Automated Methods for Surrogate Safety Analysis

Webinar for the New York City Department of Transportation

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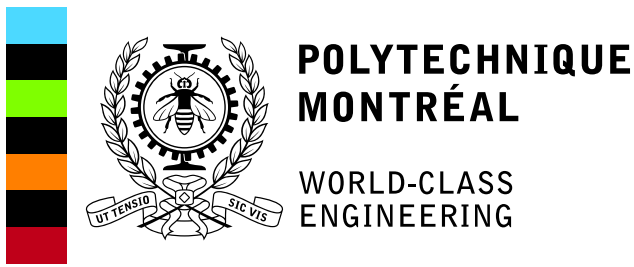

February 24th 2014

Outline

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Methods for Road Safety Analysis

There are two main categories of methods, whether they are based on the observation of traffic events or not

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   - traditional road safety analysis relying on historical collision data
   - vehicular accident reconstruction

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   - traditional road safety analysis relying on historical collision data
   - vehicular accident reconstruction
2. Accidents and other traffic events are directly observed
   - naturalistic driving studies
   - surrogate safety analysis

Main Issues with Traditional Methods for Road Safety Analysis

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3. Limited quality of the data reconstituted after the event, with a bias towards more damaging collisions
4. Traditional road safety analysis is reactive
   - the following paradox ensues: safety analysts need to wait for accidents to happen in order to prevent them

Need for Proactive (Surrogate) Methods for Road Safety Analysis

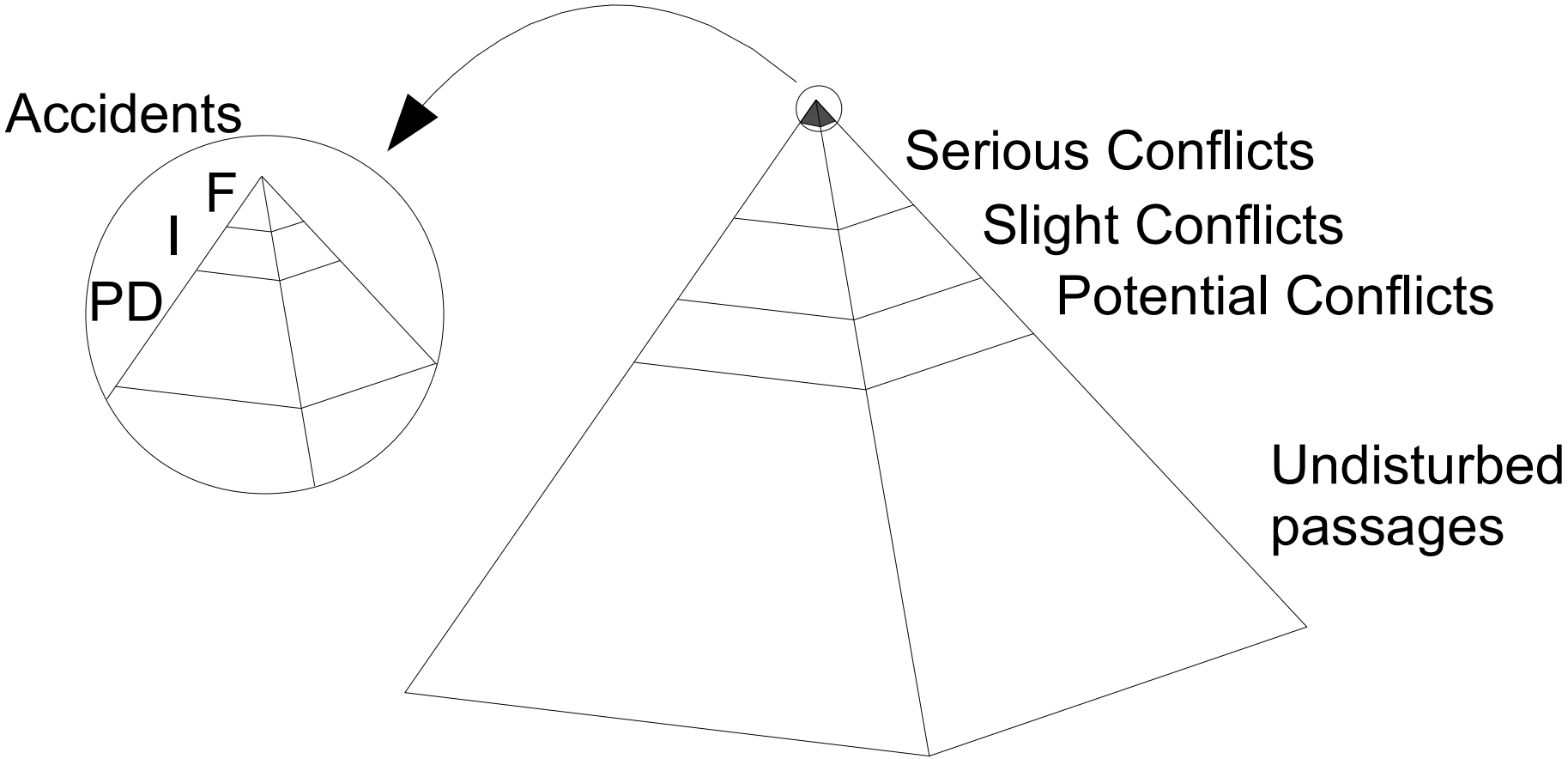
These methods should

- bring complementary information
- be related to traffic events that are more frequent than collisions and can be observed in the field
- be correlated to collisions, logically and statistically

Traffic Conflicts

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" [Amundsen and Hydén, 1977]

The Safety/Severity Hierarchy

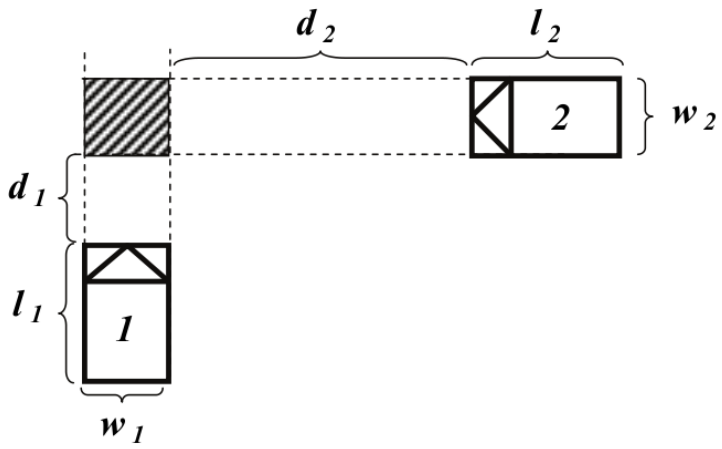


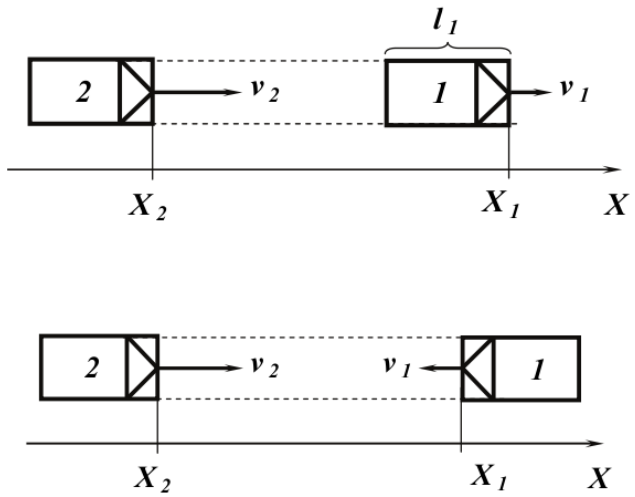
Surrogate Measures of Safety

The most famous are traffic conflict severity indicators:

- Continuous measures
  - Time-to-collision (TTC)
  - Gap time (GT) (=predicted PET)
  - Deceleration to safety time (DST)
  - Speed, etc.
- Unique measures per conflict
  - Post-encroachment time (PET)
  - Evasive action(s) (harshness), subjective judgment, etc.

Time-to-Collision





$$TTC = \frac{d_2}{v_2} \; if \; \frac{d_1}{v_1} < \frac{d_2}{v_2} < \frac{d_1 + l_1 + w_2}{v_1}$$

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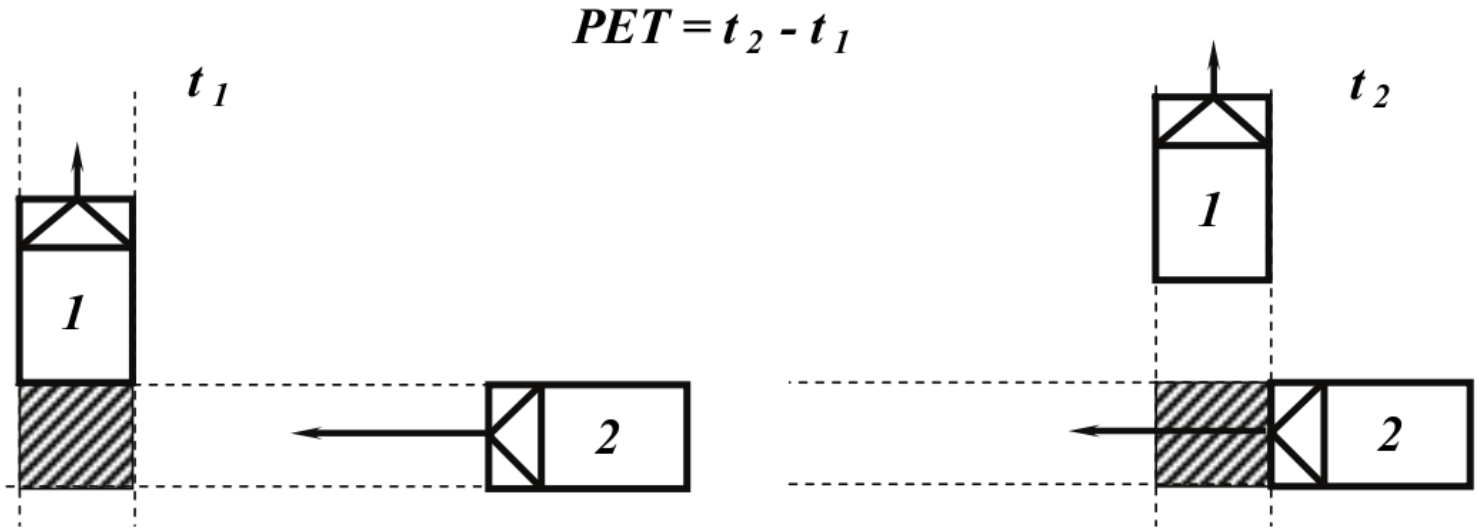
$$TTC = \frac{X_1 - X_2 - l_1}{v_1 - v_2} \; if \; v_2 > v_1 \; (rear \; end)$$

$$TTC = \frac{X_1 - X_2}{v_1 + v_2} \; (head \; on)$$

Post-Encroachment Time (PET) and Predicted PET



- PET is the time difference between the moment an offending road user leaves an area of potential collision and the moment of arrival of a conflicted road user possessing the right of way
- pPET is calculated at each instant by extrapolating the movements of the interacting road users in space and time

