Application of Autonomous Collision Avoidance Technology to Bus Transit

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NJ TRANSIT
Key Presentation Take-Aways

- Bus transit agencies are spending a fortune on casualty and liability claims
- Autonomous collision avoidance technology is available and has reduced claims for autos
- We need a program to develop and implement autonomous collision avoidance systems for buses
Good News! Travel by Bus is getting safer!

Injuries per Million Bus Passenger Miles

Source: Federal Transit Administration National Transit Database
Good News! Injuries have been trending down!
<table>
<thead>
<tr>
<th>NTD 2011 Bus Injuries and Fatalities for All Transit Agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Fatalities</strong></td>
</tr>
<tr>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>Passenger</td>
</tr>
<tr>
<td>Rev Facility Occupant</td>
</tr>
<tr>
<td>Employees</td>
</tr>
<tr>
<td>Operator</td>
</tr>
<tr>
<td>Employee</td>
</tr>
<tr>
<td>Total Employees</td>
</tr>
<tr>
<td>Other Worker</td>
</tr>
<tr>
<td>Bicyclist</td>
</tr>
<tr>
<td>Ped in Crossing</td>
</tr>
<tr>
<td>Ped not in Crossing</td>
</tr>
<tr>
<td>Other Vehicle Occupant</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Trespasser</td>
</tr>
<tr>
<td>Suicide</td>
</tr>
<tr>
<td>Other Total</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Terrible News! Claims are going through the roof!

Figure 2 US Bus Transit Industry Reported Casualty and Liability Expense 2002-2011
Average Increase 2.8% per Year
Source: Federal Transit Administration National Transit Database
<table>
<thead>
<tr>
<th>Casualty and Liability Amount</th>
<th>General Administration</th>
<th>$432,228,288</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Maintenance</td>
<td>$50,847,722</td>
<td></td>
</tr>
<tr>
<td>Sub-Total Casualty and Liability</td>
<td>$483,076,010</td>
<td></td>
</tr>
<tr>
<td>Maximum Available Buses</td>
<td>59,871</td>
<td></td>
</tr>
<tr>
<td>Sub-Total Casualty and Liability Amount Per Bus</td>
<td>$8,069</td>
<td></td>
</tr>
</tbody>
</table>
Casualty and Liability Claims are a Huge Drain on the Industry

• For the 10 year period 2002-2011, more than $4.1 Billion was spent on casualty and liability claims
• For many self-insured transit agencies these expenses are direct “out-of-pocket”
• Large reserves for claims must be budgeted
• Claims experience also is reflected in insurance premiums
• There are gaps in data reporting
Costs of Bus Crashes – Industry Wide

Tangible – C&L *
• Personal injury claims
• Property damage claims
• Workers compensation
• Insurance premiums

Tangible -likely non-C&L*
• Legal services
• Passenger and service delays
• Emergency services response
• Lost fare revenue
• D & A testing
• Overtime
• Sick time
• Accident investigation
• Vehicle recovery

• Vehicle repair
• Hearings and discipline
• Spare vehicles and replacements

Intangible
• Human loss and suffering
• Media attention
• Good will

*C&L = reported as casualty and liability expense
WE NEED TO FIX THIS!

New Technology is Available
NHTSA Preliminary Policy on Automated Vehicles

Level 0 (No automation)
- The human is in complete and sole control of safety-critical functions (brake, throttle, steering) at all times.

Level 1 (Function-specific automation)
- The human has complete authority, but cedes limited control of certain functions to the vehicle in certain normal driving or crash imminent situations. Example: electronic stability control

Level 2 (Combined function automation)
- Automation of at least two control functions designed to work in harmony (e.g., adaptive cruise control and lane centering) in certain driving situations.
- Enables hands-off-wheel and foot-off-pedal operation.
- Driver still responsible for monitoring and safe operation and expected to be available at all times to resume control of the vehicle. Example: adaptive cruise control in conjunction with lane centering
NHTSA Preliminary Policy on Automated Vehicles

**Level 3 (Limited self-driving)**
- Vehicle controls all safety functions under certain traffic and environmental conditions.
- Human can cede monitoring authority to vehicle, which must alert driver if conditions require transition to driver control.
- Driver expected to be available for occasional control. Example: Google car

**Level 4 (Full self-driving automation)**
- Vehicle controls all safety functions and monitors conditions for the entire trip.
- The human provides destination or navigation input but is not expected to be available for control during the trip. Vehicle may operate while unoccupied.
- Responsibility for safe operation rests solely on the automated system
Google Self-Driving Car (Level 3 Automation) and Someone Who Really Needs One!
### Functional Capabilities of Currently Available Commercial Collision Avoidance and Driver Assist Packages for Autos

- Adaptive cruise control
- Adaptive headlights
- Autonomous emergency braking
- Blind spot detection
- Cross traffic alert/avoidance
- Driver fatigue/inattention alert
- Forward collision avoidance
- Lane departure warning
- Lane keeping assist
- Parking assist
- Pedestrian detection/avoidance
- Rear collision warning/mitigation
- Self-parking
- Side impact detection
More Sensors, More Protection

- Highly sophisticated sensors and the necessary networked algorithms provide the foundation for innovative new functions using the same stereo camera and multistage radar sensors.

