New Directions: Modern Streetcars in the Past, Present, and Future

APTA Streetcar Subcommittee Meeting

February 2019
Oklahoma City AV Streetcar Feasibility Study Background and Objectives

Assess the current state of connected and autonomous vehicle (CAV) technologies for rail transit

Identify lessons learned from existing projects and research efforts

Understand status of regulations / legislation

Develop a scoping document and implementation plan for the use of AV for the OKC Streetcar

Define recommended next steps

Collaborative study between AECOM and Jacobs
<table>
<thead>
<tr>
<th>Benefits</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Learning Curve</td>
</tr>
<tr>
<td>Reliability</td>
<td>Public Acceptance</td>
</tr>
<tr>
<td>Customer Focus</td>
<td>Cyber Security</td>
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<tr>
<td>Operational Costs</td>
<td>Liability</td>
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<tr>
<td>Innovation / Attraction</td>
<td>Industry in its Infancy</td>
</tr>
<tr>
<td>Transportation/Transit Industry</td>
<td>Among first of its kind</td>
</tr>
</tbody>
</table>

Why an Autonomous Streetcar?

- Safety
- Reliability
- Customer Focus
- Operational Costs
- Innovation / Attraction
- Transportation/Transit Industry
STATE OF THE INDUSTRY
Connected and Autonomous Vehicles Definition

- At least some aspect of control occurs without driver input
- May be automated or connected
- Implications for safety, convenience, and physical environment
# Grade of Automation (GoA) for Train Systems

<table>
<thead>
<tr>
<th>Grade of Automation</th>
<th>Type of train operation</th>
<th>Setting train in motion</th>
<th>Stopping train</th>
<th>Door Closure</th>
<th>Operation in event of Disruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoA 1</td>
<td>ATP with driver</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
</tr>
<tr>
<td>GoA 2</td>
<td>ATP and ATO with driver</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Driver</td>
<td>Driver</td>
</tr>
<tr>
<td>GoA 3</td>
<td>Driverless</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Train Attendant</td>
<td>Train Attendant</td>
</tr>
<tr>
<td>GoA 4</td>
<td>UTO</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
</tr>
</tbody>
</table>

ATP - Automatic Train Protection  
ATO - Automatic Train Operation  
UTO - Unattended Train Operation
Automation of Transit System

- **Automatic Train Operation (ATO)**
  - 1967

- **Unattended Train Operation (UTO)**
  - 1983

- **Grade of Automation (GoA) Level 4 Systems**
  - 1986
  - 1994

- **Autonomous Streetcars and Trams**
  - 2017

- **Siemens Combino Self-Driving Trolley**
  - 2018

- **Grade of Automation (GoA) Level 2 Systems**
  - 1972

- **Grade of Automation (GoA) Level 3 Systems**
  - 1987

- **Autonomous Rail Transit, China**

- **Alstom / RATP Autonomous Tram, France**
Each vehicle is a node with the ability to send and receive critical safety + mobility information to other vehicles.
Vehicle to Infrastructure Communication (V2I)

Vehicles are able to send and receive information to surrounding infrastructure
Vehicles can communicate with other vehicles, infrastructure, and other users of the public right-of-way.
Connected Streetcar Case Study

Connected Streetcars to

• Detect other connected vehicles

• Warn operators of conflicts

• Reduce risk of collision
INDUSTRY INTERVIEWS
Industry Interviews

Universities
- Oklahoma State University
- University of Oklahoma

Transit and Public Agencies
- Colorado DOT- Otto AV Freight Demonstration
- Contra Costa County Transit Authority- GoMentum Station
- Miami Metromover
- OKC Public Agencies

Private Vendors/Technology Companies
- Alstom/RATP AV Tram
- Local Motors – Developer of “Olli”
- EMTRAC
- Quantum Spatial
- Proterra
- Gillig
- New Flyer
- Brookville
- Siemens
- Easy Mile
- DELPHI
- Here
- Opticom GPS
SYSTEM REQUIREMENTS
Applicable AV Technologies

Sensing (Geolocation/LiDAR)
- **LiDAR**
  - Essential for dead reckoning
  - Collision avoidance
  - Creates objects for internal intelligence

Seeing (Cameras)
- **Cameras**

Thinking (ML/Ci)
- **Machine Learning**
  - Example – speed bump vs. person laying in the road

Communicating (Wayside Requirements)
- **System Overview**
- **Streetcar Installation Details**
  - One Vehicle Computer Unit (VCU) and RF/GPS Antenna per Cab
  - VCU requires power, speed sensor and ignition sensor
  - Antenna is mounted on roof
  - Connection to onboard computer needed for enhanced control
Vehicle Requirements - Existing Systems

**Group 1**
Propulsion/Braking
- Propulsion System
- Dynamic Braking
- Friction Braking
- Track/Park Brake
- Pantograph/Power Collection
- Battery Charger/LVPS
- OESS – Battery Power

