A Novel Approach to Evaluate Pedestrian Safety at Unsignalized Crossings using Trajectory Data

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Outline

1. Motivation & Literature Review

2. Framework Description

3. Model Illustration – Case Study

4. Conclusion & Future Work

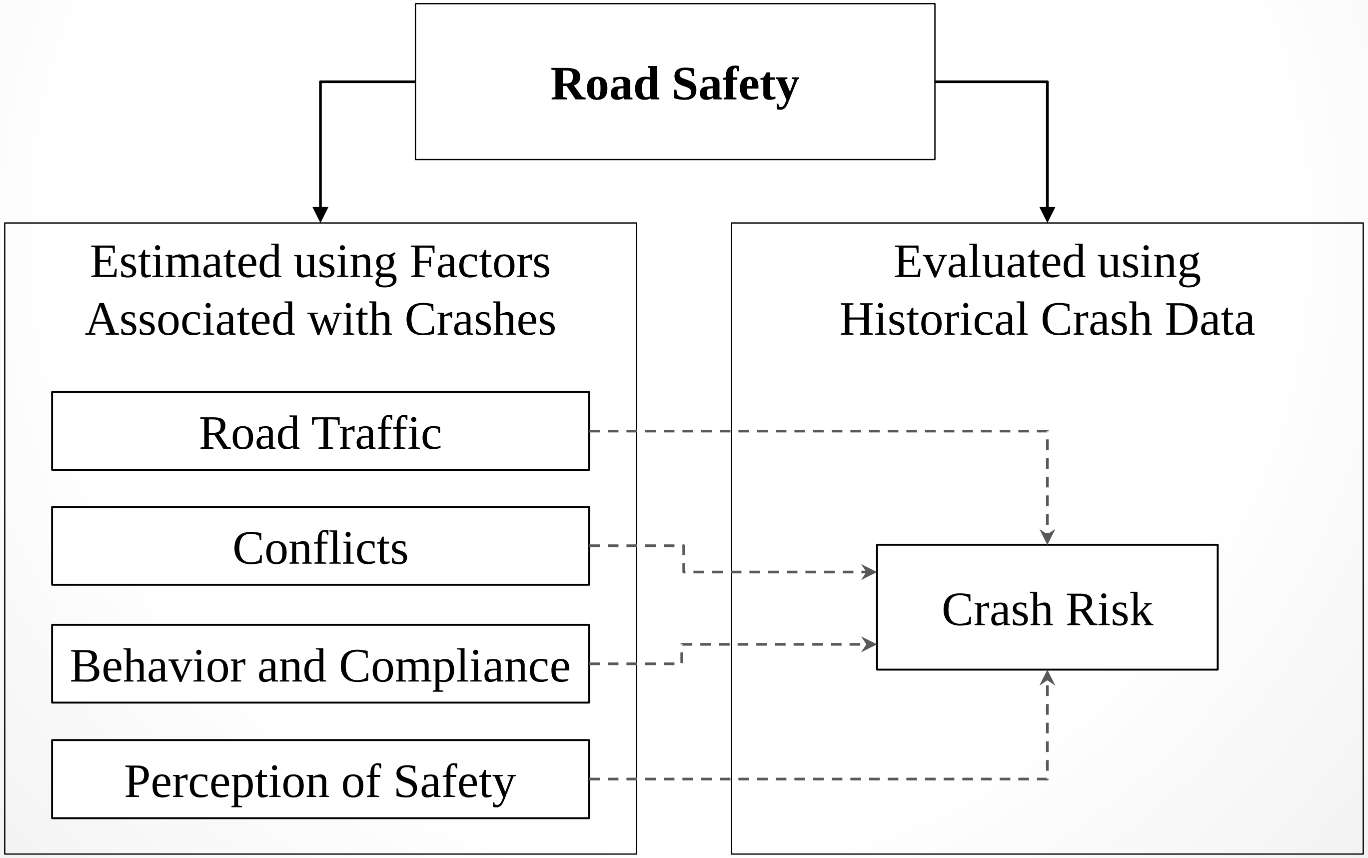
1. Motivation & Literature Review

- **Unsignalized Locations** – Not "controlled by traffic signal" (UIIG 2016)
  - **Uncontrolled**, no device assigning right-of-way
  - **Yielding sign controlled**
  - **Stop controlled**

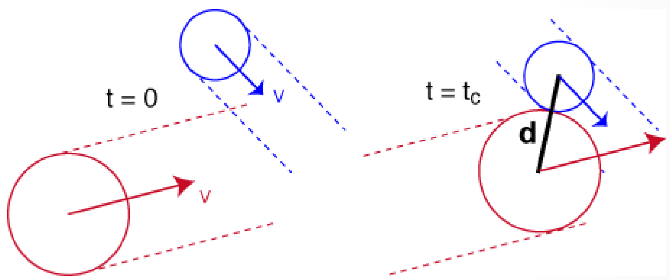
- Volume is relatively low, but crash frequency keeps high
    - US – over 70 % fatal crashes, 2010-2012

- **Past Methodologies**

undergoing literature review project



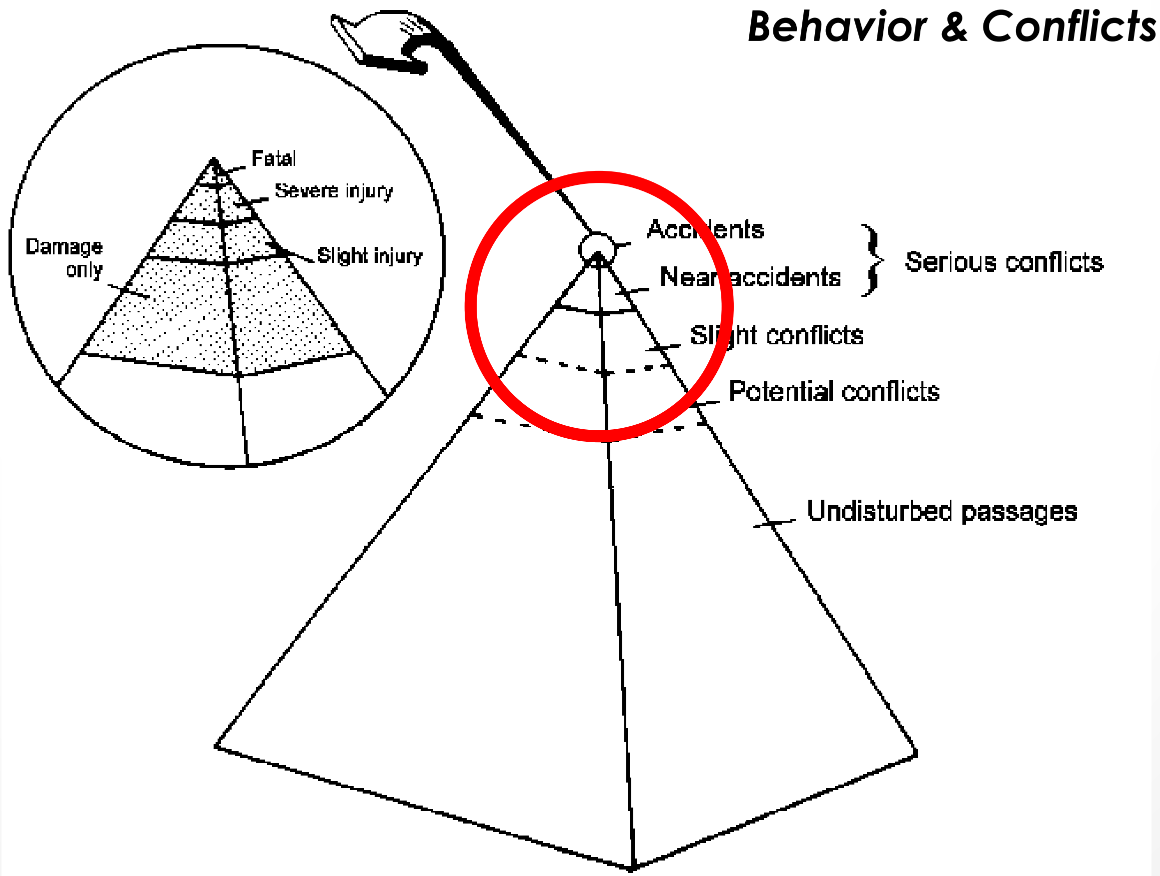
- **Past Methodologies**
  - Behavior Measures – Yielding behavior, crossing decision measures
  - Traffic Conflict Techniques (TCT) – PET, TTC, ET etc.



