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Does Bundled Parking Influence Travel Behavior?

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Does Bundled Parking Influence Travel Behavior?

A thesis submitted in partial satisfaction

of the requirements for the degree Master

of Urban and Regional Planning

by

Miriam Julia Pinski

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ABSTRACT OF THE THESIS

Does Bundled Parking Influence Travel Behavior?

by

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Master of Urban and Regional Planning

University of California, Los Angeles, 2018

Professor Michael K. Manville, Chair

Parking requirements hide the cost of storing a vehicle in housing costs, making driving a more attractive option for vehicle owners than using alternative modes of transportation. While researchers have already identified the link between vehicle ownership and use with bundled parking, no study that I am aware of has used detailed national-level data to study the link between bundled parking and the use of other transportation modes. In this study I use data from the 2013 American Housing Survey to determine if the presence of bundled parking is associated with a household's transportation mode choice. After controlling for differences in socioeconomic and built environment characteristics, I find that the presence of bundled parking is associated with a 27 percent increase in vehicle miles traveled. Bundled households drive approximately 3,800 miles more, spend nearly $580 more on gasoline, and emit 14.47 more metric tons of carbon dioxide per year. Bundled parking is also negatively correlated to transit

use, and households with unbundled parking are significantly more likely to be frequent transit users. This provides further evidence for the already strong case against parking requirements.

The thesis of Miriam Julia Pinski is approved.

Martin Wachs

Donald C. Shoup

Michael K. Manville, Committee Chair

University of California, Los Angeles

2018

Dedication

To my parents.

Table of Contents

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CHAPTER 1: INTRODUCTION

Driving provides important benefits to people by increasing individual mobility which, in turn, contributes to regional economic productivity. Access to a personal vehicle, for example, can help low-income households get and maintain employment (Blumenberg and Pierce, 2014). However, the benefits of driving also come with environmental costs. The transportation sector contributes approximately one third of all man-made greenhouse gas emissions, and it is a priority among policymakers and researchers to curb emissions in a cost-effective and equitable manner. Reducing the demand for discretionary trips by personal vehicle is one mechanism to decrease emissions. Academics and policy makers debate whether decreasing demand for driving should primarily be accomplished by enticing drivers to switch modes by offering attractive substitutes (such as light rail), or to discourage driving by making vehicle ownership and use more costly.

Residential bundled parking, which occurs when the cost of parking is combined with the cost of housing – the cost of parking spaces is included in the rent or sales price of the unit and parking is presented as “free”. This incentivizes driving by obscuring the true cost of vehicle ownership and use (Manville, 2017). Bundled parking lowers the cost of car ownership by reducing the time and energy associated with searching for parking. Further, it lowers the perceived cost of car ownership because bundled parking hides a cost of vehicle ownership in housing costs. A previous study confirms the positive relationship between bundled parking and vehicle ownership (Manville 2017). The purpose of this study is to test for a relationship between access to bundled parking and household transportation mode choice and use.

Specifically I use regression analyses to test for two relationships:

1. Is bundled parking associated with how often a household drives?
2. Does bundled parking affect whether a household uses alternative modes of transit? Does bundled parking change the frequency with which a household uses alternative modes of transit?

To answer these questions I use the 2013 American Housing Survey, a nationwide panel survey of American housing units conducted in the spring every two years by the U.S. Census Bureau. Survey questions include "core" subjects, covering the physical condition of units, housing costs, and demographic information on respondents. I used the 2013 survey, as it is the only survey year that includes additional modules with questions about public transportation and characteristics of the local built environment.

I hypothesize that households whose residences provide bundled parking are more likely to drive, and less likely to use alternative travel modes, than comparable households that do not have access to bundled parking. A study by Zhan Guo (2013) found that households that are guaranteed a parking spot at home are more likely to drive than to use other travel modes, take more trips by car, and generate more VMT. As a conservative estimate, I expect that nationwide the car mode share among households with bundled parking will be five percent greater than households without bundled parking.

CHAPTER 2: SIGNIFICANCE

Policymakers and planners often support offering ecologically-friendly alternatives to driving. These policies often take the form of improved public transportation systems, active transportation infrastructure, and a dense built environment that reduces the distances between destinations. Higher density development surrounding public transit, however, may not be an effective remedy for vehicle use. Abundant "free" parking contributes to vehicle ownership. This study examines the effect that bundled parking may have on a household's mode choice.

Given the high cost of creating transit infrastructure and altering the built environment, it is important to investigate whether parking regulations influence a household's decision to drive or to take alternative modes. Previous studies have primarily researched New York City and San Francisco, cities that are outliers in terms of travel behavior and residential density. This study will contribute to the research on bundled parking by offering a nationwide analysis. It will also include non-rail transit modes that have not been included in research on bundled parking, including commuter vans, bus, subway, carpool, car sharing, and other public transportation options. More broadly, this study aims to improve the body of knowledge surrounding policies that aim to decrease automobile VMT and the resulting emissions.

CHAPTER 3: LITERATURE REVIEW

In an effort to combat climate change, policymakers and researchers are divided as to how to reduce transportation sector emissions, which make up approximately one third of greenhouse gas emissions. Policies aimed at reducing VMT can either offer substitutes to driving a personal vehicle, or reduce the demand for driving by making it more expensive. Many recent policies aim to reduce driving by expending resources to improve transit systems and developing a dense built environment with shorter distances between trip origins and potential destinations. While offering the public substitutes to driving is an attractive option to planners, a more effective way to directly reduce VMT is to make driving more expensive, which can be achieved through various policies including pricing parking.

