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Final Report

Mode Shift in Transit Under-served Neighborhoods in New York City Region

Residential Parking Policy and Household Travel Pattern in Transit Under-served Neighborhoods in the New York City Region

Prepared by

Dr. Zhan Guo

Assistant Professor of Urban Planning & Transportation Policy
Research Director, Rudin Center for Transportation Policy and Management
Robert F. Wagner Graduate School of Public Service
New York University
295 Lafayette St, 2nd floor, New York, NY 10012
Tel: 212-998-7510
Fax: 212-995-4611
Email: zg11@nyu.edu

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NYUWagner
rudin center
for transportation policy & management

NYU • Robert F. Wagner Graduate School of Public Service
295 Lafayette Street, 2nd Floor • New York, NY 10012
phone: (212) 998-7545 • fax: (212) 995-4611
www.wagner.nyu.edu/rudincenter

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16. Abstract

This research defines the concept of transit under-served areas (TUSA), and argues that with the right policies TUSA residents have a great potential to reduce car dependency and usage and switch to public transit. It focuses on one important but often overlooked policy—residential parking, in reshaping travel patterns in TUSA neighborhoods, using the New York City region as an example. Nine hundred households were randomly selected from a regional household travel survey in the New York City region. Their parking types were identified using streetscape images from Google and Bing, and the types of parking were connected with the travel behavior identified in the travel survey. It finds that residential parking could significantly affects not only household car ownership, but also choice of commuting mode, trip frequency, trip chaining, and total vehicle time. TUSA households with only on-street parking tend to have fewer cars, make fewer vehicle trips, and drive less overall vehicle time, comparing to households with a garage. However, when on-street parking becomes a viable alternative to off-street parking--free, convenient, and readily available, households tend to have more cars and use these cars more often. Based on the results, the research suggests that in order to discourage car use and encourage mode shift, government should limit the conversion of on-street parking to off-street parking through new curb cuts in TUSA neighborhoods with insufficient off-street parking. In TUSA neighborhoods with sufficient off-street parking, government policy should limit the provision and usage of on-street parking through better street design and/or permit fees.

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Zhan Guo (PI)
Assistant Professor of Urban Planning & Transportation Policy
Research Director, Rudin Center for Transportation Policy and Management
Robert F. Wagner Graduate School of Public Service
New York University
295 Lafayette St, 2nd floor, New York, NY 10012
Tel: 212-998-7510
Fax: 212-995-4611
Email: zg11@nyu.edu

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This research defines the concept of transit under-served areas (TUSA), and argues that with the right policies TUSA residents have a great potential to reduce car dependency and usage and switch to public transit. It focuses on one important but often overlooked policy—residential parking, in reshaping travel patterns in TUSA neighborhoods, using the New York City region as an example. Nine hundred households were randomly selected from a regional household travel survey in the New York City region. Their parking types were identified using streetscape images from Google and Bing, and the types of parking were connected with the travel behavior identified in the travel survey. It finds that residential parking could significantly affects not only household car ownership, but also choice of commuting mode, trip frequency, trip chaining, and total vehicle time. TUSA households with only on-street parking tend to have fewer cars, make fewer vehicle trips, and drive less overall vehicle time, comparing to households with a garage. However, when on-street parking becomes a viable alternative to off-street parking--free, convenient, and readily available, households tend to have more cars and use these cars more often. Based on the results, the research suggests that in order to discourage car use and encourage mode shift, government should limit the conversion of on-street parking to off-street parking through new curb cuts in TUSA neighborhoods with insufficient off-street parking. In TUSA neighborhoods with sufficient off-street parking, government policy should limit the provision and usage of on-street parking through better street design and/or permit fees.

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Disclaimer

BACKGROUND

The past five years have witnessed a new era of transportation planning and policy-making in the United States, characterized by historically high gas prices, continuously worsening road congestion in urban cores and major corridors, and increasing concern with greenhouse gas emissions and energy independence. In response to these trends, federal, state, and local governments have become increasingly interested in changing when, where, and how we use private automobiles. At the same time, more and more people are finding that alternative modes, such as transit, car sharing, non-motorized travel, etc., are acceptable travel solutions. These alternatives indicate emerging market segments that could offer opportunities to build sustainable transportation systems in the decades to come, and therefore may warrant more investment. However, there is little understanding of what drives individuals to one of these alternatives rather than continue to use their personal automobiles. Moreover, there is little understanding of which alternatives work most effectively, and under which situations.

Given that the New York City region already has one of the most far-reaching transit systems in the country and that New York City Transit already has a high penetration rate, the greatest opportunities for moving even more people away from cars and onto transit will likely come from "transit under-served areas." The term "transit under-served areas" (TUSAs) refers to areas in a metropolitan region with a development density not as high as downtown, but also not as low as most suburban communities. They include primarily neighborhoods right outside the urban center but still served with plenty of transit options even though most of them are not in a very close proximity.

Comparing to TUSAs, the transit well-served areas such as downtowns already have high transit penetration rates, so the room for mode-shift is limited (TCRP Report 37, 1998), while the transit not-served areas have few options except private cars, so mode shift would be costly and slow (TCRP Report 55, 1999). This research assumes that residents in TUSAs have the greatest potential to respond to policy interventions and change their travel behavior. This research aims to elaborate this point by exploring households' travel pattern in TUSAs in the New York City region. The purpose is threefold: (1) to understand the multiple travel options that TUSA residents face; (2) to analyze current modal choice decisions and possible responses to policy interventions; and, (3) to draw policy implications that could facilitate sustainable travel pattern and increase transit ridership from TUSAs.

The New York City region provides an excellent example for studying these emerging markets. Medium-dense developments concentrate in three boroughs outside Manhattan, the Bronx, Brooklyn, and Queens, and across the Hudson River in New Jersey. Despite the dense urban and regional rail network, about 30% of New York City's population (2.4 million) lives more than 10 minutes away from a rapid transit station, most of them living in TUSA neighborhoods and using cars more frequently than their counterparts in well-served areas (PlaNYC 2007, p. 82).

There are many possible policy interventions to change TUSA residents' travel behavior and commuting pattern such as: increasing the cost of driving (gas price increases, congestion pricing, and/or higher parking fees); reducing transfer penalties between bus and rail; providing more park-and-ride facilities; adding express bus services including Bus Rapid Transit; and improving pedestrian infrastructure in and to rail station areas, among others. Due to space limit, this research could not cover all related issues, rather, it focuses on one important but often overlooked issue in reshaping the travel pattern in TUSA neighborhoods—residential parking.

Parking policy is often believed to be "the most widely accepted and readily accepted method" of limiting car use (Marsden, 2006). However, the topic in general is less studied in transportation (Verhoef et al., 1995; Calthrop et al., 2000; Shoup, 2005), and it represents a high-payoff area for future research (Ewing and Cervero, 2001). Of the few studies, most have focused on how and where drivers park once they reach their destination (Arnott et al., 1991; Gerrard et al., 2001; Hensher and King, 2001; Hess, 2001; Shiftan, 2002; Bain, 2002; Marshall and Garrick, 2006; Rye et al., 2008). Parking at the origin, or home side, of a trip has only recently begun to attract research attention (Balcombe and York, 1993; Jia and Wachs, 1999; Stubbs, 2002; Litman, 2004, Coevering and Snellen, 2008; NYCDCP, 2009; McDonnell et al., 2010).

As indicated by Weinberger et al. (2009) residential parking types (on-street vs. off-street) can significantly affect residents' commuting mode. Cervero et al. (2010) also find that parking supply in residential developments around rail stations could significantly affect transit ridership. This research follows a similar logic and aims to investigate the role of residential parking supply (garage, driveway, or on-street) in determining TUSA residents' car ownership, commuting mode choice, trip frequency, and total vehicle hours traveled. The results will shed light on the potential role of the residential parking policy in limiting car usage and encouraging mode switch in TUSAs.

This report is structured as follows: section 2 reviews the literature of residential parking and household travel; section 3 describes the analytical framework; section 4 introduces a case study of TUSAs in the New York City region; section 5 summarizes the analysis results; section 6 discusses the policy implications; and section 7 concludes the research.

RESIDENTIAL PARKING AND HOUSEHOLD TRAVEL

There is some evidence that residential parking affects household travel patterns in terms of car ownership, choice of commuting mode, and other short-term travel decisions. For example, the availability and type of parking seems to affect car ownership and vehicle type. Balcombe and York (1993) found that the distance that vehicles were parked from the home appeared to deter the purchase of better vehicles. Between 22 and 54 percent of residents surveyed said they did not buy a better vehicle due to fear of vandalism. Guo (2006) also found that parking density in a neighborhood, including both off-street and on-street parking spaces, is highly correlated with household car ownership in that neighborhood.

Because parking demand and supply can be co-determined, this finding is hardly a surprise, but there is some evidence that the relationship between car ownership and parking is more complicated. For example, Balcombe and York (1993) found that difficulties in finding a parking space might not necessarily deter car ownership or intentions to acquire additional vehicles. In his review and survey, Stubbs (2002) found that residents were reluctant to give up their parking spaces even if they did not own a car. The possession of a parking space was important to their perception of their property value or investment. A study of attitudes about parking conducted by the House Builders

Federation (2000) in the U.K. found that most residents favored the provision of a garage space, but many parked in the driveway, leaving the garage for storage. Coevering and Snellen (2008) also confirmed that residents often under-utilize their own private parking facilities, parking the car in a public space and using the driveway and parking space for other purposes. The interaction between parking types, parking habits, and car ownership is certainly worth further investigation.