Past Methodologies

Hyden's Pyramid

Behavior & Conflicts - Refined



- **Past Methodologies**
  - **Limitations of Currently used Conflict & Behavior Measures**
    - **Conflict – not quite suitable**
      - TTC – constant velocity
      - PET – waiting is ignored
      - Severity not included (speed)

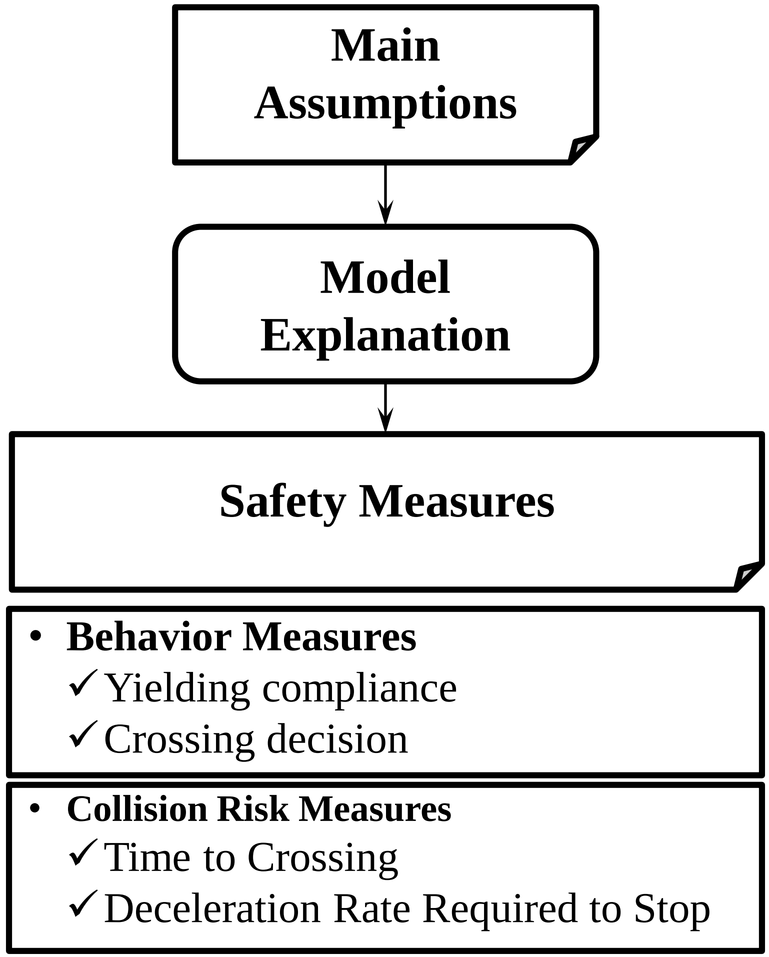
- **Past Methodologies**
  - **Limitations of Currently used Conflict & Behavior Measures**
    - **Behavior – less explored, and much unexplained**
      - Yielding – situation of being too close
      - Crossing – narrowly studied, off-road experiments
      - Quantify event severity using behaviors is limited

- **Motivation**
  - **99 % of crashes were due to human factors – behavior/reaction**
  - **Find a potential solution using behavior measures that could address all the previous mentioned issues**

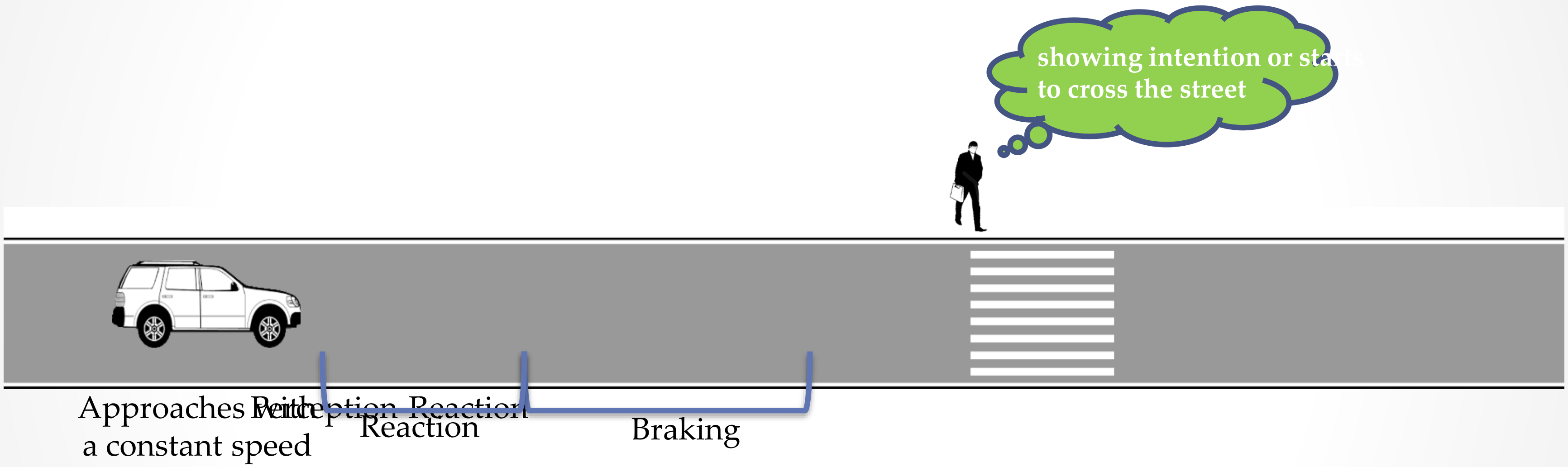
2. Methodological Framework

The Framework for Pedestrian Safety

Fu et al., TRB 2017, submitted to AAP (Minor Revision Required)


Main Assumptions
Model Explanation
Safety Measures
• Behavior Measures
✓Yielding compliance
✓Crossing decision
• Collision Risk Measures
✓Time to Crossing
✓Deceleration Rate Required to Stop

- **Main Assumptions**



- **Drivers:** perfect knowledge of being able to stop in front of the crosswalk.
- **Maximum deceleration rate:** decided by the pavement friction rate.

- **Some Basic Definitions**

  - Pedestrian Occurrence
  - Pedestrian Crossing Decisions
  - Pedestrian Groups

Refer to **Fu et al., AAP** for details.

Main Assumptions

↓

Model Explanation

↓

Safety Measures

- **Behavior Measures**
  - ✓ Yielding compliance
  - ✓ Crossing decision

- **Collision Risk Measures**
  - ✓ Time to Crossing
  - ✓ Deceleration Rate Required to Stop

Model Explanation

- Based on these assumptions, whether the driver is able to stop can be decided by the distance (D) and approaching speed (v) of the vehicle
- Minimum stopping distance (D_{min}) - the minimum required distance for the vehicle to make a stop (stop distance)

