Using Simulation to Assess and Reduce Conflicts between Drivers and Bicyclists

A SAFER-SIM Collaborative Project with UI, UMass, and UCF
Do Protected Bicycle Intersections Reduce Right-Hook Crashes?

A collaboration between the University of Iowa and the University of Massachusetts, Amherst

Presented by
Elizabeth O’Neal
The University of Iowa
The Problem

• Separated bicycle lanes are increasing in popularity in the U.S.

• Documented benefits include safer cycling and increased ridership.

• Concerns about potential conflicts between bicyclists and vehicles when they come back together at an intersection:
  • After a period of separation, drivers may be less likely to anticipate and scan for the presence of bicycles.
  • One specific risk is right-hook crashes.
Right-Hook Turn without Protected Bicycle Intersection
Right-Hook Turn with Protected Bicycle Intersection
How might protected bicycle intersections reduce right-hook turn conflicts?

• The greater distance between the driver and bicyclist is designed to
  • Create visual angles that make it easier for the driver and rider to see each other
  • Give the driver and rider more time to react before a collision

• Our goal is to systematically test whether protected bike intersections reduce the likelihood of bicycle-vehicle conflicts involving right-hook turns
  • Driver behavior
  • Bicyclist behavior
Study Design

• Conditions
  • Separated bike lane with protected intersections
  • Separated bike lane without protected intersections

• UI bicycling simulator: Study how bicyclists respond to virtual cars making right–hook turns

• UMass driving simulator: Study how drivers respond to virtual bicyclists when making right–hook turns
Thoughts on the Task and Measures

• Task Characteristics
  • We’d like to create bicyclist and driver tasks that are mirror images to the extent possible so that we can make direct comparisons
  • Does the right-hook turn conflict need to be a one-time surprise event, or could it occur multiple times throughout the drive/ride?
  • Need to get the timing right in the scenario so that there is at least one right-hook turn conflict event.

• Measures
  • Categorical measure: Is there a crash?
  • Continuous measures
    • When does the driver/bicyclist begin to slow down?
    • How much does the driver/bicyclist slow down?
    • When does the driver/bicyclist begin to look at the bicyclist/driver?
Thank you!
An Assessment of Traffic Safety between Drivers and Bicyclists based on Roadway Cross-Section Designs and Countermeasures Using Simulation

Mohamed Abdel-Aty
Juneyoung Park
Background

The safety issue between drivers and bicyclists has been recognized as one of the critical traffic safety problems, and there is a desperate need to identify and test roadway countermeasures to improve driver and bicyclist safety.

Research Objective 1

• Conduct comprehensive safety analysis to explore the safety effects of roadway geometric cross-section designs on mixed traffic condition

Research Question 2

• Investigate the effects of different roadway designs and countermeasures using micro-simulation
Preliminary Safety Analysis Results
Developing Crash Modification Functions (CMFs) to Assess Safety Effects of Adding Bike Lanes for Urban Arterials

Evaluated CMFs of adding a bike lane for urban arterials

<table>
<thead>
<tr>
<th>Calculation method</th>
<th>Crash modification factor (standard error)</th>
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<tbody>
<tr>
<td></td>
<td>All crashes (KABCO)</td>
</tr>
<tr>
<td>Before-After with EB</td>
<td>0.829(0.029)</td>
</tr>
<tr>
<td>227 segment: 2003-2005 (before) VS 2010-2012 (after)</td>
<td></td>
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<tr>
<td>Cross-Sectional</td>
<td>0.680(0.083)</td>
</tr>
<tr>
<td>2010-2012: 227 treated segments VS 517 reference segments</td>
<td></td>
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</tbody>
</table>

Note: All CMFs are significant at a 95% confidence level

- The safety effects of adding a bike lane are positive (i.e., CMF<1)
- Adding a bike lane is more effective in reducing bike crashes
Following Research Tasks

- Identification of more applicable treatments
- Development of SPFs and CMFs
- Conducting a micro-simulation experiment
- Analysis of the experiment results
# Project Schedule

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<th>Months</th>
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<td>Task 1-1: Review state-of-the-practice</td>
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<td>Task 1-2: Identification of applicable treatments</td>
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<td>Task 2-1: Comprehensive crash analysis</td>
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<td>Task 2-2: Development of SPF and CMF</td>
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<td>Task 3-1: Designing microsimulation frame</td>
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<td>Task 3-2: Microsimulation network calibration and validation</td>
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<td>Task 3-3: Build scenarios</td>
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<td>Task 3-4: Microsimulation experiments</td>
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<td>Task 4-1: Conducting statistical analysis</td>
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<td>Task 4-2: Summarizing the results</td>
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</table>
Thank you.
Any questions?

