UAM Market Forecast

Dr. Colleen Reiche, Booz Allen Hamilton, Lead Associate, Senior Lead Technologist
URBAN AIR MOBILITY (UAM) MARKET STUDY

Presented to: Aerospace Industries Association (AIA) Fall Supplier Management Council Meeting

SEPTEMBER 25, 2019
Executive Summary
Legal and Regulatory
Societal Barriers
Weather Analysis
Market Analysis
EXECUTIVE SUMMARY

Our analysis focused on three potential UAM markets: **Airport Shuttle, Air Taxi, and Air Ambulance** using ten target urban areas\(^1\) to explore market size and barriers to a UAM market. Our results suggest the following:

- Airport Shuttle and Air Taxi markets are **viable markets** with a significant total available market value of $500B\(^2\) at the market entry price points in the best-case unconstrained scenario.

- Air Ambulance market served by eVTOLs is **not a viable market** due to technology constraints, but utilization of hybrid VTOL aircraft would make the market potentially viable.

- Significant legal/regulatory, certification, public perception, infrastructure, and weather constraints exist which reduce market potential in near term for UAM.

- After applying operational constraints/barriers, **0.5% of the total** available market worth $2.5B can be captured in the near term.

- Constraints can potentially be addressed through ongoing intragovernmental partnerships (i.e., NASA-FAA), government and industry collaboration, strong industry commitment, and existing legal and regulatory enablers.

---

\(^1\) New York, Washington DC, Miami, Houston, Dallas, Denver, Phoenix, Los Angeles, San Francisco, Honolulu

\(^2\) US Domestic Airline industry has an annual market value of ~150B (Ibis, 2018)
## EXECUTIVE SUMMARY - CONSTRAINTS

**UAM MARKETS FACE SIGNIFICANT CHALLENGES AND CONSTRAINTS**

### Near Term - Immature Market

<table>
<thead>
<tr>
<th>Technology Challenges</th>
<th>Non-Technological Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economics:</strong> High cost of service (partially driven by capital and battery costs)</td>
<td><strong>Infrastructure:</strong> Lack of existing infrastructure and low throughput</td>
</tr>
<tr>
<td><strong>Weather:</strong> Adverse Weather can significantly affect aircraft operations and performance</td>
<td><strong>Competition:</strong> Existing modes of transportation</td>
</tr>
<tr>
<td><strong>Air Traffic Management:</strong> High density operations will stress the current ATM system</td>
<td><strong>Weather:</strong> Conditions could influence non-technological aspects of operation</td>
</tr>
<tr>
<td><strong>Battery Technology:</strong> Battery weight and recharging times detrimental to the use of eVTOLs for Air Ambulance market</td>
<td><strong>Public Perception:</strong> Passengers concerned about safety and prefer security screening and preference UAM only for longer trips</td>
</tr>
<tr>
<td><strong>Impacts:</strong> Adverse energy and environmental impacts (particularly, noise) could affect community acceptance</td>
<td><strong>Laws and regulations</strong> for flying over people, BVLOS, and carrying passengers (among others) are needed</td>
</tr>
</tbody>
</table>

### Longer Term - Mature Market

<table>
<thead>
<tr>
<th>Technology Challenges</th>
<th>Non-Technological Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impacts:</strong> Energy and Environmental Impacts of large-scale operations</td>
<td><strong>Competition:</strong> Emerging technologies and concepts like shared Electric and Autonomous Cars, and fast trains</td>
</tr>
<tr>
<td><strong>Cybersecurity</strong> of Autonomous systems including vehicles and UTM</td>
<td><strong>Weather:</strong> Increase in some adverse conditions due to climate change may limit operations</td>
</tr>
<tr>
<td><strong>Weather:</strong> Disruptions to operations during significant adverse conditions</td>
<td><strong>Social Mobility:</strong> New importance of travel time, increase in telecommuting, urbanization and de-congestion scenarios could reduce the viability of markets</td>
</tr>
<tr>
<td><strong>New Entrants:</strong> Large scale operations of new entrants like UAS, Commercial Space operations, private ownership of UAM vehicles could increase the complexity of airspace management and safety</td>
<td><strong>Public Perception:</strong> Passengers trust and apprehension with automation and pilot-less UAM and prefer to fly with others they know in an autonomous UAM</td>
</tr>
</tbody>
</table>