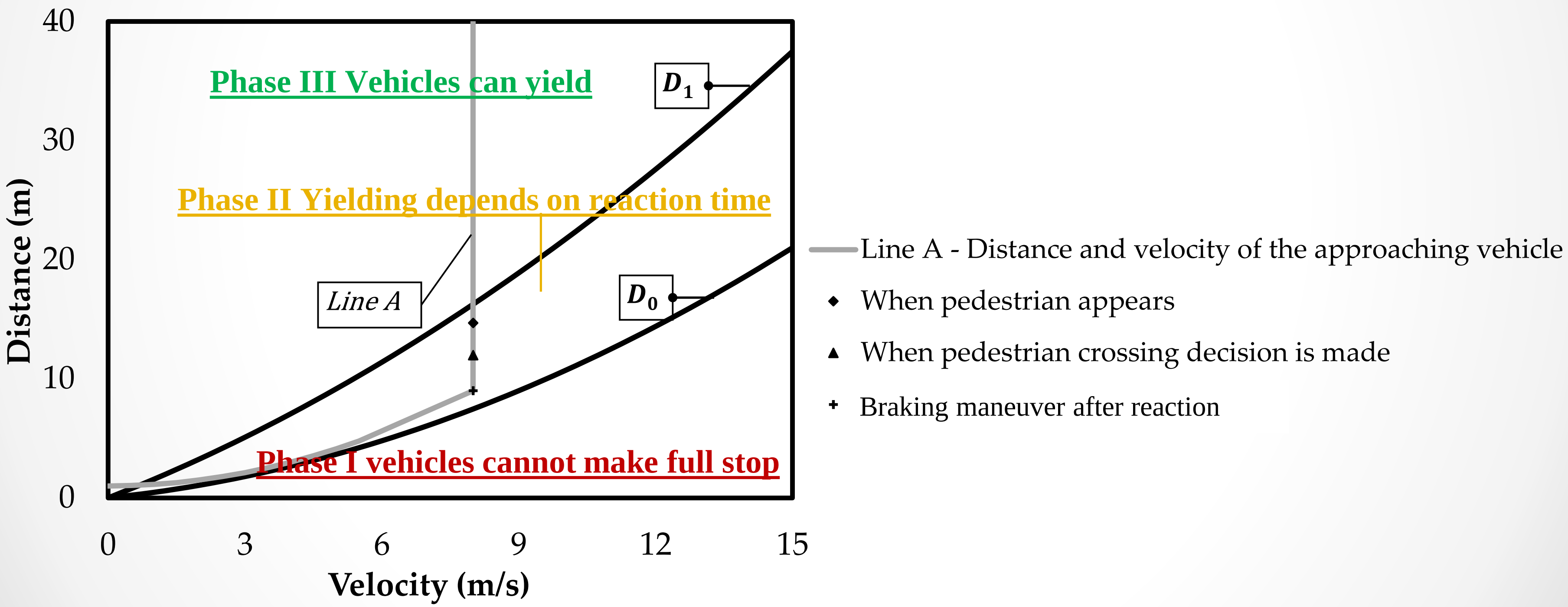
$$D_{min} = vt_r + \frac{v^2}{2g(\mu_{max} - \theta)}$$

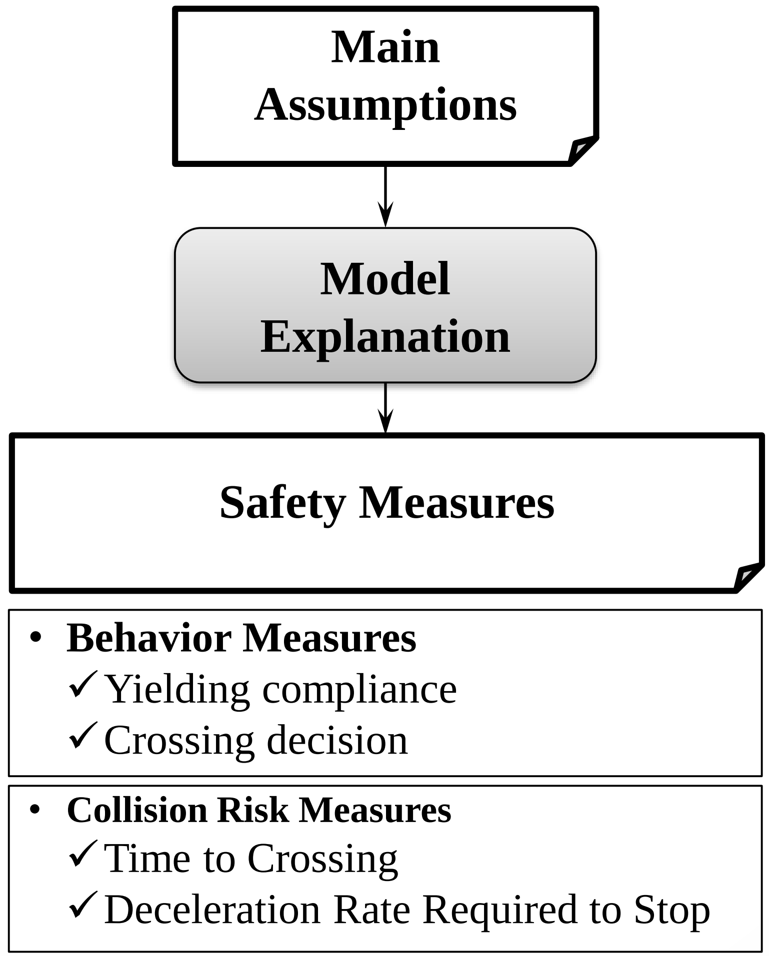
- If $D > D_{min}$, they are required to stop
- As $t_r \in [t_{r\_min}, t_{r\_max}]$,

$$\mathbf{D_{min} \in [D_0, D_1]} = [vt_{r\_min} + \frac{v^2}{2g(\mu_{max} - \theta)}, vt_{r\_max} + \frac{v^2}{2g(\mu_{max} - \theta)}]$$

where v is the approaching speed of the vehicle, t_r is the perception-reaction time, μ_{max} is the maximum friction rate the road can provide for braking, g is the acceleration of gravity, θ is the slope angle of the road. When vehicle distance is greater than the minimum stopping distance, they are required to stop and yield.

Model Explanation

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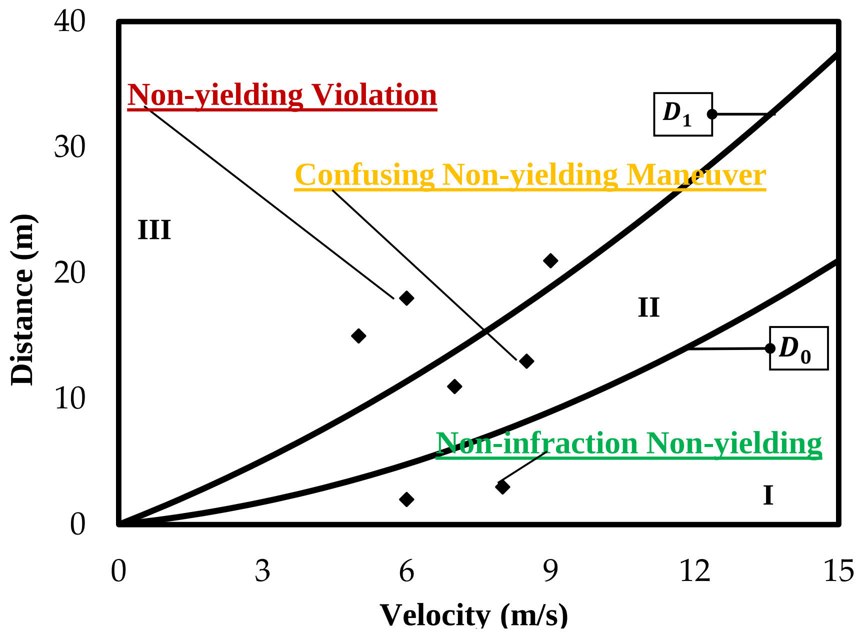
Behavior Measures



