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CAPSTONE PROJECT REPORT

UCLA Institute of Transportation Studies

PARK Smarter

Lessons in curb pricing for New York City

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Client: New York City Department of Transportation Parking Planning and Policy

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16. Abstract
Curb parking is notoriously difficult to find in certain parts of New York City (NYC). NYC Department of Transportation (DOT) is considering implementing demand-responsive pricing for its passenger metered spaces to manage parking demand. This is a pricing mechanism whereby the price of curb parking fluctuates spatially and temporally in accordance with expected or actual demand. This report assesses successful permanent citywide implementations of demand-responsive curb pricing in San Francisco and Seattle to determine the most effective strategies for NYC DOT: these include using meter transaction data and historical occupancy data to estimate current parking occupancy and exploring possibilities of vehicle-mounted license plate recognition technology. To help make demand-responsive pricing more efficient and politically acceptable, the city can implement additional policies such a two-tier system for disability placards to target placard abuse or parking benefit districts to direct meter revenue toward public services on metered blocks. A data-driven demand-responsive curb pricing program that follows a set model for rate adjustments, in conjunction with technology and legislation changes to increase support for the program and reduce parking violations, as described in this report, can effectively increase parking availability in New York City and guide other city transportation agencies in their efforts to do the same.

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PARK Smarter

Lessons in curb pricing for New York City

A comprehensive project submitted in partial satisfaction of the
requirements for the degree Master of Urban and Regional Planning

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Executive summary

Curb parking is notoriously difficult to find in certain parts of New York City (NYC). The city has tried demand-responsive pricing before, which is a pricing mechanism whereby the price of curb parking fluctuates spatially and temporally in accordance with expected or actual demand. Such pricing generally leads to shorter parking durations and greater parking availability, reducing many of the negative externalities associated with driving and parking. The pilot never became permanent, however, due to community contention and political pressure surrounding rate setting. In 2018, the city replaced the previous pricing methodology with a citywide six-tier rate structure.

This report assesses successful implementations of citywide demand-responsive curb pricing programs in San Francisco and Seattle to determine the most effective strategies that NYC Department of Transportation (DOT) can draw upon to implement demand-responsive pricing for the city's on-street passenger metered spaces, most notably:

- Using meter transaction data and historical occupancy data to estimate current parking occupancy.
- Testing vehicle-mounted license plate recognition (LPR) technology for a pay-by-plate system, collecting occupancy data, and automated enforcement.
- Adjusting parking rates three times a year.

A recently proposed New York City Council bill, if passed, will require NYC DOT to implement demand-responsive pricing in at least one area in each borough. Implementing the program through city law will reduce some political and community opposition. To help make demand-responsive pricing more efficient and politically acceptable, New York City should consider implementing additional parking programs and policies that have been successful in other states and cities. These include:

- A two-tier system for disability placards to reduce placard abuse, according to which metered parking costs will continue to be waived for drivers with serious mobility impairments, whereas those with less serious disabilities will have to pay at meters. A portion of meter revenue will be dedicated to programs and policies that improve accessibility.
- Increased meter revenue going toward public services on metered blocks, as opposed to simply contributing to the city's general fund.

While a citywide implementation seems infeasible due to resource constraints, a more data-driven demand-responsive curb pricing program that follows a set model for rate adjustments, in conjunction with technology and legislation changes to increase support for the program and reduce parking violations — as described in this report — can effectively increase parking availability in New York City.

Table of Contents

Acknowledgments *3*

Executive summary *4*

Introduction *7*

Defining demand-responsive pricing 7

Performance pricing 8

Peak pricing 8

Progressive pricing 9

Background *10*

Current parking policies and programs 10

Future policies 11

Congestion pricing 11

Local law for dynamic pricing 13

Advantages of demand-responsive pricing *14*

Reduces cruising for parking 14

Reduces illegal parking 14

Encourages mode shift 15

Provides options for differing users and needs 15

Offers greater revenue 15

PARK Smart *17*

NYC's introduction to demand-responsive pricing 17

Greenwich Village 18

Park Slope 19

Upper East Side 20

Jackson Heights 21

Atlantic, Court, and Smith 22

PARK Smart 2.0 24

Evaluating other implementations *25*

San Francisco and SF*park* 25

Seattle's Performance-Based Parking Pricing Program 29

Recommendations *34*
Data collection 34
Modelling 34
Context-specific factors 34
Challenges in implementation *36*
Placard abuse 36
Political or community opposition 38
Issues of scale 40
Conclusion *41*
Bibliography *42*

Introduction

Most cities keep curb parking free and deal with the resulting parking shortages by implementing time limits to induce vehicle turnover.[1]

Ninety-seven percent of New York City's (NYC's) on-street parking is unmetered.[2] Where curb parking is metered, base rates are set based on specific neighborhood characteristics such as land use, urban density, and demand; consequently, there are various parking rate zones across the five boroughs, with different progressive rates within each zone. Most metered curb parking has a two-hour limit, yet parking is notoriously difficult to find in certain parts of the city, causing drivers to cruise to find parking at unmetered curbs, park illegally, or overstay parking meter time limits due to poor enforcement.

No comprehensive comparison of various cities' demand-responsive curb pricing programs and their methods currently exists. This report assesses successful implementations of such programs across the United States to determine the most effective strategies for NYC Department of Transportation (DOT) to implement demand-responsive pricing for the city's on-street passenger metered spaces.

I reviewed the former pilot curb pricing implementation in New York City and the pilot and current curb pricing programs of San Francisco and Seattle, focusing on how these cities set their parking rates, to provide a set of recommendations for NYC DOT. For details on the procedures and challenges of implementation, I referenced publicly available city reports and met with employees of NYC DOT, San Francisco Municipal Transportation Agency (SFMTA), and Seattle DOT (SDOT) to discuss these programs. This report begins with a discussion of the past and current parking policies in New York City, describes San Francisco and Seattle's implementations, and concludes with implementation and policy recommendations for NYC DOT.

