Fleet Electrification for Small Vehicle On-Demand Services

Session 2A: Electrification / EV Charging

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AMS Automated Mobility Services, LLC

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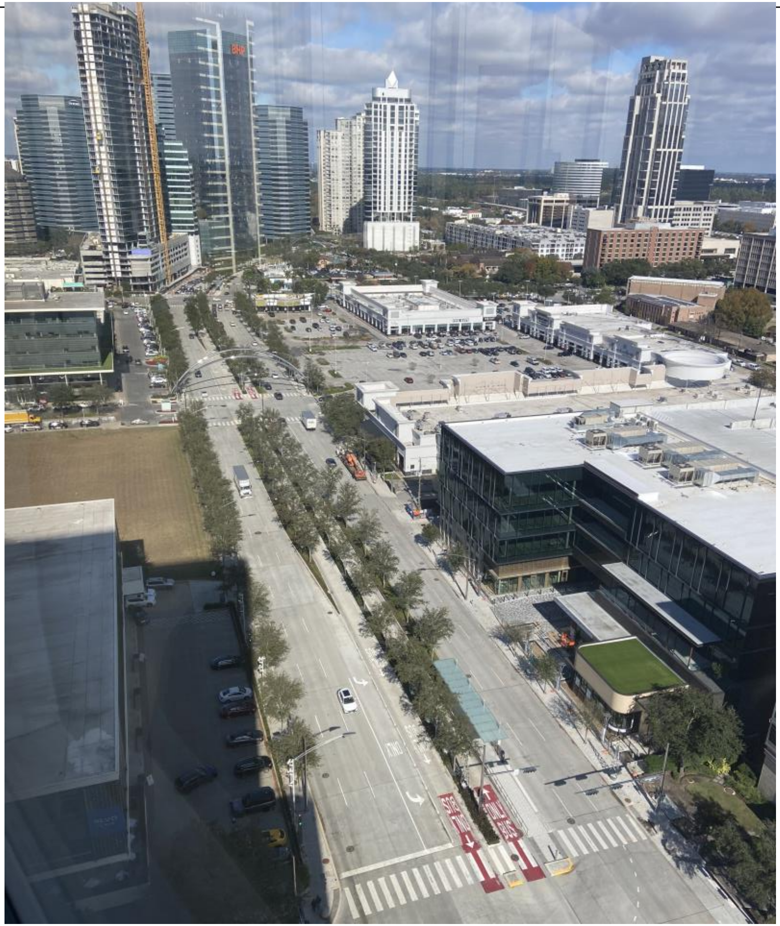
Organization of Presentation

Synopsis of NREL Automated Mobility District Research

Automated Fleet Operations in On-Demand Transit Network Service

Fully Integrated Battery Charging Systems and Infrastructure



Source: Houston Uptown District 2021

ITS Texas Annual Meeting September 29, 2022 San Marcos, TX

Synopsis of NREL Automated Mobility District Research

Development of Concepts for Automated/Autonomous Vehicle (AV) Fleets as Essential Building Blocks of Future Automated Mobility Districts (AMDs)

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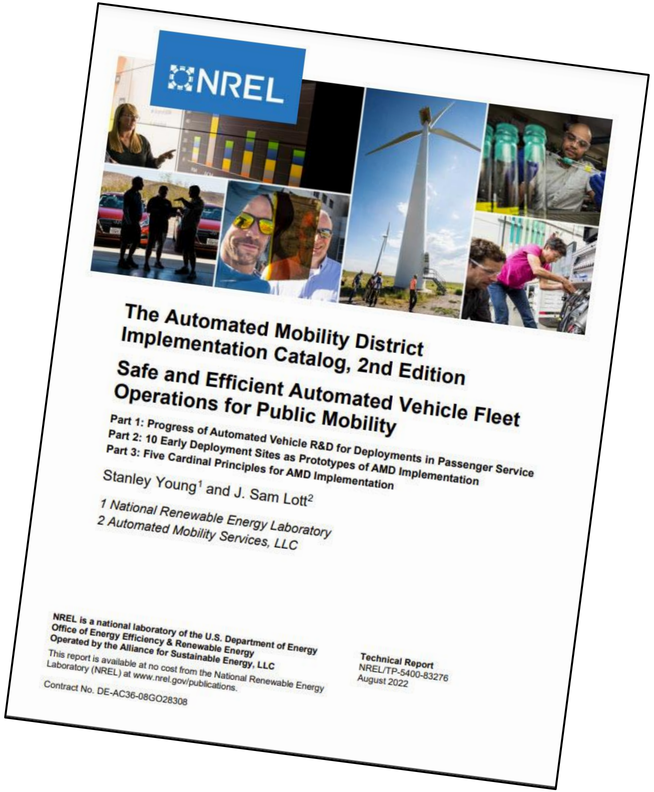
Synopsis of Automated Mobility District Research