Offering Substitutes to Reduce Driving

Transit-Oriented Developments (TOD) were built in response to American household reliance on cars, which have increased congestion, driven up commute times, worsened the air quality, and contributed to global warming. TOD attempts to slow or reverse "sprawl", by increasing the density of new land development and infill redevelopment (Chatman, 2008). This new development allows residents to travel shorter distances between trip origins and destinations. The purpose of TOD is to limit automobile reliance by increasing the availability and accessibility of more sustainable modes of travel (Van Lierop et al.) Reducing driving is not, however, the sole purpose of TOD. Advocates cite many benefits of TOD, including making more enjoyable walking environments, increasing transit's market share, and improving public safety by lowering the speed of road travel (Chatman, 2008).

The choice to make discretionary trips by car is influenced by the availability and convenience of alternative transportation modes. For vehicle owners making discretionary trips, access to fast, frequent and reliable transit service with fewer transfer requirements strongly correlate with car-owners' transit mode choice; home and workplace density, proximity to transit stop, and availability of rail are other factors that facilitate/promote discretionary transit use (Chakrabarti, 2016). People living in TODs make more trips by all modes of transportation but fewer trips by auto (Nasri et al., 2014). TOD residents travel shorter distances by all modes, which implies they are choosing destinations that are closer for all their activities. Cervero et al. found that households that live near rail stations use transit, especially rail, at a substantially higher rate than households living further away (Cervero et al., 2002). Rowe et al. found a relationship between the level of transit service and parking demand (Rowe et al., 2011). Transit service and car use are connected: in places with higher levels of transit services, parking demand was lower.

The built environment, and distances between trip origins and destinations, affect mode choice, in particular they affect vehicle ownership and use. Households that are located near high-rise apartments, retail and employment centers are less likely to own a vehicle than are households who live in single-family detached homes (Manville, 2017). Kain (1967), as well as Ewing and Cervero (2001) found that a built environment with higher density development correlates with lower auto ownership and use.

The limitations of offering mode substitutes

A densely built transit accessible environment may not achieve substantial gains in reducing driving without the presence of other factors. According to Chatman, 2008, "dense development will not influence travel very much unless road level-of-service standards and parking requirements are reduced or eliminated." Any reduction in driving that does result from household proximity to transit may be negligible. A meta analysis conducted by Ewing and

Cervero, 2010, found that average elasticity of vehicle use with respect to transit proximity was both small and not statistically significant. A more significant contributing factor to vehicle ownership and use than transit is the presence of small rental units, parking availability, and distance to retail, housing, the downtown, and employment centers (Chatman, 2013).

Reducing driving by making it more expensive

Land use and capital devoted to parking can affect the density of the built environment, which in turn affects the type of transportation residents choose. When developers construct housing, they are required by zoning codes and building regulations to provide parking spaces based on the number of units in the building. Constructing housing is more affordable with fewer parking spaces. Parking minimums incentivize lower density development, which in turn increases the distances between destinations and makes it more necessary to drive further distances (Manville et al., 2013). Parking policies that require a minimum number of parking spaces reduce both the population and development density and thereby reduce accessibility to destinations (Manville et al., 2013). Manville et al., 2013, found a strong and positive association between residential parking minimum requirements and the density, presence and use of vehicles, as well as a negative association between population density and housing density. Boarnet and Crane, 2001, also found that as population density grows, vehicle ownership and use per person decreases. In places where development is dense and parking is relatively scarce (and more expensive), the mode share for transit is higher among trips heading toward the downtown (Hess, 2001; Weinberger et al., 2009).

Parking requirements incentivize driving by making it more convenient. The type of parking a person has access to influences their driving behavior. Weinberger, 2012, found that on-site private parking reduces the time and effort spent searching for parking ("search costs").

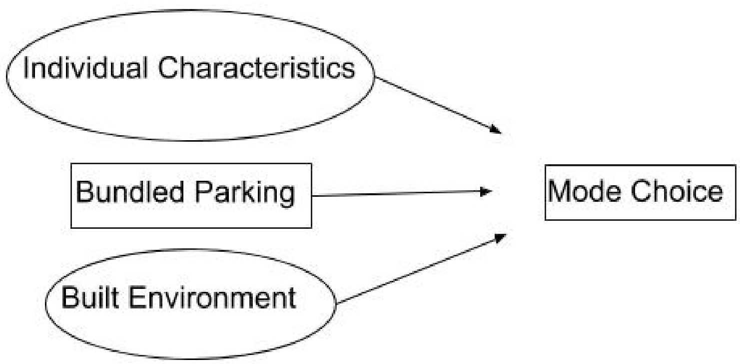
In particular, access to parking that is adjacent to the home, such as a driveway or garage, is more likely to generate driving trips to work than parking in a commercial off-site lot, which may require valet notification and additional time spent walking home. The study found that a person's decision to drive to work is influenced by whether parking is guaranteed in their residence. Weinberger infers that guaranteed residential parking likely encourages driving for non-work trips as well.

