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Modelling Probability of Critical Crossing Conflicts at Unsignalized Intersections under Mixed Traffic Conditions

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Need of Study

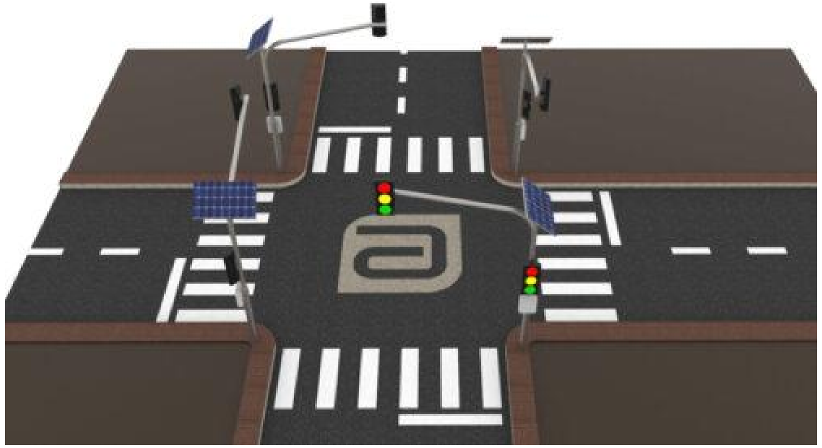
Crash-Investigation approach in India is reactive.

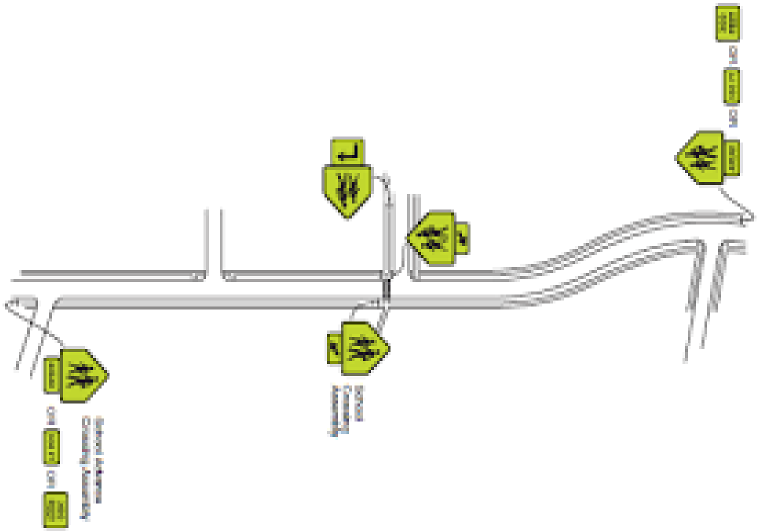
Lack of Quality Crash-data.

- Lack of data on segregated crash-types.
- Lack of crash-severity data.

Underreporting of crashes.

Accidents by Junction Control





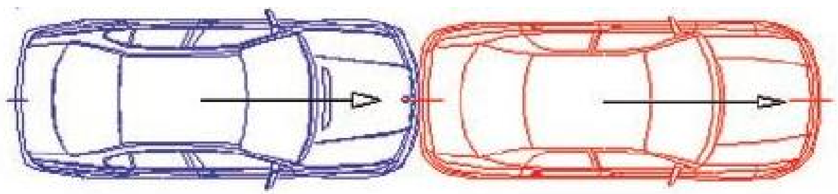
175853 Accidents on Junctions in 2019

51829 Accidents on Controlled Junction (29%)

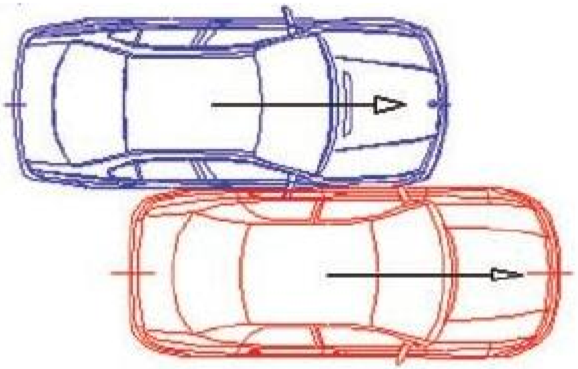
124,024 Accidents on Un-signalized Junction (71%)

