Modeling Ride-Hailing Use in Megacities: Evidence from São Paulo

Aurore Sallard*, Miloš Balać*, Kay W. Axhausen*
{aurore.sallard, milos.balac, axhausen}@ivt.baug.ethz.ch

December 15th, 2019

Keywords: Ride-hailing, Demand modeling, Emerging mobility services, Shared mobility.

1 Introduction

Major ride-hailing companies such as Uber, Lyft, Didi Chuxing and Cabify were founded less than ten years ago and have since shown strong economic growth. While more than 100 millions individuals now use Uber on a monthly basis[1], very little is known about the characteristics of customers of such platforms and of trips booked through them, in particular in newly industrialized countries. This work wishes to address these questions using survey data from the São Paulo Metropolitan Region.

Since the global emergence of ride-hailing as a popular transport mode by 2014, research has mostly focused on its impact on competition and in particular on public transportation use (Rayle, Dai, Chan, Cervero, and Shaheen, 2016, de Souza Silva, de Andrade, and Maia, 2018, Clewlow and Mishra, 2017), congestion (Li, Hong, and Zhang, 2016), vehicle miles traveled (Henao and Marshall, 2019, Clewlow and Mishra, 2017), crashes (Tirachini, 2019, Dills and Mulholland, 2018) or carbon emissions (Rodier, 2018). In the last years, significant data-sets were released that allowed for a more in-depth analysis of the socio-demographic attributes of ride-hailing users. In Clewlow and Mishra, 2017, authors present findings from a survey deployed from 2014 to 2016 in seven major US cities. They show that the average ride-hailing adopter is young, highly educated, and lives in urban neighborhoods. In Young and Farber, 2019 this trend is confirmed on the basis of a study conducted in Toronto in 2016. It is also shown that ride-hailing adopters are likely to live in a wealthy household and not to own a personal vehicle. Dias et al., 2017 focus on the Puget region

*Professur für Verkehrsplanung, ETH Zürich, Switzerland
[1]https://www.statista.com/statistics/833743/us-users-ride-sharing-services/

around Seattle, WA and produce similar results; moreover, they highlight a negative correlation between the presence of children in the household and ride-hailing adoption. In Alemi, 2018 and Alemi, Circella, Mokhtarian, and Handy, 2019, researchers analyze findings of a survey deployed in 2015 in California that specifically targeted Millenials. They investigate participants' frequency of use of ride-hailing services and show that socio-demographic attributes do influence ride-hailing adoption but not the frequency of use, which is however impacted by technology adoption and use of social media.

Other studies focus on newly industrialized areas, such as China (Tang, Li, Yu, and Wei, 2019), India (Agarwal, Mani, and Telang, 2019) and South America (de Souza Silva et al., 2018, Tirachini and del Río, 2019 and Amaral Haddad et al., 2019). Based on a survey deployed in Santiago de Chile in 2017, Tirachini and del Río, 2019 compare the social and economical attributes of Uber and Cabify in this city and perform an analysis of the frequency of use of those services. In de Souza Silva et al., 2018, authors investigate the findings of a survey conducted in several large Brazilian cities in 2017. They analyze how socio-demographic attributes influence the decision of using ride-splitting (a recent feature allowing the customer to share trips with other passengers). To the authors' knowledge, the only study focusing specifically on São Paulo is Amaral Haddad et al., 2019: on the basis of a survey that took place in 2007 merged with information from 2017 and 2018 provided by a leading ride-hailing operator, the authors simulate the emergence of ride-hailing services in this megacity. Thanks to TTC, a company specialized in transportation analysis in the São Paulo Metropolitan Region, they build different scenarios to investigate the impacts of the ride-hailing expansion on demand for public transit and traditional private modes. They find that ride-hailing is likely to dramatically reduce the commute time of workers who were previously transit-dependent, improving in that way the economic efficency and reducing spatial inequalities.

Some works, such as Alemi et al., 2019, have already pinpointed the influence of the type of built environment on ride-hailing adoption and frequency of use. However, most studies did not examine the influence of the geographical characteristics of individual journeys on the choice of a transport mode, which will be in the future a focus point of this work. The present study will investigate the socio-demographic characteristics of ride-hailing users in the São Paulo Metropolitan Region and compare these results to the ones present in the literature. The analysis will be enhanced by comparing ride-hailing trip characteristics to that of other modes. Finally, some general results about the geographical distribution of ride-hailing trips in the study area will be given.

