STRATEGIC HIGHWAY RESEARCH PROGRAM

Accelerating solutions for highway safety, renewal, reliability, and capacity

Collision Surrogates

Ken Campbell

First Human Factors Symposium: Naturalistic Driving Methods and Analysis

Virginia Tech Transportation Institute
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TRANSPORTATION RESEARCH BOARD
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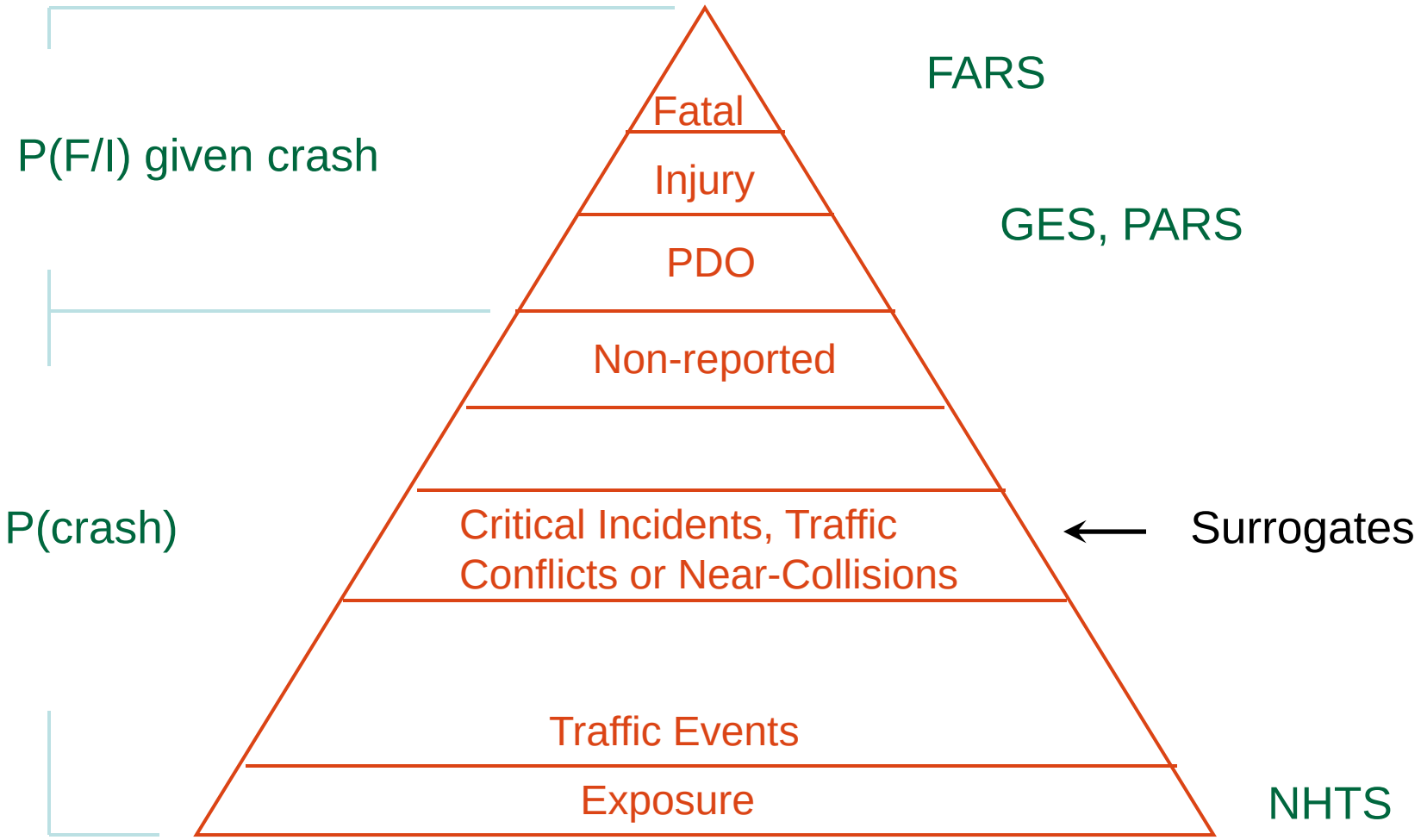
Collision Surrogates



Why are we interested?

