Modeling Induced Demand by Urban Air Mobility

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Introduction

It has been observed empirically that improvements of infrastructure capacity result in an increase of travel demand. The congestion relief of such capacity improvement is likely to be overestimated if induced demand is not considered. These effects have been measured in many road enhancement projects and were also observed when a new mode is introduced. For instance, Henao and Marshall (2018) reported that 12% of trips made by Uber would not have taken place if Uber did not exist.

The literature identifies slightly different concepts for induced demand. Some authors (Cervero 2002, Gorham 2009, Cascetta et al. 2013) propose to classify induced travel into different subgroups:

- Diverted demand: travelers' mode choice decisions towards a new mode, travelers' route choice decisions towards a new route, etc.
- Direct induced demand: short-term changes in trip generation or destination choice.
- Indirect induced demand: long-term changes in mobility patterns, relocation, etc.
- Economy-based demand growth: macroeconomic trends, such as increases of income that derive on an increase of trips.

Current innovations in vertical take-off and landing aircrafts offer a potential new transportation service for urban mobility: Urban Air Mobility (UAM). It describes personal aerial vehicles that can carry two to four passengers for trips in metropolitan areas. This service could offer congestion-free travel options in metropolitan areas and improve accessibility for remote areas. Researchers have estimated potential market share of UAM, by including UAM as another alternative on the mode choice model (Pu et al. 2014, Kreimeier et al. 2017, Syed et al. 2017, Balac et al. 2018, Rothfeld et al. 2018). Estimated UAM shares varied from 0.01 % to 18.8 %, depending mainly on the considered modes on the mode choice model and its estimation, UAM supply and UAM costs.

With the advent of UAM, which differs significantly from the existing supply, the induced demand may become highly relevant. To the authors' knowledge, no previous research has analyzed induced demand for UAM yet.

Method

The travel demand model MITO is a disaggregate trip-based model (Moeckel et al. 2019). MITO is agent-based and simulates trips microscopically. The model includes the following steps: trip generation, travel time budget, destination choice, mode choice, departure time choice and traffic assignment. MITO is fed by a synthetic population, which is generated for the simulated year by the agent-based land use model SILO.

The paper analyzes how induced demand by Urban Air Mobility of various types can be accounted for by MITO. Actual induced demand will depend on additional factors that could not be considered with this approach, such as users' acceptance or service quality.

Diverted demand

A change in the transport supply may change the travelers' mode choice and destination choice decisions. Although previous researchers call this induced demand, we define it as diverted demand, as it involves changes to the mode or the destination chosen by the travelers, but it does not generate new trips.

MITO's mode choice model includes the new mode UAM based on an incremental logit approach (Figure 1 shows two different approaches for incremental logit models with UAM). The incremental logit model starts a base mode (such as train in the left nesting structure and Auto Passenger in the right nesting structure) and the user specifically defines the difference in attributes between the base mode and the new mode. The diverted demand is captured by this approach.

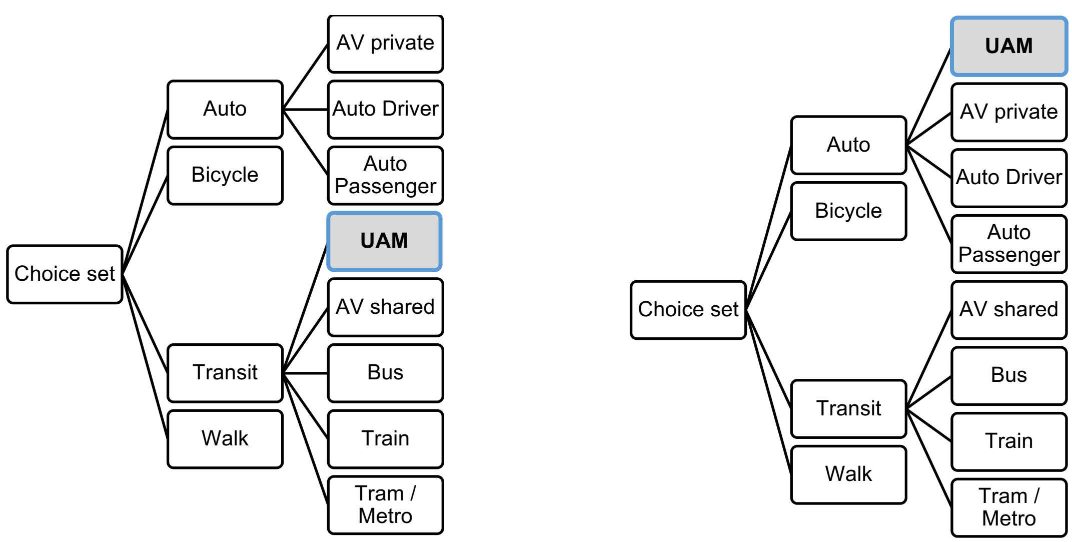

Figure 1. Two mode choice nesting structures with UAM

Direct induced demand

This includes the generation of new trips that would not take place if UAM mode did not exist and represents the actual short-term induced demand. Most of previous modeling approaches that considered induced demand have used potential accessibility as one of input variables for trip generation, defined as generalized in Equation 1 (Thill and Kim 2005, Yao and Morikawa 2005, Cordera et al. 2017, Llorca et al. 2018).

$$A_i = \sum_j {a_j}^{\alpha} \cdot \exp\left(\beta \cdot c_{i,j}\right) \tag{1}$$

Where:

- A_i is the potential accessibility of zone i
- a_j is the attraction of zone j (measured by employment, population, etc.)
- $c_{i,j}$ is the generalized cost of traveling from i to j
- α and β are coefficients (with $\beta > 0$).