Parking requirements encourage vehicle ownership and use by obscuring the true cost of vehicle ownership in the cost of housing, and reducing the total cost of vehicle ownership (Shoup, 2005). The opportunity cost of owning a vehicle in a housing unit that includes a parking space is reduced, as choosing to forgo owning a vehicle will not reduce the amount a household spends on residential parking. The total cost of owning a vehicle is also partially subsidized by non-vehicle owners in the housing unit, who must pay for the construction of parking spots they do not use. Even if every resident of a unit owned a vehicle, the cost of owning that vehicle is hidden within the cost of housing, which makes vehicle ownership seem less expensive than it really is.

Parking that is included in the cost of housing is associated with increased auto ownership and use (Manville, 2017). Households that do not have access to bundled parking are 60-80% more likely to not own a vehicle than households that do have bundled parking. Bundling the cost of parking into the cost of housing is a more common practice in regions where parking minimum requirements are higher and developers must shift the high cost of constructing parking onto residents (Manville, 2017). Manville, 2017 finds a strong, largely causal relationship between bundled parking and vehicle ownership. Households on the margin of vehicle ownership are more likely to own a car if the cost of parking is bundled.

CHAPTER 4: CONCEPTUAL MODEL

I am testing the hypothesis that having access to bundled parking is associated with transportation mode choice.



The model above depicts the various factors that influence whether a household has access to bundled parking, and how bundled parking may in turn influence a household's mode choice. The circled terms are control variables in my model. The terms in boxes represent the dependent (transit use) and independent (bundled parking) variables. Below I will define the variables and briefly outline how they interact in this model:

Factors that influence whether a household has access to bundled parking:

- *Individual Characteristics*: these include socio-demographic factors. Income, for example, is an important determinant of vehicle ownership. Bundled parking is also associated with higher housing costs, because the cost of constructing parking spaces is included in the rent (Gabbe, Pierce and Crane, 2017). If a person is unable to afford a vehicle, or to pay the cost of an apartment that is too expensive, then they may be unlikely to have access to bundled parking.

- *Built Environment*: this takes into account a household's proximity to transit and other destinations, as well as the characteristics of the neighborhood, such as the type of nearby residential units. The built environment can affect the availability, price, and type of parking. A dense built environment in which property values are high and there is limited land available typically has a more limited quantity of land devoted to parking compared to an environment in which land is cheap and building are at low densities.
- *Bundled Parking*: When the cost of a housing unit includes the price of parking. Parking regulations vary depending on geography, and influence the availability of bundled parking. In cities that have low parking requirements (such as New York City), bundled parking is more uncommon than in regions that have high parking requirements (such as Los Angeles).
- *Mode Choice*: The type of transportation mode a household chooses, and the frequency with which the household uses that mode.

My model tests for the association between access to bundled parking and mode choice. Mode choice is affected by all of the factors in the model:

- *Bundled Parking*: The availability of bundled parking may influence mode choice. If parking is free and conveniently located close to the housing unit, potential drivers may choose to drive more frequently because they do not have to spend a great deal of time searching for parking or additional money paying for parking fees.

- *Individual Characteristics*: Transportation mode is highly correlated with various socio-demographic factors, such as income, race, and vehicle ownership. For example, if a person is unable to afford a vehicle, they have few transportation substitutes and must ride transit more frequently than someone who owns a vehicle and can choose whether to drive or not. Mode is also, to a certain extent, a matter of personal preference. For example, if a person enjoys using transit and prefers it to driving, then their personal preference is clearly influencing their transit use.
- *Built Environment*: The built environment can determine which transportation mode is the most efficient in terms of time, cost, and convenience. Whether transit is easily accessible (closely located and convenient to reach) and attractive to use (such as whether headways are frequent and travel time is comparable to driving) can determine transit use. If there are numerous transit routes in a region that are frequent and fast, a person will be more likely to view transit as a substitute for driving than if transit is infrequent and slow.

CHAPTER 5: DATA MEASUREMENT

I use the 2013 American Housing Survey, a panel survey of American housing units conducted in the spring every two years by the U.S. Census Bureau. The AHS has been collected since 1973 (albeit under a different name, the "Annual Housing Survey"), but was redesigned in 1985 to better reflect the 1980 decennial census. The survey is primarily used by the government to determine changes in housing supply and demand, and to inform its housing programs. A public version of the survey results is available with certain variables concealed so as to maintain the anonymity of respondents. Survey questions include "core" subjects, covering the physical condition of units, housing costs, and demographic information on respondents. Additional topical modules are also included which change depending on the year. I used the 2013 surey, as it is the only survey year in which one of the additional topical modules included questions related to public transportation and characteristics of the local built environment.

The AHS includes both metropolitan samples that are representative of selected metro areas as well as a nationally-representative sample. The housing units are selected to represent a cross section of housing across the country. Each unit is weighted based on independent estimates of housing units, and the weights are meant to minimize the effects of sampling error and to ensure that analyses of the results do not over-represent certain demographic groups, geographic regions, and housing unit types.

To reduce the burden of extra questions on respondents, half of the respondents are randomly selected to answer half the topical module questions, and the other half respond to the remaining topical questions. Respondents include household occupants (renters and owners who are at least 16 years of age) and landlords, real estate agents or knowledgeable neighbors who can accurately answer questions about vacant units. Since 1997 the data have been collected by computer-assisted personal interviewing, and data collection is limited to English and Spanish speakers (a Spanish version of the survey was first introduced in 2009).