- Not enough accidents (and surrogates occur more frequently)
- Accident reporting is incomplete
- Focus on pre-collision and avoidance
- If surrogates are viable, we could measure safety without waiting for accidents

Collision Surrogates--Definitions

Near-Collision

Any circumstance that requires a *rapid, evasive maneuver* by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal *to avoid a crash–100-Car Study, VTTI*

Traffic Conflict

A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision *if their movements remain unchanged*—ICTCT

Critical Incident

Originally, an interview technique to identify critical events that increase the risk or “almost” led to an (industrial) accident—Flanagan, 1954

Recent Work

ANB20(3) Subcommittee on Surrogate Measures of Safety. Chair: Andrew Tarko, Purdue

Surrogate Safety Assessment Model (SSAM), FHWA
Final Report FHWA-HRT-08-051 June 2008
Doug Gettman, Siemans, and Tarak Sayed, UBC

ANB20(3)
Subcommittee on Surrogate Measures of Safety
Scope and Goals

- Scope (charge)
  - Surrogate measures of safety
  - Application methods
  - Validation of the methods
  - Conditions of implementation
- Goals
  - Promote surrogate measures among research sponsors and potential users
  - Stimulate interest in research on surrogate measures among researchers

ANB20(3)
Subcommittee on Surrogate Measures of Safety
Candidate Measures

Encroachment Time (ET)

Gap Time (GT)

Deceleration Rate (DR)

Proportion of Stopping Distance (PSD)

Post-Encroachment Time (PET)

Initially Attempted Post-Encroachment Time (IAPT)

Time to Collision (TTC)

ANB20(3) white paper, Tarko

ANB20(3)
Subcommittee on Surrogate Measures of Safety
Candidate Measures

Aggressive lane merging
Speed and speeding
Running on red
Acceleration noise
Integrated time-to-collision
Accepted gaps
Time headways
Deceleration-to-safety-time
Reaction time
Driver attention
Workload, etc.

ANB20(3) white paper, Tarko

ANB20(3)
Generalized Traffic Conflict (GTC) Method

- Precisely defined crash proximity measure T
- Traffic conflict = event with T<T0
- Collision = event with T< 0
- Opportunity for crash E (or generalized exposure) is the frequency of traffic conflicts
- Risk of crash given conflict R = Pr(T<0 | T<T0)
- Risk of crash estimated from observed values of T
- Frequency of crashes A = E·R

ANB20(3)
Summary of the Current State

1. A growing need for timely safety measurements
2. Multiple postulated surrogate measures and methods
   Traffic conflicts
   Treatment specific
3. There is no guide helping conduct indirect safety measurement/evaluation
4. Traditional traffic conflict technique cannot produce equivalent crash frequencies
5. Technological and methodological progress (sensors, driving simulators, information technology, statistical methods) brings a new hope

Surrogate Safety Assessment Model (SSAM)

- Implemented in traffic simulation models
- Traffic conflict metrics computed from vehicle trajectory data
- Safety assessment based on the conflict metrics
- Different intersection design features were analyzed
- Field validations have been carried out by comparing with crash histories at 83 signalized intersections
- Spearman rank correlations of 0.46 between hourly conflict frequency and annual crash frequency
- 0.47 for rear-end conflicts and crashes

Surrogate Safety Assessment Model (SSAM)
Candidate Measures

- Minimum Time To Collision (TTC)
- Minimum Post-Encroachment Time (PET)
- Initial Deceleration Rate (DR)
- Maximum speed (MaxS)
- Maximum relative speed difference (DeltaS)
- Location of the conflict event (CLSP, CLEP)
- Maximum “post collision” DeltaV (MaxDeltaV)

Surrogate Safety Assessment Model (SSAM) Recommendations

- Develop a composite “safety index”.
- Study the underlying nature of conflicts in real-world data.
- Collect adequate vehicle trajectory data sets from the real world.
- Investigate conflict classification criteria.