Unsignalized junctions accounted for 73.30 % of total fatalities at road junctions

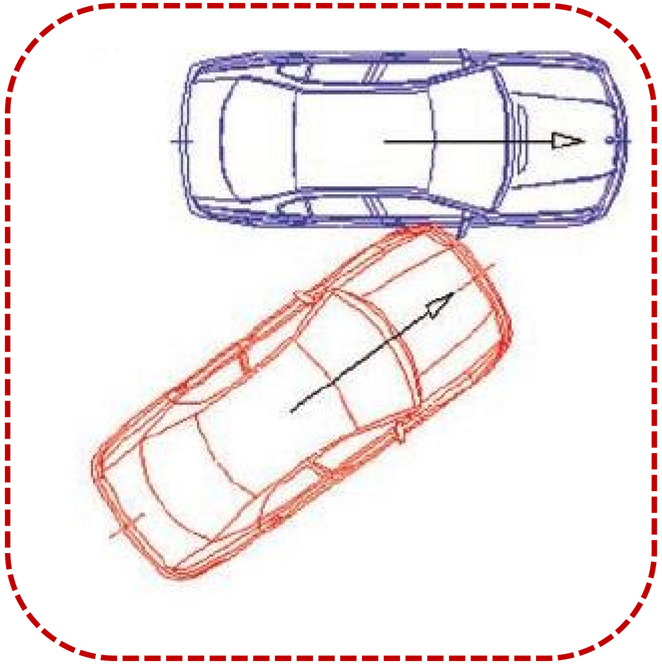
Probable Traffic Conflicts at Urban Unsignalized Intersections*



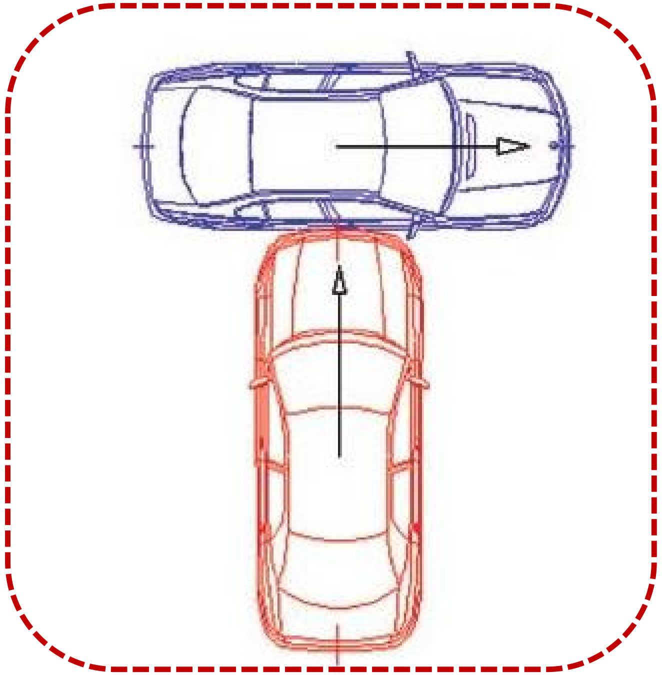
Rear End Conflicts



Side-Swipe Conflicts



Right-Turning Collisions



Right-Angled Collisions

Right-Turning and Right-angled conflicts are riskier and frequently observed.

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*Investigating traffic accidents: A Collision of two Motor-Vehicles, Transport, Taylor & Francis DOI: 10.3846/transport.2010.14, *Olegas Prentkovskis et al.*

Post Encroachment Time (PET) as Surrogate Safety Measure (SSM) for crossing-conflict evaluation

- Post Encroachment Time is a temporal surrogate measure.

  (-6 seconds >PET< 6 seconds) – Observation Threshold – Archer (2000)

  (-1 second >PET< 1 second)- Critical Threshold- Peesapati (2003)

PET is represented by :

$$PET = T_2 - T_1$$

where,

T1 = time when the offending vehicle leaves the conflict area;

T2 = time when the conflicting vehicle enters the conflict area

From, the definition PET can be both Negative and Positive based on arrival of the vehicles at the conflict area.

