New Opportunities in Predictive and Pro-active Traffic Safety Evaluation and Management in the Era of Smart Cities

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Vision Zero Town + Gown Research on the Road
06/10/2021

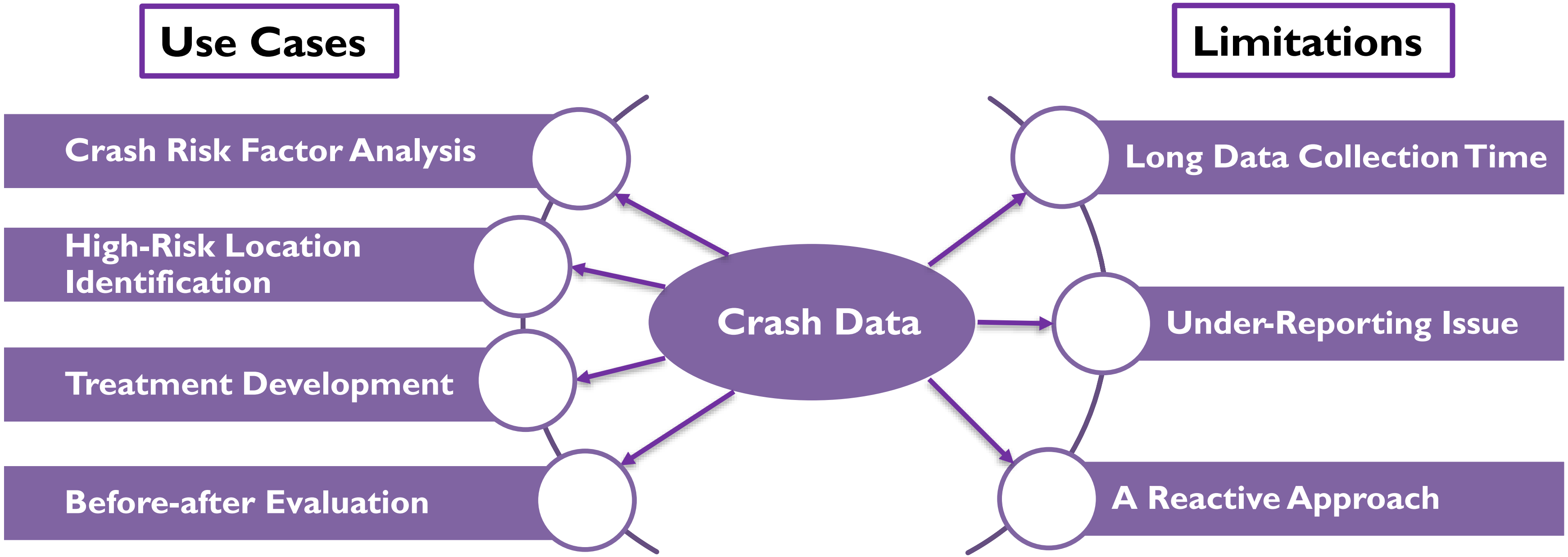
Safety Facts

NYU

- **Each year, there are about 1.35 million road traffic deaths and 50 million injured worldwide.**
- **Road crashes are expected to rise to the 7^{th} leading cause of death by the year 2030.**

https://www.togetherforsaferroads.org/; https://www.voanews.com/science-health/who-traffic-crashes-are-leading-killer-children; https://tucson.com/news/local/arizona-legislators-move-to-stiffen-penalties-for-causing-fatal-traffic/article_c5f380eb-297d-53c2-ac00-054adf70aff7.html; https://www.who.int/violence_injury_prevention/key_facts/VIP_key_fact_3.pdf

Police-Reported Crash Data



A large number of crashes need to occur before analysis can be conducted.

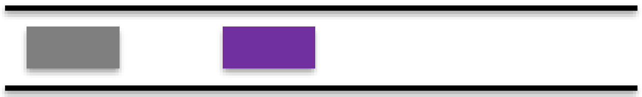
Surrogate Safety Measures

- **Surrogate Safety Measures (SSMs):**
  - Used to identify traffic conflicts or "near-misses".
  - Extracted from vehicle trajectories.

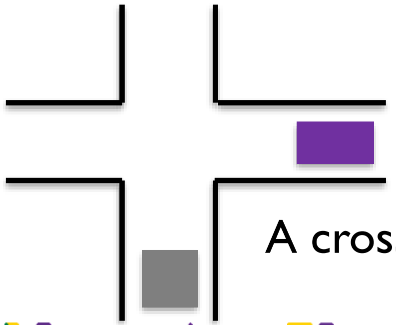
Traditionally, the collection of vehicle trajectories is relatively difficult or time consuming.

- **Traffic safety risk can thus be reflected by the identified traffic conflicts.**

- **A more proactive approach.**



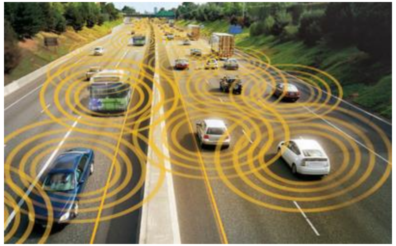
A rear-end conflict



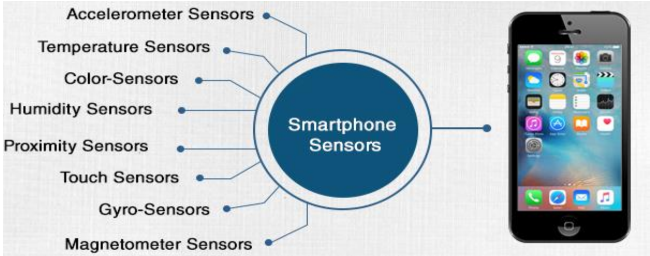
A crossing conflict

Emerging Technologies

- **In the era of smart cities, the collection of vehicle trajectories becomes easier due to various emerging technologies.**



