A Scenario Based Evaluation of Global Urban Air Mobility Demand

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Clean Sky

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OASyS: **<u>O</u>**verall **<u>A</u>**ir Transport **<u>Sy</u>**stem Vehicle **<u>S</u>**cenarios

Introduction

Urban Air Mobility (UAM): Air transportation system capable of transporting people directly above populated areas

Develop high and low demand scenarios for Urban Air Mobility demand estimation across top 542 global cities

Elements of the UAM flight movement forecasting methodology

1. **UAM Aircraft (Vehicle) Demand**
2. **UAM Utilization**
3. **UAM Performance & Infrastructure**
4. **Flight Demand Forecasting**

Research Questions

- How many UAMs will be flying?
- When will they enter the market?

- How often will UAMs be flown?
- What would be the total flight hours?
- What would be the trip purpose?

- What is the speed and range of the UAM?
- Where will be vertiports located?

- How WTP for UAM will compete other modes of transport?
- Will the service be socially accepted?

The Business Case of Urban Air Mobility

RANK BY FILTER	WORLD RANK	CITY	COUNTRY	CONGESTION LEVEL	
1	1	**Bengaluru**	India	**71%**	
2	2	**Manila**	Philippines	**71%**	
3	3	**Bogota**	Colombia	**68%**	↑ 5%
4	4	**Mumbai**	India	**65%**	0%
5	5	**Pune**	India	**59%**	
6	6	**Moscow region (oblast)**	Russia	**59%**	↑ 3%
7	7	**Lima**	Peru	**57%**	↓ 1%
8	8	**New Delhi**	India	**56%**	↓ 2%
9	9	**Istanbul**	Turkey	**55%**	↑ 2%
10	10	**Jakarta**	Indonesia	**53%**	0%

- High and rising levels of roadway congestion is driving the need for a new, faster mode of transport
- In 2017, roadway congestion cost US commuters and companies an estimated $166B for extra time and wasted fuel

  Source: TAMU Mobility Report

- Congestion level indicates additional time spent per trip, respective to uncongested baseline

Identification of cities viable for UAM Operations

Factors for Identifying Global Cities

Population

Economic Indicators

GDP of a City

Population Data (2019): Demographia [1]

GDP/Capita Data (till 2050): IHS Markit [2]

Population 2019

Population 2035

Population 2050

Growth Rates provided by DLR

$(GDP/Capita)_{country}$

$(GDP)_{City}$

$$(GDP)_{city} = (GDP/Capita)_{country} * (Population)_{city}$$

Cut-off for Population and GDP

1 Million Population, 5 Billion GDP = 717 cities

1 Million Population, 100 Billion GDP = 535 cities

7 Cities Suggested by Topic Leader (DLR)

542 Global Cities Viable for UAM Operations

[1]. “DemographiaWorldUrbanAreas,”Tech.rep.,Demographia,2019"
[2]. "https://ihsmarkit.com/index.html"

Clustering Approach

After identifying the global cities viable for UAM operation, clustering approach was performed to merge cities with similar characteristics

- Clustering goal is to reduce data dimensionality by finding sets of cities with similar characteristics
- Good clustering algorithm must produce high quality cluster in which
  - The intra-class similarity is high
  - The inter-class similarity is low

