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What the heck is a choice rider? A theoretical framework and empirical model

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Abstract: As local, state, and federal agencies began investing substantial resources into subsidizing transit in the 1960s and '70s, public documents argued that transit agencies should focus on attracting choice riders instead of dependent riders, who have no alternatives and use transit regardless of service quality. After six decades, the definitions, uses, and implications of the terms choice and dependent rider have remained consistent in the academic and professional literature. These definitions, however, lack a strong theoretical grounding or empirical evidence to support them. Using travel diary data from the Philadelphia region, I estimate discrete choice models to identify choice riders, who I define as those who have close to a 50% probability of choosing between a car or transit for a given trip. The Philadelphia region, which has a diverse range of transit users and transit services, is an ideal place to develop and fit an empirical model of choice ridership. Attributes assumed to be associated with dependent riders, such as lack of a car, low income, and being a racial or ethnic minority, are much more prevalent among choice riders than the general metropolitan population. Choice riders are also diverse, with a mix of racial backgrounds, income levels, educational attainment, and access to private cars. Transit dependency, by contrast, is rare. The lowest and highest income residents generally only choose transit when service quality is high, and transit is cost and time competitive with the car.

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1 Introduction

The term "choice rider" enters the English lexicon in the early 1960s (Google, 2021). Choice riders first appear in technical transportation-planning documents alongside captive, necessity, or dependent riders to categorize existing and future transit users. For example, the 1961 Pittsburgh Area Transportation Study groups metropolitan transit users into captive and choice riders based on private vehicle availability and describes a decline in captive ridership as more households acquire cars. While many documents provide circular definitions—a choice rider is someone who can choose to use transit—several keywords frequently coincide with each term. Choice riders have cars, licenses, and suburban homes in wealthy neighborhoods. They are White, white-collar, male workers, who take trains to downtown jobs. Captive riders are poor, racial minorities, housewives, the old, the young, the carless, and persons with disabilities. They rely on urban bus services to accomplish their daily tasks regardless of service quality.

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The introduction of the term choice rider coincides with a broad shift in the provision of US transit. Prior to World War 2, a combination of private for-profit companies and city agencies provided transit services throughout the US. Although vehicle registrations were already rapidly increasing in the early 20th century, the combination of increased automobility and suburbanization in the post-war era contributed to a substantial reduction in transit ridership, the closure of multiple transit lines, the public takeover of many private transit companies, and an increasing need for public subsidies to maintain remaining transit services. In greater Philadelphia, the city of Philadelphia and State of Pennsylvania began to subsidize transit services as early as 1960 (Hepp, 2018). In 1963, the State formed the Southeastern Pennsylvania Transportation Authority (SEPTA), which began to take over transit operations from the patchwork of transit companies throughout the region. In 1964, the Federal Government created the Urban Mass Transportation Administration (now, Federal Transit Administration) and began to pass a series of bills to support and subsidize urban transit systems throughout the country (Federal Transit Administration, n.d.). As public agencies continued to take over and subsidize transit operations throughout the 1960s and 1970s, the number reports referencing choice and dependent riders increases and peaks in 1977 (Google, 2021).

Within these technical reports, the differentiation between choice and captive riders has implicit and explicit connections to the economic and environmental justifications for subsidizing transit. One common line of argument is that, "[t]he captive rider has no choice but to wait, regardless of the headway between buses or trains, but the choice rider can get back in his car and drive (Bates, 1981, p. 13)." The captive rider market, "…will always exist…" but the choice rider market "…will exist only as long as transit service is attractive (Keefer et al., 1963, p. 58)." If transit ridership is to increase or draw passengers away from cars and thus reduce associated pollution and congestion, transit agencies should ignore captive riders and focus on choice riders. In an early article on the economics and political economy of transit subsidies, Haines (1978, pp. 64–66) argues there is no economic justification for subsidizing transit for captive riders and little reason to do so, since "…in the nature of things, captive riders are not a particularly potent political force." The direct implication of these early uses of the terms choice and captive rider is that agencies should generally focus investments and service improvements on suburban rail services to downtown job centers in wealthier, Whiter suburban communities. Urban bus services in low-income and minority neighborhoods can be safely ignored.

After six decades, the definitions, uses, and implications of the terms choice and captive rider have persisted, though the term dependent rider has largely supplanted the term captive rider. These definitions, however, are theoretically weak and empirically inaccurate. For example, just 18% of US households earning below $25,000 per year do not have a car. The adults in these low-income, carless households take 25% of trips by transit compared to 27% by car (U.S. Department of Transportation, 2017). The uses and implications of the terms may have also contributed to racist public policies. For example, the Los Angeles Bus Riders Union's sued the Metropolitan Transit Authority in 1994. The plaintiffs argued that the agency's focus on rail investments at the expense of bus investments violated the 14th amendment and 1964 Civil Rights Act by discriminating against the racial and ethnic minority groups that disproportionately used buses. The lawsuit led to a court injunction and reforms to improve bus services and stabilize transit fares (Elkind, 2014; Grengs, 2002). Additionally, mischaracterizations of choice ridership may encourage transit investments that not only attract fewer transit riders per dollar invested but also fail to draw as many transit users out of cars.

The purpose of this paper is to develop a theoretically robust and measurable definition of choice transit riders, estimate models of choice ridership, and describe the factors associated with choice transit travel. In the proceeding section, I summarize academic definitions and uses of the terms choice and dependent riders. The academic literature has a different focus than technical planning reports, but generally accepts and frequently expands on early definitions of choice and dependent riders. Next, I describe my methodological approach, definition of choice ridership, case context, data, and model specification. Relying on travel survey diaries from the Philadelphia region, I describe choice transit users as people who have close to a 50% estimated probability of choosing transit instead of a car for a given trip. Philadelphia, which has a high number of transit users that match existing definitions of dependent and choice transit users, is an ideal place to estimate and describe a model of choice transit use. Next, I describe Philadelphia's choice riders and compare them to the general population. Many of the people traditionally associated with transit dependency, such as low-income urban residents, minorities, and those without cars, are most likely to be on the fence about choosing to take transit or a car. The strongest associations with choice ridership relate to high-frequency bus and rail services near residents' trip origins and destinations.