Automated Mobility District Implementation Catalog Series is Foundational



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The Automated Mobility District Implementation Catalog, 2nd Edition

Safe and Efficient Automated Vehicle Fleet Operations for Public Mobility

Part 1: Progress of Automated Vehicle R&D for Deployments in Passenger Service
Part 2: 10 Early Deployment Sites as Prototypes of AMD Implementation
Part 3: Five Cardinal Principles for AMD Implementation

Stanley Young[1] and J. Sam Lott[2]

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2 Automated Mobility Services, LLC

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NREL/TP-5400-83276
August 2022

The Automated Mobility District Implementation Catalog 2nd Edition: Safe and Efficient Automated Vehicle Fleet Operations for Public Mobility

- Coauthors: Stanley Young; J. Sam Lott
- Published July 2022: Golden, CO: National Renewable Energy Laboratory. NREL/TP-

https://www.nrel.gov/docs/fy22osti/83276.pdf

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The Automated Mobility District Implementation Catalog 2nd Edition – Safe and Efficient Automated Vehicle Fleet Operations for Public Mobility

- **Part 1** Progress of Automated Vehicle R&D for Deployments in Passenger Service
- **Part 2** 10 Early Deployment Sites as Prototypes of AMD Implementation
- **Part 3** Five Cardinal Principles for AMD Implementation

10 Early Deployment Sites Tracked Through Phase 1 and Phase 2 Research

Site #1: Columbus, OH
Site #2: Arlington, TX
Site #3: Las Vegas, NV
Site #4: Jacksonville, FL
Site #5: Houston, TX
Site #6: M-City, Univ. of Michigan,Ann Arbor, MI
Site #7: Rivium, City of Capelle aan den Ijssel, Netherlands
Site #8: Denver, CO
Site #9: Gainesville, FL
Site #10: Babcock Ranch, FL

Synopsis of Automated Mobility District Research

Progress of AV R&D for Deployments in Passenger Service

- Challenge of preparing for mixed traffic operations.
- Improved equity of access in extended AV service within the city.

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Early Deployment Sites as Prototypes of AMD Implementation

- Multimodal environment brings added complexity of operations.
- Large scale deployments will require Intelligent Roadway Infrastructure.

