Testing Automated Collision Avoidance Systems for Transit Buses

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Innovations Deserving Exploratory Analysis (IDEA) Project Transit -82

Funding from

• Transportation Research Board
• Washington State Transit Insurance Pool
• Munich Re America
• Alliant Insurance Services, Inc.
• Government Entities Mutual, Inc.
Annual US Bus and Paratransit Injuries
2003-2015
Source: Federal Transit Administration
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>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collisions</td>
</tr>
<tr>
<td>Total Bus, Demand Responsive and Van Pool</td>
<td>90,056</td>
</tr>
<tr>
<td>Total Rail</td>
<td>6,526</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 of forward collision avoidance systems
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
August 19, 2016 Newark, NJ
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
Rosco/Mobileye Shield+ system collision avoidance warning system (CAWS) specifically designed for transit buses

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**

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**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**
  - Informs the operator a pedestrian or cyclist has been detected near the left front or left side of bus.
  - Operator should exercise additional caution until verifying that the danger of collision has passed.
- **Red flashing with beeping sound**
  - Informs the operator a pedestrian or cyclist has been detected in the left front or left side of bus and collision is imminent.
  - Operator should take action to carefully stop bus to avoid collision.

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

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**EYEWATCH READOUTS**
- **Speed Limit Indicator (SLI)**
  - Appears when the bus is traveling at least 5 mph (adjustable) over the last posted speed limit set.
  - Two vertical white hash lines on the EYEWATCH will appear with a white number indicating miles over the last posted speed limit.
  - Has a chime sound.
  - Operator should reduce speed to keep within the speed limit.
- **Lane Departure Warning (LDW)**
  - Occurs when crossing the lane markers without using turn signal.
  - Appears as a vertical white hash line on the EYEWATCH.
  - A series of sharp warning beeps of short duration.
  - The hash line will be on the EYEWATCH side corresponding to the lane marker crossed.
  - For pilots this feature is not active.
- **Headway Monitoring (HMW)**
  - Appears as a green car.
  - Indicates detection of a vehicle in the path of the bus.
  - No number shown if bus is traveling a safe distance behind the vehicle in front or when bus is traveling below 19 MPH.
- **Forward Collision Warning (FCW)**
  - Appears as a red car with an audible chime.
  - Indicates the distance between bus and vehicle in front has fallen below a safe threshold.
  - Operator is advised to reduce speed to increase distance to a safe level.
- **Headway Monitoring (HMW)**
  - Appears as a green car and number indicates how far the vehicle in front of the bus is in seconds.
  - The 2-3 indicates the seconds until a collision could occur if the front vehicle were to come to a stop.
  - Operator is advised to reduce speed if time to collision falls below preset seconds and car turns red.
  - Has a chime sound.

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**RIGHT SIDE DISPLAY**
- **Right Side Pedestrian Display**
- For detecting pedestrians and cyclists who are near right side of bus.
- **Yellow illumination with no sound**
  - Informs the operator a pedestrian or cyclist has been detected near the right side of bus.
  - Operator should exercise additional caution until verifying that the danger of collision has passed.
- **Red flashing with beeping sound**
  - Informs the operator a pedestrian or cyclist has been detected on the right side of bus and collision is imminent.
  - Operator should take action to carefully stop bus to avoid collision.
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 21:57:25</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>Warning</td>
</tr>
<tr>
<td>28/03/2016 21:57:29</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 22:00:06</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 Warning</td>
<td>ME4 - Pedestrian In Range Warning</td>
<td></td>
</tr>
<tr>
<td>28/03/2016 22:00:07</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>ME4 - 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</th>
<th>Active Fleet</th>
<th>Active Fleet Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(2 buses 17K mi)</td>
<td>(33 buses, 344K mi)</td>
<td></td>
</tr>
<tr>
<td>Forward Collision</td>
<td></td>
<td>327.76</td>
<td>93.24</td>
<td>-71.55</td>
</tr>
<tr>
<td>Pedestrian Collision</td>
<td></td>
<td>61.66</td>
<td>34.95</td>
<td>-43.32</td>
</tr>
</tbody>
</table>
Video Analyses by UW
Testing for False Positives and False Negatives

(a)  
(b)  
(c)  
(d)
<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grand Total</strong></td>
<td>100%</td>
<td>$53,159,668</td>
</tr>
<tr>
<td><strong>Claims not Impacted by CAWS</strong></td>
<td>35%</td>
<td>$18,585,081</td>
</tr>
<tr>
<td><strong>Claims Impacted by Forward Vehicle CAWS</strong></td>
<td>35%</td>
<td>$18,593,035</td>
</tr>
<tr>
<td><strong>Claims Impacted by Pedestrian CAWS</strong></td>
<td>30%</td>
<td>$15,981,552</td>
</tr>
<tr>
<td><strong>Total Claims Impacted by Forward Vehicle and Pedestrian CAWS</strong></td>
<td>65%</td>
<td>$34,574,587</td>
</tr>
</tbody>
</table>
## 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 - Continuing Research in Collision Avoidance

- Pierce Transit received $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
Thank You

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