Extreme value methods in traffic safety research

Jenny Jonasson, Astra-Zeneca, Gothenburg
Holger Rootzén, Mathematical Sciences, Chalmers
http://www.math.chalmers.se/~rootzen/
Naturalistic Driving Research

- *In Situ* investigation of driver performance
  - Use an instrumented vehicle
  - No experimenter or instructions
  - Data continuously collected for extended period
100-car study

- 100 cars, appr 250 drivers, appr 1 year
- Five video cameras, radar sensors; front, rear (for all 100 cars) and each side (for 20 cars), vision-based lane tracker, glare detectors, GPS, accelerometer
- Still not enough crashes (82) → try to use near-crashes (761) to learn about crash behavior
Crash

Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated, and includes other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, cyclists, animals.

Near-crash

Any circumstance requiring a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash. A rapid, evasive maneuver is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities. As a guide: Subject vehicle braking >0.5 g or steering input that results in a lateral acceleration >0.4 g to avoid a crash constitutes a rapid maneuver.

Selection: “trigger” as above – and then manual selection and annotation
How can information from near-crashes be used to prevent real crashes?

1. Do near-crashes resemble real crashes? Are more extreme near-crashes more like real crashes?

2. Is it possible to find driver behavior or traffic situations which is different in near-crashes than in normal driving? Are these differences even more extreme in real crashes?

Statistical methods
Regression: Is relative risk the same for crashes and for near-crashes?

Extreme Value Statistics (EVS): Can near-crashes predict the frequency of real crashes? Do covariates behave in same way for crashes and near-crashes

Extreme value statistics models behavior in extreme situations. It is a well developed area of statistics which includes all the standard statistical tools: suitable distributions (the Extreme Value distributions), estimation methods, model checking tools, multivariate and regression tools, user friendly (free) software

In this talk: the Block Maxima Method
Crash proximity measure

• Measure of how close the near-crash is to a real crash
• Examples: TTEC = Time To edge Crossing, Gap = time between first car leaves conflict area and second car enters conflict area, Time-to-collision (TTC), ...
• Here, TTC, the time it takes for the cars to collide when continuing with the same speeds – useful for rear-ending

\[
TTC = \frac{s}{v_1 - v_2}
\]
Examples TTC
100-car data, risk of rear-ending, TTC

384 near-crashes, 29 with good enough radar signals, 14 crashes.

Crash $\Leftrightarrow$ TTC < 0

Block maxima 95% confidence interval for expected number of crashes is (0.07, 0.09) (Fitted GEV conditional on −TTC > 0, profile likelihood intervals)

Observed number of crashes = 10

Doesn’t match!
Selection bias!

All real rear-ending crashes were in start-stop traffic but the near-crashes with usable TTC were in higher speed situations

So maybe still:  → yes to question 1 (?)
2

Continuous variables that could influence crash risk:

- Speed
- absolute value of yaw angle
- distance to right and left lane markings
- time the driver looks off-road during last 2 s or 3 s, total length of glances off-road longer than 1.5 s during last 15 s ...
- variance of lateral acceleration
- variance of longitudinal acceleration

Do some of these become more and more extreme as TTC gets smaller and smaller?
• Fit logistic bivariate extreme value distribution to min/max of each of these variables and TTC for near-crashes.

• A parameter $\alpha \in (0, 1]$ describes the dependence in this distribution, 0 is complete dependence, 1 is independence.

\[
\begin{align*}
\text{max(eye off road in 3 s window)} & \quad \alpha = 1 \\
\text{max (speed)} & \quad \alpha = 0.88 \\
\text{max (abs yaw)} & \quad \alpha = 0.79 \\
\text{min (dist left markings)} & \quad \alpha = 0.74
\end{align*}
\]

Fitting was not possible for the other variables.
Minimum distance to left lane marking

\[ \alpha = 0.74 \]
$\alpha = 1$

Minimum TTC vs. Maximum time eye of road in moving 3 second window
The future

• Use near-crashes to investigate how (and if) attention measures and other driving and traffic characteristics influence crash risk → high-dimensional variable selection → new research question for Extreme Value Statistics

• Develop statistical predictors of crash risk → optimal choice of predictors → new research questions for Extreme Value Statistics

• Investigate the relation of risk estimates obtained in different in naturalistic driving studies (Semifot, 100-car, SHRP 2, ...)

• Study the normal driving – near-crash/crash relation in naturalistic driving experiments

More and better data crucial
SHRP 2

- 2000 cars
- 3 years
- Much better instrumentation (?)
- Just starting
UMTRI (Gordon et al) “do near-crashes give similar risk estimates as crashes?”

Seemingly Unrelated Regression → yes to question 1 (?)

EVS: TTEC → road departure → road way departure crash

2.3 mile segment of US-23 with 117 traversals by 43 different drivers in instrumented cars.

EV distribution fit to minimum TTEC values for the 117 traversals → predicts 12 road departures/year

On the average there were 1.8 road way departure crashes/year

→ yes to question 1 (?)
Daytime right-angle collisions

- Four year actual counts of daytime right-angle collisions
- EVS estimate of crash frequency from gap measurements

Error bars show 95% Poisson confidence intervals based on observed counts

8-hour observations of crossing gaps. Signalized intersections in the Lafayette area. Summer 2003

→ yes to question 1 (?)