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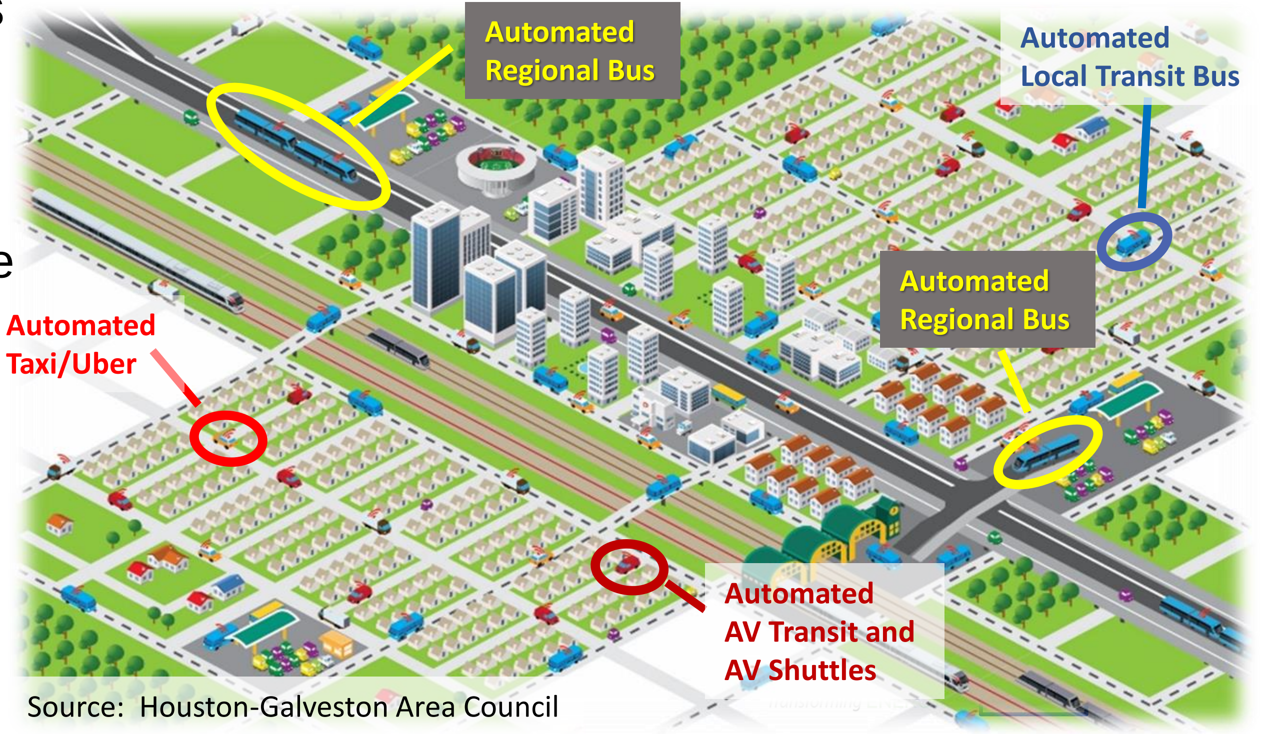
Industry Trends Show AV Technology Will Occur Primarily with Battery-Electric Vehicle Drive Trains

Synopsis of Automated Mobility District Research

AMD Concept Has Multiple AV Fleets Operating Within the District

AMDs in Urban Districts and Major Activity Centers with AV Circulation and FM/LM Connections to High-Capacity Transit Automated BRT and local bus lines.

- Automated AV fixed route transit & on-demand service transit modes.
- AV on-demand car services and AV taxi fleets.
- How will BEVs be charged?



Source: Houston-Galveston Area Council

Synopsis of Automated Mobility District Research

AV/EV Shuttle Deployment in Rivium Business Park near Rotterdam in the Netherlands Will Be a Crossover Technology

Source: 2getthere/ZF

Crossover APM technologies now beginning to enter the Automated/Autonomous Vehicle (AV) marketplace. The experience with system-level operations is an important aspect of this crossover influence in the automation of roadway transport systems.

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ITS Texas Annual Meeting September 29, 2022 San Marcos, TX

Automated Fleet Operations in On-Demand Transit (ODT) Network Service

Passenger Transport along a Network of Roads or Dedicated Transitways with AV Fleet Vehicles Dispatched in Response to Passenger Demand Calls/Requests

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Automated Fleet Operations in On-Demand Transit Network Service

Distinctions of ODT Operations Compared to Fixed Route Transit

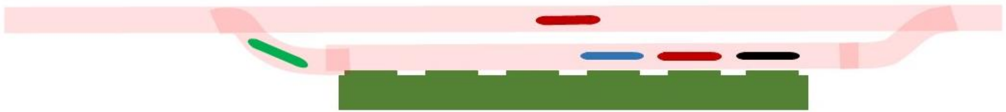
- On-Demand Service direct from Origin to Destination Station – similar to “Ride-Hailing” service, or “Robo-Taxi” operations.
- Off-roadway boarding station/curbfront allows for a robust demand-response dispatching of individual vehicles to carry their passengers:
  - Station/curb dwell time not fixed, with extended dwell possible to load multiple travel parties.
  - No other stops in-between Origin and Destination stations/curbs.
- Several prototype ODT network system concepts are now operating in early AV technology development pilot deployments.