Defining demand-responsive pricing

Demand-responsive pricing involves varying the price of a good or service to reflect changing levels of demand. The frequency of these updates can vary; the price adjustments can be based on real-time demand, or they can occur every few weeks or months based on recent data or historical demand patterns. Thus, the term "demand-

[1] Donald Shoup, *The High Cost of Free Parking*, 1st ed. (Routledge, 2017).
[2] Donald Shoup, "Opinion | A Fix for New York's Parking Problems," *The New York Times*, June 18, 2018, sec. Opinion.

responsive pricing" can be used to refer to different implementations of the same underlying pricing strategy.

Curb parking can only provide a finite number of spaces to fulfill demand. When parking demand is greater than what the available curb space can accommodate, a solution is to vary the price of curb parking based on expected or actual demand, which generally means charging higher prices during times or in places of higher demand. Lower parking rates in some areas may incentivize drivers to park in more underutilized spaces, and higher rates in other areas may motivate drivers to stay at the curb for shorter periods of time, increasing vehicle turnover.

Curb occupancy rates are defined as the ratio of the total number of occupied spaces to the total number of usable spaces. As occupancy rates decrease, entering and exiting curb parking spaces becomes easier and fewer drivers cruise to look for parking.[3] Because of this, traffic engineers generally recommend a curb occupancy rate of 85 percent, and pricing algorithms modify parking rates to achieve a target occupancy that generally falls around 60 to 85 percent.[4]

The cost of implementing demand-responsive pricing depends heavily on the frequency of updates, the granularity of data needed, and the scale of the program. Real-time demand-responsive pricing is often infeasible for cities given resource constraints. The following subsections describe several types of demand-responsive parking pricing mechanisms implemented throughout the United States.

Performance pricing

Performance pricing schemes aim to achieve specific parking occupancy rates (e.g., one to two available spaces at any time per block or 85 percent occupancy) by adjusting meter rates and hours of operation.[5] These pricing mechanisms are outcome-focused.

Peak pricing

As the name suggests, peak pricing involves pricing curb parking higher during "peak" periods, which can be certain times of the day or days of the week that tend to experience greater demand. For instance, parking rates might be higher during daytime hours compared to nighttime hours.

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[3] Shoup, *The High Cost of Free Parking*.
[4] Shoup, *The High Cost of Free Parking*; San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice," June 2014; Seattle Department of Transportation, "2021 Paid Parking Annual Report," May 2022.
[5] Gregory Pierce and Donald Shoup, "Getting the Prices Right," *Journal of the American Planning Association* 79, no. 1 (January 2, 2013): 67–81.

Progressive pricing

In a progressive pricing system, parking rates increase as parking duration increases. For example, New York City has set progressive rates for all passenger metered parking: there is a two-hour limit for passenger curb parking in most areas, and the cost of parking is higher for the second hour.[6]

[6] New York City's progressive rates are fixed in the citywide rate structure. They do not fluctuate and are not adjusted in response to changes in parking demand in the city. Thus the city's current implementation is not considered demand-responsive pricing as it is defined and studied in this report.

Background

Current parking policies and programs

New York City has over 85,000 curb parking spaces and around 13,500 parking meters. The locations of these parking meters are based on criteria including parking supply and demand, parking durations, enforcement, and land use.[7] The city fully transitioned from single-space mechanical parking meters to the current Flowbird Strada meters in 2015.[8] These current parking meters are "MuniMeters," which can regulate multiple parking spaces, thereby reducing the number of meters that need to be installed and maintained along a blockface.[9] As spaces are no longer delineated by single meters, multi-space meters can also increase the number of parking spaces on a given blockface.[10]

Drivers can pay for street parking at a meter and display a printed receipt on their dashboard in a "pay and display" process or pay electronically using the ParkNYC app, which does not require a receipt to be displayed. The MuniMeters will soon be retrofitted to have touchscreen displays and the capability to input license plate information, allowing for a "pay-by-plate" system to eliminate the outdated pay and display process.[11] Metered parking rates range from $1.25 to $7.50 per hour for passenger vehicles and are not in effect on Sundays.[12] These rates vary across the city, and the current six-tier pricing system shown in figure 1 was introduced in 2018.

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[7] NYC Open Data. "Parking Meters - ParkNYC Blockfaces." NYC Open Data, n.d.; New York City Department of Transportation, "MuniMeter," NYC Street Design Manual, n.d.
[8] New York City Department of Transportation, "MuniMeter."
[9] A blockface refers to a single side of a street on a block, which falls between two intersections with other streets.
[10] New York City Department of Transportation, "MuniMeter."
[11] Matthew Garcia, communication with author, December 12, 2022.
[12] New York City Department of Transportation, "NYC DOT - Parking Rates," New York City Department of Transportation, n.d.