Residential parking appears to affect commuting mode choice, trip frequency, and travel distance. Weinberger et al. (2009) compared two “driver hot spot” neighborhoods in New York City. Both had similar car ownership levels (0.38 vs. 0.40 vehicles per household) but differed significantly in the percentage of car use in commuting (0.23 vs. 0.18). The reason for this difference was the type of available parking: one neighborhood had abundant “guaranteed” parking spaces (off-street garage, driveway, or alley), while the other neighborhood relied primarily on shared on-street parking. Households in the second neighborhood were reluctant to drive to work because of the fear of losing their spaces.

Balcombe and York (1993) found a similar result in the U.K. Concerns over losing a parking space and the inconvenience of finding another appeared to deter car owners from making some trips, particularly shorter trips by car. Over 50 percent of car owners in the six older neighborhoods stated that they occasionally walked instead of using their cars in order to preserve their parking space. There was a greater tendency to walk in areas where residential parking was limited.

Another study by Kitamura et al. (1997) in San Francisco showed that the availability of residential parking was linked to both trip frequency and modal choice. When residential parking became more available, residents tended to make fewer and longer journeys, and these journeys were more likely to be by car. Conversely, residents with fewer parking spaces make more journeys that are shorter and less car-based. Stead (1999) reported a different result, observing that limited residential parking was associated with shorter travel distance and fewer, instead of more, journeys because residents may become more rational car users given the limited availability of parking.

The limited literature offers two interesting observations. First, there appears to be a possible impact of residential parking on both long-term and short-term household travel decisions. This impact is likely to originate from the various types of parking, either on-street or off-street (garage, driveway, parking lot, etc.). Second, people park their cars differently if they have multiple parking options. These parking habits might be closely related to the way that the cars are used. However, due to the very small number of empirical studies (eight over the past twenty years) and their inconsistent results, the two observations are far from clear and conclusive. The next section provides a theoretical discussion of why and how residential parking types and habits affect travel behavior and offers an analytical framework for the subsequent New York case study.

PARKING TYPES, PARKING HABITS, AND TRAVEL DECISIONS

Parking Types

Residential parking takes diverse forms. Table 1 lists seven parking types, six of which are off-street parking. This is certainly not an exhaustive list. *Private garage* refers to a garage accessible only to residents. It can be a self-owned garage attached to single-family housing or a shared garage in an apartment building's basement. *Driveway* refers to the parking area in front of a garage, in a front yard or back yard, or in an alley adjacent to the residence. It can be self-owned or shared with other residents in the same building. A *private parking lot* is often provided in large residential complexes and is accessible only to residents. *Public garages* and *parking lots* are commercial parking facilities available to the public for a fee. *Off-street parking* is normally provided by developers or parking enterprises, while *on-street parking* is provided and regulated by government agencies. These parking types are usually bundled—a garage is often associated with a driveway, and on-street parking is available in most situations. A household may have access to none, one, or multiple types of parking.

These parking types differ significantly in five attributes: structure, ownership, location, cost, and convenience (Table 1). *Structure* indicates whether the parking space is covered by a structure. The parking cost is normally bundled with housing cost, so residents normally do not pay out-of-pocket for parking. *Location* defines the distance between the parking space and a residence. It can be on the same property, in front of the house, or a few blocks away. Even if parking is available on the same property, walking distance might vary significantly depending on the housing type and parking structure, whether it is a self-owned garage, a shared garage for a residential tower, or a large parking lot for a housing complex.

Parking ownership refers to whether a household has the exclusive right to a particular parking space. Ownership matters because a guaranteed spot and location, like a private garage attached to a single-family house, reduces parking uncertainty and eliminates the parking search (strong ownership). The opposite example is on-street parking, where neither a space nor a location is guaranteed (weak ownership). The intermediate case might be a shared parking lot for an apartment—a tenant may have one guaranteed but unreserved spot, which may be either adjacent to or far from home (medium ownership).

Parking convenience is defined narrowly as the difficulty of parking a car in a parking space. It is largely determined by the structure of parking. Parking in a large underground garage or a small private garage may take more time and energy than parking in a driveway or a parking lot. In other words, the physical behavior of parking itself could be treated as a "transaction cost" between trips. The more difficult parking is, the less likely it is that people will pull their cars in and out frequently. Parking convenience varies by household and driver and is often unobservable.

These five attributes may affect household travel decisions differently (Table 1). For example, the structure of parking may affect car type, but not car ownership. Residents with structured parking spaces that are weatherproof might be more likely to buy more expensive cars. The location of the parking space may not affect car ownership, but it may influence car type, trip frequency and vehicle miles traveled (VMT). Parking cost may affect car ownership and type, but it probably does not influence trip making. Parking ownership may affect all travel decisions, while parking convenience may mainly influence short-term decisions.

Parking Types			Parking Attributes				
			Structured	Ownership	Location	Cost *	Convenience
Off-Street	Private Garage	Owned	Yes	Strong	Close	Free	Low
		Shared	Yes	Medium	Close-medium	Free-medium	Low
	Driveway/Alley	Owned	No	Strong	Close	Free	Medium
		Shared	No	Medium	Close	Free	Medium
	Private Parking lot		No	Medium	Close-medium	Free-medium	Medium
	Public Garage/Lot		Yes-No	Medium-Weak	Medium-Far	High	Low
On-Street			No	Weak	Close-Medium	Free	Low-High
Travel Behavior							
Long Term	Car ownership			+		+	
	Car Type		+	+	+	+	
Medium	Mode Choice			+			+
Short Term	Trip Frequency			+	+		+
	Trip length			+	+		+
	Trip Chaining			+	+		+
	Overall VMT			+	+		+

* Out-of pocket cost, free if bundled with housing cost; “+” indicates that the parking attribute influences that travel behavior

Table 1 An Analysis Framework of Parking Types, Parking Attributes, and Travel Behavior

Parking Habits

Parking behavior is as diverse as driving behavior. Even when people face the same options, some may park in a driveway all the time, while others may always pull their cars into a garage. Some move their cars to another spot the night before street cleaning, while others may double-park right before the cleaning starts. Some purchase parking permits, while others may use a neighbor's extra space and pay a negotiated fee. Some use their garage as a storage place, while others may use a twenty-year-old wagon as a storage space and leave it parked on the street. Parking habits are closely related to travel decisions, and they need to be accounted for in parking policy analysis. Unfortunately, almost no studies exist on this topic.

Due to data limitations, parking habits in this research are narrowly defined as alternative parking, which refers to alternative options available to a household in addition to the main parking. The definition of main and alternative parking is mainly based on ownership and structure. For example, if a household has an on-site garage, on-site driveway, and on-street parking, the garage is the main parking while the others are alternative parking. When a household has access only to a driveway and on-street parking, the driveway is the main parking.

Although main parking offers better control than alternative parking in terms of ownership, the latter may actually be more convenient to use (Table 1). If a trade-off indeed exists, the natural follow-up questions include the following: which type of parking do people prefer? Does the decision vary by person, time, and trip? Do parking habits influence travel patterns? For example, do people who often park in driveways tend to drive more or less than those who always park in garages? The New York case study aims to answer these questions.

RESIDENTIAL PARKING IN TRANSIT UNDER-SERVED AREAS

The New York City region is ideal for this analysis in many ways. It offers a great variety of residential parking types as well as a sufficient variation in statistical analysis, thanks to the diverse housing stock. More than 83 percent of the 3.3 million housing units in New York City are multifamily, and about half are in a building with 20 or more units, according to the New York City tax lot database (PLUTO). The median year in which structures were built is 1949. About 11 percent of the structures were constructed after 1961, when the minimum parking standard was strictly implemented. Therefore, later renovations occurred quite often citywide, both formally and informally (NYCDCP, 2009).

It is practically impossible to address all of the types of parking listed in Table 1 given the size and complexity of the New York City region. Because the data collection method (see below) is less effective for large buildings, the study area was defined as the transit under-served neighborhoods outside-core area, including three outer boroughs (Brooklyn, Queens, and Bronx), six municipalities across the Hudson River in New Jersey, and northern Manhattan (north of 110th Street) (Figure 1). Within the study region, large residential buildings with more than 30 units were excluded.

The main data source for travel behavior is the regional household travel diary survey conducted by the New York Metropolitan Transportation Council (NYMTC) in 1998, the most recent travel survey in this region. The NYMTC survey records one-day travel

	Metro Area *	Study Region	Within the Study Region		
			HH with Garage	HH with only Driveway	HH with only On-street
Household Size					
1 person	29%	26%	19%	18%	35%
2 persons	33%	28%	31%	29%	26%
3 persons	16%	18%	20%	20%	17%
4+ persons	22%	28%	30%	33%	22%
Household Income					
Low (< $35K)	22%	43%	32%	42%	50%
Medium ($35K- $75K)	33%	41%	45%	41%	39%
High (> $75K)	46%	16%	22%	17%	12%
Car Ownership					
0 car	20%	34%	18%	19%	51%
1 car	30%	41%	42%	51%	37%
2 cars	34%	19%	30%	25%	8%
3+ cars	16%	6%	10%	6%	4%
Housing Type					
Apartment	31%	38%	18%	29%	57%
Single Family Attached	11%	22%	24%	23%	23%
Single Family Detached	56%	39%	58%	48%	20%
Racial and Ethnicities					
White	74%	43%	53%	44%	36%
Black	10%	21%	16%	19%	25%
Hispanic	6%	19%	14%	20%	22%
Others	10%	17%	17%	17%	17%
# of Children (<17 year)					
0 child	69%	65%	64%	61%	68%
1 child	13%	17%	16%	19%	16%
2+ children	18%	18%	20%	20%	16%
Household Head Age					
<25	6%	13%	12%	10%	15%
25-60	68%	68%	68%	69%	67%
60+	26%	19%	20%	21%	18%
On-street Crowding Level					
1-4 (> 7-9 empty spaces)	N/A	15%	23%	16%	9%
5-6 (3-6 empty spaces)	N/A	27%	30%	34%	22%
7-8 (<=2 empty spaces)	N/A	58%	47%	50%	69%
Total # Households	10,971	840	266	178	396

* based on the 10,971 households included in the NTMTC regional household survey

Table 2 Comparison of Demographic Characteristics activities for 11,276 households (a stratified random sample) in the tri-state NJ-NY-CT region, of which 1,955 households are in the study region. For each household, the NYMTC survey provides detailed travel and demographic attributes and parking types (garage, driveway, parking lot, and street) for each vehicle trip. Because data collection is time consuming, a random sample of 900 households was selected and their parking types were identified.

