Urban Air Mobility Network Distribution in Chicago Metropolitan Area

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Introduction

Background

Tackling urban issues (traffic congestion, environmental pollution)

Problem

Determining feasible vertiport locations and the ideal number of vertiports

Challenge

Meeting UAM's potential demand and optimizing vertiport distribution

Case Study

Examining the Chicago metropolitan area

Data Selection

1 LODES

- Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics survey
- **Specific Info**: [Version 7, Year 2019, Type: Origin-Destination (OD), Part: Main, State: Illinois, Job Type: JT00]
- **Earning Level**: ≤ $1250/month, $1251/month - $3333/month, > $3333/month

2 TIGER

- Topologically Integrated Geographic Encoding and Referencing data
- The geographic location and boundaries of the census block

3 Google Maps Directions API

- The travel time between two locations
- Estimation based on historical traffic conditions and live traffic

Methodology: Assumptions

Long-haul Preference

Commuters with travel time > 30 minutes

Focus on High-Income Family

Commuters with income > $3333/month

Operating Speed

UAM flight service at 100 mph

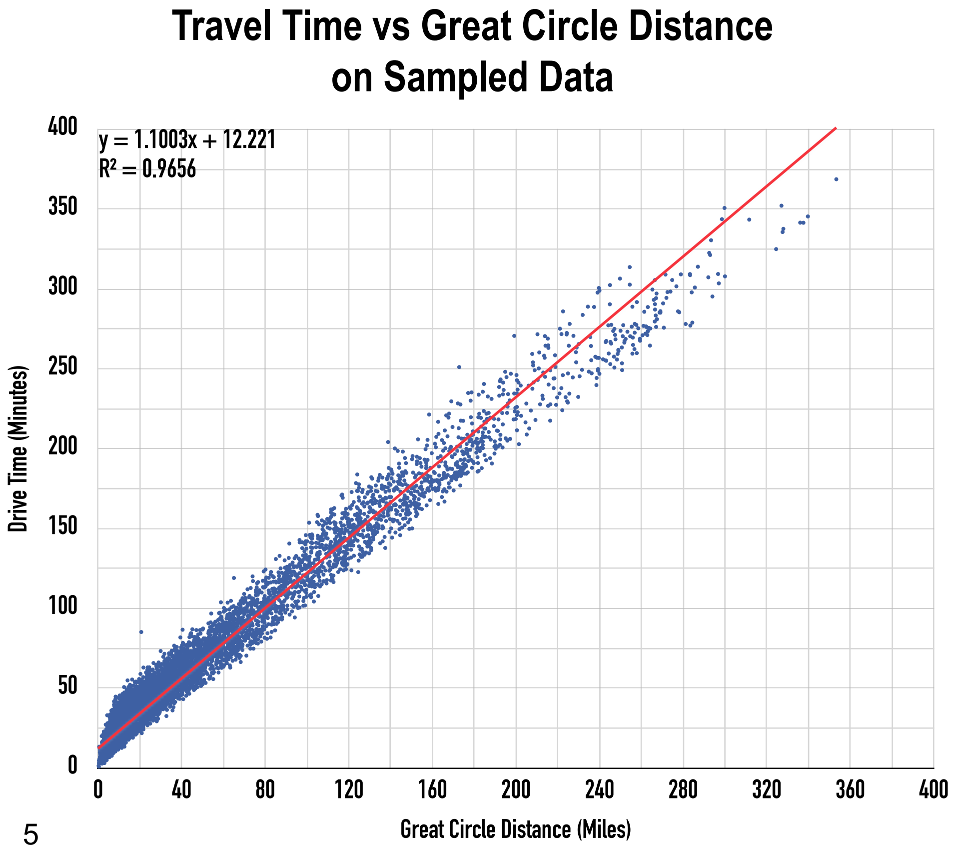
Unlimited Capacity

No capacity constraints for vertiports

In-state Travel

Commuters with origin & destination in the same state

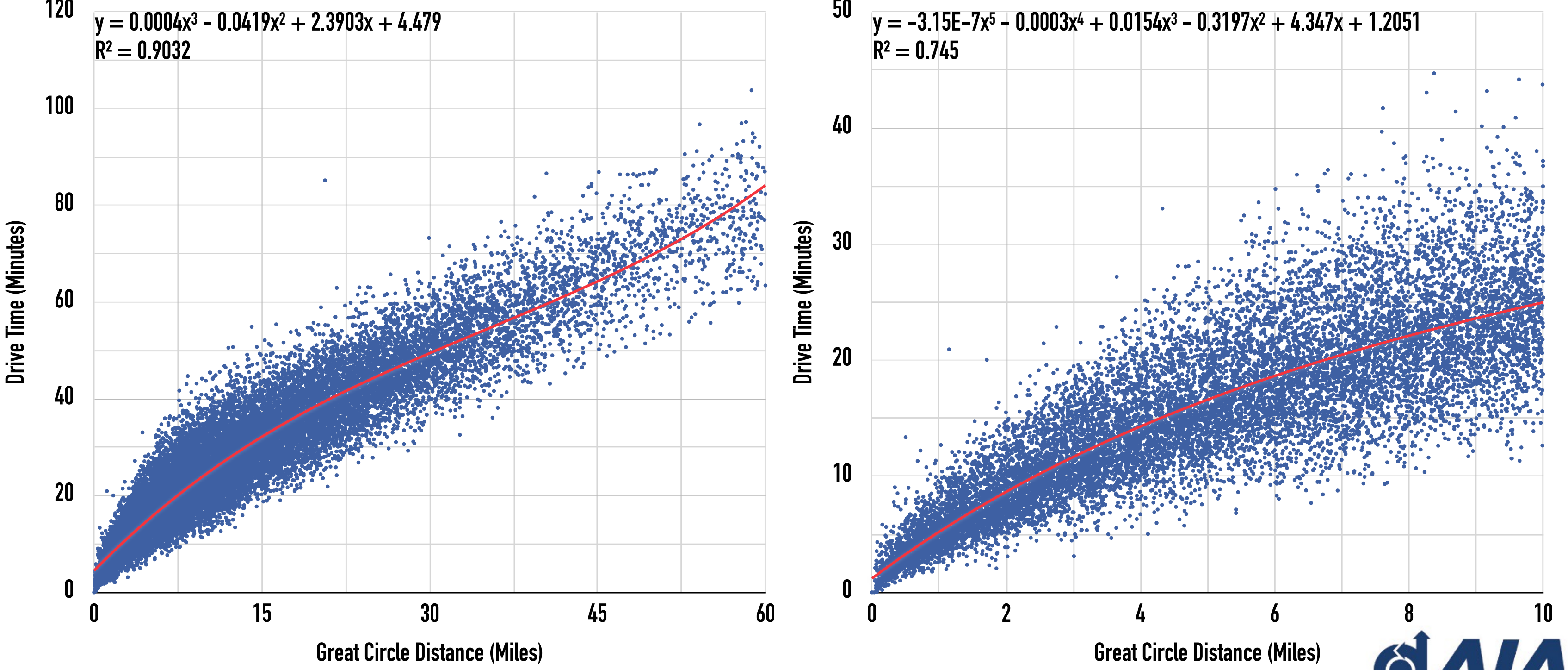
Methodology: Data Wrangling



- Utilize Google Maps Directions API to obtain travel times for 30,000 sampled data points.
- Divide data into training (n=25,000), validation (n=4,000), and testing (n=1,000) sets.
- Evaluate the performance of <u>a multi-level regression model</u> and <u>two-layer fully connected neural networks</u> for commuting time estimation.