CHAPTER 6: SAMPLE SIZE AND CHARACTERISTICS

The 2013 AHS sample size includes 70,044 interviewed units. For that year, one unit represents itself and 1,896 other units. The transportation module includes 14,490 units. The breakdown of occupancy type was: 57% of sampled units were owner-occupied, 30.3% were renter-occupied, 9.7% were vacant, and 3.1% were units occupied on a seasonal basis. Detached, single-family units make up the majority of the survey (64.2%).

Table 1 compares summary statistics of the module and of the entire AHS. The results are very similar, and establish that the public transportation module is a representative sample of the survey as a whole, which was created to be nationally-representative.

Table 1: Basic Overview of the 2013 AHS

Basic Overview of 2013 AHS	All Units	Units in Module
Total Number of Units	40,710	14,490
% Rental Units	29%	34%
% Rental Units with Poor Tenants	24%	23%
% Rental Units with Off-Street	48%	47%
% Rental Units with Garage	39%	39%
% Units with Bundled Parking	93%	93%
% Rental Units with Bundled Parking	87%	87%
% Mobile Home	7%	6%
% Single-Family Home	67%	69%
% Apartment	26%	25%
Median Cost of Rent	$787	$787

Rate of Car Ownership	81%	82%

CHAPTER 7: RELEVANT VARIABLES

I include variables that take into account household demographics (such as household income, renter status, race, vehicle ownership, household size), physical characteristics of the unit (such as whether it is a multi-story apartment building or detached single-family unit), characteristics of the local built environment (including nearby building and land use types, distance to transit, and access to bike lanes), as well as travel behavior of the respondents (such as the frequency and type of transportation mode, and household expenditures on gasoline for transportation). The specific variables, including descriptions of the survey questions and my coding of the variables, are found in the table below.

To approximate mode share and mode frequency, I use variables regarding frequency of transit use and type of transit use, as well as vehicle ownership and household gas expenditures. To determine whether a unit has bundled parking, I use the "garage" variable, which asks "Is a garage or carport included with this unit?" If the answer to this question is no, then the respondent is asked whether off-street parking is included in the rent or purchase price of the housing unit. To determine whether a unit has bundled parking, I combined the variables, and if the unit includes parking (be it off-street parking or otherwise), I coded the response as 1. I also included multiple variables to control for differences in socio-demographics and in the built environment, including household size, income, race, and distance to transit.

CHAPTER 8: LIMITATIONS OF THE DATA

Because I only have access to the public version of the survey, many variables that could provide useful geographic data are not available to me. I am only able to determine the metropolitan statistical area in which a unit is located, which limits my ability to analyze the local context for each household (such as its distance from the central business district or its local transportation network). I am also unable to combine this dataset with other data sets, such as the neighborhood index or the walkability score. The variables I am using are not as comprehensive as I would like them to be. Parking is an important variable which is limited in that I can only determine whether a unit has access to bundled parking, but not how many parking spaces the unit includes.

Further, the AHS does not give detailed descriptions of travel behavior. I must approximate car use based on vehicle ownership and household gas expenditures, which may lead to inaccurate estimations of VMT as I do not have information on the model of the household's vehicle. I must also approximate mode use based on the frequency with which respondents say they use transit, walk, or bike. Given that travel surveys and diaries are known to be inaccurate estimates of a person or household's actual travel behavior, my resulting analysis of mode share and frequency are prone to error.

CHAPTER 9: SIMILAR STUDIES

There are numerous studies that deal with travel behavior, the built environment, and access to parking. Manville, Beata and Shoup (2013) used a different year of the American Housing Survey (2002-2003) to analyze the effect of parking requirements on housing, population and vehicle densities. This analysis was done using metropolitan-level data, as opposed to the nationwide analysis I conduct. Chatman (2013) studied how residential proximity to a rail station affects auto ownership and VMT. The study created its own data set by mailing surveys to households within a 2-mile radius of 10 different rail stations in New Jersey, and collected observational data on parking availability in the area. While this data may allow for a more accurate analysis of the effect of built environment characteristics on travel behavior, it is limited to a small geographic region, whereas the AHS is nationally-representative.

Weinberger (2012) studied the effect of residential parking on commute behavior using satellite imagery from Google Maps, Google Earth, and Bing Maps to determine whether a household had a garage or driveway, as well as government data (from PLUTO and the US Census Bureau) on the square footage of housing units and the number of units from a census tract that drove to work. The study's data on access to bundled parking is less accurate than using the AHS, as it could not determine whether a unit has underground parking, and parking spots that are not clearly visible in satellite imagery were excluded. Weinberger (2013) was also unable to track individual households' travel behavior, and needed to rely on aggregate travel behavior. The AHS, while limited in providing detailed information on nearby off-street parking, does include accurate information on whether a unit has bundled parking, as well as survey data on certain travel behavior at the individual level. Manville (2017) uses AHS data to measure the effect of residential bundled parking on household vehicle ownership. Similarly, I use the AHS variables to estimate whether a household's access to bundled parking has an effect on household mode choice.

CHAPTER 10: METHODS

I conducted statistical hypothesis tests to determine whether bundled parking influences mode choice. I tested for three relationships:

1. Is bundled parking associated with whether a household uses alternative modes of transit?
2. Is bundled parking associated with the frequency with which that household drives?
3. Is bundled parking associated with the frequency with which a household uses alternative modes of transit?