Because the travel and parking surveys are not conducted at the same time, all home addresses are examined through the building permit database and the Certificate of Occupancy database. The former records construction petitions on that property including new buildings, conversions, or extensions of existing buildings. The latter records when a newly completed building is actually occupied by residents. Only home addresses without any records in the two databases between 1998 and 2010 are used in the analysis. These buildings remain the same physical structure between 2010 (year of parking survey) and 1998 (year of travel survey). Finally, a total of 840 households were analyzed. Table 2 lists the demographic characteristics of these households, comparing to those in the metropolitan region, as a whole and by parking types.

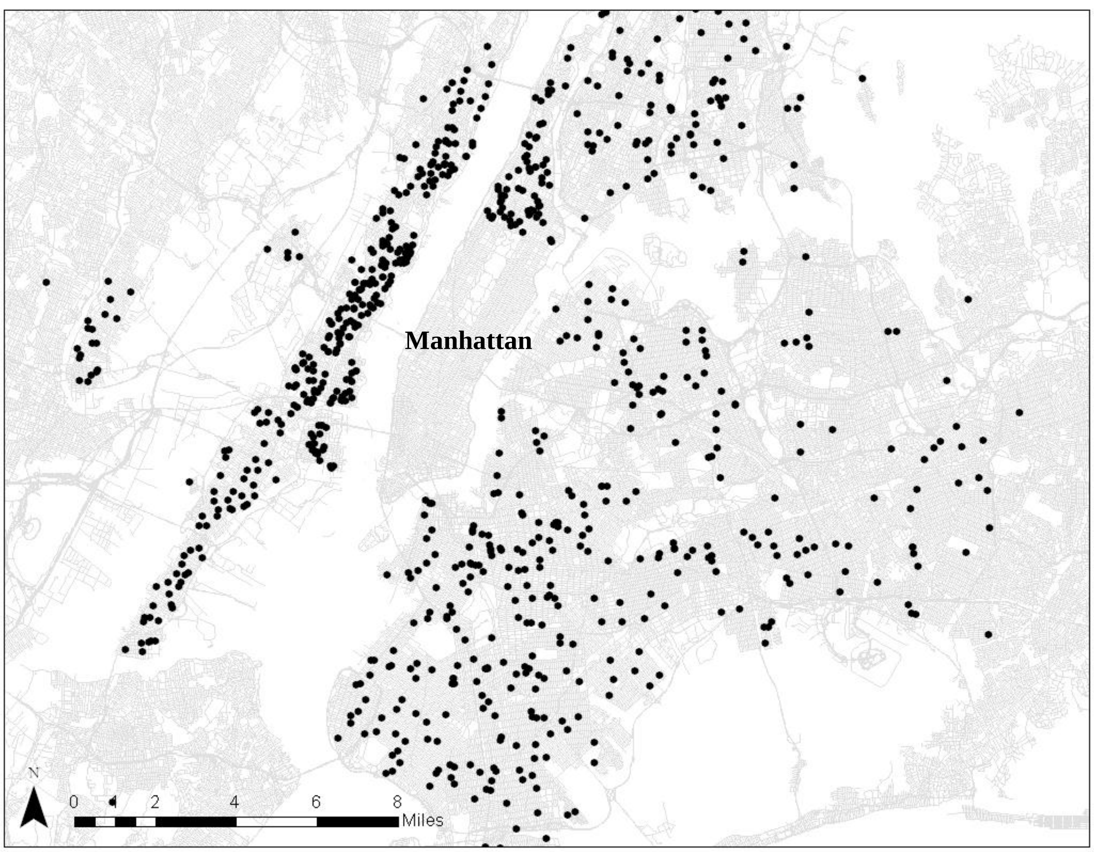

Figure 1 Study Region and Selected Households from the NYMTC Survey

Identifying Residential Parking Types

The major challenge to this research (and to most research on residential parking) is data availability. No large cities in the United States have ever collected data on (1) off-street residential parking spaces that are actually provided by developers and (2) on-street parking spaces that are available to residents. The most ambitious city, San Francisco, completed an on-street and commercial off-street parking inventory for 35 percent of its neighborhoods in spring 2010 (SFPark, 2010). In New York City, PLUTO records the square feet of parking area for structures with four or more housing units. It does not cover 1-, 2- or 3-unit buildings or non-structured parking areas.

This research collected residential parking information for the 840 selected households using internet maps and streetscape search engines like Google Maps and Microsoft Bing Maps. This method is more efficient and less costly than traditional mail or phone surveys and can cover a large number of randomized households in a short time. However, this method can only identify parking types, not parking quantity. It does not work well for large buildings, such as large apartments or housing complexes, and it cannot always identify the exact household address. The method is described below in detail. The household mailing addresses were provided to the author by NYMTC, based on a confidentiality agreement. The addresses were then submitted to internet search engines to visually identify whether a household had access to a garage, driveway, or on-street parking. To ensure the validity of the results, the process was conducted through multiple channels: aerial photos in Google Maps, Google Earth, and Bing Maps; streetscape photos in Google and Bing; and the 3D bird's-eye view from Bing. The latter is very helpful when a garage or driveway is located in the back, at one side of the building, or is blocked by trees, because it views a building from four different perspectives in different seasons.

None of the internet map and streetscape services can guarantee an exact home address. For example, Google Maps displays a mark associated with the home address, but that mark does not identity one specific building. Google Earth shows mailing addresses on the street center line, but it is difficult to identify the exact building when the street is wide, lots are narrow, and buildings are attached. Because the mailing address is not visually identifiable from the images, there is no way to confirm the result. In some cases, Google and Bing yield inconsistent results. For example, Google and Bing may locate different buildings for the same mailing address. To solve this "exact building" problem, household addresses were confirmed in the PLUTO tax lot map and then mapped back to Google and Bing.

The availability of on-street parking is measured as the crowding level of on-street parking for the street segment where a household is located. This measure works better in high-density areas because it probably does not have sufficient variation in low-density areas. It does not count turn-over rate, a concept better suit for commercial streets. Although it is straightforward, the measure has two drawbacks. First, the exact time that the aerial photos or streetscape photos were taken was unclear, which is a common problem for image-based data sources (Monkkonen, 2008). Google and Bing refuse to release the time due to the concerns of both privacy and competition since the routing of their Photo-taking vehicles is a top secret. Since the crowding level varies greatly from daytime to evening, this measure does not capture the whole picture of on-street parking crowding. Rather, it acts like a proxy of the actual crowding perceived by residents (e.g., at 7pm), assuming that a crowded street in midday is also more likely to be crowded in evening. Second, the occupancy level indicates how many spaces are occupied by cars, not exactly the availability of or difficulty in finding an on-street space for a particular household. The opposite might occur when on-street parking is convenient and people would prefer on-street parking, so there are more cars parked on street. Future research on the interaction between car ownership, ratio between on-street and off-street parking spaces, on-street occupancy, search time, and walking distance from parking to home would help understand this dynamics of on-street parking. However, due to the limit of space and the unavailability of data, this paper uses the crowding level as an imperfect but still a reasonable proxy of the availability of on-street parking. As indicated by the result, this concern does not affect the final conclusion of this particular research, but readers should be aware of the limitation of this measure.

The crowding level is measured for a 300-feet street segment with the household's residence being in the middle of the segment. This threshold is chosen because the majority of households (90 percent) are believed to park cars within 50 meters from their home (Balcombe and York, 1993). When a street is shorter than 300 feet, the entire street segment is surveyed. I believe this threshold should be sufficient to capture the crowding level of on-street parking around the household.

I measured the number of on-street parking spaces on both sides of the street in the survey area, after excluding areas at garage and driveway entrances, in front of fire hydrants, in front of "No Parking" signs, and at construction sites. Assuming an on-street parking takes a minimum length of 20 feet, the survey area can have a maximum 30 spaces. Depending on the number of parked cars and empty spaces out of the approximately 30 spaces, the crowding level was ranked from 1 to 8 as below:

8= all parking spaces are occupied by cars;
7=1-2 empty spaces out of approximately 30 spaces;
6 = 3-4 empty spaces out of approximately 30 spaces;
5 = 5-6 empty spaces out of approximately 30 spaces;
4 = 7-9 empty spaces out of approximately 30 spaces;
3 = more than 5 cars and 9 empty spaces out of approximately 30 spaces;
2 = 3-4 cars and more than 9 empty spaces out of approximately 30 spaces;
1= 1-2 cars and more than 9 empty spaces out of approximately 30 spaces.