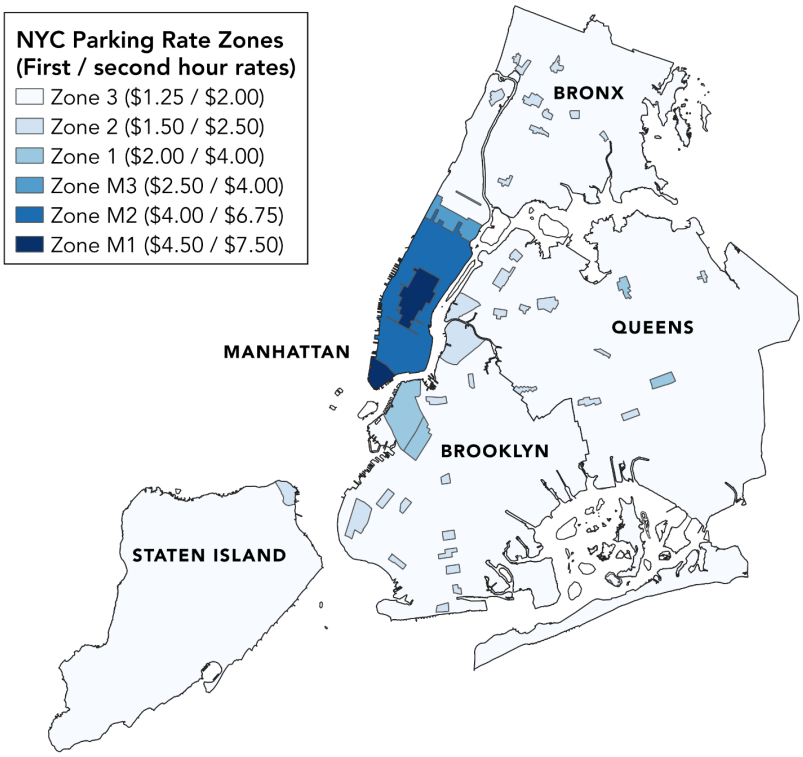

Figure 1. Parking rate zones for passenger metered parking in New York City. This map shows the parking rates for each of the six rate zones in the city. The zones prefaced with an "M" are those in the borough of Manhattan. (Figure by author).

Future policies

Congestion pricing

In 2019, former governor Andrew Cuomo proposed the Metropolitan Transportation Authority (MTA) Reform and Traffic Mobility Act, which requires MTA, the body responsible for public transit in the New York City metropolitan area, to develop and run a Central Business District (CBD) Tolling Program (CBDTP) in Manhattan.[13] This program will charge a toll on passenger vehicles that enter or remain in the CBD, defined as all roads south of 61st Street in Manhattan, as shown in figure 2.[14] The goals of the program include:

- Reducing traffic congestion.
- Improving air quality.
- Investing collected revenue in the MTA transit system.

[13] Metropolitan Transportation Authority, "Central Business District Tolling Program," MTA, n.d.
[14] Metropolitan Transportation Authority, "Central Business District Tolling Program."

- Providing greater equity by improving travel options.

The toll rates will be variable, and qualifying vehicles, such as authorized emergency vehicles or vehicles transporting people with disabilities, will be not tolled.[15] The revenue from the tolling will be distributed among various transit agencies in the following way: 80 percent for New York City Transit, 10 percent for Long Island Rail Road, and 10 percent for Metro-North Railroad.[16]

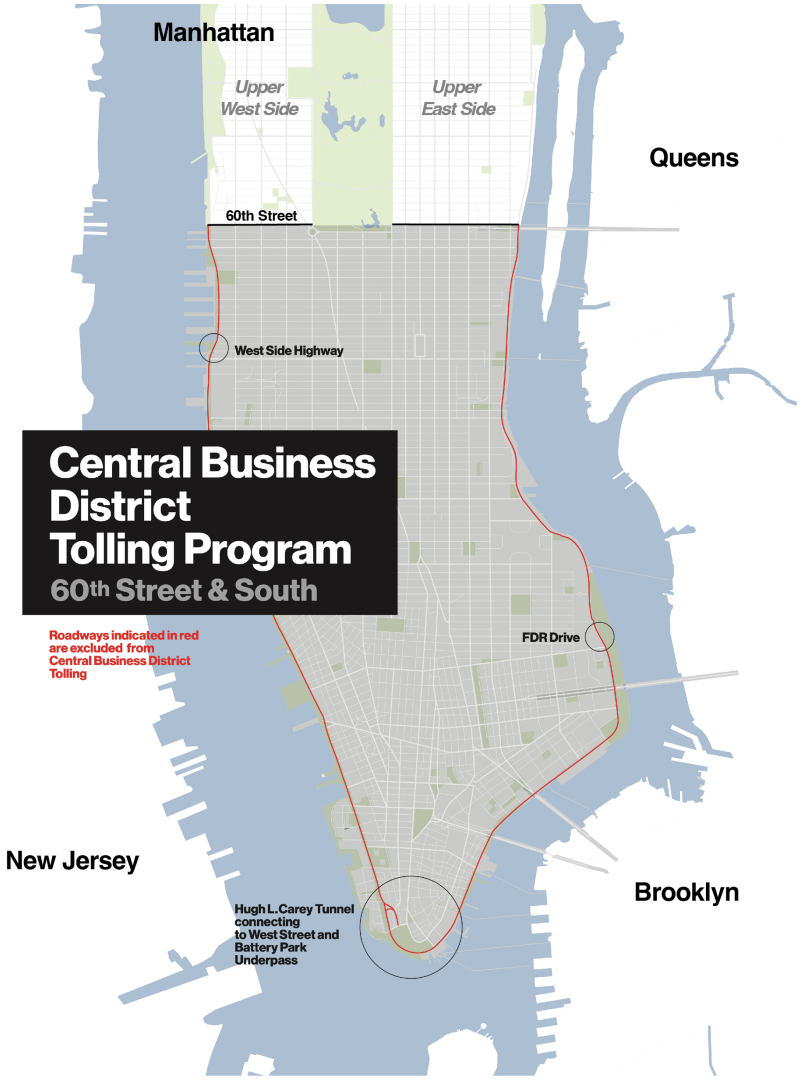

Figure 2. Central Business District Tolling Program area in Manhattan's CBD. This program will charge a toll on passenger vehicles that enter or remain in the CBD, defined as all roads south of 61st Street in Manhattan. (Figure adapted from Metropolitan Transportation Authority, "Central Business District Tolling Program").

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[15] Metropolitan Transportation Authority, "Central Business District Tolling Program."
[16] Metropolitan Transportation Authority, "Central Business District Tolling Program."