Positive and Negative PET

Source: https://www.sutliffstout.com/

T2 > T1

Positive PET

Source: https://www.hsinjurylaw.com/

T1 > T2

Negative PET

Field Observed Positive and Negative PET cases

Positive PET for Crossing Conflicts at Intersections

Negative PET for Crossing Conflicts at Intersections

Probability of Critical Crossing Conflicts (PCCC)

- Probability of Critical Crossing Conflicts (PCCC) represents the probability of critical conflicts under the critical thresholds of PET.

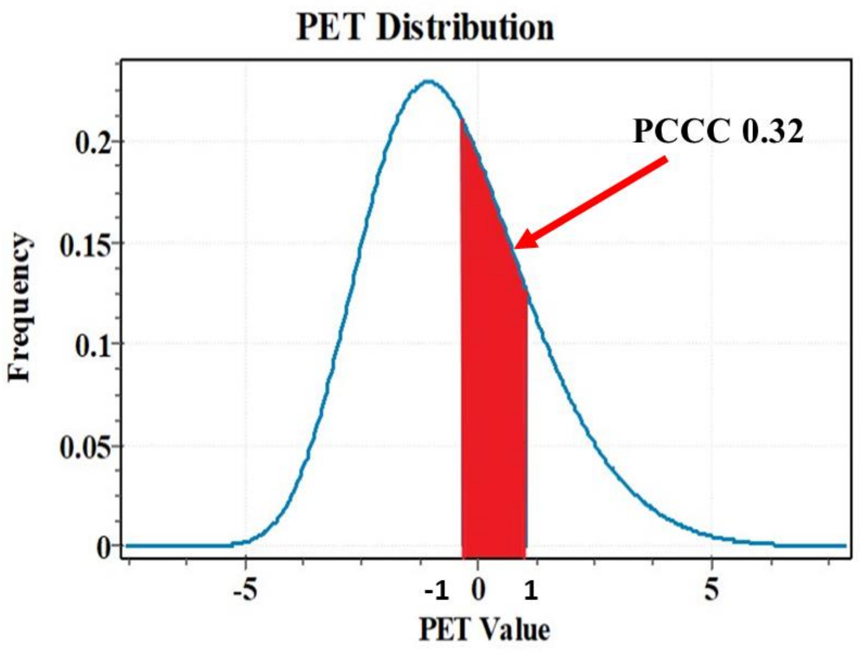
$$PCCC = \int_{-1}^{1} f(x)\,dx$$

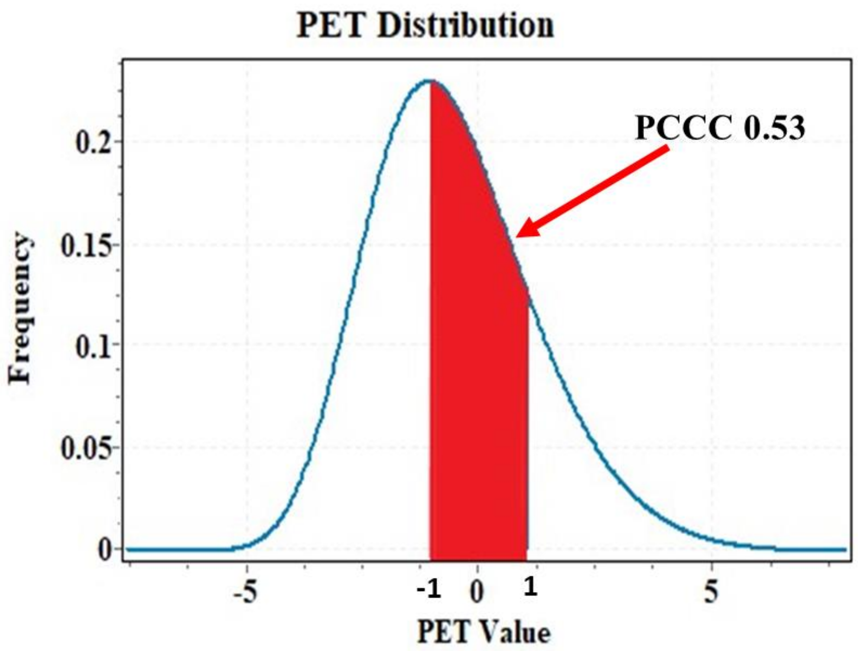
A higher value of PCCC highlights that majority of the crossing conflicts are critical, and therefore, the risk is higher.

