

PASSENGER AGGREGATION NETWORK WITH VERY EFFICIENT LISTING (PANVEL) RIDESHARING MODEL FOR URBAN AIR MOBILITY

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Bottom Line Up Front (BLUF)

Problem

- Urban Air Mobility (UAM) is expected to be relatively expensive, which may limit adoption
- Ridesharing is proposed by many, but there are challenges with implementing ridesharing that must be identified and overcome

Importance

- Ridesharing can bring down per-passenger emissions and costs and boost ridership
- Identifying higher-demand routes can aid stakeholders in decision-making

Solution

- PANVEL, an aggregation algorithm within a transportation computational framework to estimate ridesharing impact in simulations
- Considers individual-specific metrics—like value of time (VoT), travel patterns, and alternative mode choices—to achieve high load factors

Takeaways

- Ridesharing shows potential in increasing UAM trips based on an **effective-cost** metric
- Case study in Cleveland metro area shows an increase in UAM-preferred trips from 0 without ridesharing to 214 with ridesharing

Urban Air Mobility

- Typically for trips less than 75 miles in locations with relatively slow existing travel modes
- Proposed as a faster alternative to existing transportation modes like personal automobiles and public transit
- Catering primarily to people with high VoT for early adoption
- Involves multi-modal transport, combination of cars, walking, etc., for first- and last-mile segments

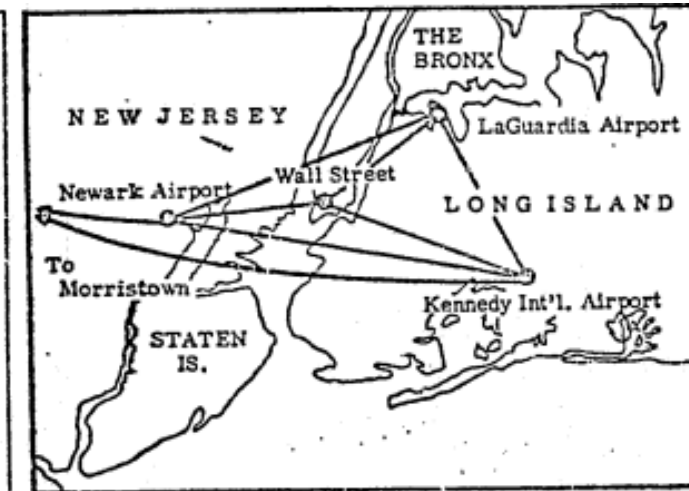
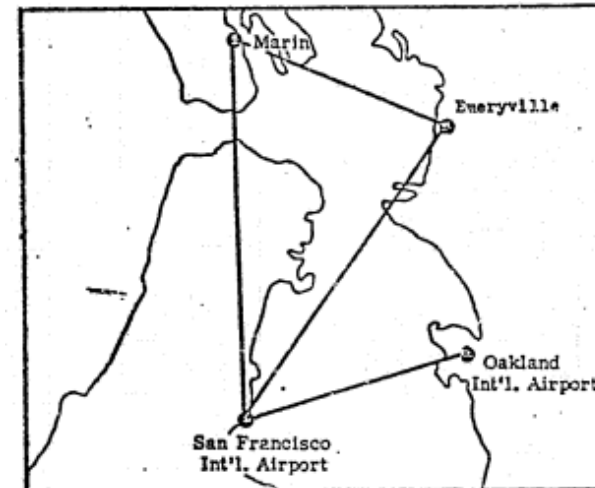
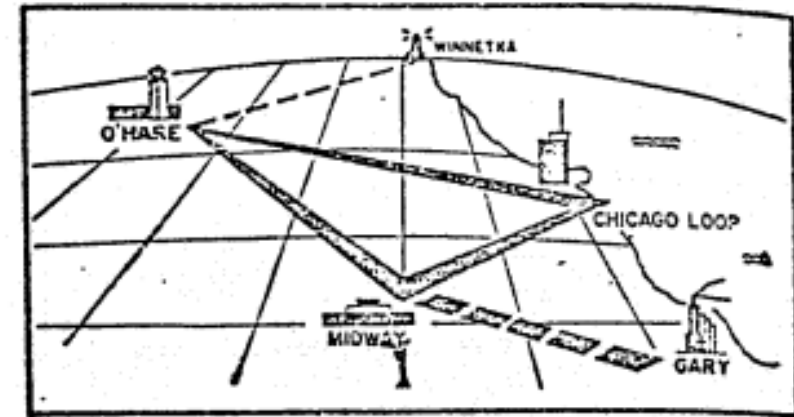


Map Data © 2024 Google

Is this the Next Big Thing?

What Has Been Done?

- Urban helicopter operations existed in the 1950s to 1970s in New York, Chicago, San Francisco, and Los Angeles
- Some reasons for their discontinuation include:
 - Government subsidy withdrawal
 - Noise regulations
 - High profile crashes
- Modern concepts have:
 - Renewed interest primarily from private sector
 - Potentially quieter and more environmentally sustainable electric technology
 - Possibly safer multi-rotor distributed propulsion



Images from Dajani, J. S., Stortstrom, R. G., and Warner, D. B., "The Potential for Helicopter Passenger Service in Major Urban Areas," National Aeronautics and Space Administration, Contractor Report, NASA/CR-145224, 1977, <https://ntrs.nasa.gov/citations/19770020143> citing sources of World Airline Record, 1972; Lovorn, 1976; and NYA, 1975.

Operational Limits for Urban Air Mobility

Work Done So Far

- Operational limits are factors that may inhibit large-scale UAM operations
- Previous work in this series have focused on quantifying limits regarding:
 - Weather
 - Emissions
 - Cargo Operations
 - Aerodrome Throughput

Evaluating Impact of Operational Limits by Estimating Potential UAM Trips in an Urban Area

Apoorv Maheshwari*, Brandon E. Sells*, Stephanie Harrington*, Daniel A. DeLaurentis† and William A. Crossley†
Purdue University, West Lafayette, IN, 47907

DOI: 10.2514/6.2021-3174

Weather Impact Assessment for Urban Aerial Trips in Metropolitan Areas

Hsun Chao*, Apoorv Maheshwari*, Daniel A. DeLaurentis†
School of Aeronautics and Astronautics, Purdue University

DOI: 10.2514/6.2021-3176

Research Article

Modeling CO₂ Emissions from Trips using Urban Air Mobility and Emerging Automobile Technologies

Apoorv Maheshwari, Daniel A. DeLaurentis, and William A. Crossley†

DOI: 10.1177/03611981211006439

A System-of-Systems Approach to Analyzing Future Advanced Air Mobility Cargo Operations

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A Comparative Study of Aerodrome-related Operational Limits for Passenger-Carrying Missions across Metropolitans

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DOI: 10.2514/6.2023-3410

Motivation: The Need for Affordable Speed

How Can UAM Be Competitive?