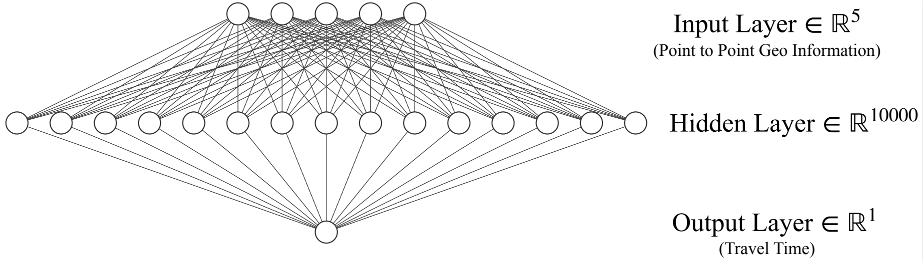
Methodology: Data Wrangling

Travel Time vs Great Circle Distance on Stratified Sampled Data



Methodology: Data Wrangling

Fully Connected Neural Network Structure

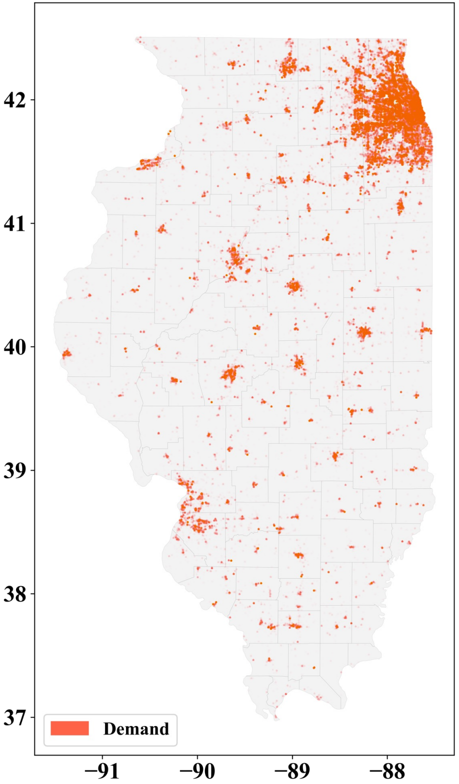


Select fully connected neural network as the preferred model for estimating commuting time of the entire population in Illinois (n=5,254,115).

Travel Time Prediction Methods Comparison

Data sets	Size	$\lvert\Delta\rvert$ Polynomial Regression	$\lvert\Delta\rvert$ Fully Connected Neural Network	*p*-value on a paired *t*-test
Training	25,000	5.965 min	5.296 min	1.82E-101
Validation	4,000	6.159 min	5.567 min	2.34E-12
Test	1,000	5.953 min	5.327 min	4.70E-06

Methodology: Clustering Analysis



Demand Distribution

Grid-Distance-based Clustering Algorithm

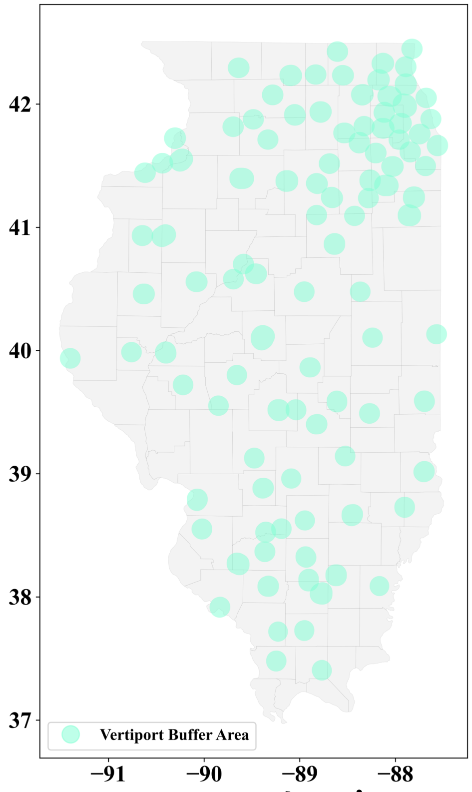
01 Assume a 10 km buffer circle around each GEOID area.