Generalized Extreme Value distibution fitted into observed PET values to derive PCCC. The CDF of the GEV is given by:

$$F(x) = exp\{-[1 + \varepsilon(x - \mu)/\sigma]^{-1/\varepsilon}$$

Levels of Risks represented by PCCC at same Volumes





PCCC is an aggregated parameter of crossing risk at Unsignalized Intersections. Within similar volume and composition, PCCC can be different.

PCCC thus represents driver's behaviour at Unsignalized Intersections

T-Intersections

Rachna Circle

Poddar Arcade

Acharya Shree Junction

Khatushyam Intersection

Muktanad Circle

Valinath Circle

Udhna Circle

Lajamani Chowk

4-Legged Intersections

Ugat Canal Intersection

Ushodaya Intersection

Honey Park Intersection

Piplod Intersection

Ranjit Circle

Modelling with Beta Regression

- PCCC is a continuous, bounded, non-negative, fractional variable bounded between 0,1.
- Beta regression is used widely for modeling continuous, bounded variables.
- two shape parameters (p, q) of density to that of the mean (μ) and precession parameter (Ψ)
- Probability Density Function of Beta Regression can be written as:

$$\boldsymbol{f\ (y;\ p,q)\ =\ \{\Gamma\ (p,q)/\Gamma(p)\Gamma(q)\}\ yp^{\ -\ 1}(1-y)^{\ q\ -\ 1}\quad 0<y<1}$$

Bayesian Framework

- Robust Framework, can account for unobserved heterogeneity.
- Uses prior information on distribution
- The information from observed data and prior distribution is used to enhance the modeling accuracy
- Prior Distribution is either sampled from legacy data or popular belief is taken.
- When no prior available, Non-informative prior is used.
- Zero Mean and large variance 10^6, normally distributed.

Right Turning Conflicts: 3-legged-Intersections

Type of Model	Variables	Coefficients	Standard deviation	Equal-tailed [95% Cred. Interval]	
PCCC model	2w C	0.016	0.005	0.006	0.025
	3w C	0.018	0.005	0.007	0.027
	4w C	0.023	0.005	0.012	0.033
	2w O	0.009	0.004	0.0010	0.019
	3w O	0.016	0.006	0.006	0.028
	4w O	0.015	0.005	0.004	0.025
	CC	0.0020	0.0002	0.0016	0.0025
	NCC	-0.002	0.000	-0.002	-0.0012
	WTWCI	-0.103	0.045	-0.19	-0.009
	MAJOR /MINOR	-0.039	0.002	-0.074	-0.004
	TOD	0.027	0.012	0.0052	0.052
	CONSTANT	-3.159	0.051	-3.26	-3.06

