A Surrogate Safety Analysis at Protected Freeway Ramps Using Cross-Sectional and Before-After Video

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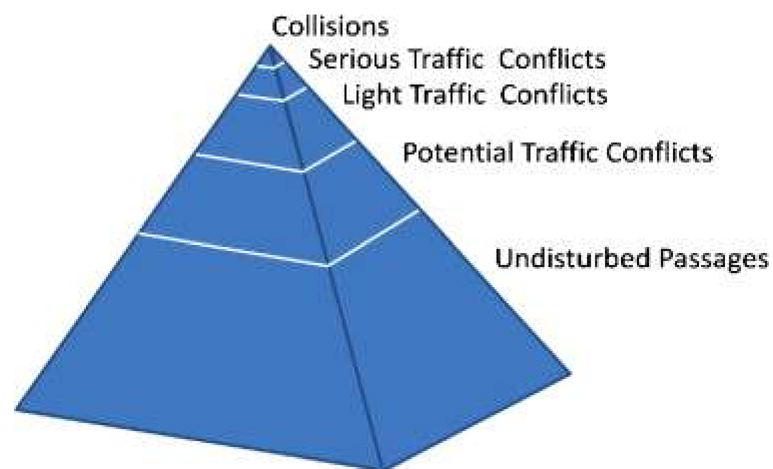
Objective

- Road safety:
  - ✓ Conflict-based diagnostic tool for road design, particularly for road safety analysis, but adaptable for other purposes
  - ✓ Complement to the classical historical analysis approach, or where limited data is available (e.g. “design exceptions”)
  - ✓ Currently implementable for small before-after analyses

- Microscopic trajectory data:
  - ✓ Lane changes
  - ✓ Small-scale changes in speed/direction
  - ✓ Driver behaviour
  - ✓ Etc.



Tarko, A. (2012), *Use of crash surrogates and exceedance statistics to estimate road safety*, Accident Analysis and Prevention vol. 48

Why Surrogate Safety?

- Native use of interactions as a measure of exposure
- Return period of accident observations are often unpractical
- Prevention over treatment
- Accident reporting has consistency, accuracy issues
- Microscopic scale of analysis possible

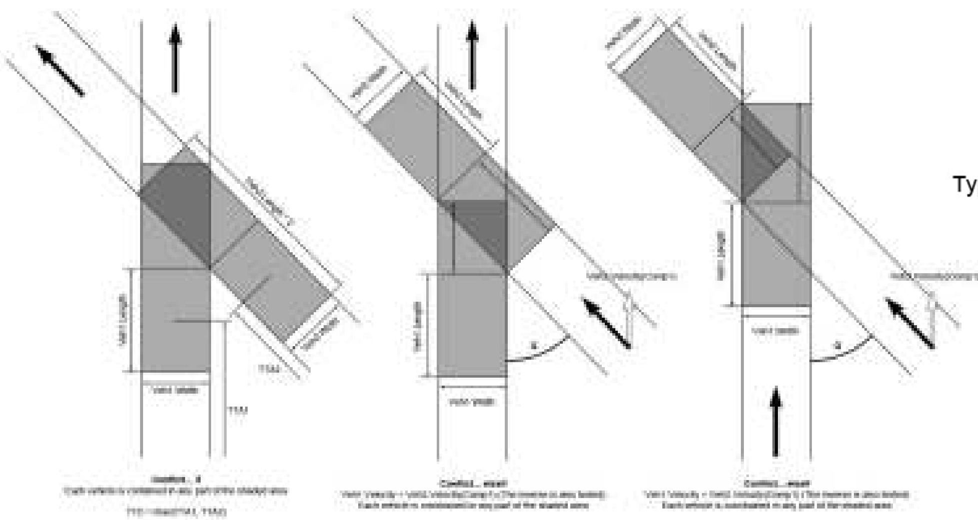
Limitations

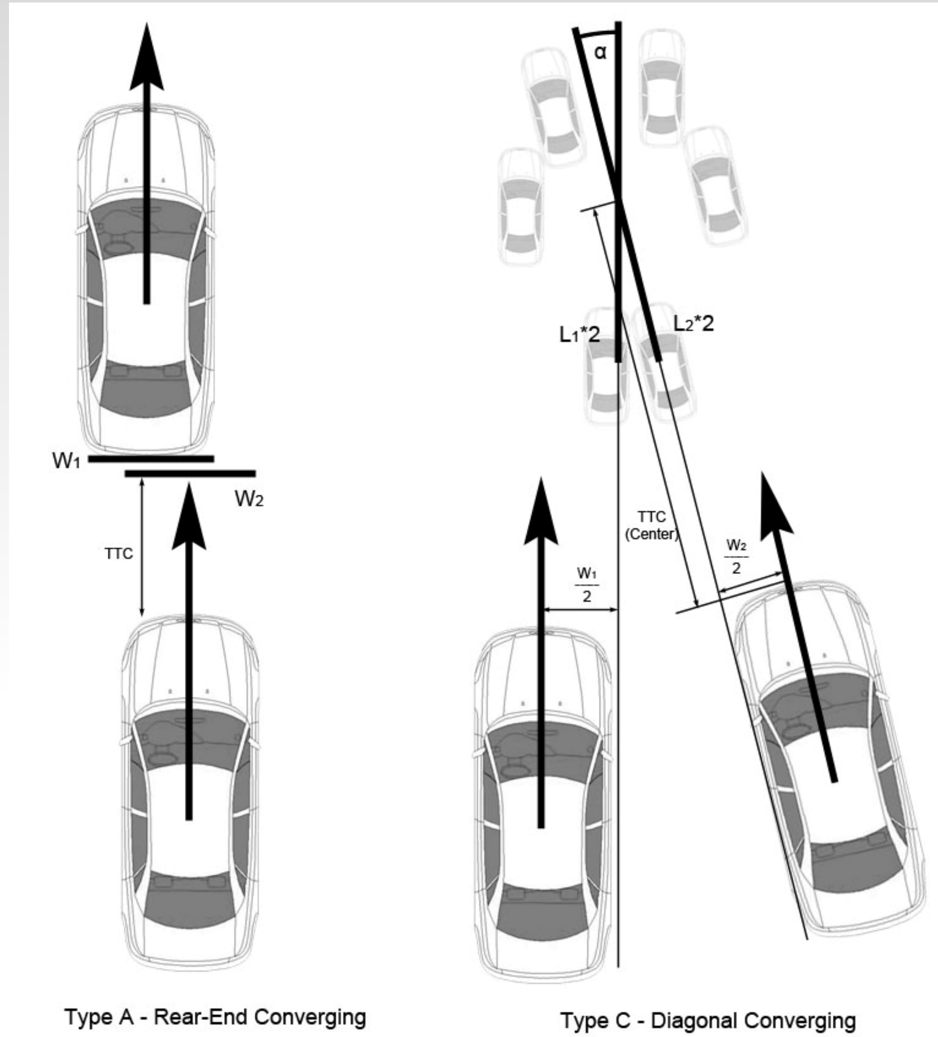
- Limited acceptance; technology still in its infancy
- Still some debate regarding transferability of results to other studies/environments
- No standard measurement

Basic Definition

- We can define the classical Time-To-Collision (TTC) measure as the travel time required for two vehicles on unchanged paths to enter a collision point (CP), if it exists:

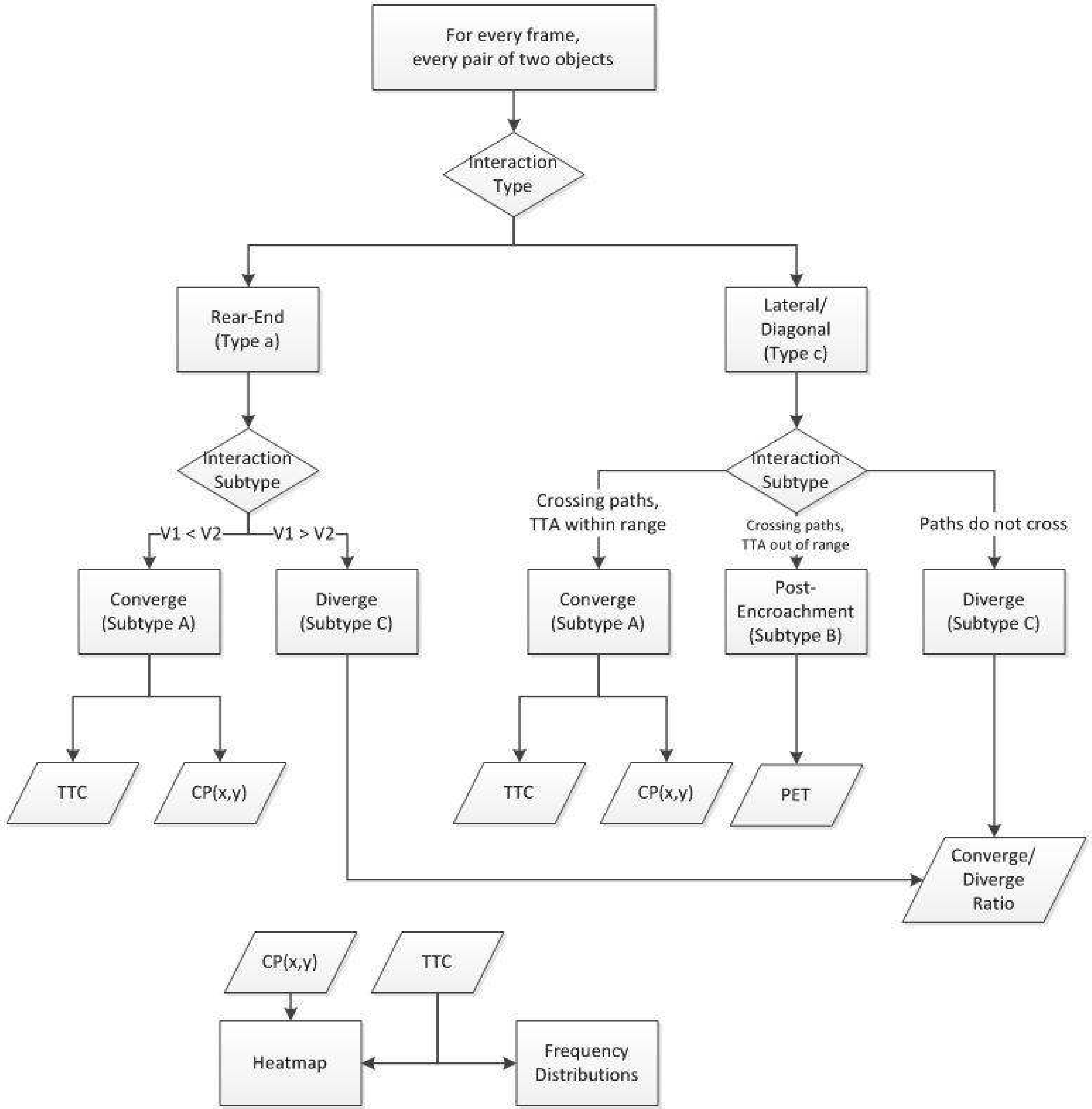
$$TTC = \frac{D_{CP}}{V}$$





Basic collision prediction used in straight highway segments, adapted from:

Laureshyn, A., Svensson, A., Hydén, C. (2010), *Evaluation of traffic safety, based on micro-level behavioural data: Theoretical framework and first implementation,* Accident Analysis and Prevention, p. 1637-1646.

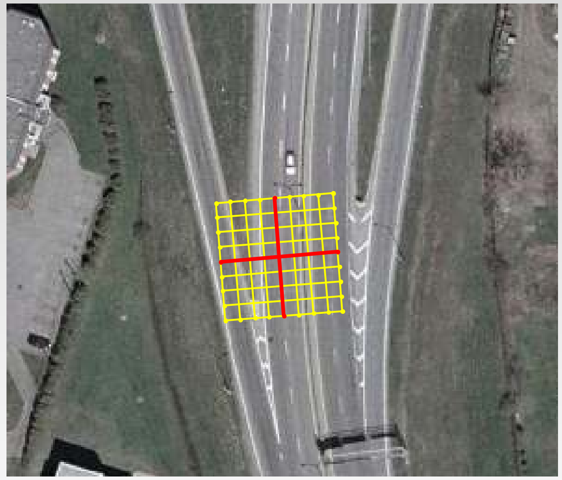


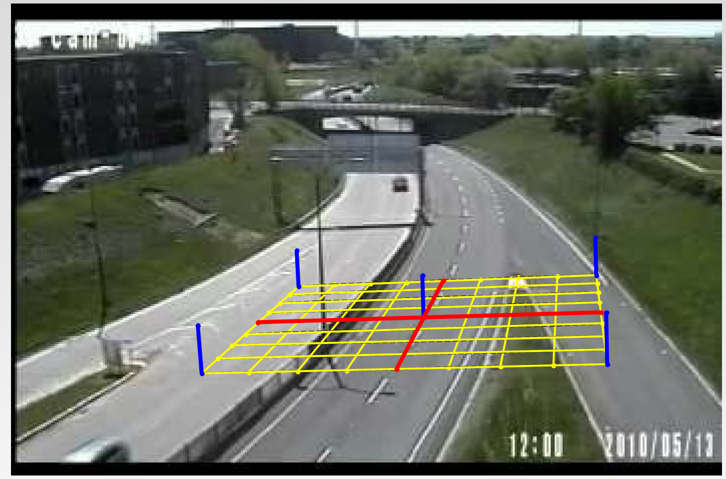
For every frame,
every pair of two objects
Interaction Type
Rear-End (Type a)
Lateral/ Diagonal (Type c)
Interaction Subtype
V1 < V2
V1 > V2
Converge (Subtype A)
Diverge (Subtype C)
TTC
CP(x,y)
Interaction Subtype
Crossing paths, TTA within range
Crossing paths, TTA out of range
Paths do not cross
Converge (Subtype A)
Post-Encroachment (Subtype B)
Diverge (Subtype C)
TTC
CP(x,y)
PET
Converge/ Diverge Ratio
CP(x,y)
TTC
Heatmap
Frequency Distributions

Automated Trajectory Tracking

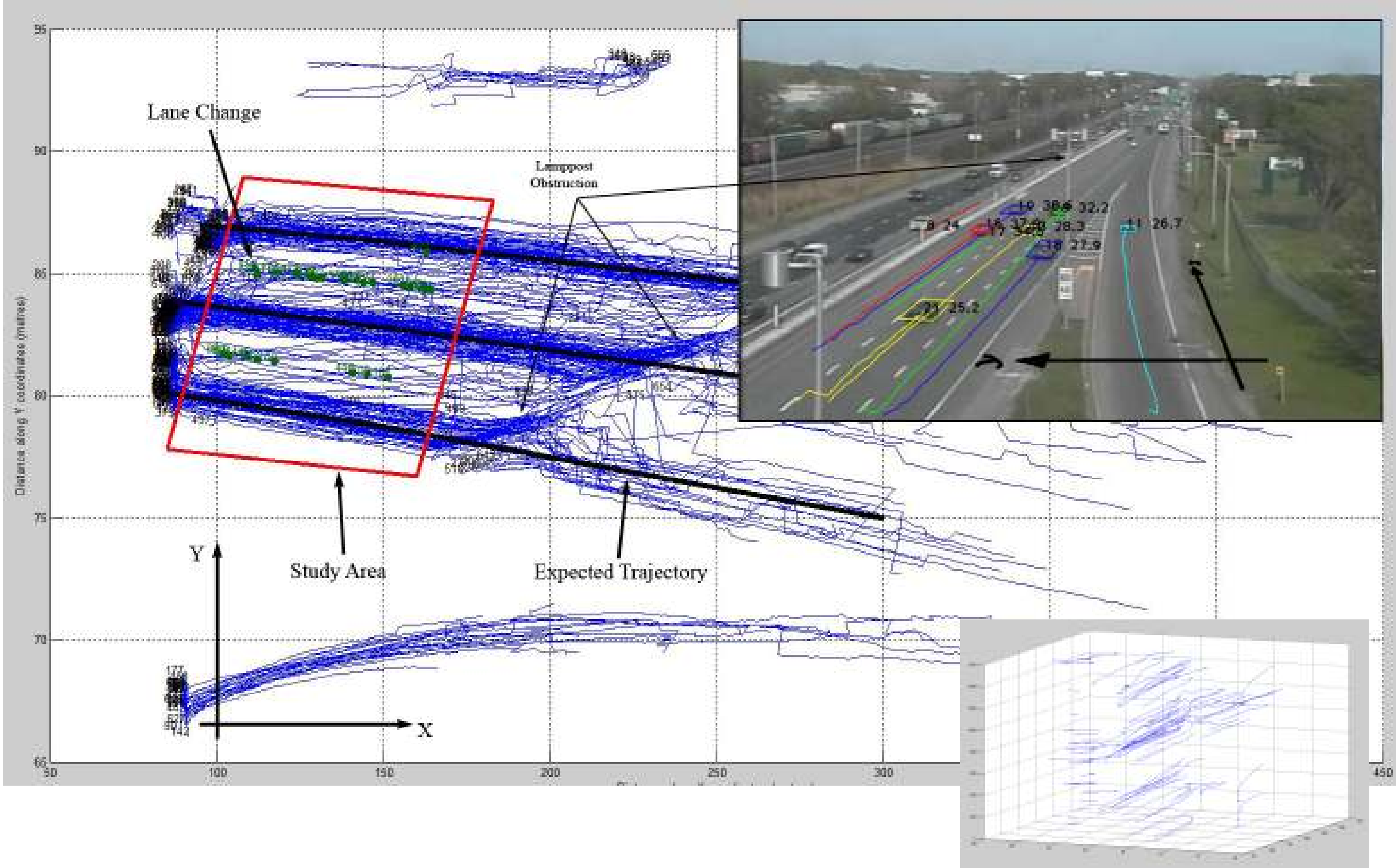
- Allows for very large datasets to be efficiently collected
- Objective readings
  - ✓ Consistent and precise acceleration/speed tracking of multiple vehicles on a projected surface
  - ✓ Previous surrogate safety criticism included subjectivity and reliability in conflict measurements
- Cheap and versatile camera sensors; computer-vision-based detection technology improving rapidly

