Statistical Modeling of E-scooter Sharing and its Potential as Auto Mode Substitution

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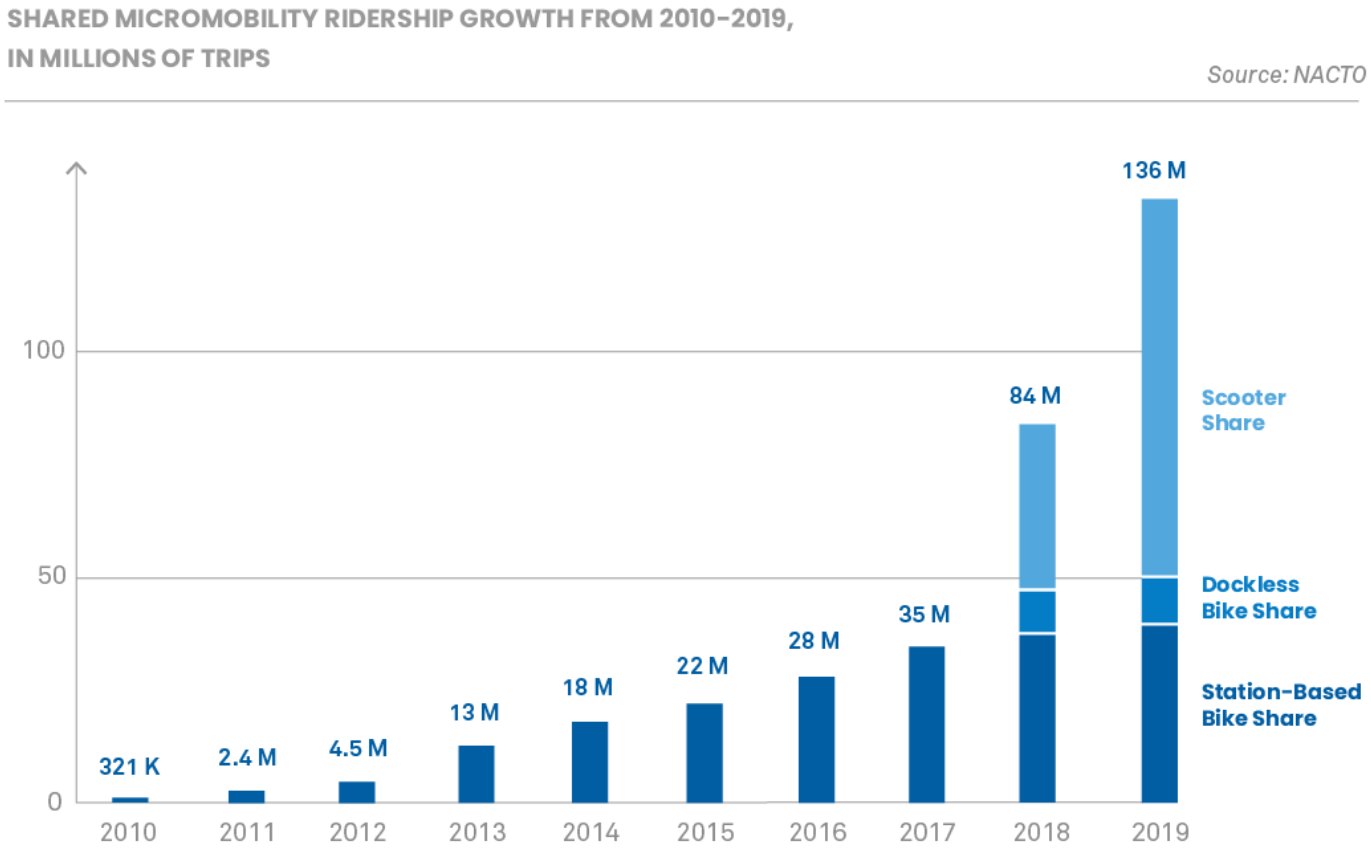
Table of Contents

Background: Growth of Shared E-Scooter Programs



Ridership growth of e-scooters and bike sharing
Source: NACTO

- First introduced in Santa Monica, 2017
- Capital driven development
- By 2019 (NACTO, 2020)
  - 109 cities
  - 63.2% of total shared micromobility trips
- Address first mile/last mile problem
- Support short trips: 35% of vehicle trips are less than 2 miles (NHTS, 2019).

