Seminar at Bergische Universität Wuppertal

Nicolas Saunier

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POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

CIRRELT

Outline

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Short biography

2001 Engineering Degree from Télécom Paris

2005 Ph.D. in Computer Science from Télécom Paris (funded by INRETS)

2005-2009 Postdoc at UBC with Prof. Tarek Sayed

2009 Professor in Transport Engineering at Polytechnique Montreal

- CGM dept, Transport Research Group, CIRRELT, RRSR and CIRODD

Main Topics

- Road safety
- Active modes of transportation
- Machine learning and computer vision
- Intelligent transportation, connected and automated vehicles
- Open science

Main Collaborations

- Luis Miranda-Moreno, McGill
- Guillaume-Alexandre Bilodeau, Owen Waygood, Polytechnique
- Aurélie Labbe, HEC Montreal
- Marie-Soleil Cloutier, INRS
- Students (non-exhaustive): Mohamed Gomaa Mohamed, Joshua Stipancic, Paul St-Aubin, Matin Nabavi Niaki, Heather Twaddle, Sohail Zangenehpour, Ting Fu, Étienne Beauchamp, Abbas Sheikh Mohammad Zadeh, Qingwu Liu

Outline

Methods for Road Safety Analysis

There are two main categories of methods, whether they are based on direct observation or not

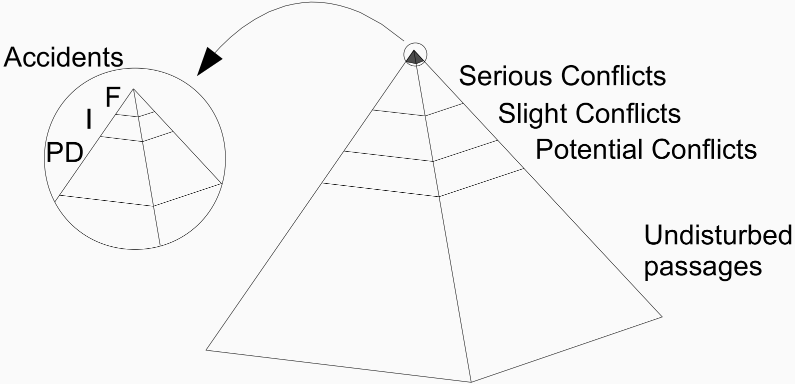
1. Accidents are reconstituted
    - traditional road safety analysis relying on historical collision data
    - vehicular accident reconstruction

Methods for Road Safety Analysis

There are two main categories of methods, whether they are based on direct observation or not

1. Accidents are reconstituted
    - traditional road safety analysis relying on historical collision data
    - vehicular accident reconstruction
2. Road user behavior, interactions and accidents are directly observed
    - behavioural observations and surrogate measures of safety (SMoS)
    - data source: naturalistic (driving) studies, probe vehicles, site observations
        - manual to automated collection method

Foundation for Proactive Safety: the Safety Hierarchy



Outline

Processing Steps

1. Video data collection
2. Data preparation
3. Road user detection, tracking and classification

Step 1: Video Data Collection

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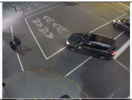
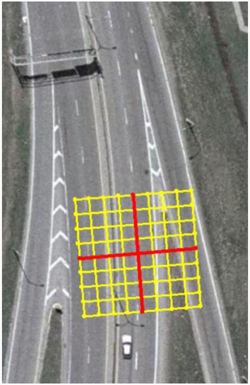
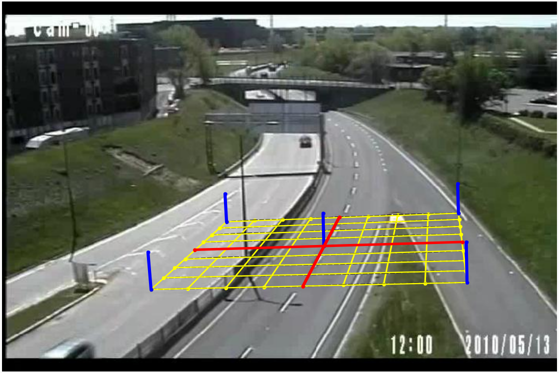
SAMPLE CAMERA VIEWS UNDER DIFFERENT LIGHTING CONDITIONS					
Daytime Conditions	**Thermal Camera**	**Regular Camera**	**Nighttime Conditions**	**Thermal Camera**	**Regular Camera**
Overcast			High visibility		
Sun, no shadows			Medium visibility		
Sun, strong shadows			Low visibility		

Step 2: Data Preparation

In particular, camera calibration: homography, distortion, etc.

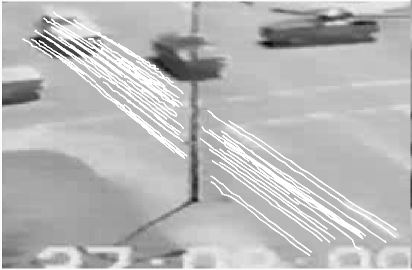




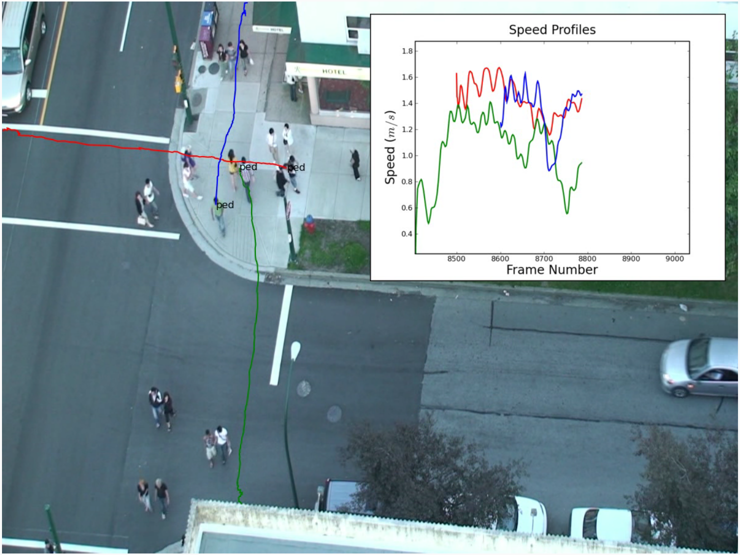
Step 2: Data Preparation

In particular, camera calibration: homography, distortion, etc.