Under all tolling scenarios, models used by MTA predict increases in passenger vehicle trips to commuter rail stations, park-and-ride facilities, and subway and light rail stations, consistent with an increase in public transit usage by people commuting to and from the CBD. For instance, commuters who previously drove directly to Manhattan's CBD might drive to stations located outside of the CBD and use transit for the remainder of the trip.[17] This would entail lesser demand for parking within the CBD but greater demand for parking in areas surrounding the CBD, such as the Upper West Side and Upper East Side immediately north of 60th Street, which may necessitate increased curb parking rates or the implementation of other parking policies in those neighborhoods.[18] NYC DOT is working to study the effects of this program and will assemble a report 18 months after it is instituted.[19] The program will likely begin in 2024.[20]

Local law for dynamic pricing

In September 2022, a bill requiring NYC DOT to establish at least one demand-responsive parking zone per borough was discussed by the New York City Council and remains in committee.[21] According to this law, parking rates would only be able to be updated within a week's notice and would fall within a range determined by NYC DOT before implementation.[22] Furthermore, vehicles that are presently exempt from the city's metered parking requirements would remain exempt from the demand-responsive parking rates.[23] This law, if passed, would take effect one year from being enacted, making this report a useful compilation of successful strategies and policies for NYC DOT Parking to consider in its own demand-responsive curb pricing implementation.[24]

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[17] Metropolitan Transportation Authority, "Central Business District (CBD) Tolling Program Environmental Assessment: Subchapter 4D, Transportation: Parking."
[18] Metropolitan Transportation Authority, "Central Business District (CBD) Tolling Program Environmental Assessment: Subchapter 4D, Transportation: Parking."
[19] Metropolitan Transportation Authority, "Central Business District (CBD) Tolling Program Environmental Assessment: Subchapter 4D, Transportation: Parking."
[20] Metropolitan Transportation Authority, "Central Business District (CBD) Tolling Program Environmental Assessment: Subchapter 4D, Transportation: Parking."
[21] Nantasha Williams, "A Local Law to Amend the Administrative Code of the City of New York, in Relation to Establishing Dynamic Parking Zones," Int 0748-2022.
[22] Williams, A Local Law to amend the administrative code of the city of New York, in relation to establishing dynamic parking zones.
[23] Williams, A Local Law to amend the administrative code of the city of New York, in relation to establishing dynamic parking zones.
[24] Williams, A Local Law to amend the administrative code of the city of New York, in relation to establishing dynamic parking zones.

Advantages of demand-responsive pricing

Demand-responsive pricing leads to shorter parking durations and greater parking availability. These reduce many of the negative externalities associated with driving and parking. The following subsections discuss a few of the advantages in greater detail.

Reduces cruising for parking

Cruising refers to the activity in which drivers search for available parking spaces, sometimes simply looking for an open space, but at other times specifically trying to find an unmetered space, a metered space with a lower rate, or a space closer to their destination.[25] This contributes to excess vehicle miles traveled and consequently increased emissions.[26] If meter rates are set based on demand, they will be higher during times of higher demand and lead to greater vehicle turnover, helping parkers find spaces more quickly. Reducing cruising also reduces congestion and increases speeds for other vehicles on the road.[27] This includes other drivers as well as bicycles, scooters, and buses, which are more fuel-efficient and sustainable forms of transportation.

Reduces illegal parking

Higher meter rates can lead to shorter parking durations, so that there are more legal spaces available on a block at a time. New York City has high rates of illegal parking, including parking in bus stops, parking in front of fire hydrants, and double parking.[28] A study conducted in the Park Slope neighborhood of Brooklyn found an exponential relationship between curb saturation and illegal parking, with the fitted trendline suggesting that reducing legal parking occupancy by 5 percent could reduce parking violations by 50 percent.[29] In San Francisco, a reduction in double parking led to an increase in transit speeds.[30] Demand-responsive pricing can increase safety by maintaining buses and fire trucks' access to curb space and reducing double parking related-crashes with other vehicles or bicyclists.

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[25] Adam Millard-Ball, Rachel R. Weinberger, and Robert C. Hampshire, "Is the Curb 80% Full or 20% Empty? Assessing the Impacts of San Francisco's Parking Pricing Experiment," *Transportation Research Part A: Policy and Practice* 63 (May 1, 2014): 76–92.

[26] Millard-Ball, Weinberger, and Hampshire, "Is the Curb 80% Full or 20% Empty?"

[27] Pierce and Shoup, "Getting the Prices Right."

[28] Double parking refers to standing or parking on the roadway side of a vehicle that is stopped, standing, or parked at a curb.

[29] Transportation Alternatives, "No Vacancy: Park Slope's Parking Problem And How to Fix It," February 2007.

[30] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."

Encourages mode shift

High prices at the curb will motivate people to use transportation modes other than private vehicles. Drivers may choose to use active transportation modes such as walking, biking, and scootering for shorter trips or carpooling and taking transit for longer ones. Thus demand-responsive pricing can encourage a shift towards more active and sustainable modes.[31]

Provides options for differing users and needs

Variability in rates allows drivers to find parking more easily for their needs. For instance, lower-income drivers may prefer to park farther from their destinations if they can avoid more expensive, perhaps progressive, rates. As people with disabled placards can park in metered spaces for free, demand-responsive pricing would allow them to more easily find spaces closer to their destinations.

Offers greater revenue

Even if the goal of demand-responsive pricing is not to raise revenue, the policy can generate more revenue than flat price structures for metered parking. When prices are the same across an area for all time periods, meter rates might be overpriced at times and drivers may avoid parking there or evade paying for parking, which can actually lead to a loss of revenue for the city.

Extending meter hours can also increase revenue without having to increase average meter rates.[32] In San Francisco, metered parking was initially extended to operate on Sundays, although this was later rescinded in most areas.[33] SFMTA has recently decided to extend meter hours until 10 pm from Mondays through Saturdays and re-implement metered parking on Sundays from noon to 6 pm.[34] This will go into effect starting July 2023 and continue in phases through December 2024.[35] The primary goal of this

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[31] In San Francisco, parking meter revenue goes towards public transit. If this improves public transit reliability, frequency, and experience, it may also encourage a mode shift towards taking transit over driving.

