Sustainable Public Transport: Providing Responsive, On-Demand Service With Clean Energy

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Photo by Dennis Schroeder, NREL 55200

Contents

On-Demand Transit (ODT) Introduction

Defining ODT

"…the transport of passengers for hire where the passenger determines the locations for the beginning and end of journey, as well as the time of travel."

- Department of Transport, Gov. of Western Australia (government)

"…transport for groups where vehicles alter their routes each journey based on demand without using a fixed route or timetable…."

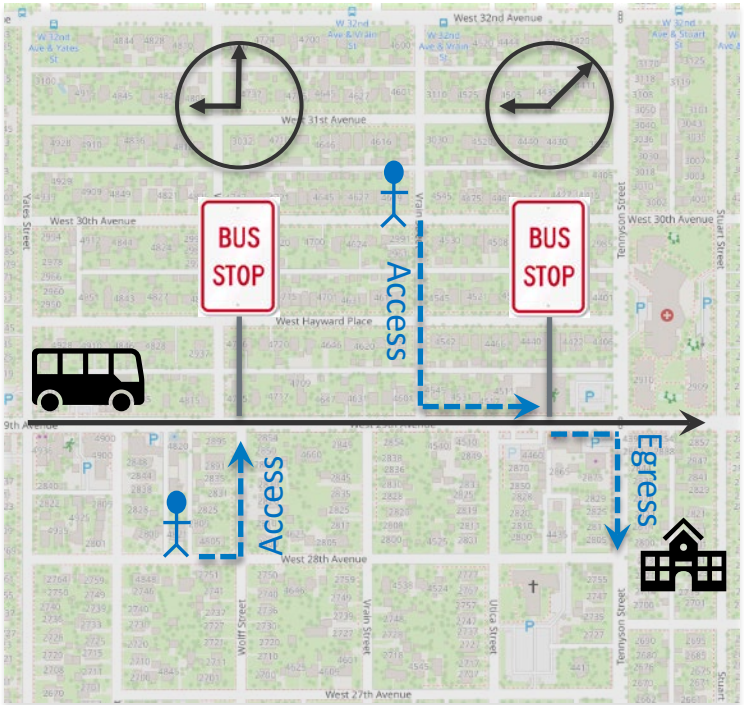
- Wikipedia (crowdsourced)

"… a form of public mobility that has more in common with private ride-hail services (Uber and Lyft) than traditional public transit fixed-route bus services—primarily app-based, but capable of phone and street hailing."

- Stanley Young, PE, Ph.D. (advanced transportation and urban scientist, National Renewable Energy Laboratory [NREL])

Key attributes: Shared public mobility, responds to demand in space and time.

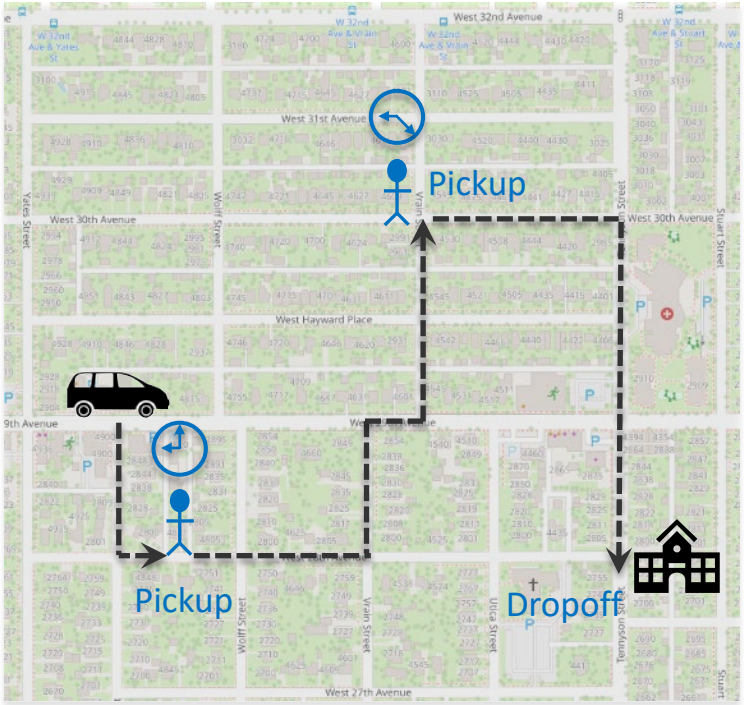
Visual Comparison of Fixed-Route and On-Demand



Source: NREL

Fixed-Route:

- Fixed schedule and stops, larger vehicles.