Step 3: Road User Detection, Tracking and Classification

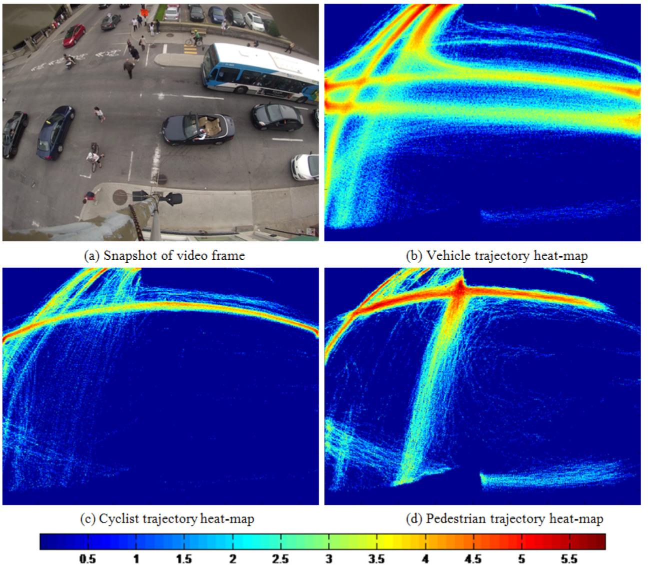


Step 3: Road User Detection, Tracking and Classification



Video

Step 3: Road User Detection, Tracking and Classification



(a) Snapshot of video frame

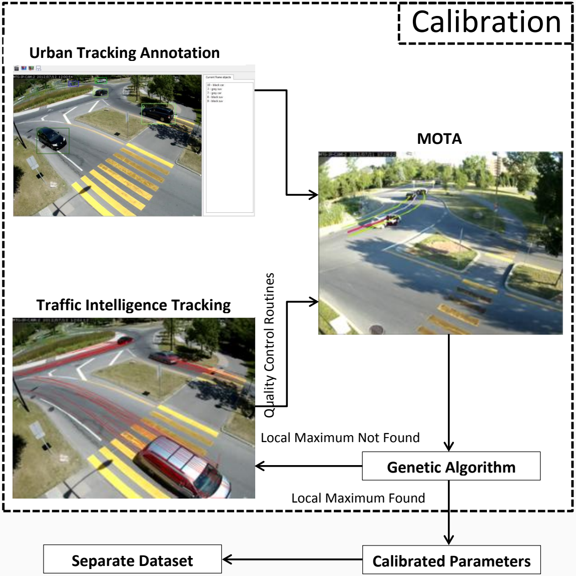
(b) Vehicle trajectory heat-map

(c) Cyclist trajectory heat-map

(d) Pedestrian trajectory heat-map

(e) Scale used for trajectorie heat-maps (log-scale)

Step 3’: Optimization of Tracking parameters



Step 3': Optimization of Tracking parameters

		Parameters optimized for				
Site	Default	S1S	S1W	S2	S3V1	S3V2
S1S	0.719046	0.904502	0.820976	0.817581	0.841254	0.823145
S1W	0.041073	0.114581	0.709927	0.077883	0.044429	0.050852
S2	0.703178	0.74025	0.622532	0.766731	0.745787	0.718321
S3V1	0.759758	0.797088	0.778268	0.793216	0.817457	0.799231
S3V2	0.750416	0.704989	0.737339	0.776115	0.700151	0.788521

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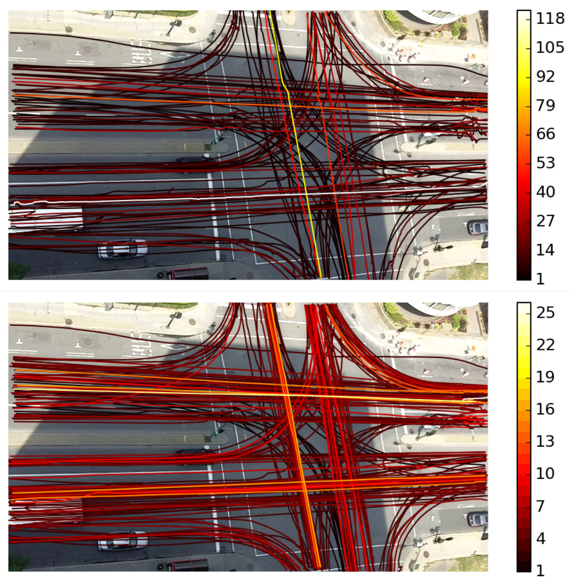
Outline

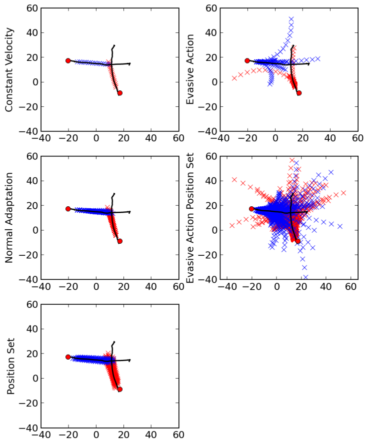
Processing Steps

4. Motion pattern learning
5. Motion prediction
6. Safety indicators
7. Interpretation

Step 4: Motion Pattern Learning

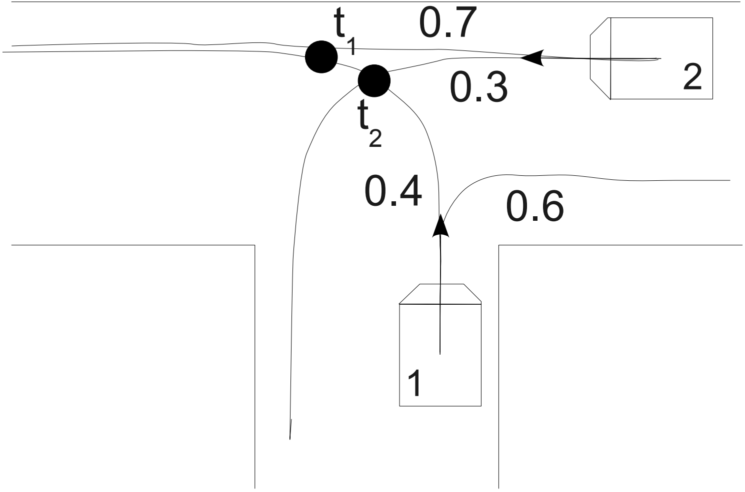


Step 5: Motion Prediction



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”

Step 5: Motion Prediction



Step 5: Motion Prediction

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Step 5: Motion Prediction

Step 6: Safety Indicators

- Continuous measures
  - Time-to-collision (TTC)
  - Gap time (GT) (=predicted PET)
  - Deceleration-based indicators, e.g. deceleration to safety time (DST)
  - Speed-based indicators, (extended) Delta-V, etc.
- Unique measure per conflict
  - Post-encroachment time (PET)
  - Evasive action(s) (harshness), subjective judgment, etc.

