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Author(s): Karina Hermanwan and Amelia C. Regan
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On-Demand, App-Based Ride Services: A Study of Emerging Ground Transportation Modes Serving Los Angeles International Airport (LAX)

by Karina Hermawan and Amelia C. Regan

This research estimates and compares travel times and costs of transportation by Uber and Lyft (the latter are referred to here as transportation network companies or TNCs) against other forms of ground transportation to Los Angeles International Airport (LAX). Using estimated travel times and costs derived from Google Maps and other sources as well as the 2015 LAX air passenger survey, we develop estimates of airport ground transportation access mode choice decisions. Among other findings, our preferred nested logit specification implies that if TNC fares were to be raised to match the current cost of taking a taxi to the airport, demand for TNC's would fall by 20.9% and 23.3% (relative to initial TNC shares) for business and leisure passengers, respectively.

INTRODUCTION

Approximately 37 million travelers initiated their flights from Los Angeles International Airport (LAX) in 2015. Passengers going to the airport have a number of airport ground transportation access options, including taxi, Flyaway bus service (a regional shuttle bus service that transports passengers non-stop to and from LAX), a shared van/shuttle, a private shuttle, public transit, or most recently, on-demand, app-based ride services provided by transportation network companies (TNCs) such as Uber and Lyft. These latter modes are now known by many names, including shared rides, rideshares, ridesource, or dynamic carpooling. Using mobile applications, they connect passengers with drivers who provide transportation using non-commercial vehicles.

On-demand app-based rides are increasingly more prevalent at major airports like LAX. Using TNCs around Los Angeles to travel to LAX has been permitted since 2011, but initially, only pricier, commercially licensed Uber services (UberBlack and UberSUV) were permitted to pick up passengers at airport curbsides. In December 2015, Lyft became the first standard TNC service allowed to provide airport pickups at LAX, while Uber followed suit in March 2016. Because of their highly reliable, convenient, and competitively priced services (except for some notable issues arising during surge or peak demand periods), TNC services attract customers who might otherwise have chosen another mode for airport ground transportation. Despite their growing presence and demand, the characteristics and usage of TNC services at airports like LAX are still not well understood. Using Google Maps among other sources, this research estimates and compares travel times and costs of trips in the Los Angeles area to LAX by TNCs as well as other modes of ground transportation. Then incorporating the 2015 LAX passenger survey, we also develop a model of LAX access mode choice decisions. In this light, we explore the following key questions:

- What is the current demand for TNCs for travel to LAX and how does that compare with the demand for other modes of ground transportation to the airport?
- For a number of reasons, we offer that TNCs are currently underpriced. Thus, on a policy level, what would happen to the demand for TNCs if their fares were regulated and set equal to more established private modal (i.e., taxi) fares?

Carpool versions of TNC services, such as Uber Pool and Lyft Line, that match small parties heading along similar routes are now also available in many cities, including Los Angeles. The

TNC's claim that with these new options, costs can be cut by up to half while detours are no more than 10 minutes. This latter possibility raises other questions, including how will the demand for standard TNCs respond to these newer services?

There are now many stakeholders involved with TNC activity in the LAX market. To this end, many transit agencies are now partnering with or considering partnering with TNCs and taxi services to improve aspects of both their standard and paratransit operations (Swegles 2016). Therefore, understanding regional airport access mode choice decisions should help provide insights to guide policies designed to measurably affect stakeholders with various transportation needs.

LITERATURE REVIEW

Statistical studies of ground transportation to airports date back to at least the early 1970s. Ellis et al. (1974) and Leake and Underwood (1977) were among the first papers to look at access mode choices for transportation to the airport using simple multinomial logit models. As is well known, a major limitation of the multinomial logit model is that it assumes independence of irrelevant alternatives (IIA - alternatives are not correlated through random disturbances) meaning that the ratio of two alternatives' probabilities is independent of the presence of the other alternatives. As it turns out, this assumption is not valid for many mode choice studies because some modes share common unobserved attributes.

Current research on surface transportation and modal choice has progressed to employing more complex generalized extreme value models, including nested logit models, in order to address this concern. Nested logit modal choice models are commonly used in airport ground access studies, usually nesting private modes such as automobiles separately from public or shared modes such as rail and buses. Recent work on airport ground transportation, including Tam et al. (2011), Akar (2013), Psaraki and Abacoumkin (2002), Alhussein (2011), all use multinomial logit models, while others, including Pels et al. (2003), Cirrilo and Xu (2010), and Gupta et al. (2008), use nested logit to analyze airport ground passenger data. Alternatively, Manzano (2010) and Tsamboulas and Nikoleris (2008) relied on related discrete choice probit models to estimate travel demand to airports. On a more theoretical choice level, the elimination by aspect model of decision making (Tversky 1972), a model where, in stages, alternatives are viewed and evaluated as a set of aspects, has not been applied within an airport access mode choice setting. However, the latter has been used to analyze the demand for urban rail in Tokyo (Kato and Kosuda 2008).

Closely related to this research, Pels et al. (2003) analyzed not only ground transportation modes to the airport but also airport choice in the multi-airport Bay Area region in California. They found that access time plays a major role in airport choice decisions and confirmed that business passengers have a higher value of time, higher access time elasticity, and lower cost elasticity than do leisure passengers.

Since publicly available data are still scarce, there are few publications on the characteristics and usage of TNCs serving major airports. Rayle et al. (2014) conducted an intercept survey in San Francisco and investigated wait times for TNCs. They also analyzed trip purposes and reasons for using TNC services. Based on the data they collected as well as data on taxis from the San Francisco Municipal Transportation Agency, they found wait times for TNCs to be markedly shorter and thus the mode has become more reliable than even private taxis.

On the cost side, in Los Angeles, Goldman and Liu (2015) found that at least one TNC service has a lower price than private taxis almost all the time (i.e., on weekdays, on weekends, and even during dynamic pricing periods). An interesting study by Smart et al. (2015) deployed riders in low income neighborhoods in Los Angeles and instructed participants to take taxis or UberX. After controlling for the same ride (same origin and destination pairs and time of day), they found the average cost of UberX for any day of the week to be about $6.40 per ride, lower than the average taxi cost of $14.63 per ride.