An Assessment of Traffic Safety between Drivers and Bicyclists Based on Roadway Cross-Section Designs and Countermeasures Using Simulation

Mohamed Abdel-Aty
Juneyoung Park
Multi-modal Distributed Simulation Combining Cars, Bicyclists, and Pedestrians
-- SaferSim Project Kickoff (UI, UW, UMass)

Yuanyuan Jiang
Ph.D. Candidate
University of Iowa

Hank Virtual Environments Lab
http://psychology.uiowa.edu/hank-virtual-environments-lab
Motivation

• Driving, bicycling, pedestrian simulators
  Causes of crashes & countermeasures

Interaction between driver, bicycler, pedestrian

• Connected simulators
  • Shared virtual environment
  • Human-to-human interaction across platforms
  • Warning, detection systems
  • Mitigating crash risk
Project Aim

• Connecting VE simulator
  UI, UW, UMass

• Potential simulator types
  Pedestrian Simulator
  Bike Simulator
  Driving Simulator
Current Simulators

• UW-Madison
  • Will integrate to Unity-based driving simulator

• UMass
  • Two RTI driving simulators integrated
  • Running experiment: multiple vehicle crashes & mitigation mechanisms
  • Integrating 2 Unity-based driving simulators to 2 RTI simulators

• UI
  • Two large screen simulators (bike or ped)
  • Connected ped VE demo – example in this talk

CAVEs in Hank
Unity Networking

Between multiple Unity
• High-Level API – Convenient *(Prototype working in Hank Lab)*
  • Network object management
  • Automatic network performance & sync management
  • Sync customized control var

• Low-Level API – Complex customized network protocol

Unity & other program
• C# UDP networking
  • Existing complex traffic server
  • Unity as client & renderer
Pedestrian Simulator

Design

Experiment

Scenario.exe

Tracking Data

unity

OptiTrack

Pedestrian Simulator
Connected Pedestrian Simulator

Same Unity Code

Client A

Avatar B
Person A

Client B

Avatar A
Person B

Avatar A

Traffic

Avatar B

Server
Connected Pedestrian Simulator

Machine A

Unity A

Client A

Skeletal Anchor Set A

Avatar B

Cars

Skeletal Anchor Set B

Skeletal Anchor Set A

Traffic

Server

Host

Machine B

Unity B

Client B

Skeletal Anchor Set B

Avatar A

Cars

Skeletal Anchor Set A

Skeletal Anchor Set B

Skeletal Anchor Set B

Retarget

CarID Pos/Ori

Person A Tracker ID Position/Orientation

Person B Tracker ID Position/Orientation
Unity Networking -- Challenges

• Steep learning curve
  • C#
  • General Unity
  • Networking APIs (c# advanced concepts, eg. delegates)

• Learning Resources
  • Unity manual
  • Youtube Unity tutorial

• Remote Collaboration
  • Network protocol establishing
  • Remote testing and debugging
  • Large size Unity project version control & sharing

• Remote Network Speed & Machine Delays
  • Minimal network traffic
  • Loop time testing & local compensation mechanism

• Remote Experiment Running Protocol
Connected VE Types -- Similarities

- Server controlled traffic objects
- Client controlled player objects
  - Pedestrian -> skeletal tracker prefab tree (pos/ori for each tracker)
  - Bike -> bike prefab position & orientation
  - Car -> car prefab position & orientation
Connected VE Types -- Challenges

**Same VE types**
- Pedestrian <-> Pedestrian
- Bike <-> Bike
  - Reduced marker tracking system
  - Player object tree serialization

**Different VE types**
- Pedestrian <-> Bike
- Pedestrian <-> Driving
- Bike <-> Driving
  - One code base for both types of VE (camera, control logic)
  - Ped relocation & re-encounter
  - Mix in agents for surprising factor
Unity Networking -- HLAPI

Drag drop + c# coding

Built in **Network Manager**

Prefab = model tree + script

Spawn prefab = create moving obj

-- Server:

    Spawn car generator prefab
    Auto sync to all clients

**Player object** = prefab spawned by client

-- Clients:

    Spawn avatar skeletal tracker set
    Auto sync to server, then to other clients

```
NetworkServer.AddPlayerForConnection(conn, player, playerControllerId);
```
Thank You

Hank Virtual Environments Lab
http://psychology.uiowa.edu/hank-virtual-environments-lab
Enhancing School Zone and School Bus Safety

Presenter: Moatz Saad
Mohamed Abdel-Aty
Jaeyoung Lee
Background

- Traffic crashes which involving school-age children are a serious concern, as there has been an increase in the number of school-age pedestrians and cyclists injured and killed throughout the years.