Step 6: Safety Indicators

- Continuous measures (* based on motion prediction methods)
  - Time-to-collision (TTC) *
  - Gap time (GT) (=predicted PET) *
  - Deceleration-based indicators, e.g. deceleration to safety time (DST) *
  - Speed-based indicators, (extended) Delta-V, etc.
- Unique measure per conflict
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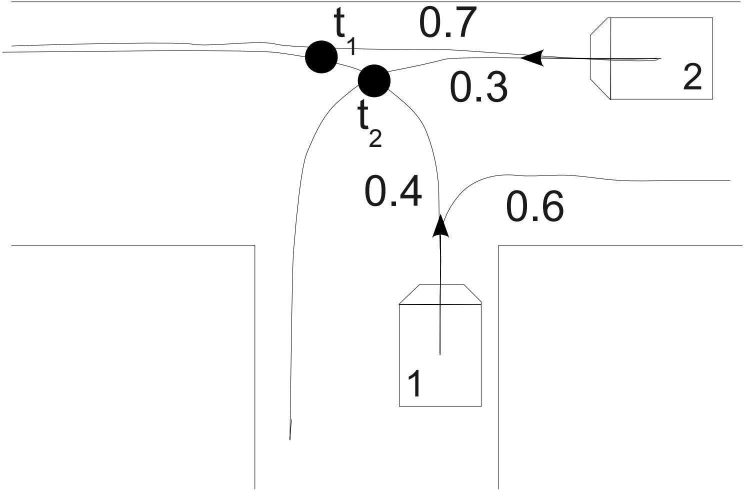
  - Evasive action(s) (harshness), subjective judgment, etc.

Step 6: Safety Indicators



Step 6: Safety Indicators

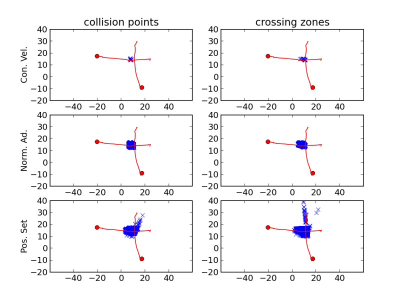
Using of a finite set of predicted trajectories, enumerate the collision points CP_n and the crossing zones CZ_m. Safety indicators can then be computed:

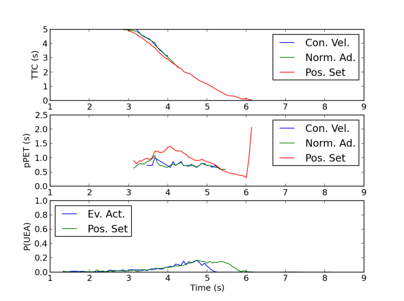
$$P(Collision(U_i, U_j)) = \sum_n P(Collision(CP_n))$$

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

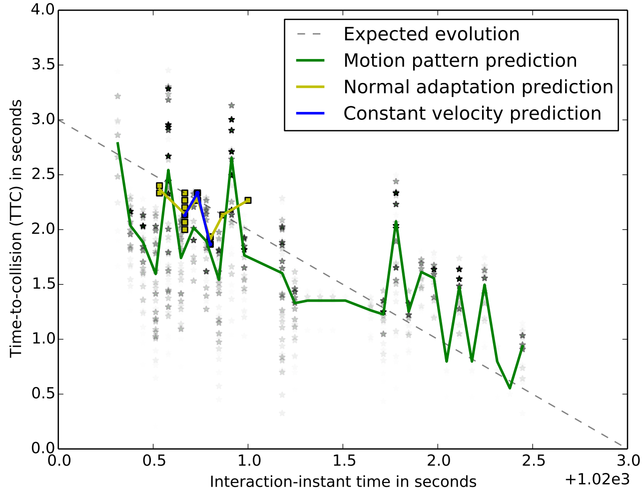
$$pPET(U_i, U_j, t_0) = \frac{\sum_m P(Reaching(CZ_m))\ |t_{i,m} - t_{j,m}|}{\sum_m P(Reaching(CZ_m))}$$

Step 6: Safety Indicators



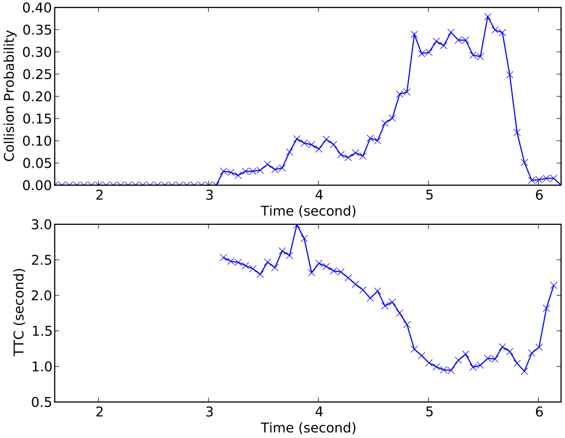


Step 6: Safety Indicators



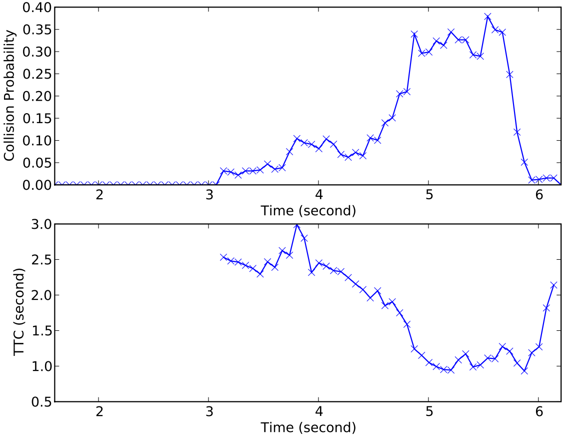
Step 7: Interpretation

For each interaction, we have



Step 7: Interpretation

How should data be aggregated?



Step 7: Interpretation

Should data be aggregated (to count severe events)?