- Limited however by weather/visibility conditions
- Practical analysis zone of 50-200 metres, depending on visibility, resolution, camera height, obstacles, etc.
- Manual steps are still required for camera calibration and tracking parameter tuning



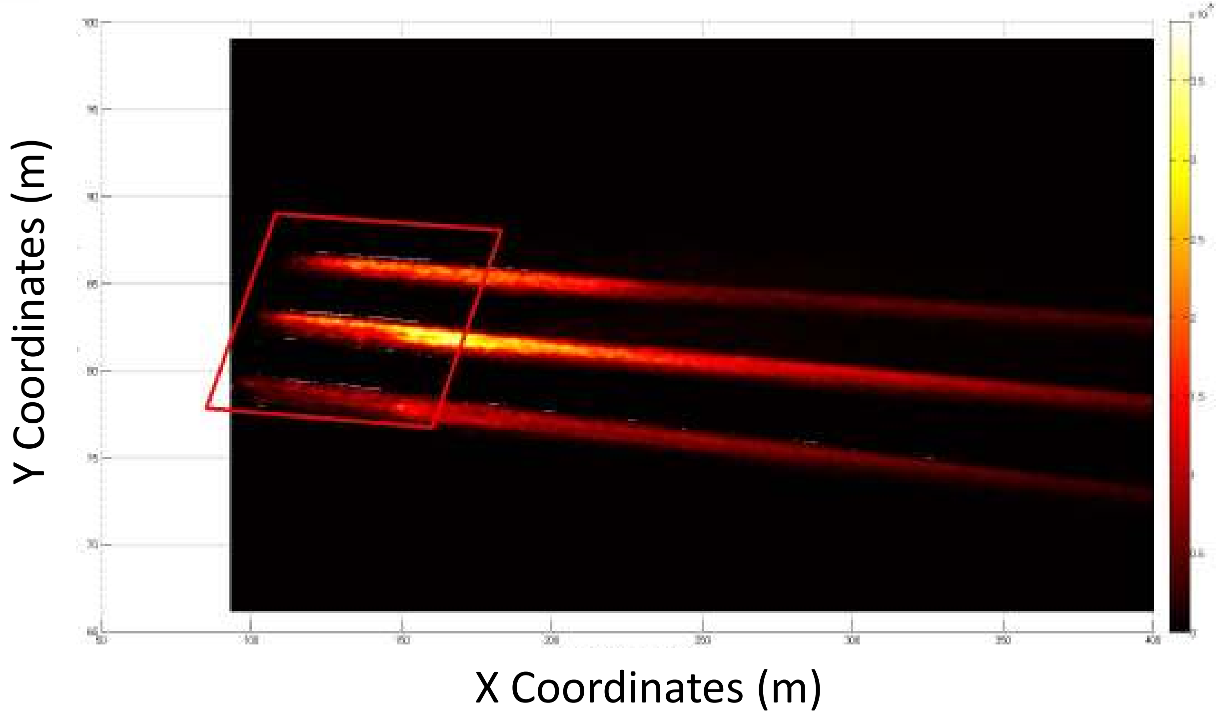


K. Ismail, T. Sayed and N. Saunier. *Automated Analysis Of Pedestrian-vehicle Conflicts: Context For Before-and-after Studies*. Transportation Research Record: Journal of the Transportation Research Board, 2198:52-64, 2010.


Lane Change
Lamppost Obstruction
Study Area
Expected Trajectory
Y
X

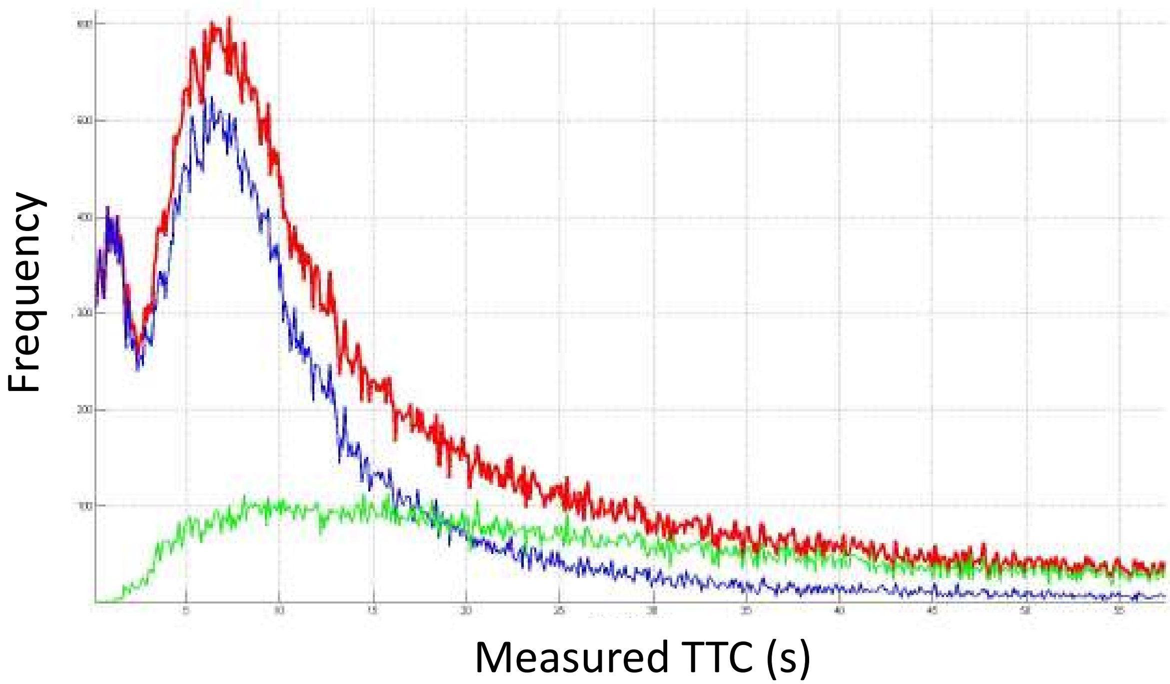
Conflict Heatmap

- Weighted density map of collision points (in this case weighted by e^{-TTC})
- Identify microscopic conflict hotspots from CP's and respective TTC measurements
- Weighing in terms of probability of collision to come with formal relationship between TTC and collision probability