Source: NREL

ODT:

- Flexible schedule, flexible stop locations.

ODT Business Model/Service Designs

Ride-Hailing Services:
Subsidized Uber/Lyft trips

Software as a Service:
Dispatching and operations software

Transportation as a Service:
Vehicles, drivers, and operations

Uber

spare

RIDECO

TransLoc

Via

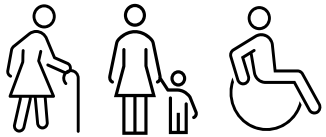
lyft

The Routing Company

Pantonium

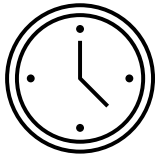
CIRCUIT

Benefits of ODT



Accessibility/Coverage

Disabled, elderly, people living >¼ mile from a transit stop, rural areas with no transit options



High Level of Service

Shorter ride times and average wait times, high customer satisfaction

Increased User Flexibility

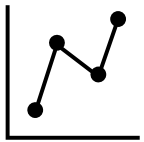
Door-to-door, real-time requests, does not require preplanning

Potential To Reduce Energy Consumption and Emissions

More shared trips, intelligently managed fleets, "right-sized" vehicles

Safety

Professional drivers, easier transportation option for elderly and/or impaired drivers



Rich Data Streams

Ridership, trajectory, highly granular spatiotemporal data

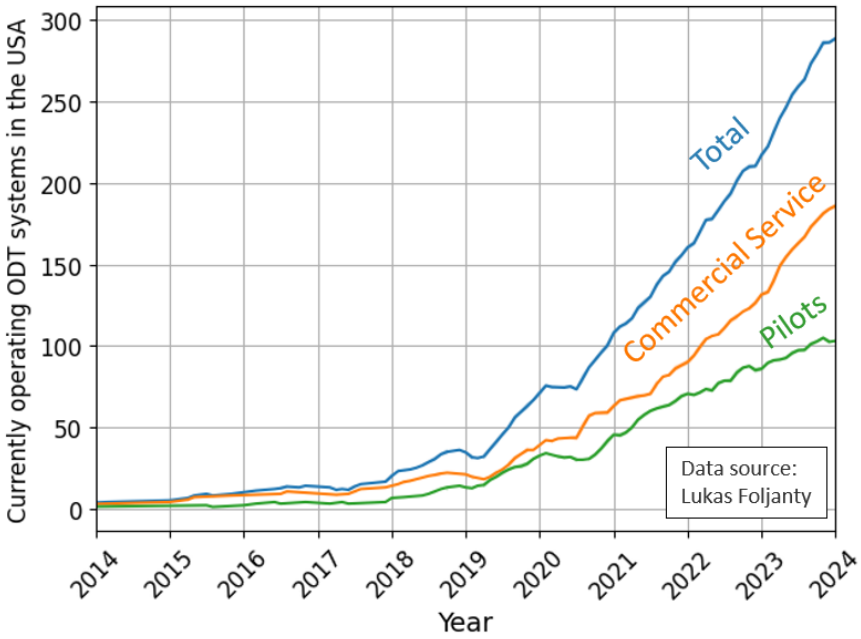
Challenges of ODT

- **Scaling up** – Small increases in ridership will require additional supply of vehicles and drivers to maintain service quality.
- Serving **peak times** – System reliability and keeping low wait times.
- No fixed schedule (uncertainty) can be **challenging for commuters**.
- **Integration** with nearby transit systems (data streams, real-time info).
- Equity for those **without smartphones** (can call to schedule but cannot track vehicle).
- **Cost scales with demand** – A double-edged sword.

