Demand Potential for Urban Air Mobility

Report prepared by MIT researchers in collaboration with EVE

Large cities face a dilemma: the population is growing while the aging transport infrastructure is becoming more congested. Efforts to expand or renew this infrastructure will require investment and may face opposition due to concerns about cost, noise, or air pollution. However, without action and strategic planning, urban populations will continue to face mobility challenges.

Urban Air Mobility (UAM) uses aircraft with vertical take-off and landing (VTOL) capabilities as “on-demand air taxis” which transport passengers or cargo within metropolitan areas. Over decades, UAM systems have relied on helicopters. However, helicopter-based networks claim only a negligible share of urban transport markets due to high costs, noise, and safety concerns. As a consequence, UAM systems have mostly lacked scalability.

Innovations in aircraft technologies offer the potential to overcome these challenges and present the UAM industry with an opportunity to scale. For example, power-train electrification (fully electric or hybrid) and batteries with high power density can be used to build propulsion systems without direct emissions. In addition, innovations in composite materials, advanced autonomous systems, and blade designs can enable lighter, more automated, and quieter flight. Together, these technologies, are leveraged to develop new VTOL aircraft called electric VTOL vehicles (eVTOLs) that have the potential to transform UAM into a scalable solution for the urban mobility challenge.

This paper discusses examples of demand estimates for UAM services, analyzes price sensitivity, and lists challenges for scaling the size of addressable markets.

Potential Demand for UAM Services

People rarely travel because they enjoy driving or riding a train. Traveling is a means to an end; it is a service that enables people to engage in experiences, connect with family and friends, go to work, or run errands. As a result, demand for transportation is thought to be derived from underlying activities.

Efforts to analyze UAM demand will need to consider different sources of demand. At the launch of eVTOL UAM services, most UAM passengers will use eVTOLs as a substitute for other modes of transportation (i.e., substituted demand). With time, a maturing market and experience in taking urban flights, travelers will gradually explore additional mobility needs in response to the availability of UAM (i.e., induced demand). For example, travelers might take a UAM flight more frequently or discover new routes that were previously associated with high travel costs or significant inconvenience. Since induced demand will only materialize over time, it is often only considered in studies of demand potential in the long term. This report focuses solely on substituted demand—the UAM demand potentials at market entry; it does not quantify induced demand.

Comparison of UAM and Ground Transportation Costs

Travelers are likely to choose UAM over ground transportation due to convenience and time savings. The convenience of UAM may stem from factors such as infrastructure and vehicle availability, the comfort of flying, or an easy-to-use booking platform. Travelers will be able to save time because a UAM flight can overfly natural and built obstacles and traffic while also avoiding the constraints of ground infrastructure such as rail and road networks.

Gains in convenience and time will come at a cost when compared to ground transportation options that include cars, trains, taxis and ride-hailing services. Studies initially expect the cost of a UAM flight, calculated per passenger-km, to range from US$3.50 to US$4.00 (Reiche et al., 2018; Binder et al., 2018); approximately twice the cost of a taxi at US$1.86/km in Los Angeles (LA). However, these costs may decrease in the future to values between US$1.60 and US$1.10 (Reiche et al., 2018; Binder et al., 2018). Table 1 provides an overview and comparison of these expected costs.

Table 1 | Expected costs for UAM vs. ground transport modes in the Los Angeles Metropolitan Area according to literature values. Note that ground transportation costs include average costs per kilometer, including fixed costs and variable costs. All prices are in USD.

Transport mode	Distance variable cost (per passenger $/km)	Time variable cost ($/min)	Fixed cost
UAM, near term	$3.56 - $3.88	-	-
UAM, long term	$1.14 - $1.55	-	-
Car, dropped off	$0.437	-	-
Car, parked for 3 days	$0.437	-	$36.00
Transportation Network Company (TNC) (i.e., on-demand car rides)	$0.665	$0.17	$6.80
Taxi	$1.86	-	$3.23
Public Transit	-	-	$6.00

In the absence of other convenience factors, travelers will be willing to switch from ground transportation to UAM if they value their time more than the cost premium of UAM. The willingness to pay (WTP) for time savings is driven by a passenger's Value of Travel Time Savings (VTTS), which can be measured empirically. The purpose of a trip (e.g., leisure vs. business) and passenger attributes (e.g., income) also drives a traveler's VTTS. Furthermore, attributes of the time saved (e.g., waiting time vs. in-vehicle time, or whether the time can be used productively) impact on how an individual values time. Other characteristics of the UAM service, like ride comfort, travel time variability, and ease of vertiport access, may also impact on the WTP.