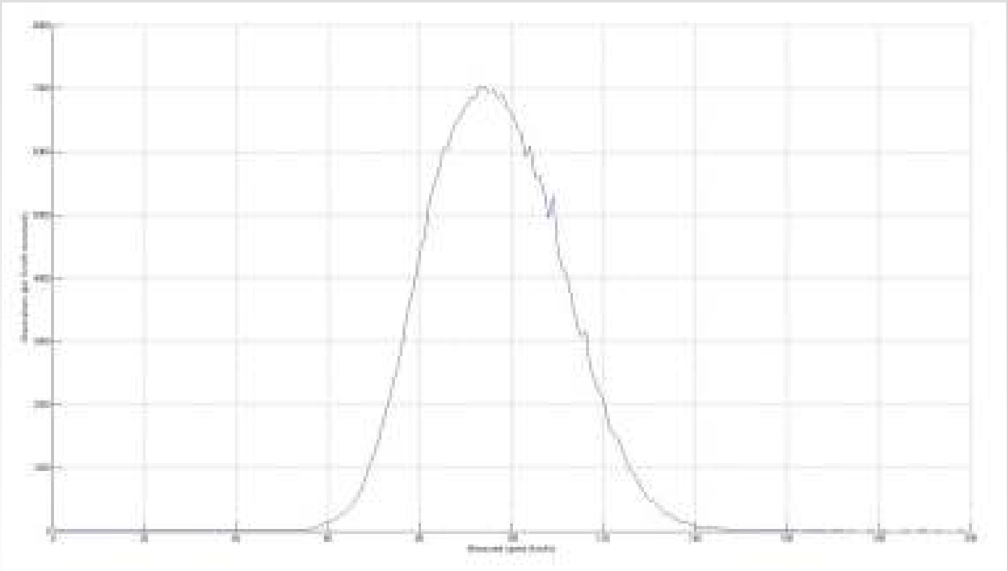
TTC Distribution

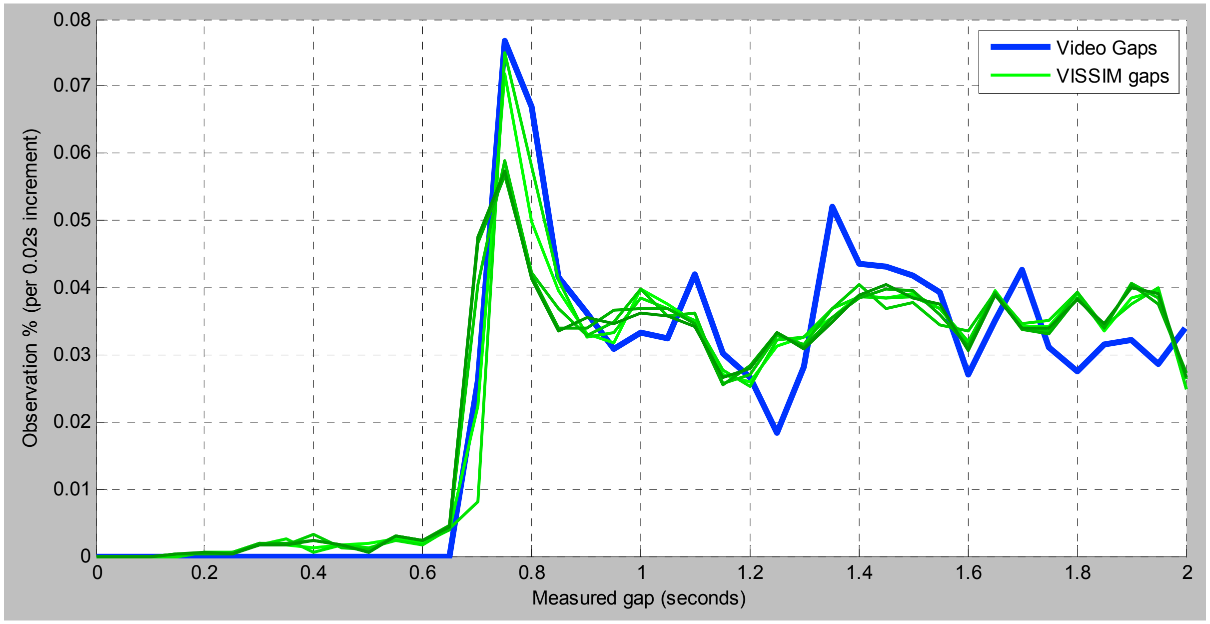
- TTC is a solid general purpose indicator for unidirectional highway conflicts
- Many options for aggregation (subsegment, lane, vehicle pair, min, max, mean, moving average, etc.)
- Link between TTC distribution and collision probability is key, future research



Other Measures

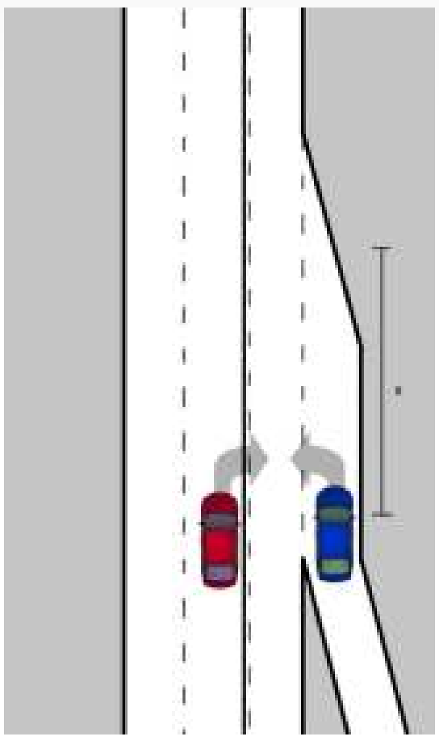
- ❑ Speed distribution
- ❑ Following distance
- ❑ Lane changes
- ❑ Etc.





Case Study: Highway Horizontal Signalisation

- Highway design exception treatment evaluation (project for the Ministère des Transports du Québec)
  - ✓ “Ligne continue à gauche de la voie 1” (LCGV1)
  - ✓ Montreal

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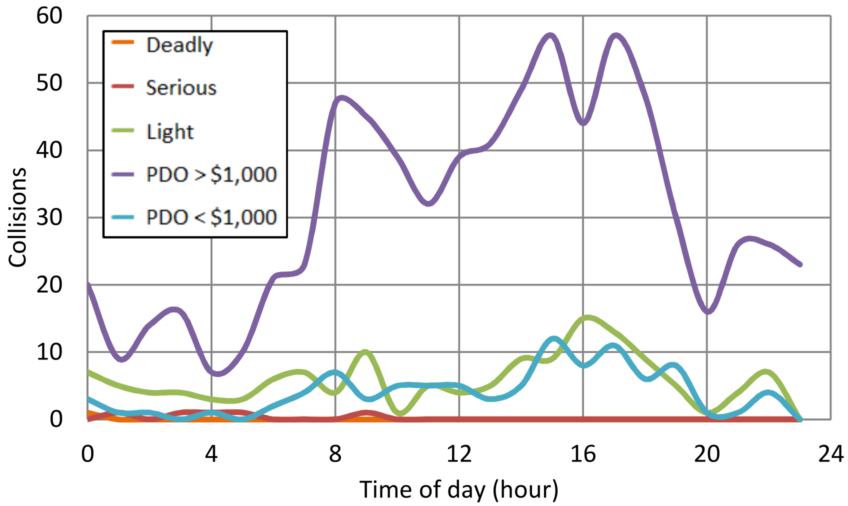
Highway Accidents

- ❑ Unidirectional
  - ✓ Rear-end converging (45%; MTQ)
  - ✓ Lateral/side-swipe converging (25%; MTQ)
- ❑ High-speed
  - ✓ Highly dependant on reaction-time, safety distances (following and merging)

Highway accident density along studied corridors

- ❑ Focus: collision probability (as opposed to severity)
  - ✓ Conflicts during congestion are, so far, too noisy to be significant
  - ✓ Observation of high-speed conflicts at off-peak periods

