Automated Methods for Surrogate Safety Analysis: Where We Are and Where to Go Next

ICTCT 2014 Workshop
University of Applied Science in Karlsruhe

Nicolas Saunier
nicolas.saunier@polymtl.ca

POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

October 16$^{\text{th}}$ 2014

Outline

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Where We Are

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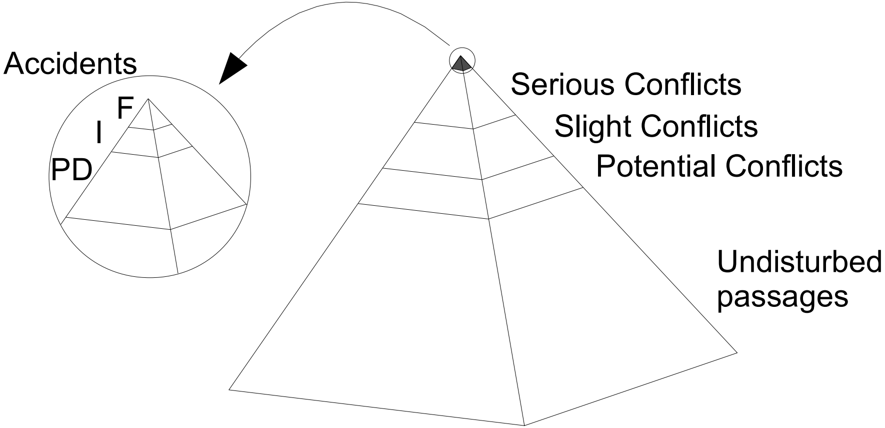
  - video analysis has thus become feasible with good enough results to extract microscopic road user data (trajectories)
- A fragmented landscape of methods for “surrogate safety analysis”

Foundation: The Safety/Severity Hierarchy



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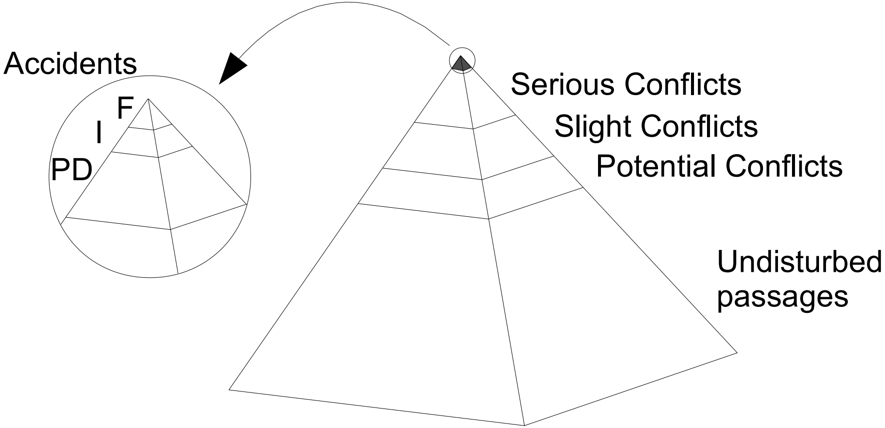

Do the boundaries actually exist and do we need them?

A plethora of surrogate measures of safety

- Continuous measures
  - Time-to-collision (TTC)
  - Gap time (GT) (=predicted PET)
  - Deceleration to safety time (DST)
  - Speed-based indicators, etc.
- Unique measures per conflict
  - Post-encroachment time (PET)
  - Evasive action(s) (harshness), subjective judgment, etc.
- Number of traffic events, e.g. (serious) traffic conflicts

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Which indicators are related to collision probability and/or severity?

Some Issues with Current Methods

- Several methods for surrogate safety analysis exist ("old" and "new" traffic conflict techniques) but there is a lack of comparison and validation
- Issues related to the (mostly) manual data collection process
  - cost
  - reliability and subjectivity: intra- and inter-observer variability
- Mixed validation results (and unavailable literature)

How do we compare models/frameworks/theories?