ODT Trends

Trends and Motivation

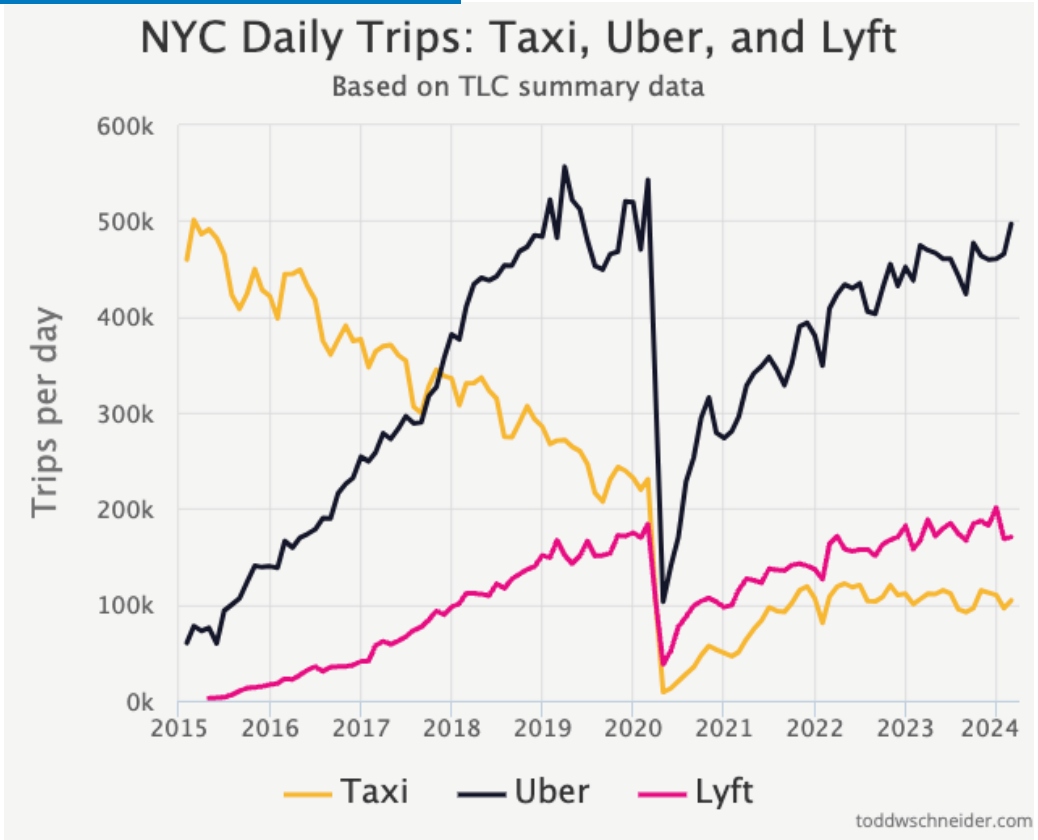
- ODT systems have been increasing rapidly since 2019 and continue to accelerate.
- NREL's Technologists in Communities team has been exploring use cases.
- More than 50% estimated compounded growth in ODT from 2017 to 2024.



Trends in ODT implementations.
Data from [Lukas Foljanty's On-Demand Ridepooling World Map (updated February 2024)]

Adoption of Ride-Hailing Services

- Uber/Lyft introduced circa 2011; acceptance and growth of smartphone-based mobility services continues to grow.
- Ride-hail services have outpaced taxis in NYC.
- Public mobility is quickly adopting for first/last miles and community circulation.
- Uber announced first profit in 2023.



Source: toddwschneider.com/posts/taxi-uber-lyft-usage-new-york-city/

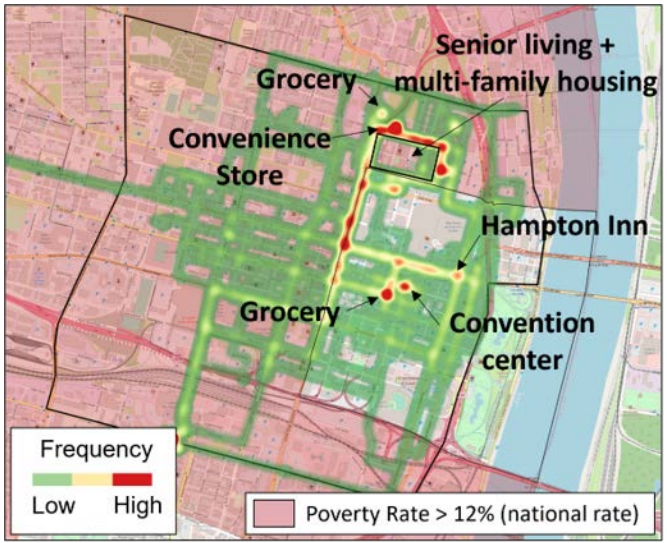
NREL ODT Case Studies

NREL Case Studies in ODT

ODT provides scalable, high-performance mobility from rural to urban.

- *Rural*
  - **Innisfil, Ontario** – Rural community public mobility through Uber.
  - **Fort Erie, Ontario** – Converted fixed-route bus to on-demand minivans.
  - **Bastrop, TX** – Provides rural/small-town community service.
- *Suburban*
  - **Arlington, TX** – Full public transit for 300,000 people, 100 square miles.
  - **Tulsa, OK** – In progress.
- *Urban*
  - **St. Louis, MO** – Provides downtown ride-hail service with 100% electric vehicles.
  - **Houston, TX** – Curb-to-curb, community circulation, first mile/last mile.