Given these findings, if TNCs have lower wait times and fares, under what conditions might they be preferred to taxis? While previous works might suggest that TNC services are increasing access and mobility for people in low income neighborhoods, an NBER working paper by Ge et al. (2016) finds disparities in the number of cancelled requests, wait times, and ratings by drivers for TNC customers with different racial names or profile pictures. And finally, a recent dissertation (Masoud 2016) examines peer-to-peer ridesharing services from the point of view of optimizing large-scale systems.

Our extension to this literature will be to explore the impact of travel time and cost on the demand for TNC rides. We feel the cited studies provide only a first step toward modeling the demand for TNC services and that research is needed to better understand the characteristics of TNC's in important transportation markets.

DATA

2015 LAX Passenger Survey

The 2015 LAX passenger survey provided much of the revealed preference data used in this analysis. Commissioned by Los Angeles World Airports, this one-on-one survey is typically conducted every five years, with the 2011 and 2015 surveys conducted by Unison Consulting, Inc. Consisting of nearly 100 multiple choice and open-ended questions, the survey is extensive and is administered using electronic tablets at LAX boarding gates. Both visitors and Southern California residents were interviewed over the course of two nonconsecutive weeks, through April 13-19 and July 13-19, 2015, with over 13,400 surveys collected. The survey asks if the passenger(s) is (are) traveling for business or for leisure, the duration of the trip, and his or her primary mode of transportation to the airport. Critically for this analysis, the 2015 survey was the first time that TNC was included as an alternative mode.

Based on the responses, there were different follow-up questions. For example, respondents who specified that their primary form of transportation was a private vehicle were asked more specific questions regarding their chosen mode of ground transportation, such as whether they were dropped off, parked at the airport, or parked off site, and how many people in their travel party were in the same vehicle.

The data used for this research consist of travelers starting their air travel at LAX, but focuses on their chosen mode of one-way access to the airport.[2] Origin and destination pairs and estimated arrival times for each passenger were extracted based, respectively, on the zip code where the traveler came from before arriving at LAX, the terminal where he or she boards, and lead time (number of hours the passenger arrives before his or her flight).

Google Maps Driving and Transit Directions

Past studies calculate travel times solely as a function of distance, but travel time depends on a variety of other factors, such as location, route, and time of day. This research uses the Google Maps Directions Application Programming Interface (API) to compute travel times for each origin-destination pair. The benefits of geocoding with this method are that it allows the user to specify the location, route, and time of day of travel (via departure or arrival time), and is thus able to better map the actual transportation network.

The origin and destination pairs and estimated arrival times were entered into Google Maps to compute the distance between the origin and destination, shortest total travel time by car, and shortest total travel time by public transit. The destination was set to the exact terminal at LAX used by the survey respondent. Some observations with rare or distant origins such as Yosemite National Park or the town of Avalon (located on Catalina Island off the California coast) were excluded because Google Maps could not generate driving distance, driving duration, or transit duration for these origins. Meanwhile, other distant origins such as the city of Bakersfield generate driving directions to LAX, but there are no public transit options listed on Google Maps. These latter observations were not excluded from the sample; rather, in these cases, the option of public transit was deemed as simply unavailable to the respondent.

EMPIRICAL MODEL

Access Mode Alternatives and Covariates

Since it is one of the busiest airports in the United States, the number of ground transportation alternatives serving LAX exceeds those at other airports in the Southern California area. This demand analysis focuses on 10 major alternative ground passenger modes serving LAX: 1) drive and park at the airport, 2) drive and park at an offsite parking lot, 3) taxi, 4) car rental, 5) limousine, 6) private shuttle, 7) shared van/shuttle, 8) TNCs, 9) public transit, and 10) the Flyaway, a non-stop regional shuttle bus service to and from LAX. Additionally, some air travelers have the option to take a hotel courtesy shuttle or simply to be dropped off by others. Individuals staying at hotels with courtesy airport shuttles have a strong incentive to use them over other modes because they are essentially zero cost to the passenger and in many cases are door-to-door. Similarly, individuals who have the option to be dropped off by family members, friends, or relatives also have a strong incentive to choose this mode because they typically do not have to pay compensation. Thus, individuals who reported in the survey that their primary form of transportation to LAX was by hotel courtesy or dropped off were excluded.

The independent variables analyzed are travel time and cost. Travel time is computed from the "driving option" of the Google API and is defined as total duration in the vehicle, whereas travel time by transit is defined as the sum of duration in the vehicle, walking to and from the stops, and waiting for transfers (if there are any transfers).

Not everyone has the same ground transportation choice set. But we did assume everyone has the option of taking a TNC, taxi, or limousine, while other modes are only available to some of the surveyed travel parties. As mentioned, depending on where they originated, some people do not have the option of taking public transit. For the purpose of this study, whether or not public transit is available to an individual was determined through Google Maps. Although service by public and private shuttles is much more extensive by than public transit, they also have limited service areas.

The availability of public and private shuttles was determined through the major shuttle providers' websites (Primetime Shuttle, ShuttletoLAX, and SuperShuttle). For the regional "Flyaway" shuttle mode, we determined this was unavailable to individuals if the nearest Flyaway stop is located more than a 15-minute drive from their originating location. Lastly, we assumed that only Southern California residents have the options of driving and parking on- or off-site, or using a rental car to go to the airport and return it there. The assumption that all residents can drive (their own vehicle or a rental) is plausible since most people in Southern California (especially those who can afford to fly) have access to a car.[3] The rental car option is unavailable to Southern California visitors because if they rented a vehicle for their trip, they must return it there (thus travelling to the airport by a rental car is the only choice for these individuals).

Description of the Alternative Modes

Passengers who reported that their primary form of transportation to LAX is private automobile either drove and parked on-site, or drove and parked off-site. This is true even if the driver drops off passenger(s) at the terminal curb before parking. Parking at the airport is located in the Central Terminal Area. Currently, the daily parking rate at LAX is $30. Parking off-airport can be at any number of locations, but the most popular among them is at the Economy Parking Lot C, which is less than a mile from the airport. This lot also has a free shuttle that stops at each terminal. The daily parking rate there is $12.