Occam's razor

There is trade-off between the complexity of a model and its explanatory power, i.e. given 2 models with similar explanatory power, the simpler one is the superior one

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- Better understand collision processes and the similarities between interactions with and without a collision
- Validate the surrogate measures of safety

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Rethinking the Collision Course

- A traffic conflict is “an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged”
- For two interacting road users, many chains of events may lead to a collision
- It is possible to estimate the probability of collision if one can predict the road users’ future positions
  - the motion prediction method must be specified

Motion Prediction

- Predict trajectories according to various hypotheses
  - iterate the positions based on the driver input (acceleration and steering)
  - learn the road users' motion patterns (including frequencies), represented by actual trajectories called prototypes, then match observed trajectories to prototypes and resample

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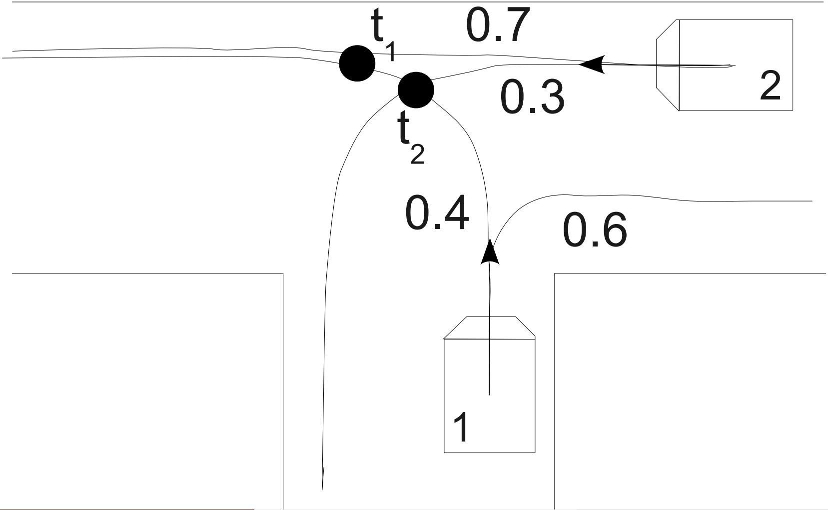
  - learn the road users' motion patterns (including frequencies), represented by actual trajectories called prototypes, then match observed trajectories to prototypes and resample
- Advantage: generic method to detect a collision course and measure safety indicators, as opposed to several cases and formulas (e.g. in [Gettman and Head, 2003])

[Saunier et al., 2007, Saunier and Sayed, 2008, Mohamed and Saunier, 2013, St-Aubin et al., 2014]

A Simple Example



Collision Points and Crossing Zones

Using of a finite set of predicted trajectories, enumerate the collision points CP_n and the crossing zones CZ_m. Safety indicators can then be computed:

$$P(Collision(U_i, U_j)) = \sum_n P(Collision(CP_n))$$

$$TTC(U_i, U_j, t_0) = \frac{\sum_n P(Collision(CP_n))\ t_n}{P(Collision(U_i, U_j))}$$

$$pPET(U_i, U_j, t_0) = \frac{\sum_m P(Reaching(CZ_m))\ |t_{i,m} - t_{j,m}|}{\sum_m P(Reaching(CZ_m))}$$

[Saunier et al., 2010, Mohamed and Saunier, 2013, Saunier and Mohamed, 2014]

Is this updated TTC sufficient?

- An extra dimension seems conceptually necessary to measure the ability of road users to avoid the collision, e.g. DST or a generic probability of unsuccessful evasive action [Mohamed and Saunier, 2013]
- Sample the space of possible evasive actions (e.g. using more extreme distribution of braking) and compute again the probability of collision

Interpret the Whole Traffic Continuum (Not Just Serious Conflicts)

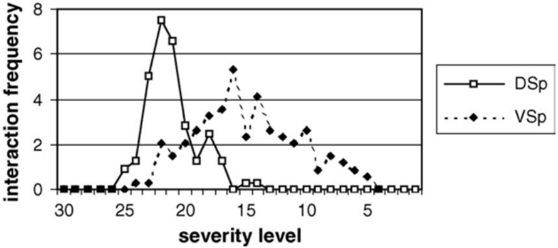


Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

[Svensson, 1998, Svensson and Hydén, 2006]

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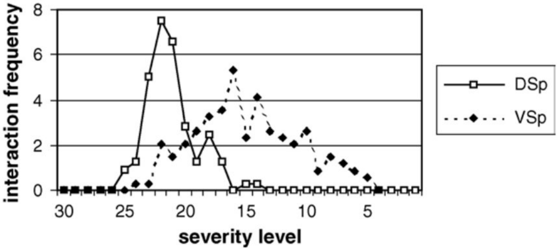

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Feedback and learning process: collisions with injuries occurred at the signalized intersection [Svensson, 1998, Svensson and Hydén, 2006]