Background: Findings from Pilot Programs

- Surveyed reports from Portland, Alexandria, Arlington, Chicago, Tampa, etc.
- Users love shared e-scooters
  - Fun to ride, fast and convenient
- Concerns of the program
  - Safety (high speed riding, reckless riding on sidewalks, accidents, etc.)
  - Lack of law enforcement
- Shared e-scooters mainly replace walking/biking and vehicle trips
  - 32% ~ 49% of trips replace vehicle trips
  - 37.6% ~ 55% of trips replace walking and biking
  - 1% ~ 10.2% of trips replace public transit
- Shared e-scooters enhanced job accessibility of people in disadvantaged areas
  - In Chicago, users in Equity Priority Area are 1.6 times more likely to use shared e-scooters for commuting.

Research Questions

- What factors motivate people to ride e-scooters frequently
- What factors encourage people to ride e-scooters to replace vehicle trips

Literature Review – Use of Shared Micromobility

- Factors that influence usage of bike sharing:
  - ***Socioeconomic variables***, ***travel patterns*** and ***perceptions of bike sharing***. (Bivariate ordered probit model to model bike sharing usage and satisfaction) (Guo, Zhou et al., 2017)
    - Male, owning private bikes, short travel time, easy access, positive perceptions towards bike sharing program increases probability of riding bikes frequently.
  - ***Socioeconomic variables***, ***travel behavior*** and ***history***, and ***health indicators***. (Random parameters logit model) (Barbour, Zhang et al., 2019)
    - Caucasian, male and those with high total daily travel time are more likely to use bike sharing frequently.
    - *Higher BMI (overweight)* users have higher probability of riding bikes frequently.
- E-scooter users:
  - E-Scooter users tend to be male, white and high-income populations. (Chicago, Portland)
  - Trip purposes: Just for fun; social/ entertainment are top two trip purposes (Alexandria, Portland)
  - Motivation factor: Get around fast, convenient/ easy access (Alexandria, Tampa)
  - Riding frequency: mostly less than once per week (Alexandria, Portland, Tampa)

Literature Review – Auto Substitution of Bike Sharing

- ***Individual characteristics*** and ***driving perceptions*** (Yang et al., 2016)
  - Long drive, inconvenience of parking, traffic congestions and high commuting expenses contributes to bike sharing use too access metro than driving
- ***Psychological perspective*** (Ma et al., 2019)
  - Perceived health benefits, ease of use, usefulness have positive effects on people's attitude on bikesharing, and positive attitude can be converted to higher willingness of mode shift from driving to dockless bike sharing.
- ***Socioeconomic variables***, ***travel behavior*** and ***history***, and ***health indicators*** (Barbour, Zhang et al., 2019)
  - Users who commute by driving alone, are obese are more likely to substitute driving by bike sharing.
  - High income populations present opposite results.