Last, I conclude with takeaways for researchers and policymakers. Existing characterizations of choice riders are almost certainly inaccurate. If attracting people out of cars is a key transit objective, then agencies would do well to focus service improvements in dense urban areas with high concentrations of low-income residents without cars. These are the kinds of places where residents are likeliest to respond to service improvements by riding transit more. Moreover, researchers and policymakers should stop referring to dependent or captive riders altogether. Even in a large city with relatively good transit, the people most likely to be characterized as transit dependents only take transit consistently when service quality is high enough to make it a reasonable choice.

2 Academic references to choice and dependent riders

The academic literature generally follows and expands upon early planning documents' definitions of choice and dependent riders. Specifically, the term transit dependency is associated with keywords, such as carless, low income, bus, racial minority, age, disability, and travel to places outside of the downtown. Grengs (2002, p. 170) even makes the explicit argument that transit operators have at least some justification in ignoring transit dependents to focus on luring choice riders out of cars:

> The dilemma of serving either "choice" or "captive" riders gets even more complicated. To lure people out of their cars requires highly attractive service. And attractive service means higher costs for cash-strapped agencies, especially for distant, low-density suburbs. Keeping transit dependent customers, by contrast, does not require good service because these riders have no other choice.

In terms of overarching research topics, academic papers that reference transit dependency and choice ridership generally either focus on defining transit-user markets or showing unfairness in the transportation system. Many of these studies also reveal that those defined as transit dependent exercise a substantial amount of choice and frequently rely on cars. Although I focus on findings from the US and Canada below, the terms transit dependency and choice ridership are also used in a variety of international contexts, including China (Cai et al., 2020; Cao et al., 2018; Sun & Fan, 2018), India (Cheranchery & Maitra, 2018), Korea (Sohn & Yun, 2009), Australia (Chia et al., 2016), and Colombia (Márquez et al., 2018).

2.1 Defining transit markets

Researchers frequently define and group choice and dependent riders as inputs into empirical models or for comparisons of travel behavior across groups. For example, Polzin et al. (2000), divide the US population into choice and dependent riders based on age, driver's license, and household vehicles to compare travel behavior across these groups. Lachapelle et al. (2016), who define transit dependency by car availability, find that transit dependents participate in more physically active travel than choice riders or car users. Beimborn et al. (2003) add a third category of auto captives and use the three categories (transit dependents, choice riders, and auto dependents) as inputs to improve predictive models of transit ridership in metropolitan Portland. The authors define choice and captivity based on car availability, transit quality, and proximity to a transit stop. Similarly, van Lierop and El-Geneidy (2016) add another category of captive-by-choice riders, who are wealthy enough to own a car but do not, and use these categorizations to develop models predicting customer satisfaction with transit.

Several researchers apply clustering algorithms, such as factor analysis or K-means clustering, to travel diary and other survey data to group and describe various transit markets and submarkets. For example, Krizek and El-Geneidy (2007) use factor analysis to group residents of the Twin City metropolitan area into four groups, which they define as transit captives, choice riders, potential riders, and auto captives based on the covariance of survey data about travel preferences, views on transit quality, and available transportation modes. Although Krizek and El-Geneidy (2007) further distinguish these four groups as regular and irregular commuters, the authors argue that transit users fall neatly into two main categories with 46% of the sample being captive riders and the remaining 54% being choice riders. Similarly, Zhao et al. (2014) group transit users from customer survey data in Chicago using factor analysis and structural equation models. The authors differentiate between choice and captive riders primarily based on whether they are likely to continue to use transit when they perceive service quality as poor.

Further distinctions within categories are also common. For example, Chia et al. (2016) distinguish between true and nontrue transit captives—similar to van Lierop and El-Geneidy's (2016) captive-by-choice riders—based on access to alternative modes of transportation. Jacques et al. (2013) cluster transit users from a travel survey of students, faculty, and staff at McGill University in Montreal into four market segments that they describe as captivity, utilitarianism, dedication, and convenience. Captivity relates to transit users who are dissatisfied with transit and whose transit service is relatively poor, while the other three groups have higher quality transit or higher satisfaction with transit.

2.2 Unfairness in transit systems

The terms choice and dependent rider also frequently occur in studies that test or discuss unfairness in transportation systems or policy. Cervero (1981), using data from three Californian transit operators, shows that flat fare systems are less fair to transit dependents who tend to travel shorter distances outside of peak hours, than those based on distance and time of day. Grengs (2001) finds that poorer, minority residents of Syracuse, New York, have worse accessibility to supermarkets by transit than wealthier, White residents, who are less dependent on transit. Using similar definitions of transit dependency, Jiao and Dillivan (2013) define transit deserts as places with relatively high shares of transit-dependent individuals but relatively poor transit service. This definition has since been used to identity transit deserts in major cities in Texas (Jiao, 2017) and China (Cai et al., 2020). Comparing spatial relationships between shared-mobility services and transit deserts in New York City, Jiao and Wang (2020) conclude that shared mobility services are mostly located in wealthier neighborhoods that already have good access to transit.

In addition to investigating unfairness, several studies highlight the gap between transit investment priorities and transit's existing customer base. Grengs (2002) examines how Los Angeles' Bus Riders Union pursued a lawsuit claiming that Los Angeles' investments in suburban rail were at the expensive of investments in bus services and discriminated against poor and minority urban bus riders characterized as transit dependents. Taylor and Morris (2015) expand on this theme using data on transit operations, travel surveys, and a survey of 50 transit agencies. Only a small share of agency representatives view serving the needs transit-dependent populations as an important goal for public transit. As a result, agencies tend to prioritize commuter-oriented rail investments that appeal to wealthier residents with more political capital instead of urban bus services on which transit dependents rely. These biases may also exist within modes. For example, Wells and Thill (2012) examine whether transit dependent neighborhoods—defined as those with a high share of non-White, poor, elderly, or student residents—get worse bus service than other neighborhoods in Asheville, North Carolina, Charlotte, North Carolina; Mobile, Alabama, and Richmond, Virginia. While the authors find better transit service in low-car-ownership neighborhoods, they find worse bus service in minority neighborhoods when controlling for other factors, such as car ownership and income.