Research Question 1

- What is the best countermeasure to maximize drivers’ speed limit compliance rate in school zones?

Research Question 2

- What are the optimal roadway environments to increase traffic safety in school zones?

Research Question 3

- What are the better school bus designs to improve driving behavior?
Research Objectives

Objective 1
Analyzing driving behavior for the reduced speed limit in school zones and countermeasures

Objective 2
Investigating the impacts of geometric design of roadways and the number of driveways on safety in school zones

Objective 3
Exploring driver’s reaction to the various designs of school buses and stop signs
Objective 1: Driving behavior for the reduced speed limit in school zones

• In a school zone, most of the states set a lowered speed at specific time periods to protect children from severe crashes. However, drivers often do not comply with these speed limits.

• Flashing beacons and dynamic speed display can increase the speed compliance (Simpson, 2008; Lee et al., 2006)
Objective 1: Driving behavior for the reduced speed limit in school zones

1. **Driving simulator experiment**
   - Investigate countermeasures for school zones that can increase the number of drivers complying with the speed limits (e.g., flashing beacons, pavement marking, two-step speed reduction).

2. **Microsimulation experiment**
   - Some school zones require drivers suddenly reduce their speed (e.g., 35 mph to 15 mph) → may cause a conflict with following vehicles and rear-end crash.
   - An additional speed limit between the regular and school zone section (two-step speed reduction).
   - Quantify several measures (e.g., TTC, conflict frequency, etc.)
Two-step Speed Reduction

- Speed Limit: 35 mph
- School Zone Speed Limit: 15 mph
- Advance Reduction Speed Limit: 25 mph
- School Zone Speed Limit: 15 mph
Objective 2: Investigating the effects of geometric design of roadways and driveways on safety at school zones

• Using microsimulation, we will examine how improved roadway environments (e.g., increasing shoulder widths, minimizing the number of driveways, etc.) affect traffic safety at school zones.

• Actual crash data will be also explored and compared with the microsimulation results.
Drivers must stop upon approaching any school bus that displays its flashing red lights and has its stop sign extended. Some drivers may react more quickly whereas other drivers may take more time to stop for a school bus.

Objective 3: Exploring driver’s reaction to the various designs of school buses and stop signs

Using driving simulator, we will investigate how vehicle type, school bus design (color, the length of extended stop bar arm, stop sign size, etc.), and personal characteristics (e.g., age, gender, driving experience, etc.) impact driving behavior (e.g., reaction time, deceleration rate, TTC, etc.)
## Project Schedule (Phase I)

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<tr>
<th>Months</th>
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<td>Task 1-1: Literature review</td>
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<td>Task 1-2: Data collection and processing</td>
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<td>Task 1-3: Evaluation of the impacts of geometric designs and speed reduction on safety</td>
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<td>Task 1-4: Construction of network in school zones</td>
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<td>Task 1-5: Microsimulation frame calibration and validation</td>
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<td>Task 1-6: Preparation of simulation model</td>
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<td>Task 1-7: Testing scenarios and summarizing the results</td>
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# Project Schedule (Phase II)

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<td>Task 2-1: Experimental design for driving simulator test</td>
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<td>Task 2-3: Recruiting subjects and conducting the experiments</td>
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<td>Task 2-4: Statistical analysis of the results</td>
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</table>
Thank you. Any questions?

Enhancing School Zone and School Bus Safety

Presenter: Moatz Saad
Mohamed Abdel-Aty       Jaeyoung Lee
Using Driver State Detection in Automated Driving

Omeed Kashef
John Gaspar
Chris Schwarz
Timothy Brown

University of Iowa
## Defining readiness in vehicle automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>DDT</th>
<th>ODDR</th>
<th>DDT fallback</th>
<th>ODD</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
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<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
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<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the ODDR subtask and supervises the driving automation system.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
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<td>3</td>
<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-related system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>System</td>
<td>Fallback-ready user (replaces the driver during fallback)</td>
<td>Limited</td>
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<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
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<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
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</table>
Transfers of control can become safety critical events for automated vehicles

<table>
<thead>
<tr>
<th></th>
<th>Expected</th>
<th>Unexpected</th>
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<tbody>
<tr>
<td>Lower to Higher</td>
<td>Button press</td>
<td>Collision avoidance</td>
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<tr>
<td>Higher to Lower</td>
<td><strong>Grab wheel</strong></td>
<td>Automation failure</td>
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Driver Monitoring

Question: Can it be used to categorize situational awareness?