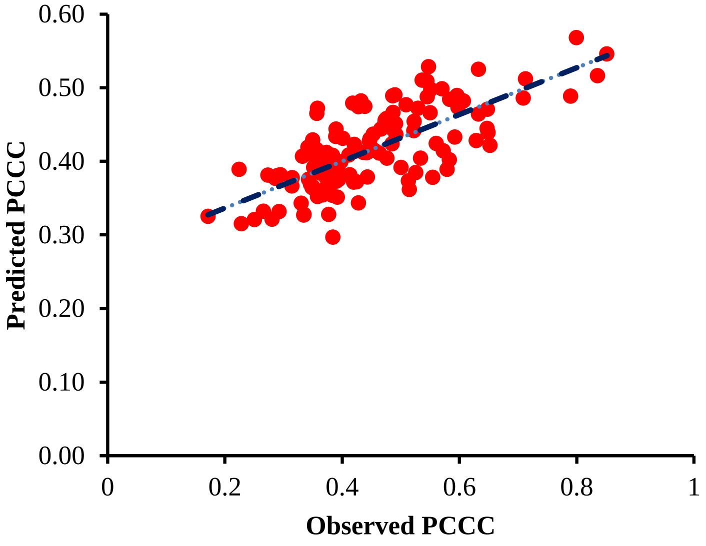
DIC	log (ML)
-531.43	86.31

Four-legged Intersections: Right-Turning Conflicts

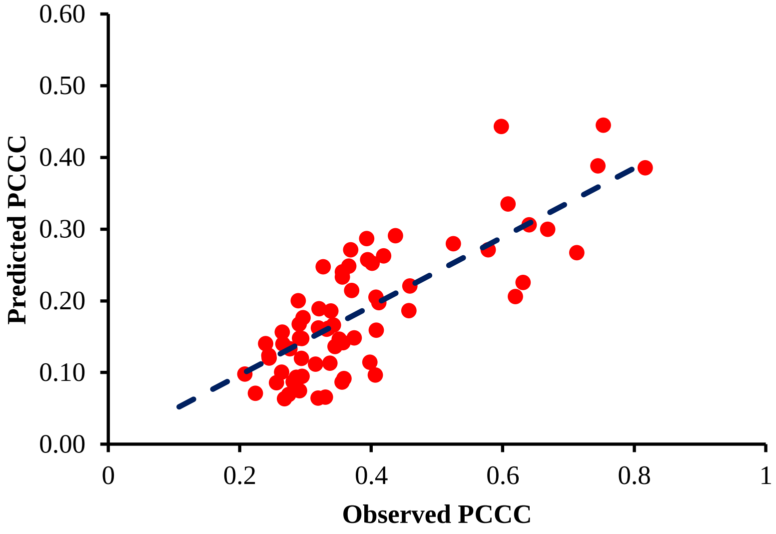
Type of Model	Variables	Coefficients	Standard deviation	*MCSE*
PCCC model	2w C	0.01317	0.00656	0.00079
	3w C	0.00474	0.00706	0.00082
	4w C	0.02292	0.00692	0.00119
	2w O	0.03446	0.00660	0.00084
	3w O	0.01428	0.00907	0.00065
	4w O	0.05579	0.00730	0.00122
	CC	0.00488	0.00071	0.00007
	NCC	-0.00409	0.00059	0.00006
	WTWCI (1)	-0.42055	0.09285	0.01507
	MAJOR /MINOR (0)	-0.05969	0.07273	0.01456
	CONSTANT	-5.12618	0.03954	0.00867

DIC	log (ML)
-301.1803	14.36362

Validation Plots



(a)



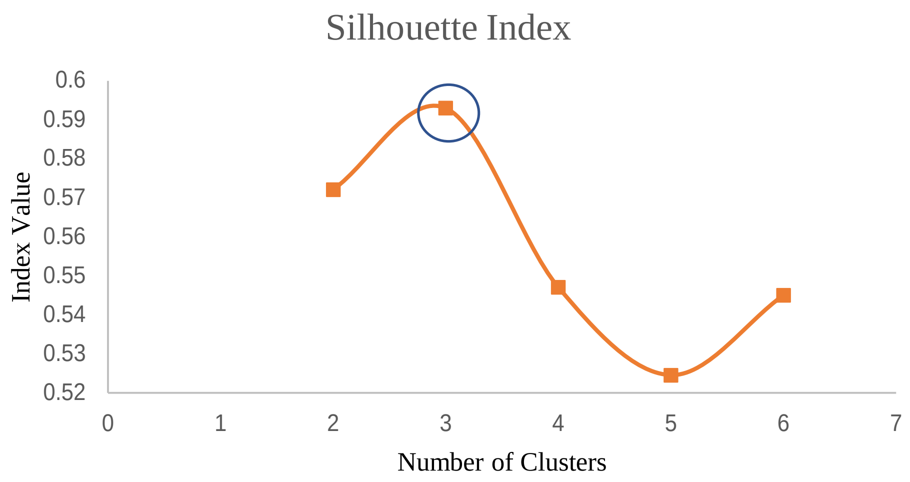
(b)

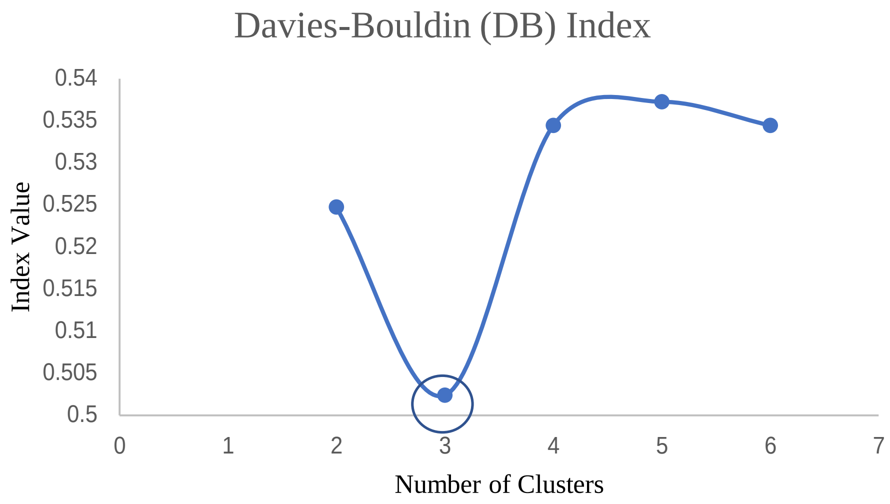
Scatter-plot of observed versus predicted PCCC at a) 3-legged and b) 4-legged intersections