Measure the similarity of interactions

- Interactions are characterized by time series of indicators (based on position and speed, and safety indicators)
- Need for measures that naturally accomodate variable length vectors: Longest Common Sub-sequence (LCSS)
- Cluster interactions to find similarities between interactions, with and without a collision

Automated Video Analysis

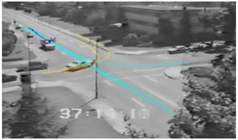
Image Sequence
+

Camera Calibration

+

Labeled Images for Road User Type

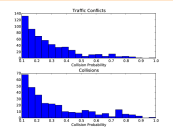
Road User Trajectories



Interactions

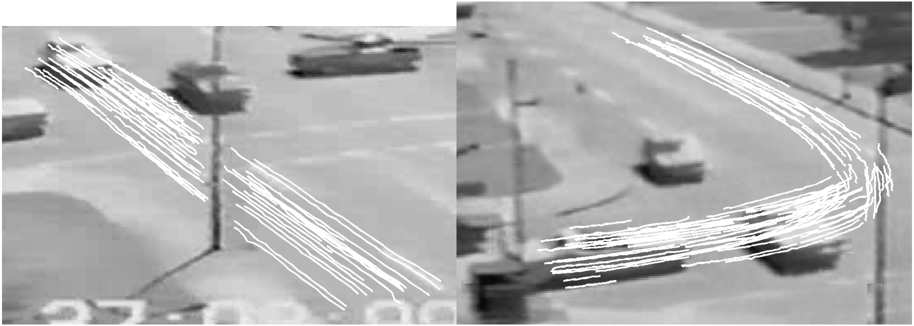
Applications

Motion patterns, volume, origin-destination counts, driver behavior



Traffic conflicts, exposure and severity measures, interacting behavior

Feature-based Road User Tracking in Video Data



Good enough for safety analysis and other applications in busy urban road locations, including the study of pedestrians and pedestrian-vehicle interactions [Saunier and Sayed, 2006]

Flexible Mobile Video Data Collection Unit

[Jackson et al., 2013]

Outline

Road User Tracking (Kentucky Dataset)

Motion Prediction

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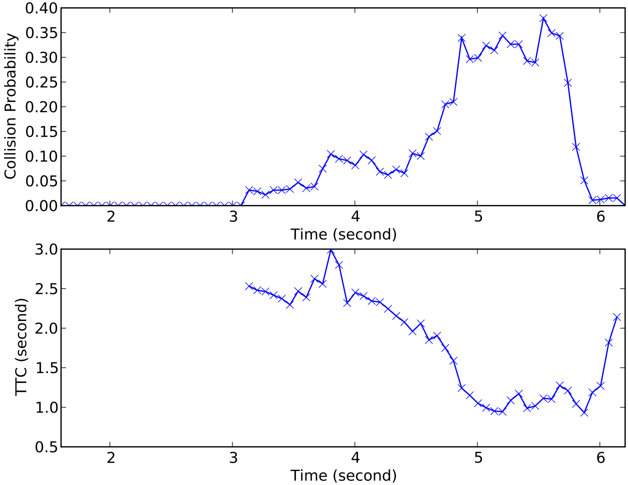
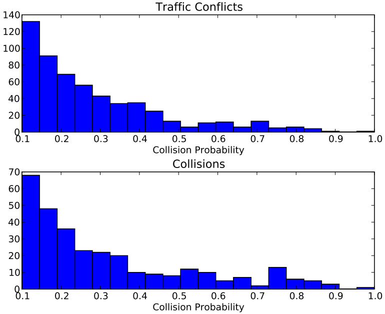
Safety Indicators



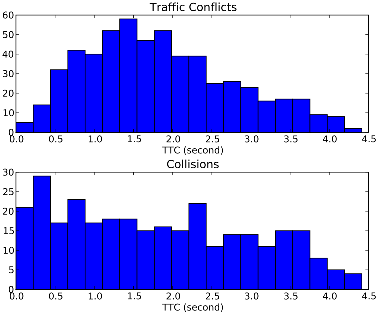
Distribution of Indicators (Event Aggregation)

[Saunier et al., 2010]