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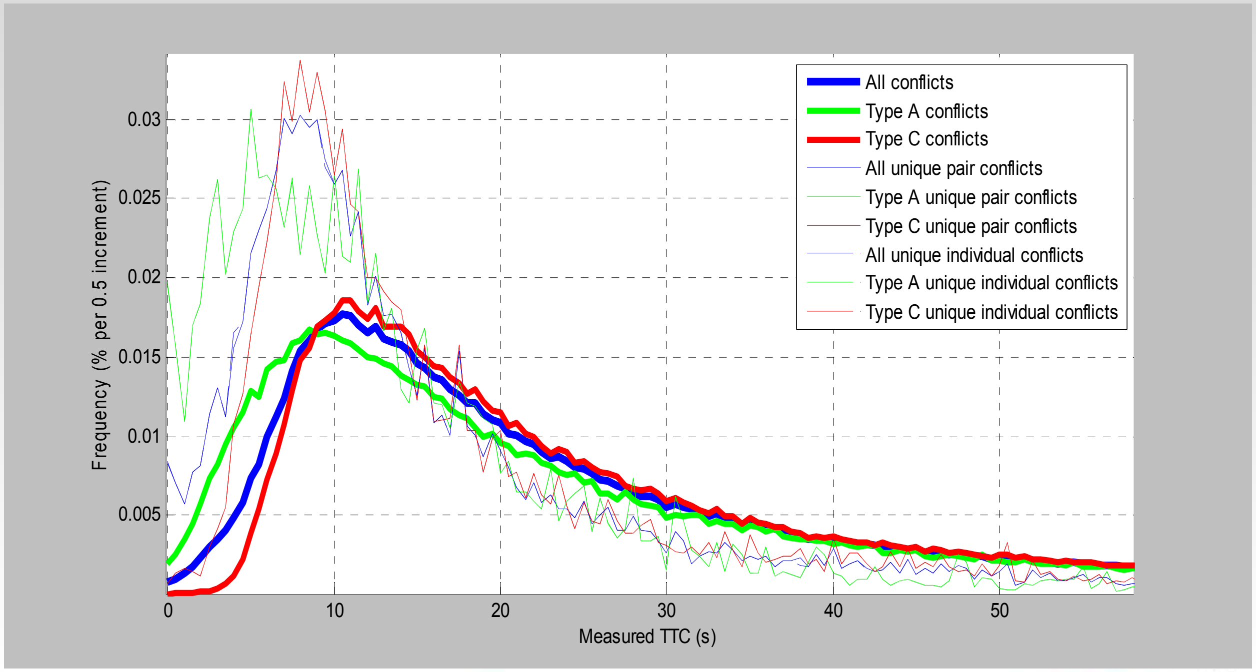
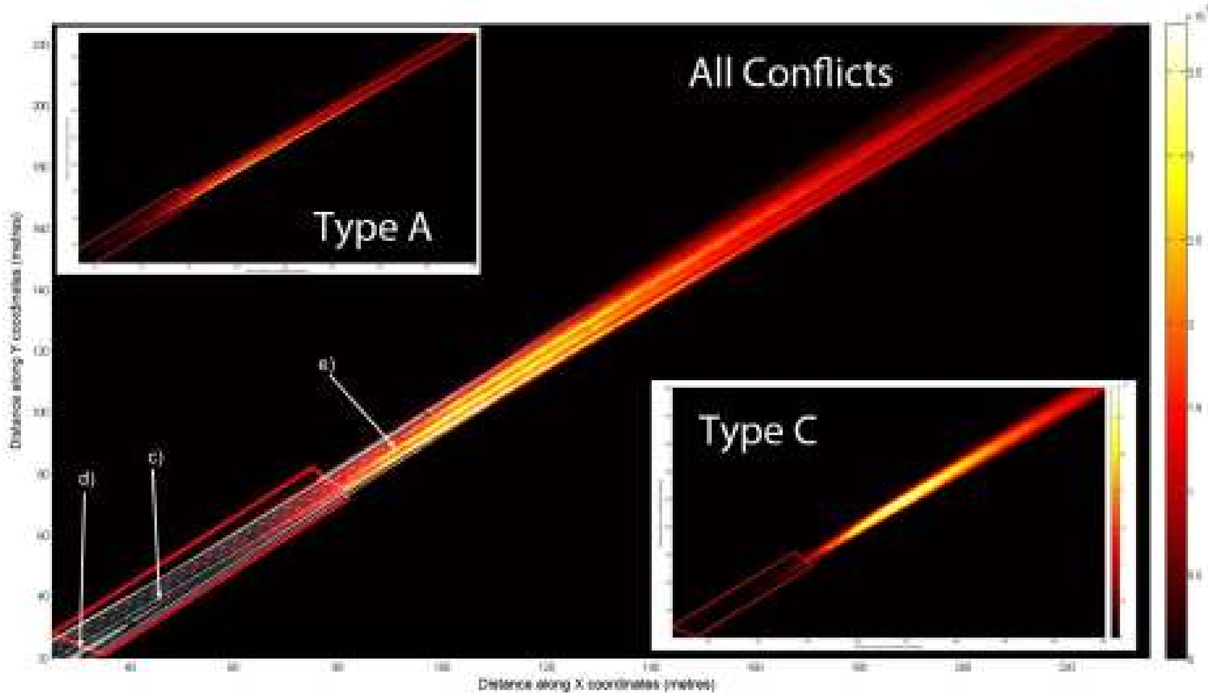
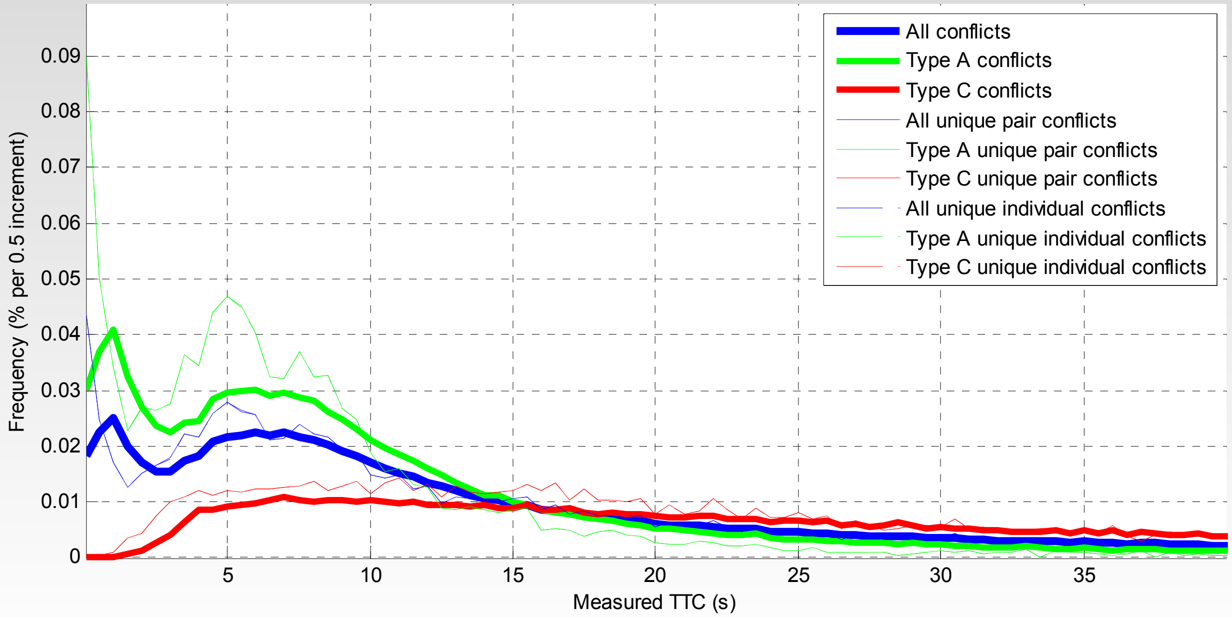
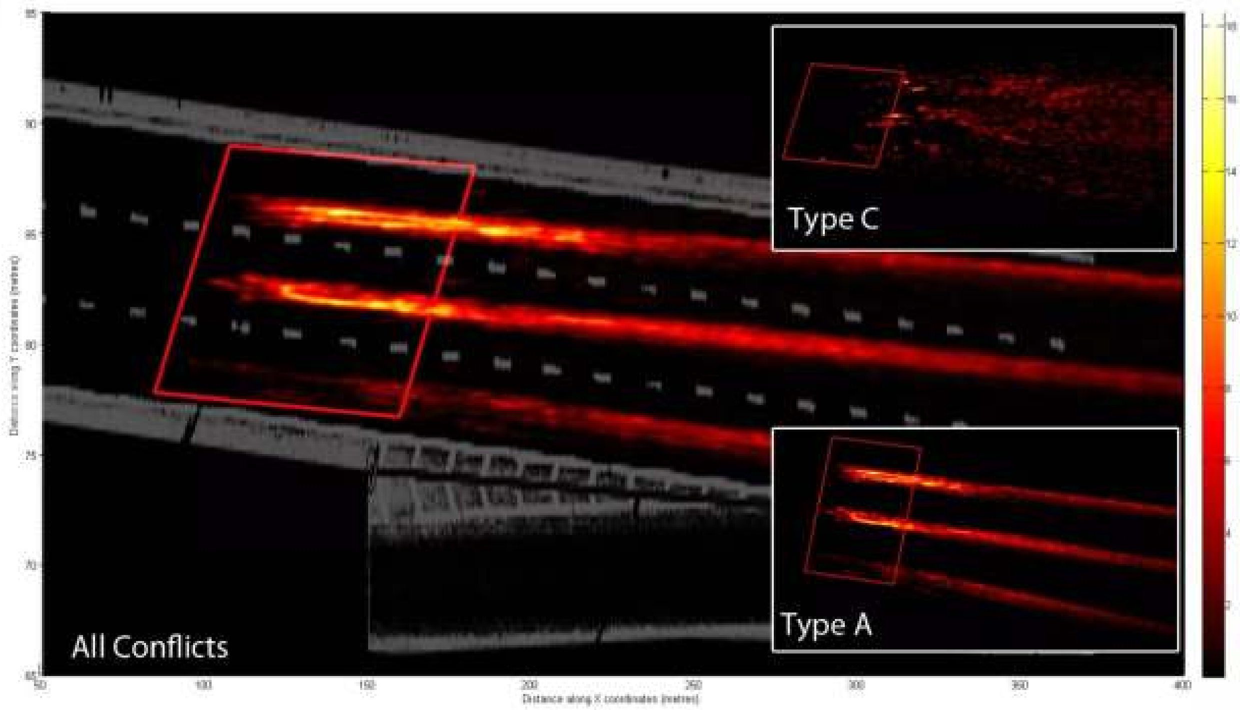

All conflicts
Type A conflicts
Type C conflicts
All unique pair conflicts
Type A unique pair conflicts
Type C unique pair conflicts
All unique individual conflicts
Type A unique individual conflicts
Type C unique individual conflicts
Frequency (% per 0.5 increment)
0.03
0.025
0.02
0.015
0.01
0.005
0
10
20
30
40
50
Measured TTC (s)


All Conflicts
Type A
Type C
a)
c)
d)
Distance along Y coordinates (metres)
Distance along X coordinates (metres)