Source: City of Arlington, TX

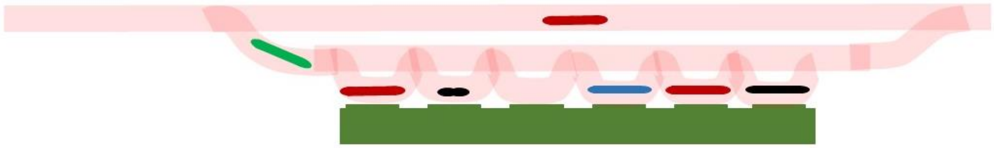
Station and Curbfront Configurations are Critically important to System Throughput Capacity

- How vehicle berthing is provided at boarding locations is fundamentally important for small-to-medium size vehicle ATN systems.
- Individual vehicle berths in parallel versus serial configuration have practical and strategic benefits to station performance and capacity.

Conceptual Serial Berth
Station Configuration

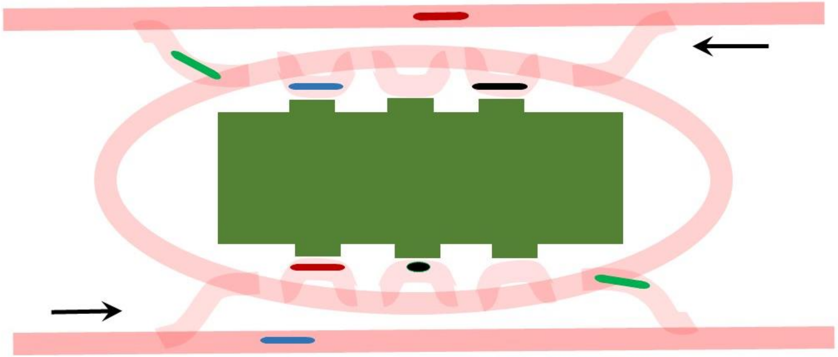