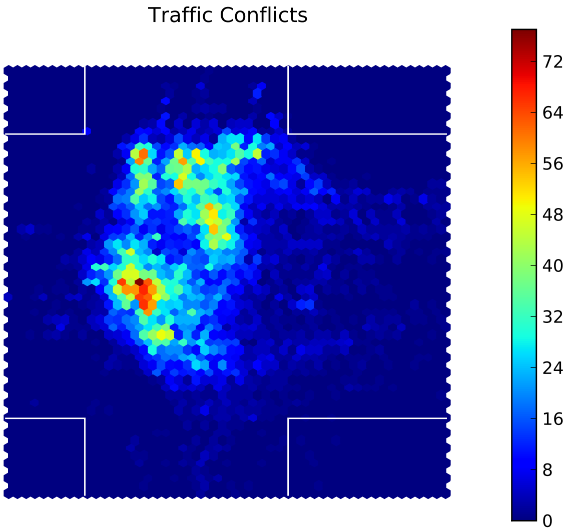
Maximum Collision Probability



Minimum TTC



Spatial Distribution of the Collision Points [Saunier et al., 2010]



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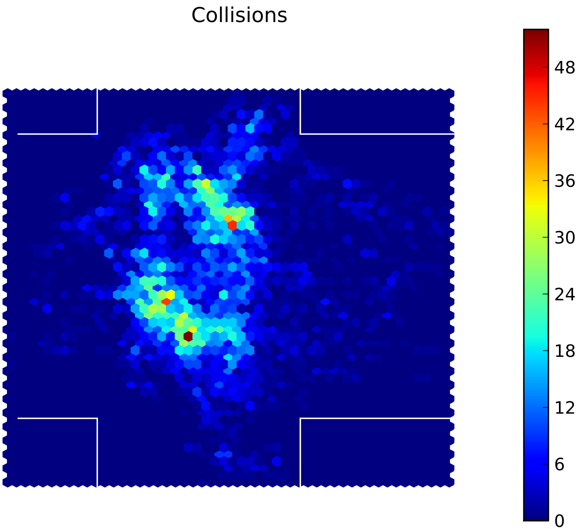
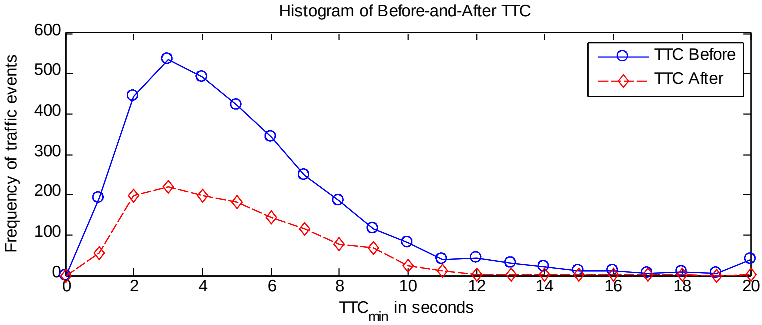


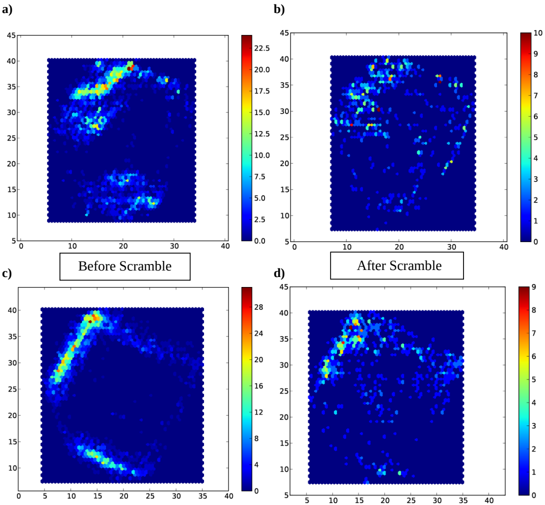
Before and After Study: Introduction of a Scramble Phase

Data collected in Oakland, CA [Ismail et al., 2010]

Distribution of Safety Indicators



Before and After Distribution of the Collision Points



Lane-Change Bans at Urban Highway Ramps

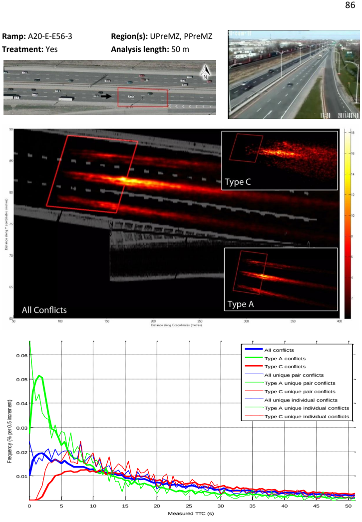


Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).