- Flying can be expensive
 - Estimates of operating costs for a 4-seat UAM aircraft can be \$605/hr [1] or more
 - Cars cost less than \$0.65/mi [2]
- UAM can be preferable when cars are slow, and aircraft are fast
 - Average driving speeds fluctuate between 15-75 mi/hr in cities
 - At 150 mi/hr of cruise speed, UAM per-mile costs fall to \$5/mi and can further reduce with ridesharing

UAM without ridesharing could be more than 6x more expensive than cars

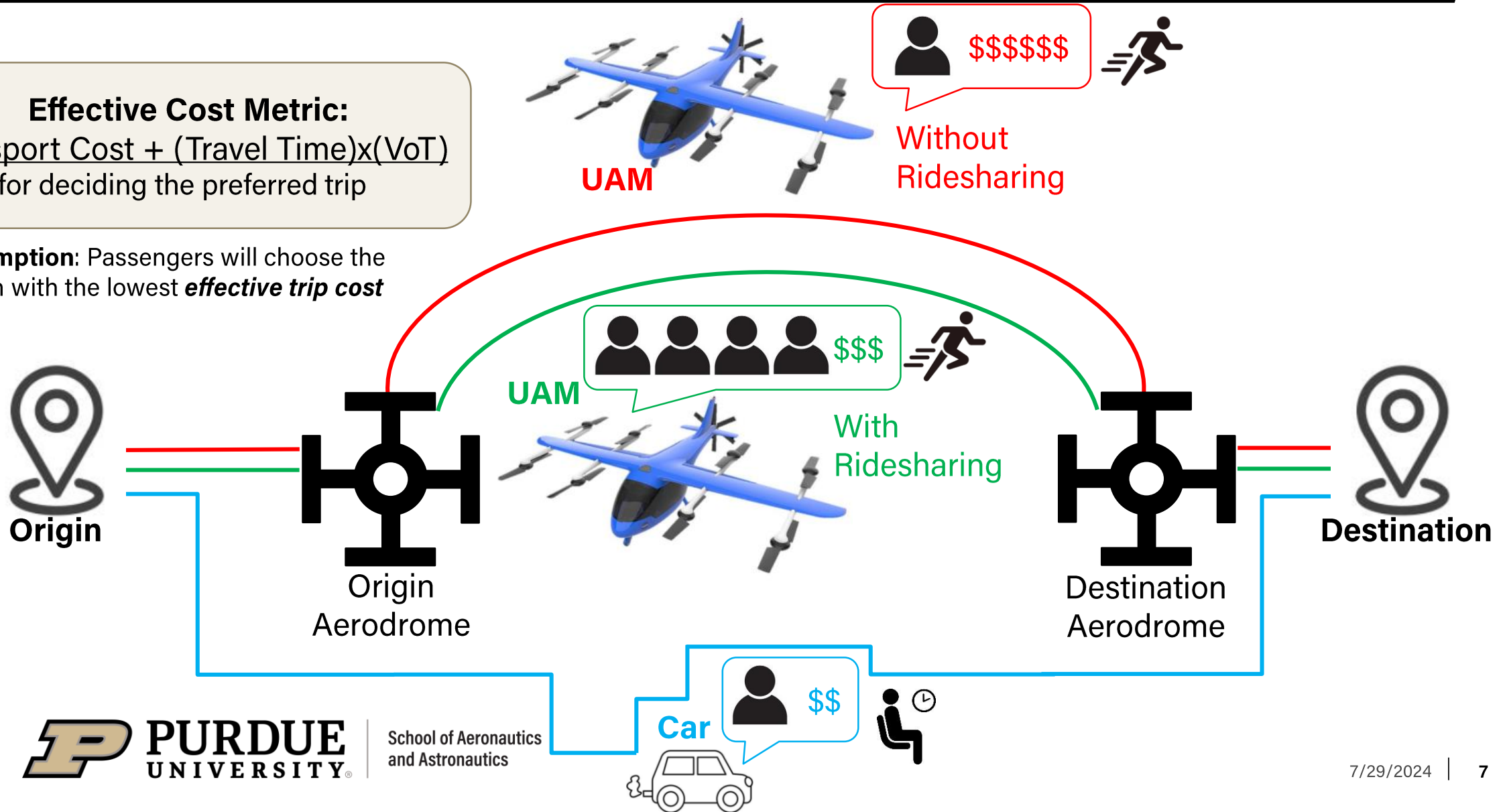
¹Holden, J., and Goel, N., "Fast-Forwarding to a Future of On-Demand Urban Air Transportation," San Francisco, CA, 2016

²IRS, "Standard Mileage Rates," <https://www.irs.gov/tax-professionals/standard-mileage-rates>, Dec 2022.

Mode Choice Alternatives

Effective Cost Metric:
 $\text{Transport Cost} + (\text{Travel Time}) \times (\text{VoT})$
Used for deciding the preferred trip

Assumption: Passengers will choose the option with the lowest *effective trip cost*



Challenges to Ridesharing

Waiting to Save Time?