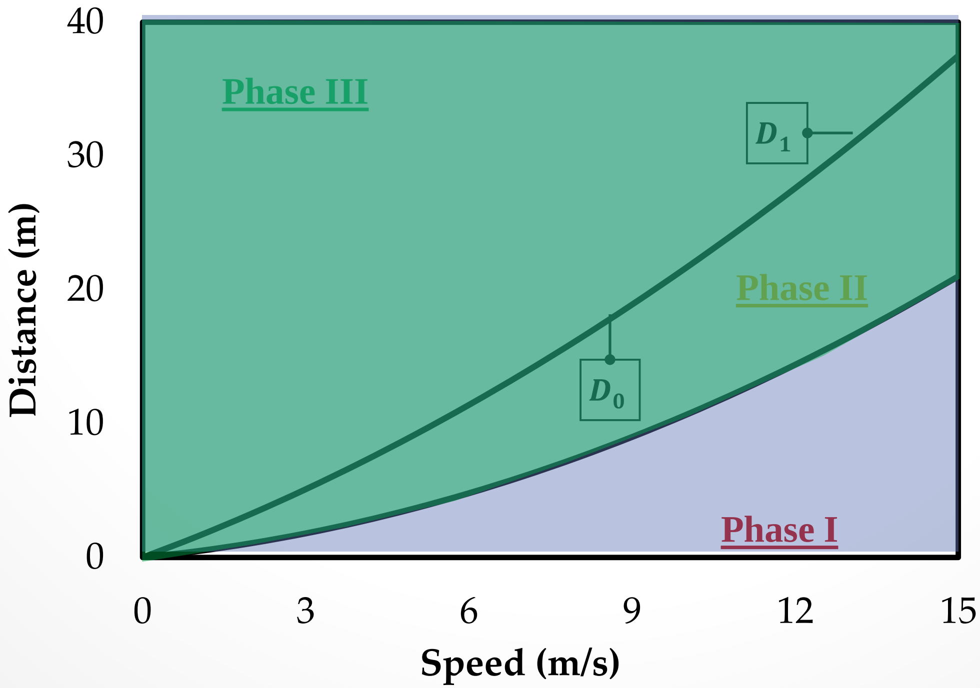
Yielding Behavior

Behavior Measures

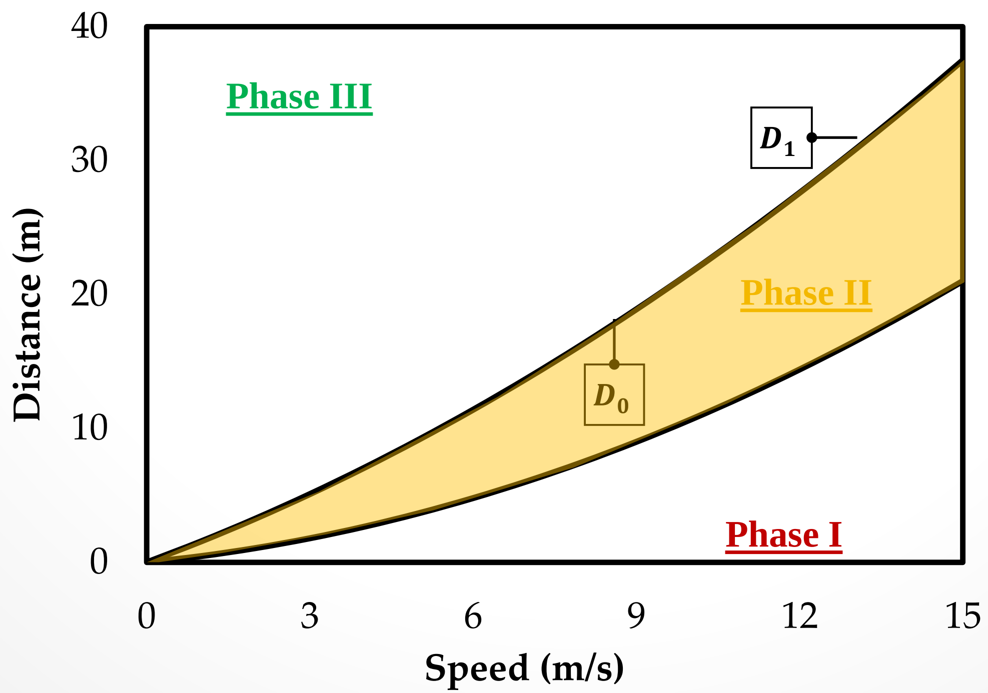
Yielding Ratios

Yielding Rate - Portion of vehicles that yield among all the interactions of interest

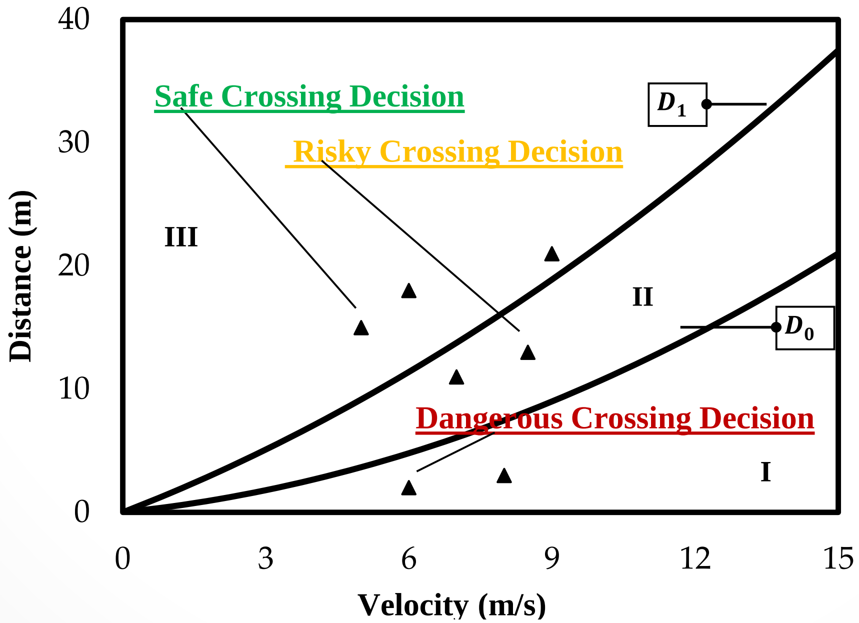
Yielding Compliance - Portion of vehicles that yield right-of-way among the drivers who are physically able to yield when they pay attention