ODT is the "PC" to the transit "mainframe."



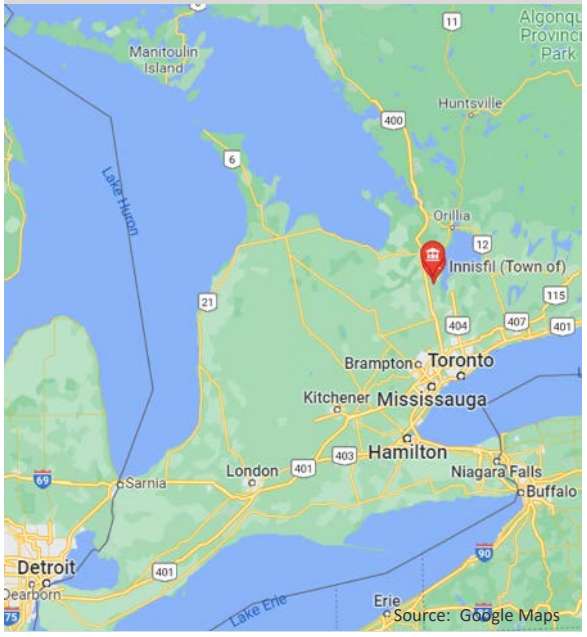
St. Louis, MO

- Serving lower-income populations.
- Inherent observability of demand/service.

NREL poster on St. Louis system: www.nrel.gov/docs/fy24osti/88265.pdf

Innisfil, Ontario

- **Innisfil Transit leverages ride-hail services for an innovative approach to rural transit.**
- Initial evaluation – Sweet (2021) found:
  - 4× the accessibility of the proposed bus alternative.
  - Comparable cost per passenger to bus services in similar communities.
  - 3× the ridership as estimated for the proposed bus service (in part due to expanded hours of operation).
- NREL work evaluated the service's sustainability, scalability, and pandemic resiliency:
  - <60% of the cost of fixed-route transit (in $/km and $/hour), but more expensive on a per-trip basis.
  - Service fits low-density areas where individuals take fewer but longer trips.
  - Lower emissions (even with >2× the number of trips) compared to two fixed-route bus options.



NREL Innisfil report:
www.nrel.gov/docs/fy22osti/80754.pdf

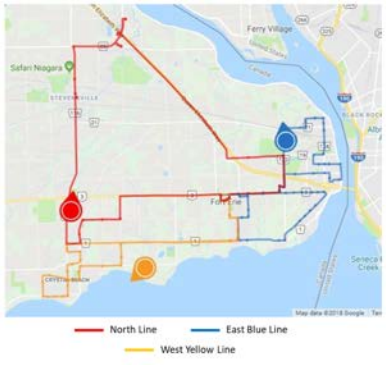
Consideration for rural America: Do we have robust cellular/data coverage?

Weigl,et al 2022. Sustainability, Scalability and Resiliency of the Town of Innisfil Mobility-on-Demand Experiment: Preliminary Results, Analyses, and Lessons Learned: Preprint. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5400-80754. https://www.nrel.gov/docs/fy22osti/80754.pdf

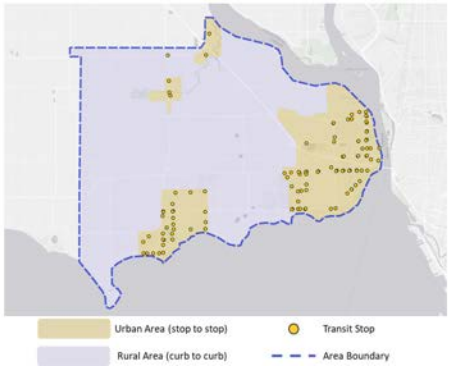
Fort Erie, Ontario

- Decreased operational cost per passenger.
- Decreased fuel use and emissions.
- Decreased passenger wait times.
- ODT serves more population than prior fixed-route system.
- Continues to increase ridership.