02 Start with initial map without clustered points.

03 Traverse points sequentially based on demand ordering.

04 Check intersection with existing clustering areas.

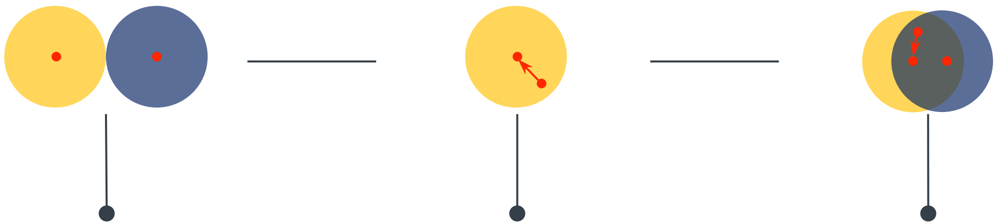
Methodology: Clustering Analysis



Top 100 Demand Vertiport

Assignment of Vertiports Based on Closest Distance

04 Check intersection with existing clustering centers.



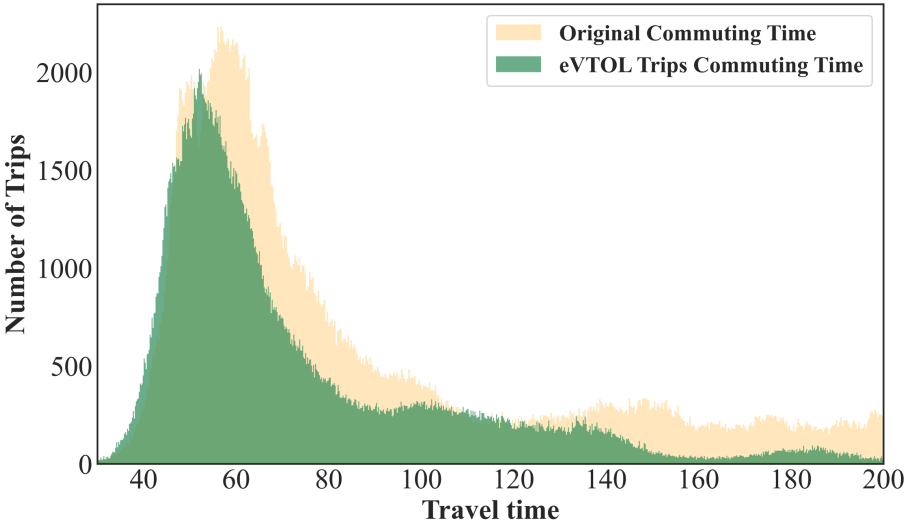
No intersection: Add region's geometric center as a clustering center point.

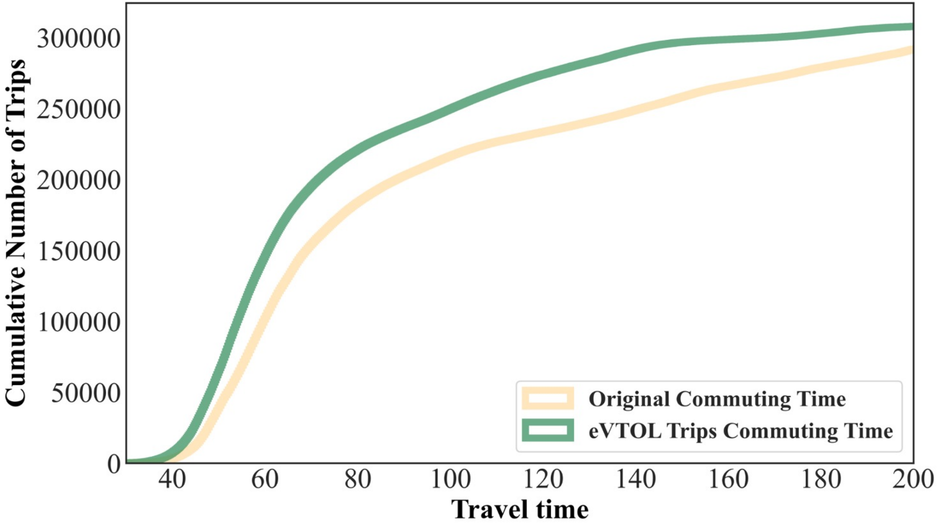
One intersection: Aggregate point into the existing clustering region.

Multiple intersections: Calculate distances and add GEOID region to the closest center.

