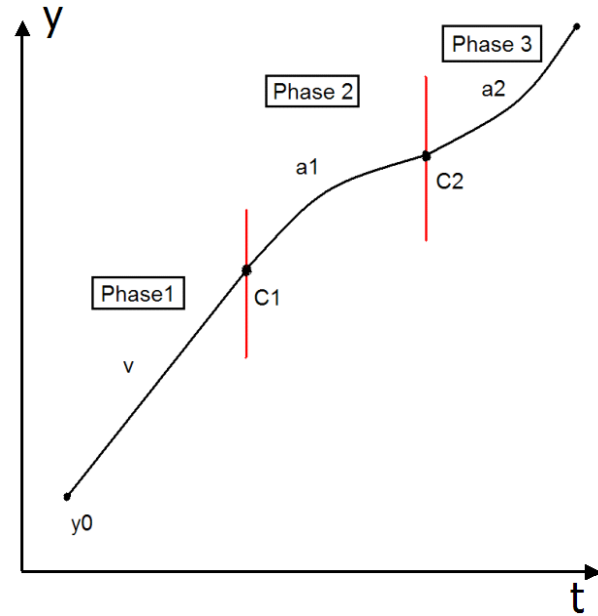
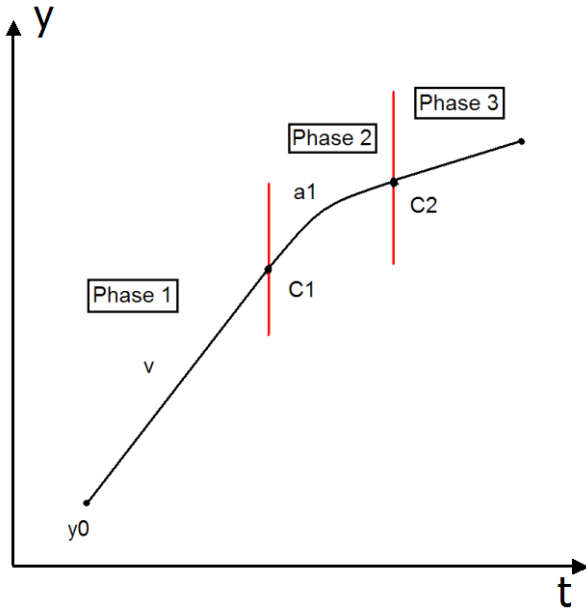


Example: Simple Rear-End Collision



$$y(u, x) = \begin{cases} 0, & \text{if } v_2 r_2 + \frac{v_2^2}{2a_2} \leq h_2 v_2 + \frac{v_1^2}{2a_1} \\ 1, & \text{if } v_2 r_2 + \frac{v_2^2}{2a_2} > h_2 v_2 + \frac{v_1^2}{2a_1} \end{cases}$$

Additional Trajectory Types



Structural Model for Complicated Trajectories

Driver behavior modeled as piecewise constant acceleration/deceleration function

$$a(t) = \begin{array}{l} a_1, t > t_1 \\ a_2, t_1 < t < t_2 \\ \text{etc.} \end{array}$$

Speed and location found by solving differential equation

$$x(t) = x(t-1) + v(t-1)\Delta, \quad x(0) = x_0$$

$$v(t) = v(t-1) + a(t-1)\Delta, \quad v(0) = v_0$$

Fitting Structural Models

1. Case data loaded into MATLAB
2. Case video reviewed
3. Initial estimates of acceleration functions determined by inspection
4. Initial values of model parameters determined via nonlinear least-squares
5. Bayes estimates of parameters computed using
 1. WinBUGS software
 2. WinDIFF differential equation interface
6. Compute avoidance profiles using counterfactual simulation

Analyses Using In-Vehicle Data



FIGURE 3.11 | View when follower stopped for case 104119

Data from 100-Car In-Vehicle Study

33 crash and near-crash events from 100-Car Study

9 Rear-ending crashes

24 Rear-ending near crashes

Data provided

~ 30 seconds video from forward camera

~ 30 second time-series (10 Hz)

x, y accelerometer

GPS latitude, longitude

heading, yaw

speedometer: speed

forward radar: range, range rate

7 Events Analyzed

Trajectory Data Used to Reconstruct Case 104119

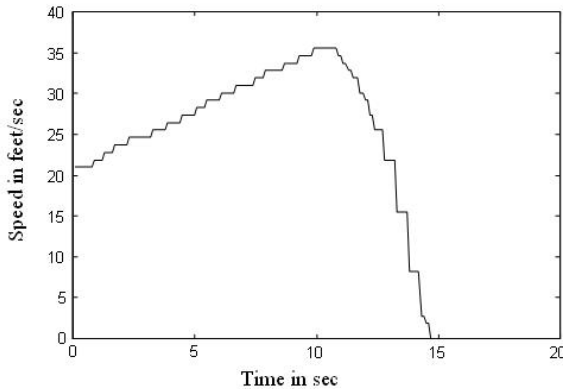


FIGURE 2.1 Speedometer speeds for following vehicle

Follower: Speedometer

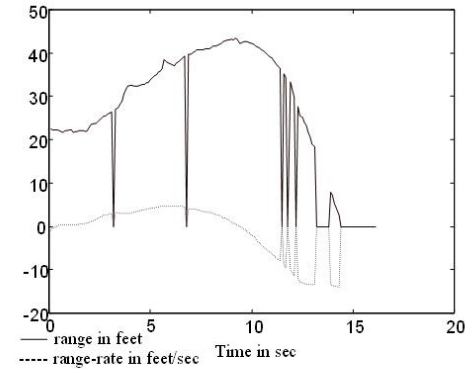


FIGURE 2.2 Range and range-rate for leading vehicle.