Car rental companies are located in very close proximity to the airport, but none are on-site. Those taking a rental to go the airport must return the vehicle off-site and then board a free shuttle that stops at each terminal. The cost of a car rental is estimated here to be about $76.00 per day (assuming it was picked up somewhere not at the airport and then returned at the airport).[4]

Public transit in Los Angeles does not directly drop off passengers at airport terminals, so transit users must also board shuttles to transfer from an off-site location to the airport. Public transit in Los Angeles consists of MTA (Metro) buses and light rail lines, Santa Monica/Big Blue Bus, Culver City Bus, and Torrance Transit. Those who take Metro rail and bus lines can take a free shuttle at the Metro Green Line Aviation Station, and those who take other public buses can take a shuttle from the Metro Bus Center. These shuttles stop at every terminal, which means that passengers have longer travel times than if being dropped off directly.

Unlike driving and parking off-site, rentals, or public transit, the Flyaway and the shared van/shuttle options take passengers directly to the airport terminals,but they stop at each terminal at LAX because they are shared modes and thus have multiple drop-offs. As mentioned, the Flyaway is a direct shuttle bus service to and from LAX. Its 2015 stations were located in Van Nuys, L.A. Union Station, Westwood, Hollywood, and Santa Monica. Applicable one-way fare is $8 per person for all of the Flyaways, except the Westwood Flyaway, which costs $10.

Shared vans/shuttles, operated by Super Shuttle or Primetime Shuttle, are shared door-to-door services. For passengers who travel from any part of a large service area in Southern California where these shuttles operate and they reserve the shuttle 24 hours in advance, the fare is a fixed $21 for the first person and $14 for each additional rider, independent of distance (ShuttletoLAX). Reservations made less than 24 hours before the pickup, or for rides outside of the service area, have different pricing schemes that depend on distance, location, and party size (ShuttletoLAX, Super Shuttle, and Primetime Shuttle).

Other alternatives, such as private shuttles, limousines, taxis and TNCs do not stop at every terminal and directly take passengers to their boarding terminal.[5] Because they are private, these modes pick up and drop off only one party (or typically two at the most) and thus often have much shorter travel times than shared vans/shuttles. Private shuttles are similar to shared vans/shuttles, except they are nonstop services and direct to destination as they do not pick up or drop off other parties. In fact, Primetime Shuttle runs a variety of private shuttle services in addition to their shared vans/shuttles. Their standard van service, private or shared, seats a maximum of seven people. Other than its standard vans, Primetime Shuttle offers other private shuttle services, including the Execucar Sedan service, the Execucar SUV service, and the Business Express SVC by Express Shuttle, all of which include a driver. These services usually have a maximum of three, four, and five passengers, respectively. Based on the pickup locations, some nonstandard shuttle services may vary or be unavailable (Super Shuttle, and Primetime Shuttle).

Another direct access mode is a limousine. Although a stretched limousine can be very luxurious and provide seats for many passengers, these vehicles often do not have adequate trunk space for luggage. Therefore, the maximum number of seats in a limousine available for passengers traveling to LAX is actually lower than if they were not going to the airport (LAX Limousine Service).

Taxi and TNCs are the final set of direct airport access modes. Taxi companies operating in the Los Angeles have a minimum fare of $2.85 and, after the first 1/9 of a mile, the fare is $2.70 per mile (Taxicabsla 2015). TNC fares were estimated based on the costs of Uber. At the time, services in Los Angeles had a booking fee of $1.65, a per-mile cost of about $0.90, and a minimum fare of $4.65 (Uber 2015). The actual per-mile charge may vary depending on traffic, discounts or promotions, or surge (i.e., peak load) pricing.

We use the various descriptions above to help estimate the travel time and trip cost by each mode for travelers to LAX relative to their own pickup location. The travel costs were further adjusted[6] by travel duration (number of days) and party size.

Model Specification

In our model development, the utility of each decision maker, n, for each alternative, a, is assumed to be a linear function of travel cost, travel time, and an alternative constant (ASC). Under the multinomial logit model specification, error terms are assumed to be drawn from independent and identically distributed extreme value distribution. The 10 alternatives chosen for the analysis cannot share common unobservable characteristics or their error terms will not be independent. Further, travel time and cost coefficients are general and do not vary over alternatives. Moreover, we assume the TNC modal alternative is fixed, making it the baseline for our alternative-specific constants. Following the utility specification shown in equation 1, equation 2 lists the associated multinomial logit probability of making a choice (Ben-Akiva and Lerman 1987).

(1) $$U_{na} = ASC_a + \beta_{cost} \cdot Cost_{na} + \beta_{time} \cdot Time_{na} + \varepsilon_{na} = V_{na} + \varepsilon_{na}$$

(2) $$P_{na} = \frac{e^{V_{na}}}{\sum_{a \epsilon A} e^{V_{na}}}$$

We noted that modes such as limousine, drive and park on-site, and drive and park off-site are private, while public transit and shared van/shuttle are shared with multiple and different parties. Any of the private modes might be correlated with each other because they share many characteristics. Specifically, they do not put strangers in the same vehicle and they do not have multiple drop-offs and pickups. For the same reasons, shared modes might be correlated because they do put strangers in the same vehicle and they have multiple drop-offs and pickups. And since there are similarities besides travel time and costs between the alternatives, their error terms may not be independent.