SHRP 2 Work
Development of Analysis Methods

Iowa State University
- Center for Transportation Research and Education (CTRE)
- with University of Iowa
- Shauna Hallmark, Linda Boyle

Pennsylvania State University
- Pennsylvania Transportation Institute
- Paul Jovanis, Venky Shankar

University of Minnesota
- Center for Transportation Studies
- Gary Davis, John Hourdos

University of Michigan Transportation Research Institute (UMTRI)
- with Virginia Tech Transportation Institute (VTTI)
- Tim Gordon, Lidia Kostyniuk, Paul E. Green

SHRP 2 Work
Development of a Site-Based Video Method

University of Michigan Transportation Research Institute (UMTRI)
UC Berkeley PATH, VTTI and Soar Technology
Tim Gordon

Objectives

- Design and develop a site-based video system to accurately capture multi-vehicle kinematics at intersections
- Justify and prove the system concept in terms of SHRP2 research questions
- Demonstrate capabilities via a small field trial, including analysis demonstration

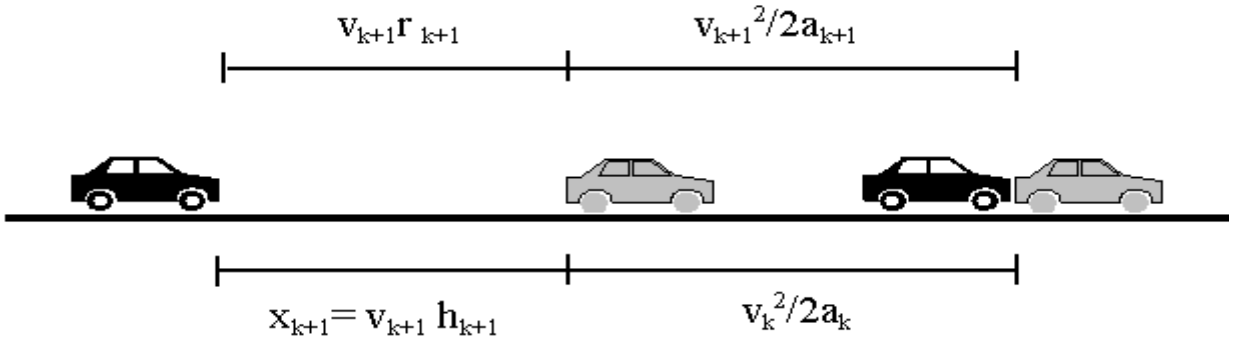
SHRP 2 Work
Development of Analysis Methods

University of Minnesota
- Center for Transportation Studies
- Gary Davis, John Hourdos