Leader: Range
Range-rate

State-Space Model

In-Vehicle Data

$$\begin{bmatrix} x1(t+1) \\ x2(t+1) \\ v1(t+1) \\ v2(t+1) \end{bmatrix} = \begin{bmatrix} 1 & 0 & \Delta & 0 \\ 0 & 1 & 0 & \Delta \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x1(t) \\ x2(t) \\ v1(t) \\ v2(t) \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ \Delta & 0 \\ 0 & \Delta \end{bmatrix} \begin{bmatrix} a1(t) \\ a2(t) \end{bmatrix}$$

$$\begin{bmatrix} y1(t) \\ y2(t) \\ y3(t) \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} x1(t) \\ x2(t) \\ v1(t) \\ v2(t) \end{bmatrix}$$

Bayes Estimates for Case 104119

Variable	Mean	Stand. Dev ¹	2.5%ile	97.5%ile
Following Vehicle				
Initial Speed (feet/sec)	20.6	0.24	20.1	21.0
First acceleration (feet/sec ²)	1.45	0.04	1.38	1.54
Second acceleration (feet/sec ²)	-9.47	0.21	-9.89	-9.05
First change (seconds)	11.15	0.06	11.04	11.26
Leading Vehicle				
Initial Speed (feet/sec)	18.92	0.31	18.3	19.52
First acceleration (feet/sec ²)	3.34	0.14	3.08	3.62
Second acceleration (feet/sec ²)	0.62	0.05	0.51	0.72
Third acceleration (feet/sec ²)	-11.94	0.32	-12.58	-11.34
First change (seconds)	3.47	0.13	3.22	3.73
Second change (seconds)	10.61	0.05	10.51	10.72

Comparison of Modeled vs Measured Trajectories

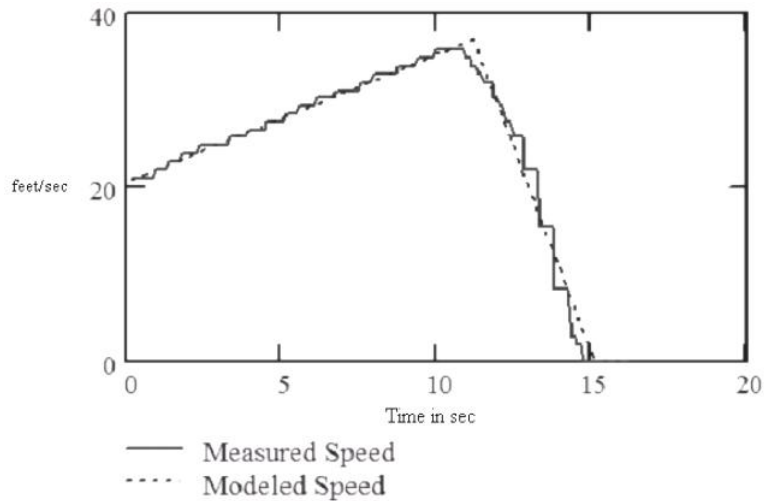


FIGURE 2.4 Measure following vehicles speeds, and posterior mean predicted speeds from MCMC sample