- Having more people in the same vehicle can reduce costs by spreading them across more passengers
- But in UAM, ridesharing **forces people to wait for others** to arrive and “fill up” the aircraft
- Extended wait times **erode the UAM time savings**, potentially making them less attractive. However, enduring longer wait times to rideshare could potentially **make UAM more affordable**
- UAM ridesharing is also more **eco-friendly** and **requires fewer takeoff and landing areas** compared to single-passenger operations

Need to balance waiting times with passenger VoT and time savings

Ridesharing and Value of Time

Higher VoT → Higher Max Wait Times

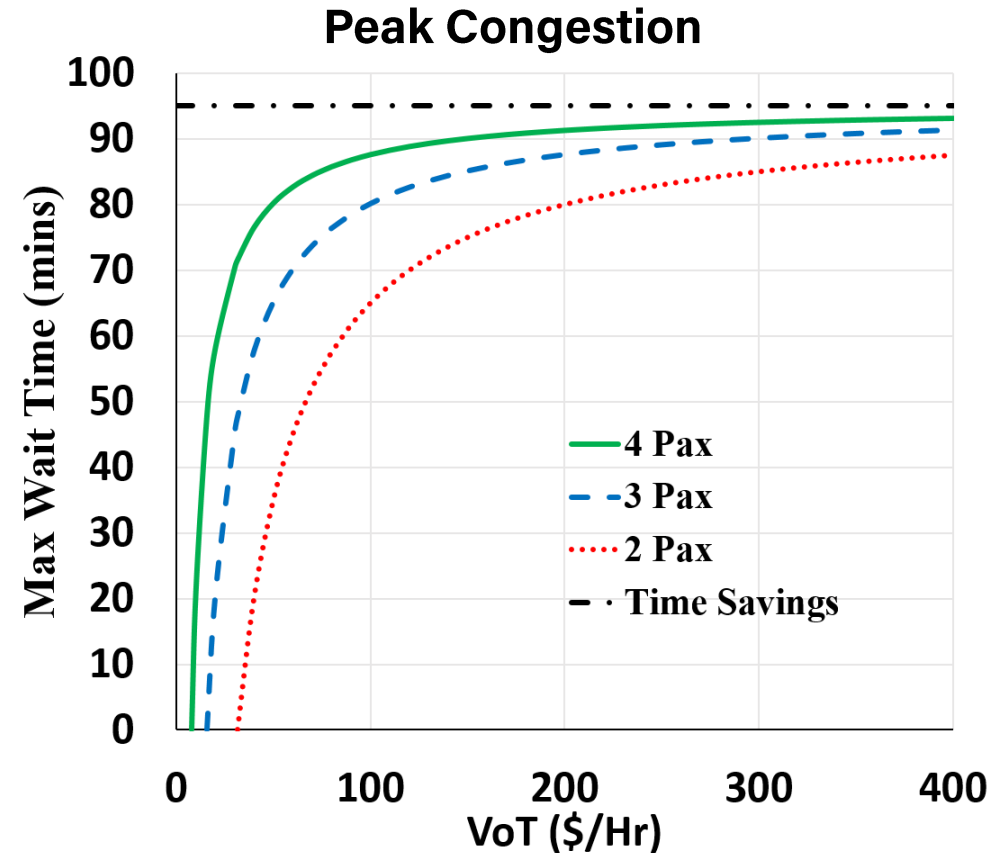
- UAM's time savings limit the maximum wait time
- Individuals with higher VoTs benefit more from time savings in the **effective cost** metric than those with lower VOT
 - Effective cost metric includes an individual's specific VoT times travel time
 - Higher-VoT travelers can realize effective cost savings over car travel with longer wait times than lower-VoT travelers

- We investigate this relation with the following equation:

$$WT_{MAX} = (t_{Non-UAM} - t_{UAM}) - \frac{P_{UAM} - P_{Non-UAM}}{VoT}$$

Select Assumptions:

- Aircraft operating costs remain constant irrespective of load factor
- Operating costs are equally divided among all passengers