**Group 2**
Operator Controls
- Horn/Bell
- Door Operation System
- Radio/Silent Alarm
- HVAC

**Group 3**
Communication/Safety & Security
- Lighting/Emer. Lighting
- PA/Intercom/APIS/APC
- CCTV/Platform Cameras
- GPS/AVL/TSP/TWC
Vehicle Requirements - Existing Systems – Operator Cab

**Group 1**
Operator Controls - Streetcar

- Master Controller
- Deadman Switch
- Key Switch
- Emergency Brake Button
- Reverser Switch
- Foot Switches - TWC
- Raise/Lower Pantograph

**Group 2**
Operator Controls – On-board Systems

- Radio/Silent Alarm
- Communications Panel
- Microphone
- Door Controls
- Horn/Bell
- Windshield Wiper/Washer
- Cab Comfort/Defroster
- CCTV - Platform
- Lights/Flashers

**Group 3**
Operational Indicators

- On/Off Wire Indicator
- Bypass Circuits – Doors, Brakes, Speed
- Status/Fault Indicators
- Speedometer
Vehicle Requirements - Vehicle Functions

Group 1
Acceleration/Braking

- Acceleration
- Deceleration
- Overspeed Protection
- Roll Back Prevention
- No Motion Detection
- Spin/Slide Control
- Speed Control
- Sanding

Group 2
Operational Functions

- Stop Request
- Doors Open/Close
- Door Annunciation
- Emergency Door Release
- Door Obstruction Detection
- Power Collection and Regeneration
- Load Weigh/Tractive Effort & Platform Height
Operating Scenario

Conductors/Ambassador – Customer Service
- Passenger Assistance
- Fare collection/enforcement
- Security
- Incident Response

Dispatchers / Controllers
- Monitor Operations
- Passenger Emergency Intercom
- Incident Response: Accidents/Silent Alarm
- Qualified as Operators
- Adjustment of Schedule, Routing Changes
Potential operational savings of 10% to 20% annually ($400k-$800k)
RECOMMENDATION
Recommendations

Create Autonomous Streetcar Test Laboratory
- City to administer
- Governed by Board of Directors (public and private)

Launch three year research and development program
- Funding from OKC, EMBARK, federal sources, private sources, stakeholders
- Dedicate Car #7 to be equipped with necessary components

A significant return-on-investment from the development of the design requirements, safety standards assessed, and lessons learned that could translate to the rest of the CAV transportation industry should be expected
PILOT PROJECT MODEL
Objectives of Pilot Project

Achieve autonomous operation at GoA 3 or 4

Thorough understanding of requirements to achieve each level of automation:

- Infrastructure requirements
- Jurisdictional approvals, including safety certification
- Operational start up procedures, including integrated testing
- Vehicle requirements and potential for retrofits
- Overall costs to implement an autonomous streetcar system
<table>
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<th>SCOPE</th>
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<tbody>
<tr>
<td>✓ Retrofit existing streetcar (Vehicle #7)</td>
</tr>
<tr>
<td>✓ Evaluate efficacy of installation of automated vehicle functionalities</td>
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<tr>
<td>Define and install necessary improvements for each phase:</td>
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<tr>
<td>✓ Wayside improvements</td>
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<tr>
<td>✓ Technological interfaces with on-board computer</td>
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<tr>
<td>✓ Supplemental processing systems</td>
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Use of Hudson Non-Revenue Track

- Benefit to testing in non-revenue mode - unique to OKC system
- Investment in the storage and maintenance facility away from the revenue line creates unique opportunity for funding/study
- Non-revenue track in center lane makes dual direction testing possible

1/3 mile test track
## Potential Phasing Plan for AV Streetcar Project

<table>
<thead>
<tr>
<th>Phase</th>
<th>AV Level</th>
<th>Location</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Hudson Non-Revenue Track</td>
<td>Operation of the vehicle can also be conducted in non-revenue times on the mainline to further evaluate the performance</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Hudson Non-Revenue Track</td>
<td>Testing could overlap with Phase 1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Bricktown Loop / Mid-town Loop</td>
<td>Non-revenue service only</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Hudson Non-Revenue Track</td>
<td>Could occur concurrently with Phase 3</td>
</tr>
<tr>
<td>5</td>
<td>1 or 2</td>
<td>Bricktown Loop / Mid-town Loop</td>
<td>Revenue service - may be beyond scope of Pilot Project</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Bricktown Loop / Mid-town Loop</td>
<td>Revenue service - may be beyond scope of Pilot Project</td>
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Outreach and Communication

- Gain an understanding of public perceptions/concerns
- Mine ideas related to other applications - cross-industry interests
- Educational materials
Findings

- An autonomous streetcar system is feasible

- Significant complexities will need to be addressed
  - Reviews and approvals from multiple agencies
  - Safety certification and start up processes would need to be established

- An AV streetcar in OKC would be the first of its kind in North America
  - Help establish new standards and best-practices
  - Could be of great benefit to surface-running transit systems
  - Important first step toward transition to comprehensive CAV transportation network

Siemens Combino Tram Potsdam, Germany
World’s First Autonomous Tram
Source: Popular Mechanics
THANK YOU

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