Potential accessibility may be used to capture induced demand effects by assuming that an increase in accessibility results in a higher probability to start a trip. Household travel survey data (MiD) is analyzed to explore the relationship between trip frequency (number of trips, or probability of traveling) and accessibility. Since MiD data do not provide the geo-referenced trip origin and destination, we will use area types, town size and distance to transit as a surrogate measure(s) of accessibility. We will carry out this analysis separately for short-distance travel and for overnight or long-distance trips.

We hypothesize that the relationship is different for each travel segment (as seen in Figure 2): a higher accessibility will involve more short distance trips, but fewer long-distance trips. For example, having more grocery stores in the neighborhood is likely to entice more short-distance shopping trips (on each of which the person might buy fewer items than the person who lives in a neighborhood with poor accessibility). On the other hand, living in a larger city is likely to reduce long-distance travel because many needs for specialized shopping or specialized doctors can be fulfilled near-by. The results will be used to predict changes in the number of trips generated due to changes in accessibility.

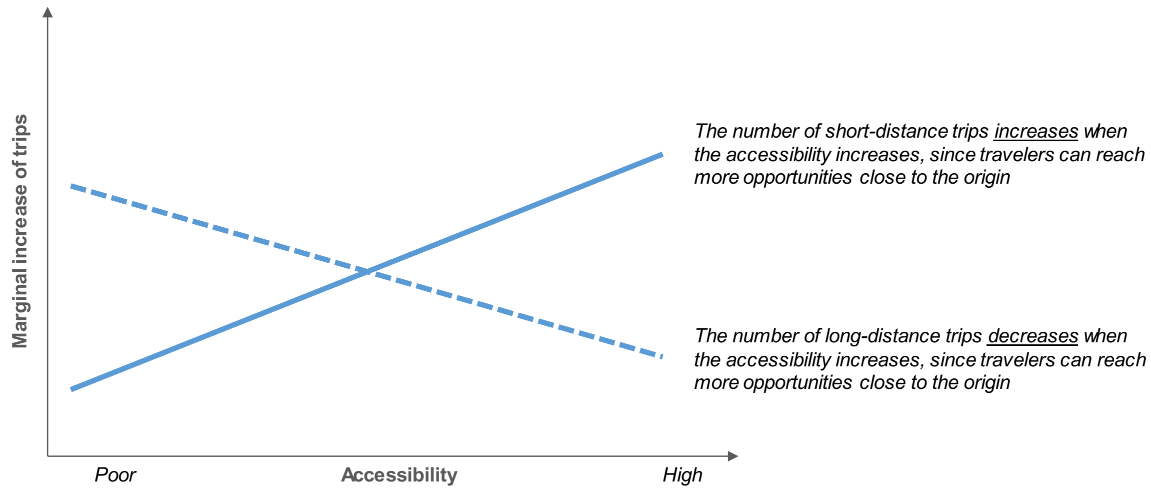

Figure 2. Relationship between accessibility and number of short- and long-distance trips

Additionally, it is possible that trip destinations change because of the availability of a new mode. Previously, MITO's destination mode choice model depended on distance by car, plus attraction variables that measure the number of opportunities. Therefore, this submodel would not capture additional travel demand induced by UAM. To overcome this limitation, mode choice logsums, which include the benefit of all modes for a given origin-destination pair, will be used in destination choice instead of auto travel times.

Indirect induced demand

Travel demand may change in a long run due to long-term land use changes. It is perceivable, for example, that a household might move to a rural location because UAM allows traveling to a central city much faster than existing modes. This change cannot be captured by traditional travel demand model like MITO. To capture such long-term changes, household relocation would need to be modeled in response to travel times by different modes, which is outside the scope of this paper.

Other changes in trip choices

The arrival of UAM may produce further changes to travel behavior that are not included in the previous induced demand categories:

Divide overnight trips into daytrips: Trips that currently are overnight trips could be condensed into daytrips, thanks to a smaller travel times and to the equivalence between costs of accommodation and travel costs. That might induce additional trips while reducing demand for accommodation. We will analyze the frequency distribution of overnight trips by distance in MiD and compare it with UAM ranges and proposed UAM networks to quantify this effect.

More frequent trips: Similarly, long trips that include more than one activity could be split into more than one trip. For example, trips from very low accessible areas for shopping or leisure that are currently combined into one single trip could be split into individual trips if travel becomes faster.

Latent unsatisfied demand for low-accessible areas: there are desired trips that are currently not completed because of insufficient transport supply. Such trips, often called latent demand (Clifton 2017), could be completed thanks to the new modes available. However, these trips are not included in the travel surveys and cannot be easily quantified.

Long-distance commuters: UAM may also entice more people for long-distance commuting, either daily or every weekend. A faster mode gives access to more job opportunities, and most likely, some people will choose work locations further away from their home location. Empirical studies on the impact of high-speed rail lines may offer some insight, but generally this effect is very difficult to measure.

Expected results

The paper provides insight to the magnitude of induced travel demand by Urban Air Mobility. Moreover, it will produce a holistic framework to estimate induced travel demand that could be applied to other new transportation modes.

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