Ridesharing and Value of Time

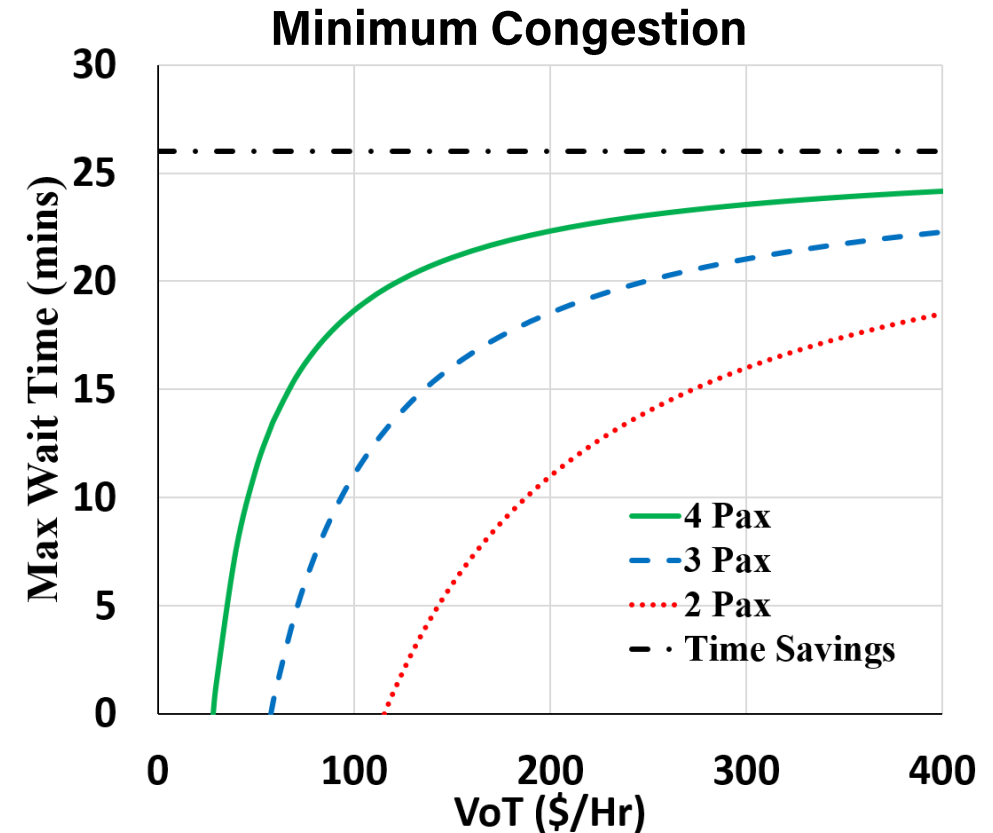
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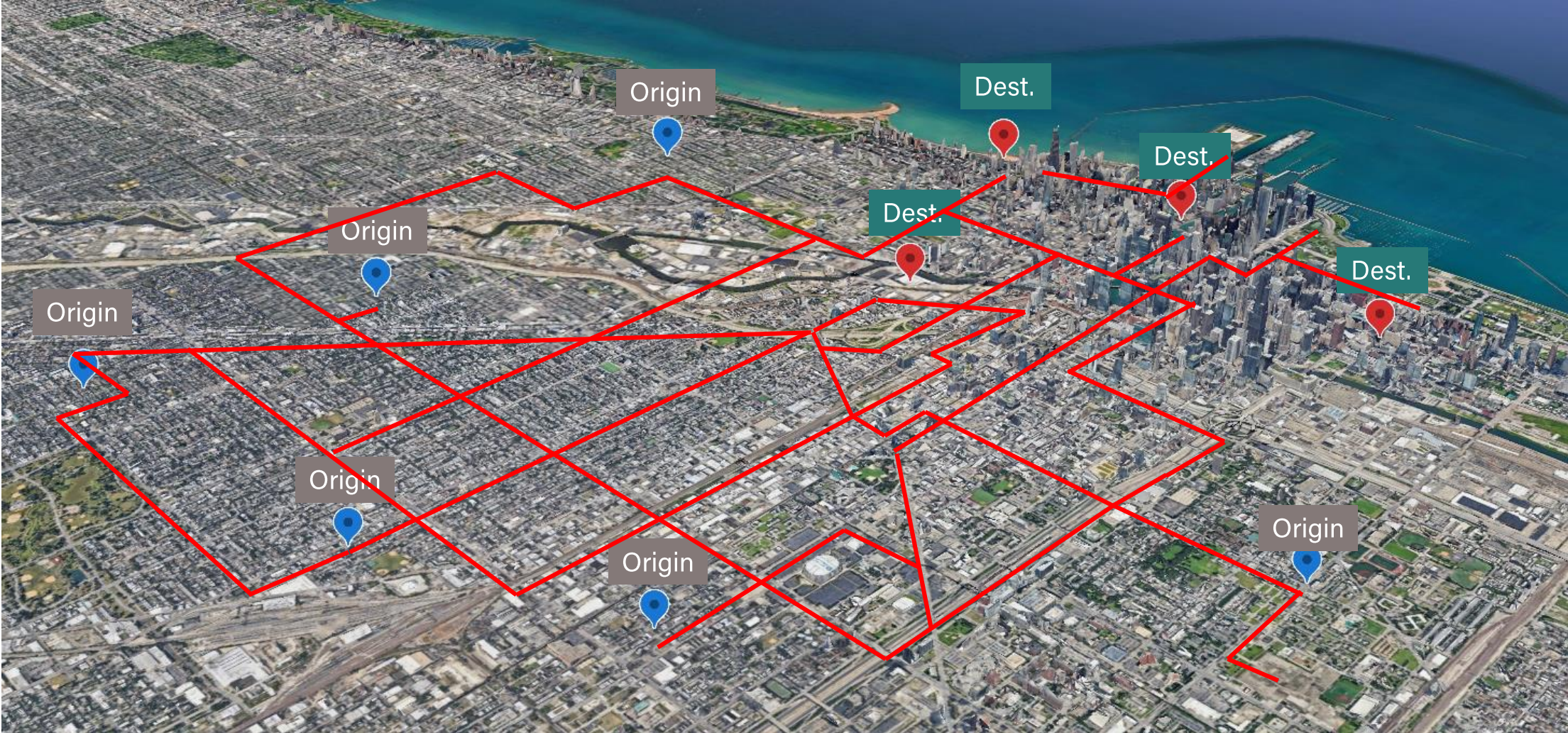
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Road Network: Chicago