- **Behavior Measures**
  - Uncertainty Zone



- **Behavior Measures**
  - Crossing decision – Ratios of Crossing Decisions

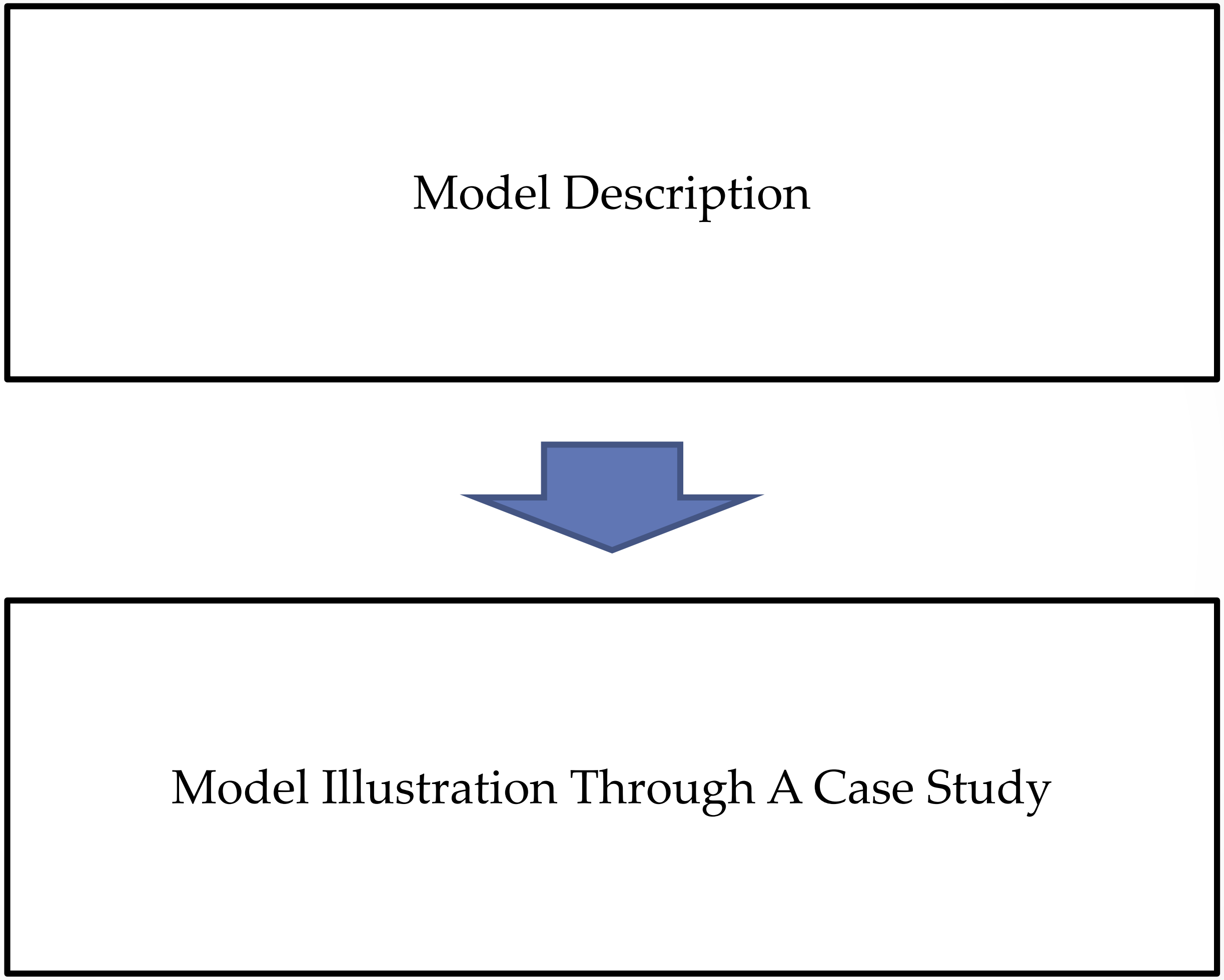


- **Collision Risk Measures – Event Analysis**
  - Interaction intensity measures: TC & DRSY
    - **Time to Crossing (TC)** – the time required for the vehicle to reach the pedestrian crossing path if continuing at constant speed, presented as

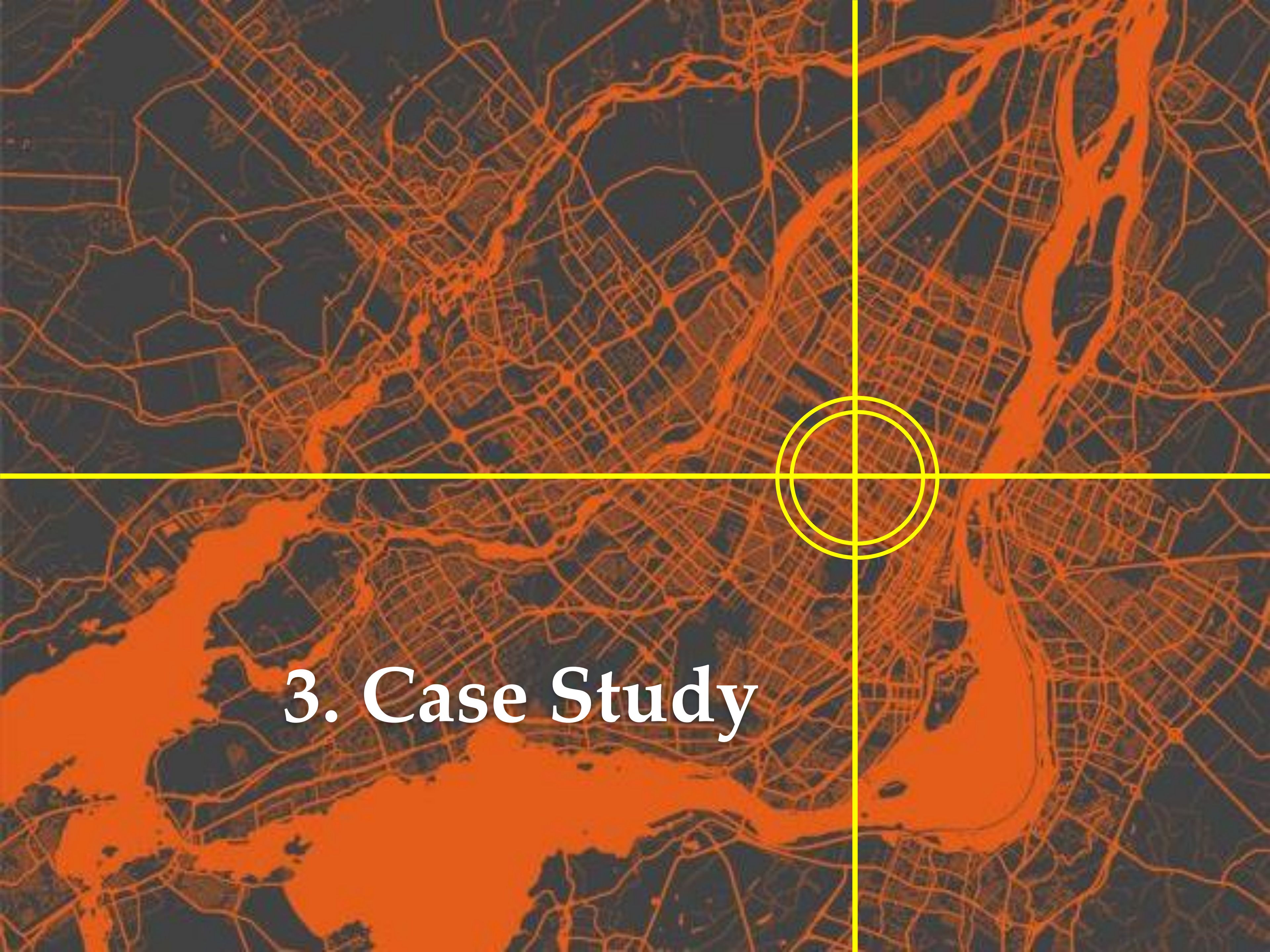
$$\mathrm{TC} = \frac{D}{V}$$

    - **Deceleration Rate Required to Stop (DRS)** – average deceleration rate required for the vehicle to stop and give right-of-way to pedestrians, assuming the driver pays attention to the pedestrian

$$DRS = \frac{v^2}{2(D - vt_{r\_min})}, \; if\ D > vt_{r\_min}$$


Model Description
Model Illustration Through A Case Study

3. Case Study



Sites

Descriptions of the Video Recorded at Each Site

Type of Crosswalk	Site name	Date	Time	Duration (hour)
Painted	Laurier_Berri	March 17th 2016	14:00-18:40	4.7
Unprotected	Laurier_Drolet	June 17th 2016	10:00-14:30	4.5
Stop signs controlled	13e_Belair	June 21st 2016	09:00-13:30	4.5

Type of Crosswalk	Site name	Duration (hour)
Painted	Laurier_Berri	4.7
Unprotected	Laurier_Drolet	4.5
Stop signs controlled	13e_Belair	4.5