Daily experiences with transit may also reveal biases in the delivery of transit services. For example, Lubitow et al. (2017) use focus groups to examine transit-dependent riders' experiences in Portland, Oregon, and conclude that public transit investments are biased toward the experiences and the benefit of White, relatively wealthy, able-bodied, male commuters. These differences in experiences and services may also have important implications for poorer residents' overall life satisfaction and quality of life. Comparing life satisfaction with available transportation alternatives and residential location, Makarewicz and Németh (2018) find that only low-income, transit-dependent residents of Denver have substantial differences in subjective wellbeing based on whether they live in the urban core or other parts of the region. The authors argue that access to transit service is particularly important for the overall wellbeing of poorer residents.

2.3 Evidence of choice

Finally, the existing literature provides substantial evidence that so-called transit dependents exercise a great deal of choice. For example, in an analysis of the travel behavior of choice and dependent riders, Polzin et al. (2000) find that transit dependents, defined by auto availability, age, and drivers license, use transit for just 16% of trips. As Giuliano (2005) observes, most poor households are car dependent rather than transit dependent and only use transit when service quality is high enough to meet daily travel needs. Policymakers should therefore focus high-capacity investments in high-density and high-poverty areas, instead of suburban rail services that are unlikely to attract substantial numbers of new transit riders (Giuliano, 2005). Thomspon et al. (2012) and Brown et al. (2014) find that transit dependents are highly responsive to service quality, price, travel time, and how well transit serves job centers outside of downtown locations in Broward County, Florida, and Atlanta, Georgia.

The overall observation that dependents exercise a substantial amount of choice and will only choose transit when it suits their needs is also consistent with research on income, car availability, and other keywords associated with transit dependency. King et al. (2019) argue that the US built environment is so auto oriented that, outside of older, denser urban centers, poor households need a private vehicle to participate in basic economic activities. In order to afford a car, people frequently drive without collision insurance (Clark & Wang, 2010) and even turn to crowd-funding to pay to replace a car lost due to unexpected circumstances (Klein et al., 2019). Many low-income residents without cars borrow them or carpool to get to work (Blumenberg & Smart, 2014; Lovejoy & Handy, 2011; Rogalsky, 2010).

3 Research approach

I use a discrete choice random utility modeling framework to define and generate estimates of choice riders. Discrete choice models are commonly applied to estimate the probability that an individual chooses one available alternative, such as transit, over others, such as a car and other modes (Ben-Akiva & Lerman, 1985; Train, 2009). Estimating transit ridership has been particularly important to the early development of discrete choice models. In his Nobel lecture, McFadden (2001) details how the success of early applications to predict the ridership of a new rapid transit system in the San Francisco Bay Area was particularly important to the popularization of random utility models.

I define choice riders simply as those travelers who have close to a 50% probability of choosing transit based on estimates generated using a random utility model. For conceptual clarity and to emphasize the existing literature's focus on drawing transit riders out of cars, I discuss and estimate models of travelers choosing between transit and a private car. Discrete choice models make a clear and direct connection between the probability of choosing transit and the relative attractiveness of transit. When transit is substantially less attractive than a car, a traveler not only has a low probability of choosing transit but is generally unresponsive to changes in the attractiveness of either cars or transit. Similarly, when the attractiveness of transit is high, changes in the attractiveness of cars or transit will only have a small effect on the probability of choosing transit. Choice transit riders, by contrast, are highly responsive to changes in the attractiveness of cars or transit and have a much higher likelihood of adjusting their travel behavior as transit agencies improve or reduce service quality. While this design is conceptually clear for choice riders, it is likely less relevant for examining transit dependency. While a choice rider is making the choice between transit and driving, a transit dependent may be choosing between transit, walking, or not taking a trip at all.

3.1 Case context

Greater Philadelphia, which has a diverse range of transit users and transit services, is an ideal place to develop and fit an empirical model of choice ridership. SEPTA and New Jersey Transit provide bus, subway, commuter rail, and trolley services throughout the region. The centrally located cities of Philadelphia, PA, and Camden, NJ, have substantial numbers of low-income, minority residents who use the cities' urban bus systems. These residents are characteristic of the literature's general definitions of transit dependents. The region also has a large network of commuter rail lines, many of which extend into wealthy, low-density, majority-White towns and neighborhoods. The term the Main Line refers to the original operator of several of SEPTA's commuter rail lines and has become shorthand for Philadelphia's wealthy western suburbs.

3.2 Data summary

Table 1 presents the predictor variables used to estimate whether an individual chooses to use transit or a car on a weekday trip in the Philadelphia region. Predictor variables include socioeconomic information about the individual making a trip, characteristics about the trip, and environmental characteristics around the trip's origin and destination. The existing literature commonly includes these predictor variables, many of which also feature in descriptions of choice and dependent transit ridership. I pay special attention to including variables that feature in descriptions of choice ridership, such as income, race, car ownership, gender, urban location, and service quality.

Table 1. Socioeconomic, trip, and environmental characteristics of trips and trip makers

Variable	Share/Mean	Std Dev	Min	Max
Socioeconomic characteristics				
Age				
18 - 24	0.051			
25 - 44	0.216			
45 - 64	0.459			
64+	0.270			
Unreported	0.004			
Race/Ethnicity				
White/Caucasian	0.854			
Black/African American	0.072			
Other/Unreported	0.078			
Educational Attainment				
High school or lower	0.176			
Associate or some college	0.195			
Bachelor	0.306			
Graduate	0.317			
Unreported	0.005			
Gender				
Female	0.553			
Male and other	0.447			
Child(ren) under 5 in household	0.084			
Occupation				
Manufacturing/production/agriculture	0.046			
Non-office services	0.278			
Office/other/unreported/not employed	0.676			
Income below $10,000	0.016			
Household motor vehicles				
0	0.050			
1	0.295			
2	0.478			
3+	0.177			
Trip characteristics				
Trip tour				
Home-based work	0.420			
Home-based other	0.518			
Non-home based	0.062			
Travel time (transit minus car)	34	31	-43	199
Travel cost (transit minus car)	-1.36	3.53	-31.96	24.45
Environmental characteristics				
Land-use mix at origin	0.55	0.24	0.00	1.00
Kilometers to Philadelphia City Hall	24.8	14.9	0.3	71.4
Hourly parking price at destination	0.17	0.44	0.00	2.00