2 Methodology and data overview

Our main data source is the 2017 Origin Destination Survey[2], a household survey conducted in the São Paulo Metropolitan Region providing insight into travel patterns observed on an average working day. Besides household and personal socio-demographic attributes such as household monthly income, gender, age, employment status, level of education, number of owned vehicles and bicycles, the survey contains information on reported trips, including geographic coordinates of origin and destination, travel mode and trip purpose and duration. Trips with the transport mode "other" were removed as they can not be used for further investigation, as well as trips undertaken by bike – they represented indeed only much less than 1% of all trips and were too few to permit reliable modelling.

It was then possible to add cost information to the available data as this was not reported in the survey. Figures from Becker, Becker, and Axhausen, 2019 were used to compute travel costs by car. A basic model for public transportation costs was set up using values from the official website of state-owned commuter rail company CPTM[3]. The taxi fares, fixed by the local government, were obtained from a travel blog [4] which constitued the most up-to-date source information. Finally, ride-hailing prices were computed using the average fares of Uber and Cabify, the two main operators present in São Paulo.

3 A (not so) young and female consumer base? Evidence from São Paulo

3.1 Who uses ride-hailing?

Descriptive statistics showing the socio-demographic attributes of the weighted sample individuals, grouped by choice of transportation mode, are presented in Table 1. Mann-Whitney-Wilcoxon and chi-square tests indicate a significant statistical relationship between choice of transportation mode and age, gender, education level, household income and car ownership.

Regarding age, ride-hailing adopters appear to be slightly younger than the global population, the 26- to 35-year-old being the most represented age group. Contrary to what most past studies pointed out, senior citizens are widely represented among ride-hailing customers. To the authors' knowledge, there is no simple explanation for this phenomenon. The relatively high prevalence of retired individuals among ride-hailing customers tends to corroborate this observation.

[2] http://www.metro.sp.gov.br/pesquisa-od/
[3] cptm.sp.gov.br
[4] https://www.iheartbrazil.com/sao-paulo-taxi-guide

Moreover, ride-hailing customers are likely to live in non car-owning and wealthier-than-average households – 32.5% of them belong to households with monthly earnings totalling over 6 000 BRL[5] (the minimum wage being about 1 100 BRL), against 17.1% in the total population, which is consistent with previous findings. They tend as well to have a relatively high education level: 43.2% of all respondents have completed high school, nearly twice as much as in the global population.

The respondents' gender, which had almost no impact on ride-hailing adoption in other studies, appears to play a major role here. Maybe because of the possibility offered to choose one's driver according to comments written by previous customers, and possibly due to the development of female-only ride-hailing platforms [6], São Paulo female inhabitants, for whom security issues in transportation are crucial, seem to have adopted ride-hailing more than their male fellow citizens at the expense of conventional taxi operators. Differences in car ownership according to gender can also be observed: while 64.7% of all male respondents live in a car-owning household, this is only the case for 57.8% of female participants. This may explain why women tend to use public or active transport modes more often than men.

3.2 What do people use ride-hailing for?

Looking at the corresponding part of Table 1, it appears that the transport modes serve distinct purposes. While car and public transit are mainly chosen for work or educational purposes, ride-hailing is likely to serve more recreational goals (bars and restaurants are indeed included within the "other" category), with less than one fifth of ride-hailing trips being associated with work and less than 10% with school.

3.3 When do people use ride-hailing?

Considering now the last rows of Table 1, the data confirms findings from other works: ride-hailing trips are more likely to be used at evening or at night than all other transportation modes. This, in addition with conclusions from the previous paragraph, corroborates the widespread idea that ride-hailing is often used in festive contexts and at time periods when public transit is no more available (or greatly restricted).

3.4 What characterizes trips made by ride-hailing?

In Table 2 and Table 3, we reported trip cost and duration for respectively four and five analyzed motorized modes. Regarding costs, ride-hailing and taxi are obviously the two most expensive modes (costs of buying and parking a personal car have not been taken into account). However, since no information