Connected Vehicles



Smartphones

Drones

Laureshyn, A., & Varhelyi, A. (2018). The Swedish Traffic Conflict Technique: observer's manual.; https://wydotcvp.wyoroad.info/; http://myphonefactor.in/2012/04/sensors-used-in-a-smartphone/; https://www.tomstechtime.com/post/2019/01/12/whats-the-best-drone-video-editing-software

USDOT NYC Connected Vehicle Pilot Deployment

New York City is one of three ***Connected Vehicle (CV) pilot deployment*** sites selected by USDOT to demonstrate the benefits of this new Connected Vehicle technology.

The CV technology is a new tool to help NYC reach its ***Vision Zero*** goals to eliminate traffic related deaths and reduce crash related injuries and damage to both the vehicles and infrastructure.

3000+ vehicles

450+ Roadside Units

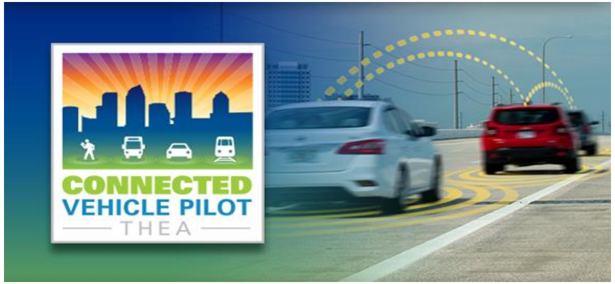
14 Mobility and Safety Applications
(include one that supports people with visual disabilities)

NYC Connected Vehicle pilot deployment Website: https://cvp.nyc

USDOT Other Connected Vehicle Pilot Deployment

- **Wyoming Connected Vehicle Pilot**
  - Objective: improving safety and travel reliability on i-80 in Wyoming
  - Scope:
    - 400 instrumented vehicles
    - 75 roadside units

- **Tampa Connected Vehicle Pilot**
  - Objective: transform the experience of drivers, transit riders and pedestrians in downtown Tampa by preventing crashes, enhancing traffic flow, improving transit trip times and reducing emissions of greenhouse gases.
  - Scope:
    - Over 1000 privately owned vehicles
    - 10 buses
    - 8 streetcars
    - 46 roadside units



https://wydotcvp.wyoroad.info/; https://theacvpilot.com/;

Video-Based Safety Evaluation (Work funded by AIG)

- **Goals: Advance data-driven traffic analytics to enhance Global Resilience**
- **Objectives:**
  - ✓ Propose a novel approach for examining traffic safety performance at intersections
  - ✓ Quantify traffic conflicts using developed "***surrogate***" safety measures
  - ✓ Develop automatic data acquisition, analysis and modeling approaches based on computer vision techniques

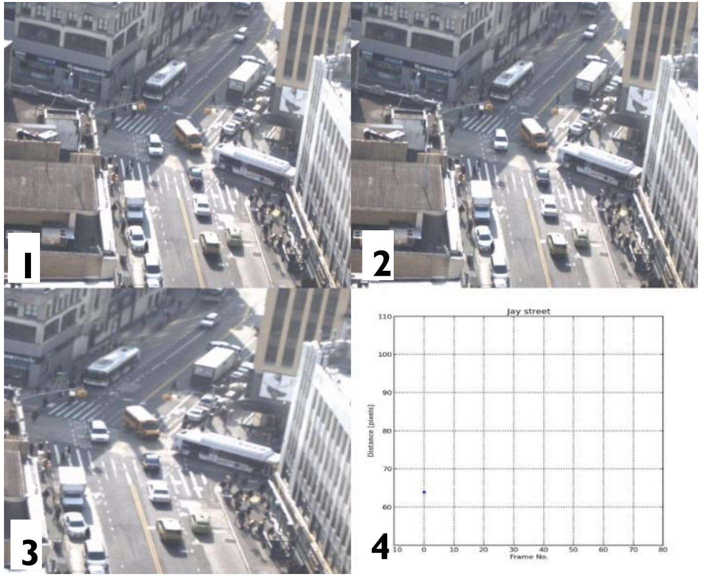
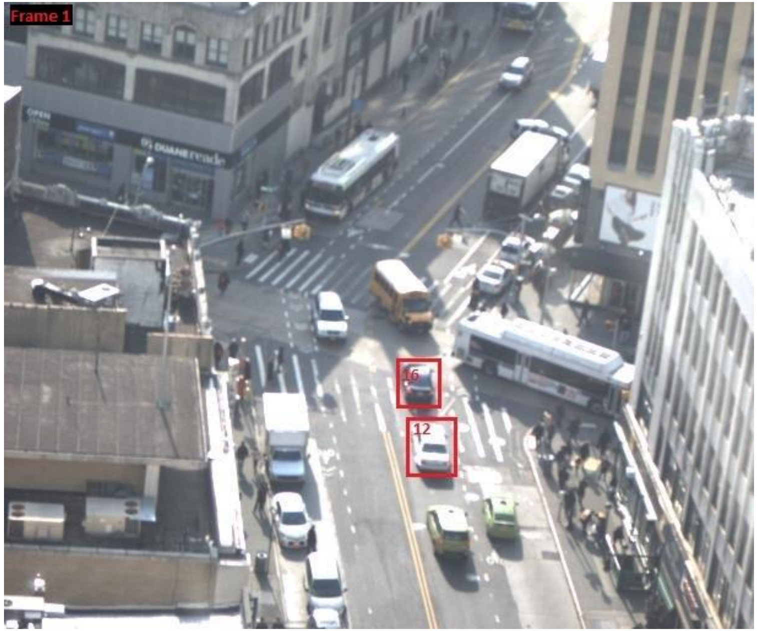