Certifications: Gaps in the existing certification framework where UAM will experience challenges, particularly system redundancy and failure management.
EXECUTIVE SUMMARY – BACKGROUND

AN EMERGING MODE OF TRANSPORTATION, THE SPECIFICS OF UAM ARE YET TO BE DEFINED

NASA defines UAM as a safe and efficient system for air passenger and cargo transportation within an urban area, inclusive of small package delivery and other urban Unmanned Aerial Systems (UAS) services, that supports a mix of onboard/ground-piloted and increasingly autonomous operations.
CONTENTS

Executive Summary

Legal and Regulatory

Societal Barriers

Weather Analysis

Market Analysis

Conclusions
Surveyed and analyzed the Federal Acts, Federal regulations, State laws, and local ordinances for each of the three UAM urban markets, identified legal barriers, along with the gaps and path to certification.

Air Taxi, Ambulance, and Airport Shuttle UAM markets share common regulatory barriers.

There will be challenges in determining which of the existing FAA certification standards apply to the types of vehicles being considered for the Air Taxi or Air Ambulance UAMs, and/or how existing certification standards can be met or should be amended.

- Air Ambulances will require further evaluation due to the requirements of an operator’s air ambulance procedures and air-ambulance-specific sections of their General Operations Manual (GOM).

Gaps in current certifications mean that new standards will need to be developed, especially in areas related to system redundancy and failure management.
LEGAL AND REGULATORY BARRIERS

Air Taxi, Ambulance, and Airport Shuttle UAM Markets share common Regulatory Barriers

Remotely piloted and autonomous UAM markets require the following aviation regulations (either modification of existing regulations, or new regulations), as the current regulatory structure does not fully allow for these activities to be performed:

- Regulations for beyond visual line of sight (currently only with lengthy waiver process)
- Regulations for operations over people, streets, etc. (currently only with lengthy waiver process)
- Regulations for when air cargo is being carried commercially and across state lines
- Regulations for when a passenger or patient is being transported in a UAM (remotely or autonomously piloted) either within visual line of sight or beyond
- Regulations for flight in instrument conditions
- Regulations for airworthiness certification of remotely piloted and autonomous aircraft
- Training and knowledge requirements for pilots and operators

A legal framework for addressing privacy concerns should be developed outside of the aviation regulatory framework.

State and local laws cover wide range of restrictions from no drones to protecting UAS in focus urban areas

Strategies moving forward: Enabling strategies can be employed to accelerate the development of a UAM legal framework:

- NASA – FAA cooperation, such as the Research Transition Teams
- FAA Aviation Rulemaking Committee
- FAA UAS Integration Pilot Program
- Leveraging strategies from automobile automation, such as voluntary standards may help UAM deployment
CONTENTS

Executive Summary
Legal and Regulatory
Societal Barriers
Weather Analysis
Market Analysis
SOCIETAL BARRIERS – METHODOLOGY

- **How Do We Conduct Research on Societal Barriers?**
  - Self-reported surveys can inform how public could respond to the advent of an innovative transportation technology, such as UAM

- **Literature Review** provided baseline understanding of public perception related to aviation and new types of transportation

- **Focus Groups** conducted in Washington, DC and Los Angeles, CA identified initial challenges and help shape survey focus and questions

- **General Population Survey** targeted approximately 1,700 respondents in five U.S. cities (~350 respondents per city)
Key Concerns

- Generally, neutral to positive reactions to the UAM concept
- Respondents most comfortable flying with passengers they know; least comfortable flying with passengers they do not know
- Some willingness and apprehension about flying alone (particularly in an automated/remote piloted context)
- Preference for piloted operations; may need to offer mixed fleets and/or a discount for remote piloted/automated operations to gain mainstream societal acceptance
- Preference for longer inter-city flights (e.g., DC to Baltimore; LA to San Diego)
- Existing noise concerns focus on traffic noise during the night and early morning
- Cost is a primary consideration for public users when choosing a transportation mode
- Safety
  - Aircraft sabotage (by passengers or people on the ground)
  - Unruly and/or violent passengers
  - “Lasing”
CONTENTS

Executive Summary
Legal and Regulatory
Societal Barriers
Weather Analysis
Market Analysis
WEATHER ANALYSIS - DATA SOURCES

- Weather can create a variety of barriers to UAM, focused on operations
- Computed seasonal average potentially impactful conditions from historical weather observations

PIREP
TEB UA /OV TEB010003/TM 1931/FLDURD/TP E35L/RM LLWS +/-10KT

- Conditions may not be fully representative of entire urban area

Vertical Sounding

METAR

Miami

Washington DC

Denver
SIGNIFICANTLY IMPACTED HOURS OF WEATHER

- Approximately half the UAM operational day potentially impacted by weather in several urban areas on average across all seasons.