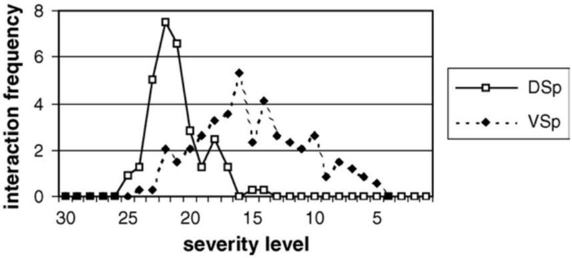
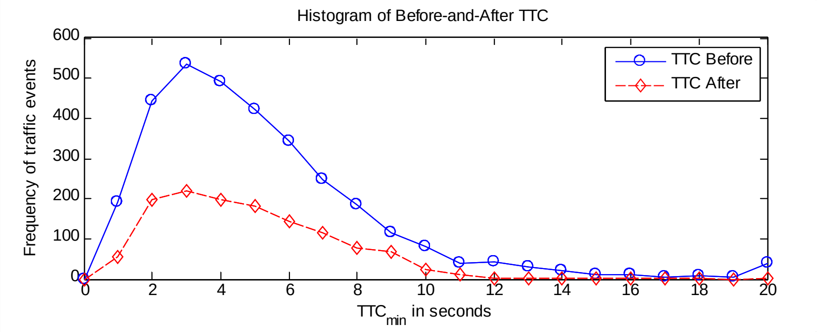


Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

Step 7: Interpretation



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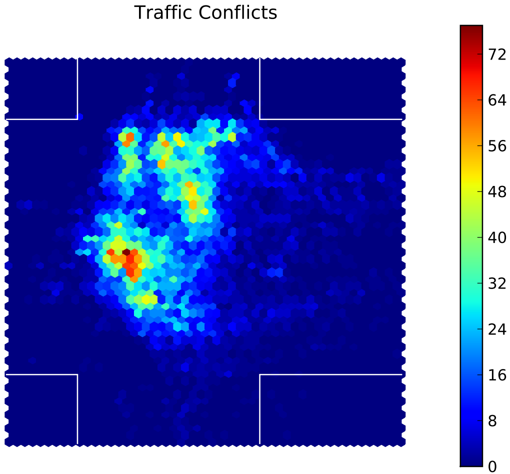

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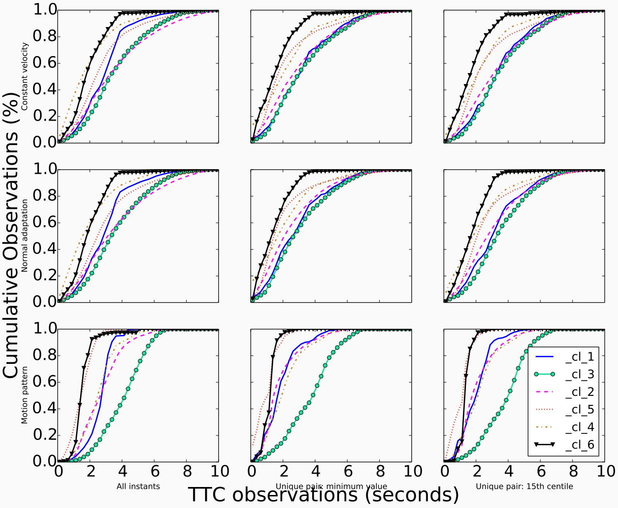
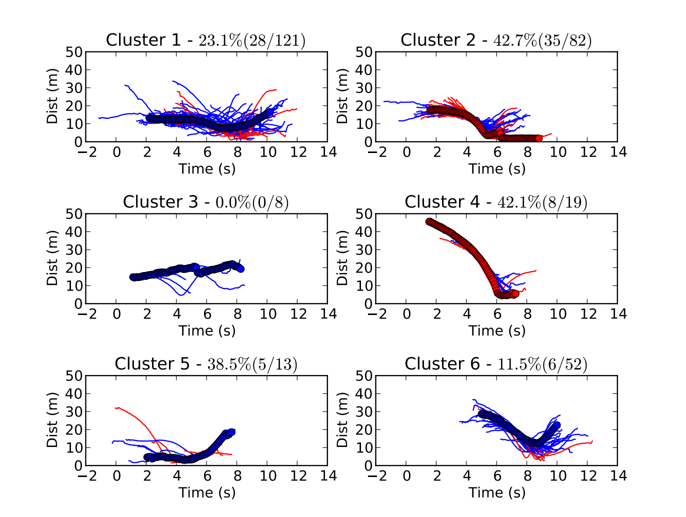


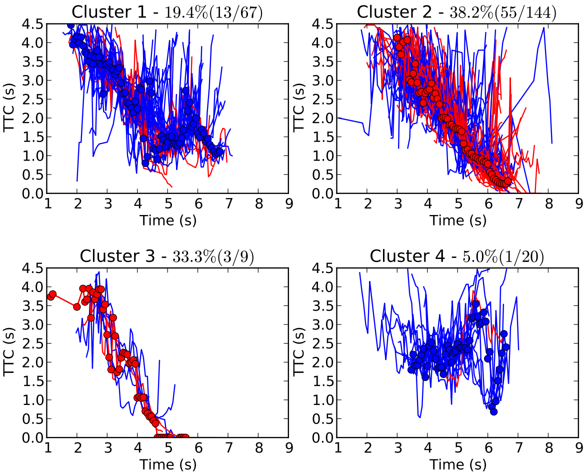
Step 7: Interpretation

	Model I. Cycle track on the right vs. no cycle track			Model II. Cycle track on the left vs. no cycle track			Model III. Cycle track on the right vs. cycle track on the left		
	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.
Cycle Track on Right	0.395	0.181	0.03	-	-	-	-	-	-
Cycle Track on Left	-	-	-	Not Significant			-0.513	0.131	0.00
Bicycle Flow for 5s before to 5s after	Not Significant			0.088	0.038	0.02	0.066	0.034	0.05
Turning-Vehicle Flow for 5s before to 5s after	-2.771	0.132	0.00	-3.265	0.090	0.00	-3.131	0.080	0.00
Number of Lanes on the Main Road	-0.151	0.078	0.05	Not Significant			Not Significant		
Number of Lanes on the Turning Road	Not Significant			0.324	0.146	0.03	0.457	0.178	0.01
Cut-off 1	-6.599	0.353	0.00	-7.372	0.301	0.00	-7.621	0.323	0.00
Cut-off 2	-4.233	0.273	0.00	-3.807	0.223	0.00	-4.125	0.265	0.00
Cut-off 3	-3.150	0.256	0.00	-2.102	0.211	0.00	-2.479	0.258	0.00
Number of Observations	2880			4803			6567		
Log likelihood	-804			-1876			-2330		

Step 7: Interpretation



Step 7: Interpretation

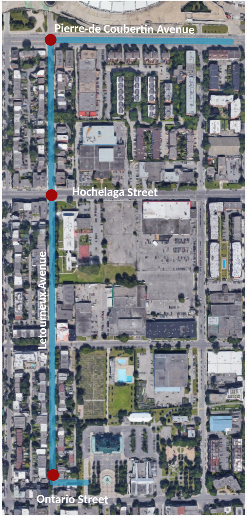


Outline

Safety Studies Using SMoS

- Highway on-ramps and roundabouts
- Cycling infrastructure and the lack thereof
- Pedestrian crosswalks
- Stop-controlled intersections: 2-way vs all-way
- Pedestrian workers (traffic police) vs their stress
- CAVs