Treated site (with lane marking)
[St-Aubin et al., 2012, St-Aubin et al., 2013a]

Lane-Change Bans at Urban Highway Ramps

70

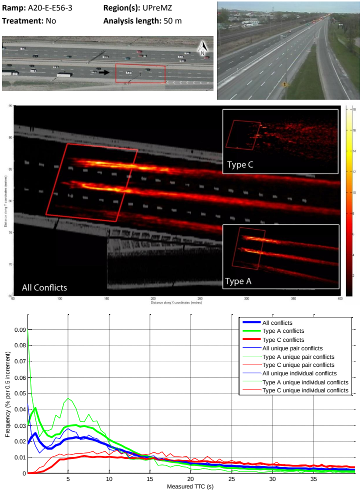
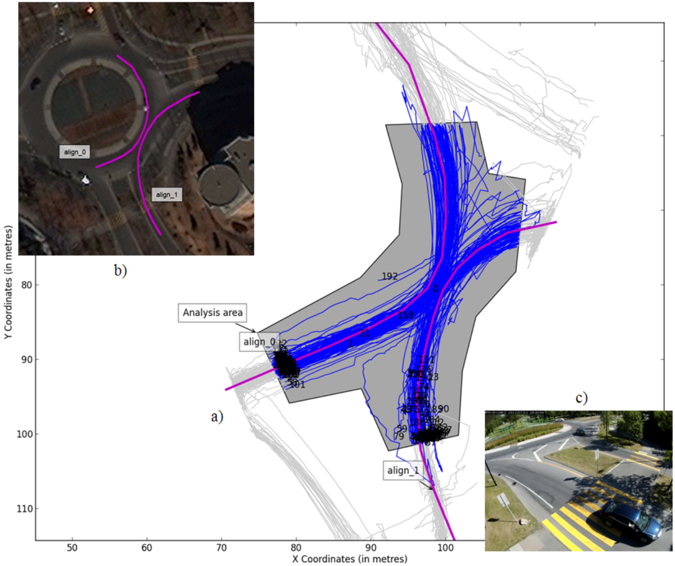


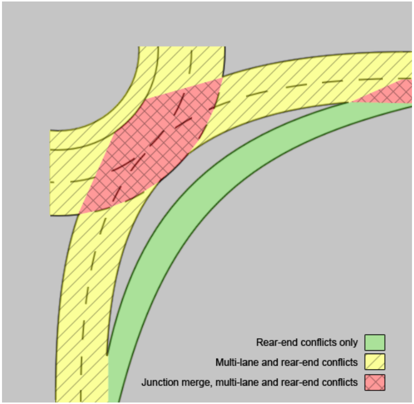
Figure 27 – Conflict analysis Cam20-16-Dorval (Untreated).

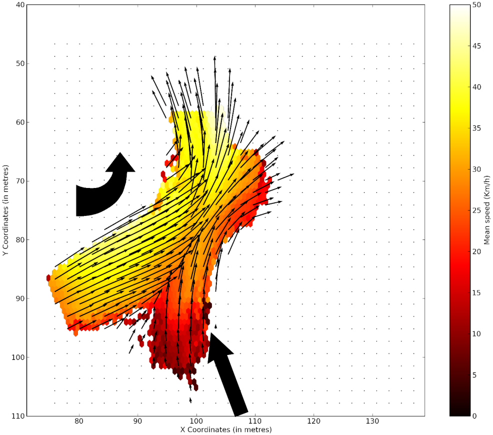
Untreated site (no lane marking)
[St-Aubin et al., 2012, St-Aubin et al., 2013a]

Big Data: Roundabout Safety in Québec



Speed Fields in Roundabouts [St-Aubin et al., 2013b]



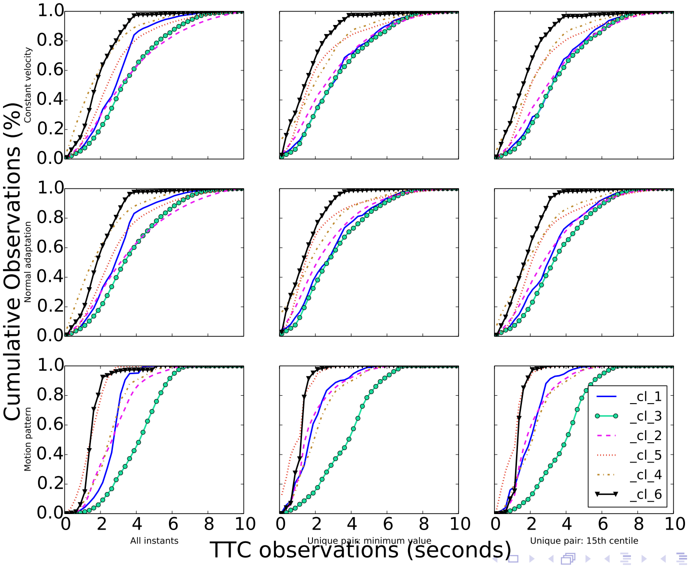


K-means cluster profile for TTC regression

[St-Aubin et al., 2015b]