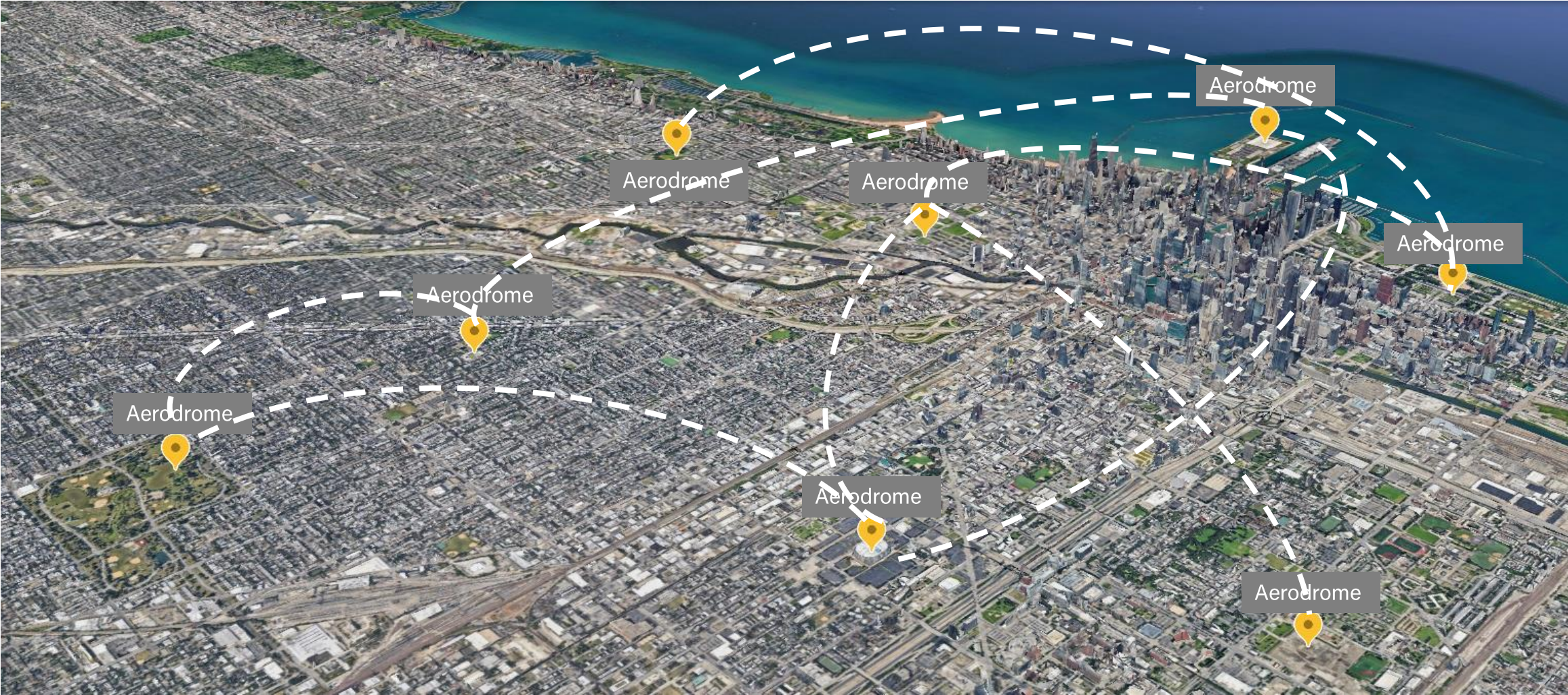


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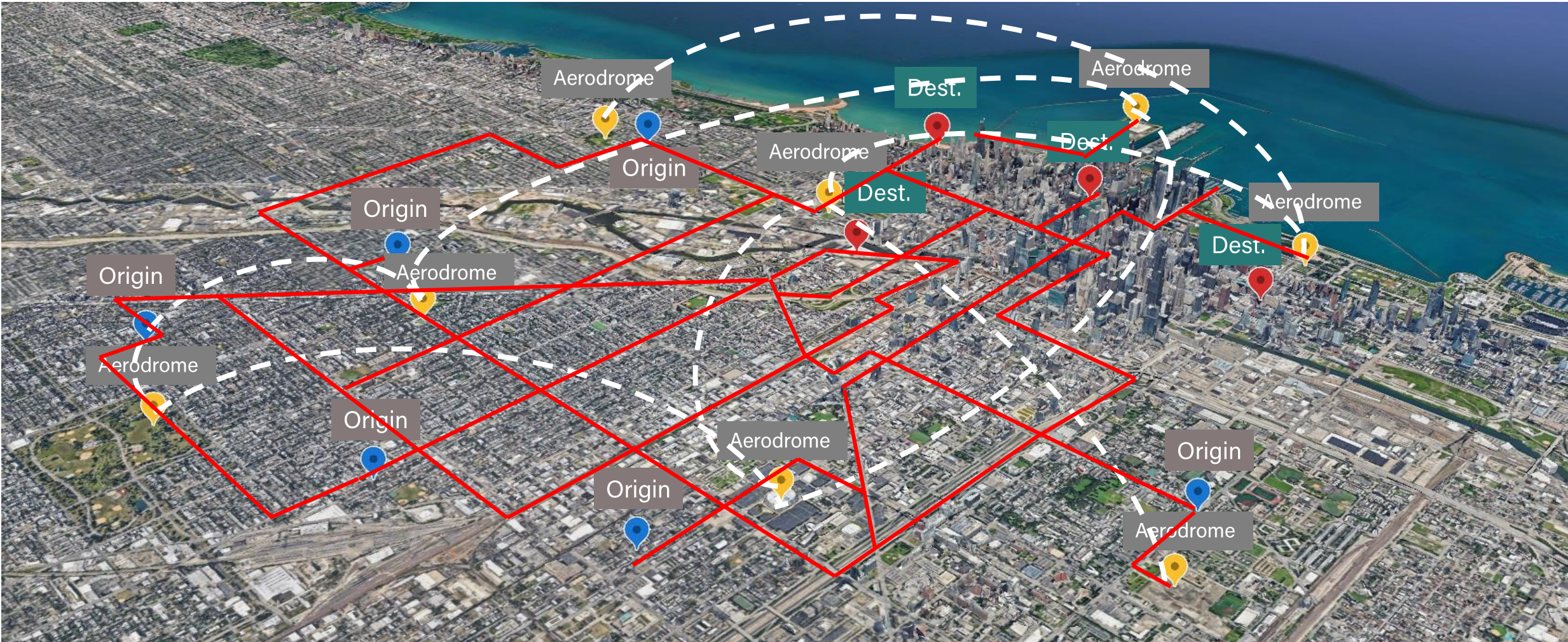
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Aerial Network: Chicago