Variable	Share/Mean	Std Dev	Min	Max
Average bus frequency at bus stops	3.3	6.0	0.0	69.6
High-capacity rail station presence				
None	0.552			
Origin and destination	0.149			
Origin or destination	0.300			
Number of observations	**20895**			

Socioeconomic and travel data are from the Delaware Valley Regional Planning Commission's (DVRPC) (2012) household travel survey. This survey provides data on 20,216 individuals and 81,940 trips undertaken by the members of 9,235 households in Philadelphia and the surrounding suburban counties of Pennsylvania, New Jersey, and Delaware between July 2012 and September 2013. The DVRPC Office of Modeling and Analysis also provided land-use data, average parking prices, and travel times, costs, and trip distances by mode during four time periods (6AM-10AM, 10AM-3PM, 3PM-7PM, and 7PM-6AM) drawn from the 2010 TIM2.1 Travel Model, which was run in VISUM 12.5 and validated for a 2010 base year. Estimated tolls, fares, and parking charges are in 2010 dollars with an additional $0.575 operating cost assigned to each mile of car travel. The land-use entropy index includes commercial, residential, and institutional land uses and varies from zero, when there is no land-use mix, to one, when there is an equal share of all three land uses.

Bus service frequency is estimated for each transportation analysis zone using 2013 and 2015 SEPTA and NJ Transit's station-level GTFS data at the four time periods presented above. The presence of high-capacity transit is estimated by whether there is a subway, commuter rail, or trolley station within 800 meters of the centroid of a transportation analysis zone. Distances to City Hall are calculated by assigning the shortest road-network path.

The dataset and analysis exclude trips made by modes other than transit or car, trips made by individuals under 18, trips outside of the Philadelphia region, trips for which transit was not a viable alternative due to a lack of service, and trips within the same transportation analysis zone. Travel time and cost estimates by mode are not available for trips outside of the service area and within the same analysis zones. The final dataset includes 26,033 trips, of which 5,138 are selected randomly by household and set aside for model validation and testing.

3.3 Model specification

The reported model fits the data using a binomial logit model predicting the probability that an individual chooses transit or a private vehicle as a function of socioeconomic information about the trip-maker, characteristics of the trip, and land use and transportation characteristics near a trip's origin and destination. To account for unobserved correlations in the mode choice of individuals making multiple trips and members of the same household, I estimate and report cluster bootstrapped standard errors by household. The reported parameter estimates have not been transformed and correspond to an estimate of the shift in the systematic utility of transit associated with each predictor variable. Calculating the exponential function of individual parameter estimates will provide the odds-ratio for readers who prefer this measure.

To emphasize legibility and parsimony, I drop variables with low statistical significance from the model and group factor variables based on legibility and model fit prior to bootstrapping standard errors. For example, population density and job density are not included in the final models because they are not statistically significantly associated with mode choice when including data on price, travel time, vehicle ownership, and other trip characteristics. The ten income groups provided in the travel survey are grouped into a single category because only those earning less than $10,000 per year have a statistically significantly higher likelihood of choosing transit over a car when including other predictor variables. The relationships between mode choice and socioeconomic and environmental predictors, which are correlated across household members, generally weaken after bootstrapping clustered standard errors. Several are no longer statistically different from zero at the 95th or 90th percent confidence level in the final reported models. In terms of legibility, I group employment categories into three types. Including all 26 employment classifications improves model fit at the margin but takes up substantial space, reduces legibility, and creates some overfitting problems for several of the categories with limited observations.

4 Model results

The model predicting whether someone uses transit instead of a car for a given trip fits the data well with a pseudo R-squared of 0.54 and generates statistically significant parameter estimates that are consistent with the existing literature on transit ridership. Travelers from the poorest households and households without cars are more likely to use transit than those from other households. Women are less likely to use transit when controlling for other predictor variables, as are those from households with young children. These differences may reflect differences in travel patterns and safety concerns by gender and presence of young children. There is only a small and statically insignificant difference in the probability that White or Black travelers choose transit when including other covariates. Other races and ethnicities, predominantly Asian and Latin American, are more likely to choose transit than either White or Black residents. The difference, however, is not statistically significant when bootstrapping standard errors. The probability of choosing transit decreases with age and educational attainment.

Table 2. Binary logit model predicting the probability of choosing transit instead of a car for trips within the Philadelphia region

	Coefficient Estimation	**Bootstrapped standard errors**
Socioeconomic characteristics		
Age		
18 - 24	Reference	
25 - 44	-1.260***	0.222
45 - 64	-1.548***	0.214
64+	-1.762***	0.239
Unreported	-1.134	1.856
Race/Ethnicity		
White/Caucasian	Reference	
Black/African American	0.055	0.175
Other/Unreported	0.238	0.177
Educational Attainment		
High school or lower	Reference	
Associate or some college	-0.291	0.177
Bachelor	-0.370**	0.168
Graduate	-0.372**	0.165

	Coefficient Estimation	Bootstrapped standard errors
Unreported	0.708	0.939
Female	-0.304***	0.105
Child(ren) under 5 in household	-0.535**	0.213
Occupation		
Manufacturing/production/agriculture	Reference	
Non-office services	-1.061***	0.355
Office/other/unreported/not employed	-0.367***	0.115
Income below $10,000	-0.606	0.364
Household vehicles		
0	Reference	
1	-3.108***	0.196
2	-3.713***	0.201
3+	-4.099***	0.247
Trip characteristics		
Trip tour		
Home-based work	Reference	
Home-based other	0.942***	0.125
Non-home based	0.771***	0.198
Travel time (transit minus car)	-0.054***	0.005
Travel cost (transit minus car)	-0.168***	0.014
Environmental characteristics		
Land-use mix at origin	0.361*	0.204
Kilometers to Philadelphia City Hall	-0.009*	0.005
Hourly parking price at destination	0.647***	0.068
Average bus frequency at bus stops	0.020***	0.005
High-capacity rail station presence		
None	Reference	
Origin and destination	1.629***	0.173
Origin or destination	0.635***	0.159
Constant	2.159***	0.473
Observations		20,895
Log Likelihood		-2,831
McFadden Pseudo R2		0.541

Notes: (1) Significance codes: *p<0.1; **p<0.05; ***p<0.01. (2) Bootstrapped standard errors are clustered by household.