The independent variable of interest is a household's access to bundled parking, and the dependent variables include variables that measure the type and frequency of transportation modes a household uses. To estimate mode choice, I have two categories of variables: one type of question is whether a household uses a certain mode or not. The second type of question is about frequency: how often does a household use a certain mode. I control for differences in access to modes (i.e. whether a household owns a vehicle), and then measure whether it uses each mode and how frequently it uses each mode. The control variables include demographic variables, such as race and household income, and geographic variables, such as distance to transit. In an appendix I list the independent, dependent, and control variables that I have access to, as well as the limitations that each variable poses.

CHAPTER 11: RESIDENTIAL SELF-SELECTION

Residential self-selection is a potential confounding variable that attributes housing choice to personal travel preferences. Bundled parking would therefore be sought out by people who prefer to drive, be avoided by people who prefer to use alternative modes, or encourage people to own a car who might otherwise forgo vehicle ownership when faced with having to purchase parking separately. People who choose housing based on travel preferences are especially sensitive to the built environment (i.e. people who choose their housing based on their desire to walk or bike will also select a built environment conducive to such travel). Research that controls for self-selection on travel behavior finds that the influence of self-selection is minimal and very small (Boarnet 2001; Chatman 2009; Manville 2017).

CHAPTER 12: DESCRIPTIVE STATISTICS

The majority of occupied units in the module are owned by the residents (65 percent), compared to 34 percent of units that are renter-occupied. A great proportion of rental units include parking in the cost of housing (87 percent).

Table 2: Renter vs. Owner-Occupied Units

Renter vs. Owner-Occupied Units		Number of Units
Number of Units in Module		14,490
Rental Units	34%	5,187
Owned Units	65%	9,099
Rental Units with Bundled Parking in Module	87%	5,184

Households without bundled parking are more likely to be poor (24 percent compared to 13 percent), earn lower household incomes, are slightly less likely to be born in the United States, and are more likely to be African American. Unbundled units are unsurprisingly more likely to be located in central cities (72 percent of unbundled units are in central cities, compared to 28 percent of unbundled units). Units built before the widespread use of the car (pre-1920) are much more likely to be unbundled, and units without bundled parking are also, on average, built two decades earlier than units with bundled parking.

Table 3: Geographic and Demographic Indicators

Geographic and Demographic Indicators		Number of Units
Central City Status	31%	4,541
with bundled parking	28%	3,717

without bundled parking	72%	1,030
Units in Poverty	14%	1,030
with bundled parking	13%	1,712
without bundled parking	24%	357
Persons in HH	2.5	
with bundled parking	2.5	
without bundled parking	2.3	
Median Household Income	$67,972	
with bundled parking	$68,940	
without bundled parking	$54,255	
Year Structure Built	1966	
with bundled parking	1967	
without bundled parking	1945	
Proportion of Units Built Pre-1920	66%	13,123
with bundled parking	5%	745
without bundled parking	23%	283
At least 1 Member of Household College-Educated	38%	13,123
with bundled parking	38%	5,226
without bundled parking	36%	488
Proportion of HH Female	52%	
with bundled parking	52%	

without bundled parking	53%	
Proportion of HH Children	12%	
with bundled parking	12%	
without bundled parking	11%	
Proportion of HH Age 65 or Older	21%	
with bundled parking	22%	
without bundled parking	15%	
Proportion of HH Native Born	87%	
with bundled parking	88%	
without bundled parking	76%	
Proportion of Household Black	13%	
with bundled parking	12%	
without bundled parking	28%	

Renter-occupied units are more likely to be located within a half-mile of transit stops than owner-occupied units are. Unbundled units are more likely to have access to a grocery store by walking, biking, or transit, than bundled units are, and may be located in more walkable neighborhoods, as three-quarters of respondents in unbundled units agree that their sidewalks are usable and well-lit, compared to about half of households with bundled parking. While unbundled units are less likely to be located within a half-mile of transit, households without bundled parking are much more likely to use transit (59 percent compared to 16 percent) and less likely to own a vehicle. These findings are in line with previous studies that show proximity to transit has a negligible effect on household VMT (Chatman, 2008; Ewing and Cervero, 2010).

Table 4: Transportation Access Indicators

Transportation Access Indicators		Number of Units
Rental Units ≤ 1/2 mile from transit	42%	4,002
Owned Units ≤ 1/2 mile from transit	32%	8,289
Units ≤ 1/2 mile from transit stop	15%	4,918
with bundled parking	36%	4,581
without bundled parking	27%	337
Average Total Household Vehicles	1.2	
with bundled parking	1.3	
without bundled parking	0.7	
Average Vehicles Per Person	0.6	
with bundled parking	0.6	
without bundled parking	0.4	
Household owns at least one car for use	82%	11,568
with bundled parking	84%	10,921
without bundled parking	52%	647
Housing Units with No Vehicles	18%	2,902
with bundled parking	16%	2,202
without bundled parking	48%	700
Access to Grocery Store by Walking or Biking	26%	4,209
with bundled parking	25%	3,477

without bundled parking	50%	732
Neighborhood has usable, well-lit sidewalks	47%	7,240
with bundled parking	45%	6,202
without bundled parking	73%	1,038
Access to Grocery Store by Public Transit	54%	7,947
with bundled parking	53%	6,914
without bundled parking	75%	1,033

Households with bundled parking spend, on average, more per month on gas and less on public transportation than households without bundled parking. These expenditures reflect transit use Households without bundled parking are more likely to use the two most common forms of transit: bus and subway, and also more likely to use commuter rail, subway, commuter shuttle or van. They are also far more likely to use transit to commute to work or to school.