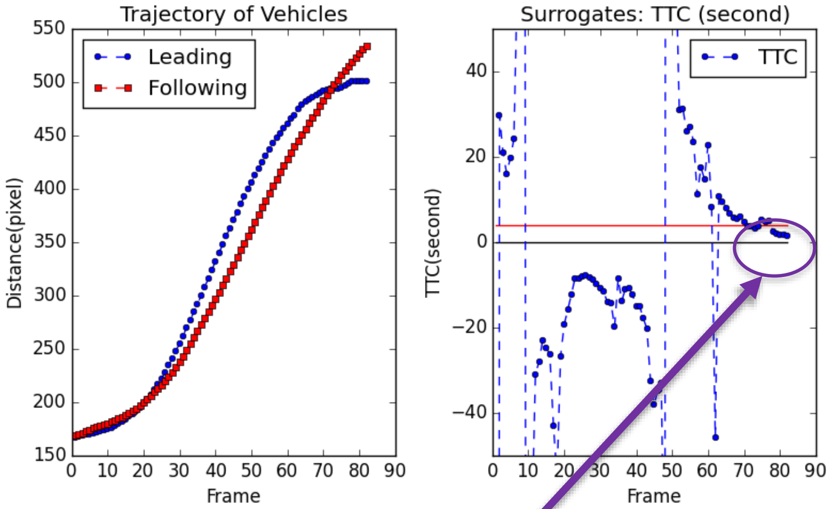
Fig. 1: Original video recording
Fig. 2: Extract feature points using Kanade-Lucas-Tomasi (KLT) Feature Tracker
Fig. 3: Group feature points using Dirchlet process mixture algorithm
Fig. 4: Convert coordinates to relative distances

NYU UrbanMITS lab (in collaboration with AIG), Development of A Comprehensive Experimental and Theoretical Methodology for Video-based Safety Assessment

Video-Based Safety Evaluation

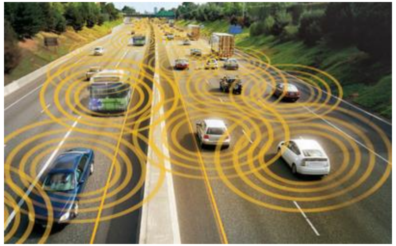


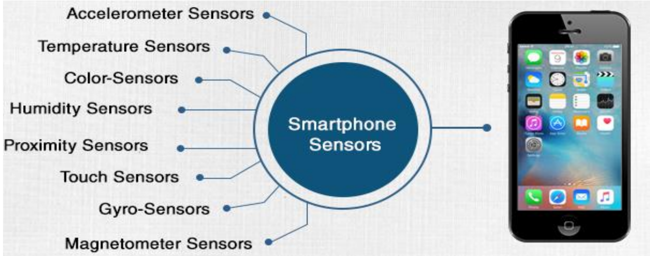
Estimated Surrogate Events based on Automatic Tracking Results



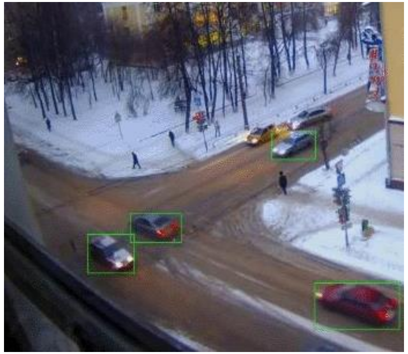
Conflicts: TTC<4.0 seconds

Proactive Safety Evaluation & Monitoring





Traffic risk can be quantified.



Suitable for proactive safety monitoring.

- Detect potential safety-related anomalies that may cause high traffic risk.
- Provide intervention.

Characteristics of Surrogate Events

Surrogate Events

- **Frequent**
  - Large amount of conflict data can be collected in a relatively short period of time (e.g., hours or days)
- **Detailed temporal and spatial information**
  - e.g., accurate at the second and the lane level

How to represent safety risk?
What method should we use to capture these characteristics?

Crashes

- **Rare events**
  - Often take months or years to accumulate.
- **Rough location and time information**
  - e.g., at the intersection level

Often aggregated yearly or monthly for statistical modeling.

Functional Data Analysis

- **A typical example**
  - X axis: 12 months from January to December
  - Y axis: mean temperature
  - Each curve: one weather station in Canada
- **Formally, FDA is**
  - A branch of statistics that analyzes data providing information about curves, surfaces or anything else varying over a continuum.
  - The physical continuum over which these functions are defined is often time.