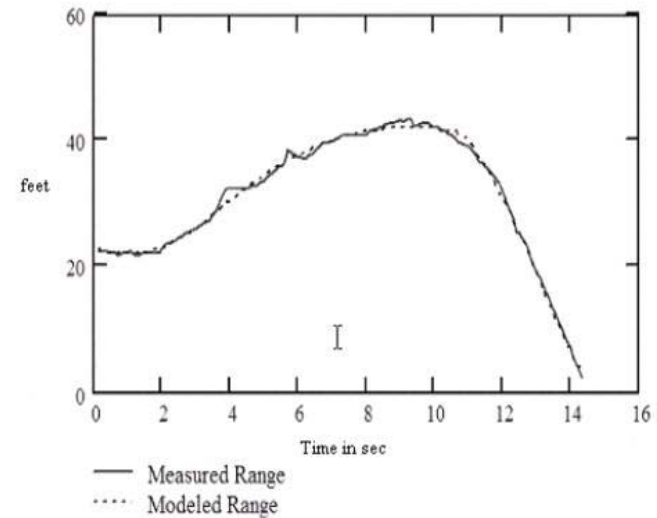


FIGURE 2.5 Measure range and posterior mean predicted range from MCMC sample

Crash Probability vs Counterfactual Follower Deceleration

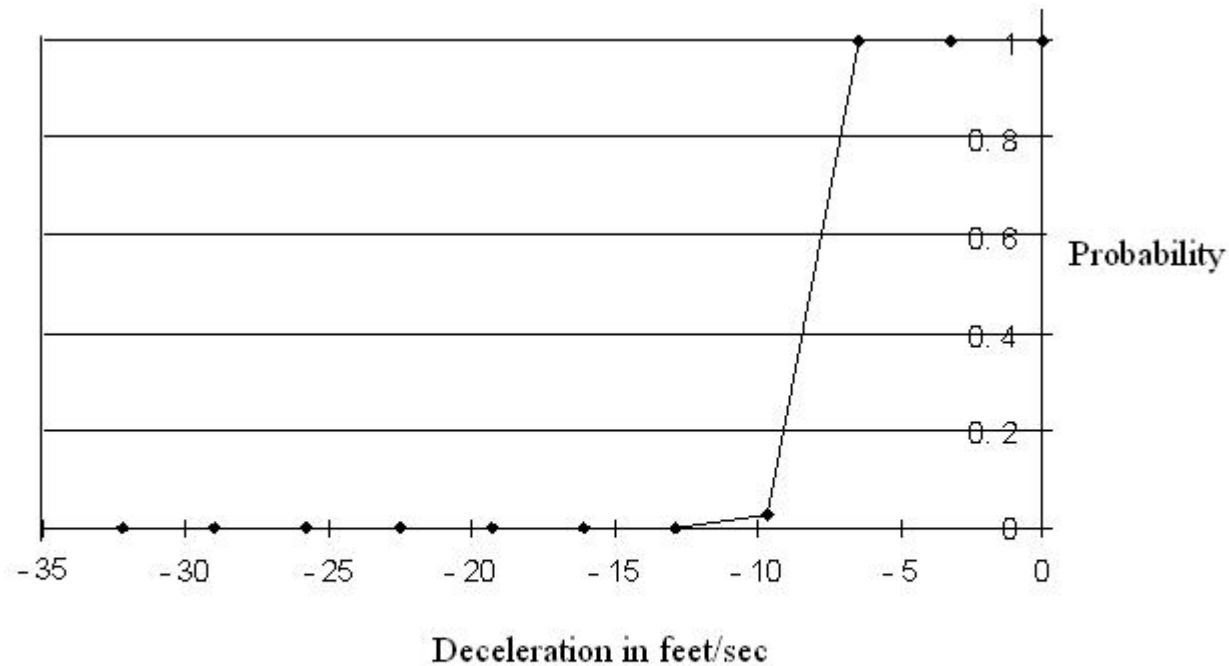
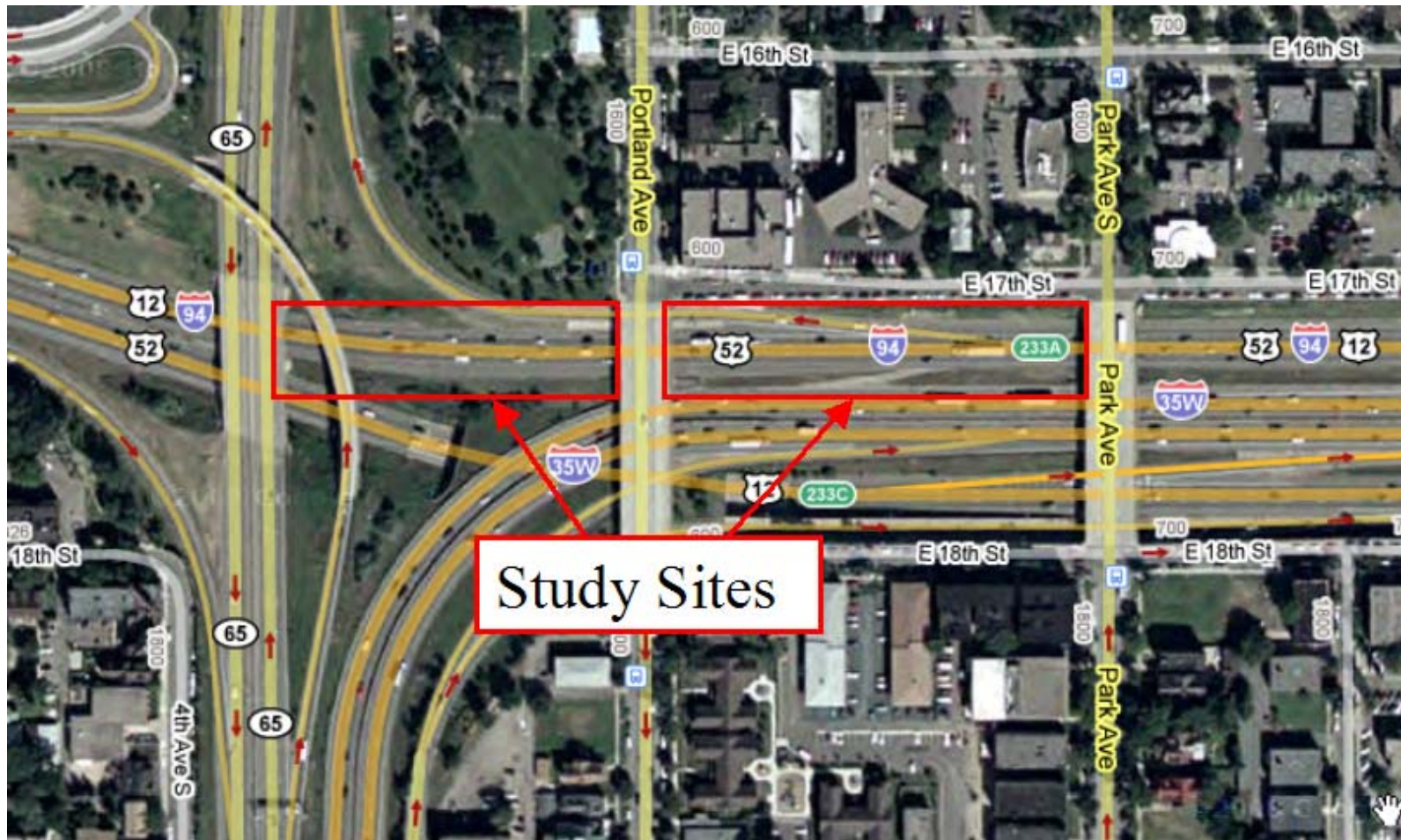


FIGURE 2.6 Collision probability as a function of counterfactual values for follower's final deceleration.

Analyses Using Site-Based Video



Manual Trajectory Extraction



FIGURE 4.2 Illustration of VideoPoint trajectory extraction

I-94 Case 3



Bayes Estimates of Structural Model Variables

Variable	Mean	Stand. Dev ¹	2.5% ile	97.5% ile
Vehicle 3				
Initial Speed (feet/sec)	51.29	0.3508	50.66	52.03
First acceleration (feet/sec/sec)	-5.618	0.3798	-6.475	-4.992
Second acceleration (feet/sec/sec)	-3.206	0.2493	-3.598	-2.617
Third acceleration (feet/sec/sec)	-10.24	2.002	-14.88	-7.215
First change (seconds)	2.295	0.3079	1.726	2.926
Second change (seconds)	5.375	0.2048	4.924	5.743
Reaction Time (seconds)	1.886	0.2197	1.412	2.285
Vehicle 2				
Initial Speed (feet/sec)	33.42	0.1933	33.03	33.80
First acceleration (feet/sec/sec)	-0.8968	0.1368	-1.156	-0.6174
Second acceleration (feet/sec/sec)	-8.004	0.2241	-8.463	-7.576
First change (seconds)	3.489	0.0792	3.333	3.645
Reaction time (seconds)	1.231	0.1336	0.9572	1.489
Vehicle 1				
Initial Speed (feet/sec)	21.33	0.3953	20.53	22.07
First acceleration (feet/sec/sec)	1.048	1.048	0.2296	1.984
Second acceleration (feet/sec/sec)	-8.8	0.5076	-9.974	-7.967
Third acceleration (feet/sec/sec)	-0.9801	0.3604	-1.535	-0.1625
First change (seconds)	2.258	0.1116	2.046	2.49
Second change (seconds)	4.595	0.1188	4.353	4.819