Issues with Traffic Conflict Techniques

- Several traffic conflict techniques exist (“old” and “new”) 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

Past research: The Whole Hierarchy

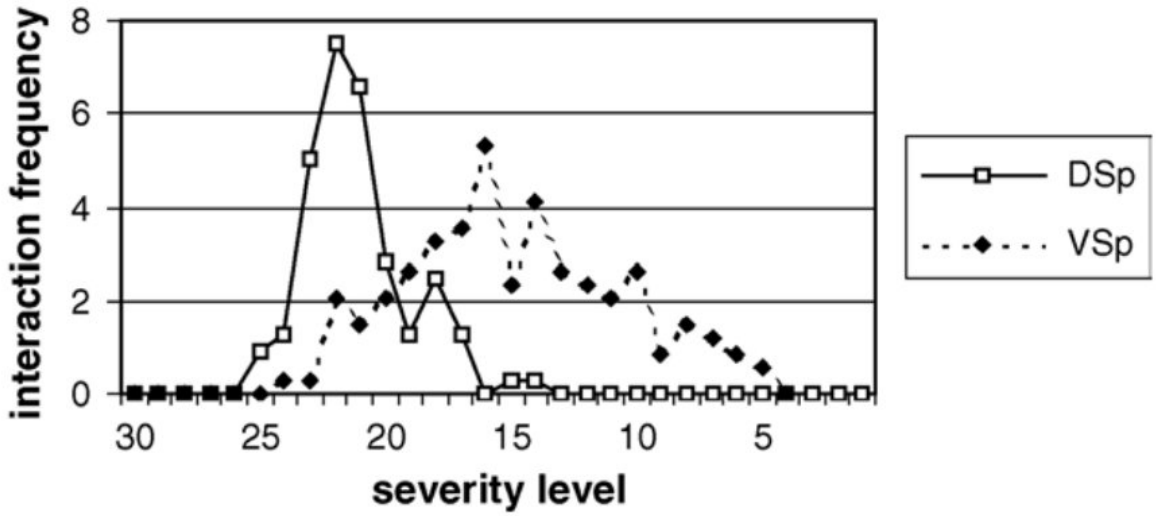


Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

[Svensson, 1998, Svensson and Hydén, 2006]

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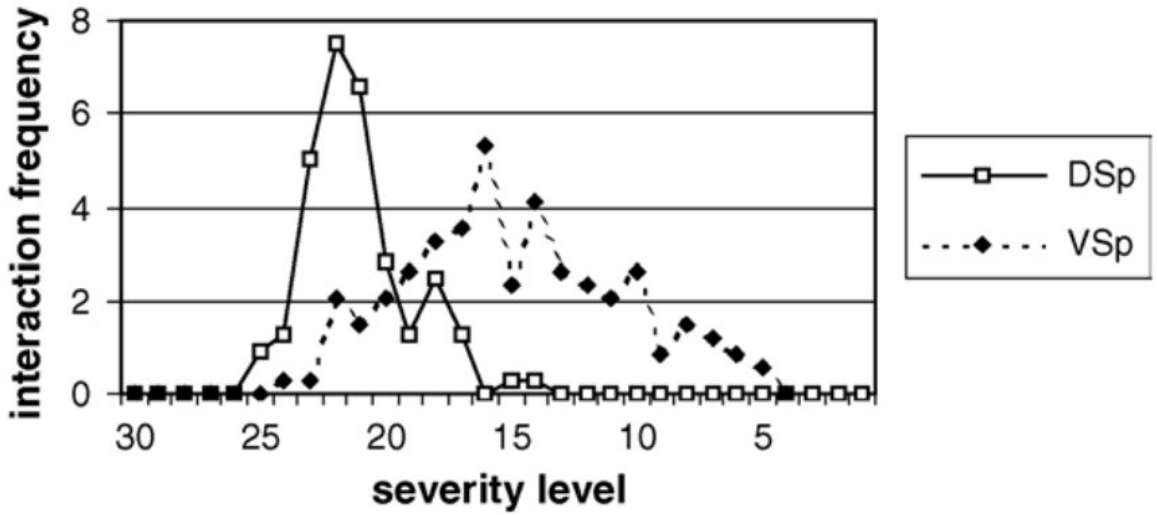


Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

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

Objectives

- Develop a robust probabilistic framework for surrogate safety analysis
- Better understand collision processes and the similarities between interactions with and without a collision
- Validate the surrogate measures of safety
- Apply the method to several case studies: urban intersections, vulnerable road users, highway

Outline

Rethinking the Collision Course

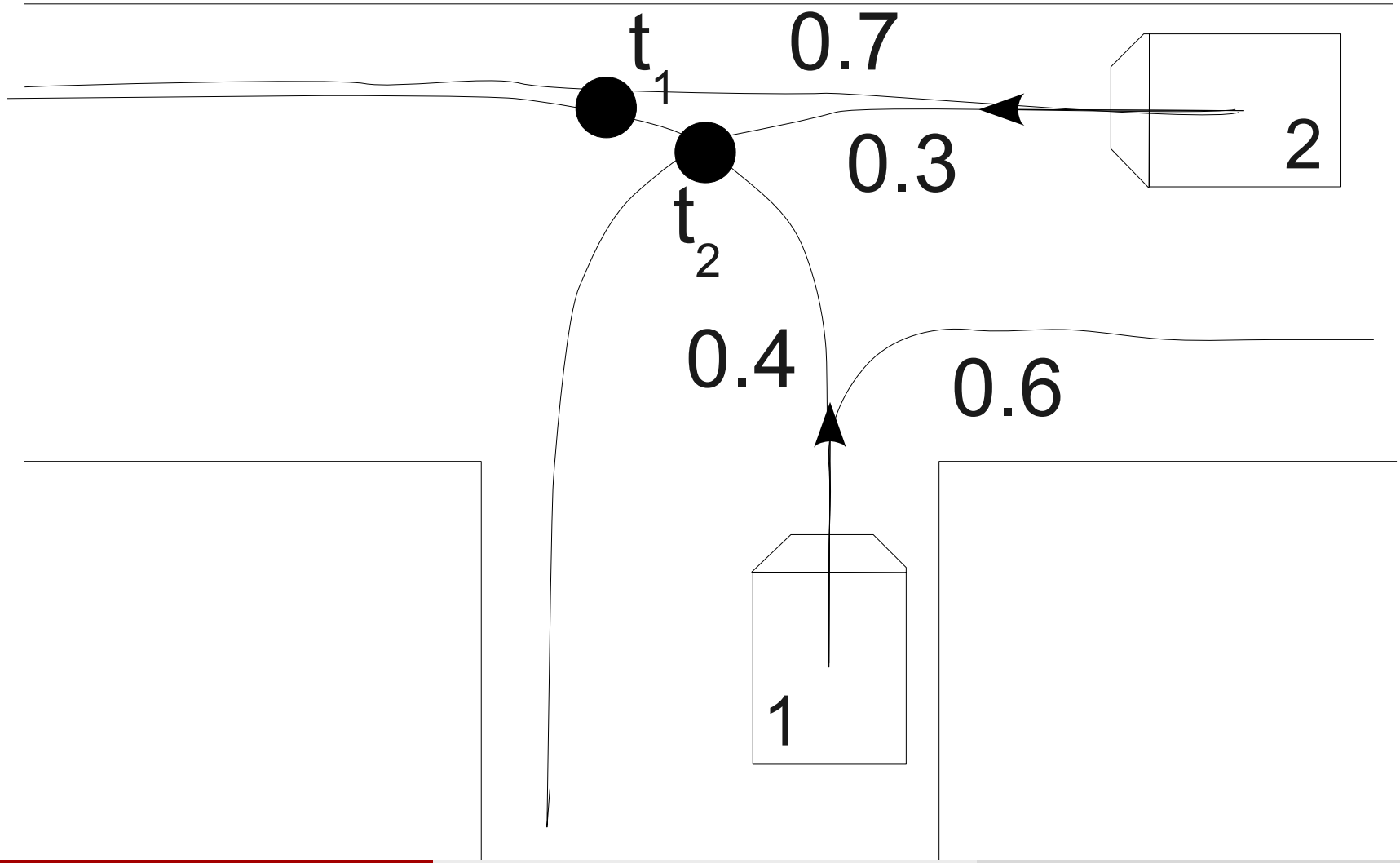
- A traffic conflict is “an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged”
- For two interacting road users, many chains of events may lead to a collision
- It is possible 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
- Advantage: generic method to detect a collision course and measure severity 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. Severity indicators can then be computed:

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

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

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

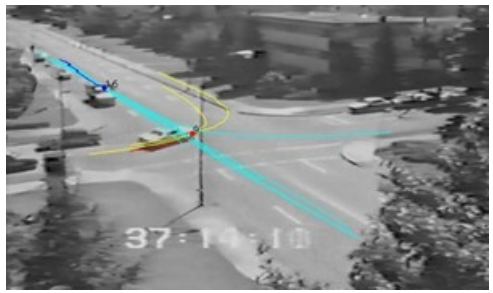
[Saunier et al., 2010, Mohamed and Saunier, 2013, Saunier and Mohamed, 2014]

