Testing Automated Collision Avoidance Systems for Transit Buses

Jerome M. Lutin, PhD, PE, F.ITE
Senior Director of Statewide & Regional Planning
NJ TRANSIT (retired)
• Bus and paratransit incur about 15,000 injuries and 100 fatalities per year
• Bus and paratransit casualty and liability expenses total about $500 million a year
• Much of this is due to collisions
• Technology is available to reduce collisions
• Transit needs to aggressively pursue R&D for collision avoidance systems
Funding from

- Transportation Research Board
- Washington State Transit Insurance Pool
- Munich Re America
- Alliant Insurance Services, Inc.
- Government Entities Mutual, Inc.
US Bus and Paratransit Injuries

Annual US Bus and Paratransit Injuries
2003-2015

Source: Federal Transit Administration
Bus Paratransit and Vanpool Casualty and Liability Expenses

Annual US Bus, Paratransit and Vanpool Casualty & Liability Expense
Source: Federal Transit Administration National Transit Database

Casualty & Liability Expense
Linear (Casualty & Liability Expense)
# Collisions, Fatalities, Injuries, Casualty and Liability Expenses for Bus and Rail Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Reporting Period 2002-2015</th>
<th></th>
<th></th>
<th>Total Casualty and Liability Expenses by Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collisions</td>
<td>Fatalities</td>
<td>Injuries</td>
<td></td>
</tr>
<tr>
<td>Total Bus, Demand Responsive and Van Pool</td>
<td>90,056</td>
<td>1,442</td>
<td>218,139</td>
<td>$6.96 Billion</td>
</tr>
<tr>
<td>Total Rail</td>
<td>6,526</td>
<td>1,453</td>
<td>97,243</td>
<td>$4.38 Billion</td>
</tr>
</tbody>
</table>
Currently available forward collision avoidance technologies for passenger and commercial vehicles ... could reduce rear-end crash fatalities.”

Forward collisions reduced 71% for trucks with collision avoidance systems, (CAS) autonomous emergency braking, (AEB) and electronic stability control (ESC)
NTSB recommendations:

- Manufacturers - install forward collision avoidance systems on all newly manufactured passenger and commercial motor vehicles
- NHTSA - expand New Car Assessment Program to include graded performance rating of forward collision avoidance systems
- NHTSA - expand or develop protocols for assessment
Transit May Be Left Behind

- Transit buses are a niche market – little incentive for OEM’s to invest in R&D
- Agencies required to retain buses for 12 + years
- Years before transit benefits from CAS and AEB on new buses
- Need to retrofit existing buses with CAS and AEB
- Need standards for CAS and AEB for retrofits and new buses
Driver killed, 18 injured after 2 NJ Transit buses crash in Newark

Newark bus crash victims to sue for at least $115M for 'catastrophic' injuries
Innovations Deserving Exploratory Analysis (IDEA)

TRB grant and funding from insurance companies

- Equipped 35 transit buses at seven member agencies and three buses at King County Metro with CAS
- Comprehensive examination of total costs for most severe and costly types of collisions
- Evaluate potential for CAS to reduce the frequency and severity of collisions, and reduce casualty and liability expenses
- Does not include autonomous braking in this phase
Participating Transit Agencies

- Ben Franklin Transit, Richland, WA
- Community Transit, Everett, WA
- C-Tran, Vancouver, WA
- InterCity Transit, Olympia, WA
- King County Metro, Seattle, WA
- Kitsap Transit, Bremerton, WA
- Pierce Transit, Tacoma, WA
- Spokane Transit, Spokane, WA
# Project Team

| Washington State Transit Insurance Pool | Allan F. Hatten | Executive Director  
|                                         | Jerry Spears   | Principal Investigator |
| Geneva Financial Services, Inc.         | Steven M. Clancy | Principal |
|                                         | Janet Gates    | Project Assistant |
| Rosco Vision Systems, Inc.              | Benjamin Englander | Vice President, Engineering |
|                                         | Mike Cacic     | Program Manager for Safety Systems |
|                                         | Gus Franjul    | Field Service Engineer |
| University of Washington               | Professor Yinhai Wang, PhD | Co-Principal Investigator |
|                                         | Ruimin Ke      | Graduate Research Assistant |
Provides alerts and warnings for events that could lead to a collision:

- changing lanes without activating a turn signal
- exceeding posted speed limit
- closing with vehicle in front of the bus
- closing with pedestrian or bicyclist in front of, or alongside the bus

Alerts and warnings

- visual indicators on windshield and front pillars
- Audible warnings issued when collisions are imminent
Shield+ system being installed on Gillig bus at C-TRAN in Vancouver, WA