Site name	# of Cameras	Camera View 1	Camera View 2
			
13e_Bélair	1		

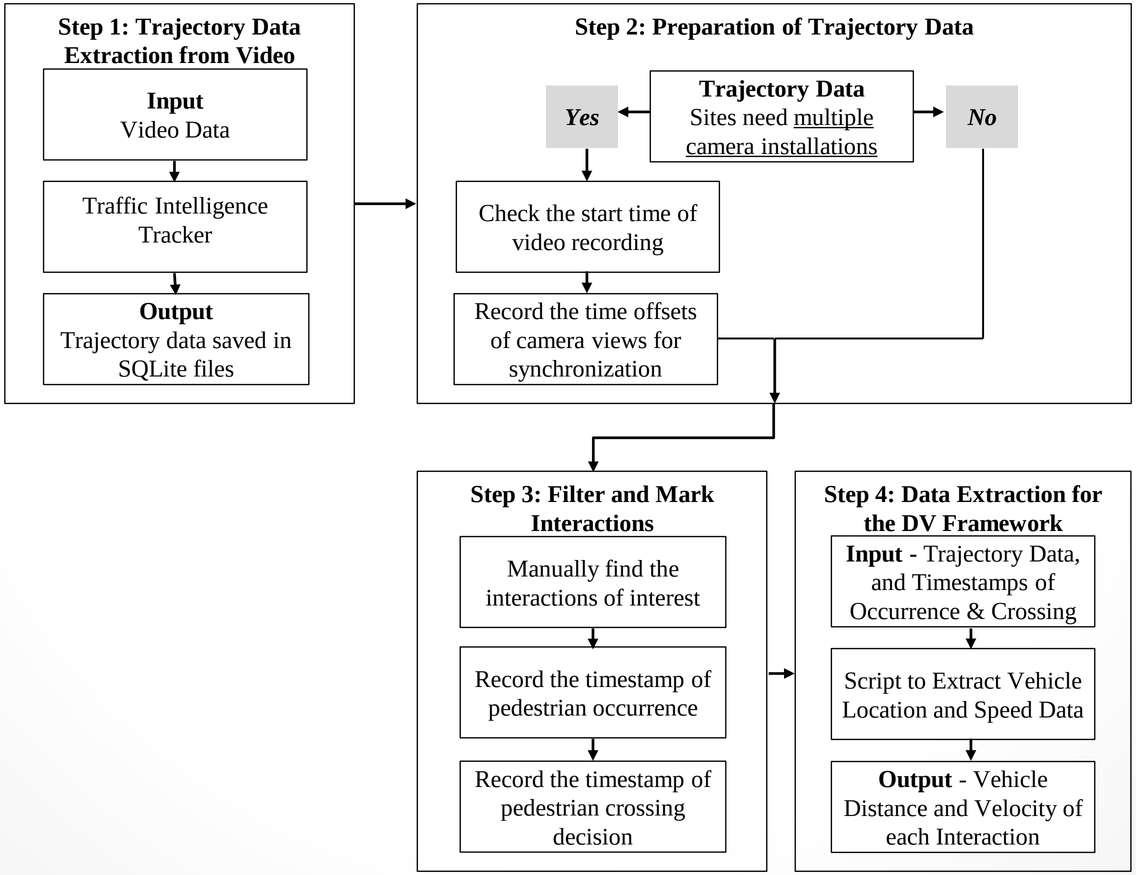
- **Data Collection**

GoPro’s Hero Edition cameras are used in HD resolution

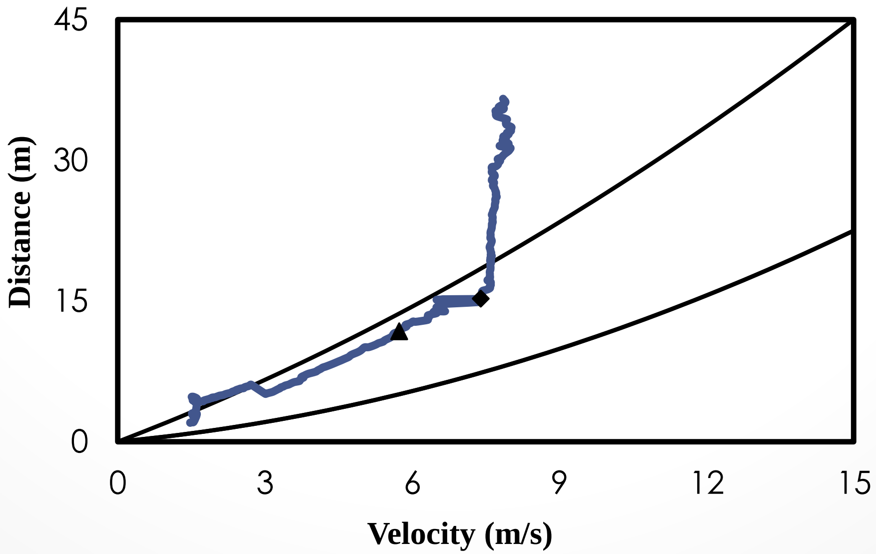
- **Data Processing – check the paper for details**
  - Semi-automated
    - using automatically extracted trajectories
    - manually identified events - pedestrian occurrences & crossing decisions

Data Processing – check the paper for details

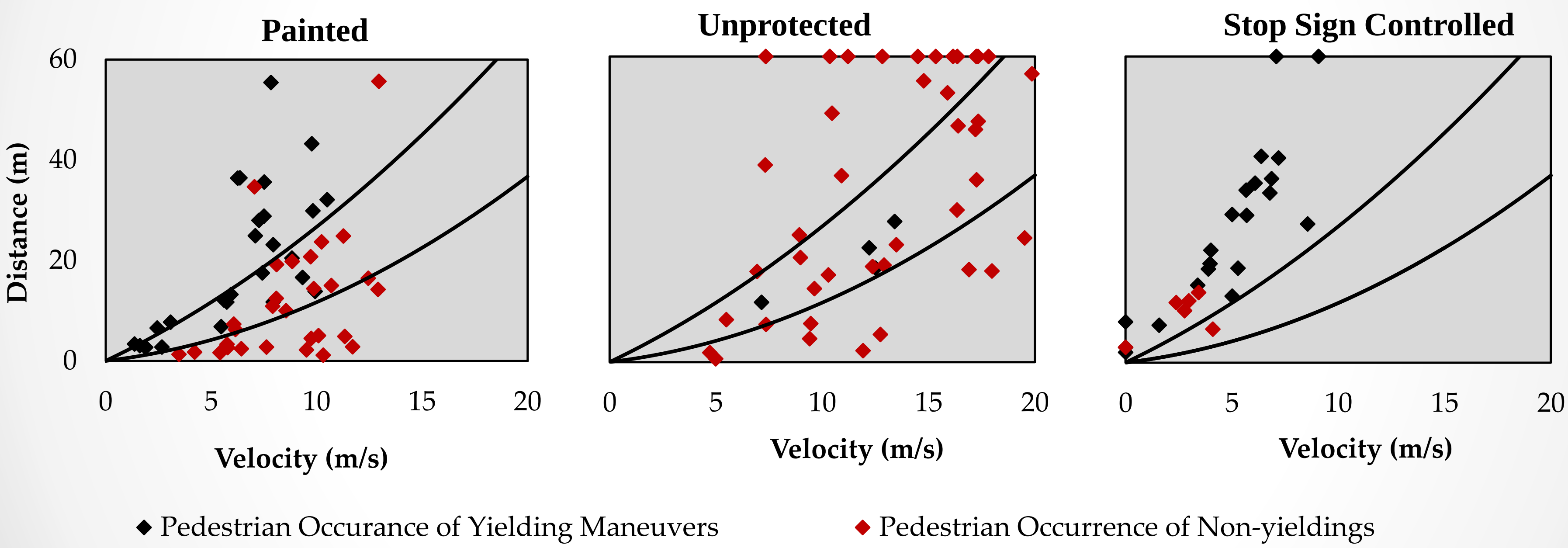
Under the help the tracker in the open source **Traffic Intelligence project**