As expected, residents are substantially more likely to choose transit when the price and speed of transit improves relative to the car. Every additional minute saved by car reduces the utility of transit by 0.05. For an average commuter, increasing the speed of transit by 10 minutes relative to car increases the odds of choosing transit by 70%. Dividing the travel time by the travel cost parameter estimate suggests that the average person is willing to spend about $20 to save an hour of travel time. In addition to overall estimated time and cost, residents are much more likely to use transit on trips that are connected by rail stations and in areas and times of day with higher bus frequency. Higher parking meter prices, a greater mix of land uses, and closer proximity to downtown Philadelphia are all also statistically associated with a higher probability of choosing transit. Whether a given feature increases or decreases the probability of taking transit, however, does not provide information about whether that feature is associated with choice or dependent ridership.

4.1 Understanding choice riders

To better understand choice ridership, I apply the model from Table 2 to generate estimates of the probability of choosing transit and summarize the data by low, middle, and high probability of transit choice (Table 3). (Appendix A provides location quotients summarizing each category relative to the full metropolitan data sample.) These categorizations best correspond to auto dependents, choice riders, and transit dependents. I draw four main findings from these groupings.

Table 3. Share or mean of socioeconomic, trip, and environmental characteristics by probability of choosing transit

	Estimated probability of choosing transit			
Variable	**0% - 100%**	**<1%**	**40% - 60%**	**>95%**
Socioeconomic characteristics				
Age				
25 - 44	0.216	0.178	0.345	0.409
45 - 64	0.459	0.472	0.415	0.330
64+	0.270	0.318	0.165	0.056
Unreported	0.004	0.003	0.003	0.000
Race/Ethnicity				
Black/African American	0.072	0.030	0.174	0.242
Other	0.078	0.062	0.104	0.135
Educational Attainment				
Associate degree or some college	0.195	0.198	0.175	0.181
Bachelor	0.306	0.331	0.264	0.298
Graduate	0.317	0.310	0.380	0.256
Unreported	0.005	0.003	0.014	0.000
Female	0.553	0.574	0.491	0.484
Child(ren) under 5 in household	0.084	0.091	0.073	0.042
Occupation				
Manufacturing/production/agriculture	0.046	0.063	0.023	0.000
Non-office services	0.278	0.270	0.266	0.251
Income below $10,000	0.016	0.003	0.042	0.205
Household vehicles				
1	0.295	0.203	0.500	0.028
2	0.478	0.556	0.252	0.033
3+	0.177	0.239	0.049	0.000
No car	0.050	0.002	0.199	0.940
Trip characteristics				
Trip tour type				
Home-based work	0.420	0.332	0.674	0.544
Non-home based	0.062	0.044	0.082	0.153
Travel time (transit minus car)	34.417	51.258	4.655	-2.760

	Estimated probability of choosing transit			
Variable	**0% - 100%**	**<1%**	**40% - 60%**	**>95%**
Travel cost (transit minus car)	-1.362	-0.845	-2.552	-2.340
Environmental characteristics				
Land-use mix at origin	0.550	0.479	0.737	0.795
Kilometers to Philadelphia City Hall from residence	24.786	31.072	9.586	5.691
Hourly parking price at destination	0.169	0.031	0.734	1.052
Average bus frequency by station	3.288	1.528	10.498	13.699
High-capacity rail station presence				
Origin and destination	0.149	0.003	0.689	0.930
Origin or destination	0.300	0.184	0.262	0.070
Number of observations	**20895**	**10827**	**576**	**215**
Share of data sample	**1**	**0.518**	**0.028**	**0.010**

First, many of the socioeconomic factors associated with the literature's definitions of transit dependency are much more common for choice riders than for the general population. Choice riders are substantially more likely to be non-White, low income, and carless than other residents of the Philadelphia region. For example, 17% of the sample of choice riders are Black compared to 7% of the total sample and 3% of auto dependents. Although just 4% of choice riders earn less than $10,000 per year, that share is almost 3 times higher than the total sample and 12 times higher than the sample of auto dependents. Choice riders are 1.6 and 4.0 times likelier to have one car or no car than the metropolitan sample average.

Second, there is substantial diversity within the group of choice transit riders. There are low-income bus users and high-income commuter rail users. There are old, young, male, female, Black, White, Asian, and Hispanic choice riders. Some have graduate degrees while others have not completed high school. Some have multiple cars. Others have none. Some work in downtown office jobs while others have retail jobs outside of Philadelphia. The strongest commonality across choice riders is that transit is generally competitive with the car in terms of cost, travel time, and convenience. Differences in the share of choice riders using transit for trips to and from work may also partially reflect transit service's general orientation toward serving job centers and peak travel hours.

This leads directly to the third main finding that transit service quality is critical to choice ridership. The travel time difference between transit and cars is just 4.5 minutes for choice riders compared to 51 minutes for auto dependents and 34 minutes for the total sample. On average, an auto dependent would need to have a value of time of less than a dollar per hour to choose transit. Choice transit riders have rail stations near the origins and destinations of their trips for two-thirds of all trips and have nearby buses arriving every six minutes on average. They are also more likely to be traveling in places with diverse land uses that are close to downtown Philadelphia. In terms of the predictive models, the measures of transit service quality are substantially stronger and more statistically significant predictors of transit use than socioeconomic predictors. Low-income and minority residents, like wealthier White residents, generally only choose transit when service quality is high. The early definitions of choice transit ridership are correct in that choice riders will choose private cars over transit when service quality is low. These definitions, however, miss that many choice riders do not have a car but will borrow one or get a ride from friends, family, and coworkers. Across the entire sample, carless travelers used cars for 38% of all trips.

Fourth and finally, transit dependents who use transit regardless of service quality because they are low income or do not own a car appear to be rare. Just 31 trips (0.015% of the sample) had a greater than 99% chance of being by transit. Due to the small number of absolute trips in this category, I expand the column to include trips with over 95% probability of being taken by transit. While these were more likely to be taken by low-income and minority residents without cars, these trips also had the highest quality transit options in the dataset. Wealthy White residents with multiple cars also have a high likelihood of taking transit when buses arrive every 5 minutes, high speed rail connects both trip ends, parking is expensive, and transit is both faster and less expensive than driving. When buses arrive infrequently and there is no high-capacity rail, most of the sample moves by car, regardless of race, income, gender, education, or the number of household vehicles. As a result, the probability of residents choosing transit is substantially higher when they live in the urban core, where service quality is high for a high share daily travel (Figure 1.) Of the more than five thousand trips with below average transit service, just 36 were made by transit. Of note, White residents with one or more cars took most of these trips.