Land Area

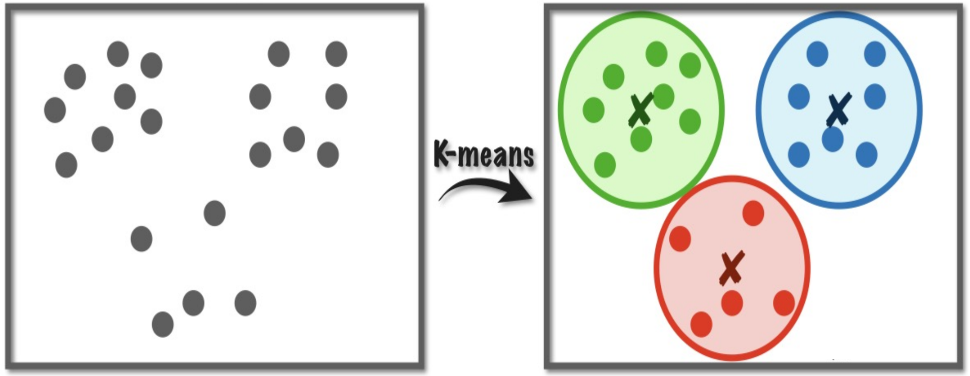
Population Density

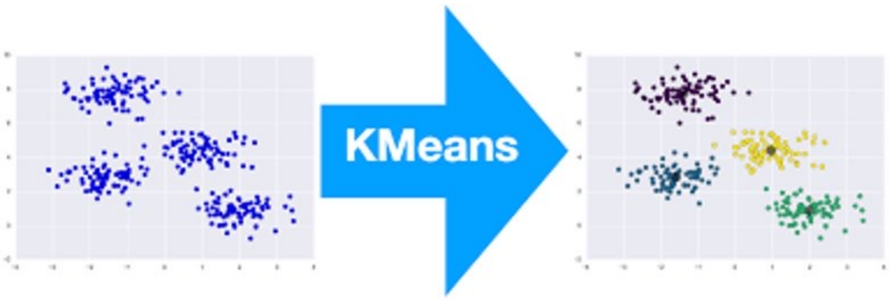
Land Area and Population Density of a city increases proportionally" [1] from current year to year of interest (2050)

GDP_{2050} (city level)

GDP_{2019} (city level)