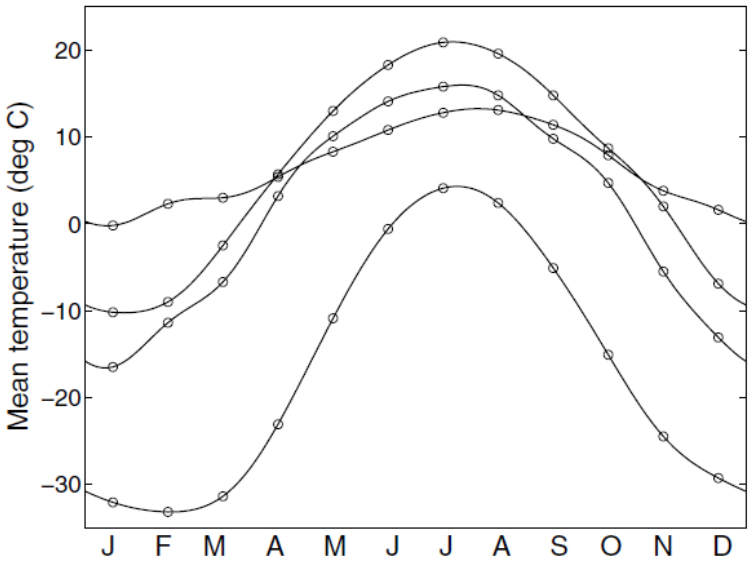
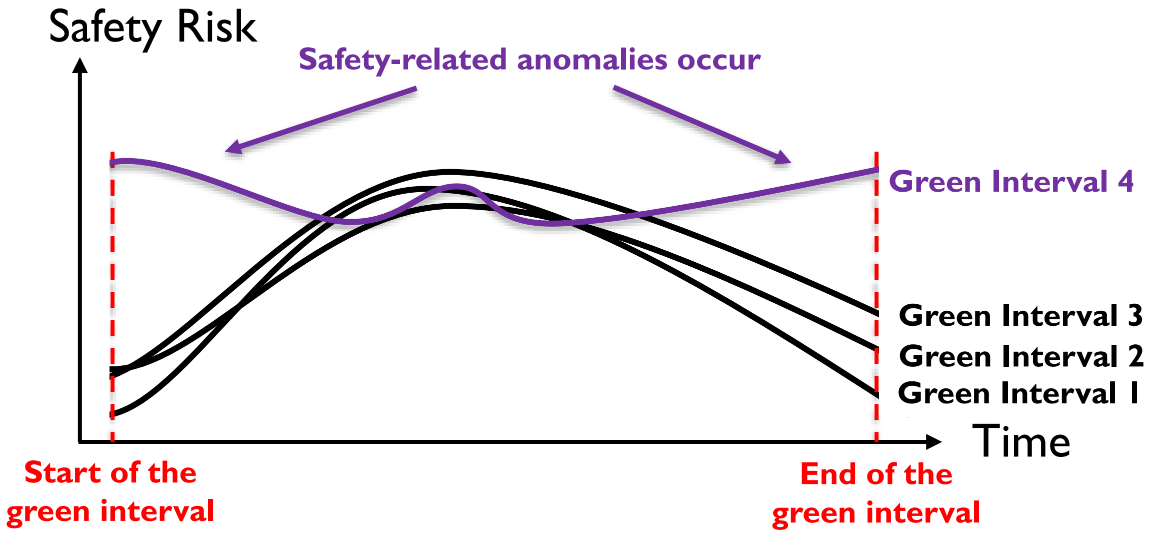


Figure 1.6 from *Ramsay and Silverman (2005).*

Functional Data Analysis for Proactive Safety Monitoring

NYU

- **Analogously, for signalized intersections with pre-timed signal mode.**
  - Model time series of traffic risk to detect green intervals with safety-related anomalies.



Safety Risk:

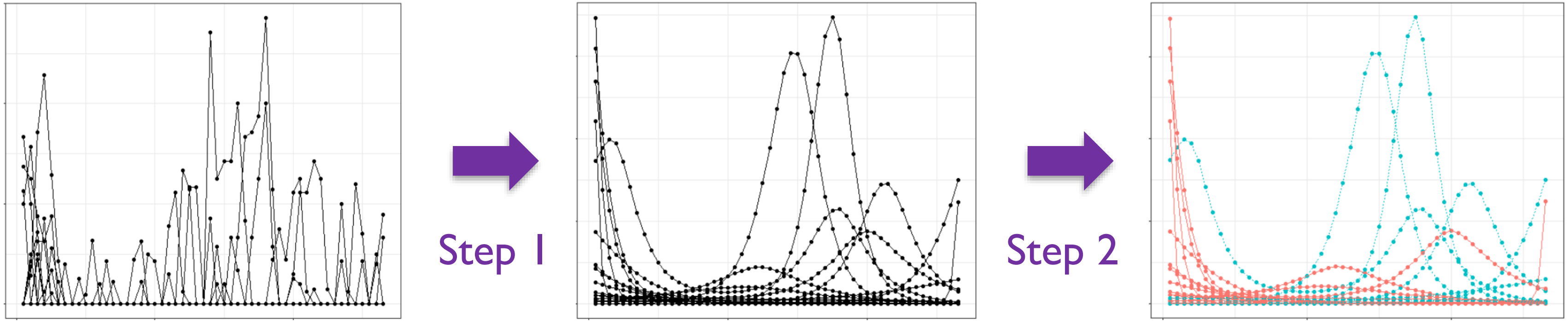
- Number of surrogate events / number of vehicles (unit: second)

Safety-related anomalies:

- **Type 1**: vehicles commit dangerous or illegal lane changing behaviors.
- **Type 2**: vehicles slow down or stop unexpectedly or abruptly.
- **Type 3**: vehicles blocked by other vehicles in the crossing directions.