Automated Video Analysis

Image Sequence
+
Camera Calibration
+

Labeled Images for Road User Type

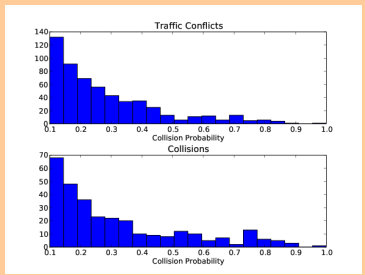
Road User Trajectories



Interactions

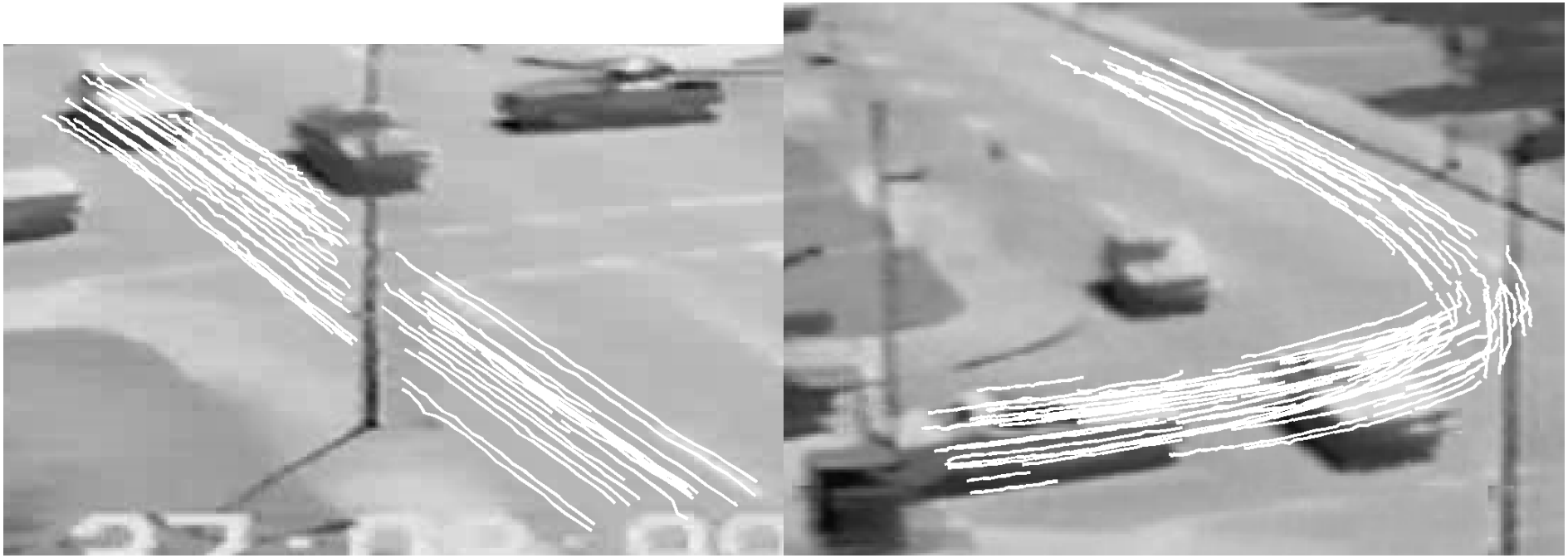
Applications

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



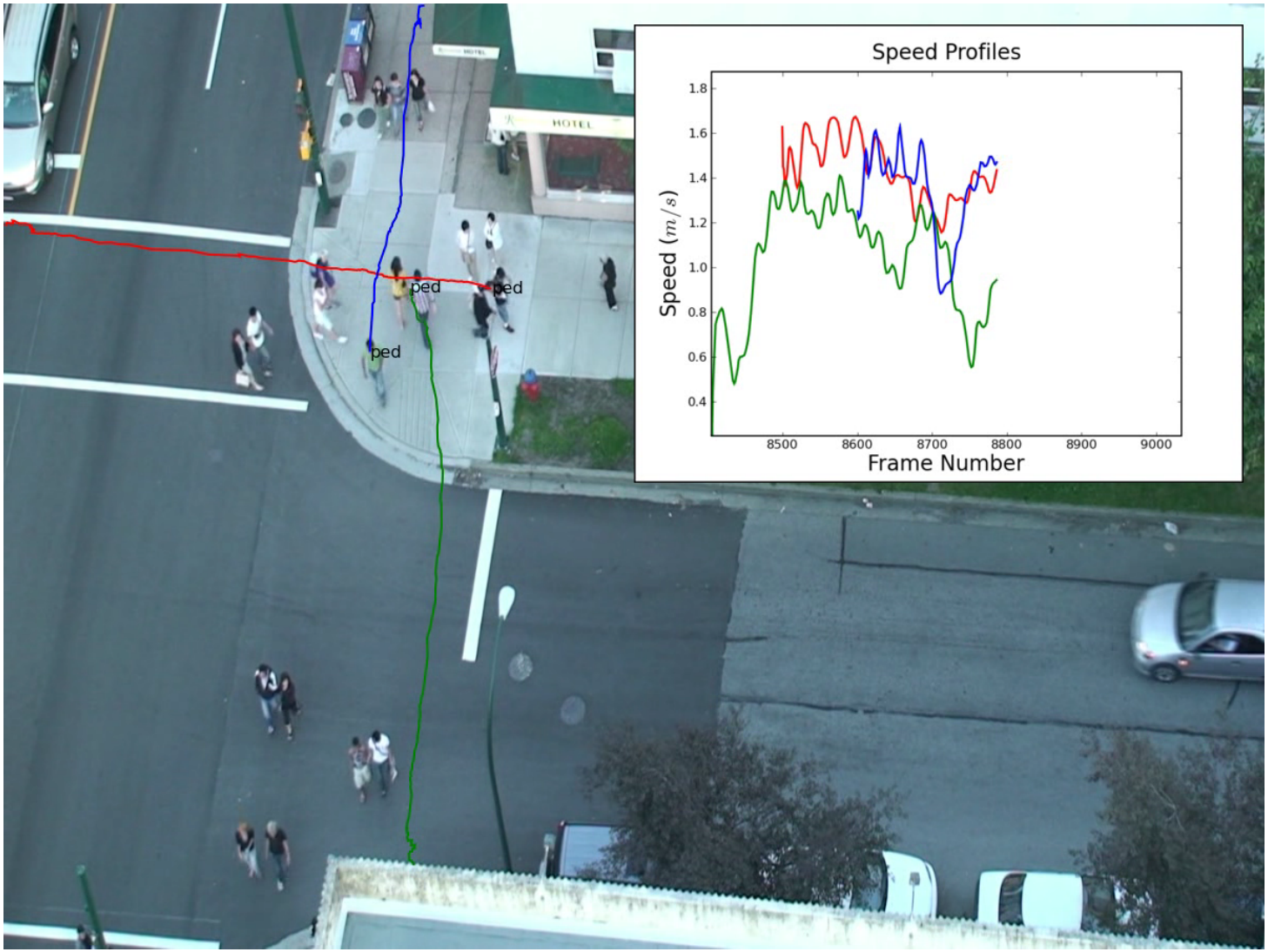
Traffic conflicts, exposure and severity measures, interacting behavior

Feature-based Road User Tracking in Video Data



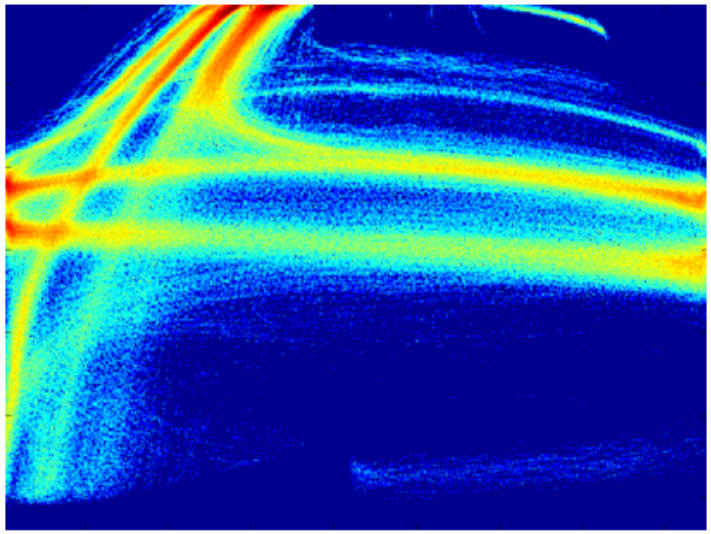
Good enough for safety analysis and other applications in busy urban road locations, including the study of pedestrians and pedestrian-vehicle interactions [Saunier and Sayed, 2006]

Road User Classification [Saunier et al., 2011]

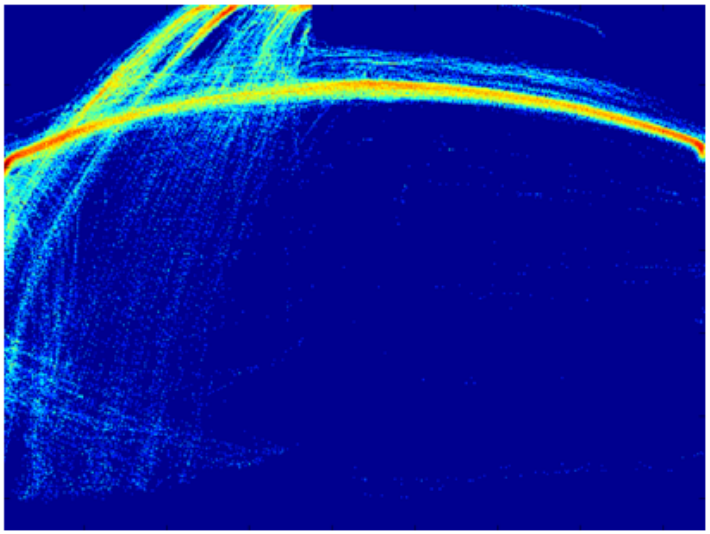


Road User Classification [Zangenehpour et al., 2014]

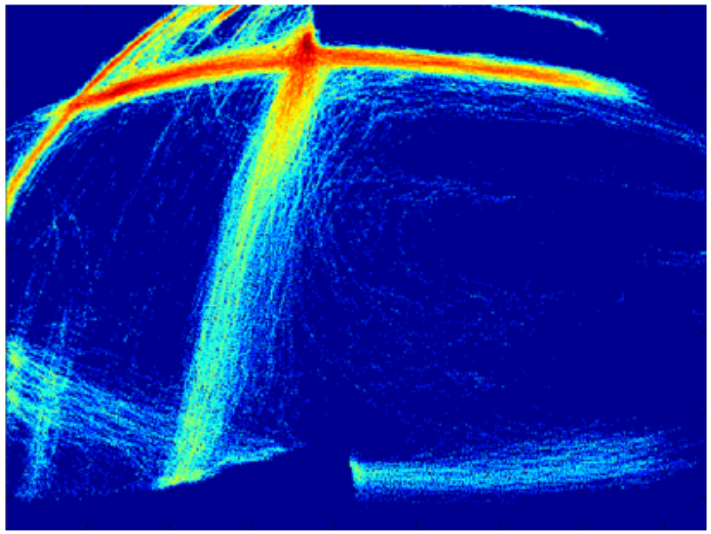
(a) Snapshot of video frame



(b) Vehicle trajectory heat-map



(c) Cyclist trajectory heat-map



(d) Pedestrian trajectory heat-map

Flexible Mobile Video Data Collection Unit

[Jackson et al., 2013]