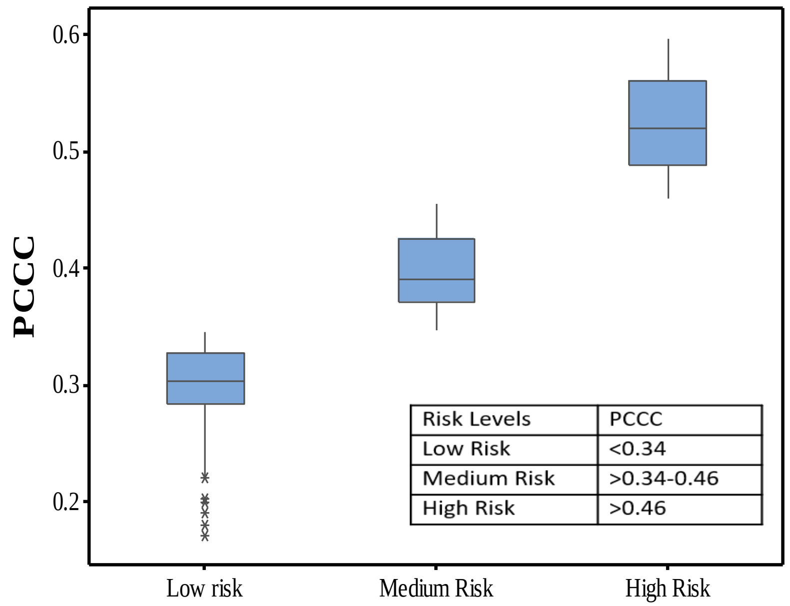
Results

- PCCC is influenced significantly by :
  - Overall Vehicular Composition of Offending and Conflicting approaches
  - Number of Critical and Non-critical conflicts
  - PCCC decreases with an increased vehicular composition and volume of vehicles from offending approach.
  - Intersection geometry has significant influence, PCCC is observed to be 25-42% lesser for intersections with Central-Island.

Risk Clusters







Risk Levels	PCCC
Low Risk	<0.34
Medium Risk	>0.34-0.46
High Risk	>0.46

Table: Goodness of fit parameters for optimal number of clusters

No. of clusters	2	3	4	5	6
Silhouette Index	0.572	0.593	0.547	0.525	0.545
DB Index	0.525	0.502	0.534	0.537	0.534

3 nos. of optimum clusters were identified and PCCC based crossing risk was classified into 3 risk categories. Low Risk, Medium Risk and High-Risk

Conclusions

- There is a lack of quality crash data for India, and there are issues with reporting of crash-types as well underreporting. The validation of crashes with derived crash risk from surrogate safety measures will always show over-estimate. Hence, parameters associated with risk would be the best estimate of operational safety at interactions.
- For Crossing conflicts at unsignalized intersections, PCCC denotes the aggregated risk. It shows the intensity of the crossing risk.
- PCCC is influenced by traffic flow, vehicle composition, intersection geometry of the intersections and can be modelled by Beta Regression under a Full-Bayesian framework.
- A comprehensive clustering framework can help decision makers identify the risky intersections for treatment priority.

Contributions of the Study

- The present study presents a framework to evaluate the safety of crossing operations at unsignalized intersections.
- PCCC is a novel EVT-based concept that represents the aggregated risk (intensity) of crossing conflicts under the critical thresholds.
- The study identified critical factors that influence the PCCC at unsignalized intersections through Beta regression under a full Bayesian framework. The factors would help in developing countermeasures to reduce the crossing risks.
- The cluster-based approach to delineate levels of risk (PCCC) enables city planners to identify and cluster intersections in the traffic network according to different levels of prevailing risk. The developed clusters will be based on actual PCCC values, and the thresholds will be network/city specific.

Thank You