WTP= Willingness to pay | VTTS=Value of Travel Time Savings

Potential UAM Customers

At market launch, eVTOL operators will likely seek to attract passengers drawn from substituted demand. From a profit maximization perspective, eVTOL operators could aim to maximize the utilization of their assets and serve a UAM market with the highest WTP. Under these criteria, the following two markets might be among the first markets to be served:

- **Metropolitan Area Commuters** Commuters generally travel in a recurring pattern. Traffic congestion during the morning and evening commutes will amplify the time savings of UAM services. As a result, this market has often been considered a likely early use case. It is important to note that while this market is attractive, typical demand patterns have significant temporal and geographic demand peaks that may be an economic challenge for the feasibility of the UAM system.

One example is the idealized demand potential of commuters (with fly-direct routes, ubiquitous vertiports, and no weather restrictions) in the Los Angeles Metropolitan Area. According to our analysis, it is estimated that up to 196,000 daily roundtrips can be made at a price of US$1.50 per passenger-km. A map of the flows associated with this demand potential (Figure 1) shows a strong concentration of traffic flows that are associated with higher-income neighborhoods and distances greater than 16.5 km.

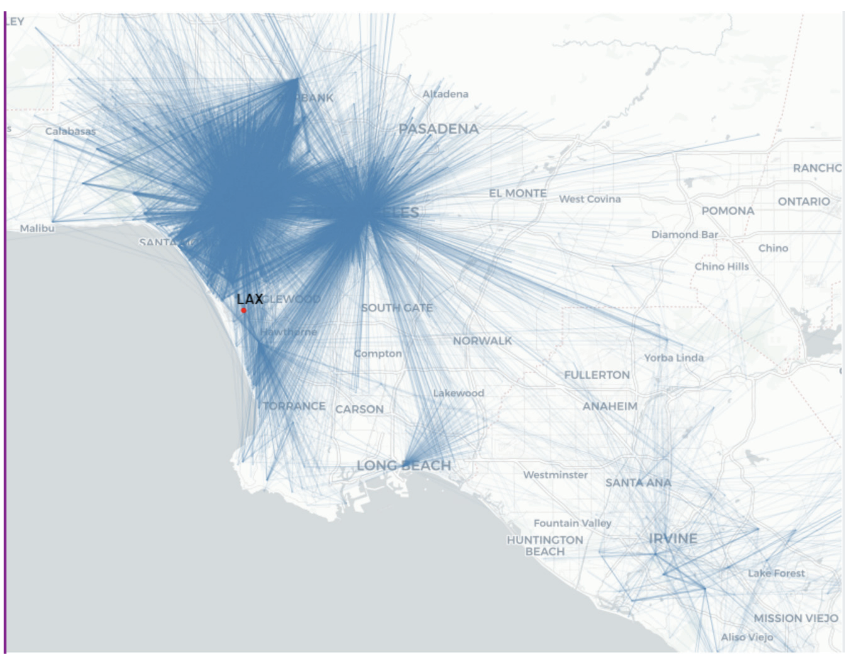

Figure 1

Unconstrained commute market potential, LA (US$1.50 $/pax-km, for aircraft that travels 200 km/h) showing greater demand in higher income locations and trips longer than 16.5 km

• **Airport Travelers.** Travelers to and from an airport are a dependable source of demand, but demand has been associated with a low price elasticity according to our analysis. Today, this market is already being served by on-demand helicopter services such as Uber Copter, or Blade in some metropolitan areas. Note that airport access flows tend to be fairly steady during the day, and UAM operations currently cater to higher income leisure and business travelers with a high VTTS. The high cost and inconvenience of missing a flight further increases the VTTS of airport travelers (Koster et al., 2011) (and makes UAM attractive over ground transportation). Going forward, to serve airport travelers satisfactorily, UAM operations will need to minimize travel time variation in the UAM system.

The idealized airport access demand potentials can be significant. For Los Angeles International Airport (LAX), UAM has the potential to reach 10% of LA's total demand potential at a price of US$1.50 per pax-km (substituted demand only). A map of LAX access demand flow potentials (Figure 2) shows a concentration of routes to and from downtown that tend to serve business travelers with a high VTTS.