- High number of impacted hours in winter and spring in the Northeast, Texas, and Denver urban areas.

- Fewest impacted hours during summer and fall at most focus urban areas.

### Average Number of Impacted Hours (7am – 6pm Local)

<table>
<thead>
<tr>
<th>Urban Areas</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Washington DC</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Miami</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dallas</td>
<td>11</td>
<td>12</td>
<td>3</td>
<td>0</td>
<td>6.5</td>
</tr>
<tr>
<td>Houston</td>
<td>9</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Denver</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>7.75</td>
</tr>
<tr>
<td>Phoenix</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1.25</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>San Francisco</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>4.75</td>
</tr>
<tr>
<td>Honolulu</td>
<td>0</td>
<td>7</td>
<td>9</td>
<td>6</td>
<td>5.5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>6.1</td>
<td>7.3</td>
<td>2.9</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>
CONTENTS

Executive Summary
Legal and Regulatory
Societal Barriers
Weather Analysis
Market Analysis
  • Airport Shuttle and Air Taxi
  • Air Ambulance
AIR TAXI - SYSTEM LEVEL FRAMEWORK

Analysis of urban Airport Shuttle and Air Taxi markets requires a system-level approach that comprise of various system level layers like supply, demand, infrastructure, legal/regulatory environment, public acceptance, safety and security. Each layer is investigated in a scenario and sensitivity based analysis framework.

**Modeling Framework**

- Public
  - Noise Population Exposure
  - Emissions

- Demand for UAT services
  - Trip Generation
  - Trip Distribution
  - Mode-Choice (Market Size)

- Supply (operator)
  - Aircraft Classification
  - Direct Operating Cost
  - Indirect Operating Cost

- Airports/Vertiports (number & location)
  - Existing Heliports
  - Existing Airports (small or large)
  - New Infrastructure

- Infrastructure Capacity Constraints
  - Ground Infrastructure
  - Air Traffic Management

- Legal / Regulatory Environment
  - Federal
  - State / Local

**Analysis Framework**

- Scenario-based Analyses
- Sensitivity Analyses

**Results (by stakeholders)**

- Public
  - Noise footprint around vertiport
  - Emissions

- Passengers
  - Cost vs time savings
  - Number of Passengers
  - Operating Cost per passenger mile
  - Fleet

- Operators
  - Vertiports Use & Distribution
  - Use/Capacity Constraints

- Infrastructure Providers

**Iterative Loop**
AIR TAXI - PRICE COMPARISON WITH OTHER MODES OF TRANSPORTATION

- 5-Seat eVTOL passenger price per mile is expected to be more expensive than luxury ride sharing on the ground
- 2-seat eVTOL aircraft is comparable to current limo type services. Operators like Blade and Skyride charges ~$30 per passenger mile while Voom charges ~$10 per passenger mile

<table>
<thead>
<tr>
<th>Mode of Transportation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limo</td>
<td>Limos¹</td>
</tr>
<tr>
<td>Luxury Ride Sharing</td>
<td>Uber², Fare Estimator³</td>
</tr>
<tr>
<td>Economy Ride Sharing</td>
<td>Uber, Fare Estimator</td>
</tr>
<tr>
<td>Taxi</td>
<td>MarketWatch⁴</td>
</tr>
<tr>
<td>Autonomous Taxi</td>
<td>MarketWatch</td>
</tr>
<tr>
<td>Vehicle Ownership</td>
<td>AAA⁵</td>
</tr>
<tr>
<td>Uber Air Launch, Helicopter</td>
<td>Uber Elevate⁶</td>
</tr>
</tbody>
</table>

¹Limos.com assessed on 1/12/2018  
²Uber Estimate available at http://uberestimate.com/prices/San-Francisco/  
³Fare Estimator available at https://estimatefares.com/rates/san-francisco  
⁴Driverless cars could cost 35 cents per mile for the Uber consumer, MarketWatch, 2016  
⁵AAA Reveals True Cost Of Vehicle Ownership, AAA, 2017/  
⁶Presented at Uber Elevate, May 2018.
AIR TAXI - BASE YEAR DEMAND COMPARISON FOR ALL URBAN AREAS

- On average ~0.5% of unconstrained trips are captured after applying constraints\(^1\). New York, Los Angeles, Houston and Dallas are potential urban areas of high daily demand.