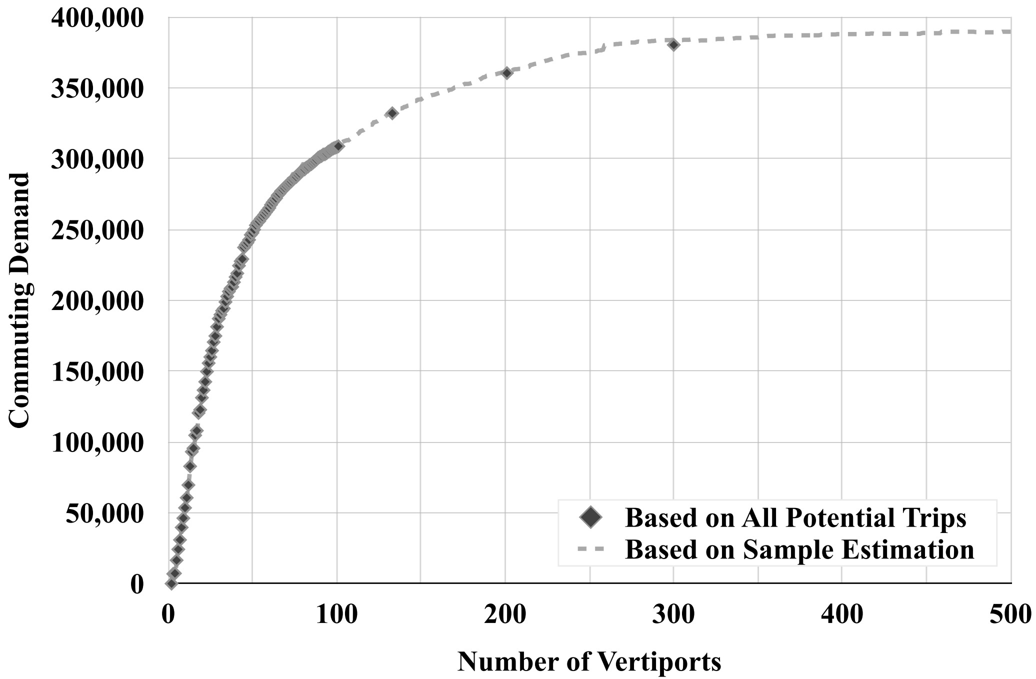
Results: Time Saving

$$t_{\text{eVTOL}} = t_{\text{dhome}} + 10\text{min} + \frac{\text{Great Circle Distance Between Vertiports}}{100\text{mph}} + t_{\text{dwork}}$$





Results: Optimal Number of Vertiport



$14.10 Hourly Values of Travel Time Savings (VVTS) from U.S. DOT[1]

$0.8M Medium-size vertiport construction cost from McKinsey[2]

Reference:

[1] U.S. Department of Transportation, "Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis," URL: https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation- travel-time-economic.

[2] Johnston, T., Riedel, R., and Sahdev, S., "To take off, flying vehicles first need places to land," , 2021. URL https://www. mckinsey.com/industries/automotive-and-assembly/our-insights/to-take-off-flying-vehicles-first-need-places-to-land.

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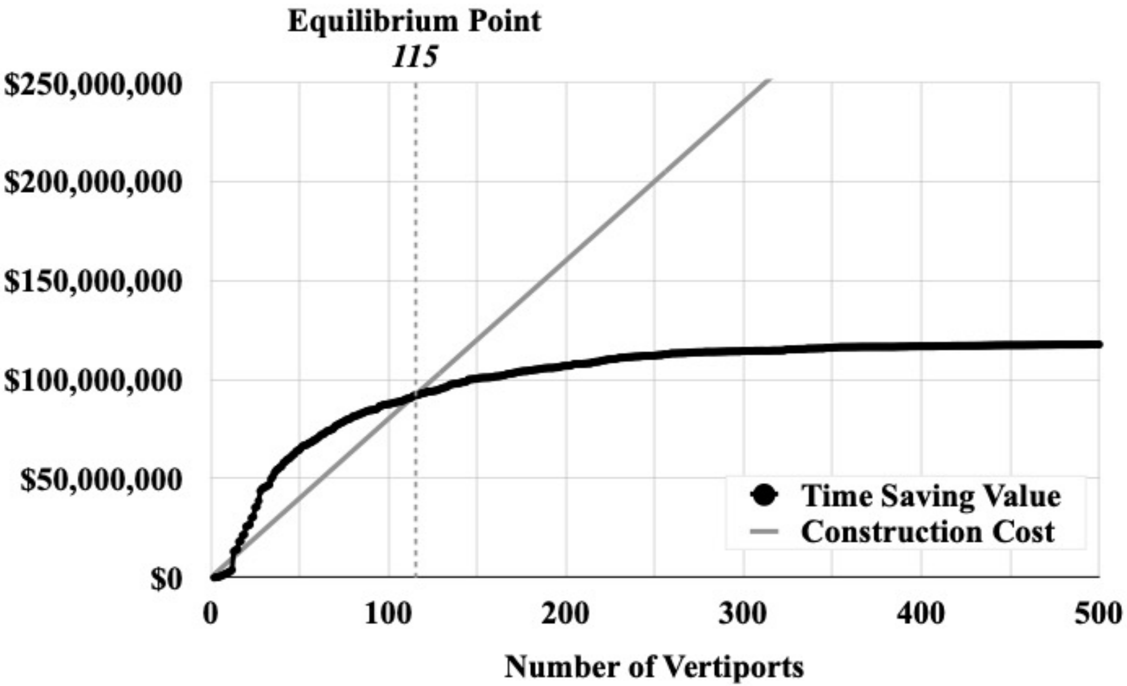

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Conclusion

Future work

- Consider benefits for both users and non-users.
- Continue to develop optimization program for vertiport placement.
- Introduce vertiport capacity constraint in system design.

Summary

- Explored UAM demand estimation and time benefits of eVTOL trips .
- Investigated optimal vertiport numbers using Chicago metropolitan area case study.

Thank You

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