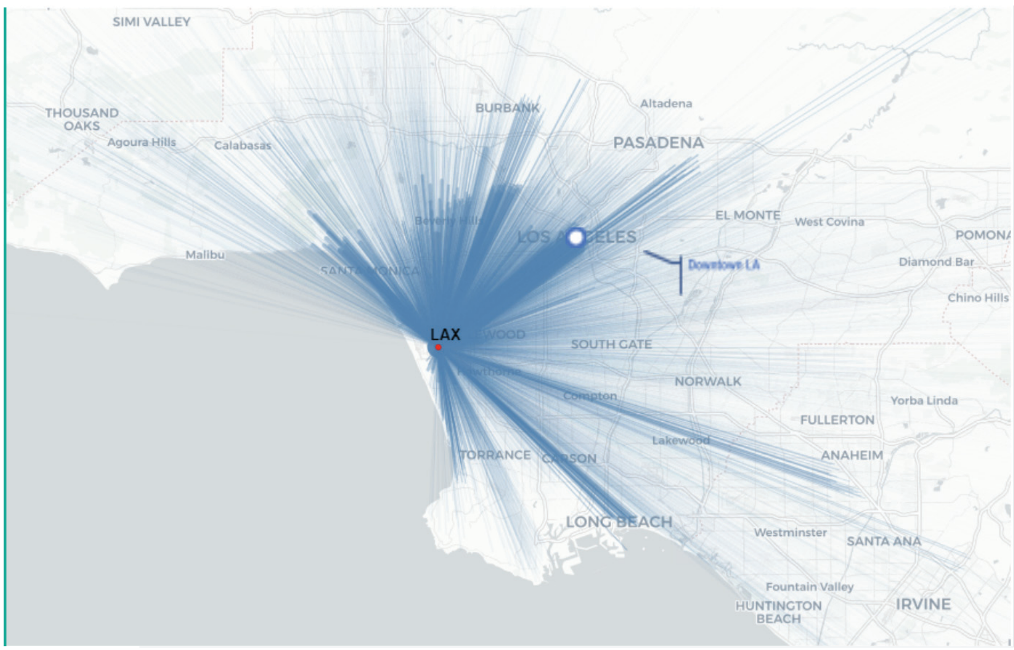

Figure 2

Unconstrained airport access market potential for LAX airport ($1.50/-pax-km, 200 km/h). Demand is highest on the LAX – Downtown LA route

Price Sensitivity of UAM Market

The trade-off between time savings and price plays a significant role in determining whether passengers choose UAM over other transport services. This trade-off is a key driver of the price-elasticity of demand. For the LA market, the demand for UAM changes rapidly at different price points (see Figure 3). A comparison of three passenger-km price points, $1.50, $2.50 and $3.50, shows a decline in UAM demand as price increases. At US$1.50 per passenger-km, the demand potential is about 7 times larger than the market potential at US$2.50 and 31 times larger than the market potential at US$3.50. The high price elasticity is the result of a strong sensitivity of mode choice to time savings, VTTS, and income on the one hand, and price premiums over ground-based transport modes on the other.

However, it is important to note differences in price elasticity between markets. For airport access markets, the price elasticity is smaller than that of the commute market. Consequently, the estimated share of LA's airport access demand potential in the total demand potential increases from 12% to 21% when going from a price of US$1.50 per passenger-km to US$3.50 per passenger-kilometer. While these numbers are focused on substituted demand only, it is to be expected that they will apply similarly for induced demand.

These results highlight that UAM services will either have to create significant additional value for passengers through the product offering (e.g., travel comfort, improved dependability in travel times), or the industry will face significant price competition from other transportation modes. The latter translates into pressures to reduce costs and maximize travel time savings whenever possible, reinforcing the importance of optimizing operational availability through robust processes and quick response to possible contingencies.