Methodology – Survey

- Survey questions:
  - *Collision experience*: whether user have collision experience with shared e-scooters, type of collision, etc.
  - *Safety perception*: speed limit, where to ride
  - *Riding behaviors*: motivations of riding e-scooters, trip purposes, frequency of riding e-scooters, helmet use, where do you mostly ride e-scooters (sidewalk, bike lane, etc.),
  - *Mode substitution*: recall the latest e-scooter sharing trip, what was the trip purpose, motivation factors, what transportation modes they would have used if e-scooter sharing program were unavailable, etc.
  - *Sociodemographic information*: gender, income, education level, age, car ownership, BMI (height, weight), etc.
- Survey data collection
  - *When*: October 29th to December 3rd, 2019
  - *Where*: City of Tampa
  - *Who*: General public
  - *How*: online survey link were sent to the public via MPO, local house owner associations, service providers, the City's official webpage and social media
  - 544 valid user responses were collected

Methodology – E-Scooter Usage Model

- Model: random parameter ordered probit model
- Dependent variable: e-scooter sharing usage (How often do you ride shared e-scooters?):
  - Regular user: ride e-scooters more than once a week (167 respondents)
  - Occasional user: ride e-scooters occasionally, but less than once per week (184 respondents)
  - Infrequent user: ride e-scooters once a while (193 respondents)
- Independent variables
  - Socioeconomic variables
  - E-scooter riding behaviors and opinions (e.g., motivation factors)
  - General trip purposes of riding shared e-scooters

Model Results: Shared E-Scooter Usage Model

Variable Description	Estimated Parameter	*t* Statistic
Constant	-1.09	-7.21
Sociodemographic factors		
Male indicator (1 if respondent is a male, 0 otherwise)	0.34	3.06
Live in downtown Tampa (1 if respondent lives in downtown Tampa, 0 otherwise)	0.45	3.76
Own an e-scooter (1 if respondent owns a private usable e-scooter, 0 otherwise)	0.50	2.32
Behavior and opinions		
Ride e-scooters on bike lane (1 if respondent usually ride e-scooters on bike lane, 0 otherwise)	0.34	2.63
Wear a helmet (1 if respondent wore a helmet at least once while riding an e-scooter, 0 otherwise)	0.40	2.51
Easy to use (1 if respondent feels shared e-scooter is easy to use, 0 otherwise)	0.53	4.62
Low speed limit (1 if respondent thinks the speed limit of e-scooters shall be lower than 10 mph, 0 otherwise)	-0.65	-3.60
General Trip purposes of riding e-scooters		
Dining (1 if respondent rides shared e-scooters for dining, 0 otherwise)	0.69	5.91
Sightseeing (1 if respondent rides shared e-scooters for sightseeing, 0 otherwise)	0.29	2.29
Recreation (1 if respondent rides shared e-scooters for recreation, 0 otherwise)	0.30	2.40
Commuting (1 if respondent rides shared e-scooters for commuting, 0 otherwise) (Standard deviation of parameter estimate, normally distributed. In parentheses)	0.75 (1.00)	6.46 (9.67)
Threshold 1	1.34	15.45
Number of observations	544	
Log-likelihood at convergence	–481.3	

Model Results: Marginal Average Effects for Parameter Estimates

Indicators	Marginal Effects		
	[*y* = 1]	[*y* = 2]	[*y* = 3]
Male indicator	-0.11	0.01	0.10
Live in downtown Tampa	-0.14	0.00	0.14
Own an e-scooter	-0.14	-0.04	0.17
Ride e-scooters on bike lane	-0.11	-0.01	0.11
Wear a helmet while riding an e-scooter	-0.12	-0.02	0.14
Easy to use	-0.17	0.01	0.16
Low speed limit	0.24	-0.07	-0.16
Dining	-0.23	0.03	0.20
Sightseeing	-0.09	0.00	0.09
Recreation	-0.10	0.01	0.09
Commuting	-0.23	0.00	0.24

(y = 1 [Infrequent user], y = 2 [Occasional user], y = 3 [Frequent user])

Findings:

- Users who ***own an e-scooter*** have higher probability of being regular users.
- Users who ***ride e-scooters on bike lanes*** have higher probability of being regular users.
- Users who think ***speed limit shall be lower than 10 mph*** are more likely to ride e-scooters less often.
- ***Commuting*** users ride e-scooters more regularly (0.24 higher probability)