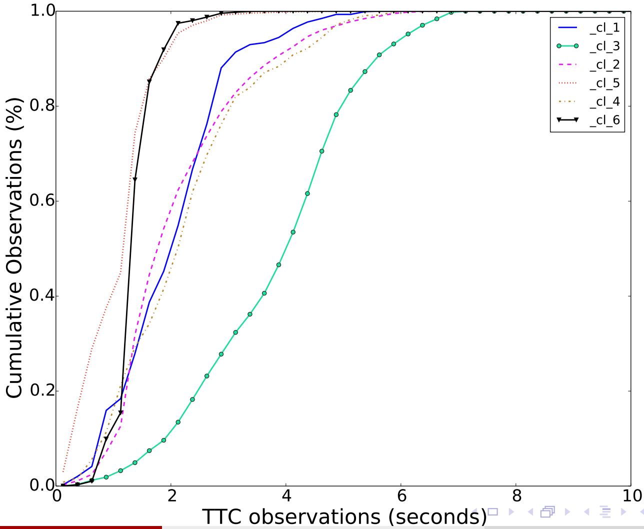
#	Description	N_{zones}	N_{obs}
1	Small single and double lane residential collectors	11	4,200
2	Single-lane regional highways and arterials with speed limits of 70-90 km/h and mostly polarised flow ratios	16	26,243
3	2-lane arterials with very high flow ratios	5	13,307
4	Hybrid lane 1 $\rightarrow$ 2, 2 $\rightarrow$ 1 arterials with very low flow ratios	3	4,809
5	Traffic circle converted to roundabout (2 lanes, extremely large diameters, tangential approach angle)	4	10,295
6	Single-lane regional highway with large-angle quadrants (140°) and mixed flow ratios	2	2,235

The Agregation Problem [St-Aubin et al., 2015a]

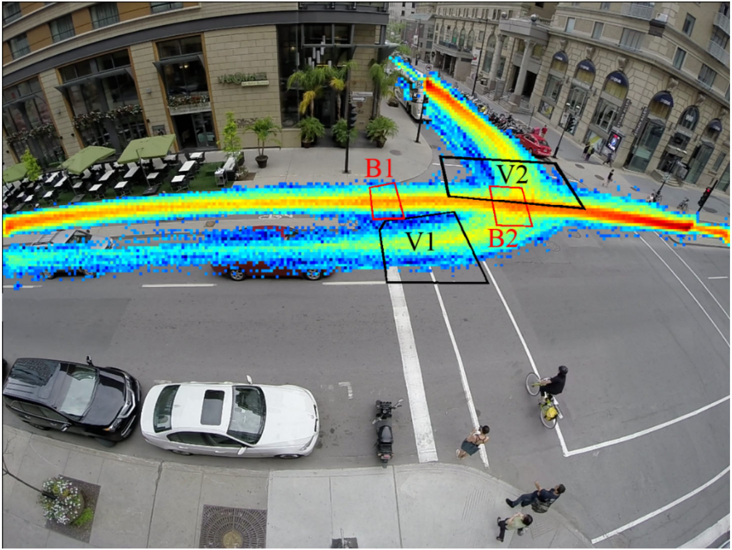


TTC Distribution Comparison by Cluster

[St-Aubin et al., 2015b]



Cycle Track Safety [Zangenehpour et al., 2015]



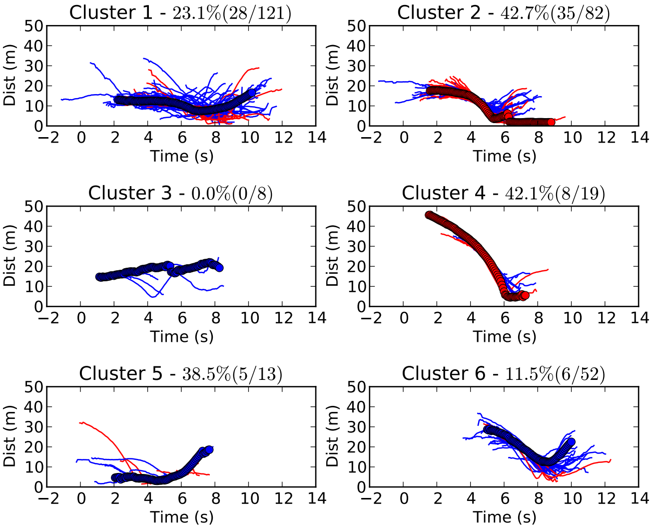
Cycle Track Safety [Zangenehpour et al., 2015]