This issue is not a problem for our analysis since we developed nested logit models to mitigate this concern. Formally, within a nest d, alternatives are correlated through the same error, while across the specified nests, the errors are assumed to be i.i.d. More generally, the nested logit marginal and conditional probabilities (Ben-Akiva and Lerman 1987) are given by:

(3) $$P_{na|d} = \frac{e^{V_{na|d}}}{\sum_{a \epsilon A(d)} e^{V_{na|d}}}$$

(4) $$P_{nd} = \frac{e^{(\alpha_{nd} + \alpha_x \cdot X_{nd} + \tilde{V}_{nd})}}{\sum_{d \epsilon D} e^{\alpha_{nd} + \alpha_x \cdot X_{nd} + \tilde{V}_{nd}}}$$

In general, X_d are variables that vary within the nest (for example, in the transit nest, it may be a factor such as headway), but we did not have access to such variables in our study. In addition, the inclusive value is $\tilde{V}_{nd} = \frac{1}{\mu_d} \ln[\sum_{a \epsilon A(d)} e^{(V_{na|d})\mu_d}]$, and $0 < \frac{1}{\mu_d} < 1$ or $\mu_d > 1$ (Ben-Akiva and Lerman 1987).

In addition to the multinomial logit specification (Figure 1), we test a nested logit model, consisting of two nests that separate shared and private modes (Figure 2). Each of our chosen nests has two levels. To list alternatives, these are drive and park at the airport, drive and park at an offsite parking lot, rentals, taxi, TNC, limousine, and private shuttle fall into the first category, while shared van/shuttle, Flyaway, and public transit fall into the second category. A limited number of TNC services can be shared with up to two different parties, but they are considered private in this study since we believe that this alternative is predominantly the standard UberX and Lyft services.

Figure 1: Multinomial Logit Model

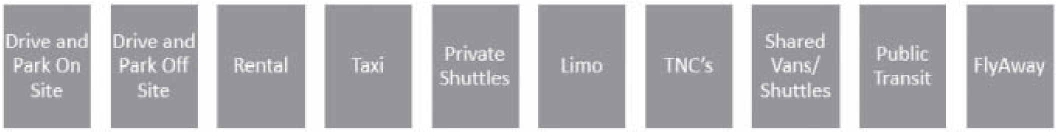


Figure 2: Nested Logit Model with Two Nests - Private and Shared

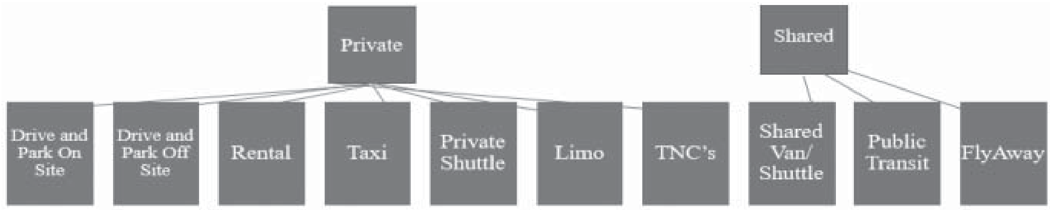


Figure 3: Nested Logit Model with Three Nests - Require Driving, Ride Services, and Transit, Non-Door-to-Door

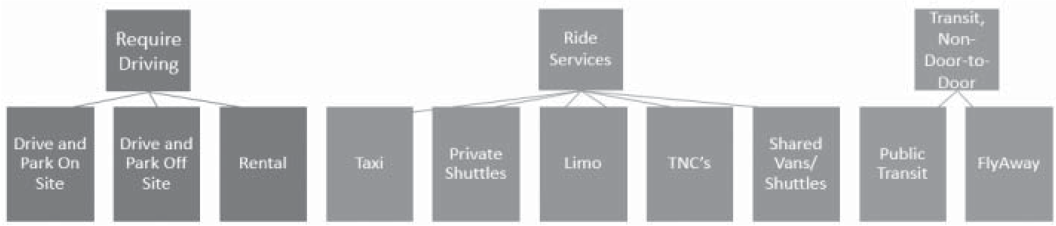
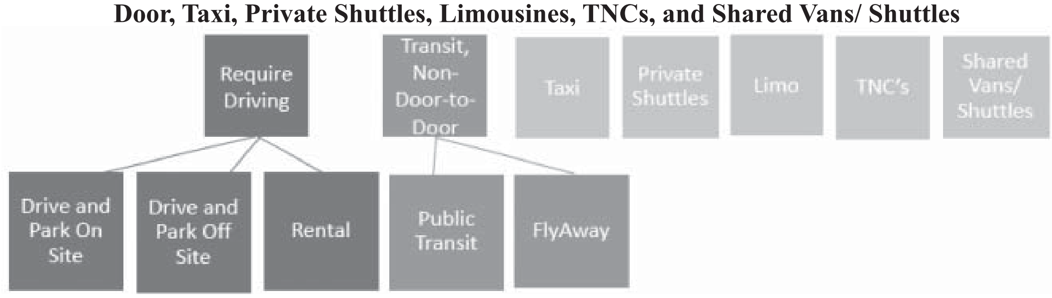


Figure 4: Nested Logit Model with Seven Nests - Require Driving, Transit, Non-Door-to-Door, Taxi, Private Shuttles, Limousines, TNCs, and Shared Vans/ Shuttles



We also tested other nesting and hierarchical structures. In Figure 3, the nested logit model has a nest grouping all modes that require driving (drive and park on-site, drive and park off-site, and car rental), and a second nest encompassing all ride services (taxi, TNC, shared vans/shuttles, private shuttles, and limousines), with a final nest containing all transit and non-door-to-door modes (public transit and the Flyaway). Under that specification, each nest contains two levels, while in Figure 4 only some nests contain two levels. In Figure 4, modes that are ride services are no longer grouped under one category, while modes that require driving and modes that are transit and non-door-to-door are grouped in their corresponding nests. In this specification, taxi, private shuttles, limousines, TNCs, shared vans/shuttles (all modes that require driving) and all modes that are transit and non-door-to-door are assumed to be distinct from each other, meaning they do not share common unobservables.