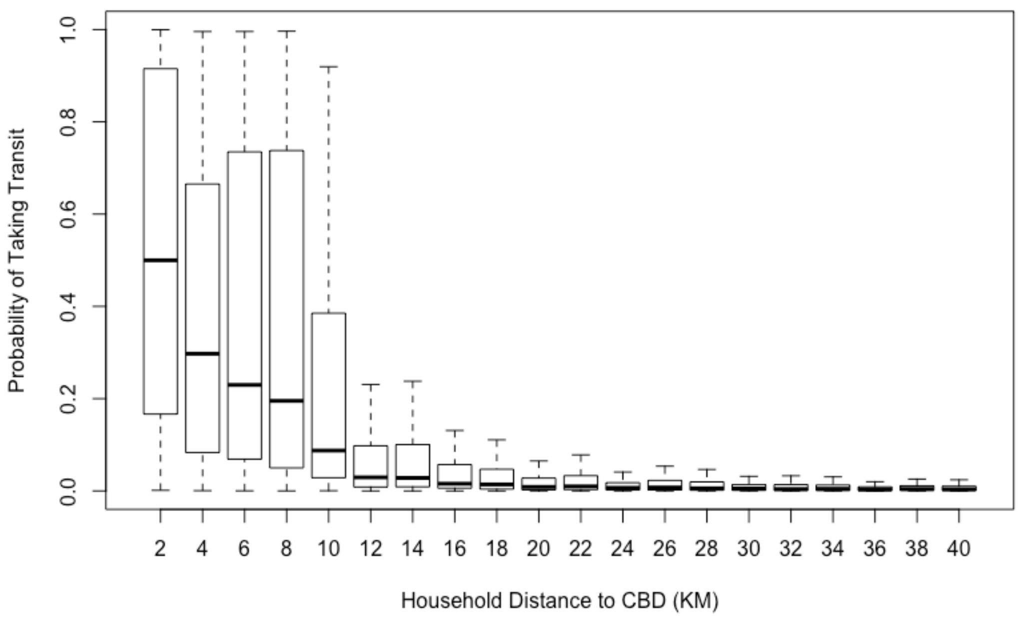

Figure 1. Estimated probability of choosing transit by how far a traveler lives from Philadelphia City Hall

Two caveats apply to this broad observation about the rarity of transit dependents. First, just because low-income individuals without cars are not systematically transit dependent does not mean that there are not individuals who depend partially or entirely on transit to meet their daily and weekly needs. That no one can depend on transit where no service exists does not contradict the fact that low-income, carless travelers are more likely to use transit despite worse service than others. For the two-thirds of transit trips taken by carless low-income survey respondents, a private car would have been 12 minutes faster than transit on average. While this is a much smaller differential than the sample average of 34 minutes, it is also much larger than the 4.7-minute average for choice riders. Second, the research design is focused on identifying choice riders rather than transit dependents. Those who most depend on transit despite poor transit service are probably more likely to be choosing between taking transit and deferring a trip than between taking transit and taking a car. Living without a car in an area with poor transit service quality almost certainly reduces travel and constrains access to employment, school, shopping, recreation, and other important destinations.

4.2 A note on residential self-selection and vehicle ownership

Due to issues of residential self-selection (Cao et al., 2009; Handy et al., 2005), it is difficult to say by how much increasing or reducing transit services into specific neighborhoods would affect transit ridership. For example, residents in auto-dependent neighborhoods may be particularly disinterested in transit and unlikely to choose transit even if service levels improve. These unobserved preferences for and against travel modes might influence the size and significance of the parameter estimates presented in Table 2. Although the model does not include controls for preferences beyond a robust set of socio-economic predictors, accounting for preferences would likely strengthen the overall finding that: (1) features commonly associated with dependent riders are more prevalent among choice riders than the general population; (2) transit service quality is critical for choice ridership; and (3) people who choose transit regardless of service quality appear to be exceedingly rare. Lower-income households without cars are least able to make travel and housing decisions to match their personal preferences.

Vehicle ownership decisions are also highly related to mode choice decisions. People who do not like to drive, for example, are unlikely to purchase a car. Including vehicle ownership likely attenuates the strength of income and other predictor variables that are associated with both vehicle ownership and mode choice. I include vehicle ownership directly in the model for two primary reasons. First, vehicle ownership is the most common defining characteristic of choice ridership in the literature and thus an essential predictor variable. Second, the research design is focused on predicting transit ridership rather than assessing the causal determinants of transit ridership. Vehicle ownership is a strong predictor of mode choice even after including variables on trip characteristics and travelers. A model focused on causal relationships would require a different modeling approach.

5 Conclusion

In this paper, I develop a theoretical model of choice ridership and apply it to data from a travel survey in the Philadelphia region using a random utility model. The Philadelphia region, which has substantial bus service in low-income urban neighborhoods and high-capacity commuter rail service in wealthy suburban neighborhoods, is an ideal place to study dependent and choice ridership. The reported model produces relatively strong predictions of whether individuals choose transit or a private vehicle for trips outside of their neighborhood that start and end within the region. The model also produces individual parameter estimates that are consistent with the existing literature on mode choice and willingness to pay for travel time savings. Low-income urban residents with no car and who are commuting to work in areas with high-quality transit service and costly parking prices are particularly likely to travel by transit.

Based on these models of transit ridership, I analyze features that are most common across choice riders. Many of the attributes assumed to be associated with dependent riders, such as a lack of a car, low income, and being a racial or ethnic minority, are much more prevalent among choice riders than the general metropolitan population. Moreover, transit dependency is rare. Residents generally only choose transit when service is high quality and transit is cost and time competitive with the car for a given trip. Those without cars frequently borrow a car or get a ride with family, friends, or colleagues.