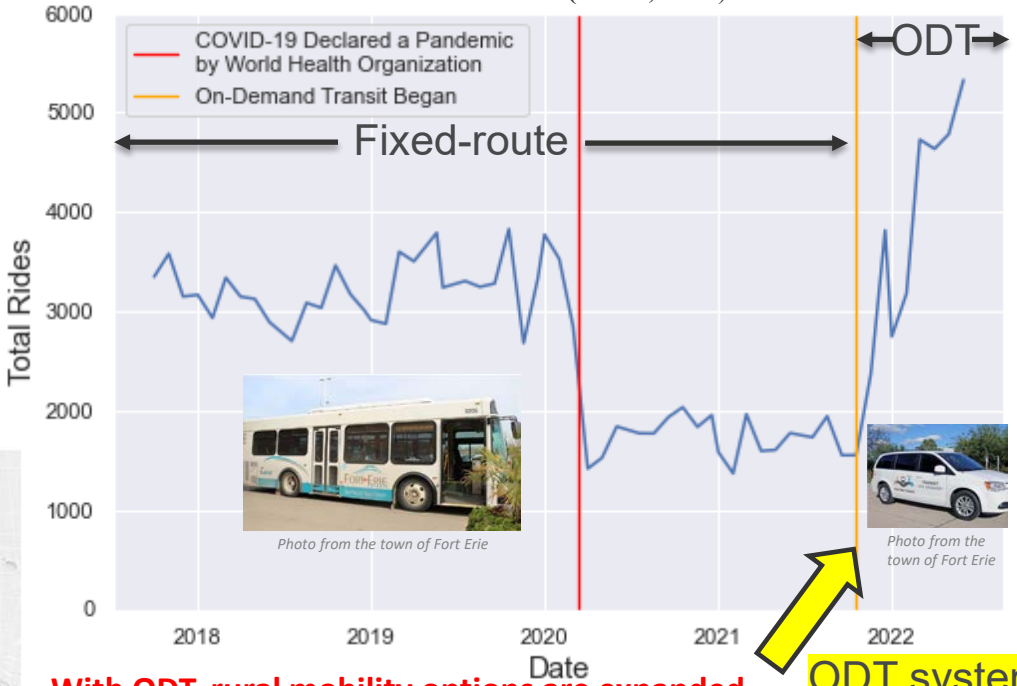
Prior fixed-route system



On-demand system area



Total monthly ridership before and after the on-demand system was instituted (Oct. 4, 2017)



With ODT, rural mobility options are expanded.

More equitable links to employment and opportunity.

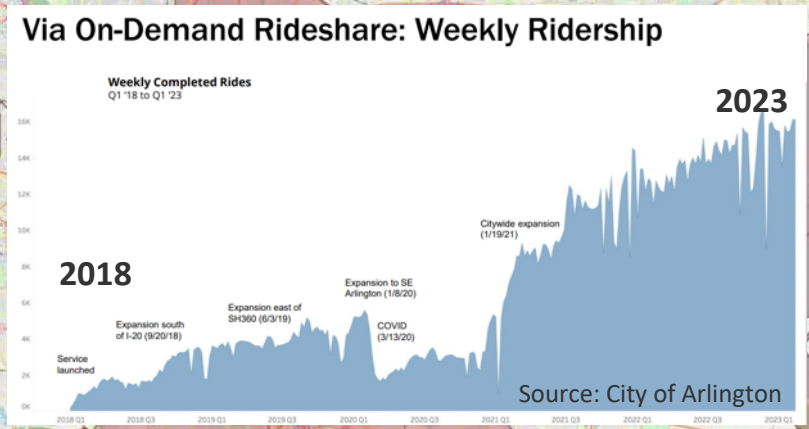
ODT system start

NREL Fort Erie report: www.nrel.gov/docs/fy23osti/84578.pdf

Arlington, TX

Arlington On-Demand

- 68 six-passenger vans, 12 automated vehicles
- Fare: $3–$5/person
- Hours: 6 a.m.–9 p.m.
- 2 million rides since launch (Q1 2018)
- Average wait time = 10–15 minutes.
- 88% of riders make <$50,000/year.



Forth Worth

Arlington

Dallas

- **Can ODT serve as primary public transit mode in large city?**
- **What are impacts to mobility, energy, and affordability?**