Finally, we suspect there might be additional disparities in airport access decisions between business and leisure passengers. Those who fly for business are typically reimbursed for their travel and thus tend to be somewhat less sensitive to travel cost. And if individuals are traveling for business, they are probably less flexible to longer travel time duration as compared with people traveling for leisure. Given this, the coefficients of the travel cost and travel time variables (as well as other characteristics beside travel cost and travel time) may not be the same for passengers traveling for different purposes. So we also test for market segmentations under different travel purposes, here represented by mainly business vs. leisure passengers. All econometric specifications presented in this research were estimated with the public domain BIOGEME software.[7]

EMPIRICAL RESULTS

Descriptive Statistics

On a broader level, how do travel times and costs of TNCs compare with those of other ground transportation modes? Table 1 (below) shows average travel times and costs by each mode from downtown Los Angeles, for zip code 90012. We chose this area as a reference example because it is located in the downtown area, 20 miles from LAX, and also contains important sites like Union Station. The average travel cost estimates are calculated for one-way trips to the airport, and based on a travel party size of one person, while parking cost is based on a trip length of about three days. Travel time estimates are calculated for one-way trips as well.

From the start, a significant tradeoff between travel time and cost among the modes is apparent. Public transit, the Flyaway, and shared vans/shuttles cost about $5, $8, and $21 respectively, while the other modes (not including TNCs) start at about $40. The former travel times are at least 80-minute duration in our sample. This is much longer than the more expensive modes, which generate an average travel time of about 45 minutes. And as mentioned, TNCs are of special interest in this market because they have both low prices and low travel times.

Table 1: Cost and Travel Time Example from Downtown LA (zip code 90012) by Mode

Mode	Avg. Cost* ($)	Avg. Travel Time (Min.)
Drive and Park Off Site	55.19†	74.8
Drive and Park On Site	121.94†	45.3
Rental	87.14	60.0
Flyaway	8.00	91.0
Limo	177.00	30.3
Private Shuttle	40.00	30.3
Shared Van/Shuttle	21	89.8
Public Transit	4.61	82.2
TNCs	28.65	30.3
Taxi	51.88	30.3

*Travel party size=1, †About 3 days of parking

Among the private modes, we find that a TNC is usually the most competitively priced option. Fares charged by a TNC in general (from downtown or elsewhere) amount to only about 55% of equivalent taxi costs. From downtown, the average cost of a TNC ride at $28.65 is much lower than the average cost of taxis at $51.88, car rental at $87.14, drive and park at the airport at $122, or limousine at $177. It is also slightly less than private airport shuttles at $40, or the drive and park off-site at $55. Note that those who drive and park off-site, where parking is least expensive, still incur a higher average travel cost than someone using TNCs. However, compared with shared modes at LAX, TNCs are costlier. Public transit has the lowest average cost of all other modes, at $4.61, followed by the Flyaway at $8.00. Shared vans/shuttles, on the other hand cost an average of $21, not much different than the cost of TNCs.

In addition to providing one of the more affordable services, we see that TNCs also have comparatively low travel times. Based on our estimates originating from downtown Los Angeles, a TNC can get passengers to the airport in about one-third of the time as compared with those modes with the greatest travel times. For the downtown origin, shared vans/shuttles and public transit have average travel times of 89.8 minutes and 82.2 minutes, respectively, while TNCs generate an average travel time of only about 30.3 minutes. We also find that taxis, private shuttle, and limousines have approximately the same average travel time as TNCs. These latter modes, including TNCs, have low travel times to LAX for good reason - passengers do not have to transfer, park, or take an off-site shuttle. Additionally, they also have fewer pickups and drop-offs since they are private by definition. All told, since TNCs are among the least expensive ground transportation options and also generate one of the lowest travel times, their services seem to provide a very competitive alternative for travelers heading to LAX.

Table 2 shows the availability and share of each ground transportation mode. Some modes are very limited in access and available to only about half of our sample. For example, recall that because the modes "Drive and Park Off-Site," "Drive and Park On-Site," and "rentals" are assumed to be only available to Southern California residents, only about 48% of the sample have access to these transportation options. The Flyaway service is available to about 41% of our sample since there are only five Flyaway stations. Many more individuals have the option of private shuttles, shared vans/shuttles, and public transit because these alternatives are available to both local residents and visitors, and they have greater coverage areas. These latter options are available to 97%, 89%, and 91% of the sample, respectively.

Our final sample contains 3,096 unique travel parties consisting of airline travelers originating their travel (but not connecting) at LAX. As mentioned, we dropped observations where the respondents chose an unavailable alternative. Of the 3,096 travel parties, 550 (17.8%) used Uber or Lyft. Even though TNCs were significantly less costly than taxis, a higher percentage of people (about 18.4%) took a taxi to the airport, and, in fact, taxis were the most frequently used alternative mode. Other modes comparable in use to TNCs were the private and shared shuttles, which had shares of 17.3% and 12.2%, respectively. Alternatively, some of the least frequently used modes were public transit at 1.5%, car rentals at 2.9%, Flyaway at 4.6 %, and limousines at 6.4%.

Table 2: Percent Mode Available and Mode Share

Mode	If Limited Availability, % Available	Mode Share (N) Total 3096	Mode Share (%)
Drive and Park Off Site	48	315	10.2
Drive and Park On Site	48	269	8.7
Rentals	48	90	2.9
Flyaway	41	141	4.6
Limo	-	199	6.4
Private Shuttle	97	537	17.3
Shared Van/Shuttle	89	378	12.2
Public Transit	91	46	1.5
TNCs	-	550	17.8
Taxi	-	571	18.4

A series of likelihood ratio tests (the first three are shown in Table 3) were conducted to formally compare choice specifications and to determine potential need for generalized extreme value models (nested logit), rather than simple multinomial logit (Ben-Akiva and Lerman 1987). First, we tested multinomial logit vs. two nest nested logit. Under the null hypothesis, both the log sum term (inclusive value) coefficients for the private and shared nests equal to unity (multinomial logit), whereas the alternative was that at least one of the log sum term coefficients was not equal to unity (nested logit). As shown in the table, the null (the simple logit model) was rejected, while the two nests nested logit model cannot be rejected. Subsequently, we tested the multinomial logit model against nested logit specifications with three nests, and a multinomial logit model against a nested logit model with seven nests. Similarly, we rejected the multinomial logit specification in the latter tests.

In the fourth test conducted in Table 3, we compared a nested logit model with seven nests against one with only three nests, also using a likelihood ratio test (Ben-Akiva and Lerman 1987).[8] We failed to reject the model with seven nests, which also suggests there is no error correlation between the following alternatives: taxi, limousine, private shuttle, shared vans/shuttles, and TNCs. Thus our findings indicate that perhaps these modes should not be grouped together.