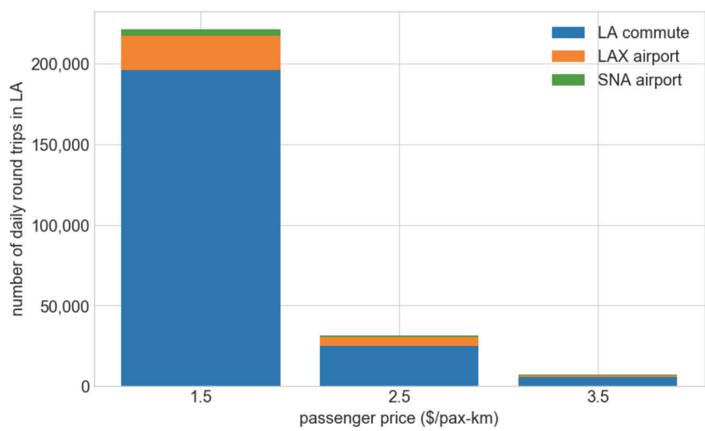

Figure 3

Los Angeles total unconstrained market potential for commute and airport access (to LAX and SNA) shows high price elasticity across three different price points

Addressable Markets

The above analyses provide insight into the idealized demand potential for UAM. In order to address a substantial share of these potentials, vehicles and networks must be designed to overcome addressability challenges, such as the following three examples:

First, weather conditions will impact flight operations: Changes in head- or tailwinds can affect speed and/or costs. More significantly, severe weather, such as thunderstorms, or poor visibility will disrupt service. For LA, these disruptions are expected to reduce the addressable markets by up to 22-26% on an average day (also considering that flights are restricted to daylight hours). However, an integrated UAM system where operational procedures, airspace design and aircraft capabilities are designed to minimize weather impacts can provide UAM operators (as well as passengers) with assurance of flight continuity.

Second, airspace constraints may require UAM flights to detour around environmentally sensitive areas and/or restricted airspace (see Figure 4). Air traffic control may also restrict airspace capacity, which may lead to delays or restrictions. Constraints would decrease passengers' time savings, increase operational costs, and thereby reduce addressable demand. Operators are actively working with air navigation service providers, such as the FAA (FAA, 2020) and Airservices Australia (Airservices Australia, 2020), to find solutions that will integrate UAM operations into airspace design and procedures. These initiatives will allow UAM to compete efficiently with other urban transport modes.

Figure 4 | Potential airspace restrictions, LA (low vs. medium vs high restrictions)

Third, the availability of vertiports and final approach and take-off areas (FATOs) (i.e., landing pads) can limit time savings and demand potentials. Expensive infrastructure assets like vertiports will require bundling of traffic flows to generate economies of scale and accommodate dense UAM traffic—they cannot be placed at all demand locations. Urban land availability may further restrict vertiport placement. If sufficiently sized vertiports cannot be located close to places of demand, travelers will need additional time to access the nearest vertiport, thereby decreasing travel time savings of UAM and increasing the cost of the trip. However, given the considerable geographical concentration of traffic flows in many cities, a small number of vertiports that have an adequate number of FATOs may be sufficient to serve significant demand.

These restrictions reduce the addressable market as compared to the demand potential. At a price point of US$1.50 per passenger-km, with 20 ideally placed vertiports, and with weather and overflight restrictions (medium restrictions, see Figure 4), the addressable market in the LA Combined Statistical Area is estimated at 6,000 daily roundtrips (substituted demand only). This value will increase to 11,000 daily roundtrips with 50 ideally placed vertiports. If fully addressed, the annual market revenue would be US$230M for the 20 vertiport scenario and US$400M for the 50 vertiport scenario.

Going Forward

UAM offers a potential solution to address urban mobility challenges. This transportation mode might attract significant passenger demand and revenue by offering travel time savings and increased convenience. For the LA Metropolitan Area, the estimates presented in this paper show that there is an addressable market with revenues of up to US$400M if there are 50 ideally-located vertiports. However, this market is sensitive to price fluctuations. Passenger demand is expected to decrease by almost 97% with an increase in price from US$1.50 to US$3.50 per passenger-km. Since the airport access market is found to be less price sensitive, it is likely to represent a significant share of UAM demand following market entry. As costs are reduced, other routes are expected to become attractive to commuters.

As the UAM network gradually establishes a presence as a transportation mode, the demand potential is expected to increase further because travelers will explore new mobility needs in response to the availability of UAM services. Greater convenience gained by using the UAM network, and positive experiences onboard or at the vertiport, can further grow this demand potential. This has implications for vehicle and network design, as strategies will need to balance cost and travel time savings, while also creating competitive advantage through increasing convenience factors.

These strategic implications are further amplified as the addressable market scales with challenges such as weather and vertiport availability. As such, smart network designs, traffic management operational concepts, and vehicle specifications, that are tailored to specific markets and their operating environments, will have severe strategic importance for the market prospects of UAM.

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