All conflicts
Type A conflicts
Type C conflicts
All unique pair conflicts
Type A unique pair conflicts
Type C unique pair conflicts
All unique individual conflicts
Type A unique individual conflicts
Type C unique individual conflicts
Frequency (% per 0.5 increment)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5
10
15
20
25
30
35
Measured TTC (s)


Type C
Type A
All Conflicts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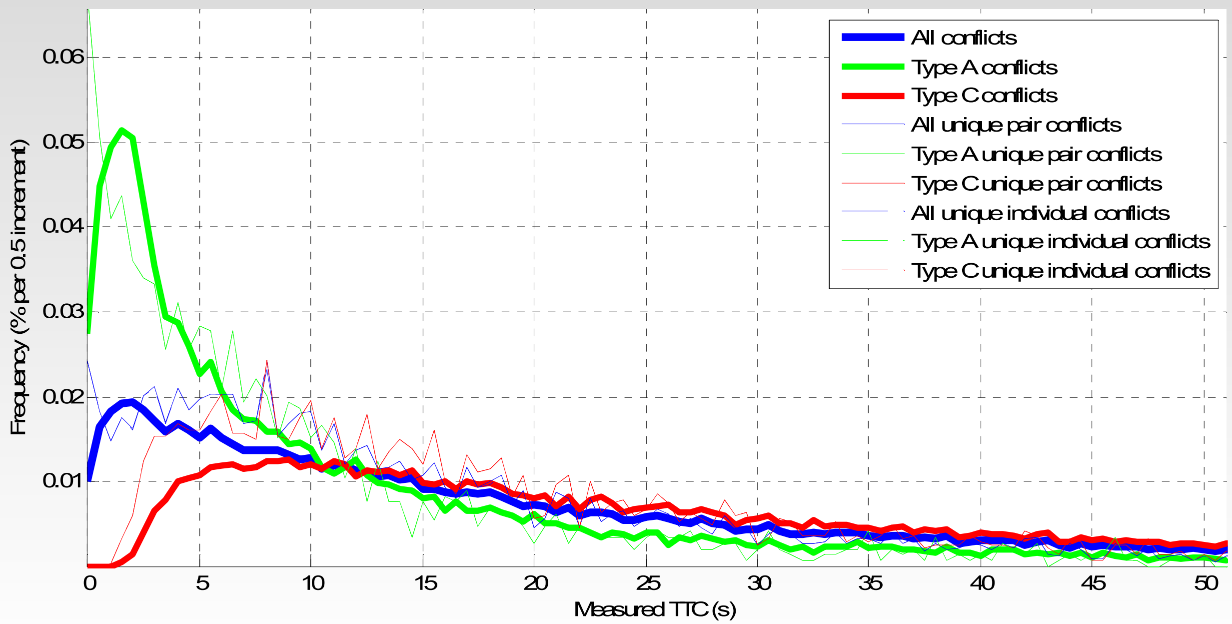
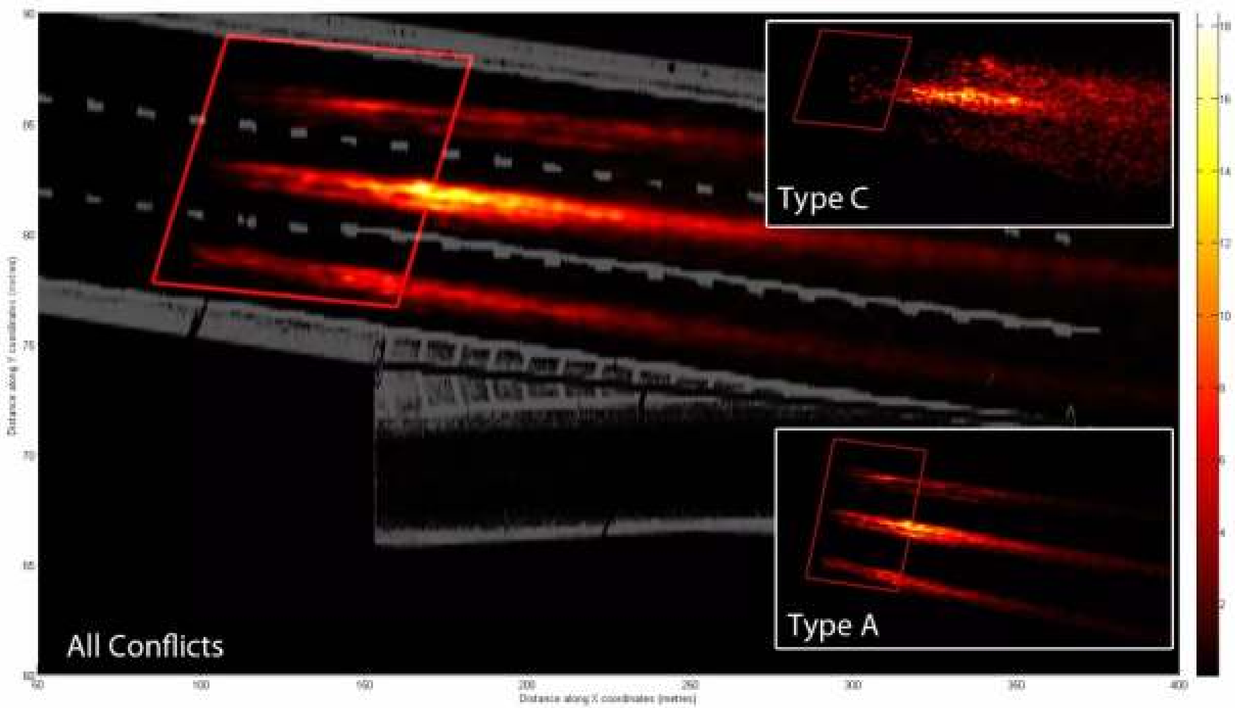


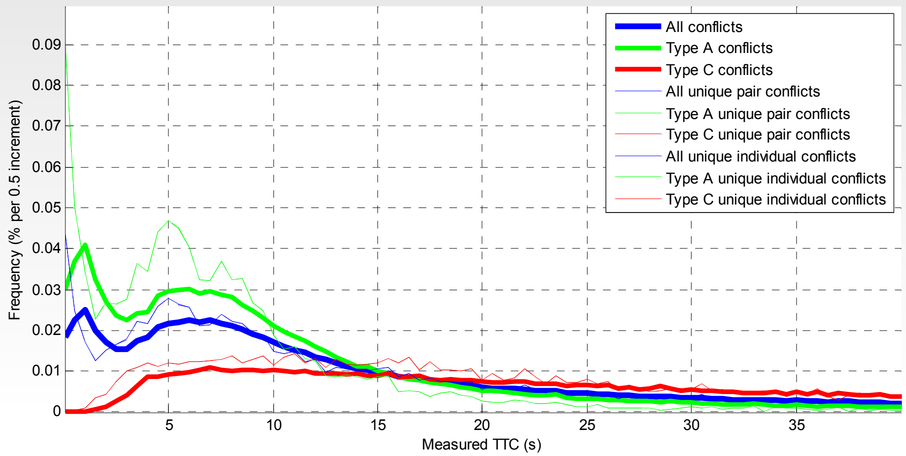
All conflicts
Type A conflicts
Type C conflicts
All unique pair conflicts
Type A unique pair conflicts
Type C unique pair conflicts
All unique individual conflicts
Type A unique individual conflicts
Type C unique individual conflicts
Frequency (% per 0.5 increment)
0.06
0.05
0.04
0.03
0.02
0.01
0
5
10
15
20
25
30
35
40
45
50
Measured TTC (s)