Methodology – Mode Substitution Model

- Model: Mixed logit model
- Dependent variable: mode substitution (For your last ride on a shared e-scooter, if the e-scooters were not available, what other transportation mode would you have used instead? (Most preferred)):
  - Substituted TNCs/taxi (141 respondents)
  - Substituted private vehicles (99 respondents)
  - Substituted Walking (202 respondents)
  - Substituted other modes including public transit, bike sharing, car sharing, private bikes/scooters (86 respondents)
- Independent variables
  - Socioeconomic variable
  - E-scooter riding behaviors for the last trip (e.g., motivation factors)
  - Trip purposes of the last trip

Model Results: Mixed Logit Model

Mixed logit model estimation results for mode substitution.

Variable Description	Estimated Parameter	*t*-Statistic
Walk constant (defined for walk substitution utility function)	1.29	6.09
Socioeconomic factors		
Male indicator (1 if respondent is a male, 0 otherwise; defined for driving substitution utility function)	0.87	2.31
College degree indicator (1 if respondent's highest completed level of education is a college degree, 0 otherwise; defined for walk substitution utility function)	−0.35	−1.81
Medium-high income indicator (1 if respondent's annual household income is more than $99,999 and less than $199,999, 0 otherwise; defined for other modes substitution utility function)	0.48	1.99
High income indicator (1 if respondent's annual household income is more than $200 k, 0 otherwise; defined for TNC/taxi substitution utility function)	0.83	3.33
Household with more than one vehicle (1 if respondent's household has more than one vehicle, 0 otherwise; defined for driving substitution utility function) (standard deviation of parameter estimate, normally distributed. shown in parentheses)	−2.17 (4.25)	−1.2 (1.81)
Live in Downtown Tampa (1 if respondent lives in Downtown Tampa, 0 otherwise; defined for TNC/taxi substitution utility)	0.43	2.01
Live in Downtown Tampa (1 if respondent lives in Downtown Tampa, 0 otherwise; defined for driving substitution utility function)	−1.24	−2.68
E-scooter riding behavior		
Once in a while user (1 if respondent rides shared e-scooter once a while, 0 otherwise; defined for TNC/taxi substitution utility function)	−0.61	−2.53
Motivation factors of riding shared e-scooter for last trip		
Just for fun (1 if respondent rode shared e-scooters for fun, 0 otherwise; defined for other modes substitution utility function)	0.36	1.6
Fast and flexible (1 if respondent thought shared e-scooter is fast and flexible, 0 otherwise; defined for other modes substitution utility function)	−0.56	−2.37
Lower cost (1 if respondent thought cost of riding shared e-scooter is lower, 0 otherwise; defined for TNC/taxi substitution utility function)	0.67	2.99
Difficult vehicle parking (1 if respondent thought parking was difficult at that time, 0 otherwise; defined for driving substitution utility function)	1.46	3.22
Trip purpose		
Social/ entertainment purpose (1 if respondent's last shared e-scooter trip was for social/ entertainment purpose, 0 otherwise; defined for TNC/taxi substitution utility function)	0.64	3.13
Health indicator		
Overweight (1 if respondent's BMI is above 25, 0 otherwise; defined for driving substitution utility function)	−0.76	−1.73
Number of observations	546	
Log likelihood at zero [$LL(0)$]	−729.2	
Log likelihood at convergence [$LL(\beta)$]	−658.9	
ρ^2 [1- ($LL(\beta)$/ $LL(0)$]	0.096	
Corrected ρ^2 [1- ($LL(\beta)$-number of estimated parameters, K)/ $LL(0)$]	0.087	