Our final specification test is more policy oriented. It explores the possible taste variations between business and leisure passengers. We re-estimated a nested logit model with seven nests for both business and leisure passengers, then just with business passengers, and then just with leisure passengers. From the first estimate, we attain a restricted log likelihood, while the remaining two (summed) give us the unrestricted log likelihood. In sum, we reject the null hypothesis that there was no market segmentation between business and leisure passengers, suggesting a future need to separate model specifications for business and leisure passengers.

In summary, based on a series of likelihood ratio specification tests, we conclude that the multinomial logit specification is inadequate, as some alternatives seem to share common unobservables. Additionally, we find that alternatives that seem to possess error correlation are modes that require driving and modes that are transit related and non-door-to-door, whereas the remaining modes do not seem to possess notable error correlations. Lastly, the specification tests also suggest a need to estimate choice models for airport transportation separately for business and leisure passengers because the two types of passengers clearly have different tastes.

Table 3: Specification Testing (Using Likelihood Ratio (LR) Test)

Multinomial Logit vs. 2 Nests NL

H_0: $\mu_{private} = \mu_{shared} = 1$

H_A: at least one $\mu_{private}$ or $\mu_{shared} \neq 1$

LR: $-2 \times (L_R - L_U) = -2 \times (-5602.757 + 5599.911) = 5.692$

$5.692 > 4.61$ (the critical value of the chi-square distribution with 2 degrees of freedom at a 90% level of confidence)

∴ Reject the Null, or there is evidence of correlation between the alternatives in the multinomial logit model

Multinomial Logit vs. 3 Nests NL

H_0: $\mu_{requires\ driving} = \mu_{ride\ services} = \mu_{transit,non-door-to-door} = 1$

H_A: at least one $\mu_{requires\ driving}$, $\mu_{ride\ services}$, or $\mu_{transit,non-door-to-door} \neq 1$

LR: $-2 \times (L_R - L_U) = -2 \times (-5602.76 + 5593.755) = 18.004$

$18.004 > 6.25$ (the critical value of the chi-square distribution with 3 degrees of freedom at a 90% level of confidence)

∴ Reject the Null, or there is evidence of correlation between the alternatives in the multinomial logit model

Multinomial Logit vs. 7 Nests NL

H_0: $\mu_{requires\ driving} = \mu_{Taxi} = \mu_{Limousine} = \mu_{Private\ Shuttle} = \mu_{Shared\ Vans/Shuttles} = \mu_{TNC's} = \mu_{transit,non-door-to-door} = 1$

H_A: at least one $\mu_{requires\ driving}$, μ_{Taxi}, $\mu_{Limousine}$, $\mu_{Private\ Shuttle}$, $\mu_{Shared\ Vans/Shuttles}$, $\mu_{TNC's}$ or $\mu_{transit,non-door-to-door} \neq 1$

LR: $-2 \times (L_R - L_U) = -2 \times (-5602.76 + 5593.755) = 18.004$

$18.004 > 12.00$ (the critical value of the chi-square distribution with 7 degrees of freedom at a 90% level of confidence)

∴ Reject the Null, or there is evidence of correlation between the alternatives in the multinomial logit model

7 Nests NL vs. 3 Nests NL

H_0: $\mu_{Taxi} = \mu_{Limousine} = \mu_{Private\ Shuttle} = \mu_{Shared\ Vans/Shuttles} = \mu_{TNC's} = 1$

H_A: at least one μ_{Taxi}, $\mu_{Limousine}$, $\mu_{Private\ Shuttle}$, $\mu_{Shared\ Vans/Shuttles}$, or $\mu_{TNC's} \neq 1$

LR: $-2 \times (L_R - L_U) = -2 \times (-5593.755 + 5593.755) = 0$

$0 < 9.24$ (the critical value of the chi-square distribution with 5 degrees of freedom at a 90% level of confidence)

∴ Fail to reject the Null, or there is not enough evidence to rule out model with no error correlation between the alternatives: taxi, limousine, private shuttle, shared vans/shuttles, and TNC's

No Market Segmentation vs. Market Segmentation between Business and Leisure Passengers

H_0: $\beta_{just\ business\ passengers} = \beta_{just\ leisure\ passengers}$

H_A: $\beta_{just\ business\ passengers} \neq \beta_{just\ leisure\ passengers}$ ** **where β are the estimated coefficients in (1)**

LR: $-2 \times (L_R - L_U) = -2 \times (-5146.913 - (-3456.592 - 1647.356)) = 85.93$

$85.93 > 19.80$ (the critical value of the chi-square distribution with 13 degrees of freedom at a 90% level of confidence)

∴ Reject the Null, there is evidence of market segmentation (taste variations) between business and leisure passengers.

Given these findings, in Table 4, we highlight the output from a nested logit model with seven nests for both leisure and business passengers. In both models, estimates of the covariates have expected signs. Since travel time and travel cost coefficients are significant and negative, this demonstrates that they have a significant impact on modal choice in that higher travel time or travel cost leads to a lower probability of that mode being chosen. Next, the implied value of travel time savings per hour from the estimates are calculated as follows: $\frac{\beta_{time}(\$)}{\beta_{cost}(\mathrm{min})} \times \frac{60\ \mathrm{min}}{\mathrm{hour}}$ (Ben-Akiva and Lerman 1987). For business passengers in the sample, we find that their value of time is approximately \$157/hr, while for leisure passengers in the sample it is about \$103/hr. Of course, this computed value of time is specific only to travel to and from LAX – and is interesting because both are greater than an expected value of time for either group as proxied by the wage rate in the region. However, we note that this computed value falls within the range found in previous airport access mode studies, including Landau et al. (2015).

In the model exclusive to leisure passengers, the alternative specific constants (ASC) for all of the modes are significant. Again, we used TNC as the baseline for the ASCs. Because the ASC for taxis is significant and positive, this suggests that, ceteris paribus, taxis are preferred over TNCs.