Table 5: Transportation Use Indicators

Transportation Use Indicators		Number of Units
Average Monthly Household Gas Expenditure	$228	
with bundled parking	$237	
without bundled parking	$105	
Average Monthly Household Spending on Transit	$12	
with bundled parking	$9	
without bundled parking	$58	
Household Uses Transit	19%	3,328
with bundled parking	16%	2,452

without bundled parking	59%	876
Household Uses Bus	13%	2,300
with bundled parking	11%	1,597
without bundled parking	46%	703
Household Uses Carpool	6%	881
with bundled parking	7%	810
without bundled parking	6%	71
Household Uses Car Sharing Service	1%	149
with bundled parking	1%	118
without bundled parking	3%	31
Household Uses Commuter Rail	2%	502
with bundled parking	2%	440
without bundled parking	4%	62
Household Uses Commuter Bus or Shuttle Van	1%	207
with bundled parking	1%	175
without bundled parking	2%	32
Household Uses Subway	7%	1,418
with bundled parking	5%	825
without bundled parking	38%	593
Household Uses Taxi	11%	1,808
with bundled parking	9%	1,318

without bundled parking	33%	490
Household Uses Other Transit	1%	179
with bundled parking	1%	149
without bundled parking	2%	30
Household Uses Transit to Commute to Work or School	19%	3,328
with bundled parking	16%	2,452
without bundled parking	58%	876

CHAPTER 16: ESTIMATION OF BUNDLED PARKING INFLUENCE ON DRIIVNG BEHAVIOR

Using an ordinary least squares regression, I look at the effect of bundled parking on household monthly gas expenditure (which I then use to estimate VMT).The model accounts for 24 percent of variance (R-squared = 0.24). Controlling for sociodemographic and geographic factors, I find that bundled parking is positively correlated with gas expenditure, and that the effect is significant ($p < 0.001$). The regression also shows that characteristics associated with a transit-friendly built environment are negatively correlated with gas expenditure (such as central city status, and access to a grocery store via biking or walking). Poverty status and age are negatively associated with gas expenditure, whereas household size, income, and number of vehicles owned are positively correlated with gas expenditure. Surprisingly, college education is negatively correlated with household gas expenditure, even though I found similar proportions of households with at least one college-educated member in units with and without bundled parking.

Table 6: Estimation of Association Between Bundled Parking and Driving Behavior

Parameter	Estimate
Bundled Parking	49.38***
Number of People	35.73***
Total Cars	28.96***
Percent Native-Born	0.32
Household Income	0.39***
Rent Control	0.42
Percent Black	-4.82

Percent College-Educated	-21.28***
Percent Women	-29.21***
Percent Children	-39.34***
Poverty Status	-42.57***
Percent Older Adult	-97.04***
Unit Built Pre-1920	0.07
Number of Units in Building	-0.06
Tenure	-22.49*
Bike Lanes Present	-6.13
Central City Status	-23.87***
Can Walk/Bike to Grocery	-26.41***
Unit is Apartment	-34.38***
N	12,959
*** p<0.001; p**<0.01; *p<0.05	
Adj. R-Squared	0.2359

Using a post-estimation analysis of the above regression (with the "margins" command in Stata), I calculated the predicted difference in household gas expenditure with and without bundled parking, with the values of all other coefficients fixed at their means. Using Federal Highway Administration data for the average fuel economy of a car (23.4 miles per gallon) and the average cost of gas in 2013 ($3.49 per gallon, according to AAA), I estimated household monthly VMT. I then used the Environmental Protection Agency's estimate for carbon emitted per gallon of gasoline of fuel (8,872 grams of CO_2) to estimate the effect of VMT on greenhouse gas emissions. The difference in gas expenditure between households with and without bundled parking was significant ($p < 0.001$) and large: households with bundled parking spend nearly $50 more per month on gas than comparable households without bundled parking. This difference translates into a difference of 331 miles per month, and 125,530 grams of carbon dioxide emitted. Annually, households with bundled parking travel 3,972 miles more, spend $593 more on gasoline, and emit 1,506,362 more grams of carbon dioxide. The results are clear: when parking is included in the cost of housing, households drive more, and by extension pollute more.

Table 7: Post-Estimation Results for Monthly Gas Expenditure and Bundled Parking

	Average Monthly Gas Expenditure	VMT Estimate Per Month	GHG Estimate Per Month
Without Bundled Parking	$183***	1,224	464,013 grams CO2
With Bundled Parking	$232***	1,555	589,543 grams CO2
Difference (Bundled - Unbundled)	$49	331 miles	125,530 grams CO2

CHAPTER 17: ESTIMATION OF BUNDLED PARKING INFLUENCE ON WHETHER HOUSEHOLD USES TRANSIT

I used a logistic regression to estimate the effect of bundled parking on whether a household uses public transit. The independent variable is bundled parking, and the dependent variable is a dichotomous variable of whether the household uses transit or not. I used both the "transit use" variable provided by the survey, and created my own "transit use" variable that I coded as "yes" if a household said they used any of the transit categories (which include bus, rail, subway, shuttle, and "other public transportation"). Because there was little deviation between the results, I continued to use the "transit use" variable provided by the survey. The results of the logistic models seem to be robust: I also used a probit model and found comparable outputs.

