Automated Road Safety Analysis using Video Data

Conférence du chapitre des étudiants de Montréal du Groupe de Recherches sur les Transports au Canada
Montreal Students' Chapter - Canadian Transportation Research Forum Conference

Nicolas Saunier
nicolas.saunier@polymtl.ca

POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

April 7th 2014

Outline

Outline

A World Health Issue

Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer non-fatal injuries. In most regions of the world this epidemic of road traffic injuries is still increasing.
(Global status report on road safety, World Health Organization, 2009)

A World Health Issue

TOTAL 2004

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

TOTAL 2030

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Chronic obstructive pulmonary disease	7.0
4	Lower respiratory infections	5.1
5	Road traffic injuries	3.6
6	Trachea, bronchus, lung cancers	3.5
7	Diabetes mellitus	2.5
8	Hypertensive heart disease	2.3
9	Stomach cancer	2.2
10	HIV/AIDS	2.0
11	Nephritis and nephrosis	1.9
12	Self-inflicted injuries	1.9
13	Liver cancer	1.7
14	Colon and rectum cancer	1.7
15	Oesophagus cancer	1.5
16	Violence	1.4
17	Alzheimer and other dementias	1.4
18	Cirrhosis of the liver	1.3
19	Breast cancer	1.3
20	Tuberculosis	1.1

Source: World health statistics 2008 (http://www.who.int/whosis/whostat/2008/en/index.html)

Methods for Road Safety Analysis

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

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

Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult attribution of collisions to a cause

Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult attribution of collisions to a cause
   - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision

Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult attribution of collisions to a cause
    - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision
2. Small data quantity

Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult attribution of collisions to a cause
    - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision
2. Small data quantity
3. Limited quality of the data reconstituted after the event, with a bias towards more damaging collisions

Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult attribution of collisions to a cause
    - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision
2. Small data quantity
3. Limited quality of the data reconstituted after the event, with a bias towards more damaging collisions
4. Traditional road safety analysis is reactive

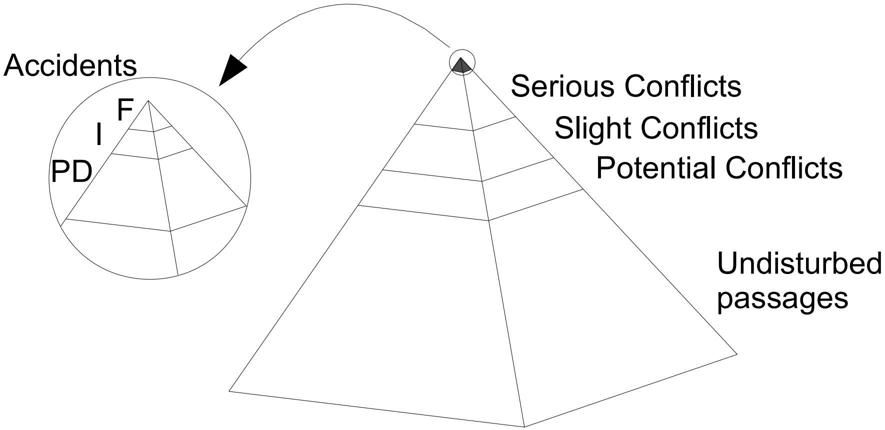
Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult attribution of collisions to a cause
   - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision
2. Small data quantity
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

