Vehicle Assist and Automation Technologies in Bus Revenue Service

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What is Vehicle Assist and Automation?

- Vehicle Assist helps the driver maintain control of the bus
- Vehicle Automation provides full control of a bus
- Applications can include
  - Precision Docking
  - Lateral Guidance
  - Collision Warning
Types of VAA

- Magnetic
- Mechanical
- Optical
- GPS

U.S. Experience

- Cleveland
U.S. Experience

Minnesota

<table>
<thead>
<tr>
<th>Project Background</th>
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<tbody>
<tr>
<td>• Minnesota Valley Transit Authority &amp; ITS Institute at Univ. of Minnesota</td>
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<tr>
<td>• $5.3 Million (10 buses + 1 simulator)</td>
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<tr>
<td>• Lateral guidance and collision avoidance in shoulders</td>
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<td>• VAA begins November 2010</td>
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<table>
<thead>
<tr>
<th>VAA Technology</th>
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</thead>
<tbody>
<tr>
<td>Lateral Guidance</td>
</tr>
<tr>
<td>• GPS based</td>
</tr>
<tr>
<td>• HUD, Vibrating Seat, and Actuated Steering</td>
</tr>
<tr>
<td>Collision Avoidance</td>
</tr>
<tr>
<td>• Forward: Radar based, visual feedback</td>
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<tr>
<td>• Side: Lidar based, visual feedback</td>
</tr>
</tbody>
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Head-Up Display

Eugene
Alameda County
San Diego
Las Vegas
Minneapolis
Cleveland
Alameda and Eugene

**Project Background**
- Caltrans, AC Transit, Lane Transit District, and PATH at UC Berkeley
- $1.9 Million + $500K (CA share)
- 3 buses
- Lateral guidance and precision docking
- HOV lane, Toll Plaza, BRT lane
- VAA begins March 2011

**VAA Technology**
- Magnetic markers - primary
- GPS – secondary
San Diego

Project Background
- SANDAG, Caltrans, MTS, & CHP
- $4.7M out of $18M federal grant
- 8 to 10, 40’ buses
- Collision avoidance, lateral guidance, and longitudinal control
- New 20 mile bus on shoulder service
- Start date still TBD

VAA Technology
- Optical and radar based sensors
- Actuated steering
- Adaptive cruise control

VAA Evaluation by NBRTI

Evaluation Goal Areas
- Customer Satisfaction
- Bus Operator Satisfaction
- Efficiency & Productivity
- Maintenance
- Safety
- Technology Performance
## Sample Hypotheses

### Efficiency/Productivity

<table>
<thead>
<tr>
<th>Hypothesis/Question</th>
<th>Measures of Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAA will facilitate greater use of the shoulders.</td>
<td>Percent of shoulder length used with and without VAA.</td>
</tr>
<tr>
<td>VAA will facilitate higher speeds in the shoulders</td>
<td>Average speed in the shoulder with and without VAA.</td>
</tr>
<tr>
<td>VAA will facilitate greater on-time performance</td>
<td>On-time performance percentage with and without VAA.</td>
</tr>
</tbody>
</table>

### Safety

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Measures of Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAA will facilitate safe operations on the shoulders</td>
<td>Comparison of accidents per revenue mile for the evaluation year to the year prior.</td>
</tr>
<tr>
<td></td>
<td>Comparison of standard deviation of speed in the shoulders with and without the VAA.</td>
</tr>
</tbody>
</table>
Sample Hypotheses

Technology Performance

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<th>Hypothesis/Question</th>
<th>Measures of Effectiveness</th>
</tr>
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<tr>
<td>VAA will result in better lane-keeping along the shoulder</td>
<td>Average and maximum deviation from the “ideal” line.</td>
</tr>
<tr>
<td></td>
<td>Frequency of steering motor activations</td>
</tr>
</tbody>
</table>

Cleveland’s Mechanical Docking Arm
Four Evaluation Areas

1. How precise was the docking?
2. How fast was the docking?
3. How much money was spent on damages related to docking?
4. How well is the docking arm regarded by the drivers?