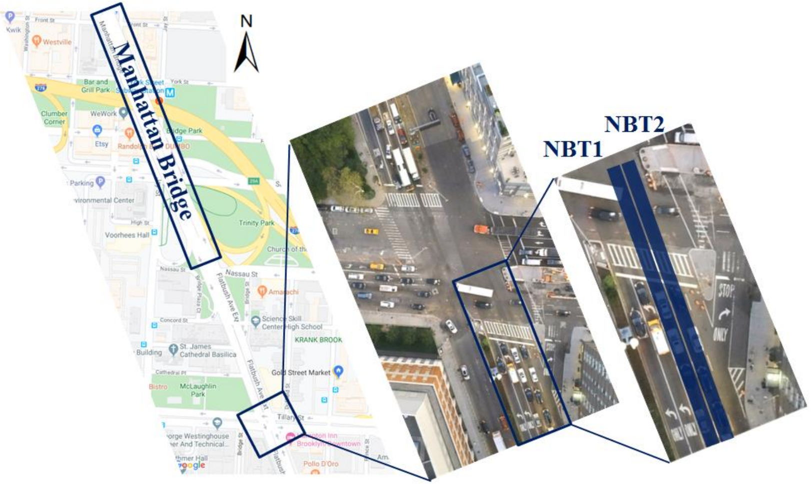
Key Steps in Functional Data Analysis

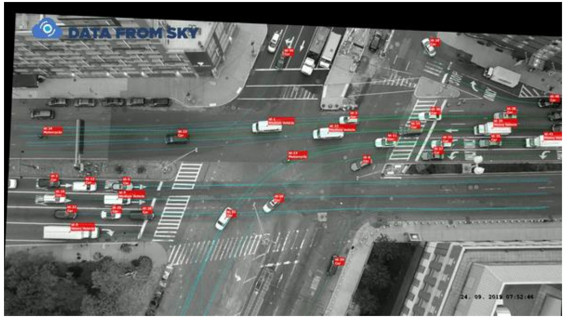
- **Two key steps of using FDA for proactive safety monitoring:**
  - Step 1: Data representation – Functional data smoothing
    - Convert from discrete observations to continuous functions for further mathematical analysis.
  - Step 2: Extract functional outlier detection measures from the estimated functional curves for outlier detection.



Data Collection

- **Location: Flatbush Avenue & Tillary Street**
  - Study movement: the northbound throughput (NBT) direction.
- **Time: Morning peak period (6 AM to 8 AM)**

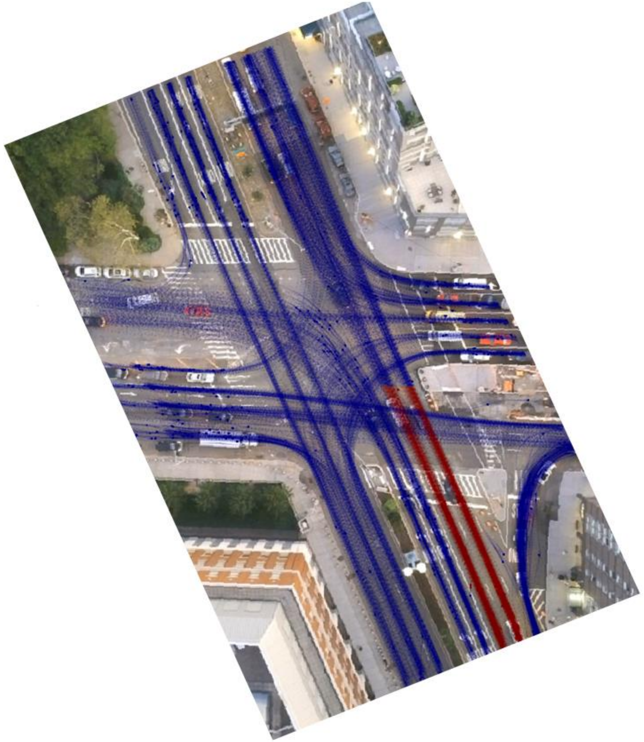




Data Collection

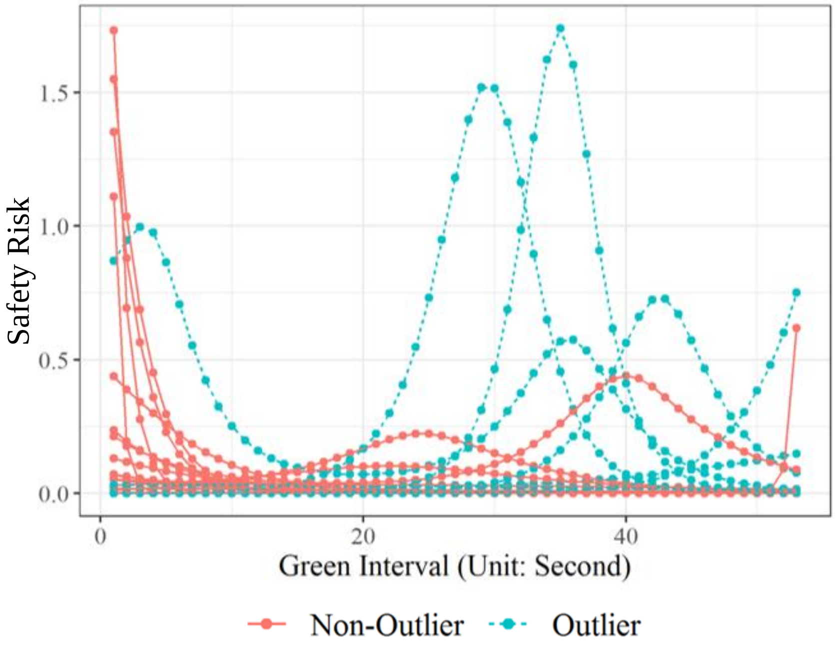
- **Extraction of vehicle trajectories**
  - Anonymous vehicle trajectories were extracted from the recorded UAV videos by a company called Data From Sky.
    - Longitude & latitude, speed, acceleration, and vehicle type