Study of Low-Speed Automated Shuttles in Montreal and Candiac



Work with Étienne Beauchamp and Marie-Soleil Cloutier, INRS

Study of Low-Speed Automated Shuttles

Montreal

Pierre-de-Coubertin

Hochelaga

Ontario

Study of Low-Speed Automated Shuttles

Candiac

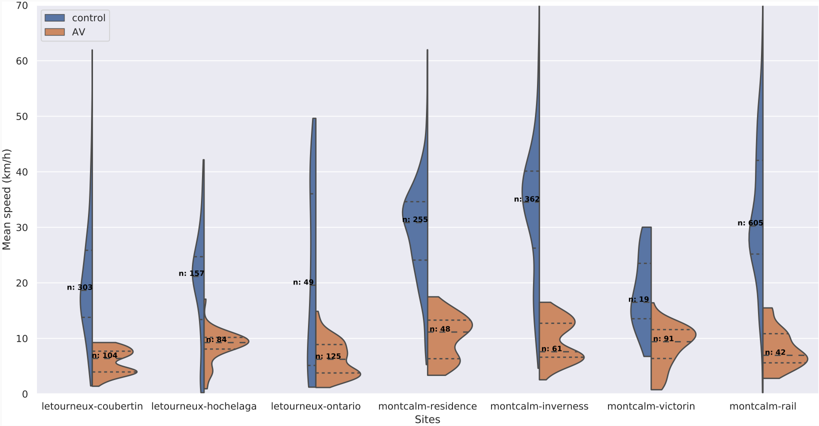
Residence

Inverness

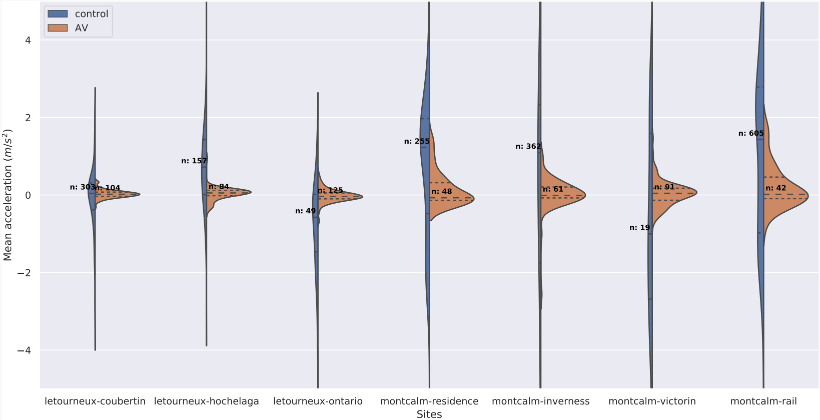
Marie-Victorin

Rail

Study of Low-Speed Automated Shuttles



Study of Low-Speed Automated Shuttles



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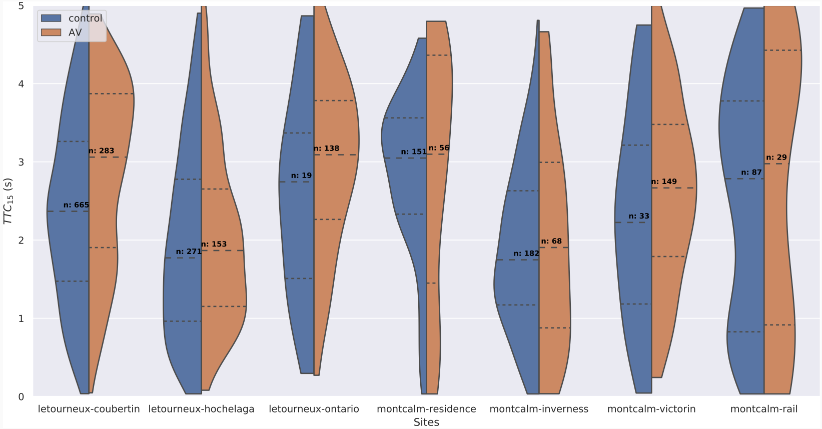

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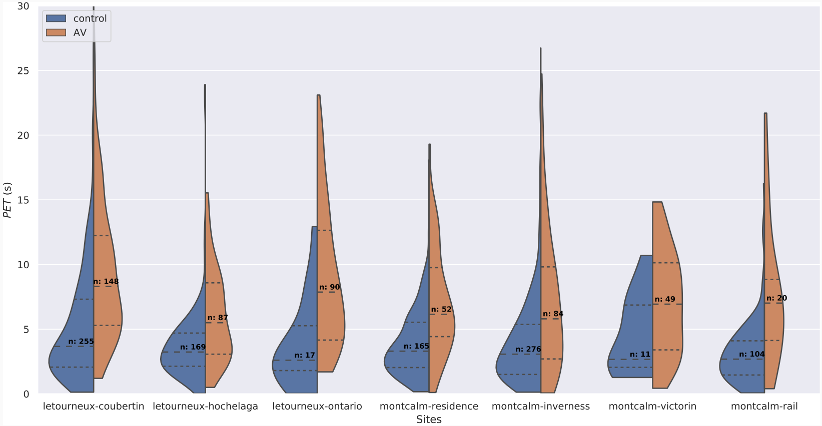

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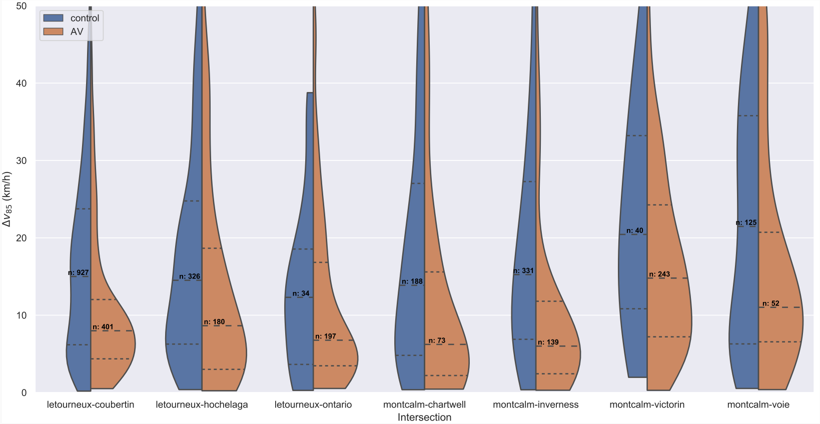