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

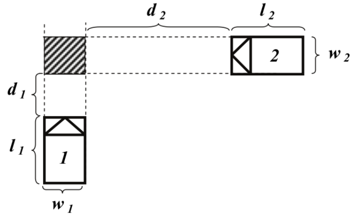


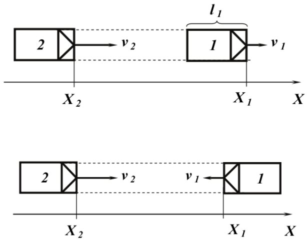
Surrogate Measures of Safety

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





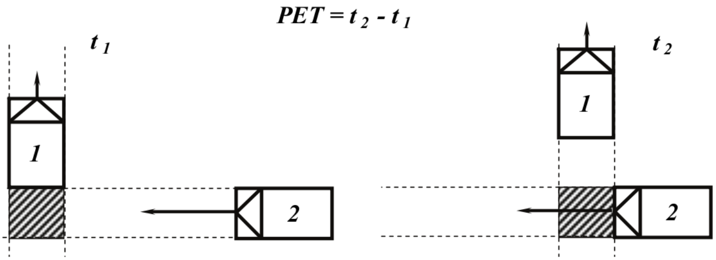
$$TTC = \frac{d_2}{v_2} \; if \; \frac{d_1}{v_1} < \frac{d_2}{v_2} < \frac{d_1 + l_1 + w_2}{v_1}$$

$$TTC = \frac{d_1}{v_1} \; if \; \frac{d_2}{v_2} < \frac{d_1}{v_1} < \frac{d_2 + l_2 + w_1}{v_2} \; (side)$$

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

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

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

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, highways

Outline

Rethinking the Collision Course

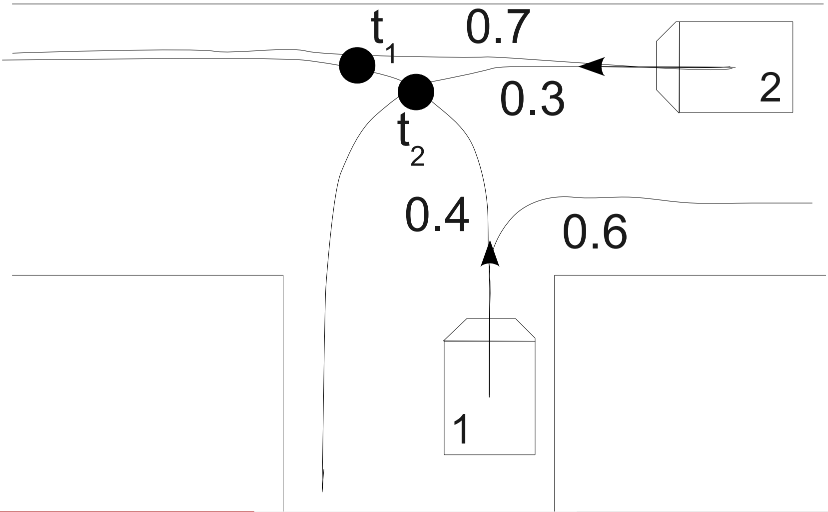
- A traffic conflict is "an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged"
- For two interacting road users, many chains of events may lead to a collision
- It is possible 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

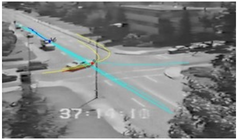
+

Camera Calibration

+

Labeled Images for Road User Type

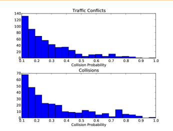
Road User Trajectories



Interactions

Applications

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



Traffic conflicts, exposure and severity measures, interacting behavior

Outline

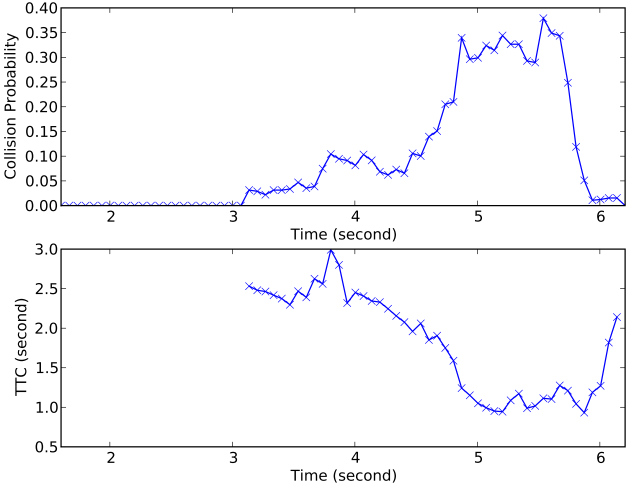
Road User Tracking (Kentucky Dataset)

