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University Transportation Research Center (UTRC)
2016 Transportation Technology Summit: Innovative Mobility Solutions
November 15, 2016
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
Trend in Rate of Bus and Paratransit Injuries per Passenger Mile

US Bus and Paratransit Data 2003-2013
Injuries/Million Passenger Miles
Source: Federal Transit Administration
Trend in Number of Bus and Paratransit Injuries per Year

US Bus and Paratransit Data 2003-2013
Injuries
Source: Federal Transit Administration
Trend in Bus and Paratransit Casualty and Liability Expenses

US Bus and Paratransit Data 2003-2013
Casualty & Liability Expense

Source: Federal Transit Administration

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 2002-2014</th>
<th>Reporting Period 2002-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collisions</td>
<td>Fatalities</td>
</tr>
<tr>
<td><strong>Total Bus, Demand Responsive and Van Pool</strong></td>
<td>85,391</td>
<td>1,340</td>
</tr>
<tr>
<td><strong>Total Rail</strong></td>
<td>6,118</td>
<td>1,303</td>
</tr>
</tbody>
</table>
National Transportation Safety Board (NTSB)

2015 - Special Investigation Report – The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear End Crashes

- “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
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
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

**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
- Indicates 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
- Indicates 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.

**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.

**RIGHT SIDE DISPLAY**
- Right Side Pedestrian Display
- For detecting pedestrians and cyclists who are near right side of bus.
- Yellow illumination with no sound
- Indicates 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
- Indicates 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.

**EYEWATCH READOUTS**
- Solid green dot
  - System is operational with bus at 0 speed.
  - System is operational.
- 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.
- Speed Limit Indicator (SLI)
  - Appears when the bus is traveling at least 5 mph (adjustable) over the last posted speed limit sign.
  - Two vertical white hash lines on each side of 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.
- Headway Monitoring (HMW)
  - Appears as green car.
  - Indicates detection of a vehicle in the path of the bus.
  - No number shows if bus is traveling a safe distance behind the vehicle in front or when bus is traveling below 10 MPH.
- Headway Monitoring Warning (HMW)
  - Appears as red car and number.
  - Indicates how far the vehicle in front of the bus is in seconds.
  - The 2.5 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.
- Forward Collision Warning (FCW)
  - Appears as flashing red car with a high pitched beeping sound.
  - Indicates near end collision is imminent.
  - Operator must stop the bus immediately.

T: 718.526.2601   www.roscovision.com
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>Warnin</td>
</tr>
</tbody>
</table>

| 28/03/2016 21:57:29 | KCM #4346 | NE | 3.29 |  | 1368-1398 Madison St, Seattle, WA 98104, USA | 14 | PDZ-R | ME4 - PDZ - Right |

| 28/03/2016 22:00:06 | KCM #4346 | NE | 3.73 |  | 1349-1397 E Madison St, Seattle, WA 98122, USA | 14 | ME - Pedestrian In Range Warning | ME4 - | Warnin |

| 28/03/2016 22:00:07 | KCM #4346 | NE | 3.73 |  | 1349-1397 E Madison St, Seattle, WA 98122, USA | 12 | ME-PCW | ME4 - |

| 28/03/2016 | KCM #4346 | NE | 3.73 |  | 1350-1398 E Madison St, Seattle, WA 98122, USA | 11 | ME - | ME4 - |
### Washington State Pilot Participants Data Analysis

<table>
<thead>
<tr>
<th>Shield + System Alerts</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceeded Speed Limits</td>
<td>19.18</td>
<td>9.57</td>
<td>16.82</td>
</tr>
<tr>
<td>HMW (Headway Monitoring)</td>
<td>386.27</td>
<td>156.95</td>
<td>66.35</td>
</tr>
<tr>
<td>UFCW (Urban Forward Collision Warning; speed 0 to 19 mph)</td>
<td>314.19</td>
<td>201.90</td>
<td>354.18</td>
</tr>
<tr>
<td>FCW (Forward Collision Warning; speed &gt; 19 mph)</td>
<td>7.85</td>
<td>7.41</td>
<td>14.33</td>
</tr>
<tr>
<td>PCW Per 1K Miles</td>
<td>20.10</td>
<td>28.08</td>
<td>31.10</td>
</tr>
<tr>
<td>PDZs Per 1K Miles</td>
<td>1275.26</td>
<td>1505.78</td>
<td>1382.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shield + System Alerts</th>
<th>Spokane Transit</th>
<th>Community Transit</th>
<th>CTRAM</th>
<th>INTERcity Transit</th>
<th>Kitsap Transit</th>
<th>King County METRO</th>
<th>Pierce Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceeded Speed Limits</td>
<td>20.20 (-5%)</td>
<td>16.55 (-14%)</td>
<td>19.19 (0%)</td>
<td>11.11 (-42%)</td>
<td>16.46 (-14%)</td>
<td>6.41 (-67%)</td>
<td>13.69 (-29%)</td>
</tr>
<tr>
<td>HMW (Headway Monitoring)</td>
<td>62.77 (-84%)</td>
<td>39.33 (-90%)</td>
<td>75.88 (-80%)</td>
<td>45.49 (-88%)</td>
<td>45.06 (-88%)</td>
<td>26.96 (-93%)</td>
<td>48.67 (-87%)</td>
</tr>
<tr>
<td>UFCW (Urban Forward Collision Warning; speed 0 to 19 mph)</td>
<td>38.32 (-88%)</td>
<td>85.39 (-73%)</td>
<td>81.14 (-74%)</td>
<td>87.30 (-72%)</td>
<td>162.07 (-48%)</td>
<td>543.54 (73%)</td>
<td>126.62 (-60%)</td>
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<td>FCW (Forward Collision Warning; speed &gt; 19 mph)</td>
<td>3.91 (-50%)</td>
<td>6.89 (-12%)</td>
<td>4.52 (-42%)</td>
<td>4.24 (-46%)</td>
<td>13.75 (75%)</td>
<td>6.76 (-14%)</td>
<td>4.95 (-37%)</td>
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<tr>
<td>PCW Per 1K Miles</td>
<td>12.54 (-38%)</td>
<td>22.55 (12%)</td>
<td>3.31 (-84%)</td>
<td>31.06 (55%)</td>
<td>38.63 (92%)</td>
<td>63.79 (217%)</td>
<td>11.91 (-41%)</td>
</tr>
<tr>
<td>PDZs Per 1K Miles</td>
<td>569.87 (-55%)</td>
<td>849.72 (-33%)</td>
<td>523.32 (-59%)</td>
<td>1009.43 (-21%)</td>
<td>1535.27 (20%)</td>
<td>3881.49 (204%)</td>
<td>717.74 (-44%)</td>
</tr>
</tbody>
</table>

- All data per 1K miles
- All data shown as monthly averages
- % Difference calculated from Spokane monthly average vs. respective transit monthly average
- % Removed data outliers from BenFrank on Exceeded Speed Limits
Comparing Frequency of Alerts and Warnings with Spokane Transit Control Group

<table>
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*Note: The table shows the frequency of alerts and warnings for different categories and transit services, with percentages indicating the reduction compared to the baseline.*
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
Video Analyses by UW
Testing for False Positives and False Negatives
Framework for Estimating Cost Savings

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

Classification

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

Learn of the conversion rates of “event to collision”

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

Before-after Analysis

Collision payment of each category

Cost-Savings Estimation
Insurance Pool Data - Major Portion of Injuries, Fatalities, and Claims are Collision Related

Examination of 232 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
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
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

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