[32] Pierce and Shoup, "Getting the Prices Right."

[33] Pierce and Shoup, "Getting the Prices Right."

[34] San Francisco Municipal Transportation Agency, "Extended Parking Meter Hours Phasing Plan," SFMTA, May 11, 2023.

[35] San Francisco Municipal Transportation Agency, "Extended Parking Meter Hours Phasing Plan."

extension is to generate revenue to help sustain the city's public transit system, the San Francisco Municipal Railway (Muni).[36]

Increased parking revenue can also be spent in more equitable ways. While San Francisco uses its parking meter revenue to subsidize public transit, a mode which disproportionately has lower-income riders, revenue can also be spent towards local public services or for programs and policies that can increase accessibility for those with disabilities.[37]

[36] San Francisco Municipal Transportation Agency, "Extended Parking Meter Hours Phasing Plan."

[37] Pierce and Shoup, "Getting the Prices Right."; Mark Garrett and Brian Taylor, "Reconsidering Social Equity in Public Transit," *Berkeley Planning Journal* 13, no. 1 (July 24, 2012).

PARK Smart

NYC's introduction to demand-responsive pricing

In 2008, NYC DOT implemented a parking program called PARK Smart in certain pilot areas throughout the city.[38] The primary goal of this program was to increase parking availability through demand-responsive pricing, to discourage long parking durations and consequently increase turnover of parking spaces.[39] Other goals included increasing safety and delivery access and reducing double parking, illegal parking, congestion, and pollution.[40]

Figure 3. PARK Smart Pilot areas. (Figure by author).

The program was piloted for periods of six months in parts of the city with identifiable demand constraints, such as retail areas.[41] These pilot areas can be seen in figure 3. The regulations and prices for each pilot were developed through a process of public

[38] The word "PARK" in PARK Smart is not an acronym.
[39] Dalila Hall, "NYCDOT PARK Smart Program."
[40] Hall, "NYCDOT PARK Smart Program."
[41] David Stein, communication with author, February 3, 2023.

engagement, with NYC DOT working with Community Boards, Business Improvement Districts, and other neighborhood community and advisory groups.[42] These areas were chosen based on whether they had high parking demand and stakeholders who might be able to work with NYC DOT in design and implementation, although the neighborhoods did have to opt into the program.[43]

Parking meter rates were set with peak or progressive pricing mechanisms. As described earlier in this report, this means that in some pilot areas, rates were higher during time periods of higher demand (peak hours), and in other areas, rates were higher during the second hour of parking. The peak hours were originally noon to 4 pm for all the pilot areas.[44] These rates were initially set based on curb occupancy surveys and community input and adjusted as needed depending on data and feedback.[45] Data collected before, during, and after the pilot periods included parking occupancy rates, parking durations, and number of unique vehicles.[46] As these pilot areas had commercial land uses, the program was also monitored using parker, passerby, and merchant surveys.[47]

The following sections describe the five pilots in greater detail.

Greenwich Village

The first pilot began in October 2008 in Greenwich Village, located in Lower Manhattan (fig. 4).[48] Rates were set at $2 per hour for the hours between noon and 4 pm (peak hours) due to increased parking demand and shifted to $1 per hour for all other hours (off-peak hours).[49] The pilot was successful: there was an increase in the number of available parking spaces, with parking occupancy decreasing by 6 percent after implementation.[50] Survey results indicated that most people felt that finding parking either became easier or remained the same; however, less than 50 percent of drivers and merchants surveyed were aware of the new rates.[51] Ultimately, as this accomplished the goal of increasing weekday parking availability, the community supported increasing the parking rates to $3.75 per hour during peak hours and $2.50 per hour during off-peak hours — and,

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[42] Hall, "NYCDOT PARK Smart Program."
[43] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[44] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[45] Hall, "NYCDOT PARK Smart Program."
[46] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[47] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[48] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[49] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[50] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[51] New York City Department of Transportation, "PARK Smart Greenwich Village Pilot Program -- Results," June 2009.

supported by ongoing data collection, these rates actually increased to $5 and $3, respectively, by summer 2011.[52]

Figure 4. Curb segments in Greenwich Village where PARK Smart was implemented. (Figure by author).

Park Slope

The next PARK Smart pilot was in May 2009 in Brooklyn's Park Slope neighborhood (fig. 5).[53] The rates were $1.50 per hour during peak hours and $0.75 during all other hours.[54] As with Greenwich Village, a majority of parkers were not aware of the new rates, even after paying for parking.[55] Traffic and parking volumes decreased during the pilot period, although parking occupancy remained mostly unaffected.[56] After discussion, the community supported doubling the PARK Smart area, having a longer time period for peak hours — such as extending them to 7 pm — and adjusting the peak rate to $2.25 in certain areas.[57]

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[52] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[53] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[54] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[55] New York City Department of Transportation, "Park Slope Pilot Program Update."
[56] New York City Department of Transportation, "Park Slope Pilot Program Update."
[57] New York City Department of Transportation, "Park Slope Pilot Program Update."

Figure 5. Curb segments in Park Slope where PARK Smart was implemented. (Figure by author).

Upper East Side

The third pilot area was in the Upper East Side of Manhattan in June 2010, on Madison Avenue and East 86th Street (fig. 6).[58] There were both passenger and commercial meters included in this pilot. The rates were initially set at $3.75 per hour during peak hours and $2.50 per hour during all other hours.[59] As numerous high-end and big-box retail stores line both sides of these corridors, the area receives many deliveries, leading to high curb utilization.[60] Pricing had little to no impact on influencing curb demand in these areas, however, as measured by parking occupancy and vehicle turnover.[61] Ultimately, the community asked to have the program suspended.[62]

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[58] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[59] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[60] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."
[61] Stein, communication with author, February 3, 2023.
[62] New York City Department of Transportation, "NYC's Peak Rate Parking Pilot."