Among the 840 households, 32 percent (266 households) had an on-site garage, 21 percent (178 households) had a driveway but not an on-site garage, and 47 percent (396 households) had access only to on-street parking. All households with a garage also had access to a driveway and on-street parking. All households with a driveway also had on-street parking as an alternative.

Figure 2 shows a typical single-family detached housing in Bronx, with a one-space garage at the back and a long driveway connecting the garage with streets. Figure 3 shows a typical single-family attached housing without a garage but a parking yard in front of the house. Figure 4 shows a small apartment building in this region without a garage but a small parking lot. Note that most apartment buildings in the study region (57 percent) do not have any off-street parking.

Figure 2 A Typical Single Family Detached Housing in Robertson Place, Bronx (Photo: NYC Department of City Planning)

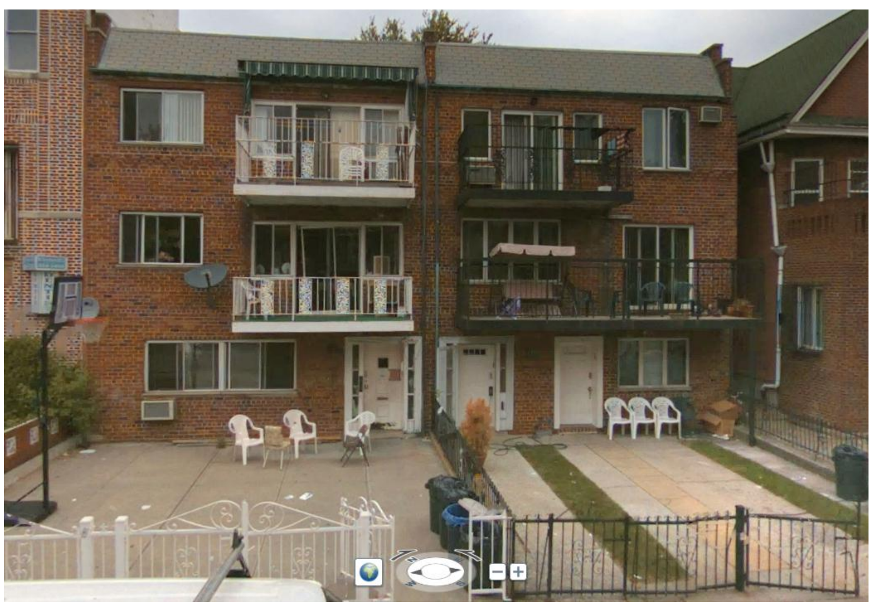

Figure 3 Single Family Attached Housing in Borough Park, Brooklyn (Photo: Bing Map)

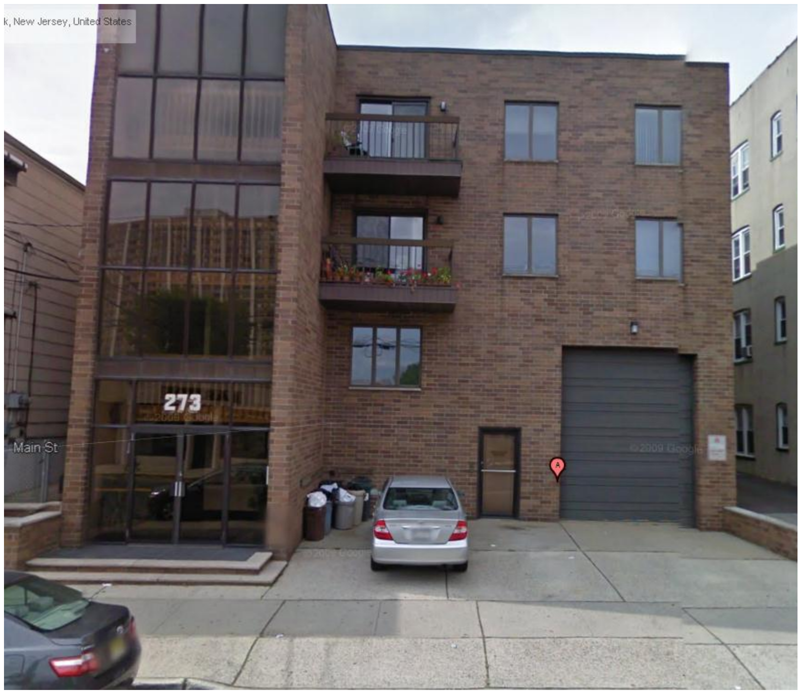

Figure 4 A Five-Unit Apartment in Cliffside Park, NJ (Photo: Google Street View)

Regarding the usage of on-street parking in the study region, the average crowding level for the 840 households was 6.3, which suggests that streets in the study region are heavily used. Only 31 percent of the households live on a street with three to six empty spaces (out of the approximately 30) at the time when the photo was taken. However, the situation for households with off-street parking is better with an average crowding level of 5.9. About 52 percent of these households live on a street with readily available on-street parking. Figures 5, 6, and 7 show the street scenes with a crowding level of 1, 4, and 7, respectively, in neighborhoods with off-street parking in the study region.

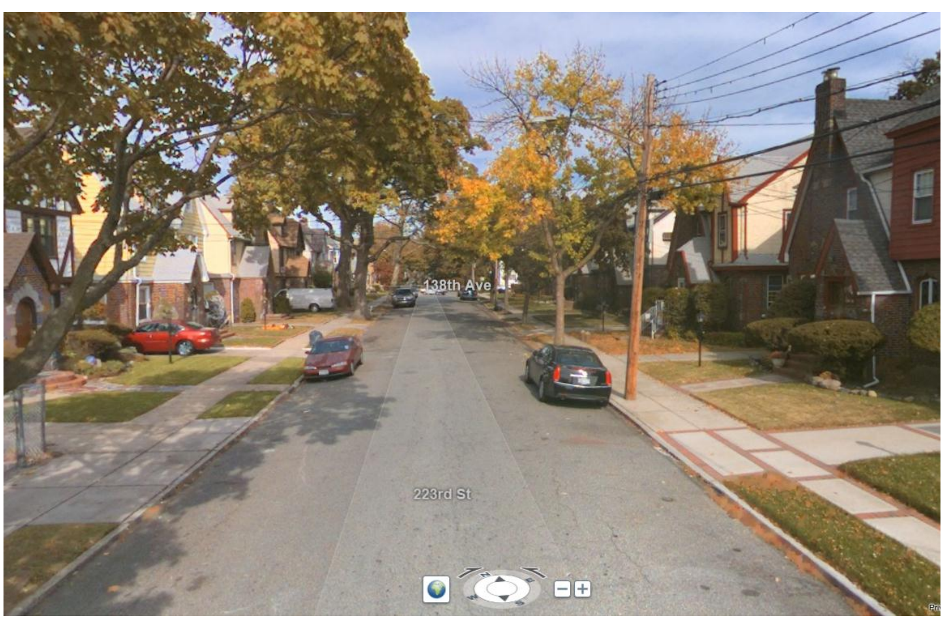

Figure 5 A Street with a Crowding Level =1 in Queens, NY (Source: Bing Map)

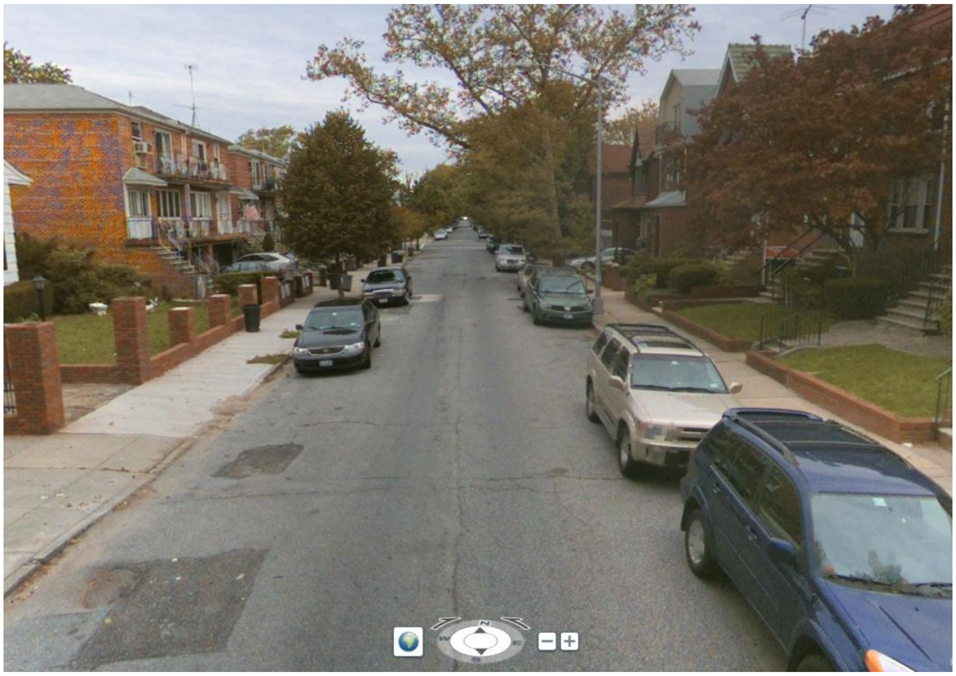

Figure 6 A Street with a Crowding Level =4 in Brooklyn, NY (Source: Bing Map)