$$(GDP)_{city} = (GDP/Capita)_{country} * (Population)_{city}$$

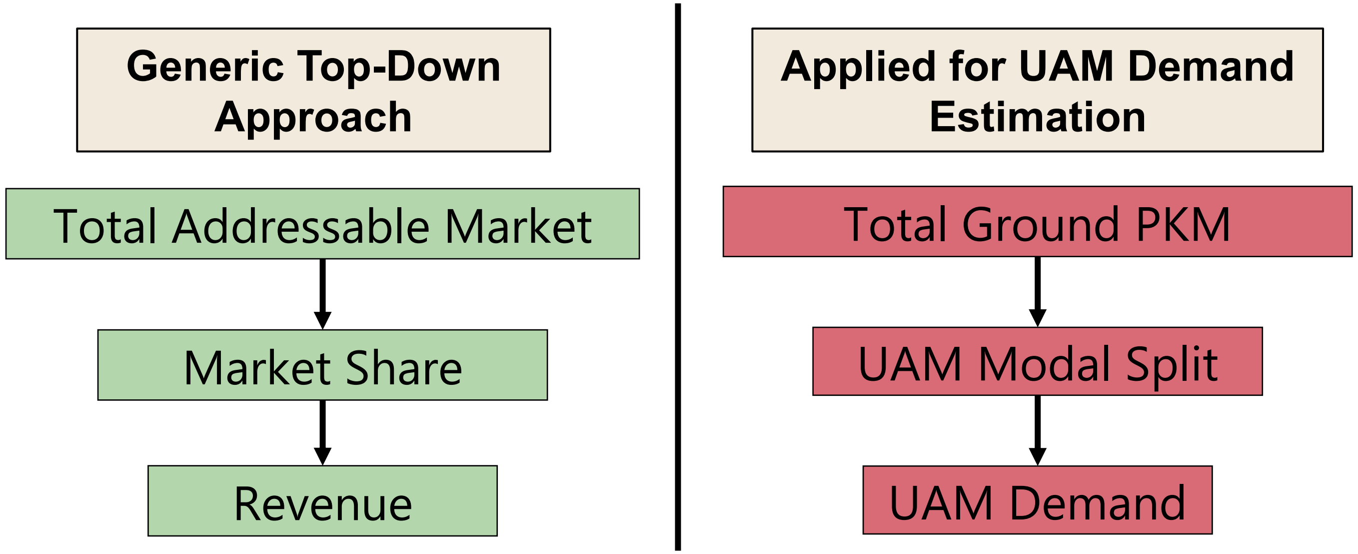


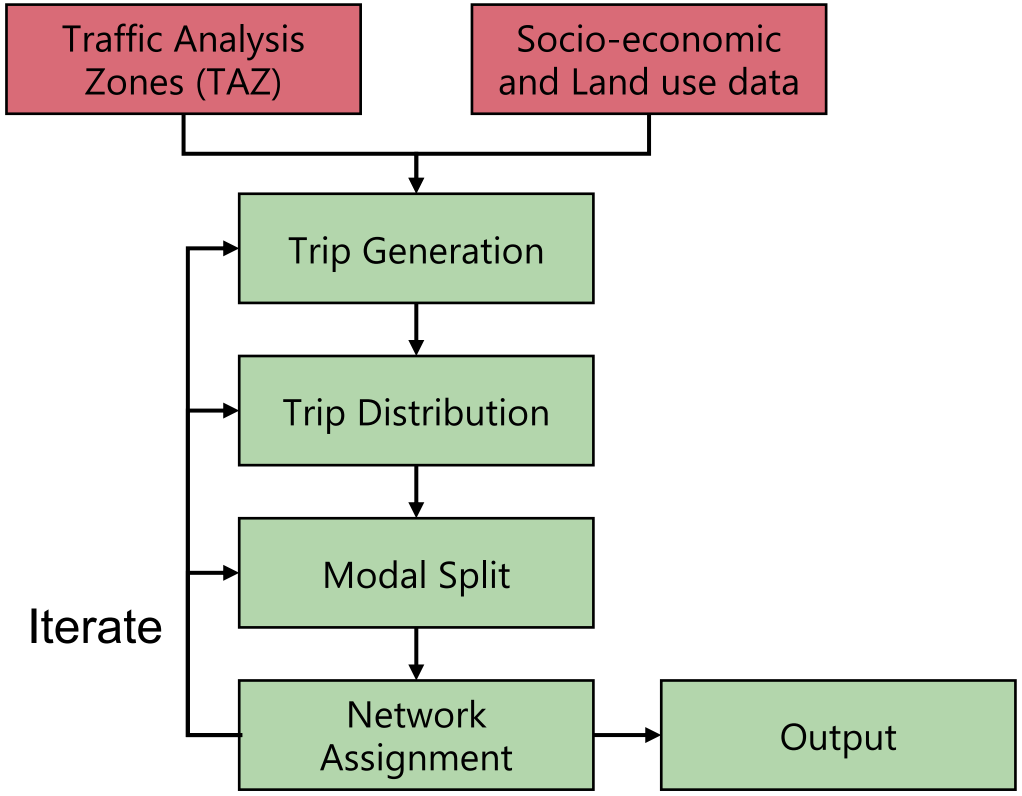


The authors pursued the K-Means Algorithm for the clustering analysis and identified 22 clusters

UAM Forecasting Assumptions

- UAM passenger kilometers traveled (PKM) may be estimated as a portion of the total PKM across all modes of ground transport
- Traffic forecasting typically conducted using four-step transportation model
  - **Infeasible to implement due to data unavailability, effort required, and computational expense**





Traditional Four-Step Transportation Forecasting Model [1]

[1] Kofi, G. E., "Network based indicators for prioritising the location of a new urban transport connection: Case study Istanbul, Turkey," 2020

UAM Forecasting Assumptions

A binary choice model considering value of travel time savings(VTTS) offers a solution [1]

$$Cost_{UAM} \leq WTP = Cost_m + VTTS * (Time_m - Time_{UAM})$$

$Cost_{UAM}$	Cost of a specific trip using UAM
$Cost_m$	Cost of a specific trip using an alternate mode m
VTTS	Dollar value an individual places per unit time saved
$Time_m$	Trip time of a specific trip using alternate mode m
$Time_{UAM}$	Trip time of a specific trip using UAM

This approach has been implemented in past UAM studies for local areas [1,2]