[5] on December 12th, 2019, 1 BRL = 0.24 USD.
[6] http://www.femitaxi.com.br/

	Car	Car passenger	Public transit	Walk	Taxi	Ride-hailing	All modes
Mode share	18.9	8.6	36.2	32.5	2.8	1.0	100%
Respondents' age (years), in percentage points							
0 – 15	0	45.1	18.2	31.8	3.1	13.7	21.1
16 – 25	6.0	13.0	23.3	16.7	19.5	15.5	16.8
26 – 35	20.5	10.1	16.9	15.4	32.7	19.2	16.9
36 – 45	30.1	10.0	15.0	13.9	24.9	15.3	17.3
46 – 55	22.5	8.4	12.8	11.2	13.0	11.5	13.7
56 – 65	15.1	7.5	9.6	7.9	3.7	14.0	9.8
66 +	5.7	5.9	4.3	3.1	3.1	10.8	4.3
Respondents' gender, in percentage points							
Masculine	67.0	39.1	44.3	46.0	82.2	32.2	49.7
Feminine	33.0	60.9	55.7	54.0	17.8	67.8	50.3
Monthly household income (BRL), in percentage points							
Average	5992	5251	3682	3436	4460	5840	4215
0 – 1999	6.5	12.5	20.5	28.3	12.7	12.2	19.4
2000 – 3999	35.1	38.3	49.8	46.9	46.9	34.7	44.9
4000 – 5999	25.1	22.5	18.0	14.1	22.9	20.6	18.6
6000 – 7999	12.7	10.1	5.6	4.8	8.3	9.6	7.2
8000 – 9999	7.9	6.9	2.9	2.6	3.1	9.0	4.1
10 000 – 14 999	7.2	4.8	2.1	2.1	3.7	6.8	3.4
15 000 – 19 999	2.8	3.0	0.7	0.6	1.3	4.1	1.3
20 000 – 39 999	2.5	1.7	0.4	0.5	1.0	3.0	1.0
40 000 +	0.2	0.2	0.0	0.1	0.1	0.0	0.1
Respondents' education level[a], in percentage points							
Illiterate	2.7	7.1	5.8	7.5	2.4	6.0	5.4
Elementary school completed	6.1	11.0	9.6	12.5	8.0	5.8	9.5
Middle school completed	8.7	13.3	13.0	17.6	14.4	8.8	13.2
High school completed	42.0	45.5	53.6	43.8	54.3	36.2	47.4
University degree completed	40.5	23.1	18.0	18.6	20.9	43.2	24.4
Respondents' employment status, in percentage points							
Employed	81.3	31.0	60.9	44.8	87.3	49.1	57.6
Unemployed	9.6	28.2	12.3	20.6	5.1	24.4	15.7
Student	0.8	33.3	20.6	31.0	4.0	11.7	20.8
Retired	8.3	7.5	6.3	3.6	3.6	14.8	5.9
Cars in the respondents' households, in percentage points							
1 or more	96.8	84.7	50.0	47.2	61.3	51.8	61.2
0	3.2	15.3	50.0	52.8	38.7	48.2	38.8
Travel mode by destination purpose (in percentage points)							
Home	44.9	45.0	47.9	44.8	46.7	49.4	46.0
Work	31.6	12.3	26.3	17.8	39.0	16.2	23.6
Education	10.6	22.9	15.2	26.8	6.4	5.1	18.4
Shopping	3.4	4.1	2.0	2.0	0.8	3.9	2.4
Leisure	3.2	5.7	1.8	5.6	2.2	8.5	3.7
Other	6.3	9.9	6.9	3.1	4.9	16.9	5.8
Start time of trips (in percentage points)							
5am – 10am	32.2	28.8	31.4	25.0	33.6	18.9	29.2
10am – 3pm	24.8	27.8	25.2	41.6	19.2	33.4	30.6
3pm – 7pm	28.7	27.4	29.7	26.3	30.5	27.3	28.2
7pm – 11pm	11.5	13.1	10.1	6.0	11.9	14.6	9.4
11pm – 5am	2.8	2.9	3.6	1.1	4.8	5.8	2.6

[a] for respondents aged 18 or more.

Table 1: Socio-demographic characteristics of respondents, start times and travel modes by trip (destination) purpose

	Car	Public transit	Taxi	Ride-hailing
0 – 5	75.5	50.5	0.0	0.7
5 – 10	17.0	48.5	3.4	18.0
10 – 15	5.0	0.6	10.6	24.5
15 – 20	1.8	0.4	12.0	19.0
20 +	0.7	0.0	74.0	37.8

Table 2: Trip cost (BRL) according to transport mode, in percentage points

	Car	Car passenger	Public transit	Taxi	Ride-hailing
0 – 20	44.0	56.6	8.4	45.8	43.1
20 – 40	31.1	28.0	25.1	35.1	38.0
40 – 60	11.7	7.4	18.4	11.0	9.7
60 – 90	9.5	5.5	23.9	7.3	6.9
90 +	3.7	2.3	24.2	0.8	2.7

Table 3: Trip duration (minutes) according to transport mode, in percentage points

is provided about how many individuals are actually sharing the vehicles, this analysis can not be further developed as of now. It should also be noted that ride-hailing trips seem to be slightly shorter than trips undertaken by car and taxi, whereas public transit appears to be the transportation mode associated with the longest trips. This analysis will be further expanded as well.