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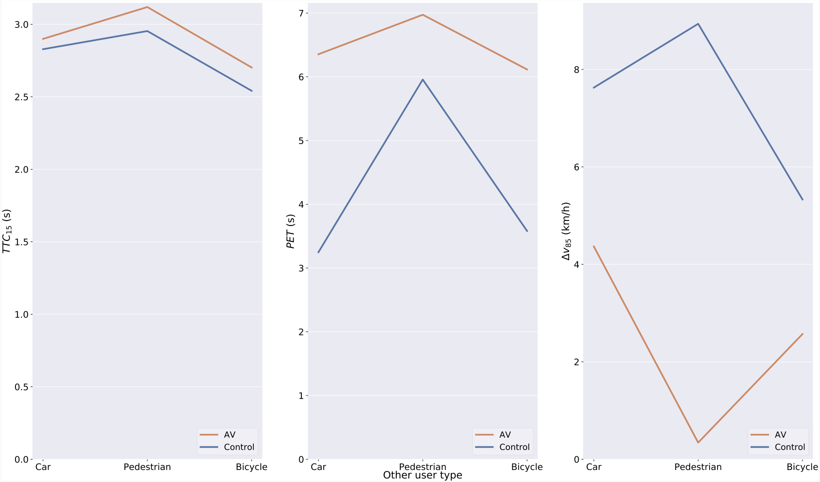

CAVs at Signalized Intersections

- Automated speed advisory system using real trajectories and simulation
- Study of the impact of pedestrian countdown information on driver behaviour and safety

CAVs at Signalized Intersections

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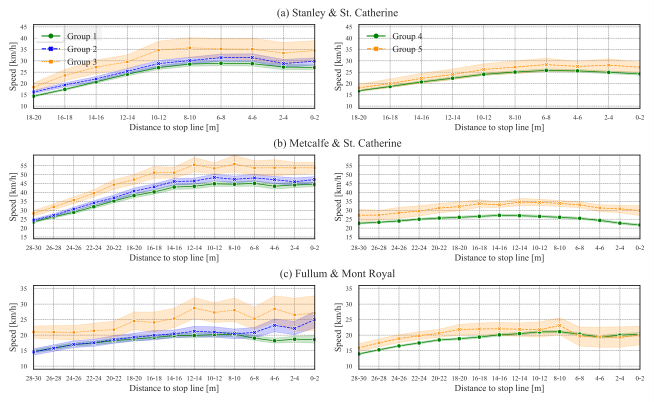
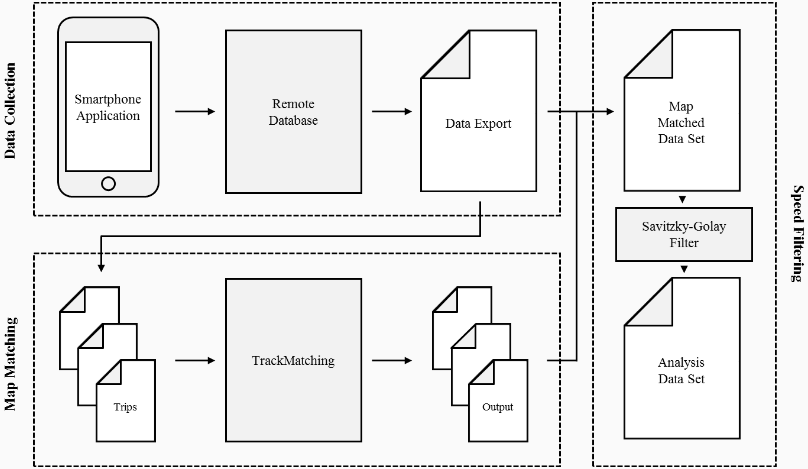
CAVs at Signalized Intersections

- Study of the impact of pedestrian countdown information on driver behaviour and safety



Outline

Extracting Indicators from Vehicle GNSS Data



Extracting Indicators from Vehicle GNSS Data

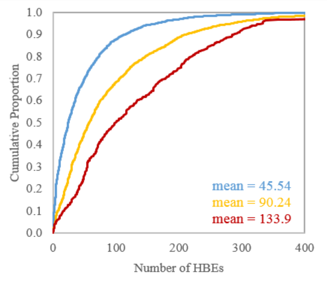
- Event-based measures: hard braking/acceleration events (threshold ± 3 $m.s^{-2}$)
- Congestion index $CI = \frac{v_f - v}{v_f}$ if free flow speed $v_f \leq$ vehicle speed v, 0 otherwise, averaged per link
- Average speed (v_f in the study)
- Coefficient of variation of speed among vehicles

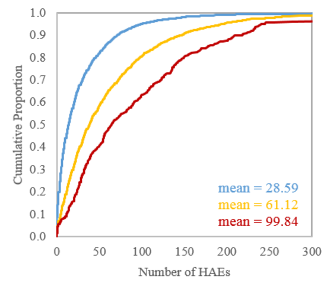
Validation of Event-based Measures

Spearman's rho for HBEs and HAEs

Link Level			Intersection Level		
Classification	**HBE**	**HAE**	**Classification**	**HBE**	**HAE**
Motorway	0.118	0.155	Motorway	0.603	0.641
Primary	0.260	0.297	Primary	0.540	0.554
Secondary	0.261	0.333	Secondary	0.532	0.536
Tertiary	0.213	0.244	Tertiary	0.573	0.584
Residential	0.270	0.256	Residential	0.615	0.625

Validation of Event-based Measures



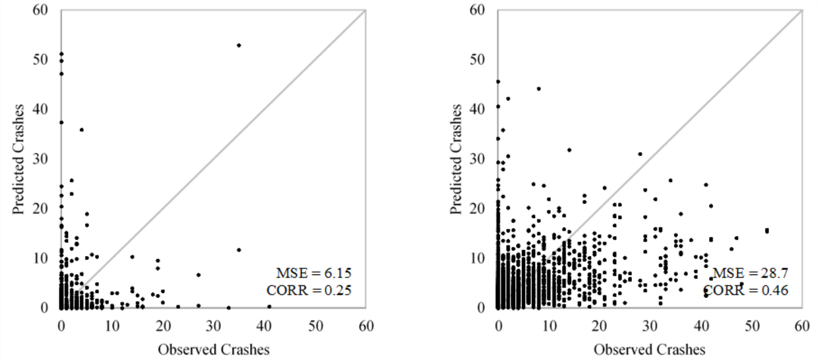


Sites were divided into groups with: 1) at least one fatal collision, 2) at least one major injury collision but no fatal, and 3) only minor injury collisions