Model I. Cycle track on the right vs. no cycle track						
Number of Observations = 2880			Log likelihood = -1420		Pseudo R^2 = 0.264	
	Coef.	Std. Err.	z	P > |z|	[95% Conf. Interval]	
Cycle Track on Right	0.4303	0.1297	3.32	0.001	0.1760	0.6846
Turning-Vehicle Flow for 15s before to 15s after	-1.4089	0.0551	-25.56	0.000	-1.5170	-1.3009
Number of Lane on the Main Road	-0.2354	0.0654	-3.60	0.000	-0.3636	-0.1073
Bus Stop	0.2658	0.1336	1.99	0.047	0.0039	0.5277
Cut-off 1	-6.6884	0.2836			-7.2443	-6.1326
Cut-off 2	-3.8927	0.1968			-4.2785	-3.5070
Cut-off 3	-2.5246	0.1812			-2.8798	-2.1695

Model II. Cycle track on the left vs. no cycle track						
Number of Observations = 4803			Log likelihood = -3241		Pseudo R^2 = 0.288	
	Coef.	Std. Err.	z	P > |z|	[95% Conf. Interval]	
Cycle Track on Left	-0.1618	0.1186	-1.36	0.172	-0.3941	0.0706
Bicycle Flow for 10s before	0.0827	0.0302	2.74	0.006	0.0235	0.1419
Turning-Vehicle Flow for 15s before to 15s after	-1.3938	0.0342	-40.79	0.000	-1.4608	-1.3268
Cut-off 1	-7.4890	0.2074			-7.8956	-7.0825
Cut-off 2	-3.5944	0.1243			-3.8380	-3.3509
Cut-off 3	-2.0168	0.1132			-2.2387	-1.7950

Model III. Cycle track on the right vs. cycle track on the left						
Number of Observations = 6567			Log likelihood = -4030		Pseudo R^2 = 0.291	
	Coef.	Std. Err.	z	P > |z|	[95% Conf. Interval]	
Cycle Track on Left	-0.5351	0.0921	-5.81	0.000	-0.7155	-0.3546
Bicycle Flow for 10s before	0.6000	0.0268	2.23	0.025	0.0074	0.1126
Turning-Vehicle Flow for 15s before to 15s after	-1.3544	0.0304	-44.52	0.000	-1.4141	-1.2948
Number of Lane on the Main Road	-0.1592	0.0660	-2.41	0.016	-0.2884	-0.0299
Number of Lane on the Turning Road	0.3855	0.1144	3.37	0.001	0.1613	0.6097
Cut-off 1	-7.7501	0.3077			-8.3532	-7.1471
Cut-off 2	-3.7916	0.2684			-4.3177	-3.2655
Cut-off 3	-2.2953	0.2650			-2.8148	-1.7758

Indicator/Interaction Clustering [Saunier and Mohamed, 2014]



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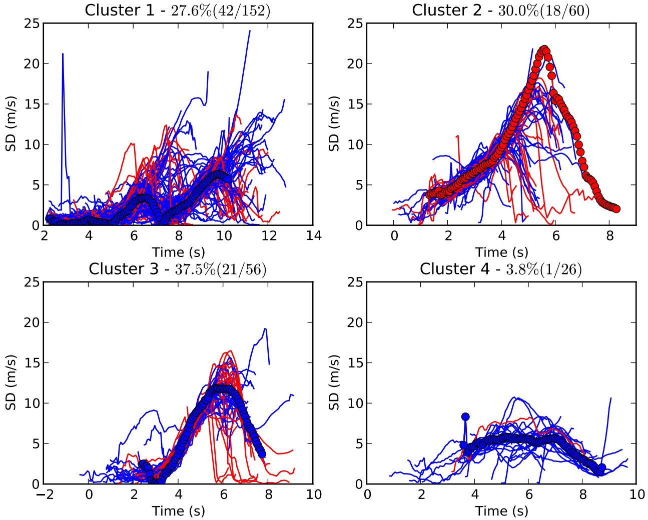