Conceptual Parallel Berth
Station Configuration



Automated Fleet Operations in On-Demand Transit Network Service

Example of a Parallel Berth Station Configuration

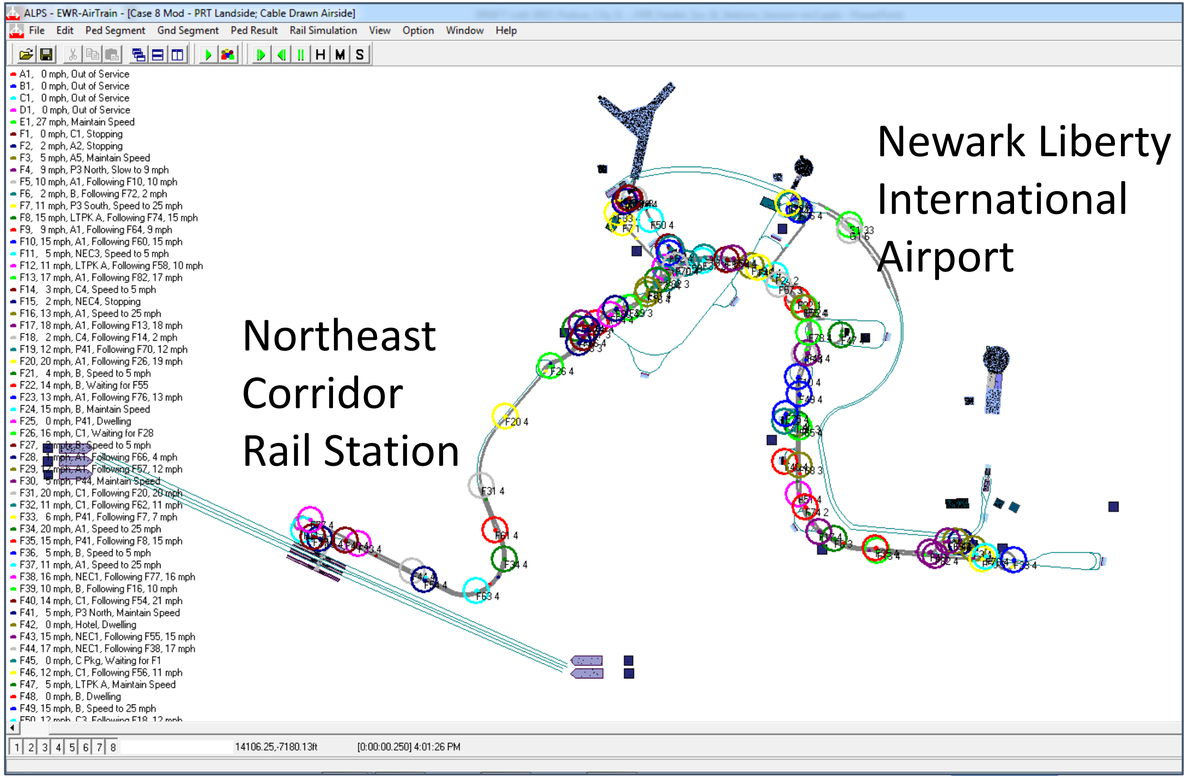


Source: The Boring Company website – https://www.boringcompany.com/lvcc Accessed 23 January 2022

Automated Fleet Operations in On-Demand Transit Network Service

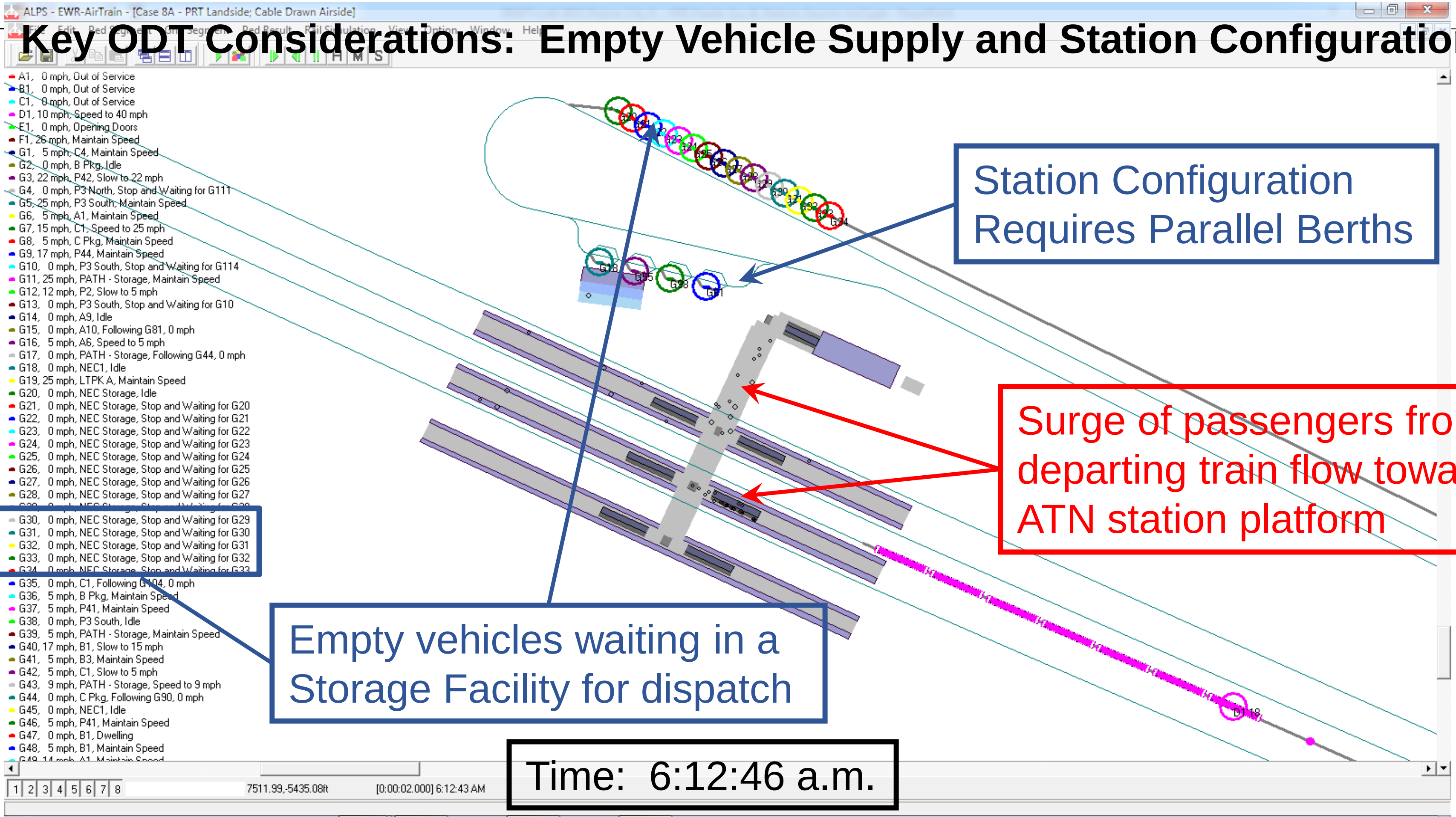
A TRB 2016 Presentation Addressed Facility Design Considerations for High Speed Rail (HSR) Intermodal Stations with ATN Feeder Service