■ Sample Outputs



Results – Vehicle Yielding



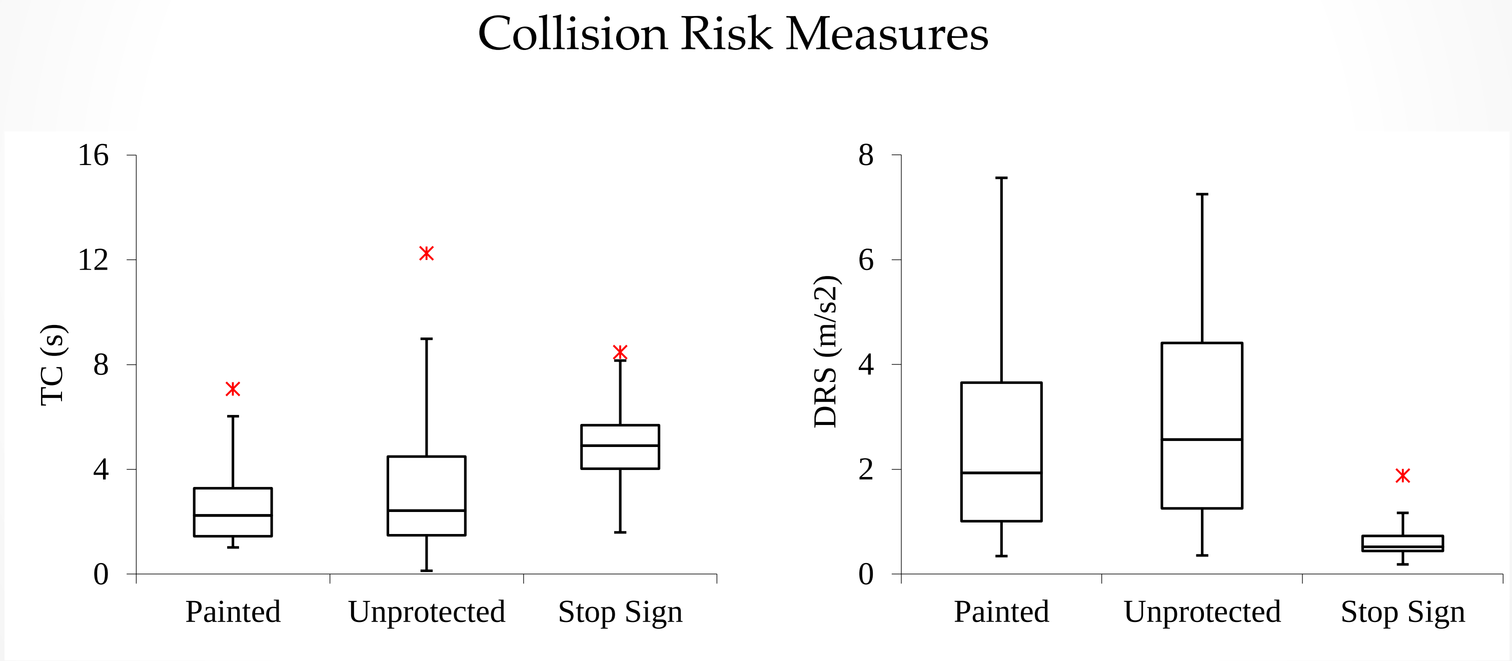
DV plot for yielding behavior

Results – Vehicle Yielding

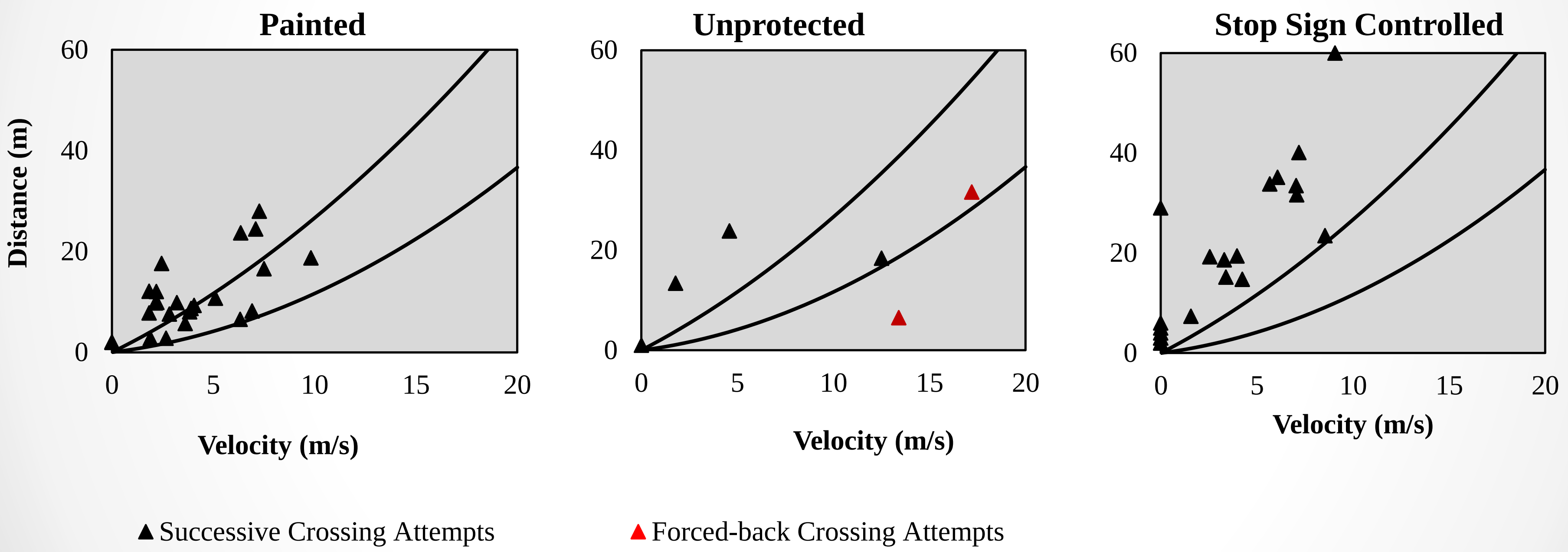
Behavior Measures

	Yielding rate (YR)	Yielding compliance (YC)
Painted	47.4 %	64.3 %
Unprotected	8.7 % (*worst*)	10.8 % (*worst*)
Stop Sign Controlled	77.8 % (*best*)	77.8 % (*best*)

