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

APTA Streetcar Subcommittee Meeting

February 2019

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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

Why an Autonomous Streetcar?

Benefits

- Safety
- Reliability
- Customer Focus
- Operational Costs
- Innovation / Attraction
- Transportation/Transit Industry

Concerns

- Learning Curve
- Public Acceptance
- Cyber Security
- Liability
- Industry in its Infancy

Among first of its kind

STATE OF THE INDUSTRY

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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**

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Grade of Automation (GoA) for Train Systems

Grade of Automation	Type of train operation	Setting train in motion	Stopping train	Door Closure	Operation in event of Disruption
GoA 1	ATP with driver	Driver	Driver	Driver	Driver
GoA 2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver
GoA 3	Driverless	Automatic	Automatic	Train Attendant	Train Attendant
GoA 4	UTO	Automatic	Automatic	Automatic	Automatic

ATP - Automatic Train Protection ATO - Automatic Train Operation UTO - Unattended Train Operation

Automation of Transit System

1967

Automatic Train Operation (ATO)

1972

Grade of Automation (GoA) Level 2 Systems

1983

Unattended Train Operation (UTO)

1986 - 1994

Grade of Automation (GoA) Level 4 Systems

1987

Grade of Automation (GoA) Level 3 Systems

2017

Autonomous Streetcars and Trams

Autonomous Rail Transit, China

Alstom / RATP Autonomous Tram, France

2018

Siemens Combino Self-Driving Trolley

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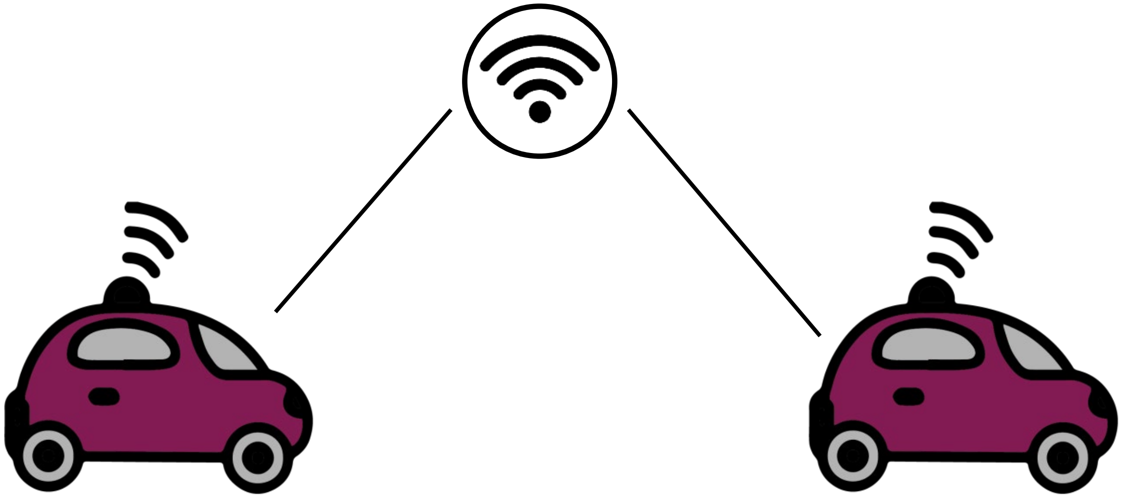
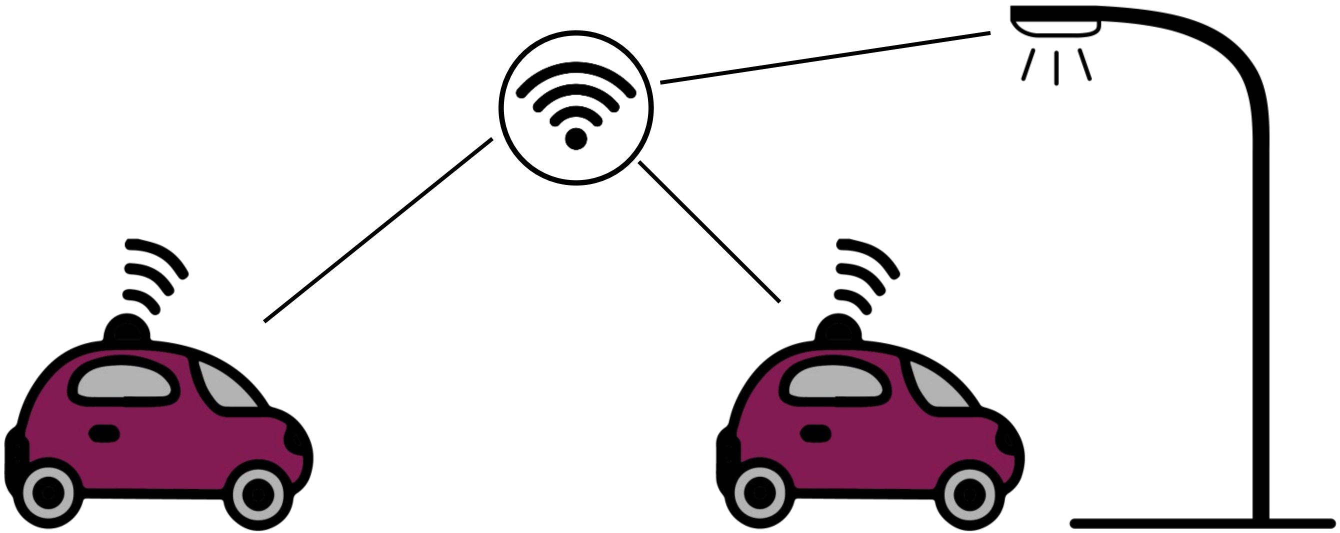
Vehicle to Vehicle Communication (V2V)