Time	Vehicle ID	Vehicle Type	Latitude	Longitude	Speed	Acceleration (longitudinal)	Acceleration (lateral)
0.1	1	Car	40.695942	-73.984531	12.5543	-0.0181	0.0647
0.2	1	Car	40.695941	-73.984527	12.5437	-0.0427	0.0831
0.3	1	Car	40.695941	-73.984523	12.5241	-0.0675	0.0998
0.4	1	Car	40.695941	-73.984519	12.4954	-0.0961	0.1202
0.5	1	Car	40.695941	-73.984515	12.5055	-0.0578	0.0889
0.6	1	Car	40.695941	-73.98451	12.4794	-0.085	0.1084
0.7	1	Car	40.69594	-73.984506	12.4443	-0.1091	0.1134
0.8	1	Car	40.69594	-73.984502	12.4024	-0.1223	0.1166
0.9	1	Car	40.69594	-73.984498	12.3571	-0.1298	0.1112
1	1	Car	40.69594	-73.984494	12.3109	-0.1268	0.1004



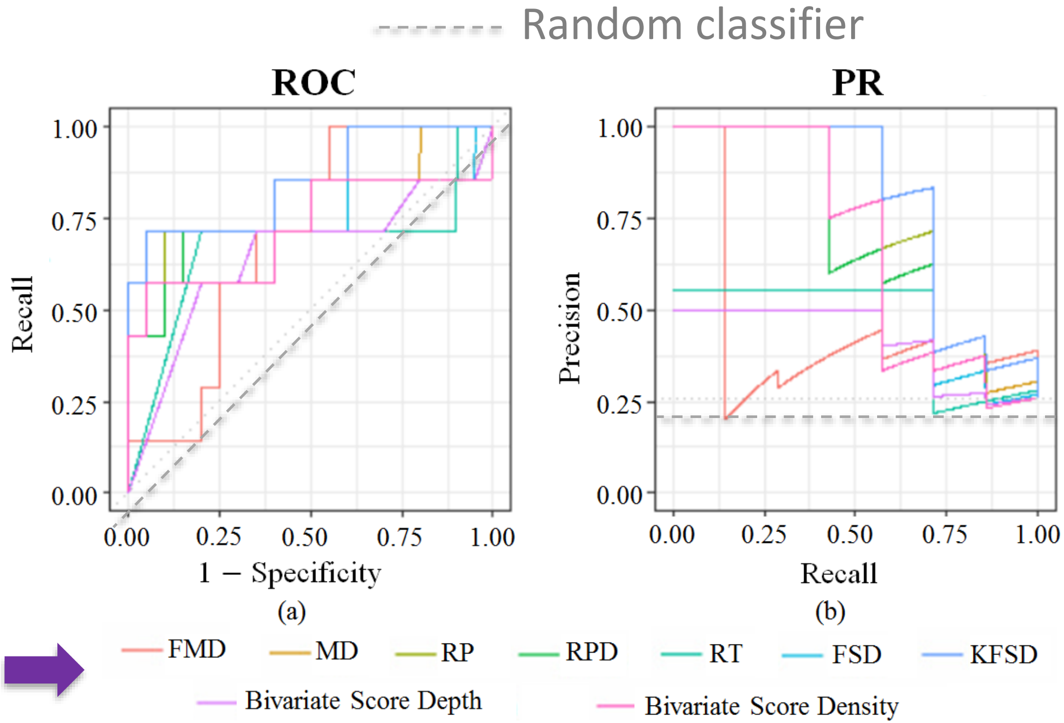
Results: Smoothing Functional Curves

- **Findings:**
  - Distinct separation between outliers and non-outliers.
  - Peaks at the beginning of the green interval.
    - Caused by early acceleration of vehicles in queue before the acceleration of the vehicles in front.
    - This pattern cannot be revealed if traffic risk is aggregated into summary statistics of any kind.



Results: Receiver Operating Characteristics (ROC) & Precision-Recall (PR) curves

- **Findings**
  - Overall, ROC curves of all the functional outlier detection measures are above the random classifier line.
  - PR curves show similar patterns.



9 functional outlier detection measures are compared.

Results: Area Under the Curve (AUC)

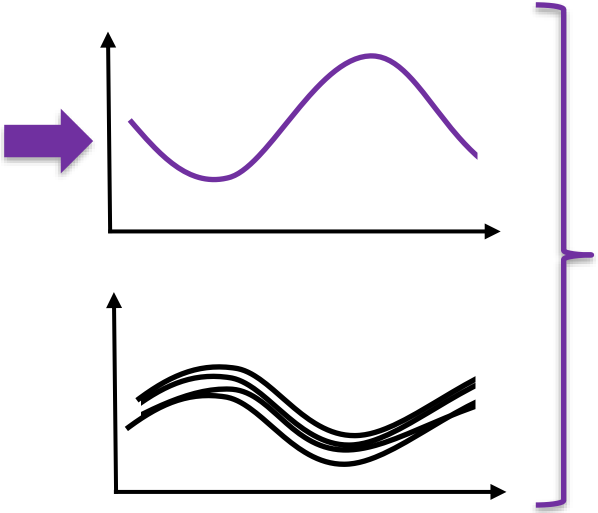
- **Findings:**
  - Best outlier detection measures is consistent for both ROC and PR AUC values.
    - Consistent between ROC-AUC and PR-AUC
  - Good separation between normal and abnomal cases are achieved.