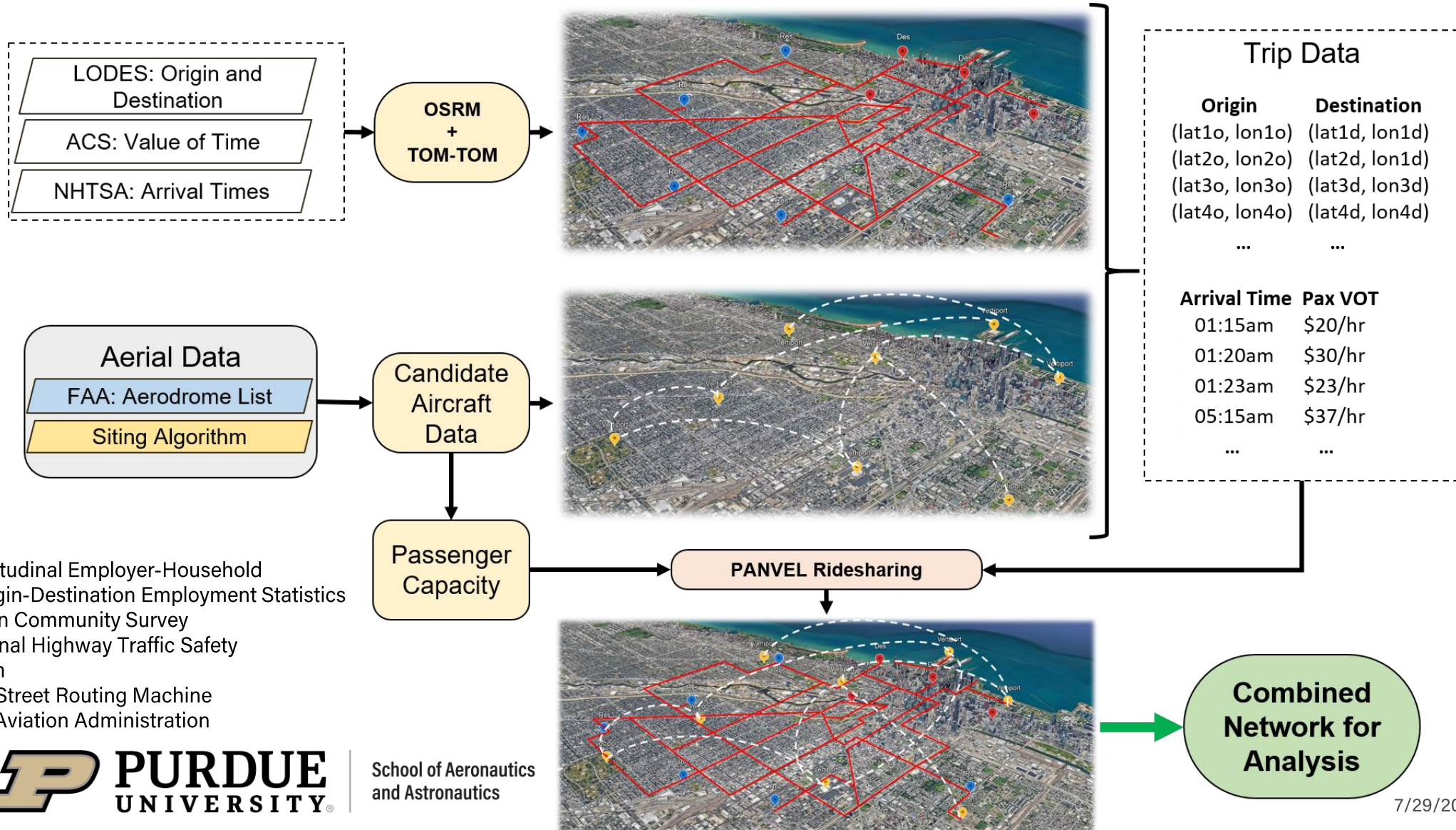
Maps Data: Google Earth, © 2024 Landsat / Copernicus NOAA Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Combined Road and Aerial Network: Chicago



Maps Data: Google Earth, © 2024 Landsat / Copernicus NOAA Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Computational Framework: Summary



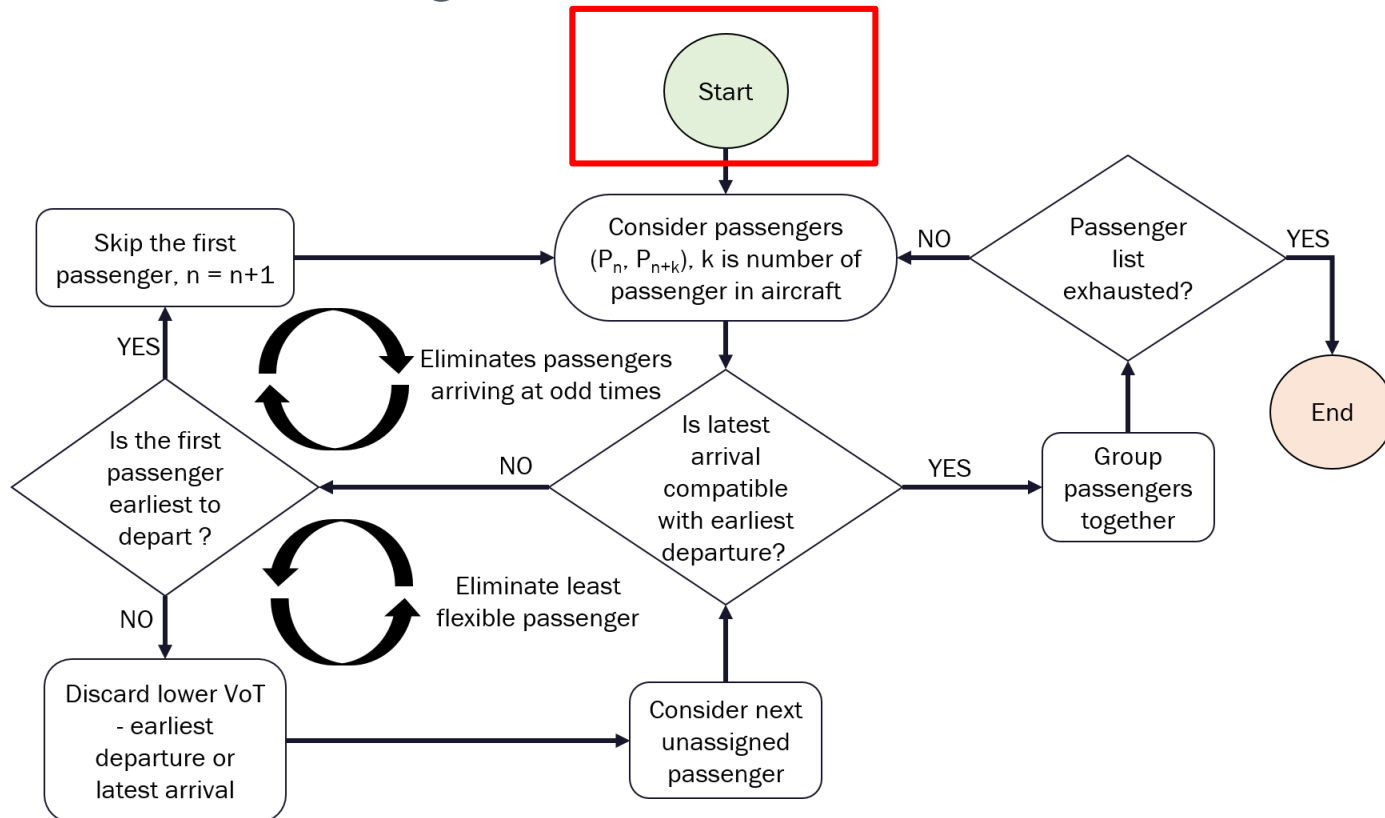
LODES: Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics
 ACS: American Community Survey
 NHTSA: National Highway Traffic Safety Administration
 OSRM: Open Street Routing Machine
 FAA: Federal Aviation Administration



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Ridesharing: A Key Enabler

PANVEL Algorithm



Eliminated passengers will be considered for 3, 2 and single passenger operations

Pax	Arrival Time*	Max Wait Time	Latest Departure Time	VoT
P1	8:05	33	8:38 ✓	164
P2	8:12	10	8:22 ✓	123
P3	8:13	6	8:19 ✗	132
P4	8:20	9	8:29 ✓ ✗	138
P5	8:21	2	8:23 ✓	104
P6	8:30	2	8:32	124
...