Trajectory Fit: Vehicle 1

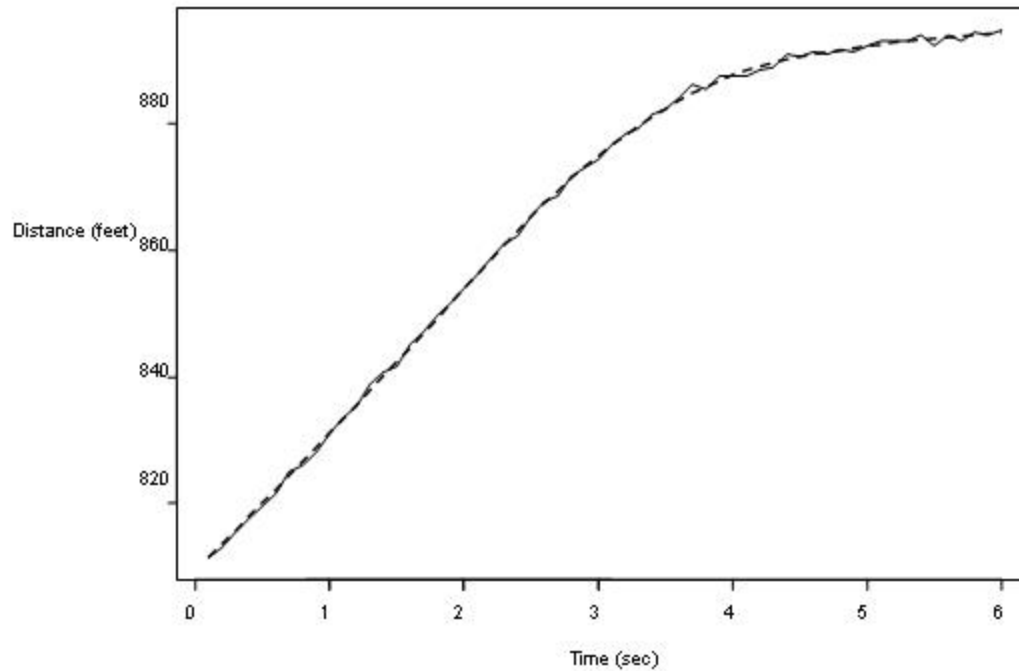


FIGURE 4.16 Measured and modeled vehicle 1 distance trajectory for I-94 case 3

Note: — : trajectory from video (feet)
- - - : trajectory from WinBUGS model-fitting (feet)

Trajectory Fit: Vehicle 2

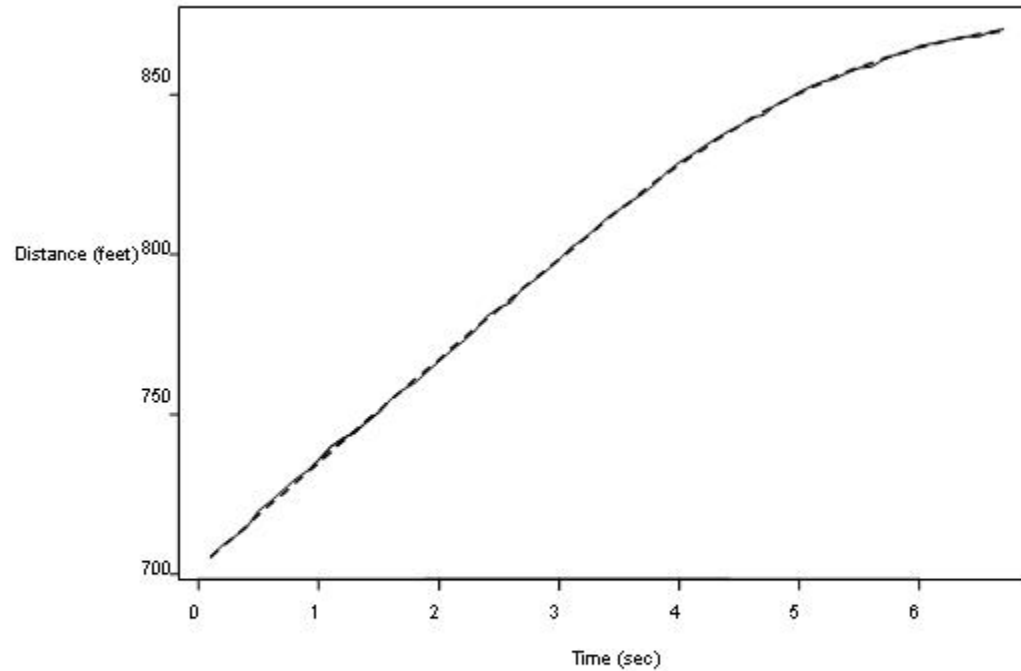


FIGURE 4.17 Measured and modeled vehicle 2 distance trajectory for I-94 case 3

Note: — : trajectory from video (feet)
- - - : trajectory from WinBUGS model-fitting (feet)