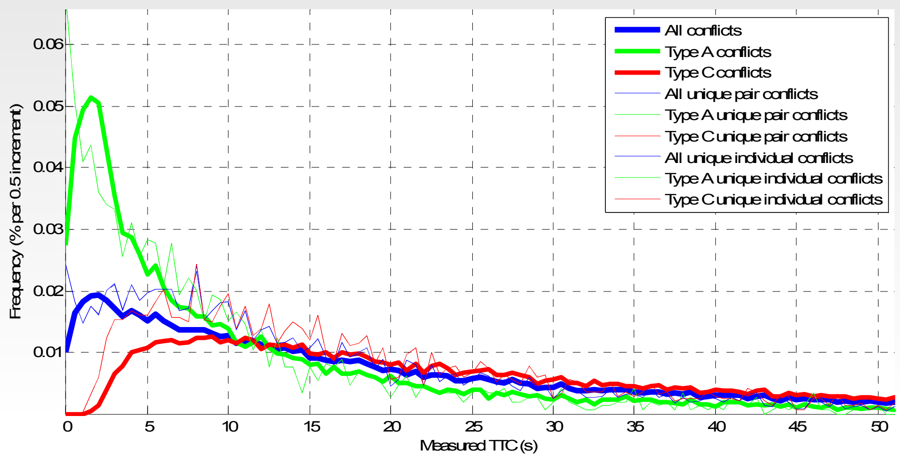


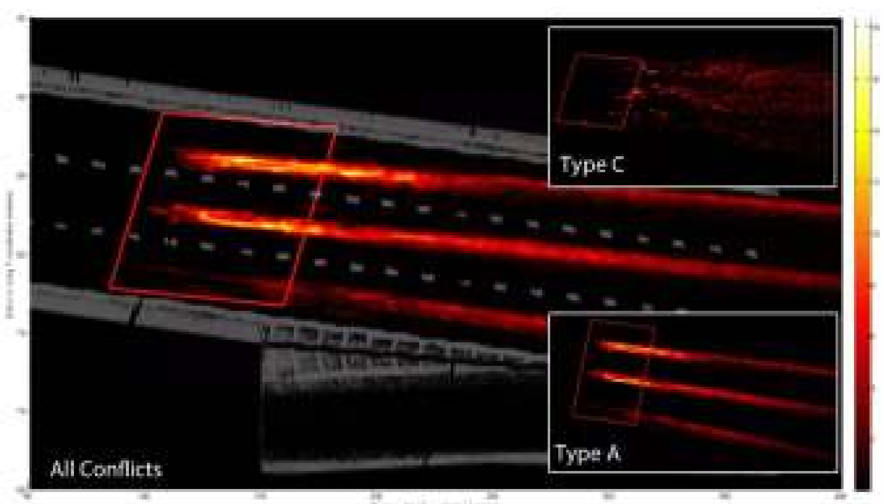
Type C
Type A
All Conflicts

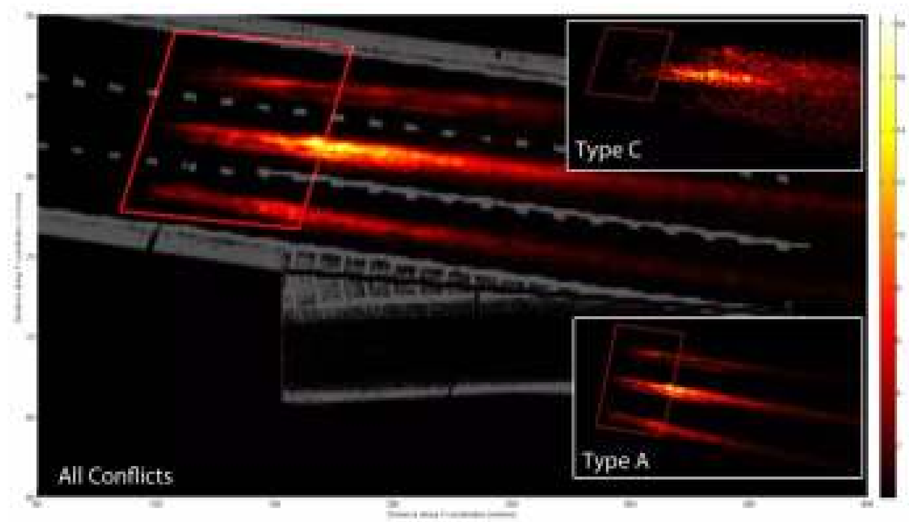
Without treatment

With treatment





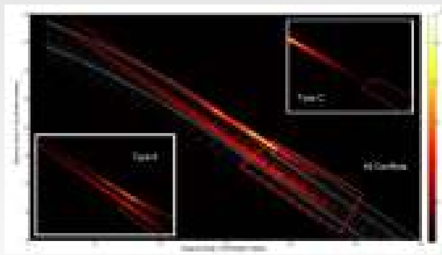


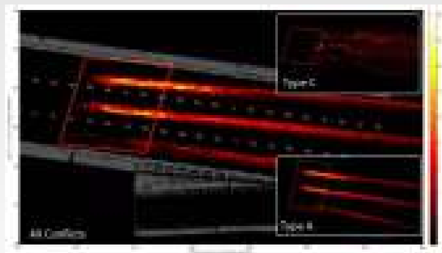


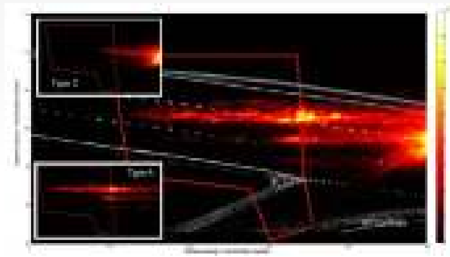
Without treatment

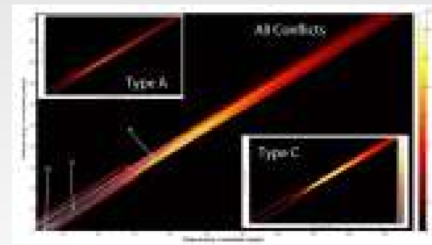
With treatment

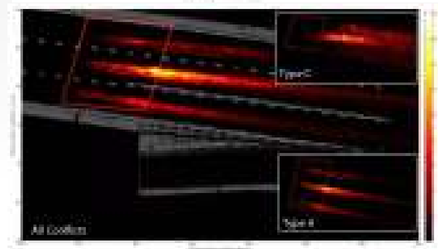
Entrance



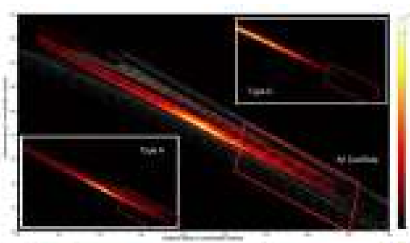


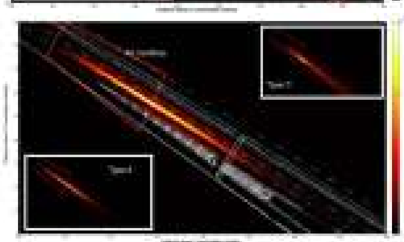


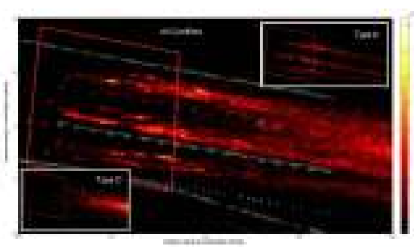


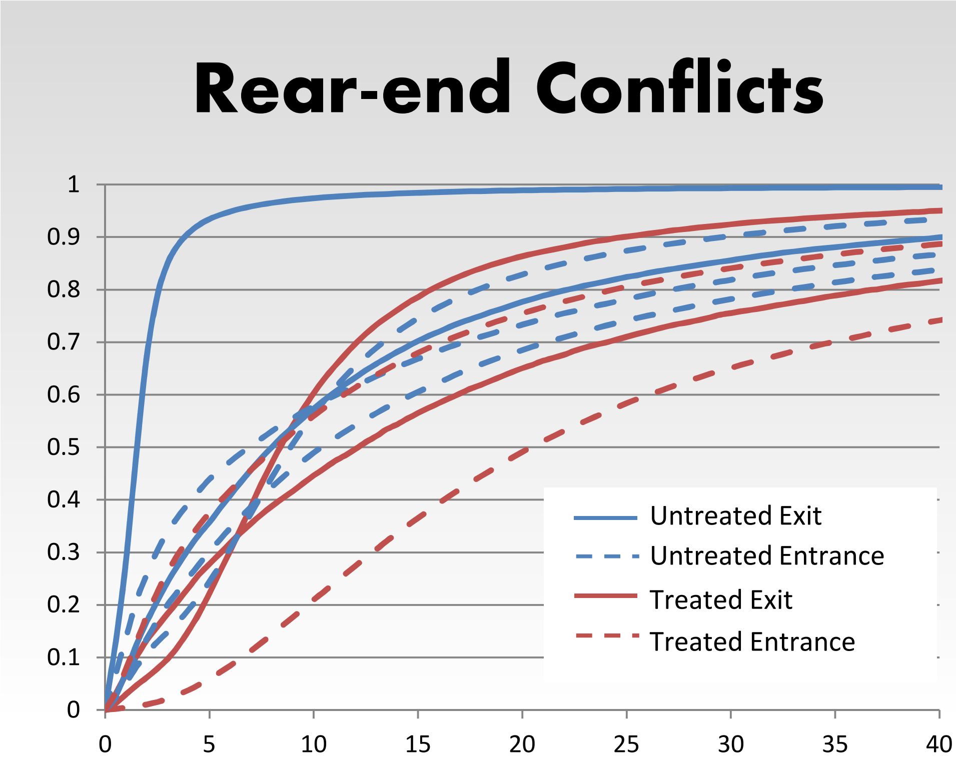


Exit

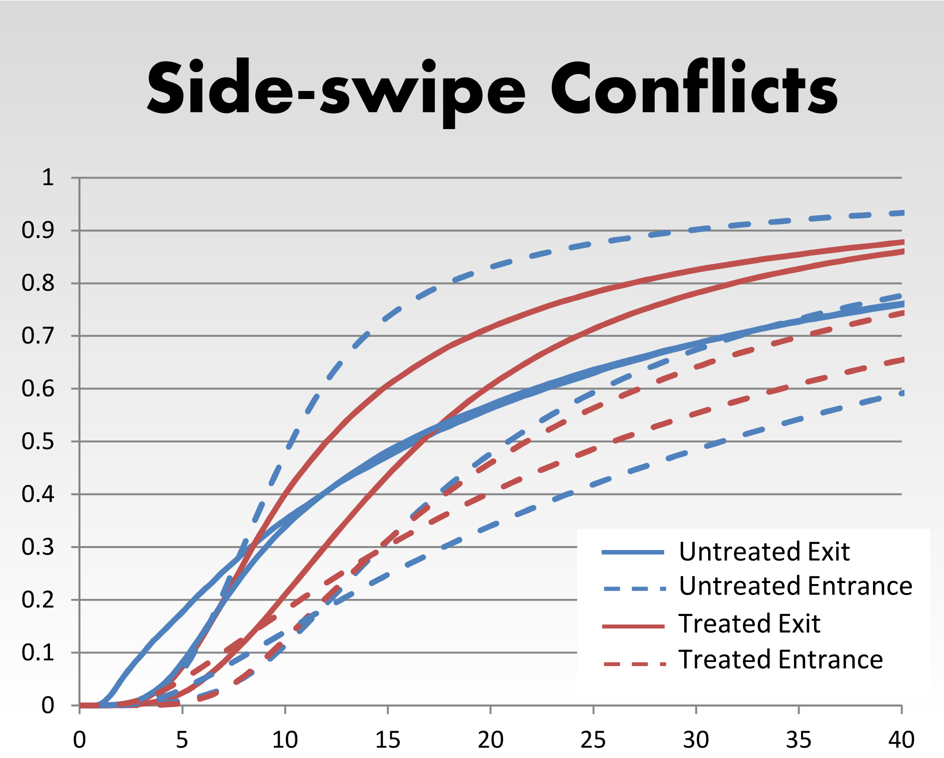








Cumulative TTC (s) distributions



Cumulative TTC (s) distributions

Flow by lane

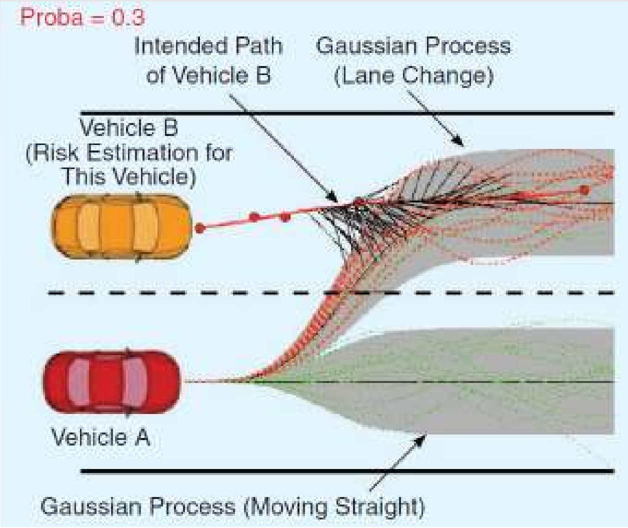
Site	Treatment	$q_{\%}$	Mean % flow by lane			
			Lane 1	Lane 2	Lane 3	Lane 4
A20-E-E56-3	No	-	27.5%	**43.9%**	28.6%	-
A20-W-E62	No	24.0%	21.3%	**42.2%**	36.5%	-
A20-E-E58	No	10.9%	12.3 %	33.5%	**54.2%**	-
A720-E-E3	Yes	3.0%	**31.4%**	29.6%	25.8%	13.2%
A20-E-E56-3	Yes	-	32.5%	**43.2%**	24.3%	-
Mean	-	12.6%	25.9%	**39.4%**	34.7%	-
A13-N-S3-1	No	5.9%	17.0%	36.9%	**46.1%**	-
A25-S-S5	No	18.2%	38.5%	**46.5%**	15.1%	-
A20-E-S58	Yes	-	27.2%	**44.8%**	28.0%	-
A25-N-S5	Yes	9.7%	23.4%	**44.5%**	32.1%	-
Mean	-	11.3%	26.5%	**43.2%**	30.3%	-

Lane changes in *lane changes per veh-km*

Site	Treatment	$1 \rightarrow 2$	$2 \rightarrow 3$	$3 \rightarrow 4$	$4 \rightarrow 3$	$3 \rightarrow 2$	$2 \rightarrow 1$**
A20-E-E56-3	No	0.148	**0.192**	-	-	0.097	0.136
A20-W-E62	No	0.126	**0.327**	-	-	0.120	0.103
A20-E-E58	No	0.024	0.068	-	-	0.096	**0.140**
A720-E-E3	Yes	**0.151**	0.091	0.046	0.025	0.065	0.093
A20-E-E56-3	Yes	0.118	0.068	-	-	0.053	**0.139**
A13-N-S3-1	No	0.175	**0.345**	-	-	0.344	0.126
A25-S-S5	No	0.184	0.162	-	-	0.042	**0.279**
A20-E-S58	Yes	0.126	0.097	-	-	0.099	**0.176**
A25-N-S5	Yes	0.184	**0.510**	-	-	0.225	0.145

Direction for Future Work

Laugier et al. (2011), *Probabilistic Analysis of Dynamic Scenes and Collision Risks Assessment to Improve Driving Safety*, IEEE Intelligent Transportation Systems



- ❑ Robot navigation
  - ✓ Overlap with smart vehicle driving systems (e.g. collision warning, Google car, etc.)
  - ✓ Changes in road design according to changes in vehicle safety performance (e.g. reduction in reaction times through automation)

- ❑ Probabilistic trajectory prediction
  - ✓ Trajectory prototypes and path prediction (Saunier et al. 2010)