In fact, in this sample, most of the other modes, holding everything else constant, are preferred to TNCs as well, including alternatives such as drive and park on-site, drive and park off-site, Flyaway, car rentals, and private and shared shuttles. The only alternatives that were found to be less preferred to TNCs (all else being equal) were limousines and public transit.

The last three estimates to examine for this specification are the inclusive value coefficients of the chosen nests. In this likelihood ratio test, we examined whether: $\mu_{\text{requires driving}} \neq 1$, $\mu_{\text{ride services}}$ and $\mu_{\text{transit,non-door-to-door}} \neq 1$ was valid. But we can also examine whether just one or some of the inequalities are true ($\mu_{\text{requires driving}} \neq 1$ or just $\mu_{\text{transit,non-door-to-door}} \neq 1$), using a t-test (Ben-Akiva and Lerman 1987). The p-value with respect to $\mu_{\text{requires driving}} = 1$ is 0.02. Since the p-value is less than 5%, this indicates that the coefficient for $\mu_{\text{requires driving}}$ is significantly different from 1, meaning we can conclude there is significant correlation between the alternatives in the "requires driving" nest and that the alternatives in that nest should be grouped together. In contrast, the alternatives in the "transit, non-door-to-door" nest are not significantly different from 1, with a p-value with respect to $\mu_{\text{transit,non-door-to-door}} = 1$ of 25%, meaning there is not enough evidence to show that the modes in that nest should be grouped together.

In the specification exclusive to business passengers, we found that many of the ASCs are significant, except those for public transit, shared vans/shuttles, and FlyAway. Note that not only is the ASC of public transit insignificant, but its standard error is very large. We believe this may be because very few business passengers took public transit to go to LAX (only about six people in the sample), making the sample size applicable to this mode choice extremely limited. Additionally, the estimates suggest driving and parking on- or off-site, limousines, shared vans/shuttles, and taxis are all preferred over TNCs, all other things being equal, while Flyaway, private shuttles, public transit, and rentals are less preferred to TNCs.

Again, the last three estimates in the model are the inclusive value coefficients of our chosen nests. In this case, the coefficients are not significantly different from unity for the "requires driving" and "transit, non-door-to-door" nests. In fact, the inclusive value coefficient of the first nest is estimated to be equal to unity. Perhaps to business passengers, driving and parking on-site, driving and parking off-site, and rentals do not share some common unobservables or belong in a group. Meanwhile, the inclusive value coefficient of the third nest is estimated to be about 0.52.[9]

Table 4: Nested Logit with Seven Nests, Leisure versus Business Passengers

	Leisure				Business			
Description	**Estimated Coefficient**	**Standard Error**	**t-stat (0)**	**p-val (0)**	**Estimated Coefficient**	**Standard Error**	**t-stat (0)**	**p-val (0)**
Alternative Specific Constants:								
Drive and Park Off Site	1.84	0.162	11.36	0	1.61	0.278	5.78	0
Drive and Park On Site	1.74	0.148	11.73	0	1.85	0.209	8.86	0
Flyaway	0.65	0.201	3.25	0	-0.47	0.340	-1.38	0.17*
Limousine	-0.29	0.143	-2.00	0.05	0.48	0.216	2.21	0.03
Private Shuttle	0.34	0.078	4.38	0	-0.23	0.121	-1.93	0.05
Shared Vans/ Shuttle	1.00	0.186	5.37	0	0.40	0.323	1.24	0.21*
Public Transit	-0.89	0.291	-3.05	0	-2.16	1.800 ×	0.00	1.00*
Rental	0.44	0.192	2.29	0.02	-0.67	0.408	-1.64	0.10
TNC's	0.00	--fixed--			0.00	--fixed--		
Taxi	0.22	0.083	2.61	0.01	0.39	0.106	3.69	0
Covariates:								
Travel Cost ($)	-0.00605	0.000705	-8.58	0	-0.00952	0.00125	-7.6	0
Travel Time (Minutes)	-0.0158	0.00259	-6.09	0	-0.0164	0.00487	-3.36	0
Inclusive Value Coefficients (1/μ):			**t-stat (1)**	**p-val (1)**			**t-stat (1)**	**p-val (1)**
Requires Driving Nest	0.72	0.175	2.24	0.02	1.00	0.126	0.01	0.99*
Ride Services Nest	1.00	--fixed--			1.00	--fixed--		
Transit, Door-to-Door Nest	0.77	0.265	1.15	0.25*	0.52	1.800×	0.00	1.00*
Additional Information:								
Number of Estimated Parameters	13				13			
Number of Obs.	1884				925			
Final Log Likelihood	-3456.592				-1647.356			

Scenario Analysis

The probabilities of choosing a TNC for each decision maker were calculated using the estimated coefficients of the linear utility functions. The average of these probabilities is the projected demand for TNCs (Table 5). Currently, TNCs account for 17.8% of the market among the alternatives we considered. If the TNC demands for passengers traveling on business and leisure are evaluated separately, they are estimated to be about 16.8% and 19.8%, respectively.

Possible changes to modal charges or costs, such as a 10% increase in TNC fares, an increase in TNC fares to match taxi fares, or a 50% fare cut plus 10-minute travel time increase, are considered. These scenarios are simulated by calculating the equivalent probabilities using the estimated coefficients, but changing the prices and/or travel times of TNCs.

Table 5: Projected Demand for TNC's Under Various Price & Travel Time Changes

	Business	Leisure
Initial Share Using TNC (%)	16.83	19.76
With 10% TNC Price Increase	Business	Leisure
Share Using TNC With Price Increase (%)	16.42	19.24
Change Relative to Initial TNC Share (%)	-2.5	-2.7
With TNC Price Increase to Match Taxi Fares	Business	Leisure
Share Using TNC with (Price Increase (%)	13.92	16.03
Change Relative to Initial TNC Share (%)	-20.9	-23.3
With 50% TNC Price-Cut & 10 min. Travel Time Increase	Business	Leisure
Share Using TNC With Carpooling Changes (%)	16.80	19.99
Change Relative to Initial TNC Share (%)	-0.2	1.2

The first scenario (10% increase in TNC fares) can be expected to lower the demand for TNCs to about 16.4% for business passengers and 19.2% for leisure passengers or, respectively, 2.5% and 2.7 % decreases relative to the initial TNC shares. It seems that increasing TNCs cost by 10% does not affect demand very much.