Question: Can it be used to modify the timing of a takeover request?
Takeover
Takeover situations

<table>
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<tr>
<th>Event</th>
<th>More Capable</th>
<th>Less Capable</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>#1 Work zone</td>
<td>No TOR</td>
<td>TOR with 10-second warning</td>
<td>Warning occurs about 15 seconds ahead of the work zone. Traffic in left lane.</td>
</tr>
<tr>
<td>#2 Missing lane lines</td>
<td>No TOR</td>
<td>TOR with 10-second warning</td>
<td>Warning occurs when lane lines are lost.</td>
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<tr>
<td>#3 Sharp curve</td>
<td>No TOR</td>
<td>TOR with 10-second warning</td>
<td>Elevated ramp with walls.</td>
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<td>#4 Slow lead vehicle</td>
<td>TOR with 10-second warning</td>
<td>TOR with 5-second warning</td>
<td>Lead vehicle driving at 25 mph with hazards on. Traffic in left lane.</td>
</tr>
<tr>
<td>#5 Exit highway</td>
<td>TOR with 30-second warning</td>
<td>TOR with 30-second warning</td>
<td>Always the last event of the drive. No difference between A and B.</td>
</tr>
</tbody>
</table>

*Examples from prior SaferSim study at the NADS

- 5-minute acclimation to driving simulator
- 15-minute trust building period with automation
- Driving in automated mode with takeover requests
  - Planned takeover
  - Unexpected hazard event(s)
    - Failure without takeover request
Readiness during takeover

- Identify SA ground truth measure
- Classify readiness using ground truth
- Relationship of driver monitoring to SA ground truth
- Machine learning techniques to predict using DMS data
- Determine whether takeover requests could have come earlier

- Latent hazard detection
- Eyes on forward road
- Freeze-probe technique
How does driver state influence takeover and acceptance?

• Takeover Quality
  • Takeover time
  • Driver errors
  • Stabilization in steering and lane
  • Eye gaze and head behavior

• Subjective trust and acceptance
• Subjective workload
The Impact of Connected Vehicle Market Penetration and Connectivity Levels on Traffic Safety in Connected Vehicles Transition Period

Mohamed Abdel-Aty

Yina Wu (Presenter)
The development of information and communication technologies have facilitated connected vehicle (CV) technologies, in which vehicles communicate with other vehicles (V2V), roadway infrastructures (V2I), and pedestrians (V2P) in real-time.

- **Level 0**: no connection
- **Level 1**: vehicles connect to infrastructures
- **Level 2**: vehicles connect to vehicles
- **Level 3**: vehicles connect to vehicles and infrastructures
Research Objectives

Objective 1
Proposing strategies to help CV to avoid crash in fog conditions

Objective 2
Using V2V and V2I information to predict the traffic parameters of conventional vehicles

Objective 3
Recommending the optimal CV technology and active traffic management strategies under a CV environment in fog conditions

Objective 4
Building car-following models for CV platoons

Objective 5
Recommending the number of CV platoon managed-lanes under different penetration rates
Communicate with road condition: such as downstream congestion, signal status, stop sign, speed limit

Communicate with another vehicle: Information including movement dynamics such as speed, heading, brake status

Detect driving Environment, control the vehicle autonomously

What is CAV Technology?

At Intersections: Manipulated by V2I detection; At Non-Intersections: Manipulated by AV detection;
V2I Safety Benefits

Help a driver know Road Conditions like downstream congestion, speed limit on a curve, signal status, stop sign and pedestrian crosswalks, so that the driver could adjust his/her driving speed, awareness or travel route and so on to avoid a potential crash or congestion.

### Examples of V2I Technology Warning Pre-crash Scenario

<table>
<thead>
<tr>
<th>Scenario and Warning Type</th>
<th>Scenario example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road departure collision scenarios</strong></td>
<td>Curve speed warning</td>
</tr>
<tr>
<td></td>
<td>Approaching a curve or ramp at an unsafe speed or decelerating at insufficient rates to safely maneuver the curve</td>
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<tr>
<td><strong>Crossing path collision scenarios</strong></td>
<td>Running red light/stop sign</td>
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<td></td>
<td>Violation at an intersection controlled by a stop sign or by traffic signal</td>
</tr>
</tbody>
</table>

Why CV Technology could be helpful?
Help a driver know an unobservable presence or an unpredictable movement of another vehicle in pre-crash scenarios, so that an evasive action for the driver could be made in advance.