Comparative Study of HealthLine and EmX BRTs

Both use same model New Flyer 60’ articulated vehicle
Comparative Study of HealthLine and EmX BRTs

HealthLine platforms: 14 ½ inches

Both have elevated station platforms in the median

EmX platforms: 14 inches

Comparative Study of HealthLine and EmX BRTs

HealthLine uses docking arm

EmX uses guide strip
Comparative Study of HealthLine and EmX BRTs

HealthLine uses docking arm

EmX uses guide strip

Sticks out 5 ½ inches

Identified Comparable Stations

HealthLine 9th Street Station

EmX Hilyard Street Station

- Left side boarding
- Straight approach
Identified Comparable Stations

- HealthLine 6th Street Station
- EmX Dad’s Gate Station

- Left side boarding
- Approach has slight curve to the right

Precision Docking

Measured from the same spot at rear door

1 day of data collection
- 6 to 9 a.m.
- 4 to 6 p.m.

HealthLine: 102 samples
EmX: 54 samples
1. At stations with straight approaches, HealthLine and EmX docked with close to same precision (8 to 8 ½ inches).

2. At stations with curved approaches, HealthLine performed better.
   - HealthLine: about 6 inches
   - EmX: about 10 inches
Docking Times

Measured a distance 120’ from station stop and marked it with chalk

Timed from when bus crossed the chalk to when it stopped at station

HealthLine: 75 samples
EmX: 55 samples

Precision Docking Results

<table>
<thead>
<tr>
<th></th>
<th>Average Time (seconds)</th>
<th>Min. Time (seconds)</th>
<th>Max. Time (seconds)</th>
<th>Std. Dev. (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HealthLine</td>
<td>9th Street Station</td>
<td>14.04</td>
<td>9.15</td>
<td>21.59</td>
</tr>
<tr>
<td>EmX</td>
<td>Hilyard Station</td>
<td>8.66</td>
<td>7.51</td>
<td>10.59</td>
</tr>
<tr>
<td>HealthLine</td>
<td>6th Street Station</td>
<td>15.79</td>
<td>9.66</td>
<td>21.44</td>
</tr>
<tr>
<td>EmX</td>
<td>Dad’s Gate</td>
<td>8.18</td>
<td>7.07</td>
<td>9.78</td>
</tr>
</tbody>
</table>
Docking Time Results

1. HealthLine vehicles took 5 to 7 ½ seconds longer to dock.
   - Wide variation in times.

2. Driver experience could be a factor.
   - More experienced drivers may dock faster.

3. EmX drives do not make contact with guide strip.
   - May contribute to faster times.

Damages and Repairs

<table>
<thead>
<tr>
<th></th>
<th>Repair Costs CY 2009</th>
<th>Revenue Miles CY 2009</th>
<th>Cost per Revenue Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>HealthLine</td>
<td>$15,060</td>
<td>723,000</td>
<td>$0.02</td>
</tr>
<tr>
<td>Emx</td>
<td>$1,252</td>
<td>203,699</td>
<td>$0.01</td>
</tr>
</tbody>
</table>

HealthLine repairs for broken docking arms
EmX repairs to replace damaged tires
Opinion of HealthLine Drivers

<table>
<thead>
<tr>
<th>HealthLine</th>
<th>Strongly Agree or Agree</th>
<th>Strongly Disagree or Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. The mechanical guide wheel helps me to dock the vehicle more precisely</td>
<td>89.4%</td>
<td>10.6%</td>
</tr>
<tr>
<td>Q2. The mechanical guide wheel helps me to dock the vehicle more quickly</td>
<td>80.9%</td>
<td>19.1%</td>
</tr>
<tr>
<td>Q3. The mechanical guide wheel makes docking the vehicle less stressful for me</td>
<td>76.6%</td>
<td>23.4%</td>
</tr>
<tr>
<td>Q4. Learning how to use the mechanical guide wheel was easy</td>
<td>83.0%</td>
<td>17.0%</td>
</tr>
<tr>
<td>Q5. I would recommend the mechanical guide wheel to other transit systems with elevated platforms</td>
<td>84.4%</td>
<td>15.6%</td>
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</tbody>
</table>

47 completed surveys

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