- 6 different types of transit buses produced by three mfrs.
- high floor, low floor, Diesel, hybrid, and electric trolley buses
- 2-person team complete one bus installation in 8 hour period
Center indicator illuminates as pedestrian crosses in front of moving bus during testing
System Configuration
System Configuration - Alerts and Warning Displays

"MOBILEYE SHIELD+" OPERATOR REFERENCE GUIDE

LEFT SIDE DISPLAY
- Left Side Pedestrian Display
  - For detecting pedestrians and cyclists who are near left front corner of bus or left side of bus.
  - Yellow illumination with no sound
    - Warns the operator a pedestrian or cyclist has been detected near the left front or left side of bus.
  - Operator should exercise additional caution and verify that the danger of collision has passed.

CENTER DISPLAY & EYEWATCH
- Center Display
  - Contains Pedestrian Display and EYEWATCH.
  - The EYEWATCH readouts and explanations can be found below on this document.

RIGHT SIDE DISPLAY
- Right Side Pedestrian Display
  - For detecting pedestrians and cyclists who are near right side of bus.

EYEWATCH READOUTS
- Solid green dot with beeping sound on each side:
  - System is operational with beeps at 5 second interval.
  - System is operational.

- Lane Departure Warning (LDW):
  - Occurs when crossing the lane markings without using turn signal.

- Adaptive Cruise Control:
  - A series of sharp warning beeps of short duration.

  - The path will be on the Eyewatch side corresponding to the lane crossed over.
  - For photos this feature is not active.

- Speed Limit Indicator (SLI):
  - Appears when the bus is traveling at or below posted speed limit.

  - Two vertical white hash marks on each side of the Eyewatch will appear with a white number indicating miles per hour in the last posted speed limit.

  - Has a chime sound.

- Highway Monitoring (HMP):
  - Appears on green car.

  - Indicates the distance between bus and vehicle in front of bus.

  - The S indicates the seconds until a collision would occur if the front vehicle were to come to a stop.

  - Operator is advised to reduce speed to increase distance to a safe level.

  - Has a chime sound.
System Configuration - Alerts and Warning Displays

**CENTER DISPLAY & EYEWATCH**

- **OFF**
  - Center Display
  - Contains the Pedestrian Display and EyeWatch.
  - The EyeWatch readouts and explanations can be found below on this document.

- **DETECTION**
  - Yellow illumination with no sound
  - Indicates a pedestrian or cyclist is in front of the moving bus or coming towards the moving bus.
  - Operator should exercise additional caution until verifying that the danger of collision has passed.

- **ALERT**
  - Red flashing with beeping sound
  - Indicates a pedestrian or cyclist is in front of the moving bus or coming towards the moving bus and collision is imminent.
  - Operator should take action to carefully stop bus to avoid collision.
Telematics - Monitoring System Performance

- The CAS does not record video
- Additional cameras record video of events
- Additional technology is used to generate data that can be used to evaluate the systems’ effectiveness
- Telematics unit captures and transmits data
Monitoring System Performance with Telematics and Video
Field Testing the CAS-Mapping Telematics Data
Field Testing the CAS

- Checking System Performance in Revenue Service –
- comparing real time observations with telematics data
Field Testing the CAS- Logging Telematics Data

<table>
<thead>
<tr>
<th>Report Name</th>
<th>Vehicle name</th>
<th>Heading</th>
<th>Distance In Miles</th>
<th>Driver name</th>
<th>Address</th>
<th>Speed</th>
<th>Status Name</th>
<th>Rule name</th>
<th>POI Original</th>
</tr>
</thead>
<tbody>
<tr>
<td>28/03/2016</td>
<td>KCM #4346</td>
<td>NE</td>
<td>3.29</td>
<td></td>
<td>1333-1367 Madison St, Seattle, WA 98104, USA</td>
<td>14</td>
<td>ME - Pedestrian In Range</td>
<td>ME4 - Pedestrian In Range</td>
<td></td>
</tr>
<tr>
<td>28/03/2016</td>
<td>KCM #4346</td>
<td>NE</td>
<td>3.29</td>
<td></td>
<td>1368-1398 Madison St, Seattle, WA 98104, USA</td>
<td>14</td>
<td>PDZ-R</td>
<td>ME4 - PDZ - Right</td>
<td></td>
</tr>
<tr>
<td>28/03/2016</td>
<td>KCM #4346</td>
<td>NE</td>
<td>3.73</td>
<td></td>
<td>1349-1397 E Madison St, Seattle, WA 98122, USA</td>
<td>14</td>
<td>ME - Pedestrian In Range</td>
<td>ME4 - Pedestrian In Range</td>
<td></td>
</tr>
<tr>
<td>28/03/2016</td>
<td>KCM #4346</td>
<td>NE</td>
<td>3.73</td>
<td></td>
<td>1349-1397 E Madison St, Seattle, WA 98122, USA</td>
<td>12</td>
<td>ME - PCW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28/03/2016</td>
<td>KCM #4346</td>
<td>NE</td>
<td>3.73</td>
<td></td>
<td>1350-1398 E Madison St</td>
<td>11</td>
<td>ME -</td>
<td>ME4 -</td>
<td></td>
</tr>
</tbody>
</table>
Data Collection
April 1, 2016 – June 30, 2016