Outline

Road User Tracking (Kentucky Dataset)

Motion Prediction

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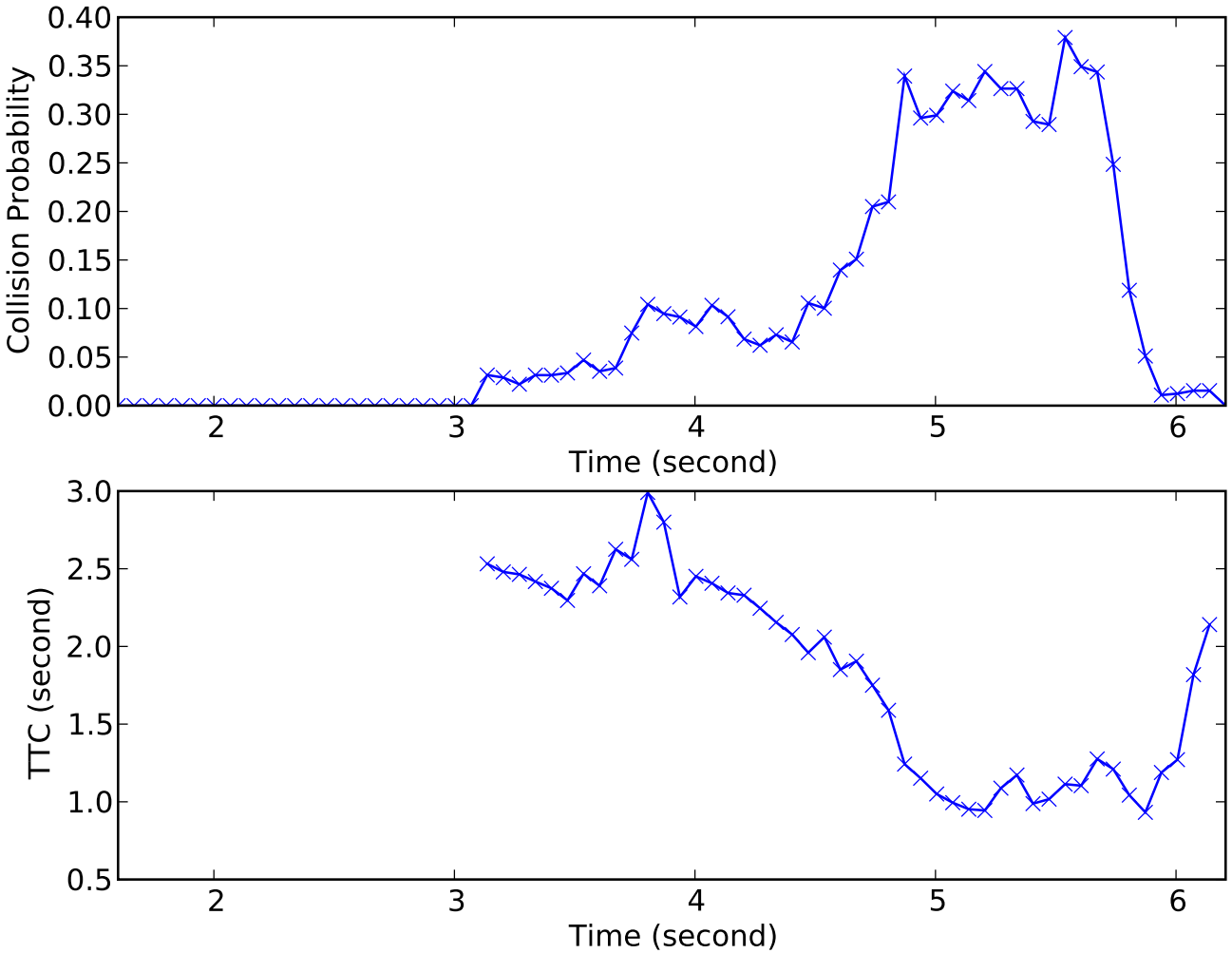
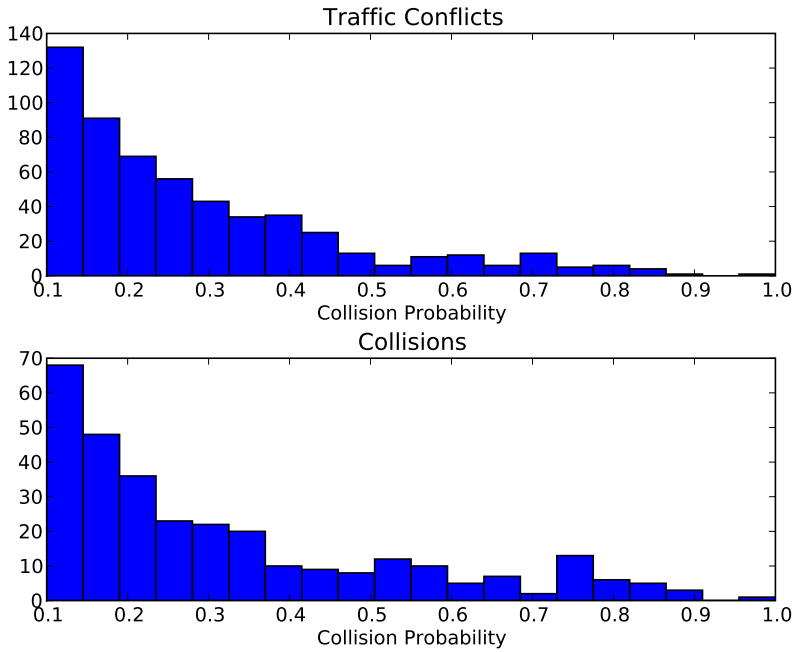
Motion Prediction

