#### A real-time crash risk estimation framework for signalized intersections

by Yasir Ali, Md Mazharul Haque, and Simon Washington



#### Presenter

#### Shimul (Md Mazharul) Haque

Professor of Transportation Engineering | Director of Smart Transport Safety Research Lab

Queensland University of Technology

8<sup>th</sup> Road safety and Simulation International Conference 2022, Athens, Greece



# Background

- In Australia, 1195 people killed and 39,330
   hospitalised annually (BITRE 2019)
- Social cost of road crashes = \$29.7 billion<sup>1</sup>

(BITRE 2009) <mark>≈1.3% of Australia's GDP</mark>



#### Road Crash Deaths by Road User Type in Australia





## **Challenges in Road Safety Analysis**





#### Traffic Conflicts: Dangerous traffic interactions, potential road crashes



#### Road Crashes: End results of traffic conflicts



#### Courtesy: LJ Raggy (https://www.youtube.com/watch?v=Xx7NCbzxlzl)



## **Safety Pyramid of Traffic Events**







# **Safety Pyramid of Traffic Events**



QUT

the university

for the real world

# Objective

To develop a real-time crash risk estimation framework using traffic conflicts

- How can Extreme Value Theory be leveraged to obtain real-time crash risk?
- ➢How crash risk varies with different time periods of the day (e.g., peak vs. off-peak hours)?
- Does incorporating a covariate in the model yield better fit and crash estimates?



# Methodology

→Extreme Value Theory to model traffic extremes at the signal cycle level

→Given that  $z_{ij}$  corresponds to the maximum value of a traffic conflict indicator for cycle *i* at site *j*, a GEV distribution function can be written as

$$G(z_{ij} < z | \mu_{ij}, \phi_{ij}, \xi_{ij}) = exp\left(-\left[1 + \xi_{ij}\left(\frac{z - \mu_{ij}}{exp(\phi_{ij})}\right)\right]^{-1/\xi_{ij}}\right)$$

where  $\mu$ ,  $\sigma$ , and  $\xi$  represents location, scale ( $\phi = log\sigma$ ), and shape parameters



## **Data Collection**

# Video recording of traffic movements at intersections







#### **Data Collection**

A total of 96 hours of traffic videos from a four-legged signalized intersection in Brisbane, Australia







### **AI-based Traffic Conflict Data Extraction**

1. Setting up cameras at vantage points



5. Road user tracking using DeepSORT



2. Video observation of targeted traffic



3. Camera calibration and homography matrix

6. Extracting traffic conflicts (all interactions with time-to-collision  $\leq 3$  s)



Smart Transport Safety Research Lab

## **Advanced Mobility Analytics Group (AMAG)**

Mobility     Analytics						SHIMUL HAQUE V (	② ⊕ ∽ ⊨
SMART Operations	SMART Transport Anal	ytics Platform					
Alerts		Sor Nount Beppo	merset Dam	N-SY			
Live Stream	Map Satellite nduram	ba Dialita	Noundario	Burpengary	Moreton		
⇒ Live Data	Haden Pinelands	- Eskuale	Dayboro	North Lakes Pack/	Island		
<ul> <li>Historical Data</li> </ul>	Crows Nest	Share Esk	Lake				
	ombungee Pechey		Ivenhoe Dundas				
		avensbourne Mount Hallen	Cedar Creek	Brenda	Kooringal		
SMART Safety		Buaraba	iya	mside	Amity Point		
🔅 Operations Data			Patrick Estate		Point Lookout		
Crash Risk Visualizations	regulated s		Lowood Fernvale	Brisvane			
II. Benchmarking				Indocroopily rindale Circulate Cieveland	d North		
2 Evaluation	Toowcomba Helidon S	Pa Gatton Lawes Plainland	Marburg	Sunnuhank	Island		
🖶 Report Manager	Kearneys Spring		Ipswich	Victoria	a Point d Bay		
Site Maintenance		Laidley	Rosewood Redbank Plains	Browns Plains		SMAR	RT Safety Site
	Camboova			Loganholme	Russell Island	SMAR	T Operations Site
SMART Surveys	Fordsd	lale Mulgowie		Beenleigh	1824	-	
	Greenmount	Mount Mort	Peak Crossing			Came	ra Available
Classified Volumes	COORTS -	Thornton	Harrisville	Flagstone	r. A	Keyboard shortcuts Map data ©2022 www.	uae report a map enter
Classified Speeds	Sites					O Search	
🛱 Report Manager							
	Drag headers here to group by						
SMADT Infractructure	Site Name	Available Product(s)	Status	Jurisdiction/City	Date Added	Updated Date	
tin Mining & Accete		SMART Safety					
	AMAG HQ	SMART Operations	Processed	Brisbane	27 Aug 21	03 Dec 21	
Comin	NG SOON						
	Appleby-Stafford Intersection	SMART Safety	Processed	TMR	22 Sep 21	23 Nov 21	
SMART Pavements							
🛱 Roads & Highways	Cold Coast	SMADT Safety		TMP	02 Mar 21	23 Jan 22	
Report Manager COMIN	VIG SOON	SMART Safety	V Processed		UZ MIDI Z1	23 Jan 22	