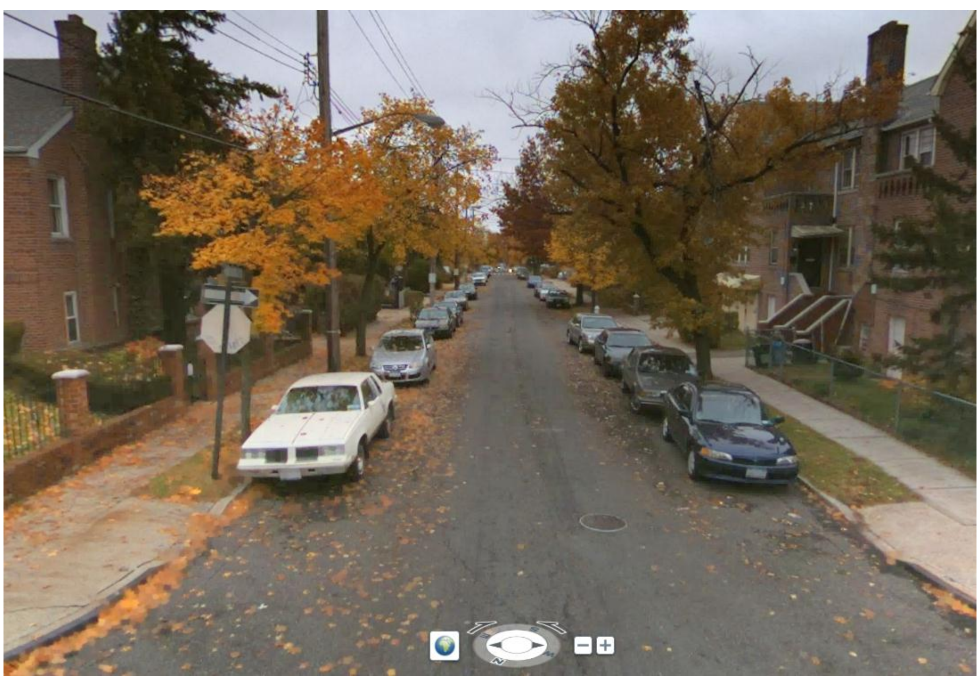

Figure 7 A Street with a Crowding Level = 7 in Bronx, NY (Source: Bing Map)

Parking Types and Parking Habits

Because the travel diary survey recorded where a driver parked the car (garage, driveway, parking lot, or on the street) after s/he drove home, parking habits can be directly compared with the available parking supply. Among the 840 households, only 324 (out of 554 car-owning households) used their vehicles on the survey day. Of these 324 households, 160 households had garages, 97 had access to driveways, and 67 had only on-street parking. Of the 160 garage-owning households, most (87.5 percent) chose to park either in a driveway or on the street instead of in the garage (Table 3). Of the 97 driveway households, about half (52 percent) decided to park on the street instead of in the driveway on the property.

# Households	**Parking Habits (N=324 households)**			
Parking Types	**In Garage**	**On Driveway**	**On-Street**	**Total**
Garage	20	100 *	45 *	160
Driveway	N/A	47	50	97
On-Street	N/A	N/A	67	67
Total	20	147	162	324

* Five households parked both in the driveway and on the street because they either made multiple vehicle trips and parked at different locations after returning home or because they had multiple cars. NA: not applicable

Table 3 Parking Types and Parking Habits of Selected Households

This indicates that when possible (e.g., on-street parking is not crowded), a household tends to prefer alternative parking over the main parking, despite the fact that the latter often offers better control and protection of the parking space. This is probably because alternative parking facilitates pulling the car in and out. The pattern shows that parking habits may be very different from parking types. About 50 percent of households owned a garage (out of the 324 households who used their vehicles on the survey day), but only 6 percent used them on a typical weekday. A garage-owning household was five times more likely to park in the driveway and two times more likely to park on the street. About 50 percent of households park on the street, and 59 percent of them do so by choice.

Next, the percentage of vehicles by parking type in the study region was calculated, assuming the same parking habits. Only 5 percent of all the vehicles parked in garages, 39 percent parked in driveways, and 56 percent parked on the street. This indicates the dominance of on-street parking for vehicle usage at the home end. The percentage is higher than in London, where garages, driveways, and on-street parking account for 15, 40, and 42 percent of all vehicles, respectively (RAC Foundation, 2004), and where on-street parking is certainly more crowded than in the study region (outside south Manhattan).

The discrepancy between parking types and parking habits raises two interesting questions. First, is on-street parking over-supplied, especially in TUSAs with abundant off-street parking? If not, why do so many households (95 out of 257) park on the street even when they have private parking available on the property? Second, should parking habits be regulated if they affect travel decisions associated with different externalities (congestion, pollution, greenhouse gas emissions, etc.)? The next section looks at the influence of parking types and parking habits on various travel decisions.

IMPACT OF PARKING TYPES AND HABITS ON TRAVEL DECISIONS

Parking types and parking habits each include three variables:

Garage: 1 if a household has a private garage onsite, 0 otherwise
Driveway: 1 if a household has no garage but can park in a driveway, 0 otherwise
On-street: 1 if a household only has access to on-street parking, 0 otherwise
Park in garage: 1 if a household parked their car at least once in a garage on the survey day, 0 otherwise
Park in driveway: 1 if a household parked their car at least once in the driveway on the survey day, 0 otherwise
Park on street: 1 if a household parked their car at least once on the street on the survey day, 0 otherwise

The three parking type variables are mutually exclusive (one household can only belong to one category), but the three parking habit variables are not (a household can belong to multiple categories if it parked a car in different places). However, only five households did so in the sample (see Table 2).

In order to identify the impact of parking on travel behavior, other factors must be controlled for, including household attributes and land use characteristics. The former includes household size, income (on a scale of 1-10), number of workers (both full-time and part-time), number of children (17 years and younger), residence type (single-family detached, attached, and multifamily), housing tenure, etc. These variables were extracted from the NYMTC household travel survey, which includes job density, population density, the network distances to the closest train station and downtown (Times Square), the percentage of residential land within a 0.5 mile buffer, a land use entropy index (Forsyth, 2007), and the neighborhood's average year of construction. The information was obtained from the Census, the PLUTO database, the New Jersey 2002 Land Cover database, and transit authorities in the region (the Metropolitan Transportation Authority, New Jersey Transit, and the New York-New Jersey Port Authority). The descriptive statistics are listed in Table 4.

Variables	Mean	Standard deviation	Source
Household Attributes			
Car ownership	1.28	0.93	NYMTC Survey
Household Size	2.8	1.40	NYMTC Survey
Household income (scale 1-10)	5.02	1.93	NYMTC Survey
# of workers (full + part time)	1.32	0.96	NYMTC Survey
# of children (=<17 year old)	0.64	0.95	NYMTC Survey

Single family detached (yes/no)	0.52	0.50	NYMTC Survey
Single family attached (yes/no)	0.25	0.44	NYMTC Survey
Apartment (yes/no)	0.23	0.42	NYMTC Survey
Household head Black (yes/no)	0.16	0.37	NYMTC Survey
Household head Hispanic (yes/no)	0.17	0.38	NYMTC Survey
Land Use Attributes			
Job density (per sq mile in the zip code)	5,115	4,348	Business Pattern 2007
Population density (per sq mile in the block group)	37,386	23,204	Census 2000
Network distance to the nearest train station (mile)	2.54	2.42	*
Entropy (within 0.5 mile buffer of residence)	0.49	0.21	**
Household live in North Manhattan (yes/no)	0.01	0.09	NYMTC Survey
Household live in Bronx (yes/no)	0.11	0.32	NYMTC Survey
Household live in Queens (yes/no)	0.21	0.41	NYMTC Survey
Household live in Brooklyn (yes/no)	0.25	0.44	NYMTC Survey
Household live in New Jersey (yes/no)	0.42	0.75	NYMTC Survey
Availability of On-Street Parking			
On-street parking crowding level (scale 1-8)	5.94	1.82	Author
Total number of observations	770 households with off-street parking		

* GIS data obtained from PATH, NJ Transit, New York City Subway, and MTA Commuter Rail.
** From 2008 PLUTO files for parcels and New Jersey 2002 Land Cover by Watershed Management Area http://www.nj.gov/dep/gis/lulc02cshp.html#WMA20

Table 4 Descriptive Statistics for Independent Variables

Impact of Parking Types
This section discusses the long-term car ownership decisions and the short-term commuting mode decisions, trip rates, trip chaining, and trip time.

Car Ownership
Table 5 summarizes the parking types and car ownership for all 840 households. Only 66 percent of households owned at least one car. This percentage is slightly higher than the New York City average because the sample excluded households in south Manhattan (south of 110th Street). Among households with private parking (garage or driveway), most (81 percent) had cars, while many (51 percent) of the households that had only on-street parking chose not to own a car. However, there are two interesting findings in Table 3. First, 49 households did not have a car but had an on-site garage. Second, 47 households had two or more cars even they only had on-street parking available. This suggests that the relationship between parking supply and car ownership is probably less straightforward than traditionally thought, especially in high- and medium-density areas. Both on-street and off-street parking affect car ownership and should be considered jointly in making parking policies.