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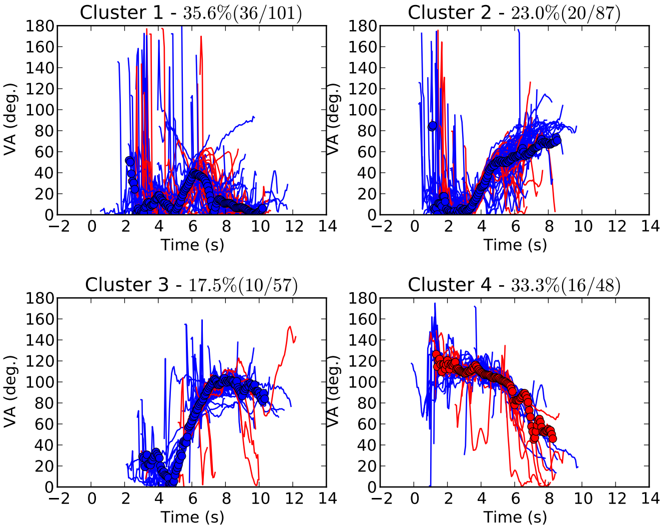

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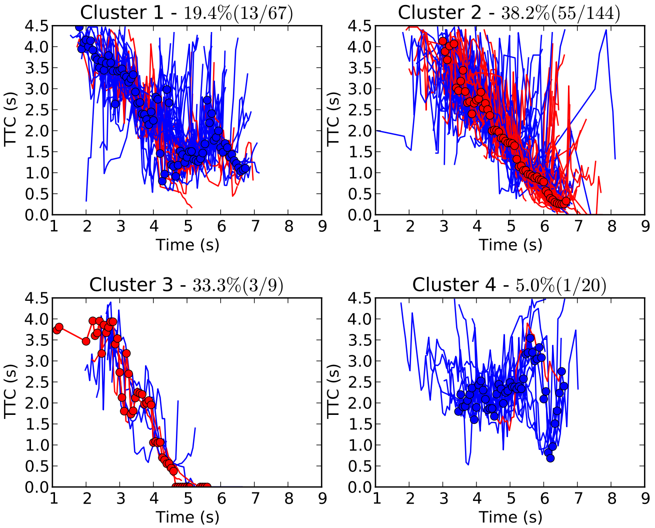

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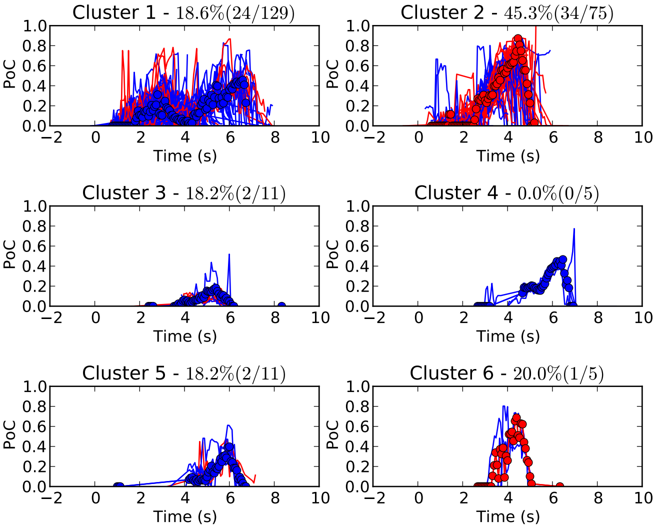

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Open Questions

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- How can we compare the various methods and indicators?
- How do we validate the methods? With respect to what?
- How do we account for exposure? Conflicts are, by definition, not exposure [Hauer, 1982]

The Groundhog Day Syndrom

We must stop reinventing the wheel

Steps Forward: Some Challenges to the Research Community

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  - maybe we need new calibration conferences (Malmö and Trautenfels)?

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- Beware of boundaries: study the whole continuum of interactions and similarities between interactions with and without a collision

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  - Traffic Intelligence open source project
    `https://bitbucket.org/Nicolas/trafficintelligence`

- Collaboration with Tarek Sayed (UBC), Karim Ismail (Carleton), Marilyne Brosseau, Mohamed Gomaa Mohamed, Paul St-Aubin (Polytechnique Montréal), Luis Miranda-Moreno, Sohail Zangenehpour (McGill), Aliaksei Laureshyn (Lund)
- Funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), the Québec Research Fund for Nature and Technology (FRQNT) and the Québec Ministry of Transportation (MTQ)

Questions?

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