Based on these findings, researchers and policymakers should avoid undertheorized and under analyzed descriptions of choice and dependent riders. The prevailing descriptions of choice and dependent riders are inaccurate and may divert investments and service improvements away from riders who are most likely to choose transit for more trips as service improves. The analysis of choice riders, moreover, suggests that there may be opportunities to differentiate across types of choice riders. For example, some may be particularly sensitive to travel time and service frequency, while others may be more sensitive to the price of parking or the ease of access to commuter and heavy rail stations. Latent-class choice modeling may offer opportunities to better understand whether there are important and systematic differences in choice riders, by location, income, and other features.

The findings also suggest that the debate between using transit investments to reduce automobile use or increase accessibility for low-income transit users is largely misplaced. Improving urban bus service into low-income neighborhoods almost certainly attracts people out of cars. Future analysis could help shed light on the relative costs and benefits of attracting specific types of trips from specific locations. Suburban commuter rail trips, for example, may be more expensive to attract, but they are also more likely to replace longer-distance car trips. Urban bus trips may replace shorter car trips, but these trips may occur on relatively congested local urban streets. These shorter car trips may also be relatively harmful if they are likelier to occur in older vehicles that produce more local pollution and crash with higher frequency and severity. In any case, focusing transit policy on expanding its existing customer base, who tend to live in the urban core where service quality is already relatively high, is probably the most cost-effective way to draw new riders.

Finally, even in a transit-friendly region like Philadelphia, most residents live and travel in areas where transit is simply not a reasonable option. Across our sample, taking a trip by car saves an average of 34 minutes per trip. For the 51% of the sample with a lower than 1% chance of taking transit, the difference is nearly an hour per trip. Attracting auto dependents to transit through either transit investments or land-use policy therefore is likely to be prohibitively expensive and time-consuming. Unless new technologies or business models can make transit competitive with cars on these types of trips, focusing investments into urban areas with high concentrations of high-probability transit riders will not only improve service for existing users, but likely do the most to draw riders out of cars.

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Data availability

Guerra, E. (2022). Choice ridership data. Harvard Dataverse. https://doi.org/10.7910/DVN/EP2UV4

Appendix

Appendix available at https://www.jtlu.org/index.php/jtlu/article/view/2096.

References

Bates, J. (1981). *Case study VI: Marketing in marta* (DOT-I-81-1 Final Rpt.; Mass transit management: Case studies of the metropolitan Atlanta Rapid Transit Authority). Athens, GA: University of Georgia. Retrieved from https://rosap.ntl.bts.gov/view/dot/527

Beimborn, E. A., Greenwald, M. J., & Jin, X. (2003). Accessibility, connectivity, and captivity: Impacts on transit choice. *Transportation Research Record, 1835*(1), 1–9. https://doi.org/10.3141/1835-01

Ben-Akiva, M., & Lerman, S. (1985). *Discrete choice analysis: Theory and application to travel demand* (1st ed.). Cambridge, MA: MIT Press.

Blumenberg, E., & Smart, M. (2014). Brother can you spare a ride? Carpooling in immigrant neighborhoods. *Urban Studies, 51*(9), 1871–1890.

Brown, J., Thompson, G., Bhattacharya, T., & Jaroszynski, M. (2014). Understanding transit ridership demand for the multidestination, multimodal transit network in Atlanta, Georgia: Lessons for increasing rail transit choice ridership while maintaining transit dependent bus ridership. *Urban Studies, 51*(5), 938–958. https://doi.org/10.1177/0042098013493021

Cai, M., Jiao, J., Luo, M., & Liu, Y. (2020). Identifying transit deserts for low-income commuters in Wuhan Metropolitan Area, China. *Transportation Research Part D: Transport and Environment, 82,* 102292. https://doi.org/10.1016/j.trd.2020.102292

Cao, X., Chen, H., Liang, F., & Wang, W. (2018). Measurement and spatial differentiation characteristics of transit equity: A case study of Guangzhou, China. *Sustainability, 10*(4), 1069. https://doi.org/10.3390/su10041069

Cao, X., Mokhtarian, P. L., & Handy, S. (2009). Examining the impacts of residential self-selection on travel behavior: A focus on empirical findings. *Transport Reviews, 29*(3), 359–395. https://doi.org/10.1080/01441640802539195

Cervero, R. (1981). Flat versus differentiated transit pricing: What's a fair fare? *Transportation, 10*(3), 211–232. https://doi.org/10.1007/BF00148459

Cheranchery, M. F., & Maitra, B. (2018). Investigating perception of captive and choice riders for formulating service standards of ordinary and premium buses in Indian cities. *Transport Policy, 72*, 89–96. https://doi.org/10.1016/j.tranpol.2018.10.002

Chia, J., Lee, J., & Kamruzzaman, M. (2016). Walking to public transit: Exploring variations by socioeconomic status. *International Journal of Sustainable Transportation, 10*(9), 805–814. https://doi.org/10.1080/15568318.2016.1156792

Clark, W. A., & Wang, W. W. (2010). The automobile, immigrants, and poverty: Implications for immigrant earnings and job access. *Urban Geography, 31*(4), 523–540.

Delaware Valley Regional Planning Commission. (2012). *2012-2013 household travel survey for the Delaware Valley region.* Retrieved from https://www.dvrpc.org/Products/14033/

Elkind, E. (2014). *Railtown: The fight for the Los Angeles Metro Rail and the future of the city.* Berkeley, CA: University of California Press. https://www.ucpress.edu/book/9780520278271/railtown

Federal Transit Administration. (n.d.). *About FTA.* Retrieved from https://www.transit.dot.gov/about-fta

Giuliano, G. (2005). Low income, public transit, and mobility. *Transportation Research Record, 1927*(1), 63–70. https://doi.org/10.3141/1927-08

Google. (2021). *Google books ngram viewer.* Retrieved from https://books.google.com/ngrams#

Grengs, J. (2001). Does public transit counteract the segregation of carless households? Measuring spatial patterns of accessibility. *Transportation Research Record, 1753*(1), 3–10. https://doi.org/10.3141/1753-01

Grengs, J. (2002). Community-based planning as a source of political change: The transit equity movement of Los Angeles' Bus Riders Union. *Journal of the American Planning Association, 68*(2), 165–178. https://doi.org/10.1080/01944360208976263

Haines, R. L. (1978). The politics of economics in transit planning. *Urban Affairs Quarterly, 14*(1), 55–77. https://doi.org/10.1177/107808747801400103

Handy, S., Cao, X., & Mokhtarian, P. L. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment, 10*(6), 427–444. https://doi.org/10.1016/j.trd.2005.05.002

Hepp, J. (2018). SEPTA. In *Encyclopedia of Greater Philadelphia. Mid-Atlantic Regional Center for the Humanities.* Retrieved from https://philadelphiaencyclopedia.org/archive/septa/

Jacques, C., Manaugh, K., & El-Geneidy, A. M. (2013). Rescuing the captive [mode] user: An alternative approach to transport market segmentation. *Transportation, 40*(3), 625–645. https://doi.org/10.1007/s11116-012-9437-2

Jiao, J. (2017). Identifying transit deserts in major Texas cities where the supplies missed the demands. *Journal of Transport and Land Use, 10*(1), 529–540.