Arlington, TX

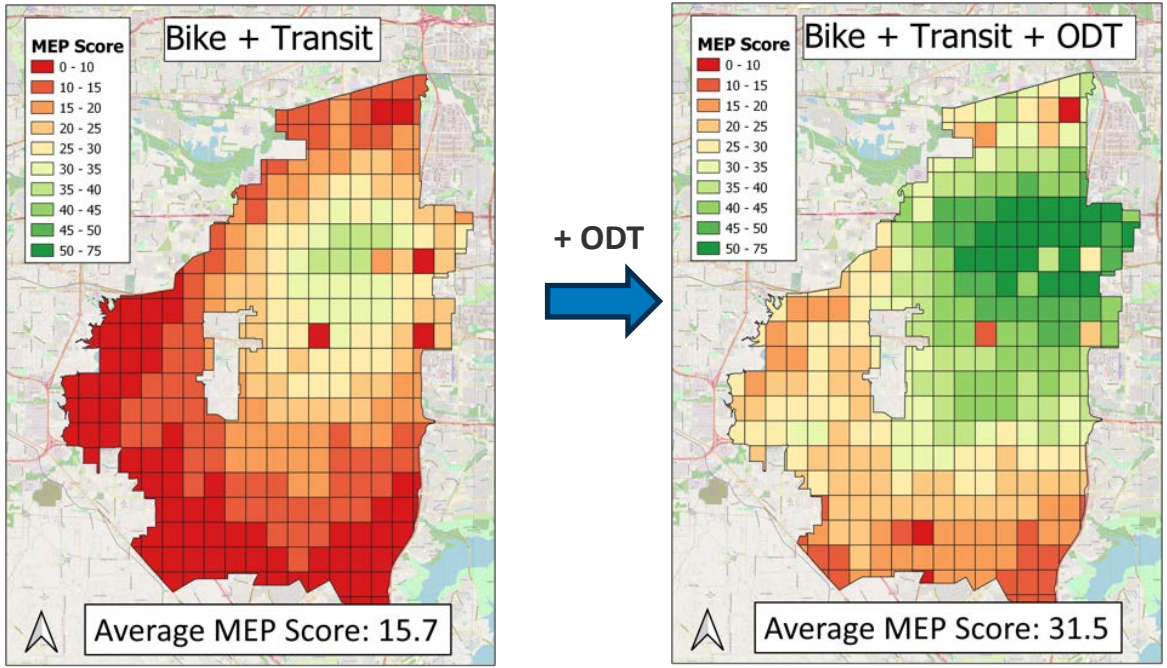
Impacts of City-Scale ODT on Mobility Energy Productivity (MEP)

MEP: A measure of access to goods and services weighted by travel time, cost, and energy use.

MEP score = α(cost) + β(travel time) + γ(energy use)

Inputs for ODT service

- **Wait time** = 15 minutes
- **Travel speed** = 0.75 × private auto
- **Cost** = $0.96/mi (based on fares and average trip distance)



Findings

(not considering private auto)

- Adding ODT doubled MEP non-vehicle score in Arlington.
- Benefits were spread throughout the service region.
- Greatest benefits in downtown.

Arlington, TX

ODT Instead of Traditional Transit

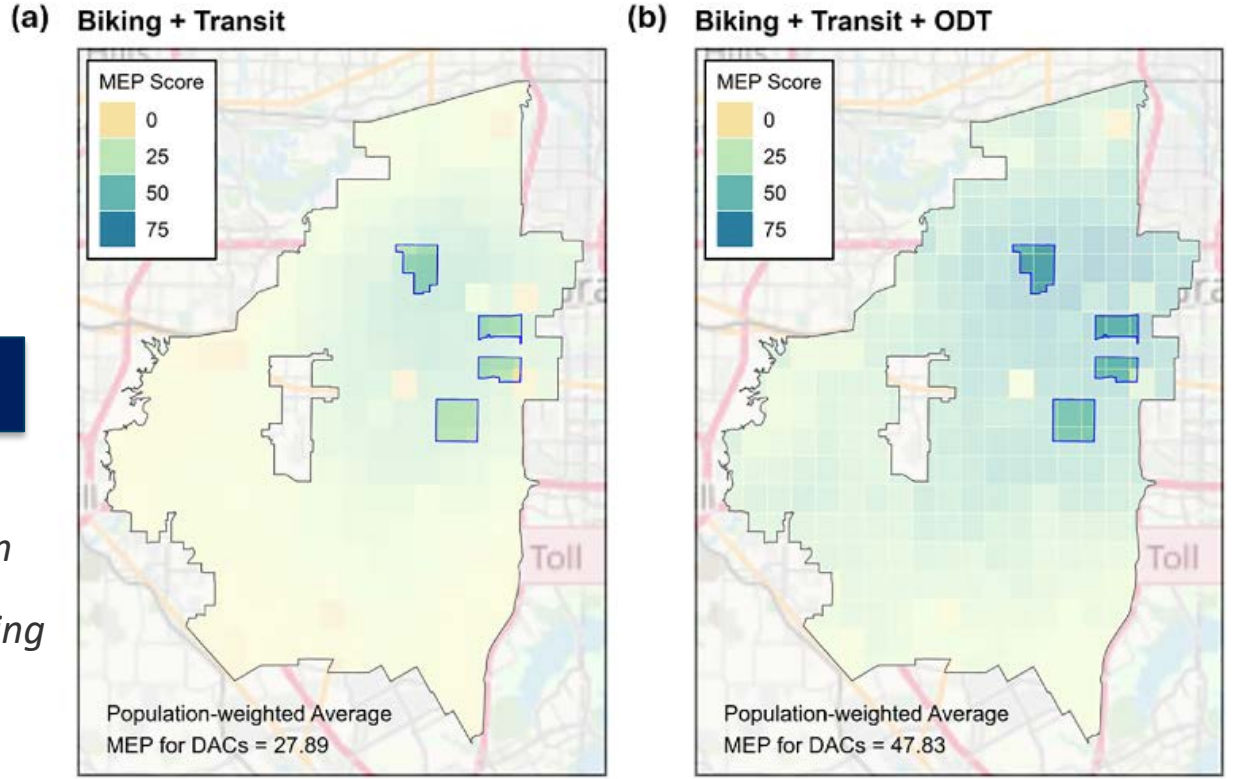
Transportation Research Record paper: "Mobility Energy Productivity Evaluation of On-Demand Transit: A Case Study in Arlington, Texas" (April 2024). doi.org/10.1177/03611981241234901