Modelling Crash Frequency and Severity

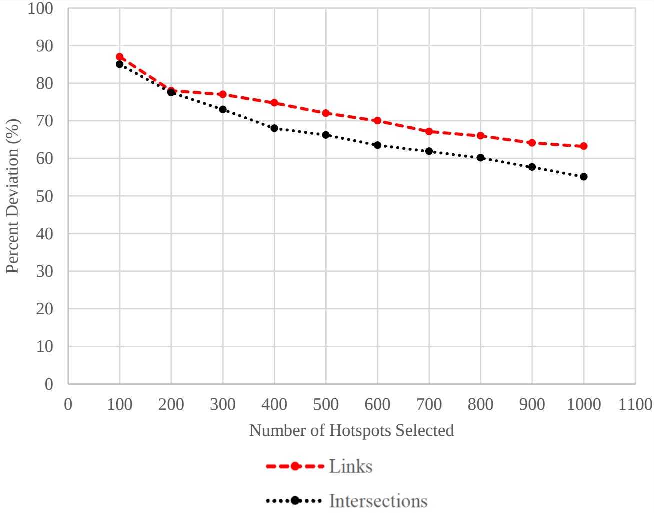
- Full Bayesian Spatial Latent Gaussian Model (LGM) accounting for spatial correlations for crash frequency
- Fractional Multinomial Logit (FMNL) model for crash severity
- Site ranking using different costs per severity level (and link length) and comparison to a traditional crash-based approach
- Validation using cross-validation

Results



Predicted Crashes
Observed Crashes
MSE = 6.15
CORR = 0.25
Predicted Crashes
Observed Crashes
MSE = 28.7
CORR = 0.46

Results



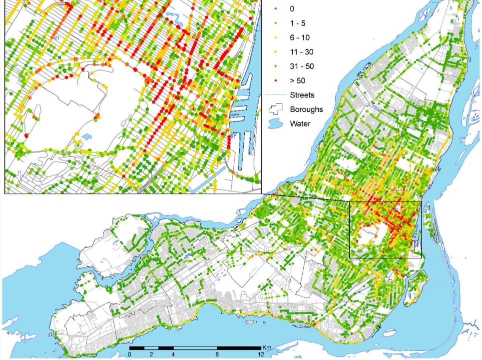
100
90
80
70
60
50
40
30
20
10
0
Percent Deviation (%)
0
100
200
300
400
500
600
700
800
900
1000
1100
Number of Hotspots Selected
Links
Intersections

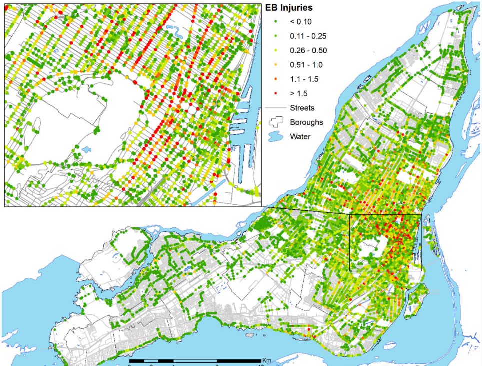
Results

- Calibrated models achieved a correlation of 0.60 with the observed data, while prediction resulted in correlations of 0.46 for intersections and 0.25 for links
- Site rankings were between 20 % and 45 % similar measured on the validation data set, depending on the number of hotspots considered
- The results have been replicated in Montreal and Ottawa through a collaboration with an insurance company

Results

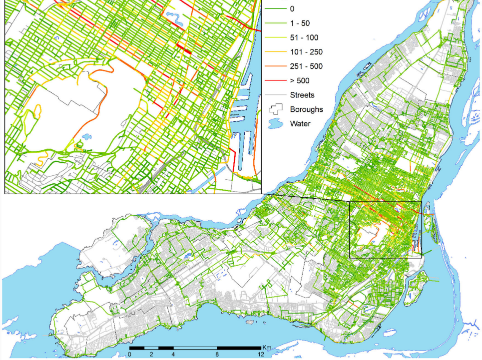
	Classification	CI	$\bar{V}$	CVS	HBEs
Mon Trajet, Quebec City	Motorway	0.05	-0.27	0.17	0.05
	Primary	0.21	-0.35	0.16	0.25
	Secondary	0.11	-0.41	0.1	0.26
	Tertiary	0.12	-0.22	0.16	0.21
	Residential	0.08	0.05	0.15	0.27
Intact UBI, Quebec City	Motorway	0.14	-0.30	0.32	0.25
	Primary	0.11	-0.42	0.42	0.40
	Secondary	0.15	-0.45	0.46	0.40
	Tertiary	0.12	-0.37	0.42	0.29
	Residential	0.04	-0.17	0.24	0.31
Intact UBI, Montreal	Motorway	0.01	-0.29	0.30	0.34
	Primary	0.04	-0.56	0.48	0.30
	Secondary	0.05	-0.53	0.50	0.30
	Tertiary	0.16	-0.53	0.53	0.21
	Residential	0.04	-0.22	0.20	0.27
Intact UBI, Ottawa	Motorway	0.60	-0.61	0.58	0.44
	Primary	-0.15	-0.49	0.30	-0.09
	Secondary	0.18	-0.66	0.60	0.14
	Tertiary	0.18	-0.52	0.44	0.21
	Residential	0.06	-0.19	0.18	0.18

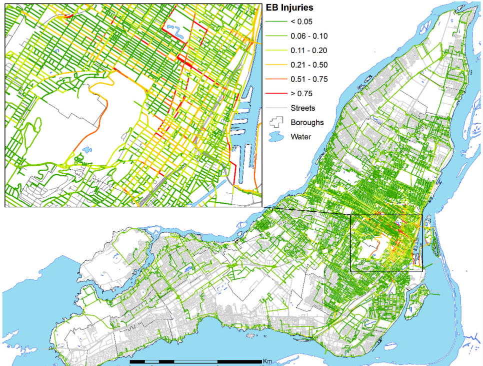




Cyclist Probe Data

Correlation of the number of hard cyclist decelerations with the Empirical Bayes estimator of the number of cyclist injuries at intersections: 0.6 and 0.53 for signalized and unsignalized intersections resp.