Severity Indicators

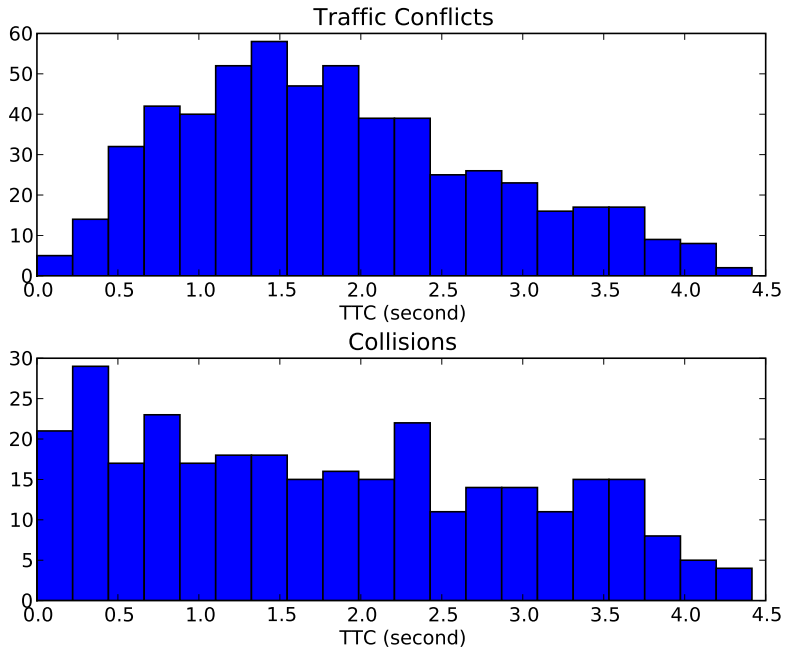


Distribution of Indicators

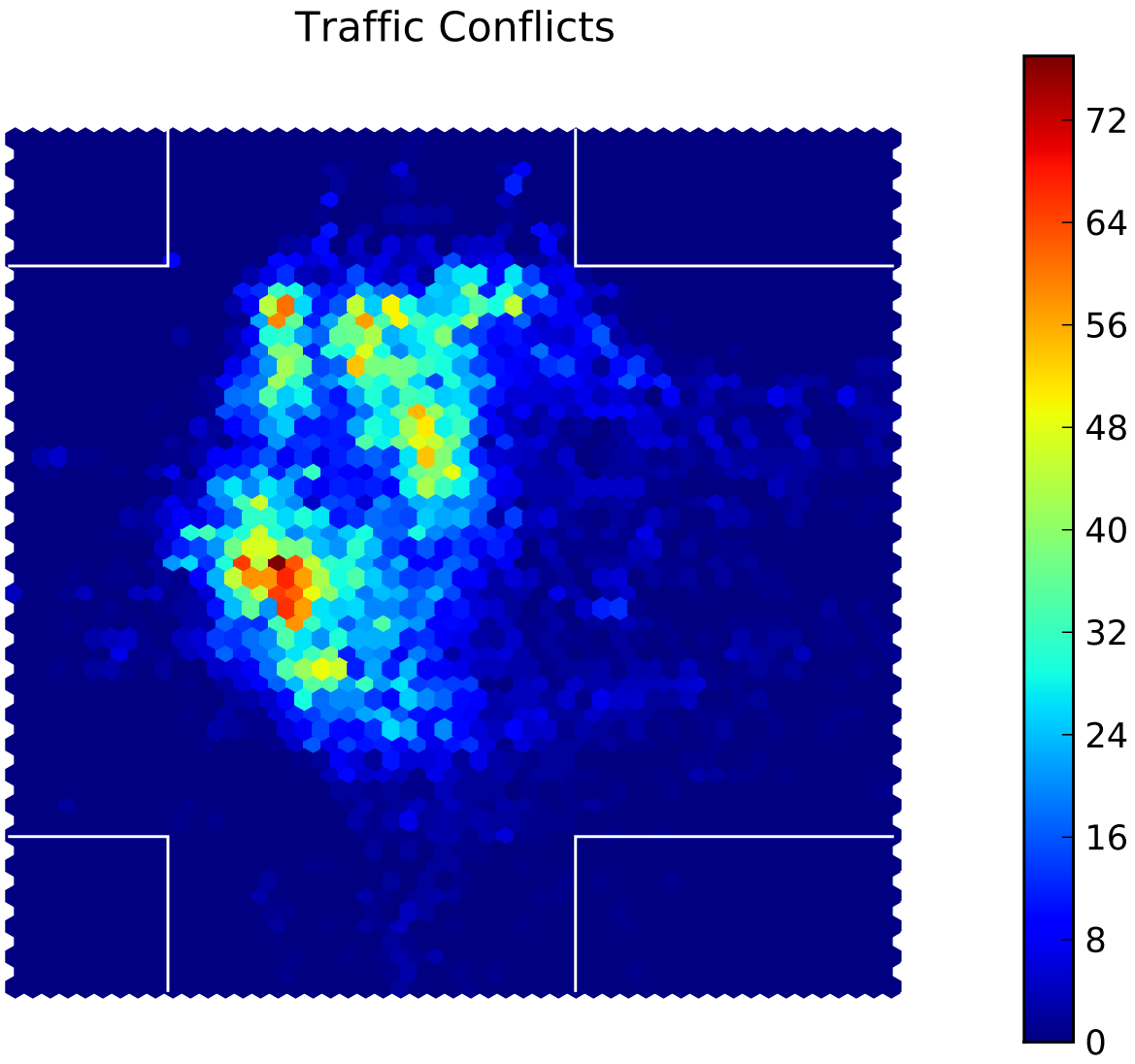
Maximum Collision Probability



Minimum TTC



Spatial Distribution of the Collision Points



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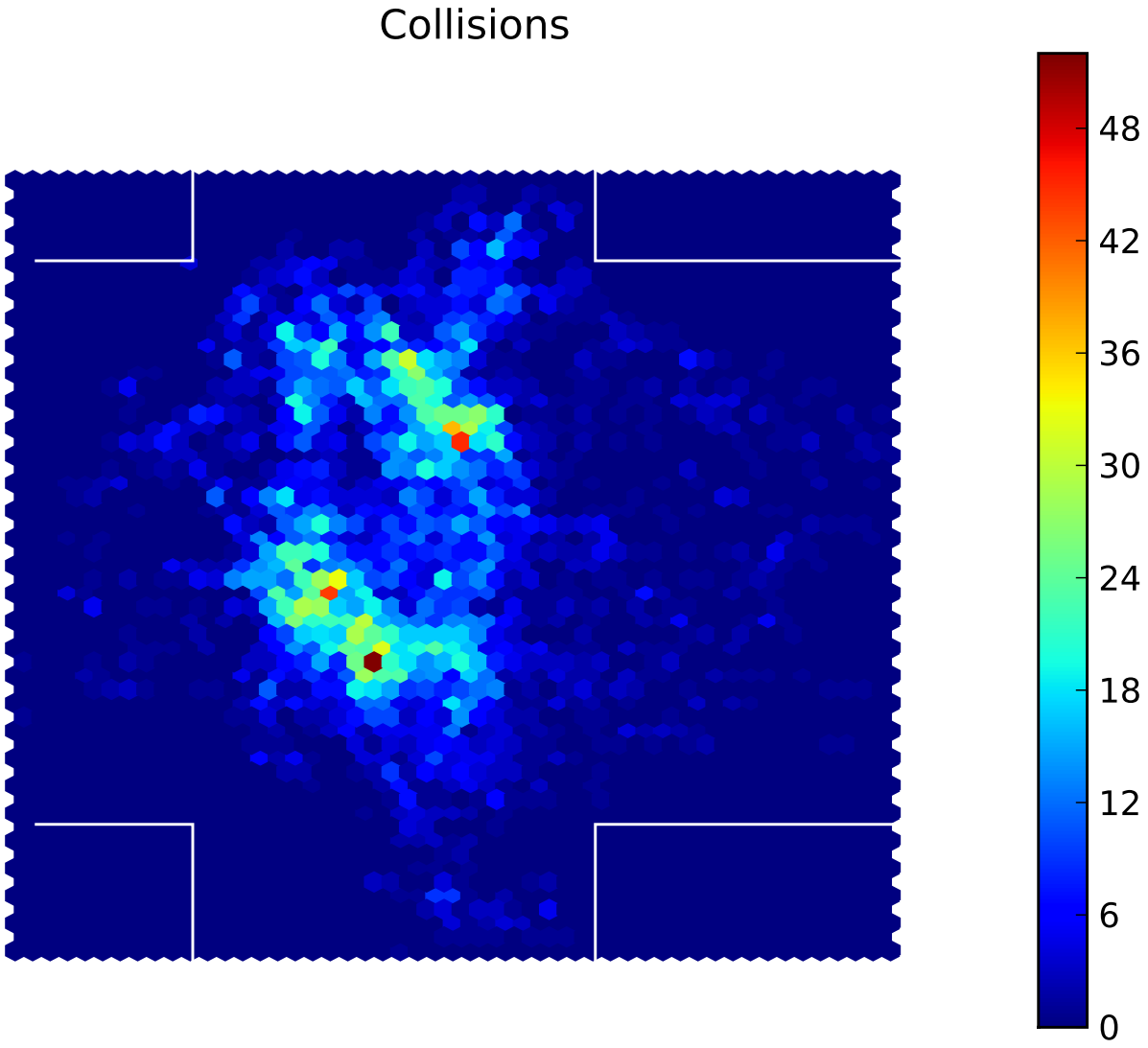
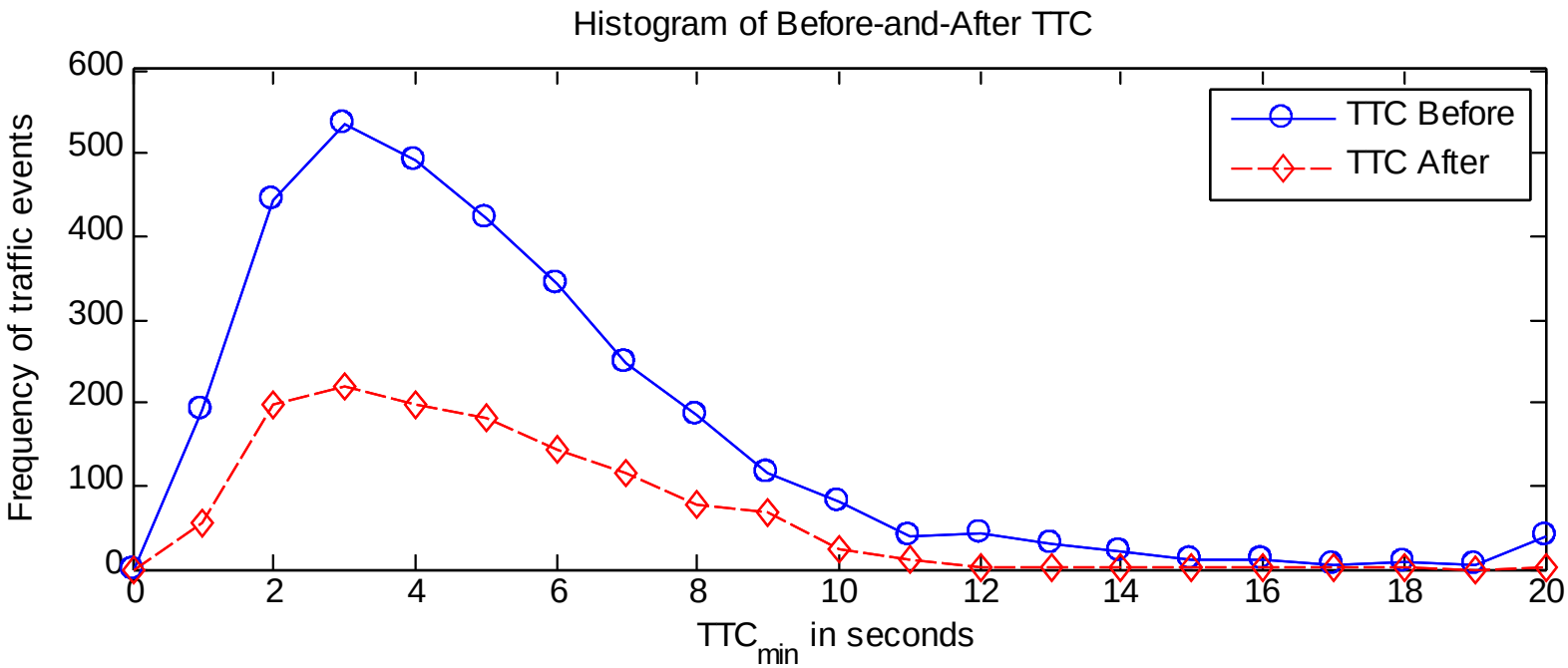


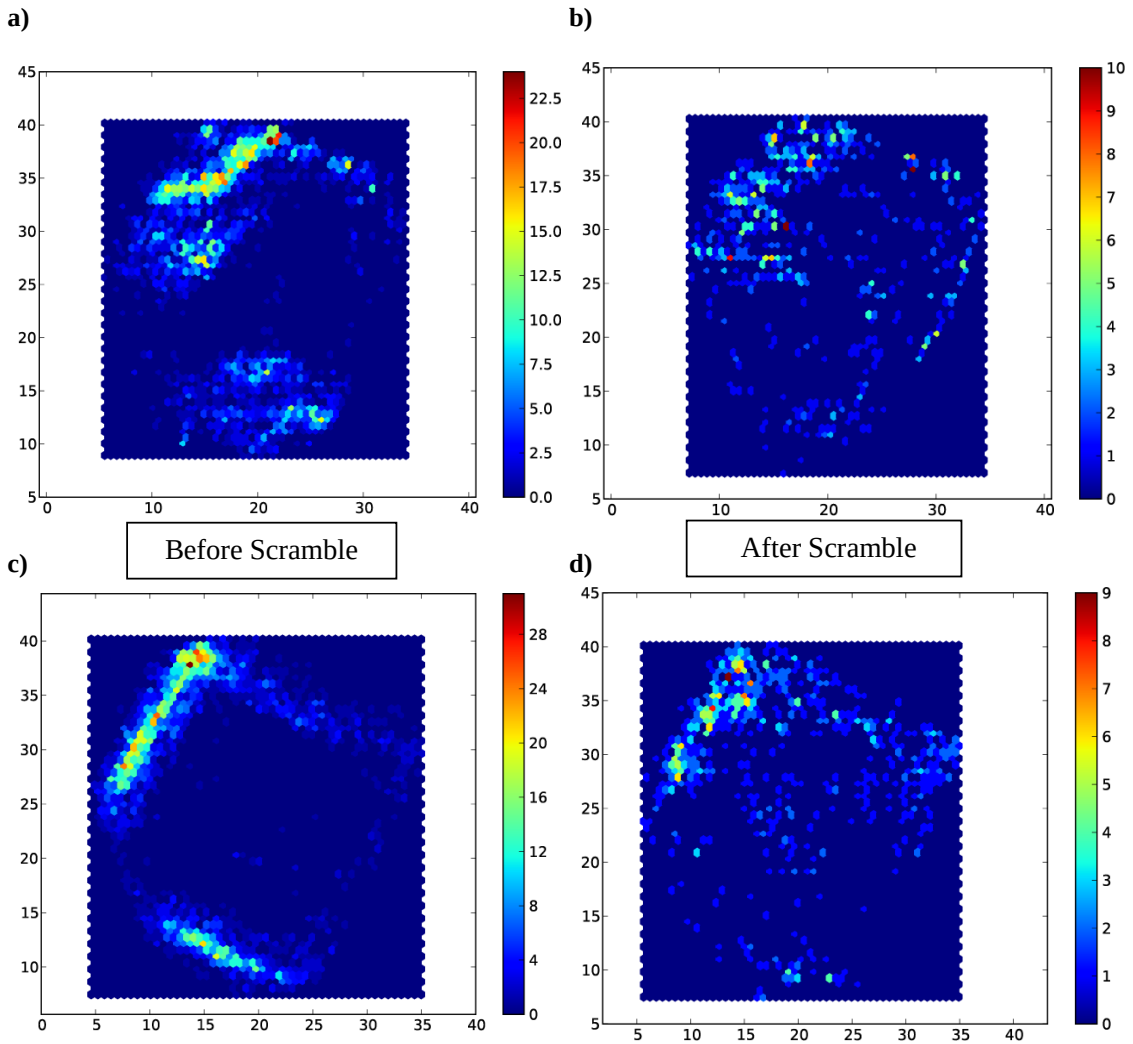
Before and After Study: Introduction of a Scramble Phase