Jiao, J., & Dillivan, M. (2013). Transit deserts: The gap between demand and supply. *Journal of Public Transportation, 16*(3), 23–39. https://doi.org/10.5038/2375-0901.16.3.2

Jiao, J., & Wang, F. (2020). Shared mobility and transit-dependent population: A new equity opportunity or issue? *International Journal of Sustainable Transportation, 15*(4), 1–12. https://doi.org/10.1080/15568318.2020.1747578

Keefer, L., Witheford, D., Thomas, S. J., Schwartz, A., Kolesar, E. R., Cominsky, R., … & Carroll, J. D. (1963). *Pittsburgh area transportation study: Final report in two parts. Volume 2 Forecasts and plans.* Pittsburgh, PA: Commonwealth of Pennsylvania, County of Allegheny, City of Pittsburgh, and U.S. Department of Commerce: Bureau of Public Roads.

King, D. A., Smart, M. J., & Manville, M. (2019). The poverty of the carless: Toward universal auto access. *Journal of Planning Education and Research,* 0739456X18823252. https://doi.org/10.1177/0739456X18823252

Klein, N. J., Tran, M., & Riley, S. (2019). *Desperately in need of car: Analyzing crowdfunding campaigns for car purchases and repairs on gofundme.com* [Preprint]. Retrieved from https://doi.org/10.31235/osf.io/8x7d2

Krizek, K., & El-Geneidy, A. (2007). Segmenting preferences and habits of transit users and non-users. *Journal of Public Transportation, 10*(3), 71–94. https://doi.org/10.5038/2375-0901.10.3.5

Lachapelle, U., Frank, L. D., Sallis, J. F., Saelens, B. E., & Conway, T. L. (2016). Active transportation by transit-dependent and choice riders and potential displacement of leisure physical activity. *Journal of Planning Education and Research, 36*(2), 225–238. https://doi.org/10.1177/0739456X15616253

Lovejoy, K., & Handy, S. (2011). Social networks as a source of private-vehicle transportation: The practice of getting rides and borrowing vehicles among Mexican immigrants in California. *Transportation Research Part A: Policy and Practice, 45*(4), 248–257.

Lubitow, A., Rainer, J., & Bassett, S. (2017). Exclusion and vulnerability on public transit: Experiences of transit dependent riders in Portland, Oregon. *Mobilities, 12*(6), 924–937. https://doi.org/10.1080/17450101.2016.1253816

Makarewicz, C., & Németh, J. (2018). Are multimodal travelers more satisfied with their lives? A study of accessibility and wellbeing in the Denver, Colorado metropolitan area. *Cities, 74,* 179–187. https://doi.org/10.1016/j.cities.2017.12.001

Márquez, L., Pico, R., & Cantillo, V. (2018). Understanding captive user behavior in the competition between BRT and motorcycle taxis. *Transport Policy, 61*, 1–9. https://doi.org/10.1016/j.tranpol.2017.10.003

McFadden, D. (2001). Economic choices. *The American Economic Review, 91*(3), 351–378.

Polzin, S., Chu, X., & Rey, J. (2000). Density and captivity in public transit success: Observations from the 1995 nationwide personal transportation study. *Transportation Research Record, 1735*(1), 10–18. https://doi.org/10.3141/1735-02

Rogalsky, J. (2010). Bartering for basics: Using ethnography and travel diaries to understand transportation constraints and social networks among working-poor women. *Urban Geography, 31*(8), 1018–1038.

Sohn, K., & Yun, J. (2009). Separation of car-dependent commuters from normal-choice riders in mode-choice analysis. *Transportation, 36*(4), 423–436. https://doi.org/10.1007/s11116-009-9209-9

Sun, T., & Fan, Y. (2018). Inequitable job accessibility across educational and hukou groups in Beijing: An analysis of transit-based accessibility to sectoral jobs. *Journal of Transport and Land Use, 11*(1), 791–803.

Taylor, B. D., & Morris, E. A. (2015). Public transportation objectives and rider demographics: Are transit's priorities poor public policy? *Transportation, 42*(2), 347–367. https://doi.org/10.1007/s11116-014-9547-0

Thompson, G., Brown, J., & Bhattacharya, T. (2012). What really matters for increasing transit ridership: Understanding the determinants of transit ridership demand in Broward County, Florida. *Urban Studies, 49*(15), 3327–3345. https://doi.org/10.1177/0042098012443864

Train, K. (2009). *Discrete choice methods with simulation* (2nd ed.). Cambridge, UK: Cambridge University Press. http://elsa.berkeley.edu/books/choice2.html

U.S. Department of Transportation. (2017). *National household travel survey.* Retrieved from http://nhts.ornl.gov/

van Lierop, D., & El-Geneidy, A. (2016). Enjoying loyalty: The relationship between service quality, customer satisfaction, and behavioral intentions in public transit. *Research in Transportation Economics, 59*, 50–59. https://doi.org/10.1016/j.retrec.2016.04.001

Wells, K., & Thill, J.-C. (2012). Do transit-dependent neighborhoods receive inferior bus access? A neighborhood analysis in four U.S. cities. *Journal of Urban Affairs, 34*(1), 43–63. https://doi.org/10.1111/j.1467-9906.2011.00575.x

Zhao, J., Webb, V., & Shah, P. (2014). Customer loyalty differences between captive and choice transit riders. *Transportation Research Record, 2415*(1), 80–88. https://doi.org/10.3141/2415-09