*Assumption: Passenger arrival times at the origin aerodrome gate are known

Case Study

Cleveland: Public Aerodrome Network

- Inputs:
 - 72 publicly accessible aerodromes
 - ~2 million total daily trips
- Results:
 - 20 aerodromes with UAM service
 - 214 passengers on 58 UAM flights
 - 92% load factor

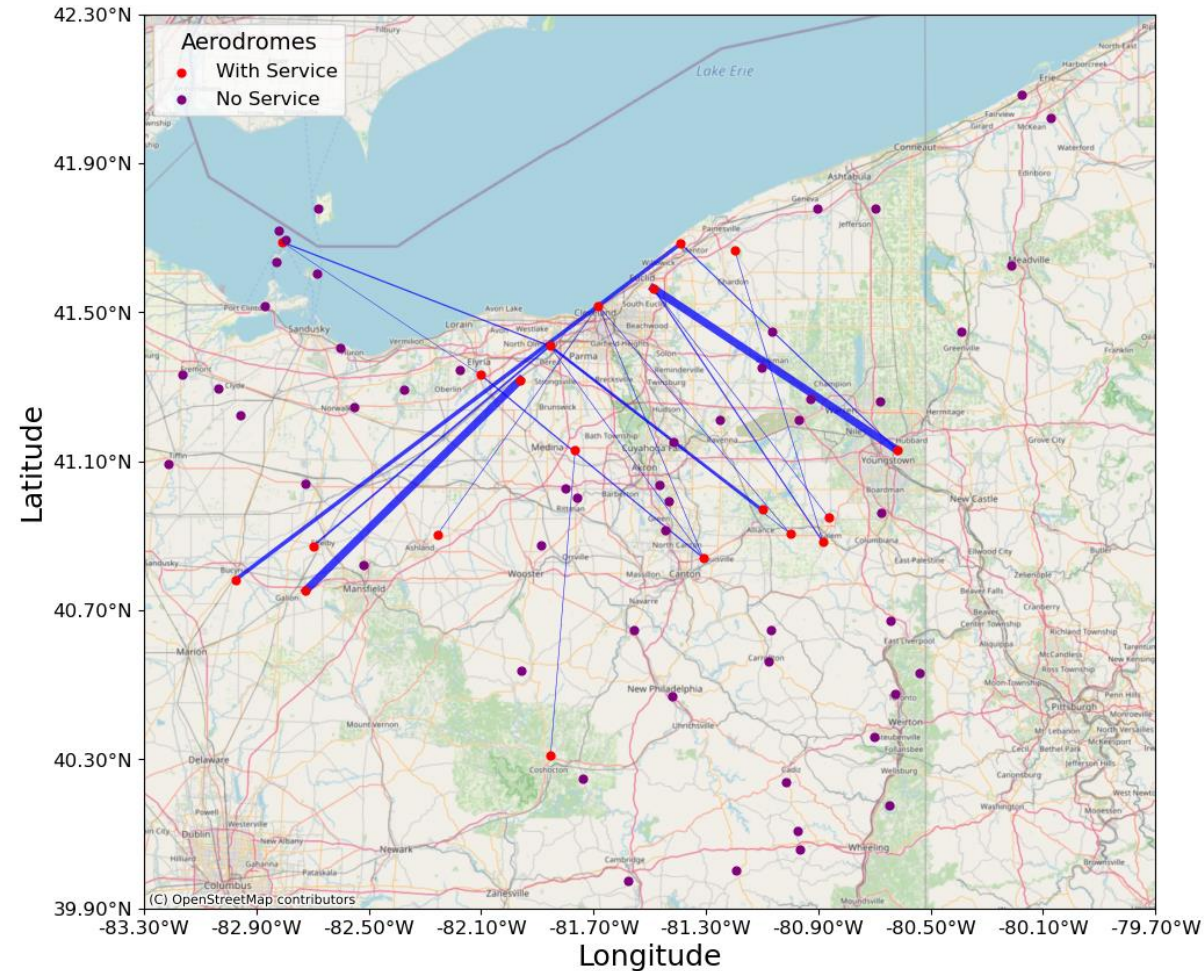
Increased UAM-preferred trips from 0 without ridesharing to 214 with ridesharing

Select Assumptions:

1. Embarkation takes 15 minutes and disembarkation takes 10 minutes
2. Aircraft operating costs remain constant irrespective of load factor
3. Operating costs are equally divided among all passengers



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Background map data © OpenStreetMap contributors
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Summary and Future Work

Summary

- The PANVEL algorithm was introduced to study the impact of ridesharing
- Ridesharing may make increase the feasibility of UAM

Future Work

- Future work is geared towards improving the ridesharing algorithm
- Results have also been generated for Chicago, Denver, Dallas, New York, and Orlando, and will be published*
- Including aerodrome throughput limits is expected to play a significant role given the possible increase in ridership

Thank You!

We welcome any comments or questions!

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Check out our other related paper at 2024 AIAA AVIATION:
Refined Analysis of CO₂ Emissions in Urban Air Mobility Networks
(Summit Ball Room 232, 29-July – 3:30pm)