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

Distribution of Severity Indicators



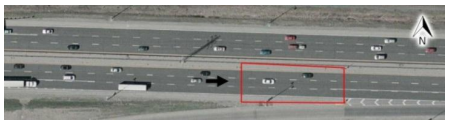
Before and After Distribution of the Collision Points

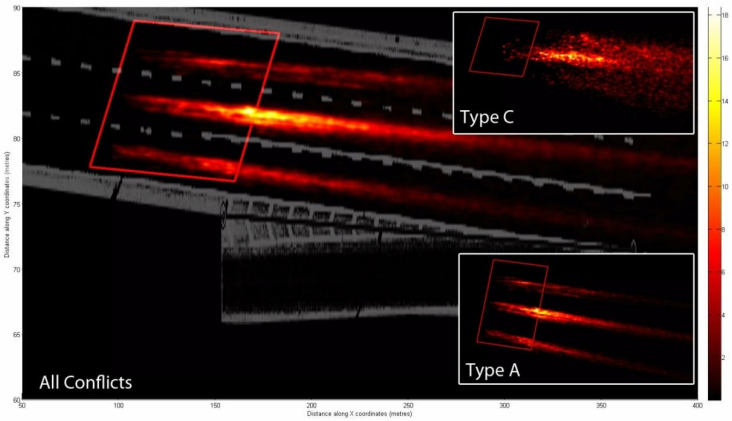


Lane-Change Bans at Urban Highway Ramps

86

Ramp: A20-E-E56-3 **Region(s):** UPreMZ, PPreMZ
Treatment: Yes **Analysis length:** 50 m





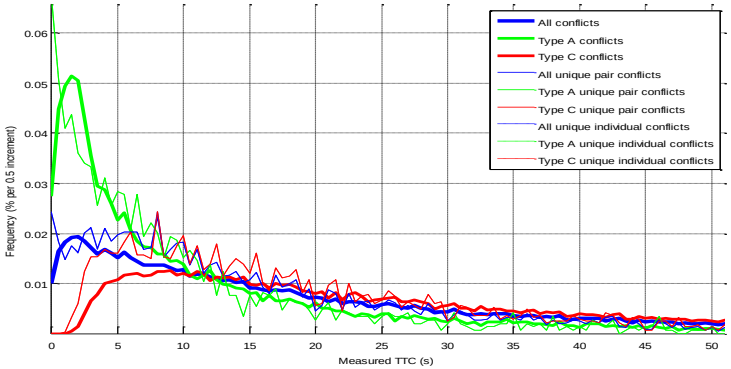


Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).

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

Lane-Change Bans at Urban Highway Ramps

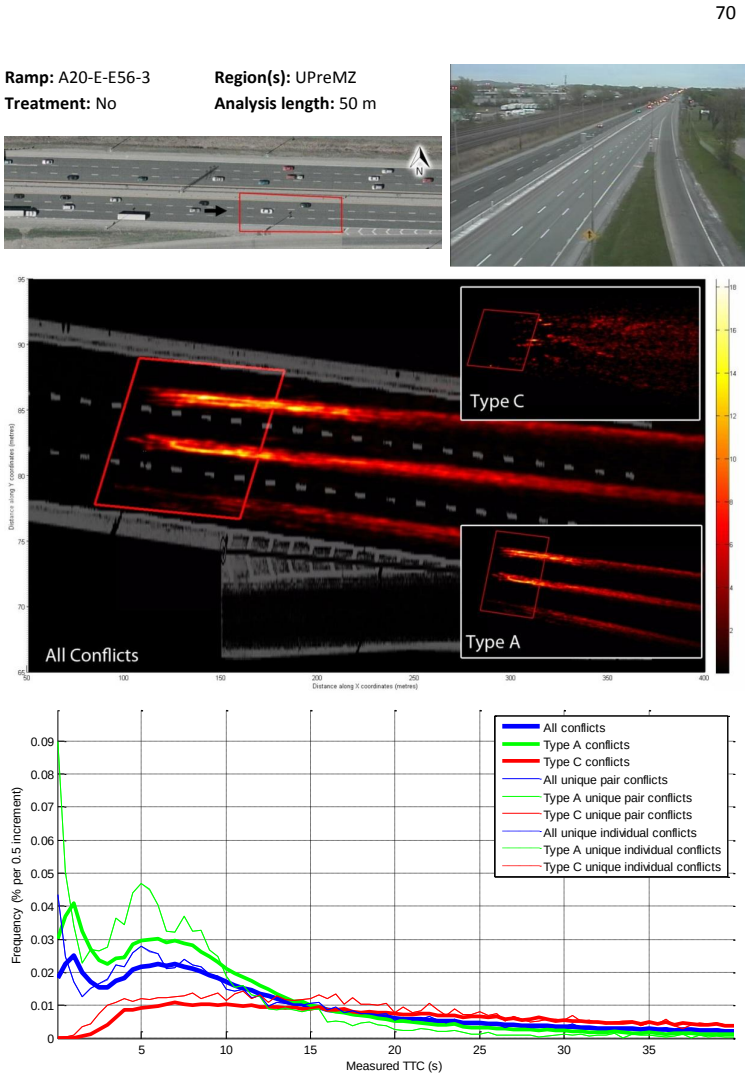
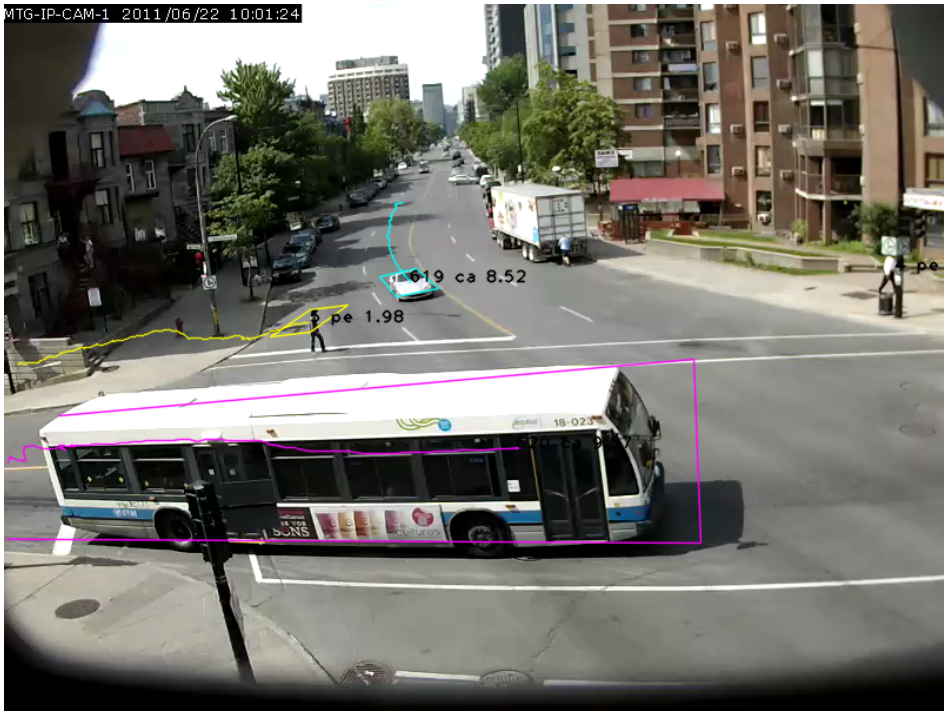
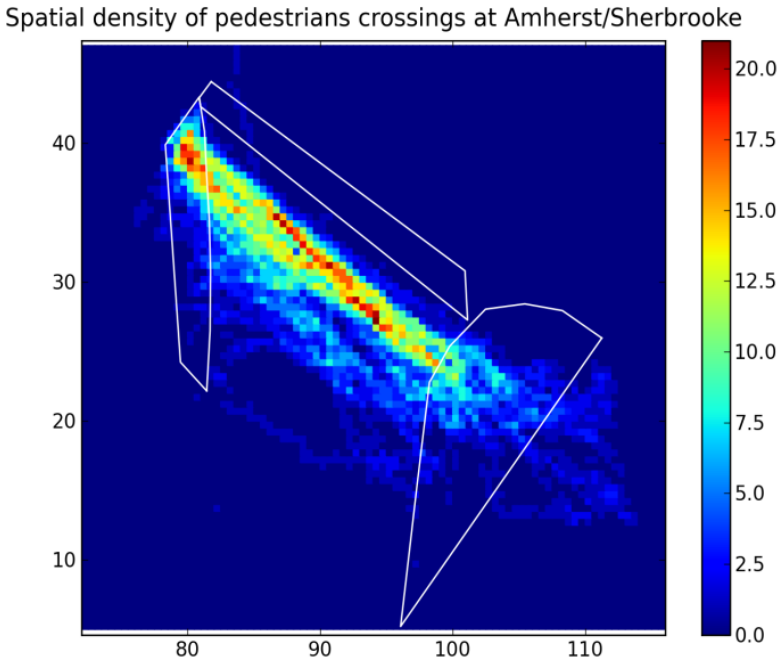


Figure 27 – Conflict analysis Cam20-16-Dorval (Untreated).