4 Towards a versatile model of ride-hailing use in megacities

Based on the 2017 Origin Destination Survey, this study highlighted socio-demographic attributes of ride-hailing adopters in the São Paulo Metropolitan Region. As already pointed out in previous works, these tend to be young and wealthier-than-average, and to have a high qualification level. Two peculiarities were pinpointed: the unusually high prevalence of senior citizens among ride-hailing customers and the significant influence exerted by gender. Ride-hailing trips are often taken at night for recreational purposes as in many other areas.

Using spatial data-sets representing the 517 zones constitutive of the São Paulo Metropolitan Region, this study will be further enhanced with more details about the geographical distribution of ride-hailing trips. In particular, the interactions between public transportation and ride-hailing will be investigated. Combining all evidence, it will finally be possible to develop a Discrete Choice Model (McFadden et al., 1973) for ride-hailing use in São Paulo.

References

Agarwal, S., Mani, D., & Telang, R. (2019). The impact of ride-hailing services on congestion: Evidence from indian cities. *Available at SSRN 3410623*.

Alemi, F. (2018). *What makes travelers use ride-hailing? exploring the latent constructs behind the adoption and frequency of use of ride-hailing services, and their impacts on the use of other travel modes*. University of California, Davis.

Alemi, F., Circella, G., Mokhtarian, P., & Handy, S. (2019). What drives the use of ride-hailing in california? ordered probit models of the usage frequency of Uber and Lyft. *Transportation Research Part C: Emerging Technologies*, *102*, 233–248.

Amaral Haddad, E., Vieira, R. S., Jacob, M. S., Guerrini, A. W., Germani, E., Barreto, F., & Sayon, P. L. (2019). A socioeconomic analysis of ride-hailing emergence and expansion in São Paulo, Brazil. *Transportation Research Interdisciplinary Perspectives*, 100016.

Becker, H., Becker, F., & Axhausen, K. W. (2019). Impact of vehicle automation and electric propulsion on production costs for mobility services worldwide. In *19th Swiss Transport Research Conference (STRC 2019)*. STRC.

Clewlow, R. R., & Mishra, G. S. (2017). *Disruptive transportation: The adoption, utilization, and impacts of ride-hailing in the United States*. University of California, Davis.

de Souza Silva, L. A., de Andrade, M. O., & Maia, M. L. A. (2018). How does the ride-hailing systems demand affect individual transport regulation? *Research in Transportation Economics*, *69*, 600–606.

Dias, F. F., Lavieri, P. S., Garikapati, V. M., Astroza, S., Pendyala, R. M., & Bhat, C. R. (2017). A behavioral choice model of the use of car-sharing and ride-sourcing services. *Transportation*, *44*(6), 1307–1323.

Dills, A. K., & Mulholland, S. E. (2018). Ride-sharing, fatal crashes, and crime. *Southern Economic Journal*, *84*(4), 965–991.

Henao, A., & Marshall, W. E. (2019). The impact of ride-hailing on vehicle miles traveled. *Transportation*, *46*(6), 2173–2194.

Li, Z., Hong, Y., & Zhang, Z. (2016). An empirical analysis of on-demand ride sharing and traffic congestion. In *Proc. international conference on information systems*.

McFadden, D. et al. (1973). Conditional logit analysis of qualitative choice behavior.

Rayle, L., Dai, D., Chan, N., Cervero, R., & Shaheen, S. (2016). Just a better taxi? a survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. *Transport Policy*, *45*, 168–178.

Rodier, C. (2018). The effects of ride hailing services on travel and associated greenhouse gas emissions.

Tang, B.-J., Li, X.-Y., Yu, B., & Wei, Y.-M. (2019). How app-based ride-hailing services influence travel behavior: An empirical study from China. *International Journal of Sustainable Transportation*, 1–15.

Tirachini, A. (2019). Ride-hailing, travel behaviour and sustainable mobility: An international review. *Transportation*, 1–37.

Tirachini, A., & del Río, M. (2019). Ride-hailing in Santiago de Chile: Users' characterisation and effects on travel behaviour. *Transport Policy*, *82*, 46–57.

Young, M., & Farber, S. (2019). The who, why, and when of Uber and other ride-hailing trips: An examination of a large sample household travel survey. *Transportation Research Part A: Policy and Practice*, *119*, 383–392.