Motion Prediction

Motion Prediction

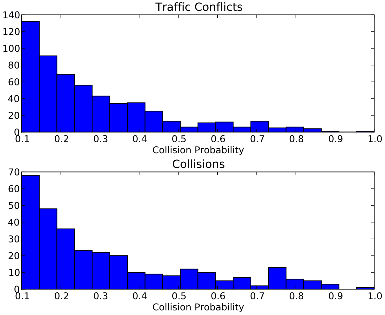
Motion Prediction

Severity Indicators

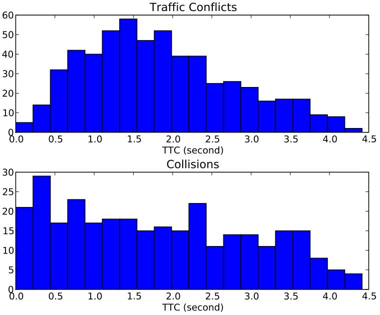


Distribution of Indicators

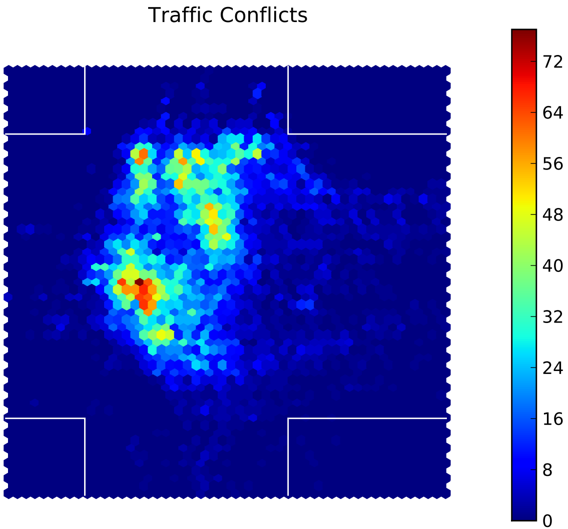
Maximum Collision Probability



Minimum TTC



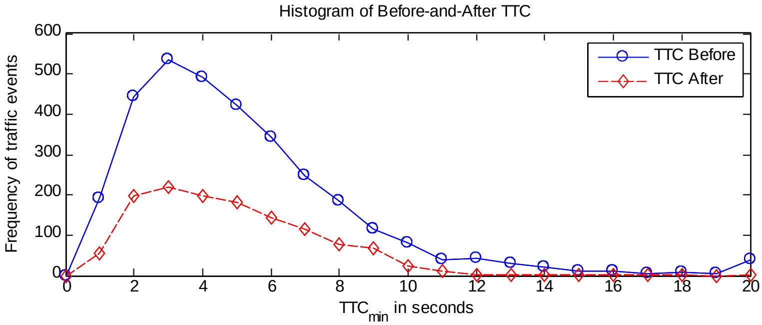
Spatial Distribution of the Collision Points



Before and After Study: Introduction of a Scramble Phase

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

Distribution of Severity Indicators



Lane-Change Bans at Urban Highway Ramps

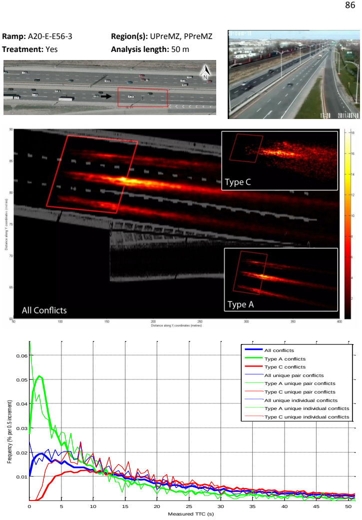


Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).