Figure 6. Curb segments in the Upper East Side where PARK Smart was implemented. (Figure by author).

Jackson Heights

PARK Smart was then implemented in the Jackson Heights neighborhood in northwestern Queens in July 2013 (fig. 7).[63] This was the first pilot to try progressive rates.[64] Progressive pricing was implemented on all but one street (Roosevelt Avenue) in the program area, to encourage long-term parkers to shift away from other streets and park on the street with lower demand, thus lowering rates throughout the area.[65] Roosevelt Avenue had a value rate that mirrored the old rate, although the meter limit was extended to two hours. The remaining streets had a progressive rate, as shown in table 1, with one street (74th Street) having a two-hour meter limit and the remaining streets (82nd Street, 37th Avenue, and Broadway) maintaining their original one-hour limit. The progressive rates contributed to decreasing occupancy rates and average parking durations, which allowed more visitors and shoppers to park. NYC DOT estimated a 12 percent increase in the number of drivers finding parking spaces.[66]

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[63] Manzell Blakeley and William Carry, "Jackson Heights PARK Smart: One Year Evaluation."
[64] Blakeley and Carry, "Jackson Heights PARK Smart: One Year Evaluation."
[65] Blakeley and Carry, "Jackson Heights PARK Smart: One Year Evaluation."
[66] Blakeley and Carry, "Jackson Heights PARK Smart: One Year Evaluation."

Figure 7. Curb segments in Jackson Heights where PARK Smart was implemented. (Figure by author).

Table 1. Parking rates for Jackson Heights PARK Smart pilot

Parking time	Old rate	Progressive rate	Value rate
15 minutes		$0.25	
30 minutes		$0.50	
1 hour	$1.00	$1.50	$1.00
90 minutes		$2.50	$1.50
2 hours		$4.00	$2.00

Note: Meters on Roosevelt Avenue were extended to two hours, with a value rate that mirrored the old rate. The remaining streets had a progressive rate, with a two-hour limit on 74th Street and the original one-hour limits on 82nd Street, 37th Avenue, and Broadway.

Atlantic, Court, and Smith

The final PARK Smart pilot was done on portions of Atlantic Avenue, Court Street, and Smith Street in Brooklyn in Fall 2013 (fig. 8).[67] One-hour parking meters were extended to two hours, and progressive pricing was implemented at all the meters in the pilot

[67] New York City Department of Transportation, "PARK Smart: Atlantic, Court & Smith."

area.[68] Table 2 summarizes the parking rate changes in the pilot area. Parking occupancy and duration decreased during most periods, despite the expansion of the meter time limits.[69] The two-hour time limits provided more flexibility for parkers and the progressive rate increased parking turnover, making it easier to find parking on all three corridors.[70]

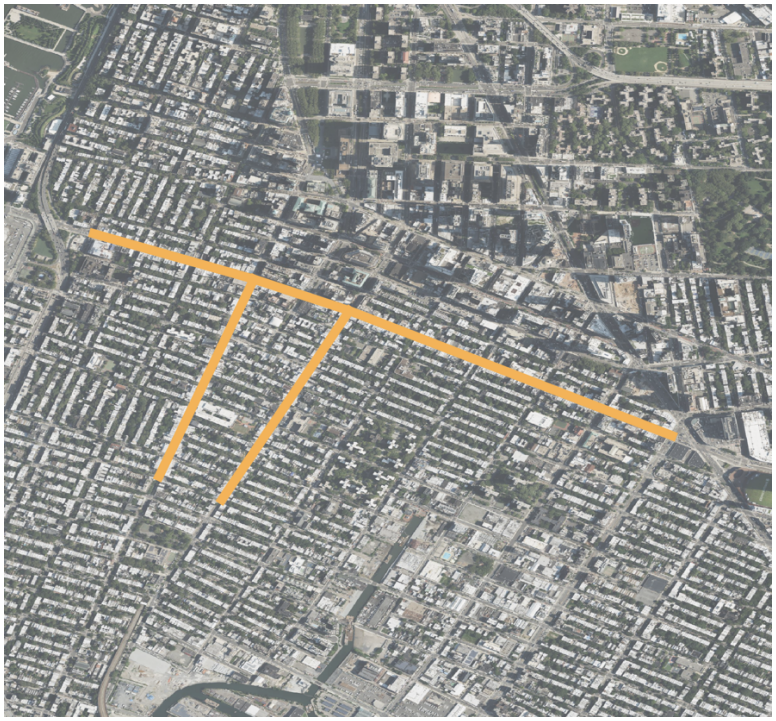

Figure 8. Curb segments on Atlantic Avenue, Court Street, and Smith Street where PARK Smart was implemented. (Figure by author).

Table 2. Parking rates for Atlantic, Court, and Smith PARK Smart pilot

Parking time	Old rate	Progressive rate
15 minutes	$0.25	$0.25
30 minutes	$0.50	$0.50
1 hour	$1.00	$1.50
2 hours	$2.00	$4.00

Note: All one-hour parking meters were extended to two hours, with a new progressive rate.

[68] New York City Department of Transportation, "PARK Smart: Atlantic, Court & Smith."
[69] New York City Department of Transportation, "PARK Smart: Atlantic, Court & Smith."
[70] New York City Department of Transportation, "PARK Smart: Atlantic, Court & Smith."