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

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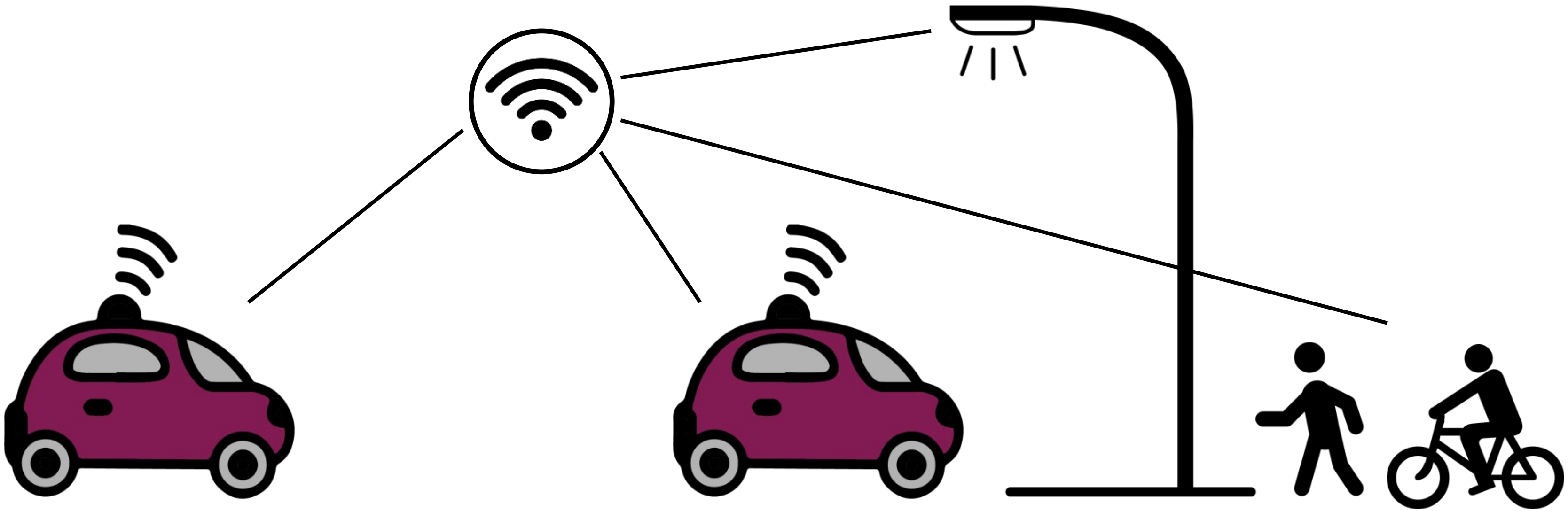
Vehicle to Everything Communication (V2X)