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

Dangerous Pedestrian Crossings and Violations at Signalized Intersections





[Brosseau et al., 2013]

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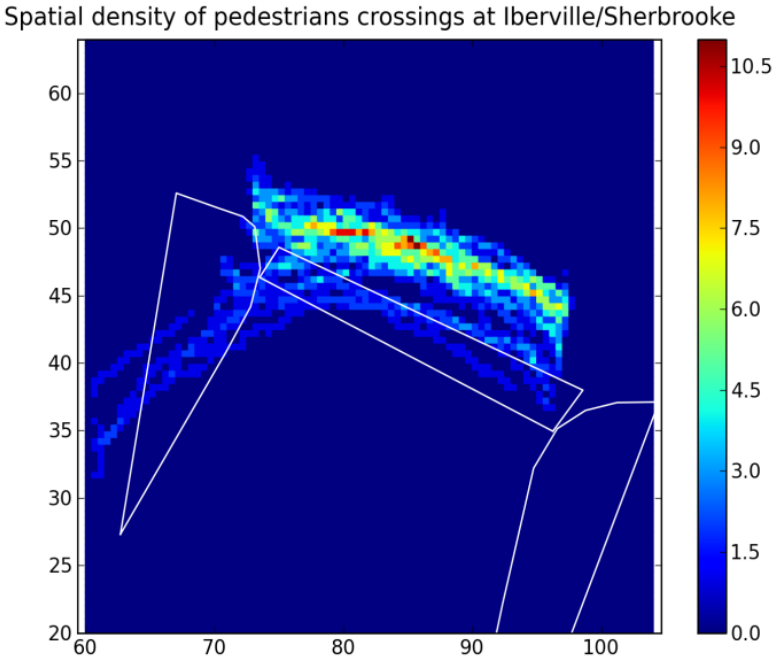
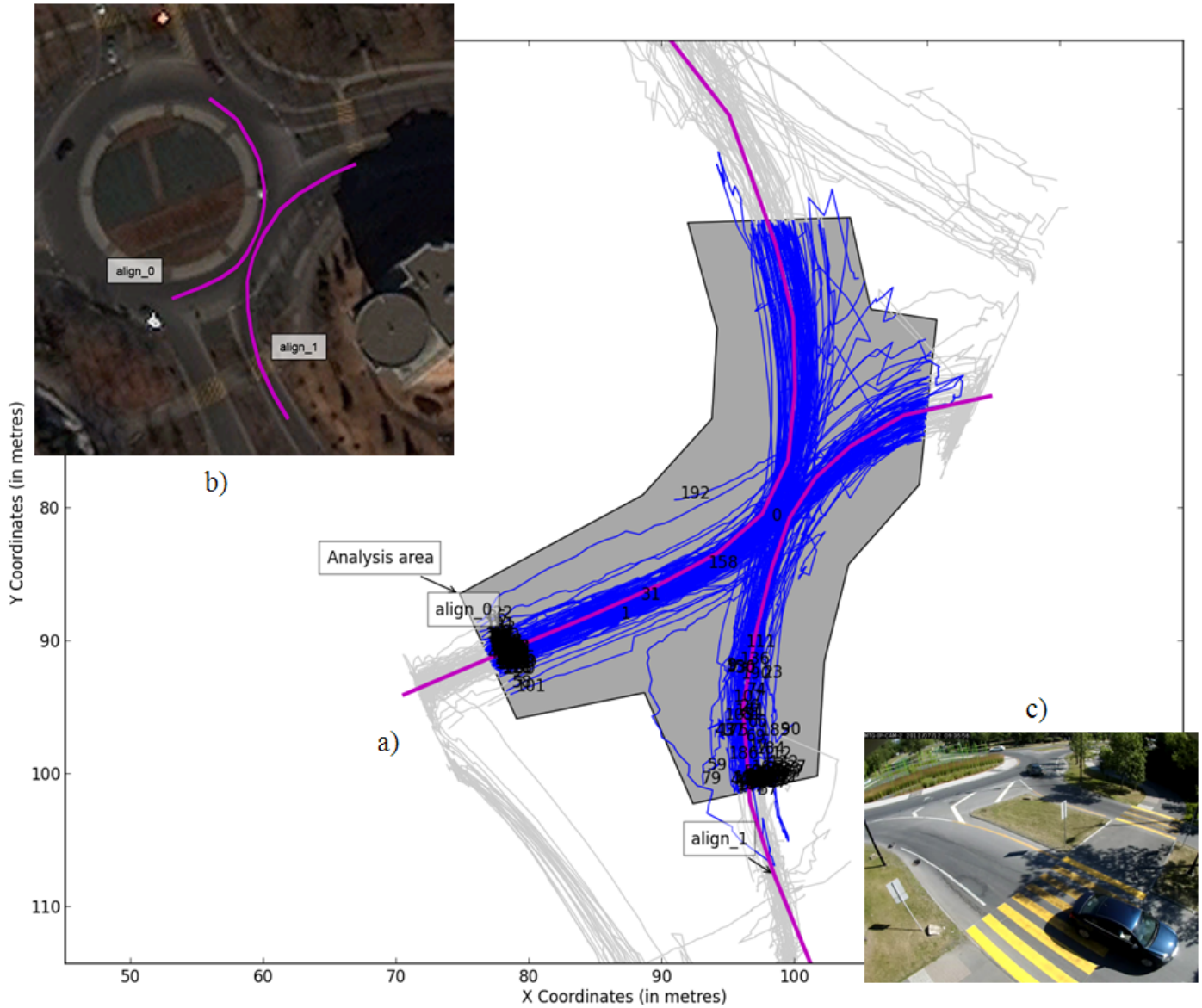
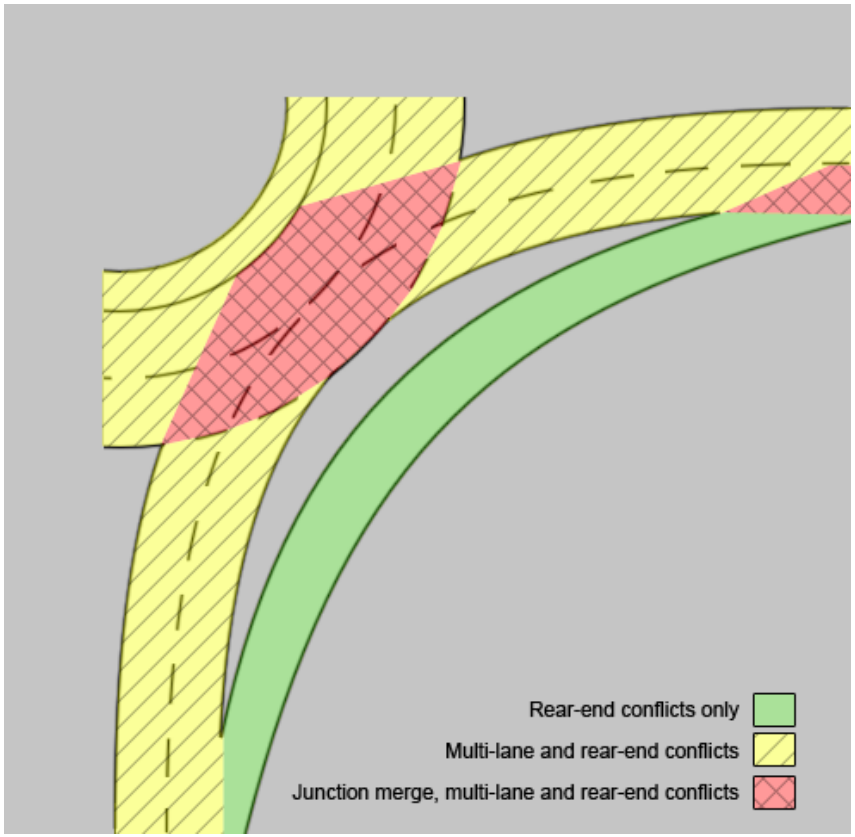


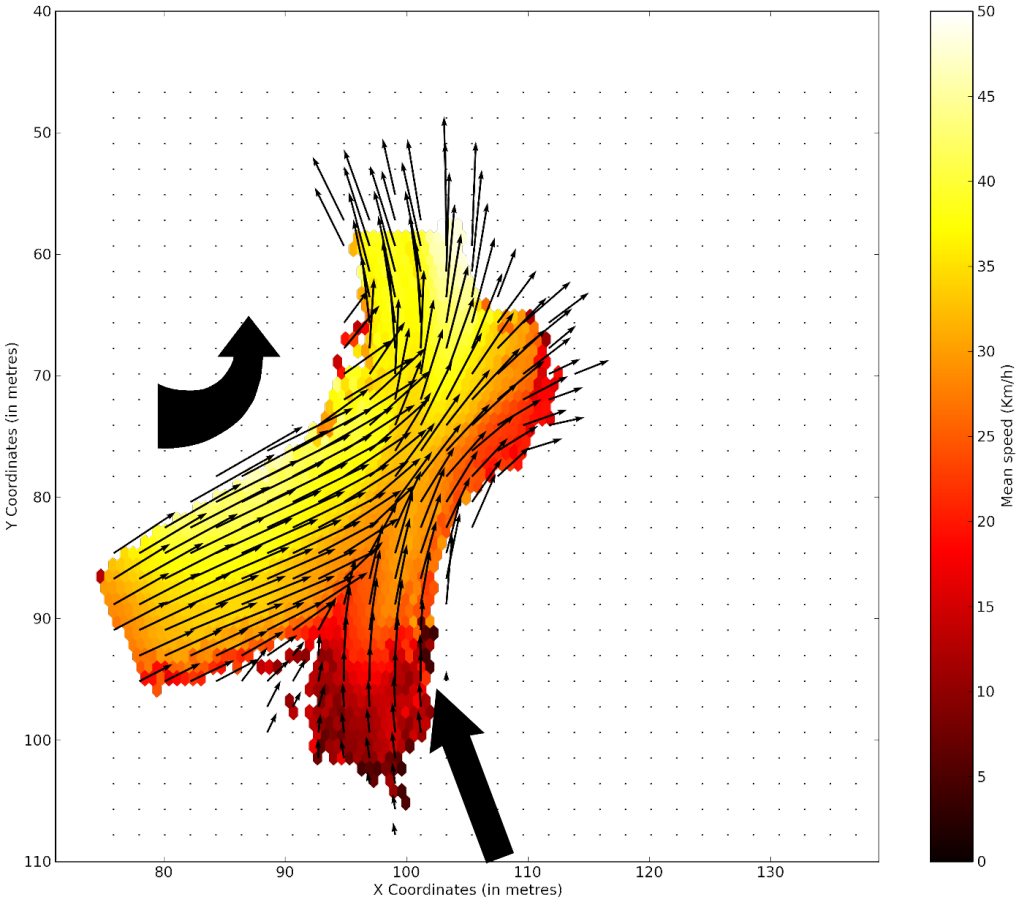
[Brosseau et al., 2013]