# Households	**Car Ownership (N=840 households)**				
Parking Types	**0 Car HH**	**1 Car HH**	**2 Car HH**	**3+ Cars HH**	**Total**
Garage	49	111	79	27	266

Driveway	34	90	44	10	178
On-Street	203	146	33	14	396
Total	286	347	156	51	840

Table 5 Parking Types and Car Ownership of Selected Households in New York City

To further illustrate the relationship, a car ownership model was developed using a multinomial logit model. The base for comparison was zero-car households. Because not all 840 households had a geocodable home address and their land use characteristics could not be identified, only 770 households were used in this analysis. Table 6 shows the results.

Most variables are significant with an expected sign. For example, higher income increases car ownership; households with more workers tend to have more cars; household size encourages car ownership, but only for households with three or more vehicles; higher number of children reduces the likelihood of owning three or more vehicles, probably due to the number of legal drivers in the household; single-family housing (either attached or detached) and housing ownership increase car ownership; density (either job or residents) deters car ownership; and convenient access to transit significantly reduces car ownership at all levels.

For parking type variables, the results are based on comparison with on-street parking (the base). For example, the garage variable has a positive sign, which means that a household with a private garage tends to have more cars than a household with only on-street parking. The effect is significant at all three levels of car ownership. Households with only driveways are more likely to own one or two cars than households with only on-street parking, but there is no difference for three or more cars, which supports our expectation.

The effect of on-street parking on car ownership is straightforward for households with only on-street parking, but less so for households with off-street parking. To investigate the relationship, both the on-street crowding variable and the interaction between garages (for 2- and 3+-car options) and driveways (for the 2-car option) are included. As expected, the on-street parking variable is significant with a negative sign only for the one-car option. However, both interaction terms have a negative sign, and one variable, the garage interaction term specified for 3+ cars, is significant at the five percent level. This indicates that even households with a private garage would buy a third vehicle (or even more) if on-street parking was readily available nearby. This effect is significant after controlling for parking types and development density.

Variables	**1 Car**		**2 Cars**		**3+ Cars**	
	beta	t	beta	t	beta	t
Constant	-0.43	-0.7	-4.3	-3.4	-13.1	-6.2
Household Attributes						
Income level (1-10 scale)	0.34	5.0	0.53	5.7	0.73	5.4
Household size (# of persons)	0.17	1.2	0.22	1.1	0.89	3.6
# of children (17 year or younger)	0.00	0.0	0.16	0.6	-1.14	-2.8
# of workers (full- and part-time)	0.14	0.9	0.75	3.6	0.79	2.7
Building						

Single-family detached (yes/no)	0.43	1.7	-0.04	-0.1	2.22	2.5
Single-family attached (yes/no)	0.65	2.3	0.48	1.2	2.45	2.8
Owner (yes/no)	0.56	2.2	1.21	3.5	1.70	3.2
Parking Supply						
Driveway (yes/no)	0.74	2.6	2.9	2.4	-0.17	-0.3
Garage (yes/no)	0.65	2.6	3.1	2.7	5.1	2.7
On-street crowding (1-8 scale)	-0.30	-3.9	-0.13	-0.8	0.25	1.0
Interaction Terms						
Driveway * on-street crowding			-0.27	-1.5		
Garage * on-street crowding			-0.27	-1.6	-0.71	-2.6
Land Use						
Pop. Density (10,000 / sq. miles)	-0.05	-1.6	-0.17	-3.1	-0.05	-0.5
Job density (10,000 / sq. miles)	-0.21	-1.6	-0.80	-2.4	-0.76	-1.4
Network distance to subway station (miles)	0.16	2.8	0.24	3.4	0.34	3.8
Final log-likelihood:	-674.392					
Adjusted Rho-square:	0.326					
Number of Observations	N=770 Households					

Note: model type is multinomial logit, and the base for comparison is Car = 0

Table 6 Impact of Parking Supply on Household Car Ownership

Commuting Mode

This analysis was applied to household members who had a job but did not work at home, had access to cars, and possessed a driver's license. To avoid the complexity of travel arrangements among different members in a household, only one representative member from each household (the head of household) was covered by the analysis. A simple binary logit model was applied, with the dependent variable of 1 if the head of household drove to work on the survey day and 0 otherwise.

The independent variables include household attributes, parking types at home, parking cost at work, urban form measures at the home point, and characteristics of the workplace in terms of its location and distance from home. Because workplace variables were estimated from actual trips made on the survey day, they were extracted for some, but not all, households. Two models were developed, with and without the workplace variables. The first had a sample size of 309, and the second model had 189 observations. All variables are specified for the driving option. Table 7 shows the best specifications.

Variables	**Model 1**		**Model 2**	
	beta	beta	t-test	t-test
Constant	1.30	2.0	-0.35	-0.3
Household Attributes				
Income level (1-10 scale)			0.26	2.2
Household size			-0.23	-1.4
Male (yes/no)	0.68	2.5	0.88	2.3
# of Vehicles	0.40	2.0	0.31	1.1
Single-Family Detached	-0.75	-2.3	-1.47	-2.7
Single-Family Attached	-0.48	-1.4	-1.11	-2.1
Parking Attributes				

Driveway at Home (yes/no)				
On-street at Home (yes/no)	-0.61	-2.2	-1.39	-2.9
On-street Crowding at Home (1-8 scale)	-0.10	-1.3		
Parking Cost at Work ($ per day)	-0.09	-3.4	-0.05	-1.6
Urban Form at Home Origin				
Network distance to Time Square (miles)			-0.14	-1.7
Network distance to a subway station (miles)	0.09	1.5	0.28	2.8
Entropy	-1.13	-1.8	-1.10	-1.1
Percent of residential land within ½ mile			-0.87	-1.0
Work Place Attributes				
Distance from home (miles)			0.06	1.7
Located in New Jersey (yes/no)			1.23	2.5
Located in the Bronx, Queens, or Brooklyn (yes/no)			2.89	4.6
Sample size	N= 309 household heads		N= 189 household heads	
Final Log likelihood	-170.033		-88.802	
Adjusted rho-square	0.107		0.146	

Note: Empty cells indicate the variable was included in the initial model but excluded because its t-statistic had an absolute value of less than 1.0. In other words, these variables were deleted from the final model because doing so produced a model with a higher adjusted rho-square.

Table 7 Impact of Parking Supply on the Commuting Mode of Heads of Household

The results clearly show that parking types affect commuting mode. The on-street parking has a negative sign and is significant at the five percent level, which means that compared to households with a private garage, those with only on-street parking are less likely to drive to work (given they all own at least one car). This is probably caused by the concern that they might lose their parking spaces. The result is consistent with the finding by Weinberger et al. (2009) in two neighborhoods in Queens and Brooklyn. The driveway variable does not appear in the model and is no different from a private garage.

Most control variables perform as expected. A head of household is more likely to drive to work if the person is male, from a high income household, owns more vehicles, works outside Manhattan (New Jersey, the Bronx, Brooklyn, or Queens), and lives far from the workplace and subway stations. Higher parking cost at the workplace deters driving to work. Surprisingly, single-family housing is significant with a negative sign, which seems counterintuitive. One possible explanation might be that single-family housing might be associated with factors that encourage transit use but are not captured by the control variables, such as an employer's subsidy to use transit or good and safe walking paths to transit stops/stations.

Tour Rate, Trip Chaining, and vehicle Hours

This analysis was performed only for the 504 households who owned cars in order to control for the car ownership effect. *Tour* is defined a set of successive trips that start and end at home. A work and school tour is defined as at least one trip in the tour for work or school purposes.

Three tour aspects were investigated. *Tour rate* refers to how many vehicle tours were made by a household on a survey day. *Chaining* refers to how a household combined different trips into one tour. *Tour chaining* is measured by the average number of middle stops and the average length of a trip in a tour. *Tour time* refers to the total length of time to complete a tour.

As Table 8 shows, household attributes are the main determinants of tour rate, but parking types also matter. For example, on-street parking tends to deter tour generation for all tour types. On average, a household with only on-street parking made 0.3 fewer vehicle tours per day than a household with a private garage did. Parking types also affected total tour times, but to a lesser extent. Both driveway and on-street parking have a negative sign, but only the latter is significant at the 10 percent level. The estimation indicates that, on average, households with only on-street parking use their vehicles 21 minutes less per day than those with a garage.

Variables	Vehicle Tours							
	All Vehicle Tours		Work/School (WS) Tours		Non-WS Tours		Total Vehicle Hours	
	N=503		N=503		N=503		N=503	
	beta	t stat	beta	t stat	beta	t stat	beta	t stat
Constant	-0.40	-1.9	-0.27	-2.2	-0.59	-2.2	**154.3**	**5.7**
# Cars	**0.25**	**4.3**	**0.14**	**3.9**	**0.11**	**2.4**	8.10	1.4
Household size	**0.31**	**5.8**			**0.27**	**5.6**	**-12.8**	**-2.5**
Income	*0.05*	*1.8*	0.02	1.0	0.03	1.2	3.16	1.2
# Workers			**0.30**	**8.3**	**-0.25**	**-4.7**		
# Children	**-0.16**	**-2.1**	**0.12**	**3.8**	**-0.24**	**-3.6**	7.99	1.1
Single-family detached								
Single-family attached					0.11	1.3	-10.6	-1.0
Parking Supply								
Driveway							-17.8	-1.6
On-street	**-0.32**	**-3.2**	**-0.18**	**-2.9**	**-0.17**	**-2.1**	*-21.1*	*-1.8*
On-street crowding							-3.52	-1.3
Land Use								
Pop. density					0.02	1.1	0.00	1.4
Network dist. to a subway station	0.03	1.4	**0.03**	**2.2**				
% Residential	**0.41**	**2.1**	0.19	1.5	*0.27*	*1.9*	**-45.3**	**-2.6**
Avg. year built					*0.01*	*1.9*		
Adj. R sq	0.211		0.271		0.102		0.041	

Note: A blank area means the variable is omitted from the best specification; bold font indicates a significant level at 5 percent, and italic font indicates a significant level at 10 percent.