Trajectory Fit: Vehicle 3

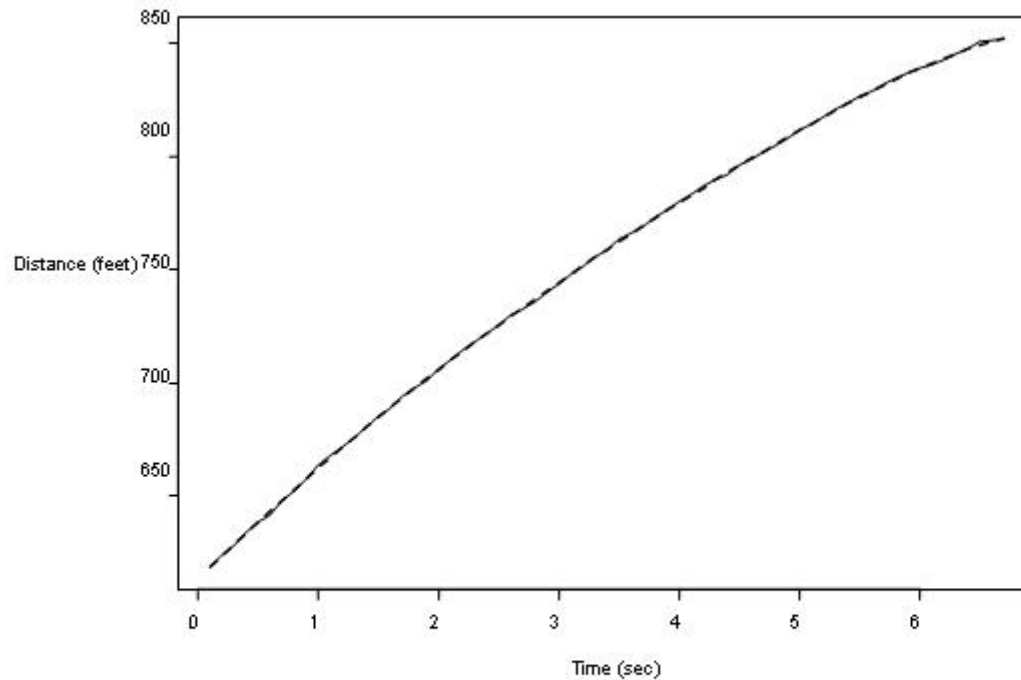


FIGURE 4.18 Measured and modeled vehicle 3 distance trajectory for I-94 case 3

Note: —: trajectory from video (feet)
---: trajectory from WinBUGS model-fitting (feet)

Collision Probability vs Counterfactual Braking: Driver 2

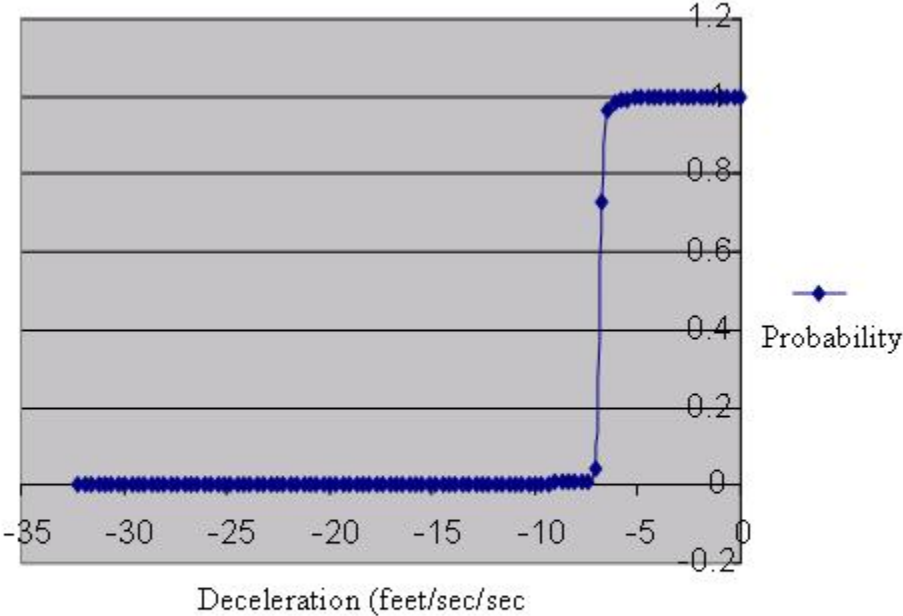


FIGURE 4.20 Probability of collision as a function of counterfactual final deceleration by driver 2 for I-94 case 3