The second event (increase in TNC fares to match taxi fares) is also expected to lower the demand for TNCs but by a much greater degree. In this scenario, prices had to be almost doubled (about 80% increase). The projected demands for TNC services of business and leisure passengers, respectively, were 13.9% and 16.0%. These represent a 20.9% drop with respect to the initial TNC share for business passengers and a 23.3% drop with respect to the initial TNC shares for leisure passengers.

Since the drop in demand is smaller for business passengers in the first two cases, it seems that business passengers are less responsive to modal price hikes. As found in other studies of business travel, people traveling on business are far less sensitive to price changes than those traveling for pleasure or personal reasons, most likely because their time is considered to be more valuable, and also that they might not be personally liable for the cost of their travel.

Finally, the third simulated change (50% fare cut plus 10-minute travel time increase, which represents the difference that would be imposed by pooled TNC services) is projected to decrease the demand for TNCs by business passengers by about 0.2% (relative to initial share), while increasing the demand for TNCs by leisure passengers by about 1.2% (relative to initial share). Essentially, we consider these values insignificant.

CONCLUSION

Using Google Maps and various other data sources, we estimated travel time and trip cost by each mode for ground travelers to LAX relative to their pickup location. Our estimated travel costs reflect each travel party's travel duration (number of days) as well as party size.

We found that in the absence of TNC services as a modal alternative, many air travel passengers heading to LAX would face stark tradeoffs between long travel times and high travel costs. They could choose a mode like shared vans/shuttles that do not cost a lot, but are characterized by multiple pickups and drop-offs generating long travel times. Alternatively, they can choose a mode like taxi, which costs considerably more but is private and direct. Meanwhile, few passengers to LAX take public transit because those modes have even longer travel times than shared vans/shuttles and, unlike many major US cities, there is no direct rail service to LAX.

Multinomial logit and nested logit models of airport ground transportation decisions were estimated to help understand the drivers of current market shares of TNCs in this large market. Our measured travel time and trip cost by each mode were used as inputs. We also used our specifications to simulate demand for TNCs under policy events like regulated fare increases or decreases combined with a small modal travel time increase.

Likelihood ratio tests rejected the simple multinomial logit structure of demand estimation in this ground transportation market. Our preferred specification is nested logit. Statistical tests also provide some insights on how the alternatives should be grouped for this market, i.e., grouping all modes that require driving, grouping all modes that are transit and non-door-to-door, while we find that remaining modes seem to be dissimilar to each other. Finally, testing suggested a need to estimate separate models for airport destined passengers traveling with different purposes (business and leisure). After considering the simulation scenarios (increasing the cost of TNC rides by 10%, increasing the cost of TNC rides to match the cost of taxis, or cutting TNC fares for a 10-minute travel time increase), we find that these policy shocks would have differential effects on passengers traveling for business or for leisure. By way of example, in our second simulated scenario (a TNC fare increase to match the cost of taxis), the expected drop in demand for TNC (relative to the initial demand for TNC services) was estimated to be about 21% for business passengers and about 23% for leisure passengers. With respect to ground transportation at LAX, business passengers appear to be slightly more sensitive to travel time while leisure passengers are more sensitive to travel costs.

Future research will focus on improving airport ground access mode choice models by making them more robust. In addition, we plan to apply the methodology to explore the impacts of other relevant scenarios, such as an increase in the cost of airport parking.

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Endnotes

1. TNCs fares on average are much lower than taxis. It may be because they offer lots of promotions to passengers when they first operate in a city, or they can charge lower fares since they have lower operating costs, because they do not have fingerprint-based FBI background checks for their drivers (Farren 2017). With time and stricter regulations, we expect TNC fares to be more in line with that of taxis in the future.

2. These are one-way access trips to the airport. We assume that the access trip is independent of the egress trip, even though in some cases they are not independent. For example, some people drive to the airport because they want to have their car to drive home when they return from their air travel (egress trips).

3. The average vehicles per household in the city of Los Angeles is about 1.5 and this number increases with higher income (Governing the States and Localities [2015]).

4. The cost of the rental is higher than if the vehicle was returned at the same location where it was picked up. The estimate is based on rates by enterprise.

5. TNC services like Uber Pool or Lyft lines may have more than one party, but the maximum number of separate travel parties and stops is two.

6. Each observation in the passenger survey had different travel durations (number of days) and party size. Our adjustments for total travel time and costs were done in a standard way; for example, we multiplied the number of passengers in the travel party by the cost of individual bus fares to get the total bus fares.

7. Biogeme, developed by Michel Bierlaire at the Ecole Polytechnique Fédérale de Lausanne, Switzerland, is an open source freeware designed for the maximum likelihood estimation of parametric models in general, with a special emphasis on discrete choice models.

8. The two models are nested in a sense that all terms of a smaller model (nested logit with seven nests) occur in a larger model (nested logit with three nests). This is a necessary condition for using most model comparison tests like likelihood ratio tests.

9. The closer this value is to 0 means that alternatives in the nest are very similar and probably belong in a group; however, it is not significant.

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Karina Hermawan *received a BA degree in economics from the University of California, Berkeley, an MA degree in economics and an MS degree in transportation science from the University of California, Irvine. She is currently a Ph.D. student in transportation science at the University of California, Irvine.*

Amelia C. Regan *received a BAS degree in systems engineering from the University of Pennsylvania, an MS degree in applied mathematics from Johns Hopkins University, and both MS and Ph.D. degrees in transportation systems engineering from the University of Texas, Austin. She is a professor of computer science and transportation systems engineering at the University of California, Irvine. Her research is focused on algorithm development for optimization of transportation and communication systems. She has also taught short courses at the Athens University of Business and Economics and the National Technical University of Denmark and was an operations research analyst with the Association of American Railroads and United Parcel Service prior to earning her Ph.D.*