	FMD	MD	RP	RPD	RT	FSD	KFSD ✓	Bivariate Score Depth	Bivariate Score Density
AUC-ROC	0.70	0.82	0.79	0.82	0.77	0.77	0.85 ✓	0.65	0.72
AUC-PR	0.45	0.79	0.76	0.71	0.57	0.77	0.80 ✓	0.42	0.68

Practical Implementation

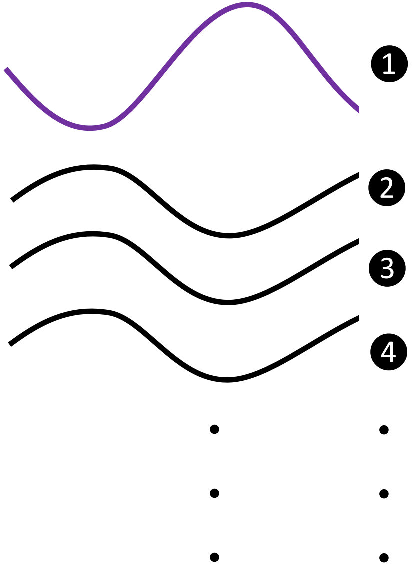
Step 1:
Collect real time data feed

Step 2:
Generate new risk function

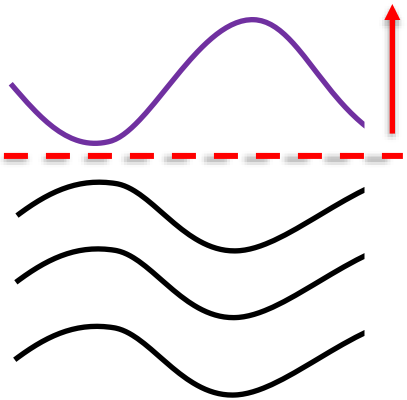


Reservoir of historically identified normal risk functions

Step 3:
Calculate outlier detection measure



Step 4:
Identify anomalies based on a preset threshold.



Our Paper

- **Yang, D., Ozbay, K., Xie, K., Yang, H., Zuo, F., Sha, D., 2021. Proactive safety monitoring: A functional approach to detect safety-related anomalies using unmanned aerial vehicle video data. Transportation Research Part C: Emerging Technologies 127, 103130.**
  - DOI: https://doi.org/10.1016/j.trc.2021.103130

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Transportation Research Part C: Emerging Technologies

Volume 127, June 2021, 103130

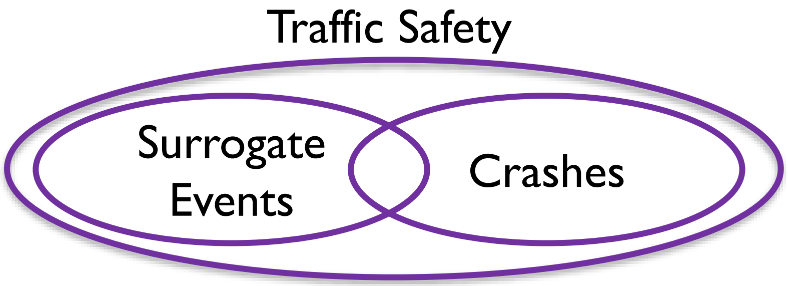
TRANSPORTATION RESEARCH

Proactive safety monitoring: A functional approach to detect safety-related anomalies using unmanned aerial vehicle video data

Di Yang [a], Kaan Ozbay [a], Kun Xie [b], Hong Yang [c], Fan Zuo [a], Di Sha [a]

What About Crash Data?

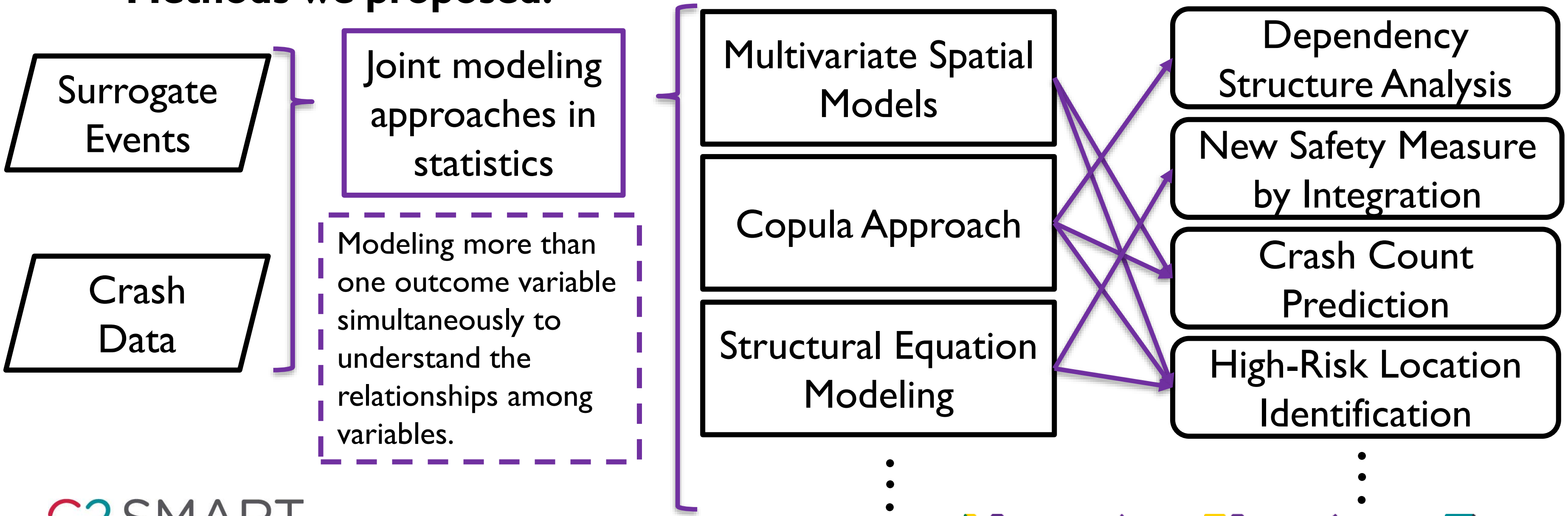
- **Only surrogate events are used above to quantify traffic safety risk.**
- **However, both crash data and surrogate events can provide information regarding traffic safety conditions.**
  - Most of the studies in the literature used only one of these.
  - However, this may lead to inaccurate safety estimates, which accordingly may lead to incorrect decision making and waste of sources.
- **It is important to combine both of these together in a robust way.**