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

Lane-Change Bans at Urban Highway Ramps

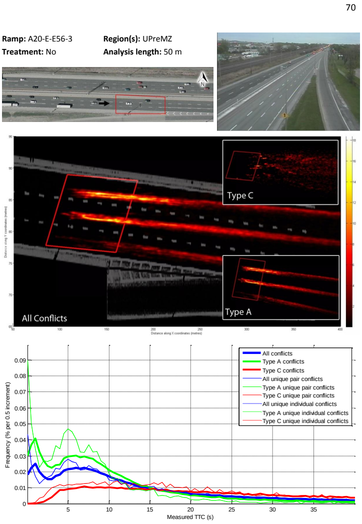
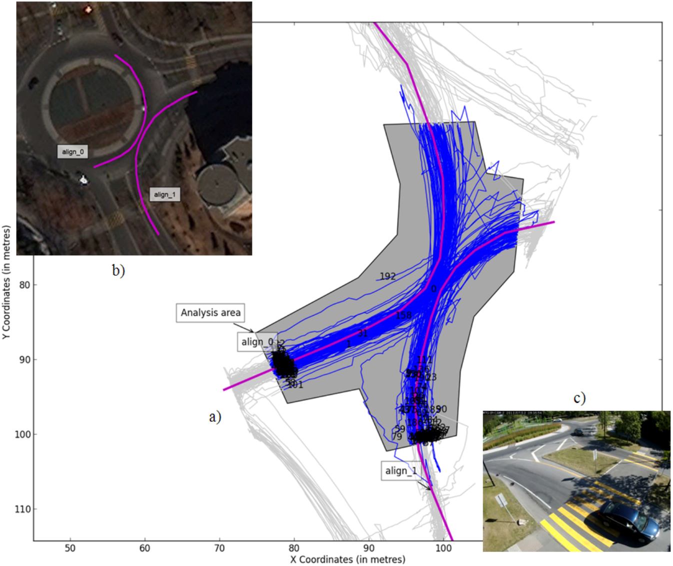


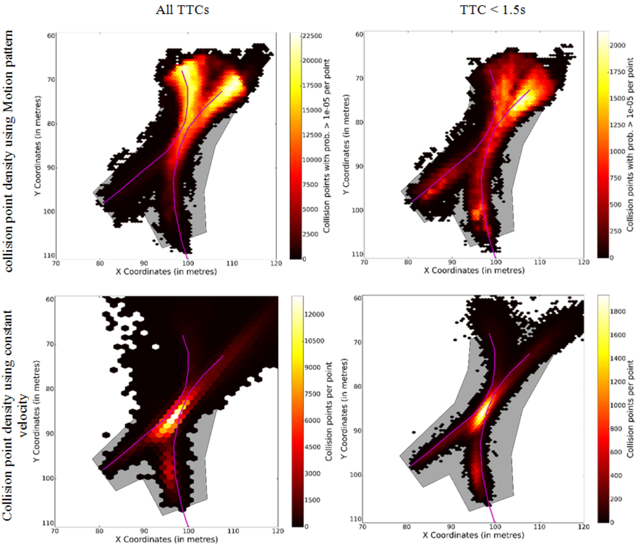
Figure 27 – Conflict analysis Cam20-16-Dorval (Untreated).

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

Roundabouts Safety in Québec



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



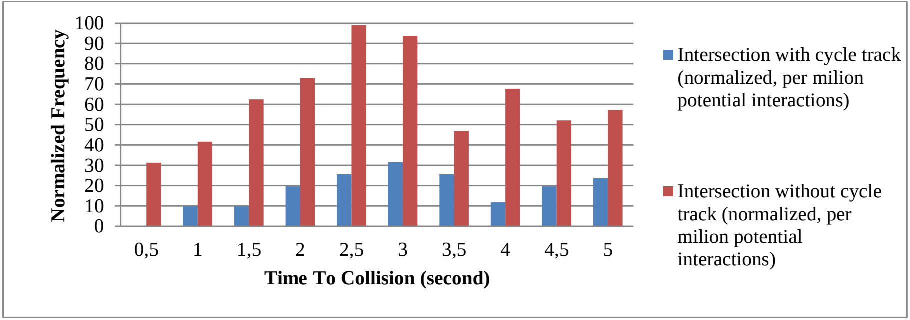
Cycle Track Safety (First Results)