- Small vehicle technology (4-passenger) with shared-ride operations.
- System performance is impacted by remote NEC Station location.
- Initial studies showed an inability to sustain adequate vehicle supply to the NEC Rail Station during airport access peak periods, creating “empty vehicle starvation” at the remote rail station facility.



Automated Fleet Operations in On-Demand Transit Network Service

Key ODT Considerations: Empty Vehicle Supply and Station Configuration



Station Configuration Requires Parallel Berths

Surge of passengers from departing train flow toward ATN station platform

Empty vehicles waiting in a Storage Facility for dispatch

Time: 6:12:46 a.m.

Fully Integrated Battery Charging Systems and Infrastructure

Multiple AV fleets in operation within an AMD will be best served by a common automated battery charging system and infrastructure.

BEV Fleet Operations Requires Dedicated Infrastructure

Small Vehicle Charging Levels	Charging Time (Hrs)*	Power Supply (Amps @Voltage)	Power (kW)
Level 1 Charging Station			
○ 110v house circuit plug-in	12+	20 A @120 VAC	2.4
Level 2 Charging Station			
○ 240v house circuit plug-in	8+	40 A @240 VAC	9.6
○ Tesla Home 100kWh Charging Unit	6+	50 A @240 VAC	11.5
Level 3 DC Fast Charging Station			
○ Commercial Grade Fast-Charge Station	2+	120 A @240 VAC	36
○ Tesla Supercharger Station	0.75	250A @480 VAC	120

*** Reference – Tesla Model X, 200 mile Range**

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Fully Automated Systems – Integrated Battery Charging Systems

Full Size Bus Battery Charging Requires Special Infrastructure

Bay Area EV Bus Operator

- "Deep" Charging (depot) – 90kW with 2-4 Hours Charge Time
- On-Route Charging (periodic) – 50 kW 10 minute Charge Times

Proterra EV Bus Data

- 50-60 Mile Range (periodic) – 10 min. periodic charge time, 350 KW max charge rate
  - Uses Overhead Fast-Charge Technology
- 150-200 Mile Range (depot) – 3 hour charge time
- 250-350 Mile Range (depot) – 4-5 hour charge time

These values have been rounded-off for simplicity of presentation

<u>In comparison to Small Vehicle ODT Transit Network Service</u>:

Fixed Route Bus Operations allow fewer dedicated charging stations to adequately serve the operating fleet along the "line-haul" operating route.

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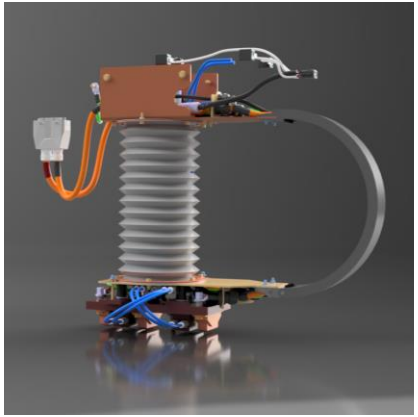
Fully Automated Systems – Integrated Battery Charging Systems

Battery Charging Aspects of the System Design Can Add to the Complexity of Automated Fleet Operations

<u>DC Fast Charge Power Transfer can be Accomplished with High-Precision Docking of AV Fleet Vehicles at Stations</u>

Rivium 3.0 vehicle technology applies an automated contactor deployment device in selected station berths for “opportunity charging” with DC fast charge equipment.