* w/Driver Assistance Pkg.
Active Lane Keeping Assist recognizes critical situations such as overtaking vehicles, vehicles to be overtaken and parallel traffic, and it can also respond effectively to oncoming traffic. If the system detects the vehicle crossing the lane markings when the adjacent lane is not clear, not only does it cause the steering wheel to vibrate in pulses as a haptic warning for the driver, it guides the vehicle back into lane by single-sided braking via the ESP®.
This radar-based function is now enhanced by the addition of Steering Assist, which helps drivers to stay centered in their lane by generating the appropriate steering torque when travelling on a straight road and even in gentle bends.
Brake Assist BAS PLUS is capable of more than just helping the driver to avoid collisions with vehicles ahead or lessen their consequences in a purely longitudinal direction: the new Cross-Traffic Assist function can also come to the driver's aid when there is a risk of a collision with cross traffic at junctions.
PRE-SAFE® Brake

with pedestrian detection and urban braking function

- Visual and acoustic warning
- BAS PLUS: boosts inadequate braking by the driver as appropriate to the given situation
- PRE-SAFE® Brake: autonomous braking when the driver fails to respond

Detection of pedestrians in the area in front of the vehicle
PRE-SAFE® PLUS: Rear-end Collision Protection

- Using a radar sensor in the rear bumper to monitor the traffic behind the vehicle, PRE-SAFE PLUS provides occupant protection for rear passengers by engaging measures and increasing the brake pressure in order to keep the vehicle firmly braked during a possible rear-end collision.
Enhanced ATTENTION ASSIST®

- Display of current ATTENTION ASSIST levels (5), display of system state (active vs. passive due to speed), journey time since last pause
- Additional mode of “sensitive” for tired drivers
- Interaction with navigation system including additional warning and advice of service areas
History and Development of DISTRONIC:
Price reduction, intelligent packaging and availability cross-carline

MY 2000

Introduce DISTRONIC
Adaptive Cruise Control
In package for +$3,700
Only available on S/CL

MY 2006 - Current

DISTRONIC PLUS
Autonomous Braking Intervention
In “Driver Assistance Package” with Blind Spot
Assist/Lane Keeping Assist $2,950
Available Cross-Carline on almost every model

MY 2014 - Future

Enhancements to Driver Assst. Package

• Steering Assist
• BAS with Cross-Traffic Assist
• PRE-SAFE Brake with Pedestrian Detection
• PRE-SAFE PLUS – protection during rear collisions

In “Driver Assistance Package” with Blind Spot Assist/Lane
Keeping Assist +$2,800
Only available on S/E
These Systems are Reducing Claims

Vehicles rated “Superior” in front crash avoidance by the Insurance Institute for Highway Safety

- Cadillac ATS sedan and SRX crossover-utility vehicle
- Mercedes-Benz C-Class sedan
- Subaru Legacy sedan and Outback wagon
- Volvo S60 sedan and XC60 crossover
What we need to do
Prepare for Technological Evolution and Obsolescence

• Buses last from 12 to 18 years or more
• Computer technology becomes obsolete in 18 months to two years
• Expect to replace components and systems several times during the life of a bus
• Do not expect replacement parts to still be available
• Sometimes stuff does not work as expected
Open Architectures and Standards

• Avoid problems of legacy systems and sole source procurements
• Modular systems and components
• Standard interfaces between systems and components
• Multiple sources and innovation from vendors
• “Plug and play”
A Proposed Research and Development Program
Proposed Work Program - Phase 1

- Create a stakeholder working group of transit agencies, bus manufacturers, technology developers, and researchers.
Proposed Work Program - Phase 2

• Conduct a research assessment of why casualty and liability claims are increasing and determine the potential for automated collision avoidance systems to reduce fatalities, injuries and claims.
Proposed Work Program - Phase 3

• Initiate the development of functional requirements and standards to allow installation of collision avoidance and driver assist technology on new transit buses and retrofit of existing buses.
Proposed Work Program - Phase 4

• Develop a prototype test bed that would allow developers of innovative collision avoidance and driver assist technologies to work with transit agencies and researchers to expedite development and deployment.
We need your input and support
THANK YOU!