- 352,129 operating miles
- 23,798 operating hours
- 250 driver surveys returned
- 178 comments received
- 16,600 hours of video
- 10,000 events logged
- 19 TB of video storage
- No pedestrian or forward collisions
## Comparing Frequency of Alerts and Warnings with Spokane Transit Control Group

<table>
<thead>
<tr>
<th>Warning Type</th>
<th>Warnings per 1000 miles</th>
<th>Control Group (2 buses 17K mi)</th>
<th>Active Fleet (33 buses, 344K mi)</th>
<th>Active Fleet Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Limit</td>
<td>16.74</td>
<td>15.39</td>
<td>-8%</td>
<td></td>
</tr>
<tr>
<td>Headway (HW)</td>
<td>185.84</td>
<td>50.31</td>
<td>-73%</td>
<td></td>
</tr>
<tr>
<td>Forward Collision &lt;19 mph (UFCW)</td>
<td>317.74</td>
<td>96.04</td>
<td>-70%</td>
<td></td>
</tr>
<tr>
<td>Forward Collision &gt;19 mph (FCW)</td>
<td>10.99</td>
<td>6.27</td>
<td>-43%</td>
<td></td>
</tr>
<tr>
<td>Pedestrian Collision (PCW)</td>
<td>27.67</td>
<td>18.00</td>
<td>-35%</td>
<td></td>
</tr>
</tbody>
</table>
Video Analyses by UW
Testing for False Positives and False Negatives
Insurance Pool Data - Major Portion of Injuries, Fatalities, and Claims are Collision Related

Examination of 282 closed claims for Washington State Transit Insurance Pool spanning 2006-2015

- 100% of fatalities (6 total) were collision-related (vehicle, pedestrian, and bicyclist)
- 88% of injuries (335 total) resulted from collisions or sudden stops
- 94% of claims ($24.9 million total) resulted from collisions or sudden stops

MANY OF THESE COULD HAVE BEEN PREVENTED WITH CAS AND AEB
Framework for Estimating Cost Savings

**Event Data (March-April)**
- Event Location
- Event Time
- Event Type

**Historical Collision Data**
- Collision Location
- Collision Time
- Collision Type
- Collision Payment

Classification

Learn of the conversion rates of “event to collision”

**Event Data (May-June)**
- Event Location
- Event Time
- Event Type

**Before-after Analysis**

Cost-Savings Estimation

Collision payment of each category
### Research Implications – The Business Case for CAS/AEB

<table>
<thead>
<tr>
<th>Bus Type</th>
<th>2015 Casualty &amp; Liability Expense per Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commuter Bus</td>
<td>$6,229</td>
</tr>
<tr>
<td>Motor Bus</td>
<td>$7,986</td>
</tr>
<tr>
<td>Rapid Bus (BRT)</td>
<td>$4,116</td>
</tr>
<tr>
<td>Trolley Bus</td>
<td>$11,796</td>
</tr>
</tbody>
</table>
What Next - Autonomous Braking

- The curved line shows velocity of the bus when braking
Pierce Transit’s Continuing Research in Collision Avoidance

• Pierce Transit receives $1.66 million grant from Federal Transit Administration (FTA) to install bus safety technology
• 176 buses will be equipped with Shield+ CAWS
• Buses will be operated and data recorded for a full year
• Some buses will also be equipped with Automated Emergency Deceleration (AED) for testing
The Need for Standards and Specifications

Transit buses require different CAS-AEB technology than cars and trucks

- Blind spot locations are different
- Operator training and workload
- Proximity of pedestrians and waiting passengers
- Standing passengers could be injured from sudden stops
- Buses in service 12-18+ years - ability to retrofit is key
- Can not take buses out of service for long periods – standards help design systems for quicker retrofits and maintenance
- Most buses purchased through competitive bidding requiring detailed specifications for CAS-AEB
Thank You

Jerome.lutin@verizon.net