Source: 2getthere/ZF



Source: Oceaneering International

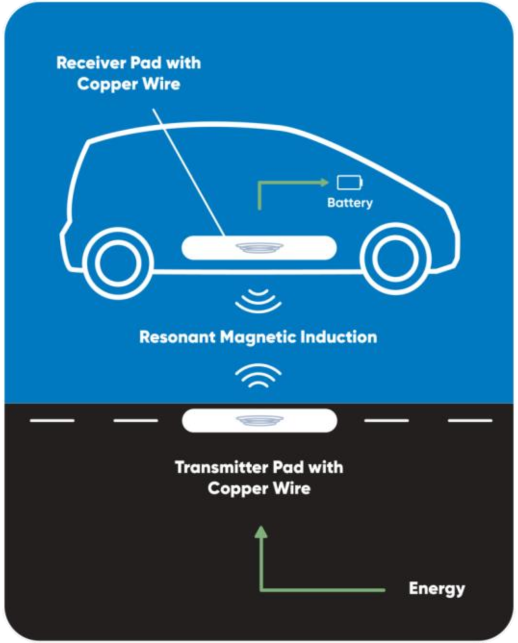
Fully Automated Systems – Integrated Battery Charging Systems

Inductive Power Transfer for Moderately High Battery Charging Rates Will be an Option with Semi-Precise Station Docking of AV Fleets

Volvo will test wireless charging with EV Taxis

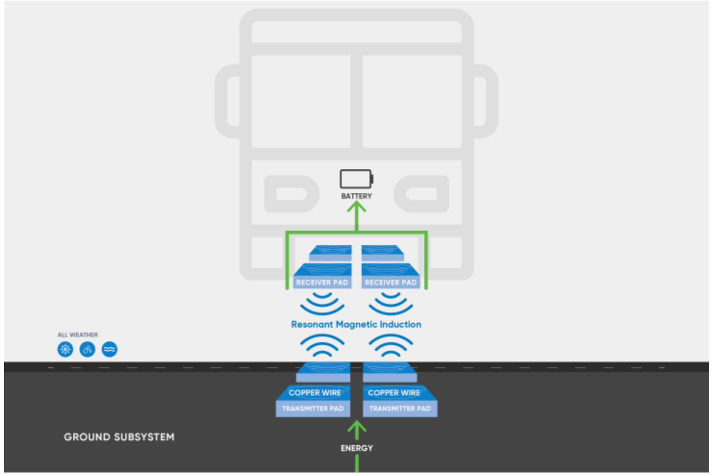
Mar. 4, 2022 Autoweek Magazine

Source: Momentum Dynamics Website
https://momentumdynamics.com/solution/#publictransit



Inductive Power Transfer for Contactless Battery Charging an Option for Large and Small Vehicles in an AV Fleet Operation

Inductive Power Transfer charging will require careful design of vehicle body for protection of passengers onboard from potentially harmful effects.