Table 8 Impact of Parking Supply on Trip and Tour Generation (Regression Models)

The tour chaining behavior was investigated for 304 households who used their vehicles on the survey day. Only these households produced vehicle tour information. The number of middle stops and average trip length were analyzed for all vehicle tours, work and school tours, and non-work and school tours. However, none of the variables explain the tour chaining behavior, with most adjusted R squares being smaller than 0.1. Therefore, the results are not presented. This indicates that parking types, in general, have a weak influence on tour chaining behavior.

Impact of Parking Habits

Unlike parking types, parking habits are assumed to influence only the short-term tour decisions, such as tour rates, tour chaining, and tour time. In order to control for the parking supply effect, the analysis was conducted for a fixed parking type (garage or driveway) for all tours, work and school tours, and non-work and school tours. Table 9 shows the results of 12 regression models for 150 households with a private garage. Of these households, 104 made at least one work and school tour, and 84 of them made at least one non-work and school tour on the survey day.

Where people park their cars is not associated with their total number of tours. The two parking habit variables either do not appear or are insignificant in the three tour rate models (Models 1, 5, 9). However, parking habits seem to affect tour chaining and tour time, especially for work and school tours. On-street parking is significant with a positive sign for the average trip time of all tours (Model 3, at the five percent level) and for the number of middle stops and average trip time for work and school tours (Model 6 and 7, at the ten percent level). This indicates that when a household chooses to park on the street instead of in a private garage or driveway, the household is more likely to make longer trips (14.9 minutes longer) and more stops (0.51 more) for a work and school tour. The effect is insignificant for non-work and school tours.

On-street parking is also significant (at the five percent level) for tour time for all tours (Model 4) and work and school tours (Model 8) with a positive sign. This means that if a household is used to parking on the street, the household on average spends 47.7 more minutes per day driving than a household that parks in a driveway or garage, assuming they have access to all three options. The average household daily vehicle time in the sample was 125 minutes.

Parking in a driveway seems to encourage tour making compared to parking in a garage, but the effect is not significant. The variable appears in two models (Models 1 and 5), but it is statistically insignificant. On-street parking crowding seems to deter tour making. It appears in four models (Models 3, 4, 7, and 8), all with a negative sign, but it is only significant at the 10 percent level in Model 3. When on-street parking is crowded, a household tends to make shorter trips and spend less time on a tour.

The same relationship was examined for 84 households that had driveways and on-street parking but not private garages. However, no clear behavioral difference was found between parking in a driveway and parking on the street, so the results are not presented.

This above pattern does not ensure a causal relationship, such as “parking habits affect tour-making decisions.” It might be possible that a household that makes many vehicle tours is more likely to park on the street to save time. Nevertheless, the relationship suggests that on-street parking is conducive to tour making because it is convenient to park on the street when it is not crowded and there is a reduced “transaction cost” between two subsequent tours. This “convenience” is more obvious when compared to a structured garage, but less so when compared to a private driveway or alley.

Variables	All Tours (N=150)								Work/School Tours (N=104)								Non-Work/School Tours (N=84)							
	Tour Rates		Tour Chaining				Tour time		Tour Rates		Tour Chaining				Tour time		Tour Rates		Tour Chaining				Tour time	
			# middle stops		Avg. trip time						# middle stops		Avg. trip time						# middle stops		Avg. trip time			
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8		Model 9		Model 10		Model 11		Model 12	
	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t	beta	t
Constant	-0.23	-0.4	3.08	7.7	60.5	4.9	225.6	4.4	-0.08	-0.3	3.20	10.6	78.8	4.6	278.0	5.0	1.74	6.0	3.18	7.4	12.5	1.6	74.8	2.9
# Cars	**0.30**	**3.6**					14.2	1.3	**0.19**	**2.3**							0.11	1.4			**4.88**	**2.1**	**22.5**	**3.2**
Household size	**0.18**	**3.5**	*-0.12*	*-1.8*	-2.05	-1.0	*-11.9*	*-1.8*					*-6.27*	*-1.7*	*-22.0*	*-1.8*			**-0.16**	**-2.2**				
Income (1-10)			0.06	1.2					*0.06*	*1.9*							-0.08	-1.6						
# Workers									**0.20**	**2.7**							-0.09	-1.1					*-12.3*	*-1.8*
# Children									**0.11**	**2.0**			6.39	1.1	18.6	1.0	**0.16**	**2.1**			**-7.24**	**-3.0**	**-25.9**	**-3.8**
Single-family detached							-36.9	-1.4													-4.87	-1.0	*-31.3*	*-1.7*
Single-family attached	*0.28*	*1.7*			-8.94	-1.4	**-58.8**	**-2.0**	0.15	1.2			-14.2	-1.6	-43.4	-1.5	0.19	1.1	-0.36	-1.5			-29.5	-1.4
Parking Habits																								
Park Driveway (yes/no)	0.22	1.2							0.15	1.4														
Park On-street (yes/no)	0.30	1.4	0.32	1.5	**12.7**	**2.0**	**47.4**	**2.2**			*0.51*	*1.8*	*14.9*	*1.7*	**58.8**	**2.1**					7.94	1.5	18.5	1.2
On-street Crowding					*-2.77*	*-1.8*	-6.97	-1.3					-2.55	-1.2	-7.30	-1.1								
Land Use																								
Pop. density																								
Network dist. to a subway station	*-0.07*	*-1.7*									-0.08	-1.4							0.10	1.5				
% of residential			-0.05	-1.0							-0.08	-1.4									-1.51	-1.4	*-5.26*	*-1.7*
Avg. year built	**0.72**	**2.7**	-0.51	-1.4	-15.9	-1.5	*-66.2*	*-1.9*	0.30	1.6			**-28.1**	**-2.0**	**-106.6**	**-2.3**			-0.62	-1.5	**20.2**	**2.1**	**57.2**	**2.0**
Adj. R sq	0.227		0.034		0.034		0.053		0.300		0.035		0.054		0.074		0.091		0.098		0.111		0.186	

Note: A blank area means the variable is omitted from the best specification; bold font indicates a significant level at 5 percent, while italic font means a significant level at 10 percent.

Table 9 Association between Parking Habits and Tour Making for Households with Garages

RESIDENTIAL PARKING POLICY AND MODE SHIFT IN TUSA

The analysis offers two interesting observations: First, households who only have access to on-street parking tend to have fewer cars, make fewer car trips, and drive fewer miles comparing to households who have a private garage, not only because the parking spaces are limited but also because they are not guaranteed. Second, when on-street parking becomes a free and viable alternative to a private garage, it could encourage car ownership and usage (at least in the study region): households tend to have more cars when this alternative is easily available, and those who use it tend to make more car trips and drive longer miles than those who do not.

The first observation describes a competition effect that over-consumes free accessible public resources, which, in the case of residential on-street parking, actually prevents people from making some car trips. The second observation describes a subsidy effect on car ownership and usage from (over-supplied) on-street parking in areas with sufficient off-street parking. But are the two effects unique to the New York City region? The answer is probably not.

The competition effect is likely to hold in other metropolitan areas. It is hardly to believe that people elsewhere will not over-exploit free, valuable public recourses like on-street parking. For the subsidy effect of on-street parking, planners need to compare the "transaction costs" between garage parking and on-street parking to make a conclusion. Such a cost for garage parking is probably affected by factors like the location and size of a garage, width of driveway, etc. The cost for on-street parking is likely determined by factor such as street width, parking occupancy, and regulations (permit, time limits, street cleaning, etc.). When the transaction cost is high for garage parking but low for on-street parking, the subsidy effect is more likely to occur.

The study region represents a high transaction cost for not only garage parking but also on-street parking, because streets are usually narrow, on-street is often crowded, and parallel parking could be challenging. In some low-density communities, the transaction cost could be low for both garage and on-street parking. Therefore, whether the subsidy effect holds in these communities can only be tested empirically case by case. However, given the wide usage of on-street parking in residential neighborhoods across the country, it is unlikely that the New York City region is the only place having this problem.

Now what are the implications to policy-makers if they plan to reshape the travel pattern in TUSAs and encourage the usage of public transit? Two recommendations to reshape could be directly inferred from the findings: First, government should protect on-street parking spaces in TUSAs with a tight parking supply, and, especially, limit the conversion of on-street parking to off-street parking through curb cuts. Second, government should limit the supply of on-street parking in TUSAs with sufficient off-street parking to avoid subsidizing private car ownership and usage (or private property values).

Limiting Conversion of On-Street to Off-Street Parking When Off-Street Parking Is Insufficient

In dense-developed areas like New York City, San Francisco, Boston, etc., where many residential buildings were built before the car era, residents heavily rely on on-street parking and the demand for off-street parking is strong. However, comparing to off-street parking, on-street parking (as shared parking) is more efficient to meet parking demand [1] (DCLG, 2007), occupies less accessory road space, and encourages more rational usage of cars. Adding off-street parking spaces (garage or driveway) in these communities, either through modification of existing buildings or construction of new buildings is a bad practice because it replaces one or more on-street parking spots through new curb cuts, just like replacing a taxi with a private car.