Collision Probability vs Counterfactual Braking: Driver 3

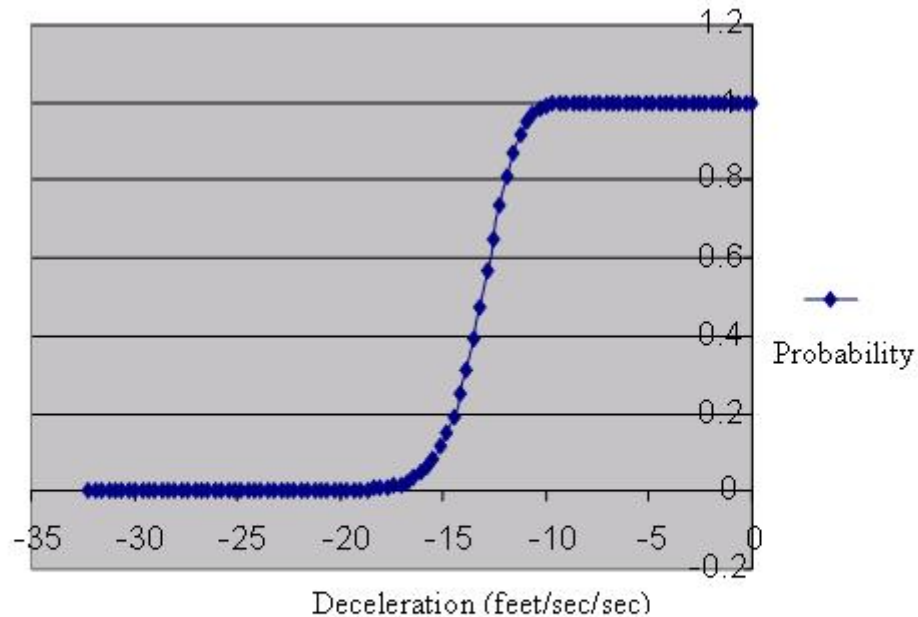