PARK Smart 2.0

Given the successes of most of the PARK Smart pilot areas in increasing parking availability, NYC DOT considered developing a new program that could be more community-centric and involve other policies and mechanisms beyond pricing.[71] However, this program never came to fruition, due to a combination of factors including political pressure related to rate setting and delays in integrating certain technologies.[72]

Additionally, PARK Smart was not equally welcomed or supported in all areas. The process in each community was quite lengthy and fraught with political tension. Due to varying levels of demand in different areas, rates in some neighborhoods were significantly higher than those in other areas. This upset some community members, as it became more expensive for them to park on their local streets. For instance, in the Upper East Side pilot, when the increased rates did not significantly increase parking availability, there was opposition towards the pricing policies and a lack of community support for testing out higher rates in the area.

At the same time, there was ongoing discussion about moving towards a comprehensive citywide parking rate system, instead of continuing to perform community-focused studies to modify parking rates in individual neighborhoods. In 2018, a six-tier rate structure with progressive pricing was introduced across all five boroughs, which replaced the previous pricing methodology and recommendations with an overall pricing framework.[73] This pricing structure is visualized in figure 1 earlier in this report.

[71] Stein, communication with author, December 15, 2022.
[72] Stein, communication with author, December 15, 2022.
[73] Stein, communication with author, December 15, 2022.

Evaluating other implementations

Numerous cities in the United States have piloted demand-responsive pricing in the last fifteen years. This section will focus on two that are citywide and permanent. Cities have implemented demand-responsive pricing in different ways depending on their timelines, pilot areas, existing price structures, resources, and funding.

San Francisco and SF*park*

The San Francisco Municipal Transportation Authority (SFMTA) conducted SF*park*, one of the earliest demonstrations of demand-responsive pricing in the United States, in 2011.[74] It was funded through a $19.8 million grant from the United States Department of Transportation, a $22 million loan from the Bay Area's Metropolitan Transportation Commission, and local funds of $4.95 million.[75]

Prior to SF*park*, San Francisco parking meters charged fixed hourly rates that varied by zone, but not by the time of day or day of the week.[76] These rates were periodically set by the San Francisco Board of Supervisors based on recommendations provided by SFMTA, usually during city budget planning meetings.[77] As there was no official method for determining rates, however, these meetings were often very contentious.[78]

SFMTA chose to do "time-of-day" pricing: this is a variation on peak pricing where meter operating hours are split into several time bands that may charge different parking rates, as opposed to simply having peak and off-peak periods.[79] For instance, most meters in San Francisco operate within the hours of 9 am and 6 pm, with the three distinct rate periods of 9 am to noon, noon to 3 pm, and 3 pm to 6 pm.[80] The rates are set differently for weekdays and weekends and changed no more than once per month.[81]

The goal of SF*park* was to offer at least one available parking space per block, quantified by an occupancy rate of no more than 80 percent; thus, it was also a performance pricing

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[74] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[75] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[76] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[77] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[78] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[79] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[80] Charles Belov, "Parking Meters," Text, SFMTA (San Francisco Municipal Transportation Agency, May 12, 2021).
[81] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."

program.[82] This was achieved by using the following formula for rate adjustments, applied for each time band on a block-by-block basis:

- If occupancy is higher than 80 percent, raise the hourly rate by $0.25.
- If occupancy is within 60 and 80 percent, do not modify the hourly rate.
- If occupancy is within 30 and 60 percent, lower the hourly rate by $0.25.
- If occupancy is less than 30 percent, lower the hourly rate by $0.50.

As parking demand in San Francisco varies per block, SFMTA chose to adjust rates at the block level as opposed to the zone or neighborhood level.[83] This higher granularity also allows parking demand to be redistributed across larger areas more effectively.[84] These rates vary between $0.50 and $8.00, as defined in the city's transportation code.