According to this research, replacing one on-street with one off-street parking is associated with seven more VMT per day, 1,750 VMT per year (assuming 250 weekdays), and 1,610 pounds of annual CO_2 emission (assuming 0.92 pound per mile) (Weinberger et al., 2009). Considering San Francisco, a city of 0.8 million people, has about 200,000 curb cuts and New York City, with 8 million population, probably has much more, curb cuts could have a tremendous impact on street congestion, pollution, and carbon emission, often in communities with the best public transit services. The calculation is still an underestimate because one curb cut could add multiple off-street parking spaces and their effect on car ownership is not counted.

Replacing on-street parking with off-street does not necessarily increase the net parking supply. For example, a survey in Mission District, a 40-block neighborhood in San Francisco, found that curb cuts take 30 percent of the total curbside length, and result a combined total loss of 356 out of 878 potential on-street parking spaces, a decrease of 41 percent. This percentage is higher than 30 percent because many residual spaces are too short for most automobiles. Because this neighborhood has a total 883 registered cars, in theory, all but five cars could have parked on the street simultaneously if garages had not been added (Brown, 2007).

Except for the implication for traffic, curb cuts often damage the façade of historical buildings, convert front gardens or lawns to concrete parking pads, and interrupt sidewalk and pedestrian movement. From the social equity point of view, curb cuts represents a regressive policy because, as observed by Brown (2007), higher income groups are more likely to request a curb cut, which shifts the burden (loss of on-street parking) to the lower income groups that live in nearby neighborhoods.

Government should protect on-street parking and control curb cuts in TUSAs. For existing buildings, conversion of front yards, gardens, or lawns to parking spaces should be strictly regulated. For new buildings, the minimum parking requirement could be waived so developers are not forced to provide off-street parking that they probably would not without the requirement. In other words, the curb cut policy should act as an effective tool to manage travel demand and promote sustainable travel patterns, instead of a passive response to residents' petitions.

There are signs that some cities are moving towards that direction. For example, some boroughs in London have adopted the "no-reduction" policy for on-street parking and will gradually increase on-street parking spaces in their local development plans (Kensington and Chelsea, 2002). In April 2010 in New York City, the City Council passed a zoning amendment to limit the conversion of front yards to parking in order to preserve the streetscape and on-street parking (NYCDCP, 2010). The amendment also introduces curb cut rules for many residential districts outside the Manhattan core that

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[1] According to the DCLG analysis for three-bed room households, it requires 13 percent more parking spaces to meet the same level of parking demand if all parking spaces are provided off-street on each property instead of as shared parking on street due to the heterogeneous parking demand across households.

currently do not have a policy on curb cuts. In San Francisco, new legislations in spring 2010 require a conditional use authorization to install a garage in an existing building in some downtown neighborhoods [2]. Curb cuts should be oriented to minimize the loss of on-street parking, and the new garage shall not take more than two on-street parking spots. The new policy also replaced minimum parking requirements with maximum ones, prohibited driveways, and charged new curb cuts a minimum $100 annual fee. In Washington DC, a new policy effective in 2010 will not approve any new curb cuts if the parking could be accessed from an alley instead of from the street.

However, most of efforts are initiated for historical preservation, not travel demand management. In general, curb cut regulations are not well designed and cross-cut the institutional boundaries between transportation, planning, and building agencies. In New York City, illegal curb cuts are not required to be removed after fine is paid. Inconsistency often occurs between Department of Building and Department of City Planning regarding the interpretation of rules to approve or reject curb cuts requests. In San Francisco, when curb cuts are not functional due to the conversion of garages to other uses, there is no rule to restore them back to the original condition. Curb cut policy is critical to the transportation problems in these TUSA communities, and deserves more attention from planners and policy-makers.

Limiting On-Street Parking Supply When Off-Street Parking Is Sufficient

Some TUSA communities (like those in east Queens) have abundant off-street parking, probably due to the minimum requirement by government, despite the availability of multiple public transit services. Garage together with driveway are sufficiently to meet a resident's parking demand, however, government often provide free on-street parking to local residents. As discussed earlier, these on-street parking spaces, acting as a viable alternative to off-street parking, could encourage private car ownership and usage. The policy could also be potentially regressive because larger lots tend to have access to more on-street parking spaces in front of the property.

Limiting the provision of on-street parking when off-street parking is sufficient could be done either by design that physically eliminates on-street parking or by regulation that prohibits on-street parking in certain areas or at a certain time. By design, on-street parking could be convert into exclusive pedestrian, bike, or bus lanes. Such restriping efforts have been proposed or implemented in many communities such as the Bloor Street in Toronto (CAP, 2009), Prince Street in New York City (TA, 2006), Euclid Avenue in South Tampa, FL, and in Eugene, OR where the most used on-street bike lanes occupy former car parking space [3]. Many private communities owned and maintained by homeowner associations (HOA) completely ban on-street parking through their Covenants, Conditions and Restrictions (CC&R). For example, in Baldwin Park, a private community in Orlando, FL, streets are only 20 to 22 feet wide and on-street parking is not allowed except in the designated parking area along major roads

[2] Including Chinatown, the North Beach Neighborhood Commercial District (NCD), the Broadway NCD, and the Telegraph Hill-North Beach Residential Special Use District.

[3] http://www.webikeeugene.org/index.php/2010/08/eugene-bicycle-history-online-at-city-of-eugene-website/

surrounding the subdivision [4]. Another example, Village Home in Davis, CA eliminate on-street parking completely in street design. Streets, therefore, could be narrower and the total construction cost to developers could be reduced. The saved space could be used for widened sidewalk, new bike lanes, expanded open space, or new playground (Village Home, 2009). Although these examples are not exactly TUSA communities, they indicate that on-street parking could be excessive when off-street parking is sufficient. Private developers understand this better than government.

By regulation, government can either limit the time duration that on-street parkingt could be used, or charge a price. In the first case, many cities prohibit on-street parking for more than a number of consecutive hours. This number could be 24 hours in a few cities, such as Houston, TX, Lincoln, NE, New Orleans, LA, Fitchburg, WI, Bayport, MN, etc. or 72 hours in many other cities. In the second case, government can revise the existing resident permit program and charge fees for the usage of on-street parking. Currently, almost all resident permit programs act like an exclusionary policy to none-residents instead of a tool for demand management. Most time, the fee is minimum normally less than $30 per year [5] and there is generally no limit on how many permits should be issued to a household, a driver, or a vehicle. In contrast, such a fee is much higher in the European cities, for example, €135 ($180) in Vienna, £132 ($208) in Westminster, London, and €182 ($244) in Center Amsterdam. The cap of the number of permits issued is also much lower [6], one permit per household in Lodnon, one per driver in Vienna, and two per households in Paris and Rome. In Amsterdam, the waiting time to get a permit could range from one month to four years depending on the location of residence.

In the revised permit program, the fair price could act as a sustainable policy to reduce car dependence, encourage low-emission vehicles, and benefit alternative travel means. In Westminster, London, electric, hybrid and fuel cell vehicles are waived from the fee. In Waltham Forest, London, vehicles with an engine cylinder capacity greater than 3000 cc pay almost five times than vehicles with an engine cylinder capacity smaller than 900 cc. Kensington and Chelsea in London charge an extra fee for the second and each additional permit to a household. Charging on-street parking is possible in the TUSA neighborhoods in the study region. In a survey of 173 households conducted by the author in New York City in summer 2010, a significant number of households (40 percent) are willing to pay for a permit even though it will not guarantee them a parking spot and all on-street parking is currently free. A major obstacle might be politics—such a program need the approval from the state legislation in Albany.

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[4] Based on the phone conversation between the author and Baldwin Park Property Owners Association on October 13, 2010

[5] San Francisco probably has the highest residential permit fee at $98 per year. It increased dramatically from $30 per year in 2006, to $60 in 2007, and $76 in 2008. However, the fee hike was primarily driven by the deficit of the local transportation agency, not by a goal to manage parking demand. See http://www.sfexaminer.com/local/Parking-permit-fee-hike-seen-as-unfair-82030747.html#ixzz10qBk69AC

[6] As a comparison, San Francisco has a four permit per household policy after 2002. In Seattle, five permits are allowed for a household address including one for guests. In Chicago, each vehicle can apply for one permit, but there is no cap at the household level. In New York City, no parking permit program exists at all because it needs approval from the state legislation.

CONCLUSION

This research investigates the impact of residential parking on household travel behavior in transit under-served areas (TUSA) in the New York City region. It finds that TUSA households with only on-street parking tend to have fewer cars, make fewer vehicle trips, and drive less overall VMT, comparing to households with a garage. However, when on-street parking becomes a viable alternative to off-street parking--free, convenient, and readily available, households tend to have more cars and use these cars more often.

With the findings, the research offers two distinct policy recommendations in order to reshape TUSA residents' travel behavior and encourage mode shift from private cars to public transit: First, in TUSA neighborhoods with insufficient off-street parking, government should protect on-street parking and limit curb cuts that replace on-street with off-street parking. Second, in TUSA neighborhoods with sufficient off-street parking, governments should limit the provision of on-street parking by (1) converting on-street parking lanes into exclusive bike lanes, bus lanes, or sidewalk,; (2) limiting the time usage of on-street parking; or (3) charging households for a permit fee that could be designed to discourage car ownership and promote alternative travel means. Since the research is based on the TUSA neighborhoods in the New York City region, future research in other metropolitan areas would help better understand the travel pattern in TUSA and the importance of efficient, effective, and equitable residential parking policy.

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