All alternate travel mode options
All possible trip purposes
Discretized range of trip distance
Discretized range of income level

→ WTP Function

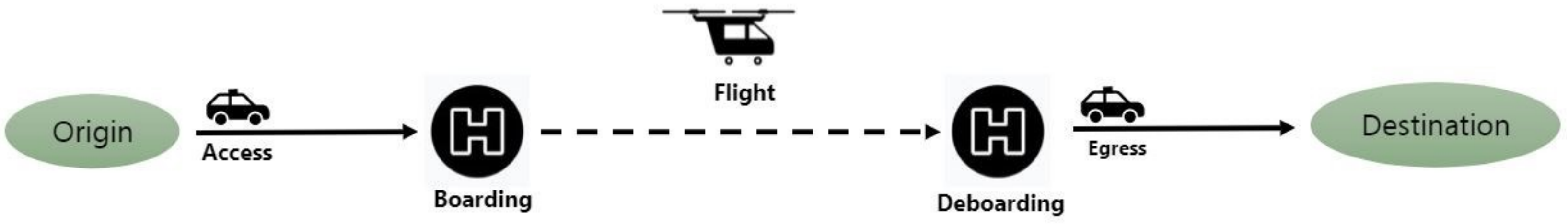
$$Cost_{UAM} \leq WTP = Cost_m + VTTS * (Time_m - Time_{UAM})$$

→ Viable space for UAM Travel → Calculate PKM → Total UAM PKM

[1] N. Sirirojvisuth, S. Briceno, and C. Justin, "Life-Cycle Economic Analysis and Optimization for Urban Air Mobility (UAM)" (2020)
[2] Booz Allen Hamilton, "UAM Market Study - Technical Out Breif" (2018)

UAM Concept of Operations

- Range and Cruise Speed
- UAM Ticket Cost
- Time for Alternate Mode
- Trip Time for UAM
- Vertiport Density
- Cost for Alternate Mode + Parking Cost
- VTTS: Value of Travel Time Savings
- Purpose Split
- Mode Split
- Trip Distribution
- Income Distribution
- Total Ground PKM



Assumed Demand Parameters		
Parameter	**Lower Bound**	**Upper Bound**
Average Speed of UAM Vehicle	**120 km/hr**	**240 km/hr**
Range of UAM Vehicle	**60 km**	**120 km**
VTTS (Personal, Business) [1]	**(35%, 80%)**	**(60%, 120%)**
Vertiport Network Density [2]	**300 sq. km**	**120 sq. km**

[1] P. Belenky, "Revised Departmental Guidance on Valuation of Travel," U.S. Department of Transportation, Washington, DC, 2011
[2] Mayakonda M. et al. "A Top-Down Methodology for Global Urban Air Mobility Demand Estimation," AIAA Aviation Forum (2020)

Concept of Operations

The elements of the CONOPS can be filled by different data sources or combinations of the data sources

1. **Population, GDP Data**
2. **Trip Distribution Data**
3. **Income Data**

UNITED NATIONS
DEMOGRAPHIA
IHS Markit
DLR

INRIX
SLA SINGAPORE LAND AUTHORITY
Deloitte.
TOMTOM
International Transport Forum
Parkopedia

THE WORLD BANK
pwc
DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA
INTERNATIONAL MONETARY FUND
NUMBEO

Each module can be supplied or filled with different levels or sources of data

UAM Demand Forecast Algorithm

City Selection
Selection of potential cities worldwide (542)
Identification of representative cities (22)

Scenario Specific Assumptions
Average Speed of UAM (km/hr)
Range for UAM (km)
Vertiport Density (sq. km)
Value per hour time saved (Personal/ Business) (%)

Fixed Model Assumptions
Boarding Time (mins)
De- boarding Time (mins)
Passenger Carrying Capacity
Cost of Ride Share ($/km)
Cost of Operating a Personal Vehicle ($/km)
Ticket Cost Intra- city ($/km)
Ticket Cost Inter- city($/km)
Parking Cost ($) (4 hours)
Purpose Split (Private/ Business) (%)
Modal Split (%)**
Travel Time of Alternate Modes**