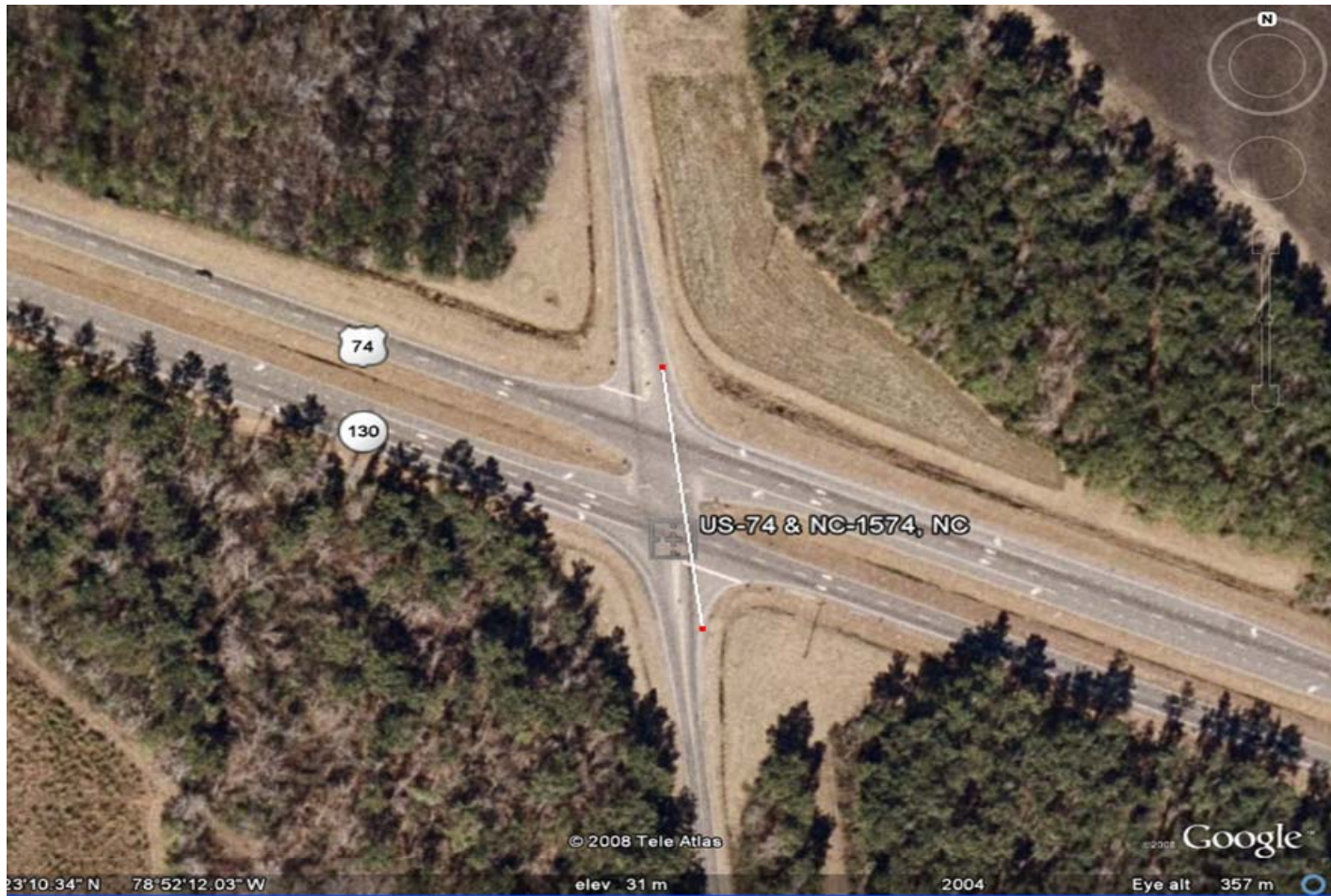
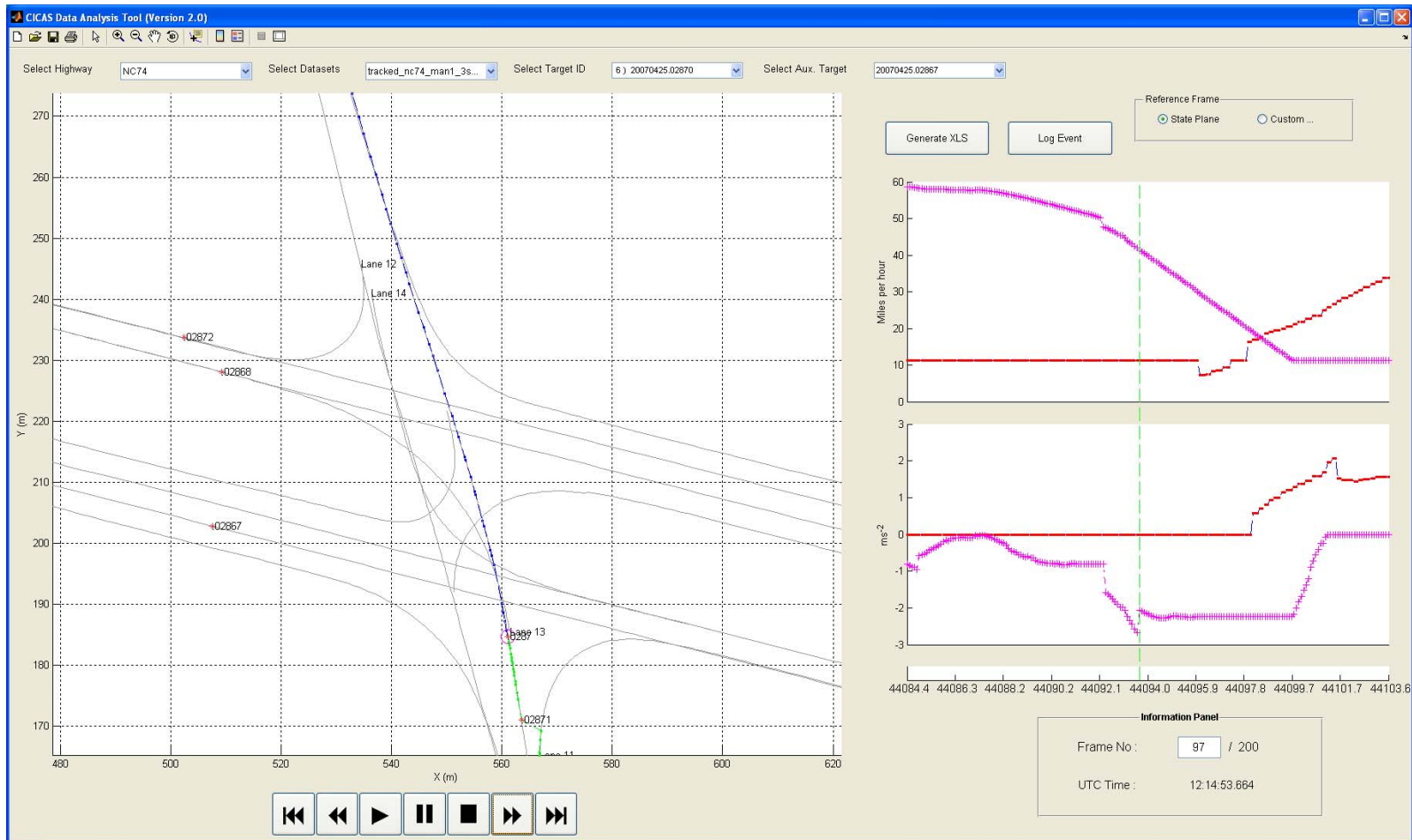