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Systems Specifications and Requirements for Bus Acquisition or Retrofit to Allow for Autonomous and Connected Vehicle Technology

- Steering
- Braking
- Throttle
- Transmission
- Engine and Drivetrain Instrumentation
- Sensor/Camera Locations and Connections
- Vehicle Area Network
- Communications V2V, V2I
- Antenna Locations
- Logic Unit/Mobile Data Terminal
- Electrical power/conditioning
- Electromagnetic radiation interference
- Human Factors
A Case Study Example

for NJ TRANSIT
2002-2012 Safety and Claims Data for Service Directly Operated by NJ TRANSIT Bus Operations

<table>
<thead>
<tr>
<th></th>
<th>Total for Period 2002-2012</th>
<th>Annual Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidents</td>
<td>3,077</td>
<td>280</td>
</tr>
<tr>
<td>Collisions</td>
<td>1,753</td>
<td>159</td>
</tr>
<tr>
<td>Injuries</td>
<td>4,417</td>
<td>402</td>
</tr>
<tr>
<td>Fatalities</td>
<td>25</td>
<td>2.3</td>
</tr>
<tr>
<td>Estimated Bus Claims</td>
<td>$112,400,000</td>
<td>$10,220,000</td>
</tr>
<tr>
<td>Peak Buses</td>
<td>n/a</td>
<td>1,769</td>
</tr>
<tr>
<td>Total Buses Operated</td>
<td>n/a</td>
<td>2,106</td>
</tr>
<tr>
<td>Estimated Bus Claims/Total Buses Operated</td>
<td>$53,305</td>
<td>$4,846</td>
</tr>
</tbody>
</table>
Potential for Cost Savings in Annual Claims Paid by Installing a Collision Avoidance System on NJ TRANSIT Buses

<table>
<thead>
<tr>
<th>Estimated Average Annual Claims Reduction per Bus (%)</th>
<th>Collision Avoidance System Installation Costs Based on Mercedes Intelligent Drive System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2,800 per Bus – 2014 Base Price</td>
</tr>
<tr>
<td>10</td>
<td>484.60</td>
</tr>
<tr>
<td>20</td>
<td>969.20</td>
</tr>
<tr>
<td>30</td>
<td>1,453.80</td>
</tr>
<tr>
<td>40</td>
<td>1,938.40</td>
</tr>
<tr>
<td>50</td>
<td>2,423.00</td>
</tr>
<tr>
<td>60</td>
<td>2,907.60</td>
</tr>
<tr>
<td>70</td>
<td>3,392.20</td>
</tr>
<tr>
<td>80</td>
<td>3,876.80</td>
</tr>
<tr>
<td>90</td>
<td>4,361.40</td>
</tr>
</tbody>
</table>

Estimated Years to Recoup Installation Cost
A Capacity Bonus for NJ TRANSIT
Exclusive Bus Lane (XBL) to New York City

Source: Port Authority of New York and New Jersey
Potential Increased Capacity of Exclusive Bus Lane (XBL) Using Cooperative Adaptive Cruise Control (CACC) (Assumes 45 foot (13.7 m) buses @ with 57 seats)

<table>
<thead>
<tr>
<th>Average Interval Between Buses (seconds)</th>
<th>Average Spacing Between Buses (ft)</th>
<th>Average Spacing Between Buses (m)</th>
<th>Buses Per Hour</th>
<th>Additional Buses per Hour</th>
<th>Seated Passengers Per Hour</th>
<th>Increase in Seated Passengers per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>2</td>
<td>3,600</td>
<td>2,880</td>
<td>205,200</td>
<td>164,160</td>
</tr>
<tr>
<td>2</td>
<td>47</td>
<td>14</td>
<td>1,800</td>
<td>1,080</td>
<td>102,600</td>
<td>61,560</td>
</tr>
<tr>
<td>3</td>
<td>109</td>
<td>33</td>
<td>1,200</td>
<td>480</td>
<td>68,400</td>
<td>27,360</td>
</tr>
<tr>
<td>4</td>
<td>150</td>
<td>46</td>
<td>900</td>
<td>180</td>
<td>51,300</td>
<td>10,260</td>
</tr>
<tr>
<td>5 (Base)</td>
<td>212</td>
<td>64</td>
<td>720</td>
<td>-</td>
<td>41,040</td>
<td>-</td>
</tr>
</tbody>
</table>