Model Results: Marginal Average Effects for Parameter Estimates

Variable	Average marginal effects			
	Walk	TNC/taxi	Drive	Other
Constant (defined for walk substitution utility function)	0.26	−0.13	−0.05	−0.08
Socioeconomic factors				
Male indicator (defined for driving mode substitution)	−0.02	−0.01	0.04	−0.008
College degree indicator (defined for walk mode substitution utility function)	−0.03	0.02	0.006	0.01
Medium-high income indicator (defined for other modes substitution utility function)	−0.01	−0.007	−0.003	0.02
High income indicator (defined for TNC/taxi substitution utility function)	−0.02	0.03	−0.004	−0.006
Household with more than one vehicle (defined for driving substitution utility function)	−0.02	−0.02	0.05	−0.009
Live in downtown Tampa (defined for TNC/taxi substitution utility function)	−0.02	0.03	−0.003	−0.006
Live in downtown Tampa (defined for driving substitution utility function)	0.01	0.01	−0.03	0.004
Riding behaviors				
Infrequent user (defined for TNC/taxi substitution utility function)	0.02	−0.03	0.004	0.008
Motivation factor of riding shared e-scooter for last trip				
Just for fun (defined for other modes substitution utility function)	−0.02	−0.01	−0.004	0.03
Fast and flexible (defined for other modes substitution utility function)	0.02	0.01	0.004	−0.03
Lower cost (defined for TNC/taxi substitution utility function)	−0.02	0.04	−0.007	−0.007
Difficult vehicle parking (defined for driving substitution function)	−0.02	−0.01	0.04	−0.006
Trip purpose				
Social/ entertainment purpose defined for TNC/taxi substitution utility function)	−0.04	0.07	−0.01	−0.02
Health indicator				
Overweight (defined for driving substitution utility function)	0.01	0.01	−0.03	0.006

Model Results: Mode Substitution Model

- Substitute private vehicle driving
  - Users in households with more than one vehicles are more likely to substitute driving with shared e-scooters (0.05 higher probability)
  - Difficult parking motivates private vehicle substitution (0.04 higher probability)
- Substitute ride hailing
  - Users who have higher household income or live in Tampa Downtown (0.03 higher probability)
  - Regular/occasional users tend to use shared e-scooter to replace ride hailing (0.03 higher probability)
  - Users who think cost of riding shared e-scooter is lower (0.04 higher probability)
  - Social and entertainment trip purposes (0.05 higher probability)

Policy Implications

- To encourage users to ride shared e-scooters more frequently
  - Provide regular training sessions or online tutorials for unskilled users
  - Improve the bike lane network in the service area
  - Offer free helmets with the support of operators and other traffic safety organizations
- To encourage users to ride shared e-scooters to replace vehicle trips
  - Parking
    - Deploy shared e-scooters to areas with high traffic demand but limited parking spaces
    - Increase parking fee or reduce parking space to stimulate the mode shift
  - Reduce the cost of using shared e-scooters to attract TNC/taxi users

Reference

- NHTS (2019). Popular vehicle trips statistics. Retrieved 3/28, 2020, from https://nhts.ornl.gov/vehicle-trips.
- CTO. (2020). Shared micromobility in the U.S.:2019. Retrieved from https://nacto.org/shared-micromobility-2019/
- PBOT (2018). 2018 E-scooter Pilot user survey results.
- Mobility Lab (2019). Arlington County shared mobility (SMD) pilot evaluation report.
- Guo, Y., et al. (2017). Identifying the factors affecting bike-sharing usage and degree of satisfaction in Ningbo, China. PloS One **12**(9).
- Barbour, N., et al. (2019). A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. Journal of Transport & Health **12**: 253-262 %@ 2214-1405.
- Yang, M., Liu, X., Wang, W., Li, Z., & Zhao, J. (2016). Empirical analysis of a mode shift to using public bicycles to access the suburban metro: Survey of Nanjing, China. Journal of Urban Planning and Development, *142*(2), 05015011.
- Ma, X., Cao, R., & Wang, J. (2019). Effects of psychological factors on modal shift from car to dockless bike sharing: A case study of Nanjing, China. International Journal of Environmental Research and Public Health, 16(18), 3420.

Thank you!

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