Tarko, A., 2018. Surrogate measures of safety. Safe mobility: Challenges, methodology and solutions. Emerald Publishing Limited, 383-405.

Integration of Crashes and Safety Risk for Safety Analysis

- **Integrating both crash data and safety risk may result in more comprehensively evaluation of traffic safety.**
- **Methods we proposed:**



Our Research

- **Yang, D., Xie, K., Ozbay, K.,Yang, H., Budnick, N., 2019. Modeling of time-dependent safety performance using anonymized and aggregated smartphone-based dangerous driving event data. Accident Analysis and Prevention 132, 105286.**

- **Yang, D., Xie, K., Ozbay, K., Zhao, Z.,Yang, H., 2021. Copula-based joint modeling of crash count and conflict risk measures with accommodation of mixed count-continuous margins. Analytic Methods in Accident Research 31, 100162.**

- **Yang, D., Xie, K., Ozbay, K.,Yang, H., 2021. Fusing crash data and surrogate safety measures for safety assessment: Development of a structural equation model with conditional autoregressive spatial effect and random parameters. Accident Analysis and Prevention 152, 105971.**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Accident Analysis & Prevention
Volume 132, November 2019, 105286

Modeling of time-dependent safety performance using anonymized and aggregated smartphone-based dangerous driving event data

Di Yang [a], Kun Xie [b], Kaan Ozbay [c], Hong Yang [d], Noah Budnick [e]


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Analytic Methods in Accident Research
Volume 31, September 2021, 100162

Copula-based joint modeling of crash count and conflict risk measures with accommodation of mixed count-continuous margins

Di Yang, Kun Xie, Kaan Ozbay, Zifeng Zhao, Hong Yang


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Accident Analysis & Prevention
Volume 152, March 2021, 105971

Fusing crash data and surrogate safety measures for safety assessment: Development of a structural equation model with conditional autoregressive spatial effect and random parameters

Di Yang [a], Kun Xie [b], Kaan Ozbay [a], Hong Yang [c]

The Future of Proactive Safety Management

- **Other potential approaches for integrating surrogate events and crashes**
- **Other potential use cases of functional approach in transportation safety**
  - Facilitate proactive safety management for signalized intersections
  - Calibration of microsimulation models for safety evaluation
  - Signal timing optimization accounting for safety
  - Ramp-metering control strategy development accounting for safety

Comprehensive Evaluation of Feedback-Based Freeway Ramp-Metering Strategy by Using Microscopic Simulation: Taking Ramp Queues into Account

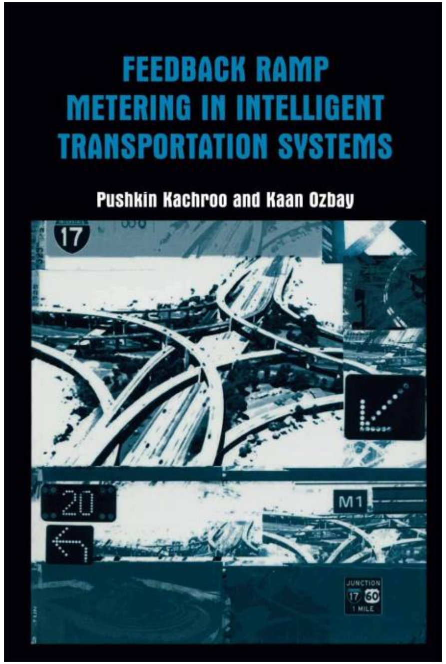
Kaan Ozbay, Ilgin Yasar, Pushkin Kachroo

First Published January 1, 2004 | Research Article
https://doi.org/10.3141/1867-11

ELSEVIER
Accident Analysis & Prevention
Volume 38, Issue 2, March 2006, Pages 279-288

Quantifying effects of ramp metering on freeway safety ☆

Chris Lee [a], Bruce Hellinga [b], Kaan Ozbay [c]



https://jackuldrich.com/blog/future/questioning-a-different-and-better-future-in-4-minutes/attachment/future-road-ahead-with-question-mark/


Source: NYCDOT

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