NREL Arlington presentation: www.nrel.gov/docs/fy24osti/88432.pdf

Future Challenges:

Sustainable funding, electrification of vehicles, implementation "dynamic-direct" service, connecting to other regional services.

ODT access improves MEP score in Arlington disadvantaged communities



Coevolution of ODT and Autonomous Vehicles (AVs)

On-Demand Mobility Milestones

2009

Uber Technologies is founded

2012

Via and Lyft are founded

2014

Bridj & Chariot micro-transit companies founded

2014

California's CPUC coins term "TNC", becomes first state to regulate TNCs.

2016

FTA recognizes micro-transit as public transport ation

FTA
Federal Transit Administration

2016

34 states pass legislation approving ride-hailing companies

2017

Lyft averages 1 million rides per day, Uber 5.5 million

Covid Pandemic

2019

Uber opens public transit division

AV Deployment Milestones

1984
DARPA Strategic Computing Initiative at Carnegie Mellon

1997
FHWA demonstrates AHS in San Diego

2004-2005
1st and 2nd DARPA Grand Challenges

2005
DARPA Grand Challenge spinoffs –
STARTUP
Cruise
Waymo
Udacity

2007
DARPA Urban Challenge

2010
Avg. annual investment in AV mobility reaches ~$2.4 billion

2011-2012
First states to authorize AVs: Nevada, Florida, California

2014
Tesla Announces first version of autopilot

2016
USDOT Federal Automated Vehicles Policy

2016-2017
Waymo begins testing on public streets in Phoenix, drivers removed one year later

2018
Uber test AV kills pedestrian in Tempe, AZ, first AV death

Covid Pandemic

AHS: Automated Highways System
DARPA: Defense Advanced Research Projects Agency
FHWA: Federal Highway Administration
USDOT: U.S. Department of Transportation

AV–ODT Deployment Milestones

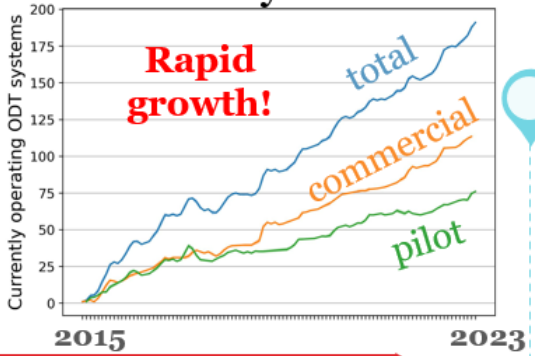
2020
Innisfil, ON
Report on ODT system success

2020
Uber and **Lyft** announce public transit partnerships

2021
Arlington, TX
Via expands to all of Arlington, largest ODT system nationwide

2023
Uber records first operating profit

On-demand systems in USA



20??
Shared Automated Service: **yet to be done**
?