Note that this regression is not related to how frequently a household uses transit (that analysis is in the following section). I found that bundled parking is negatively correlated with transit use, and that this effect is significant ($p < 0.001$). Variables serving as proxies for a transit-friendly built environment are positively correlated with transit use (such as central city status, presence of bike lanes in the neighborhood, and the ability to walk or bike to the grocery store).

Table 8: Estimation of Association Between Bundled Parking and Whether Household Uses Transit

Parameter	Estimate
Bundled Parking	-0.85***
Total Cars	-0.29***
Percent HH Female	-0.03

HH Income	0.003***
Poverty Status	0.28***
Rent Control	-0.05*
Number of People	0.32***
Percent Black	0.71***
Percent U.S. Born	-0.41***
Percent Older Adult	-0.29**
Percent Children	-1.12***
Percent College-Educated	0.51***
Monthly Gas Expenditure	-0.001***
Central City	0.34***
Unit is Apartment	0.57***
Can Walk/Bike to Grocery Store	0.87***
Bike Lanes	0.39***
Can Walk/Bike to Retail	0.19
Can Access Bank by Transit	0.49***
Unit Built Pre-1920	0.18
Tenure	0.001*

Number of Units in Building	0.001*
N	12,620
*** p<0.001; p**<0.01; *p<0.05	
Additional control variables not shown in this table include the following major metropolitan statistical areas: New York City, San Francisco, Boston, Los Angeles, and Philadelphia.	

Using the post-estimation tool "margins" to predict probabilities from this logit model, I found that the likelihood for a household without bundled parking to use transit is higher than the probability for a comparable household with bundled parking, and that this difference is significant (p<0.001). A household without bundled parking has a 30 percent probability of using transit, compared to 18 percent for a household with bundled parking (see table below). The results from the logistic regression and the post-estimation provide evidence that when the cost of parking is separated from the cost of housing, transit ridership increases.

Table 9: Post-Estimation Results for Monthly Gas Expenditure and Transit Use

	Probability of Transit Use	Z	Confidence Interval
Without Bundled Parking	0.2983	20.81	0.2701 - 0.3263
With Bundled Parking	0.1829	52.07	0.176 - 0.1898

CHAPTER 18: ESTIMATION OF BUNDLED PARKING'S INFLUENCE ON WHETHER HOUSEHOLD USES TRANSIT FREQUENTLY

In addition to understanding the influence of bundled parking on transit use, I analyzed differences in transit frequency. Because the survey does not ask how frequently respondents use transit generally, I broke transit use down into specific modes. While I chose to focus on subway and bus use, as they are the most commonly used transit modes in the survey, I also tested for other transit modes and found few differences in the results.

In order to determine the influence of bundled parking on bus use frequency, I used a logistic model. I defined frequent bus use as households that use the bus at least four to six times per week and coded these responses to equal the value one, and all other responses I coded to equal zero. I found that bundled parking is negatively associated with frequent bus and subway use, and the effect is significant for both ($p < 0.001$). Vehicle ownership and gas expenditure are negatively associated with frequent bus and subway use, whereas proxies for a transit-friendly built environment (such as central city status, bike lanes, and access to bank by transit) are positively associated with frequent transit use. There were some differences in coefficients between the two regressions. For example, poverty was positively correlated with frequent bus use, but negatively correlated with frequent subway use.

Table 10: Association Between Bundled Parking and Frequent Bus Use
Dependent Variable: Frequent Bus Use

Parameter	Estimate
Bundled Parking	-0.59***
Total Cars	-0.49***

Percent HH Female	0.002
HH Income	-0.001
Poverty Status	0.16
Rent Control	-0.08**
Number of People	0.46***
Percent Black	0.77***
Percent U.S. Born	-0.58***
Percent Older Adult	-0.48***
Percent Children	-1.28***
Percent College-Educated	-0.11
Monthly Gas Expenditure	-0.002***
Central City	0.64***
Unit is Apartment	0.80***
Can Walk/Bike to Grocery Store	0.91***
Bike Lanes	0.17
Can Walk/Bike to Retail	0.03
Can Access Bank by Transit	0.8***
Unit Built Pre-1920	-0.07
Number of Units in Building	-0.0003
N	12,628

*** p<0.001; p**<0.01; *p<0.05
Additional control variables not shown in this table include the following major metropolitan statistical areas: New York City, San Francisco, Boston, Los Angeles, and Philadelphia.

Table 11: Association Between Bundled Parking and Frequent Subway Use
Dependent Variable: Frequent Subway Use

Parameter	Estimate
Bundled Parking	-1.49***
Total Cars	-0.16
Percent HH Female	0.11
HH Income	0.003***
Poverty Status	-0.61***
Rent Control	-0.04
Number of People	0.38***
Percent Black	1.06***
Percent U.S. Born	-0.72***
Percent Older Adult	-0.95***
Percent Children	-0.95**
Percent College-Educated	0.83***
Monthly Gas Expenditure	-0.002**
Central City	0.67***

Unit is Apartment	0.53**
Can Walk/Bike to Grocery Store	0.73***
Bike Lanes	0.41**
Can Walk/Bike to Retail	0.41*
Can Access Bank by Transit	0.02
Unit Built Pre-1920	0.09
Number of Units in Building	0.002*
Tenure	0.103
N	12,628
*** p<0.001; p**<0.01; *p<0.05	
Additional control variables not shown in this table include the following major metropolitan statistical areas: New York City, San Francisco, Boston, Los Angeles, and Philadelphia.	