BACKUP SLIDES

Better to have it and not need it, than to need it and not have it

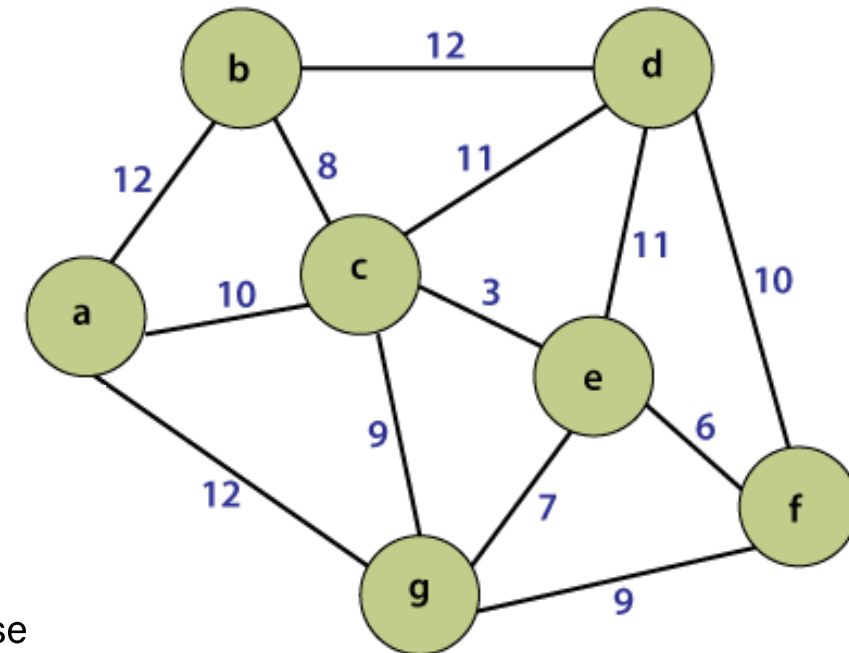
Select Assumptions

- Passengers will chose the option with the lowest **effective trip cost**
- **Effective Trip Cost:** Cost of transport + (Transit Time) x VoT
- Aircraft operating costs remain constant irrespective of load factor
- Aircraft operating costs are equally divided among all passengers
- Passenger arrival times at the origin aerodrome gate are known
- Embarkation/mode change takes 15 minutes and disembarkation/mode change takes 10 minutes
- Car trip cost is determined by a fixed cost per mile (\$0.65/mi) based on IRS (Internal Revenue Service) estimates

Computational Framework

How Do We Do This? Network Theory

- UAM requires multimodal transport that include mixes of surface and aerial modes
- **Model Inputs:**
 - OSRM (Open Street Routing Machine) to get road network distances
 - Tom-Tom to account for road congestion at all hours of the day
 - Federal Aviation Administration (FAA) databases for potential infrastructure resources that could be modified for UAM operations
 - Demand Dataset from US Census, Longitudinal Employer Household Database (LEHD), American Community Survey (ACS), National Highway Traffic Safety Administration (NHTSA) and Municipal databases to find everyday trips

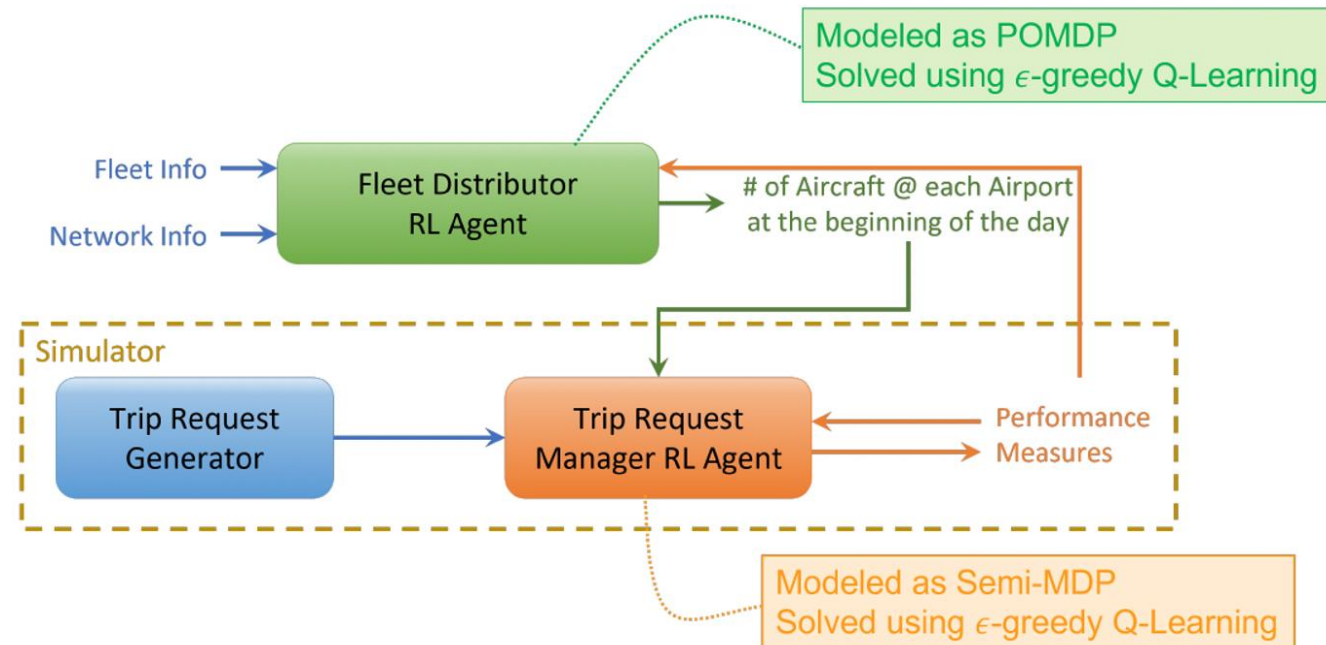


Sample network map with weighted links

RL BASED RIDE-SHARING ALGORITHM

By Apoorv Maheshwari [3]

- Used in conjunction with On Demand Air Service (ODAS)
- Reinforcement Learning (RL) model to effectively position the fleet to minimize waiting
- Multiple reward and penalty functions in *Built trip manager*
- The algorithm may choose to reject a trip to better position the fleet than carry passengers, if it deems (from experience) that fleet repositioning can bring in more revenue
- Penalties imposed if trips rejected or if the aircraft not filled to capacity
- A maximum fixed waiting time assumed for each passenger



COMPARISON

RL Model (A. Maheshwari)

- Works with on-demand air service model
- Looks at fleet positioning
- Works with dynamic data
- Computationally expensive
- Works for 2-passenger aircraft (currently)
- Requires extensive training and deployment

PANVEL Model

- Computationally Cheap
- Works for n-sized passenger aircraft
- Requires no prior training (listing method)
- Doesn't look at fleet positioning
- Depends on consistent passenger arrival data
- Doesn't employ on-demand features