#### **AI-based Traffic Conflict Data Extraction**





### **Traffic conflict indicator**

Modified time-to-collision (MTTC)

$$MTTC = \frac{\Delta s \pm \sqrt{\Delta s^2 + 2\Delta a (x_{LV} - x_{FV} - D_{LV})}}{\Delta a},$$

 $\Delta s$  = relative speed,  $\Delta a$  = relative acceleration,  $x_{LV}$  &  $x_{FV}$  = positions of leading and following vehicles,  $D_{LV}$  = length of leading vehicle

Parameter	Statistics			
	Mean	Standard deviation		
Number of cycles	444			
V (volume count per cycle)	13.13	4.51		
MTTC (s)	1.25	0.29		
Total rear-end conflict	2,915			
Crash record (2015 – 19)	9			



# Three separate Bayesian hierarchical models are estimated $\int \left( \int dx \, dx \, dx \, dx \, dx \right) dx \, dx$

$$G(z_{ij} < z | \mu_{ij}, \phi_{ij}, \xi_{ij}) = exp\left(-\left[1 + \xi_{ij}\left(\frac{z - \mu_{ij}}{exp(\phi_{ij})}\right)\right]^{-1/\xi_{ij}}\right)$$

#### ≻A stationary model

- ➤A model with traffic volume as a covariate to the scale parameter
- A model with traffic volume as a covariate to the location parameter



Model	Parameter location		scale		shape			
MOGEI		$\mu_0$	$\mu_{_V}$	$\sigma_{_0}$	$\sigma_{_V}$	$\xi_0$	DIC	
	mean	-0.5391		0.2588		-0.4734		
Stationany	s.d.	0.0048		0.0040		0.085	1107.77	
Stationary	2.50%	-0.5489		0.2510		-0.4894		
	97.50%	-0.5298		0.2667		-0.4566		
	mean	-5.5398		-4.3589	0.500	-0.4714		
Model with covariate	s.d.	0.005		0.0208	0.010	0.0079	1005 07	
in scale	2.50%	-5.5482		-4.3947	-0.514	-0.4895	1095.27	
	97.50%	-5.529		-4.3197	0.522	-0.4569		
	mean	-0.5572	0.0020	0.2571		-0.4644		
Model with covariate	s.d.	0.006	0.0002	0.0037		0.0075	1006 74	
in location	2.50%	-0.5301	0.0018	0.2503		-0.4771	1080.74	
	97.50%	-0.5057	0.0011	0.2644		-0.449		





#### Model 1: Stationary Model

Model 2: With traffic volume as a covariate in the scale parameter

Model 3: With traffic volume as a covariate in the location parameter



#### Tail of a GEV distribution ending after the negated MTTC = 0 indicates a positive crash risk

- ➤Greyed Cycles have positive crash risk (and are risky cycles)
- Kolmogorov–Smirnov test to compare the equality of distributions across signal cycles
- ➤Cycles with positive crash risk are significantly different from other cycles



**QUT** the university for the real world

 $\rightarrow$  Crash risk varies across the time of the day

→ This difference in variation is statistically significant





## Conclusions

□ Extreme Value Theory provides a good framework to estimate real-time crash risk from traffic conflicts

□ Non-stationary models are preferable

□ The suitability of traffic conflict indicators for other crash types needs to be rigorously tested.