Results – Vehicle Yielding

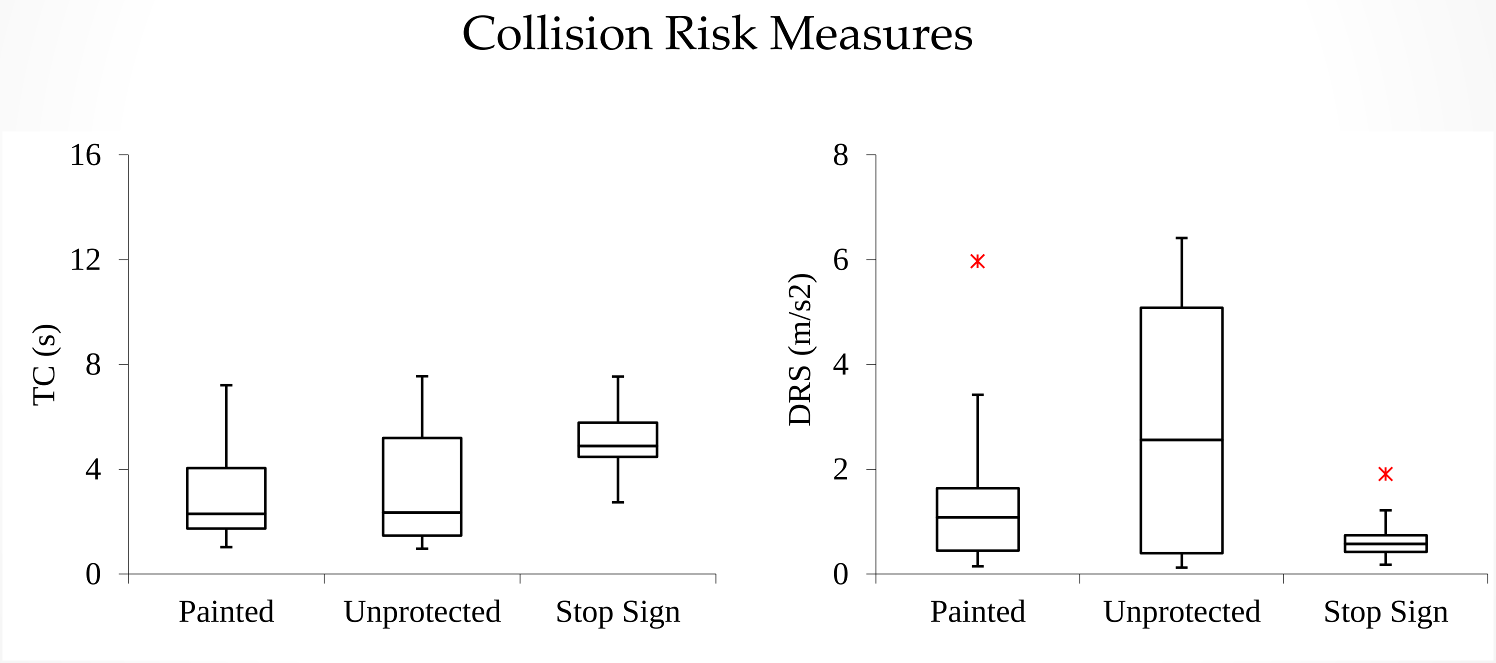


■ Results – Pedestrian Crossing Decisions



DV plot for yielding behavior

Results – Pedestrian Crossing Decisions



- **Discussion**

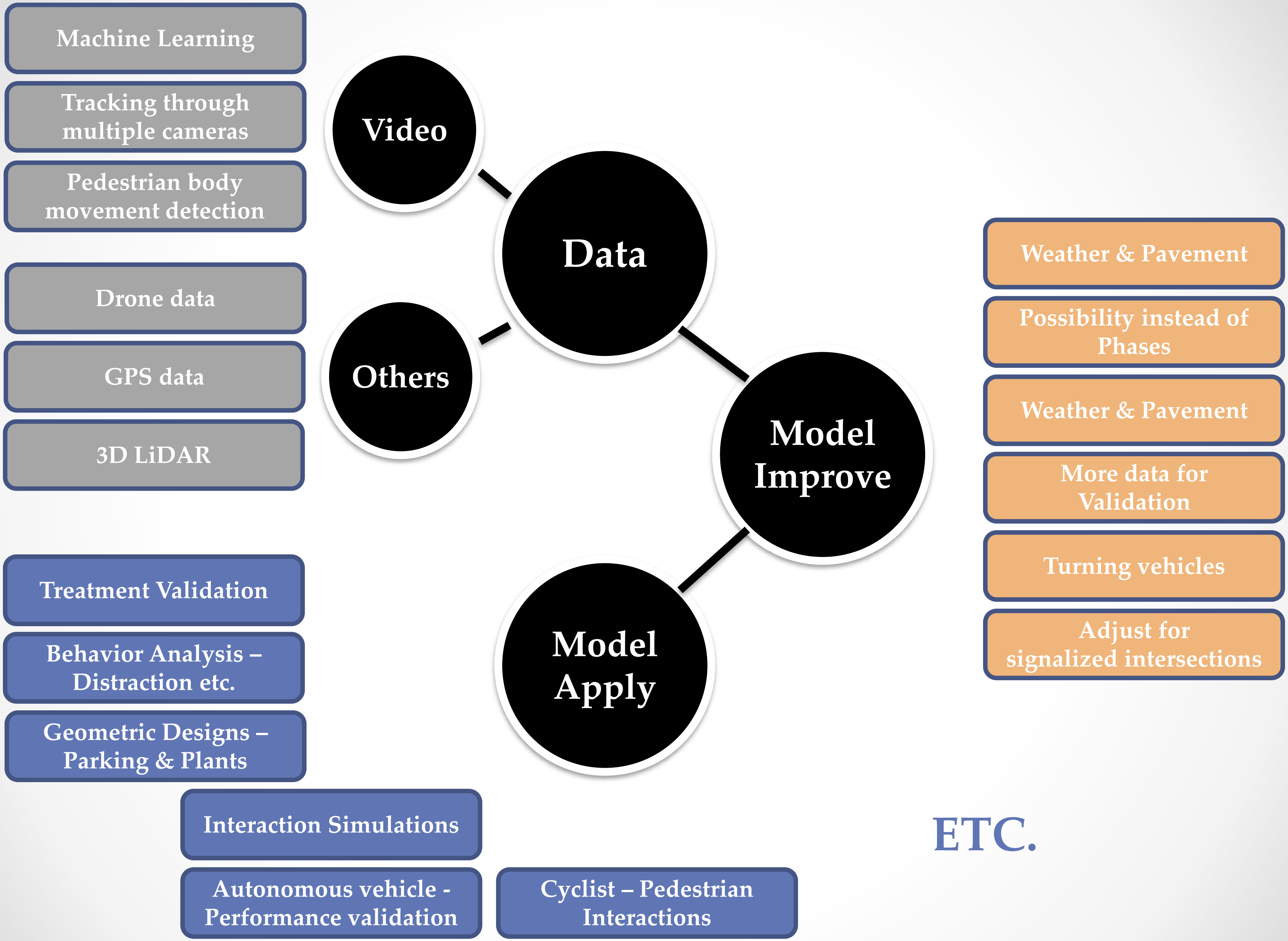
  - Results generally meet the framework assumptions. For instance, no single yielding maneuver is observed for interactions in situation 1) / Phase I.

  - Significant differences with huge variance between the yielding rate and the compliance were observed for the different crosswalk types.

  - Comparison results show that crosswalk with stop sign performs best for pedestrian safety, while the unprotected crosswalk is the least safe.

6. Conclusions & Future Work

- **Conclusions**
  - A new framework is proposed to study pedestrian-vehicle interactions in a potentially more precise and microscopic way.
    - It can be used for different purposes including treatment evaluation, behavior analysis, safety monitoring (violation detecting), pedestrian-vehicle interaction modeling, and improving yielding enforcement policy.
    - Results from the case study indicate the framework works reasonably. However, the model needs to be further validated through a sufficiently large number of observations


Machine Learning
Tracking through multiple cameras
Pedestrian body movement detection
Drone data
GPS data
3D LiDAR
Video
Others
Data
Model Improve
Model Apply
Weather & Pavement
Possibility instead of Phases
Weather & Pavement
More data for Validation
Turning vehicles
Adjust for signalized intersections
Treatment Validation
Behavior Analysis – Distraction etc.
Geometric Designs – Parking & Plants
Interaction Simulations
Autonomous vehicle - Performance validation
Cyclist – Pedestrian Interactions
ETC.

Representative Work

Finished

1. **T. Fu***, S. Zangenehpour, P. St-Aubin, L. Fu, and L. F. Miranda-Moreno. "Using Microscopic Video Data Measures for Driver Behavior Analysis during Adverse Winter Weather: Opportunities and Challenges", Journal of Modern Transportation, 2015. (ESCI) – **Journal Article**

2. **T. Fu***, L. F. Miranda-Moreno, and N. Saunier. "Pedestrian Crosswalk Safety at Non-signalized Crossings during Nighttime using Thermal Video Data and Surrogate Safety Measures", Transportation Research Record: Journal of the Transportation Research Board, 2016 (SCI) – **Journal Article**

3. **T. Fu***, J. Stipancic, S. Zangenhpour, L.F. Miranda-Moreno, and N. Saunier. "A Comparison of Regular and Thermal Cameras for Traffic Data Collection under Varying Lighting and Temperature Conditions in Multimodal Environments", Journal of Advanced Transportation, 2017 (SCI) – **Journal Article**

4. **T. Fu***, L. Miranda-Moreno, and N. Saunier. "Automatic Traffic Data Collection under Varying Lighting and Temperature Conditions in Multimodal Environments: Thermal versus Visible Spectrum Video-Based Systems", submitted to Accident Analysis & Prevention (Minor Correction Required), 2017 (SSCI) – **Journal Article**

5. **T. Fu***, D. Beitel, B. Navarro, L. Miranda-Moreno, and N. Saunier. "Investigating Cyclist-Pedestrian Interactions and Cyclist & Pedestrian Behavior using a Novel Distance-Velocity Model", submitted to Transportation Research Part F, 2017 (SSCI) – **Journal Article**

Almost Done

Project 1: Literature Review on Methodologies in Investigating Pedestrian Safety at Unsignalized Crossings

Project 2: Literature Review on Stop Sign Safety & Operation Efficiency: Methodologies, Topics and Limitations

Undergoing

Project 3: Investigating Pedestrian Safety at Unsignalized Locations with Different Traffic Control Methods under Different Geometric Conditions

Project 4: Cycling Attitude and Behavior towards Pedestrians in Shared Spaces using the DV Framework

Thank you!

Questions or comments?

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