FIGURE 4.19 Probability of collision as a function of counterfactual final deceleration by driver 3 for I-94 case 3

Analyses Using CICAS Site-Based Radar



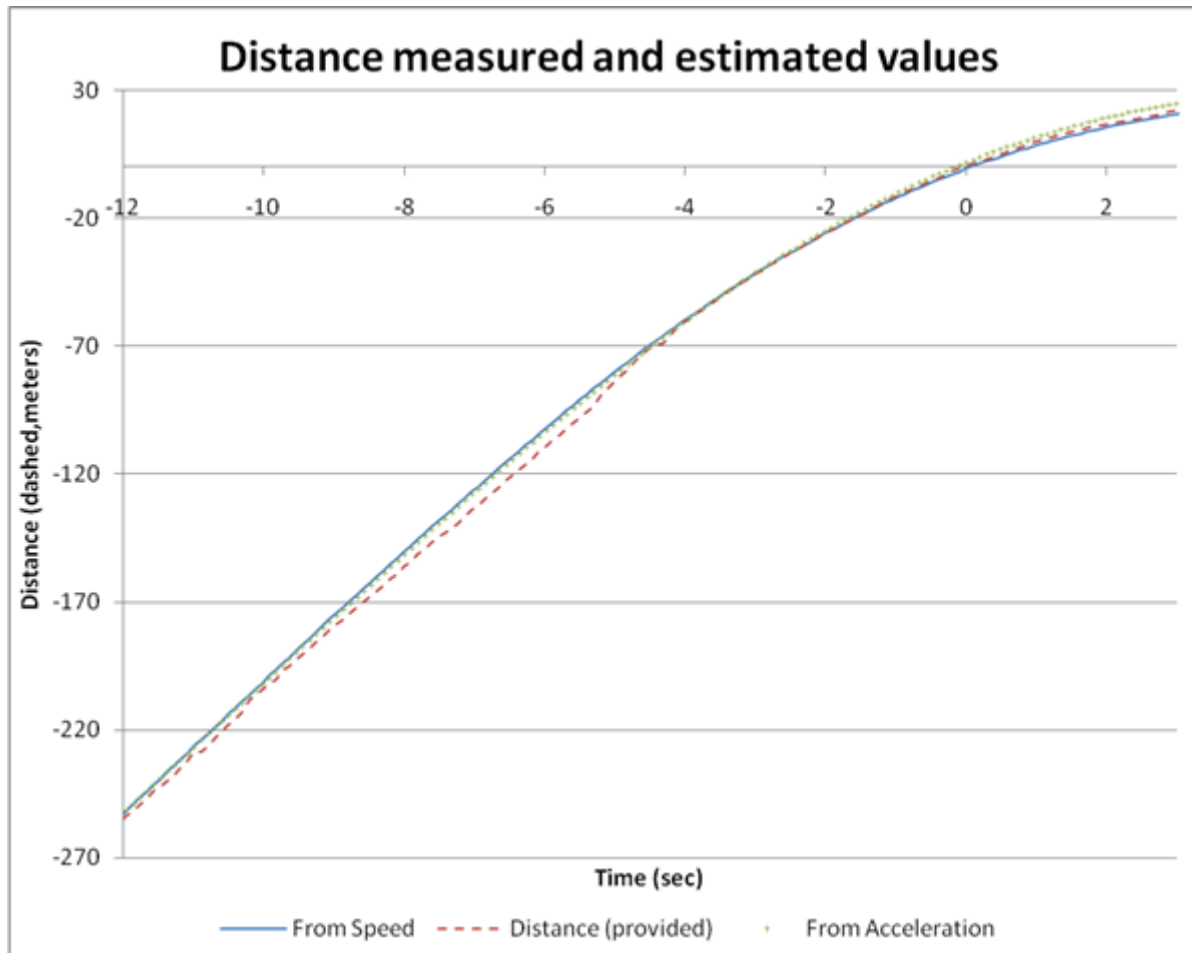
Screen Shot of MATLAB Data Browser



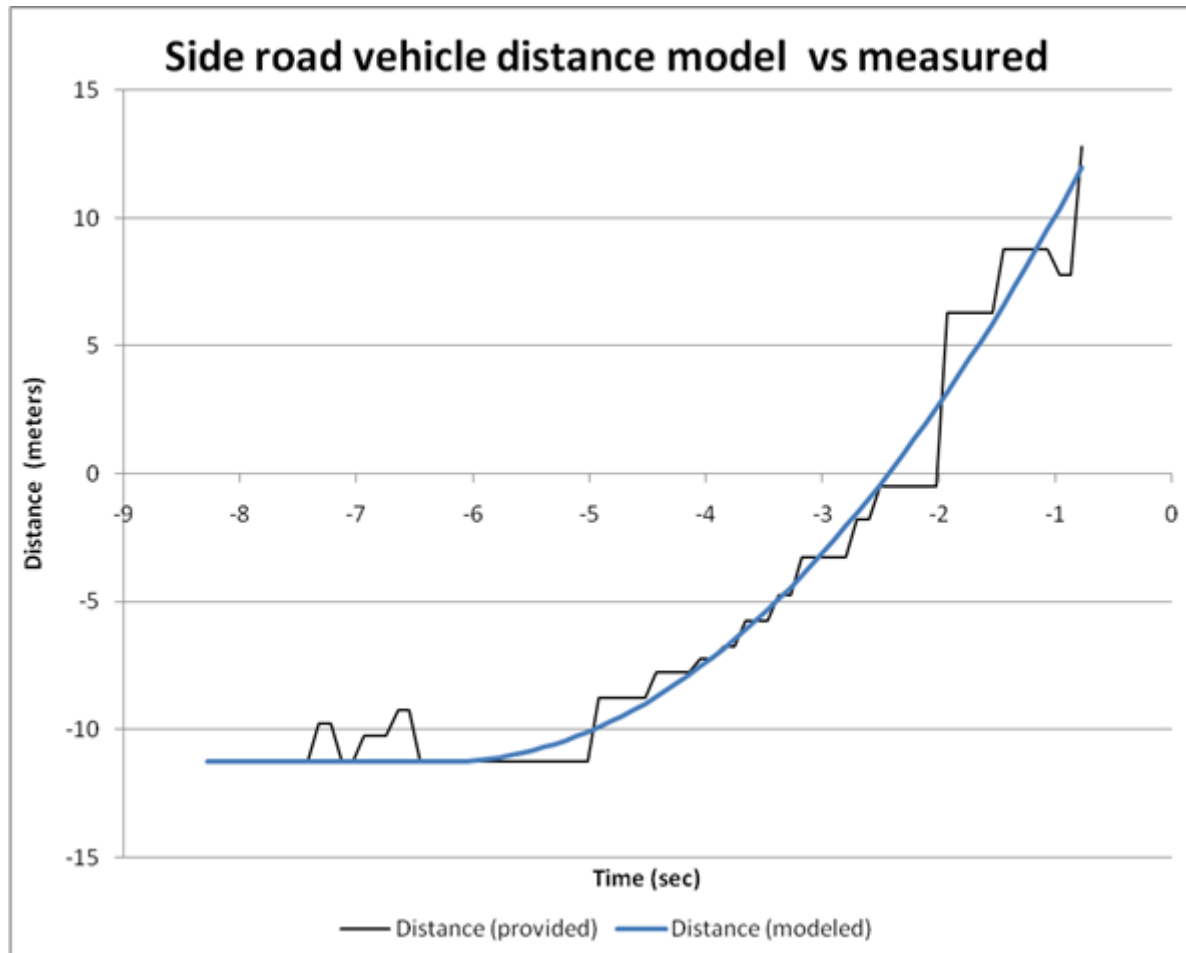
Bayes Estimates for Intersection Conflict

Variable	Mean	Stand. Dev ¹	2.5%ile	97.5%ile
Side Road Vehicle (initial speed zero)				
First acceleration (m/sec/sec)	1.447	0.06672	1.319	1.582
Movement start (seconds)	-6.1422	0.102	-6.339	-5.95308
Main Road Vehicle				
Initial Speed (m/sec)	25.01	0.01521	24.98	25.04
First acceleration (m/sec/sec)	-0.7618	0.008252	-0.7778	-0.7452
Second acceleration (m/sec/sec)	-1.622	0.002149	-1.712	-1.503
Third acceleration (m/sec/sec)	-2.149	0.006138	-2.16	-2.136
First change (seconds)	-5.23692	0.03635	-5.31564	-5.17452
Second change (seconds)	-4.323	0.06229	-4.45548	-4.22988

Observed and Modeled Trajectory for Main Road Vehicle



Observed and Modeled Trajectory for Side Road Vehicle



Conclusions

1. Trajectory-based reconstruction is feasible using both vehicle-based and site-based data.
2. It is possible to extend methods of counterfactual analysis to differential equation models.
3. Limited evidence that the distributions of evasive actions for crashes and near-crashes overlap
4. CICAS system, with technical modifications, could support site-based field research (lower volume intersections)
5. Usefulness of vehicle-based field data will be strongly dependent on the ability to calibrate and maintain the data collection systems.

Recommendations

1. Modeling method should be extended to handle two-dimensional trajectories.
2. Models that close feedback loop between existing conditions and driver actions should be pursued using the data from the SHRP 2 field studies.
3. Trajectory modeling should be enhanced to allow for serial correlation.
4. SHRP 2 vehicle-based field study should be complemented with site-based research.
5. Clear descriptions of data collection and processing should be required in future major data collection efforts.

QUESTIONS?