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

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INDUSTRY INTERVIEWS

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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

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SYSTEM REQUIREMENTS

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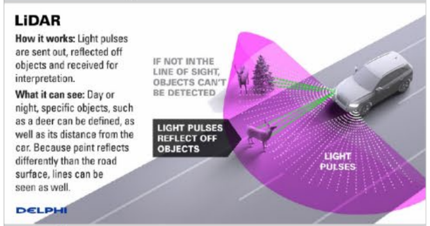
Applicable AV Technologies

Sensing (Geolocation/LiDAR)

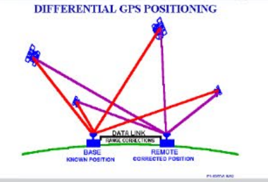
LiDAR

- Essential for dead reckoning
- Collision avoidance
- Creates objects for internal intelligence



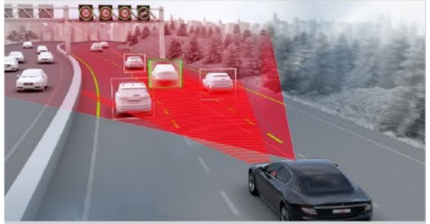
Geolocation

- Geo-fencing creates autonomous events
- GPS can be used but not 100% reliable – particularly in "urban canyons"
- Differential GPS could be used to supplement
- Many use dead reckoning



Seeing (Cameras)

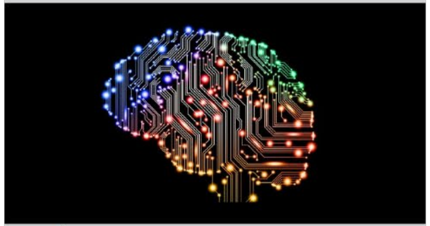
Cameras



Thinking (ML/CI)

Machine Learning

- Example – speed bump vs. person laying in the road

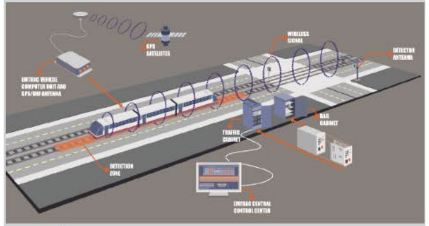


Cognitive Intelligence

- Used for human machine interface
- IBM Watson example – "It's raining, did you bring an umbrella?"
- Example – speed bump vs. person laying in the road

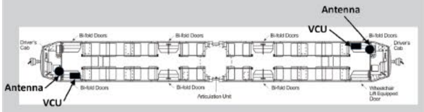
Communicating (Wayside Requirements)

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



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VEHICLE REQUIREMENTS

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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 3
Operational Indicators