  - ✓ HMMs, K-Means, FCM, Similarity Threshold, I-kMeans, Agglomerative, Divisive, SOM, Fuzzy SOM and SOFM (Morris & Trivedi, 2008)

Conclusion

- ❑ Safety benefit not significant
- ❑ LCGV1 treatment has its flaws
  - ✓ For some sites, its use may be justified, but for many sites, it creates or, at the very least, only displaces problems instead of correcting them.

- ❑ Conflict analysis methodology is in place, currently adequate for basic comparative analysis
- ❑ Computer vision tracking algorithms constantly improving
- ❑ Next steps:
  - ✓ Improvements in path and collision prediction
  - ✓ Continued use of methodology in a wider variety of environments
  - ✓ Comparison with historical accident data

We want to acknowledge the support of the Ministère des Transports du Québec which funded this project

Questions?

- **Tarko**, A. (2012) *Use of crash surrogates and exceedance statistics to estimate road safety*, Accident Analysis and Prevention vol. 48
- **Laureshyn**, A., **Svensson**, A., **Hydén**, C. (2010) *Evaluation of traffic safety, based on micro-level behavioural data: Theoretical framework and first implementation,* Accident Analysis and Prevention, p. 1637-1646.
- **Ismail**, K., **Sayed**, T., **Saunier**, N. (2010) *Automated Analysis Of Pedestrian-vehicle Conflicts: Context For Before-and-after Studies*. Transportation Research Record: Journal of the Transportation Research Board, 2198:52-64
- **Laugier** et al. (2011) *Probabilistic Analysis of Dynamic Scenes and Collision Risks Assessment to Improve Driving Safety*, IEEE Intelligent Transportation Systems
- **Morris**, B. T., & **Trivedi**, M. M. (2008) *A Survey of Vision-Based Trajectory Learning and Analysis for Surveillance*. IEEE Transactions on Circuits and Systems for Video Technology, *18*, 1114-1127.
- **Saunier** N.**, Sayed** T. **and Ismail** K. (2010) *Large Scale Automated Analysis of Vehicle Interactions and Collisions*. Transportation Research Record: Journal of the Transportation Research Board, 2147:42-50
- **St-Aubin**, P., **Miranda-Moreno**, L., **Saunier**, N. (2012) *Surrogate Safety Analysis at Protected Freeway Ramps Using Cross-sectional and Before-After Video Data*, Proc. TRB-XCI, Washington, D.C.; January 22-26.
- **St-Aubin**, P. (2012) *Traffic Safety Analysis for Urban Highway Ramps and Lane-Change Bans Using Accident Data and Video-Based Surrogate Safety Measures*, Master of Engineering, McGill University, Montréal, 100 pages.