Calculation of UAM results for each city based on the following information
Total Ground PKM*
Trip Distance Distribution**
Household Income Distribution*
UAM Ticket price Assumption Ranges

If
WTP > UAM Price

Results
Annual UAM Passenger Trips
Annual UAM PKM
Annual UAM Utilization
Annual UAM Vehicle Trips

*city- level; based on country- level per capita values
**city- level; based on 22 representative cities

UAM Specific Factors
External Factors

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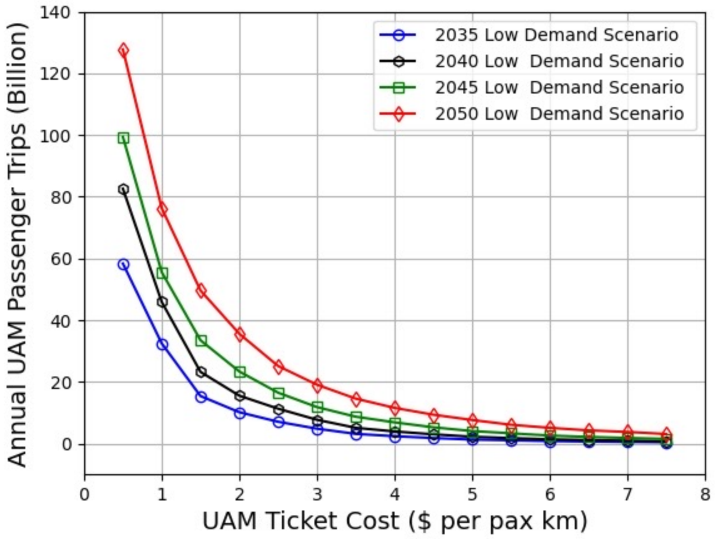
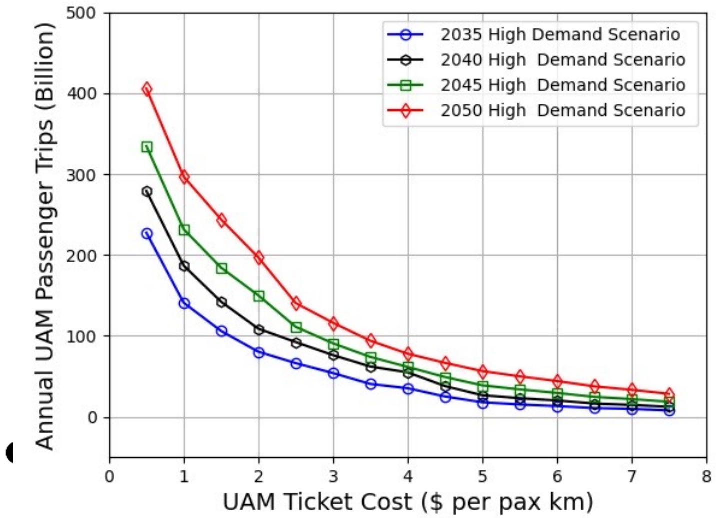
UAM Results and Conclusions

Low Demand



High Demand



Overall Bounded Scenario Outcomes (Low – High)

	2035	*2050*
UAM Pax Trips (Billion)	0.43 - 227.35	3.09- 405.54
UAM Utilization (Billion Hrs)	0.07 - 11.51	0.37 - 20.79
UAM PKM (Billion)	8.68 - 2762.11	43.88- 4990.71

- Strong market demand exists for a range of UAM ticket prices and vertiport densities, ranging from 0.43 billion annual pax trips globally up to 400 billion pax trips
- Demand expands exponentially with decreases in ticket price and vertiport network density
- Manufacturers may leverage these results to identify and plan for an optimal production rate
- City planners must focus on developing vertiport infrastructure quickly and efficiently
- UAM demand estimates are highly sensitive to the assumption made during the research

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Thank you!

Questions?

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