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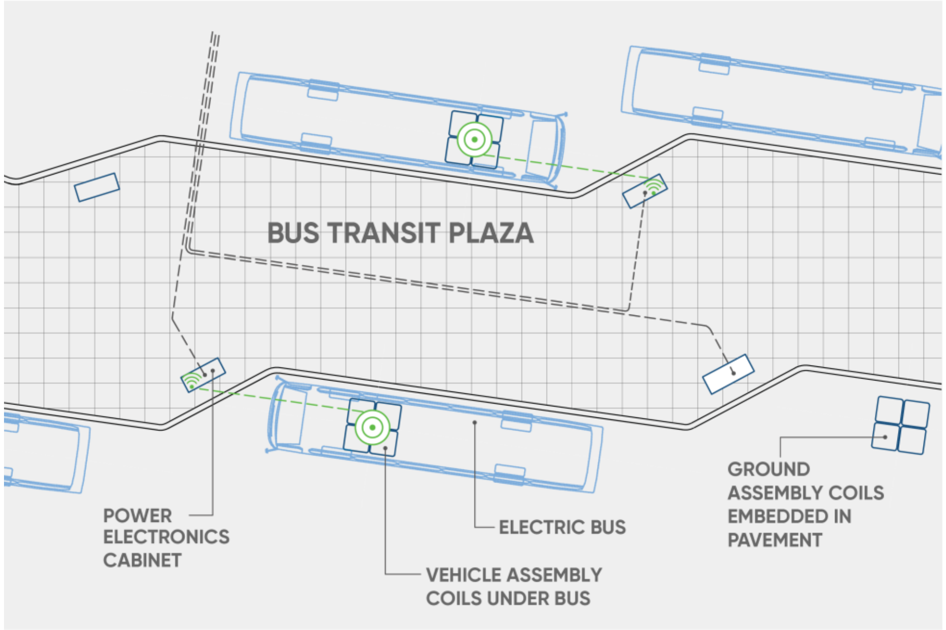

Battery Charging Philosophy Affects System Design and Fleet Size

Depot or Storage Area Charging Takes Vehicles Out of Service

- Allows placement of charging stations where it is convenient and cost effective.
- Manual plug-in charging more manageable with Operations Staff.
- Deep Charging in Depot and a few storage locations can supplement other charging.
- Fleet size impacts can be as high as +20% to +30% extra vehicles.

Fully Automated Systems – Integrated Battery Charging Systems

Battery Charging Philosophy Affects System Design and Fleet Size

Opportunity Charging in Stations Keeps Vehicles in Service While Maintaining a Ready-Dispatch Vehicle Status

- Station berth charging system provides for fully automated charging.
- Power transfer design for vehicle/ charging station interface is a key design factor.
- Precision Docking in station berths is best for a general design requirement.
- Parallel Berth configuration allows an extended vehicle dwell time when needed for battery charging.

Fully Automated Systems – Integrated Battery Charging Systems

Battery Charging Philosophy Affects System Design and Fleet Size

Source ULTra PRT

A mixed design with both Opportunity Charging in the station berths and Deep Charging at strategically located off-line storage locations will be the best approach for Small Automated Vehicles operating in managed fleets in an On-Demand Transit Network System.

Conclusions on Fleet Electrification for Small Vehicle Fleet Operations with ATN Type of On-Demand Services

1. AV technology is a natural fit with battery-electric vehicle fleets.
2. Fully automated AV fleets will be best served by fully automated battery charging capability.
3. Off-line stations with parallel berth configuration allow vehicles to dwell for an extended time until they are dispatched into service.
4. Battery charging in station berths is an excellent option for “opportunity charging” during off-peak periods without disrupting station capacity and performance levels.
5. “Deep Charging” of vehicle batteries with high-power charging stations can also be accomplished in fully automated mode in the depot or in storage areas specifically designed for this purpose.

Fleet Electrification for Small Vehicle On-Demand Services

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Conference Papers and Presentations Formulating Concepts for Phase 3 Research Plan

1. Passenger Boarding Station and Curbfront Configuration Concepts for On-Demand Services with Small Automated Vehicles
   - Coauthors: J. Sam Lott; Stanley E. Young, Ph.D.; Andrew Duvall, Ph.D.; Alejandro Henao, Ph.D.
   - Proceedings of the ASCE Intl. Conference on Transportation and Mobility, Automated People Mover and Automated Transit Systems, June 2022
   - NREL Online Publication of Conference Paper:

     https://www.nrel.gov/docs/fy22osti/81976.pdf

2. Fleet Electrification for Small Vehicle On-Demand Services
   - ITS Texas Annual Meeting, San Marcos, TX; September
   - Presenter: J. Sam Lott


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Passenger Boarding Station and Curbfront Configuration Concepts for On-Demand Services with Small Automated Vehicles

Preprint

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