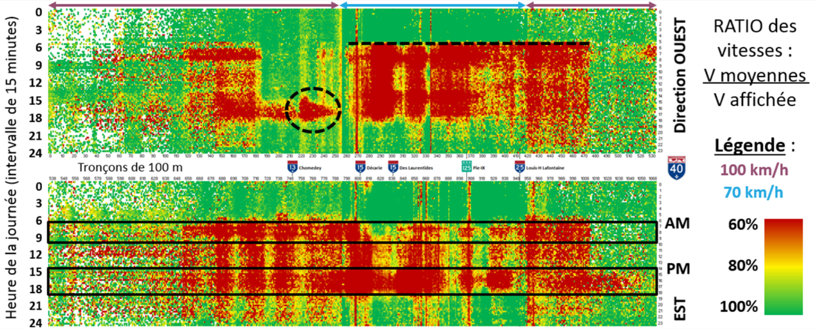


Cyclist Probe Data

Correlation of 0.57 for the number of hard cyclist decelerations with the Empirical Bayes estimator of the number of cyclist injuries on links

GNSS data has many applications

- Traffic monitoring



GNSS data has many applications

- Traffic monitoring
- Driver behaviour, e.g. speed limit infractions

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- Driver behaviour, e.g. speed limit infractions

But one needs to be careful of privacy

Outline

The Functions of Streets

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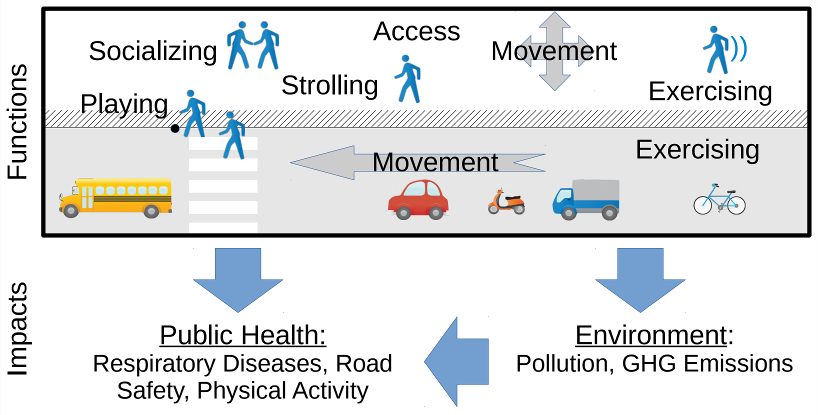
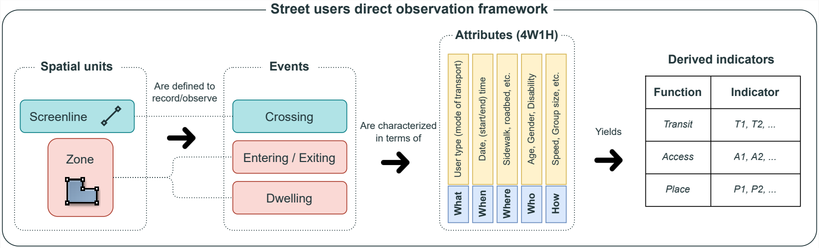
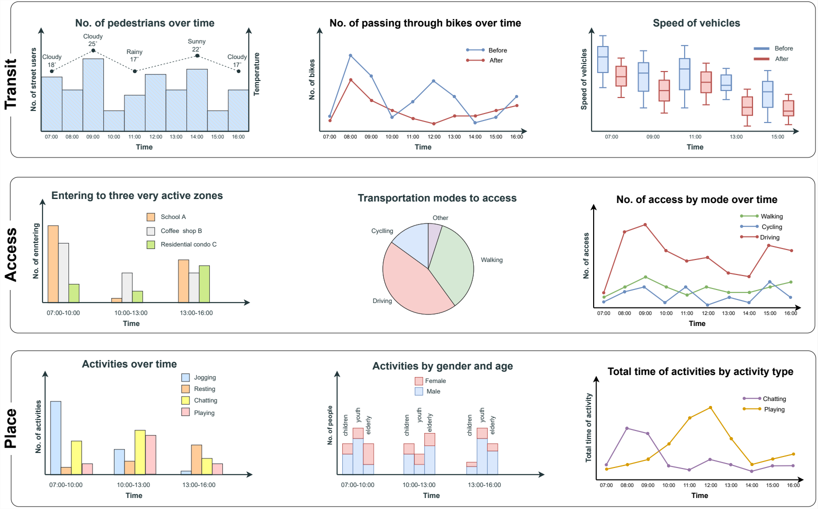


Framework for Street Use Analysis

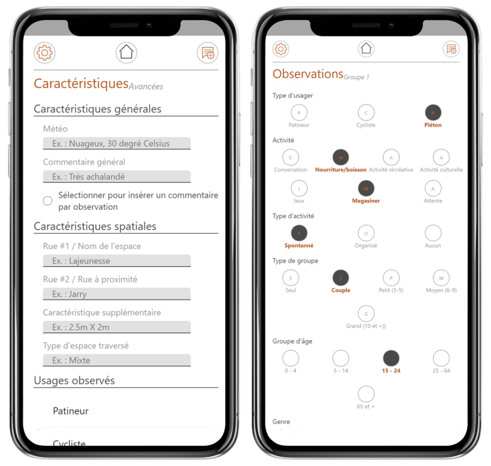
Framework for the integrated evaluation of the functions of streets and the impacts of their use based on the naturalistic observation of all users



Framework for Street Use Analysis

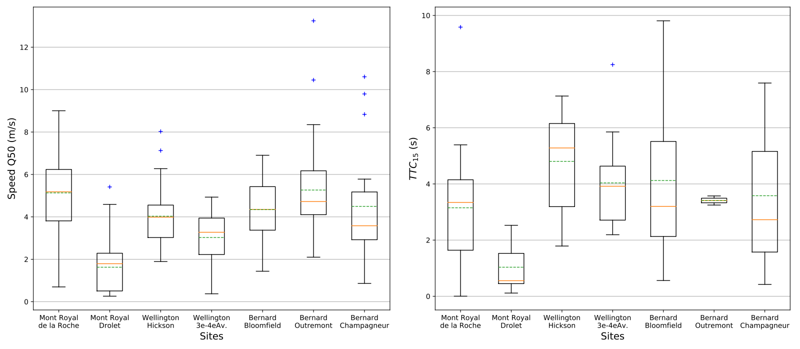


Mobile application to observe activities in public spaces



Cyclist-Pedestrian Interactions in Pedestrian Streets

Streets at closed to car traffic for the Summer in Montreal, with different rules for cyclists



Other Work

- Computer vision for activity recognition
- Impact of automated shuttles on traffic, especially pedestrians and cyclists

Outline

Other Topics

- Traffic simulation for safety, for the impact of cyber attacks on traffic controllers
  - optimization using vehicle trajectories
  - large scale metropolitan areas using open data
- Cycling network analysis
- Other sensors: thermal cameras, stereo cameras, LIDAR
- “AWD” pedestrians (with Assisting and Walking Devices)

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Questions?

Jackson, S., Miranda-Moreno, L. F., St-Aubin, P., and Saunier, N. (2013).
A flexible, mobile video camera system and open source video analysis software for road safety and behavioural analysis.
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