To determine whether households with and without bundled parking differ significantly in their propensity to be frequent transit users, I conducted post-estimation tests using the "margins" command in Stata. The results show that there is a significant difference in the likelihood of frequent bus and subway use between households with and without bundled parking. Households without bundled parking are more likely to be frequent subway and bus users, controlling for socioeconomic and built environment factors, such as proximity to transit and household income. It is clear that bundled parking discourages households from using transit frequently.

Table 12: Post-Estimation Results for Bundled Parking and Frequent Bus Use

	Probability of Frequent Bus Use	Z	Confidence Interval
Without Bundled Parking	0.1103***	14.73	0.0956 - 0.125
With Bundled Parking	0.0734***	28.87	0.0684 - 0.0783

Table 13: Post-Estimation Results for Bundled Parking and Frequent Subway Use

	Probability of Frequent Subway Use	Z	Confidence Interval
Without Bundled Parking	0.0984***	12.67	0.0831 - 0.1136
With Bundled Parking	0.0335***	19.60	0.0302 - 0.0369

CHAPTER 19: CONCLUSION

Including the cost of parking in the cost of housing conceals the true cost of vehicle ownership. Previous studies have shown that bundled residential parking encourages vehicle ownership, particularly among marginal vehicle owners (Manville, 2017). Whereas the existing literature tends to focus bundled parking research in major metropolitan areas, this study uses a nationwide dataset to assess the influence of bundled parking on travel behavior.

After controlling for differences in sociodemographic and built environment characteristics, I find that households with bundled parking drive 27 percent more than households without bundled parking. Specifically, bundled households drive approximately 3,800 miles more, spend nearly $580 more on gasoline, and emit 14.47 more metric tons of carbon dioxide per year. Bundled parking is also negatively correlated with transit use, and households with unbundled parking are significantly more likely to be frequent transit users. Based on these findings, I conclude that when parking is included in the cost of housing, households are disincentivized from using transit. Policymakers concerned with climate change, as well as falling transit ridership, must consider the consequences that parking requirements have on travel behavior.

BIBLIOGRAPHY

Blumenberg E, Pierce G., 2014. "A Driving Factor in Mobility? Transportation's Role in Connecting Subsidized Housing and Employment Outcomes in the Moving to Opportunity (MTO) Program." *Journal of the American Planning Association.* 80(1), 52-66.

Boarnet M, Crane R., 2001. *Travel by Design.* Oxford, UK: Oxford University Press.

Cervero R., Ferrell C., Murphy S., 2002. *Transit-oriented development and joint development in the United States: A literature review*. Washington, DC: Transit Cooperative Research Program.

Chakrabarti, Sandip. 2016. How can public transit get people out of their cars? An analysis of transit mode choice for commute trips in Los Angeles.

Chatman, Daniel, 2008. Deconstructing Development Density: quality, quantity, and price effects on household non-work travel.

Chatman, D. 2009. Residential choice, the built environment and nonwork travel: Evidence using new data and methods. Environment and Planning A 41: 1072–1089.

Chatman, Daniel, 2013. Does TOD Need the T? On the importance of factors other than rail access.

Environmental Protection Agency. Sources of Greenhouse Gas Emissions. Source from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

Ewing R., Cervero R., 2010. Travel and the built environment: A meta-analysis. *Journal of the American Planning Association*, 76(3), 265-294.

Ewing, Reid and Robert Cervero. 2001. Travel and the Built Environment: A Synthesis. Transportation Research Record number 1780: 87-114.

Gabbe, C. J., & Pierce, G. (2017). The hidden cost of bundled parking. *Access*, *51*(Spring).

Guo, Zhan, 2013. Home parking convenience, household car usage, and implications to residential parking policies. *Transport Policy*, 29, 97-106.

Hess, Daniel, 2009. Effect of Free Parking on Commuter Mode Choice: evidence from travel diary data. *Transportation Research Board.*

Kain, 1967. Postwar Metropolitan Development: Housing Preferences and Auto Ownership.

Manville, 2017. Bundled parking and Vehicle Ownership, *Journal of Transport and Land Use*.

Manville, Beata and Shoup, 2013. Turning Housing into Driving: Parking Requirements and Density in Los Angeles and New York.

Rowe, D.H., Bae, C.H.C., Shen, Q., 2011. Evaluating the impact of transit service on parking demand and requirements. *Transportation Research Record*, *2245*, 56-62.

U.S. Department of Transportation, 2011. Summary of Travel Trends: 2009 National Household Travel Survey.

Weinberger, Rachel, 2012. Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive.

Weinberger, Seaman and Johnson, 2009. Residential off-street parking impacts on car ownership, vehicle miles traveled, and related carbon emissions: New York City case study. *Transportation Research Record* 2118: 24-30.

Zamir K., Nasri A., Baghaei B., Mahapatra S., & Zhang L., 2014. Effects of Transit-Oriented Development on Trip Generation, Distribution, and Mode Share in Washington, D.C., and Baltimore, Maryland.