Comparison of two nearness-to-collision surrogate indicators at a signalized intersection in Minsk using Extreme Value Theory

Attila Borsos, University of Győr, Hungary
Haneen Farah, TU Delft, Netherlands
Aliaksei Laureshyn, Lund University, Sweden

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Content
• Problem statement
• Literature review
  – Surrogate measures of safety
  – Application of EVT
• TTC vs. T2
• Application of BM and POT
• Discussion
• Further steps

Safety Hierarchy
• Shape can be different
• Heterogeneity in the frequency-severity relationship

What interactions are considered?
• Low-severity interactions should be utilized
• Svensson limited the events to interactions with a collision course
• Possible extensions e.g. including crossing course interactions, PSMS
TTC vs. T2
- Time until a collision
- Assumes unchanged speed and trajectory
- Acceleration/deceleration not taken into account
- Requires a collision course
- Ignores many potential conflicts
- Continuous (min value)

Example in T-Analyst

Example in T-Analyst

TTCmin = 2.16 s (collision course) No collision course (No TTC value)
T2min = 1.76 s (crossing course) PET= 3.3 s (first vehicle leaves conflict p.)

EVT and SMS
- First study by Tarko (2006)
- Studies applied BM and/or POT
- Contradicting results on which one is better
- Mostly used TTC and PET
- Mostly univariate, just a few bivariate (TTC&Speed, TTC&Time headway)
- Linking EVT with accident data
Research gap/question

• Comparison of surrogate indicators using EVT
• Esp. collision course vs. crossing course
• What can we learn from applying EVT using indicators describing collision course and crossing course interactions at signalized intersections for vehicle-vehicle interactions?

Case

• Two-phase signalized intersection in Minsk
• 32 PDO crashes (5 straight-left turn) 1999-2009
• Recordings for 3 days (6AM – 9PM)
• 2749 interactions
• 1616 - subset of straight – left turning
• Subsets for indicators
  – TTC: n=194
  – T2: n=792

Extreme Value Theory

Block maxima (GEV)  Peak over Threshold (GPD)

Block Maxima

$$
G(z) = \exp\left(1 + \left(\frac{z - \xi}{\sigma}\right)^\gamma\right).
$$

Generalized Extreme Value (GEV) distribution, where location parameter ($\xi$), scale parameter ($\sigma$), shape parameter ($\gamma$)

3 cases:
• If $\gamma > 0$, Fréchet distribution, heavy right tail and the right endpoint is infinite;
• if $\gamma < 0$, Weibull distribution, which has a finite endpoint ($\sigma / \gamma$);
• if $\gamma=0$, Gumbel distribution, light right tail
Peak over Threshold

\[ H(x) = 1 - \left[ 1 + \left( \frac{x - u}{\sigma u} \right)^{-\frac{1}{\xi}} \right] \]

- threshold \((u)\) excesses have a Generalized Pareto Distribution (GPD) with two parameters, the shape \(\xi\) and the scale \(\sigma\) parameters
- similar to BM the shape parameter \(\xi\) determines the behavior of the GPD

Block Maxima (results)

- Minima (negated values), block-interaction
- Selection of near-crashes – “sub sampling of maxima”
- But what is a near-crash?
- Steps:
  - 3.5 s as an initial value for both TTC and T2
  - Several threshold values tested

Block Maxima (<3.5s)

- TTC (n=31)
  - \(\xi = 1.0987\) (Fréchet)
  - \(Pr(TTC=0) = 0.0733\) (!)
- T2 (n=443)
  - \(\beta = -0.1294\) (Weibull)
  - \(Pr(T2=0)=0.0016\)

Block Maxima (different thresholds)

- 3.5 s \(\to\) 5 s (see plot)
  - TTC (n=31 \(\to\) 100)
  - \(\xi = 1.0987 \to 0.0873\) (Fréchet \(\to\) Gumbel)
  - \(Pr(TTC=0) 0.0733 \to 0.0040\) (return periods 14 \(\to\) 247)
- 3.5 s \(\to\) 2 s (see plot)
  - T2 (n=443 \(\to\) 130)
  - \(\beta = -0.1294 \to 0.1664\) (Weibull \(\to\) Gumbel)
  - \(Pr(T2=0)=0.0016 \to 0.0098\) (return periods 596 \(\to\) 101)
Peak over Threshold (results)

• What threshold should we use?

Peak over Threshold (results) (TTC<4s, T2<2s)

• Pr(TTC=0) = 0.00017 (return period 5,884)
• Pr(T2=0) = 0.00055 (return period 1,807)

Summary of results

• POT seems to give more reasonable results
• Model fits for T2 are more reliable

Discussion

• Sample size issues with TTC (also because of the type of interaction itself)
• Trade-off between a good model fit and reasonable threshold values
• Motion prediction
• How to validate?
Further steps

- Bivariate models using e.g. speed, extended Delta-V
- Using EVT to differentiate severity levels

Thank you!