Roundabouts Safety in Québec



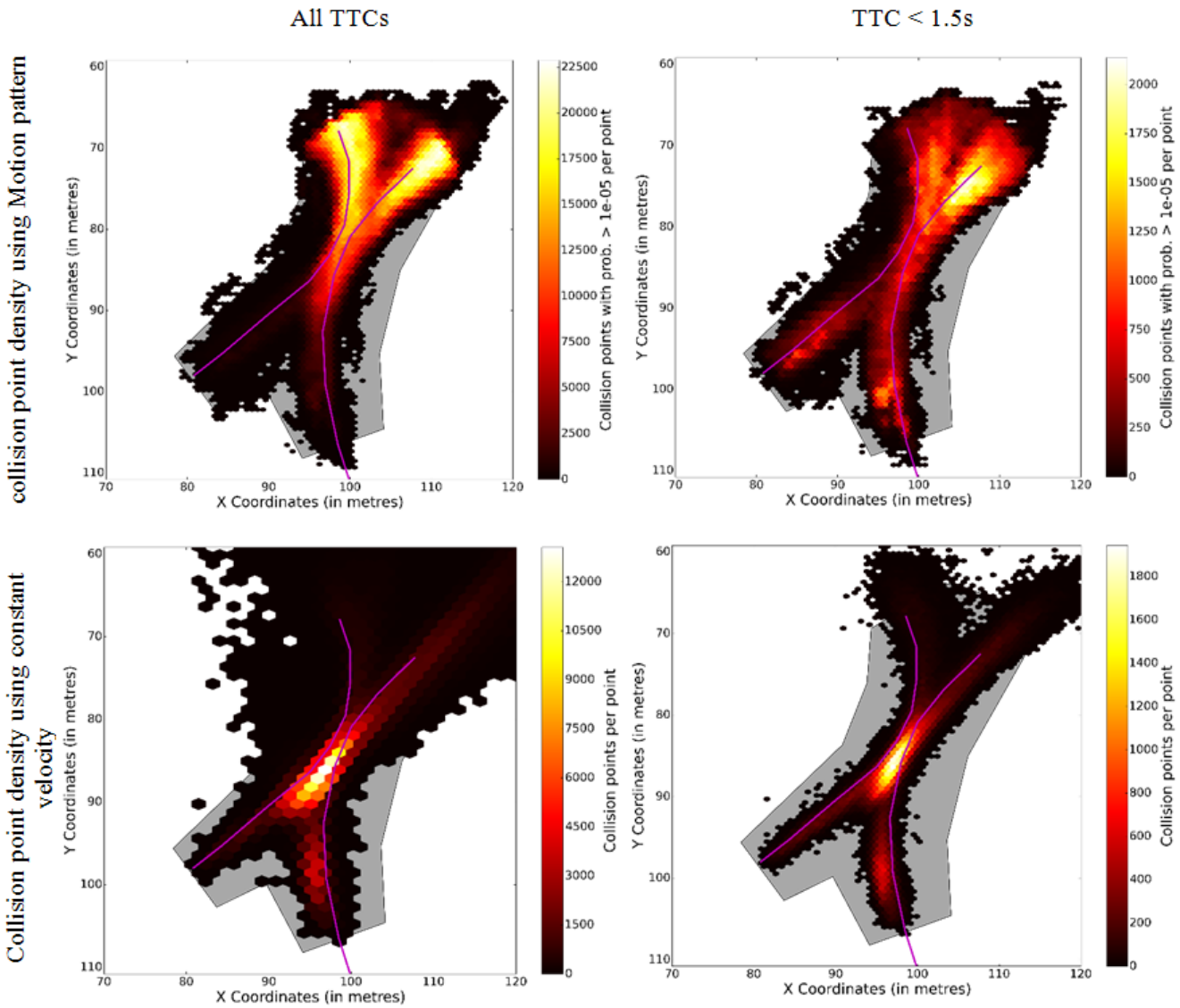
Speed Fields in Roundabouts





[St-Aubin et al., 2013b]

Roundabout Safety [St-Aubin et al., 2014]



Cycle Track Safety (First Results)

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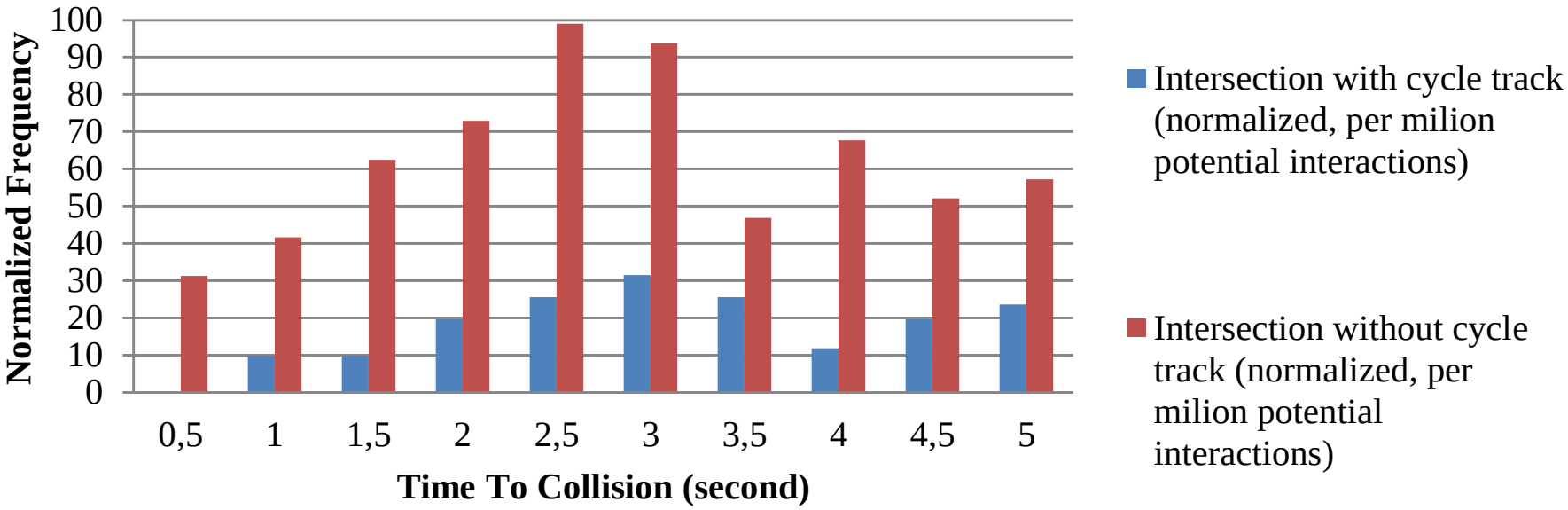
Table 1. Surrogate measures for the intersections with and without a cycle track

	Minutes	Cyclists	Right Turning Vehicles	Conflicts (TTC < 5s)	Dang. Conf. (TTC < 1.5s)	Conflict Rate*	Dang. Conf. Rate*
Without Cycle Track	154	384	500	120	26	625	135
With Cycle Track	232	912	556	90	10	177	20

* Conflicts per million potential conflicts



Outline

Conclusion

- Surrogate methods for safety analysis are complementary methods to understand collision factors and better diagnose safety

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- Surrogate methods for safety analysis are complementary methods to understand collision factors and better diagnose safety
- The challenge is to propose a simple and generic framework for surrogate safety analysis, instead of pretending more special cases and indicators are needed

Perspectives

- Improve computer vision for all road users in busy urban locations

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- Validation of surrogate methods for road safety analysis

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- Improve computer vision for all road users in busy urban locations
- Validation of surrogate methods for road safety analysis
  - 20 roundabout sites with video observations and accident records
- Understanding and modelling of collision processes: collect more data
- Pedestrian modelling: collaboration with Bilal Farooq

Researchers Need to Share More

- Scientific principle of reproducibility
  - to what extent are the mixed validation results reported in the literature related to a lack of comparisons and reproduciblity of the various methods proposed for surrogate safety analysis?
- Need to share data and tools used to produce the results
  - public datasets and benchmarks [Saunier et al., 2014]
  - public / open source software: adoption and contributions by researchers and practitioners
- Traffic Intelligence open source project `https://bitbucket.org/Nicolas/trafficintelligence`

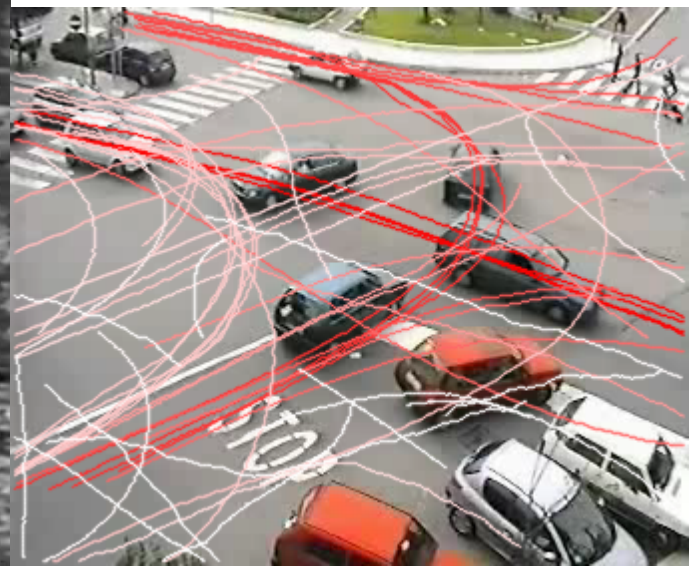
- Collaboration with Tarek Sayed (UBC), Karim Ismail (Carleton), Marilyne Brosseau, Mohamed Gomaa Mohamed, Paul St-Aubin (Polytechnique Montréal), Luis Miranda-Moreno, Sohail Zangenehpour (McGill), Aliaksei Laureshyn (Lund)
- Funded by the Natural Sciences and Engineering Research Council of Canada (NSERC),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

Questions?

Motion Pattern Learning

Traffic Conflict Dataset, Vancouver

58 prototype trajectories
(2941 trajectories)



Reggio Calabria, Italy

58 prototype trajectories
(138009 trajectories)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