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

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

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

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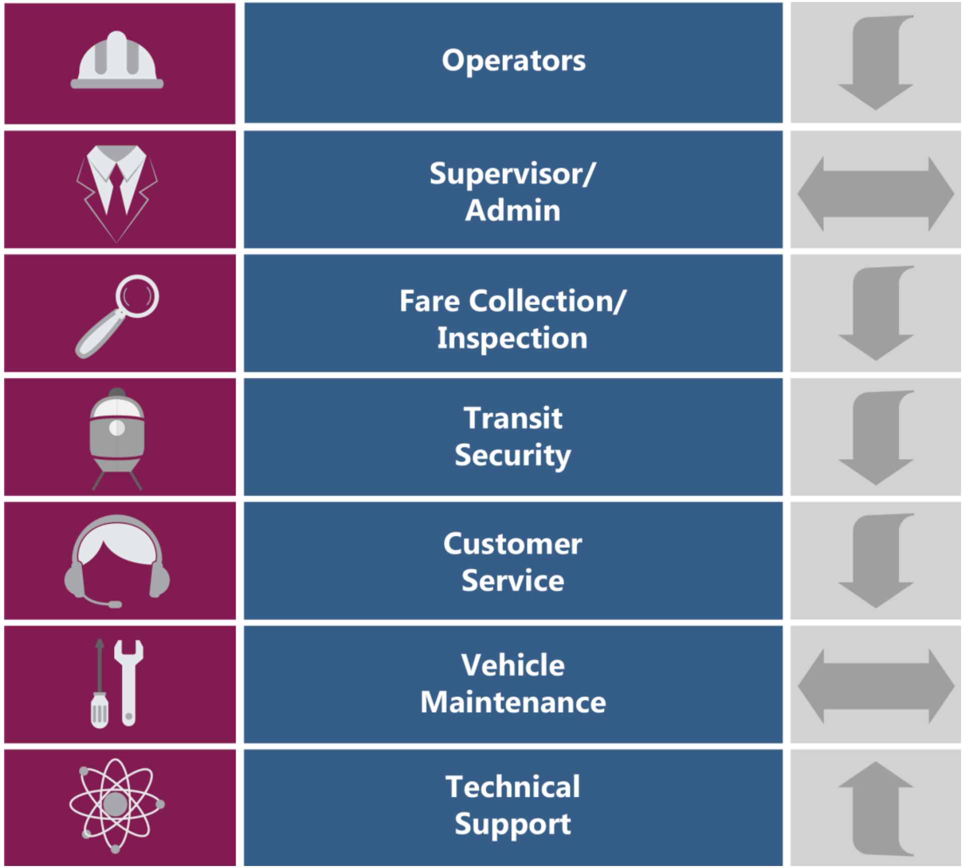
Cost Impacts



Potential operational savings of 10% to 20% annually ($400k-$800k)

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RECOMMENDATION

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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

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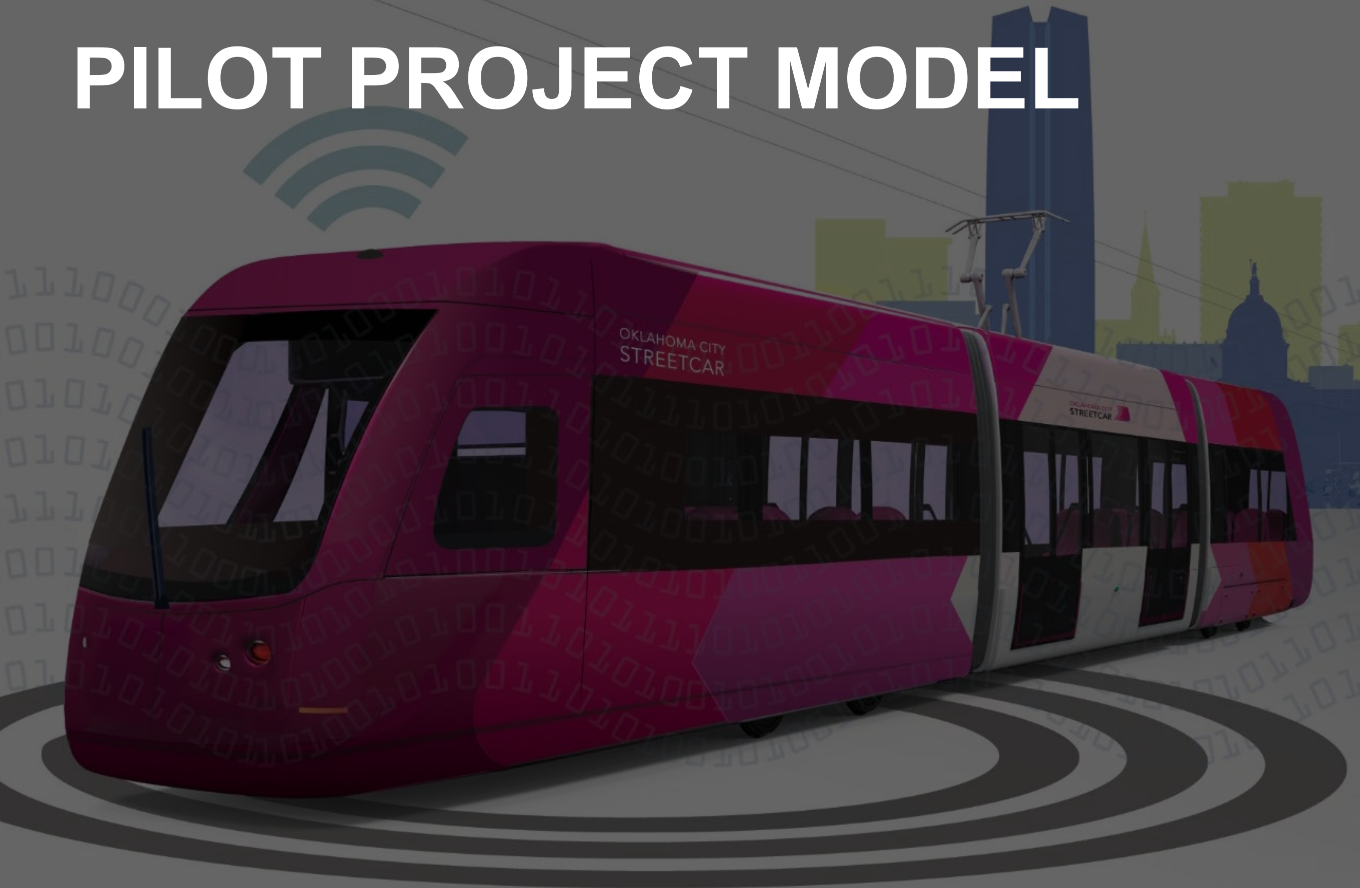
PILOT PROJECT MODEL