Examples of V2V Technology Warning Pre-crash Scenario

<table>
<thead>
<tr>
<th>Scenario and warning type</th>
<th>Scenario example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rear end collision scenarios</strong></td>
<td><img src="image1.jpg" alt="Scenario" /></td>
</tr>
<tr>
<td>Forward collision warning</td>
<td>Approaching a vehicle that is decelerating or stopped.</td>
</tr>
<tr>
<td>Emergency electronic brake light warning</td>
<td>Approaching a vehicle stopped in roadway but not visible due to obstructions.</td>
</tr>
<tr>
<td><strong>Lane change scenarios</strong></td>
<td><img src="image2.jpg" alt="Scenario" /></td>
</tr>
<tr>
<td>Blind spot warning</td>
<td>Beginning lane departure that could encroach on the travel lane of another vehicle traveling in the same direction; can detect vehicles not yet in blind spot.</td>
</tr>
<tr>
<td>Do not pass warning</td>
<td>Encroaching onto the travel lane of another vehicle traveling in opposite direction; can detect moving vehicles not yet in blind spot.</td>
</tr>
<tr>
<td><strong>Intersection scenario</strong></td>
<td><img src="image3.jpg" alt="Scenario" /></td>
</tr>
<tr>
<td>Blind intersection warning</td>
<td>Encroaching onto the travel lane of another vehicle with whom driver is crossing paths at a blind intersection or an intersection without a traffic signal.</td>
</tr>
</tbody>
</table>

Source: NHTSA analysis of Crash Avoidance Metrics Partnership information.
Why CV Technology could be helpful during fog?

(1) No Connected Vehicle Condition

(2) Connected Vehicle Condition (V2V)
Microsimulation, such as VISSIM, can be used to model connected vehicle behavior in reduced visibility conditions, which is controlled by VISSIM driver model through API.
### Project Schedule (Phase I)

<table>
<thead>
<tr>
<th>Task I-1: Review CV, fog-related traffic studies, managed-lanes, and platoon</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Task I-2: Conduct a driving simulator experiment for fog conditions</td>
<td></td>
</tr>
<tr>
<td>Task I-3: Develop car-following models of CV platoon vehicles</td>
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</tbody>
</table>
# Project Schedule (Phase I)

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
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<tbody>
<tr>
<td>Task I-4: Conduct a microsimulation experiment for CV platoon managed-lanes</td>
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<td>Task I-5: Analysis of the results and recommendations</td>
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<td>Task I-6: Final report</td>
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</tbody>
</table>
The Impact of Connected Vehicle Market Penetration and Connectivity Levels on Traffic Safety in Connected Vehicles Transition Period
Traffic Control Devices and Augmented Reality

University of Massachusetts Amherst
Traffic Control Devices (TCD’s)

Importance

• Driver-to-infrastructure Interactions (D2I)
• Vehicle-to-infrastructure interactions (V2I)

https://goo.gl/images/G2Yk98
Issues with current TCD’s

• Operations cost millions of dollars/year nationwide
• non-conformation (or non-perception)
• Localization

Need for a mechanism that is

• Low cost ✓
• User centric ✓
• Robust ✓
Alternative Mechanism

Augmented reality (AR)

- Flexibility
- Control

The question is…

“How such safety-critical traffic control information (and what specific information) can be delivered effectively to the driver using AR without causing any form of distraction or engagement-related problems.”
Methodologies

Variables
• head/eye movements
• vehicle handling measures
• task-engagement behaviors
• physiological parameters
Contributions

The results help

• Investigate safety benefits of using AR to deliver traffic control messages
• Ascertained the feasibility of eventually replacing physical TCD’s with AR signs.
• Thank You!
Augmented Reality for Safer Pedestrian-Vehicle Interactions

October 4, 2017

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Project Motivation
Advancements in AR technologies

- Braking distance indicators
- Lane markings
- Vehicle detection
- Pedestrian detection
Project Focus
Safer pedestrian-vehicle interaction
Project Objectives

- Create a streamlined platform for testing AR concepts

- Workforce development component
  - Acquire the skills to create in-vehicle warning systems
  - Understand the design process

- Educational component
  - Build a framework for testing in the simulator
Driving Simulator

Wisconsin Traffic Operations and Safety Laboratory

Department of Civil and Environmental Engineering | Engineering
University of Wisconsin-Madison
Tasks Ahead

- **Continue literature review**
  - Identify most promising types of AR designs for enhancing vehicle-pedestrian interactions

- **Build scenario for testing designs**
  - Flexible platform that allows continuous design iteration by students without the need for significant changes.

- **Conduct testing**
  - Focus on the identification of best procedures for a streamlined process that can be repeated in the future.
Augmented Reality for Safer Pedestrian-Vehicle Interactions

October 4, 2017

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