\(^1\) WTP constraint not shown here but is applied
Air Taxi market has a potential demand of ~55k daily trips (or ~80k daily passengers) across the US that can be served by ~4k aircraft. Based on near term market entry assumptions, annual market value is projected to be ~$2.5 bn for the first few years of operation. Longer term, high demand may be achieved by high network efficiency but autonomous cars are expected to provide strong competition.
CONTENTS

Executive Summary
Legal and Regulatory
Societal Barriers
Weather Analysis

Market Analysis
  • Airport Shuttle and Air Taxi
  • Air Ambulance
AIR AMBULANCE IS A COMPLEX POTENTIAL MARKET

<table>
<thead>
<tr>
<th><strong>AIR AMBULANCE OVERVIEW</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition:</strong> The Air Ambulance market includes travel to/from the hospital for emergencies and potentially hospital visits. Both public and private operations are considered.</td>
</tr>
<tr>
<td><strong>Selection Criteria:</strong> A complex market and likely to highlight technology barriers in terms of technical capabilities needed on board the aircraft, in addition to other legal and regulatory barriers. Air Ambulances have high public acceptability.</td>
</tr>
<tr>
<td><strong>Value Proposition:</strong> Lifeline; public safety; reduction of travel time by 1.5-2 times, hence reducing fatalities</td>
</tr>
<tr>
<td><strong>Market Dynamics:</strong></td>
</tr>
<tr>
<td>- <strong>Market Size:</strong> Relatively limited market; however, the services are of high value</td>
</tr>
<tr>
<td>- <strong>Market Drivers:</strong></td>
</tr>
<tr>
<td>- Events i.e. Accidents, health related events etc.</td>
</tr>
<tr>
<td>- Demographic trends</td>
</tr>
<tr>
<td>- Healthcare legislation</td>
</tr>
<tr>
<td>- Changes in insurance policies</td>
</tr>
<tr>
<td>- <strong>Potential Business Models at Play:</strong> Insurance subscription, hospital ownership, fleet operators, pay per ride</td>
</tr>
<tr>
<td><strong>Connected Markets:</strong> Emergency Response markets such as law enforcement, natural disaster response, and firefighting</td>
</tr>
</tbody>
</table>

Source: BAH Analysis; Ibis, 2016
After performing 10,000 iterations of Monte Carlo, the median cost of operating an eVTOL air ambulance is ~$9,000 per transport and hybrid air ambulance is ~$9,800 as compared to ~$10,000 for rotary wing helicopter (source: AAMS) and ~$500 for ground ambulance. About 80% is fixed cost.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise Altitude (ft)</td>
<td>500</td>
<td>5,000</td>
</tr>
<tr>
<td>Medical Equipment Weight (lb)</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>Pilot Training ($ per year)</td>
<td>10,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Paramedic and EMT Training ($ per yea)</td>
<td>10,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Indirect Operating Cost (% of DOC)</td>
<td>5%</td>
<td>50%</td>
</tr>
<tr>
<td>Bad Debt (% of Operating Cost)</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>Electricity Price ($/kwh)</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Profit Margin (% of Cost)</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>Disembarkation Time (in mins)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Climb Descend Distance (miles)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Energy Conversion Efficiency (%)</td>
<td>90%</td>
<td>98%</td>
</tr>
</tbody>
</table>
AIR AMBULANCE - MARKET SIZE CAPTURE UNDER DIFFERENT OPERATION SCENARIOS

Due to high recharging time, dispatch reliability of eVTOLs for 90% of the market may be below the acceptable standard. Therefore, under current technology, eVTOLs may not be an attractive option for air ambulances. Fast Recharging and Battery Swapping capabilities may propel the capture of available RW market for eVTOLs.

Fast Recharging:

- Assumes a scenario where battery recharging rate increases with respect to current rates
- On increasing Battery recharge rate approximately 4 times to current rate, eVTOLs may address the total available RW market because of the following
  - Dispatch reliability similar to current RW market achieved
  - Cost per transport less than current RW market

Battery Swapping:

- ~100% of RW market is available for eVTOLs with Battery Swapping capabilities