ODT

Covid 2020 Pandemic

AV

2021
1,400+ self-driving cars, trucks and other vehicles in testing by 80+ companies in 36 U.S. states

2023
Waymo expands to 300+ sq. miles, 700 vehicles across SF, Austin, Phoenix

2023
Cruise reaches Austin, Dallas, Houston, Phoenix, Miami, SF, Nashville, Atlanta, and 400+ vehicles

2023
CPUC approves Waymo, Cruise expansion in SF, begin charging fares

2023
Cruise and Waymo operating driverless in 3 cities

2023
Cruise hits pedestrian, self-driving car permit revoked in SF

Next-Generation ODT: Automated Ride-Hail

- Waymo currently leads in the market.
- Ideally AV/ODT enables consistency in performance.
- Competition is driving innovation.
- Growing pains: Cruise service is suspended in early 2023.

Waymo automated ride-hail vehicle.
Photo by Andy Duvall, NREL

Key Metrics for Evaluation of ODT Service

Key Metrics

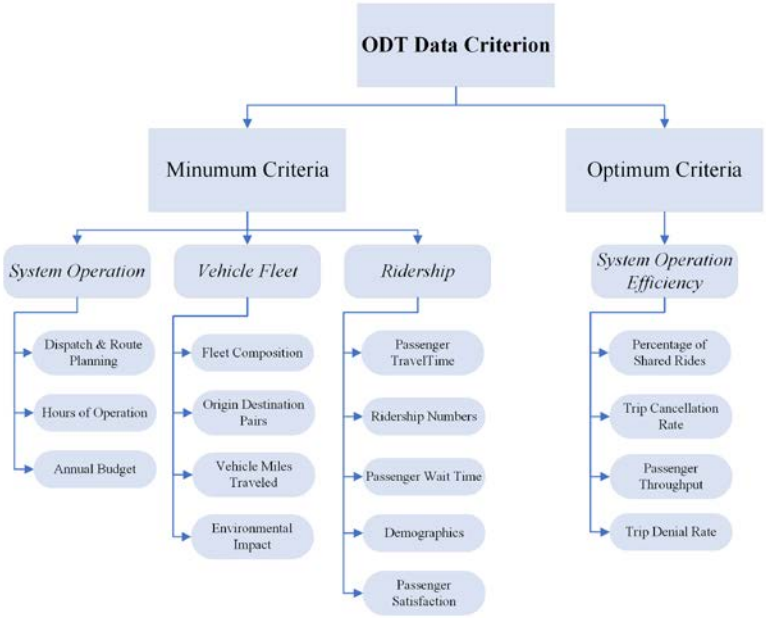
- **System Operation**:
  - Dispatch and route planning
  - Hours of operation
  - Annual budget.
- **Vehicle Fleet:**
  - Fleet composition
  - Origin–destination pairs
  - Vehicle miles traveled
  - Environmental impact.
- **Ridership:**
  - Passenger travel time
  - Ridership numbers
  - Passenger wait time
  - Demographics
  - Passenger satisfaction.

Minimum Criteria

All the minimum criteria in addition to:

- **System Operation Efficiency:**
  - Percentage of shared rides
  - Trip cancellation rate
  - Passenger throughput
  - Trip denial rate.

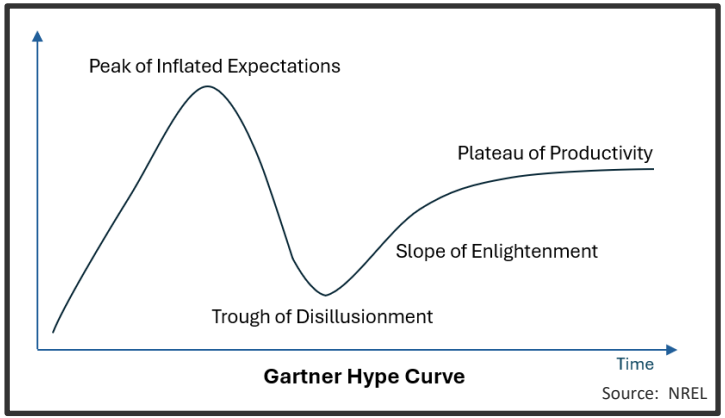
Optimum Criteria



Discussion and Closing

Summary

- ODT systems are expanding rapidly
  - Stand-alone in rural/small communities.
  - Complementary service to legacy transit in urban areas.
- Convergence emerging for ODT and AV technologies
  - Waymo is current leader; deployments growing.
  - Likely large market share to be had as technologies mature.
- AV/ODT systems still in early stages
  - Continued growth as AVs reduce operating costs and make ODT viable in more places.
  - Will require policies and standards to achieve maturity.
- Ascending from the “trough of disillusionment.”



Questions?

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