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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

Scope of Pilot Project

SCOPE

- ☑ Retrofit existing streetcar (Vehicle #7)
- ☑ Evaluate efficacy of installation of automated vehicle functionalities
- ☑ Define and install necessary improvements for each phase:
  - Wayside improvements
  - Technological interfaces with on-board computer
  - Supplemental processing systems

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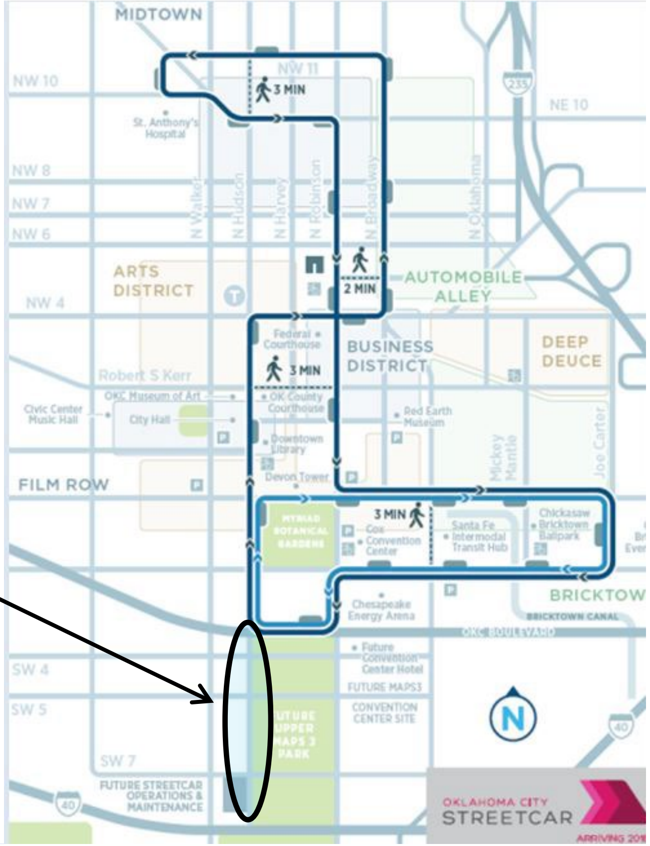
Use of Hudson Non-Revenue Track



1/3 mile test 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

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Potential Phasing Plan for AV Streetcar Project

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

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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

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SUMMARY OF FINDINGS

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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

Veronica Siranosian, AICP, LEED GA
Veronica.Siranosian@aecom.com

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