Cycle Track Safety (First Results)

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

Conclusion

- Surrogate methods for safety analysis are complementary methods to understand collision factors and better diagnose safety
- Automated video analysis is feasible to collect traffic data and better understand road user behaviour

Two Final Messages for Transportation Students

1. Computational skills are essential and increasingly so: learn how to program!

Two Final Messages for Transportation Students

1. Computational skills are essential and increasingly so: learn how to program!
    - Computing is the new math

Two Final Messages for Transportation Students

1. Computational skills are essential and increasingly so: learn how to program!
   - Computing is the new math
2. Open science is necessary to enable true reproducibility which is a corner stone of science

Two Final Messages for Transportation Students

1. Computational skills are essential and increasingly so: learn how to program!
    - Computing is the new math
2. Open science is necessary to enable true reproducibility which is a corner stone of science
    - if you cannot reproduce and check another researcher's method, this is not science

Two Final Messages for Transportation Students

1. Computational skills are essential and increasingly so: learn how to program!
   - Computing is the new math
2. Open science is necessary to enable true reproducibility which is a corner stone of science
   - if you cannot reproduce and check another researcher's method, this is not science
   - as young researchers, you can choose to continue research as if the Internet and open source software do not exist, or to embrace sharing data and (software) tools as enabled by the Internet

Traffic Intelligence open source project

https://bitbucket.org/Nicolas/trafficintelligence

- Collaboration with Tarek Sayed (UBC), Karim Ismail (Carleton), Mohamed Gomaa Mohamed, Paul St-Aubin (Polytechnique Montréal), Luis Miranda-Moreno, Sohail Zangenehpour (McGill)
- 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?

Amundsen, F. and Hydén, C., editors (1977).
Proceedings of the first workshop on traffic conflicts, Oslo, Norway. Institute of Transport Economics.

Gettman, D. and Head, L. (2003).
Surrogate safety measures from traffic simulation models, final report.
Technical Report FHWA-RD-03-050, Federal Highway Administration.

Ismail, K., Sayed, T., and 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.
presented at the 2010 Transportation Research Board Annual Meeting.

Mohamed, M. G. and Saunier, N. (2013).

Motion prediction methods for surrogate safety analysis.
In *Transportation Research Board Annual Meeting Compendium of Papers*.
13-4647. Accepted for publication in Transportation Research Record: Journal of the Transportation Research Board.

Saunier, N. and Mohamed, M. G. (2014).
Clustering surrogate safety indicators to understand collision processes.
In *Transportation Research Board Annual Meeting Compendium of Papers*.
14-2380.

Saunier, N. and Sayed, T. (2008).
A Probabilistic Framework for Automated Analysis of Exposure to Road Collisions.
Transportation Research Record: Journal of the Transportation Research Board, 2083:96–104.

presented at the 2008 Transportation Research Board Annual Meeting.

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.
presented at the 2010 Transportation Research Board Annual Meeting.

Saunier, N., Sayed, T., and Lim, C. (2007).
Probabilistic Collision Prediction for Vision-Based Automated Road Safety Analysis.
In *The 10th International IEEE Conference on Intelligent Transportation Systems*, pages 872–878, Seattle. IEEE.

St-Aubin, P., Miranda-Moreno, L., and Saunier, N. (2012).

A surrogate safety analysis at protected freeway ramps using cross-sectional and before-after video data.
In *Transportation Research Board Annual Meeting Compendium of Papers*.
12-2955.

St-Aubin, P., Miranda-Moreno, L., and Saunier, N. (2013).
An automated surrogate safety analysis at protected highway ramps using cross-sectional and before-after video data.
Transportation Research Part C: Emerging Technologies, 36:284–295.

St-Aubin, P., Saunier, N., and Miranda-Moreno, L. F. (2014).
Road user collision prediction using motion patterns applied to surrogate safety analysis.
In *Transportation Research Board Annual Meeting Compendium of Papers*.
14-5363.