Project Focus
- Car-Following
- Gap Selection

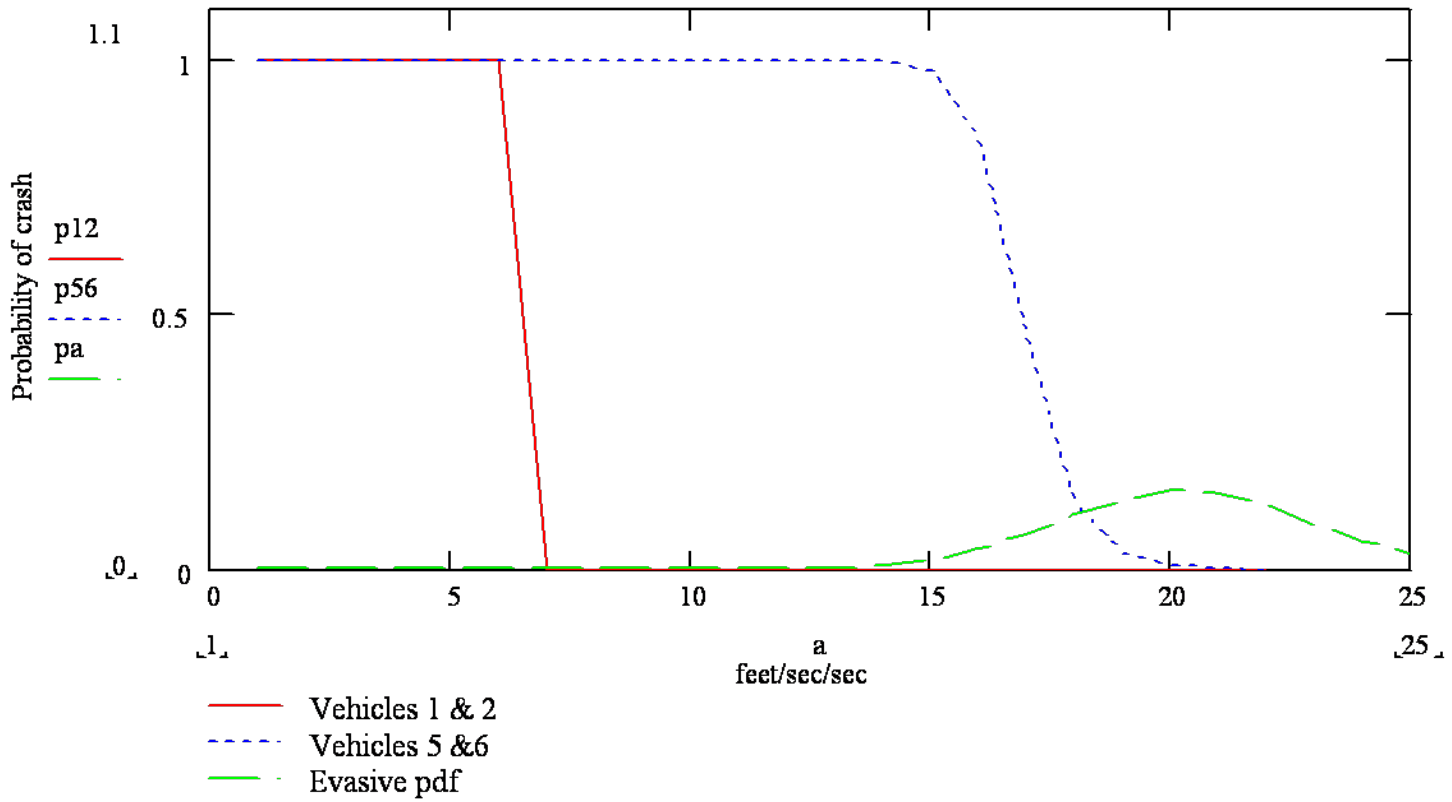
How do we estimate crash propensity from observations of surrogate events?

Example:
Simple Rear-End Collisions



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

Crash Probabilities with Evasive Action Distribution



Bottom Line

When we can

(1) Specify a physical model of conflict

(2) Estimate the conflict's background variables

(3) Identify plausible model of evasive action

Then we can

Compute probability that conflict could have been a crash

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Ongoing Work

(1) Structural Models/Background Estimation
- Emphasis on difference equation models,
- Nonlinear least-squares/time-series,
- Bayes estimation via Gaussian process approximations.

(2) Evasive Action Models
- More realistic model of rear-end braking,
- Modeling steering as additional evasive action

(3) Angle crashes
- Structural modeling
- Identification of near-crashes from CICAS database

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SHRP 2 Work
Development of Analysis Methods

University of Michigan Transportation Research Institute (UMTRI)
with Virginia Tech Transportation Institute (VTTI)
Tim Gordon, Lidia Kostyniuk, Paul E. Green

Road Departure—Collision Surrogate

- Control - effectiveness of tactical and operational aspects of the driving task
- Disturbed control - any interruption or delay in the process of
  - perception (seeing lane edge or other boundary features)
  - recognition (filtering of the road scene)
  - judgment/decision (of steering, throttle or brake pedals)
  - action (apply corrections)

SHRP 2 Work
Development of Analysis Methods
University of Michigan Transportation Research Institute (UMTRI)

Candidate Surrogates

- Imminent lane departure warning (LDW Alert)
- Approach speed too fast for curve (curve speed warning)
- Inverse time to lane crossing
- Peak lateral deviation in lane
- Peak projected lateral deviation
- Driver looking away for 2 sec+
- Coherency between tracking error and steer response
- Steering rate less than small threshold for at least 4 seconds
- Others from search for benchmarks of disturbed control
  - Cell phone use
  - Yaw deviation associated with discontinuity in lane markings

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Bayesian Multivariate Generalized Model

Crash Data

Response	Crash Events
	(Exposure)
Explanatory Factors	Driver
	Environment
	Vehicle
	Highway

FOT Data

Response	Surrogate Events
	(Exposure)
Explanatory Factors	Driver
	Environment
	Vehicle
	Highway

Exploratory Analysis

Fit Two Separate Poisson Models for Rates

Parameter	Estimates: Crash Model	Estimates: Alert Model
Intercept	8.31	9.78
Curve	-0.39	-0.56
Freeway	-5.90	-6.69
Area	-3.81	-3.08
Shoulder	-7.66	-7.35
Curve*Freeway	-0.22	-0.17
Curve*Area	1.27	1.83
Curve*Shoulder	-0.17	0.16
Freeway*Area	-0.29	-1.84
Freeway*Shoulder	6.30	6.45
Area*Shoulder	1.55	1.05

Seemingly Unrelated Regressions (SUR)

Zellner (JASA, 1962) describes a method for estimating the parameters in a set of regression equations called Seemingly Unrelated Regressions (SUR).

$$Y_1 = X_1\beta_1 + \varepsilon_1$$
$$Y_2 = X_2\beta_2 + \varepsilon_2$$

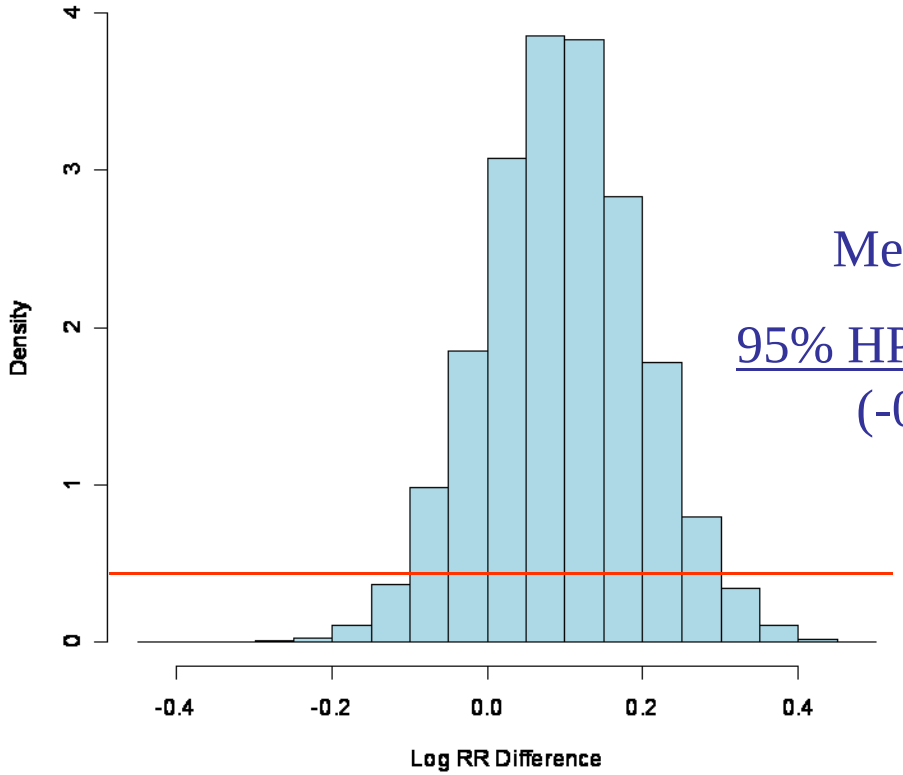
LDW Alerts as Good Surrogate

Estimated Difference in Log Relative Risks (RR)
(Histogram of 30,000 Random Variables Simulated from the Posterior Distribution of the Log RR Difference)

Comparing:

Curve to
No Curve

Not On Freeway
In Rural Area
With Shoulder



Mean: 0.1

95% HPD Credible Set
(-0.1, 0.3)

Unresolved Issues

What are the best surrogate measures?
- Not one answer
- Conflict types

How are surrogates related to collisions?
- Collisions = C x Surrogates (probably too simple)
- need other variables

What distinguished conflicts from collisions?
- Avoidance maneuver—Davis

What about a rate formulation?
- Collision rate = C x Surrogate rate

Exposure
- Conflict types (or traffic events)
- Automatic classification

Conflict Severity
- How close to a collision was it? TTC = 0.5 sec or 0.05
- What was the potential severity of the collision? (Max Delta V)