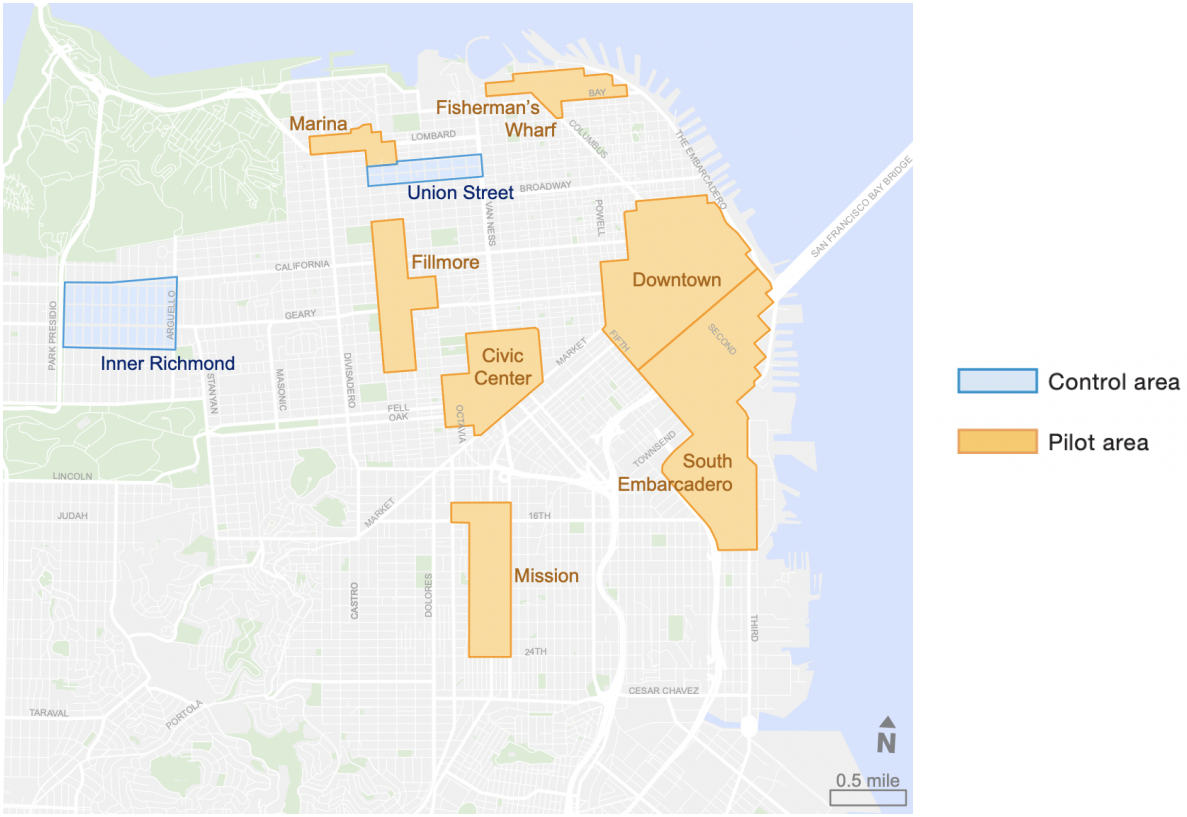

Figure 9. SF*park* pilot and control areas. This map shows the pilot and control areas for SF*park* in San Francisco. (Figure from San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice").

[82] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[83] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[84] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."

SFMTA selected the seven control and two pilot areas shown in figure 9.[85] During the pilot, the agency estimated parking occupancy using in-ground parking sensors that had been installed in late 2010.[86] These were placed under each available parking space in pilot and control areas and they registered whether a space was occupied or unoccupied.[87] SFMTA also collected meter payment data from parking meters that could wirelessly communicate their payment status – for instance, indicating if a space was being paid for or not, or whether there might be any issues with the meter.[88] As many parking sensors were failing by 2013, the sensor occupancy data was no longer reliable.[89]

SFMTA wanted to continue demand-responsive rate adjustments even though the sensor data was unusable.[90] The agency could not use the meter transaction data to estimate occupancy directly, however, because the resulting estimates tended to be lower than actual parking occupancy rates (e.g., due to the use of disabled parking placards and other permits, drivers not paying or staying over time, or broken meters).[91] The agency then created its Sensor Independent Rate Adjustment (SIRA) model which uses meter payment data instead of sensor data to estimate parking occupancy.[92] The SIRA model solves the discrepancy between the two values (the occupancy indicated by meter revenue and the actual occupancy) by using payment data to estimate parking occupancy using multiple linear regression.[93] This model includes type of day (weekday or weekend) as well as type of neighborhood as covariates, which accounts for more variation in occupancy.[94] The resulting estimates are slightly less accurate than the sensor data, but the model errs towards suggesting lower rather than higher rates, and undercharging is less of a concern than overcharging at meters.[95] The coefficients from this final model are used once a quarter to update meter rates.[96]

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[85] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[86] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[87] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[88] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[89] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[90] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[91] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[92] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[93]San Francisco Municipal Transportation Agency, "SFpark: Sensor Independent Rate Adjustments (SIRA) Methodology and Implementation Plan," May 14, 2014.
[94] San Francisco Municipal Transportation Agency, "SFpark: Sensor Independent Rate Adjustments (SIRA) Methodology and Implementation Plan."
[95] San Francisco Municipal Transportation Agency, "SFpark: Putting Theory Into Practice."
[96] The following report has more detailed information about the SIRA model and its implementation: https://www.sfmta.com/sites/default/files/reports-and-documents/2018/01/sira-methodology-and-implementation-plan_2014_05-14.pdf.

There have been a few updates since the SIRA model was introduced, although the coefficients themselves have remained unchanged since the original model.[97] As some blocks had high parking occupancy but low meter revenue due to the prevalence of drivers with disabled parking or authorized vehicle placards, estimated occupancy rates were very inaccurate for these blocks. SFMTA performed in-person data collection to confirm which blocks tended to be high placard usage blocks and, in 2018, created a threshold of 40 percent: if the ratio of payment rate to occupancy rate of a block did not exceed 40 percent at any time of day, then the block was excluded from the rate adjustment process.[98] This would ensure that a block with an occupancy rate vastly different from its payment rate would not wrongly affect calculations of predicted demand from the SIRA model.[99] SFMTA found this 40 percent threshold to be the most optimal in accurately flagging low-payment compliance blocks.[100]

SFMTA also implemented its Demand-Responsive Pricing Program throughout the city on December 5, 2017.[101] This program has been successful since, despite the impact of the COVID-19 pandemic.[102] While average meter rates have decreased due to reduced demand, revenue has not decreased as significantly — high-demand blocks that generate the most revenue have rates that are staying about constant or increasing during the quarterly adjustments, and low-demand blocks with decreasing rates do not have a large impact on total revenue.[103] Overall, the agency has received very few complaints from the community.[104]

The agency is also testing the use of license plate recognition (LPR) to more accurately collect occupancy data, which can be used to update the coefficients previously determined from the SIRA model at a finer block level.[105] SFMTA estimates it can gather updated baseline occupancy data for all metered blocks in San Francisco in around one year.[106] Occupancy data gathered passively by LPR-equipped enforcement vehicles that

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[97] Hank Wilson, communication with author, May 15, 2023.
[98] San Francisco Municipal Transportation Agency, "SFpark: Sensor Independent Rate Adjustments (SIRA) Methodology and Implementation Plan."
[99] San Francisco Municipal Transportation Agency, "SFpark: Sensor Independent Rate Adjustments (SIRA) Methodology and Implementation Plan."
[100] Wilson, communication with author, May 15, 2023.
[101] San Francisco Municipal Transportation Agency, "Demand-Responsive Parking Pricing," Text, SFMTA (San Francisco Municipal Transportation Agency, August 29, 2017).
[102] Wilson, communication with author, May 15, 2023.
[103] Wilson, communication with author, May 15, 2023.
[104] Wilson, communication with author, May 15, 2023.
[105] Hank Wilson, communication with author, January 13, 2023.
[106] Wilson, communication with author, May 15, 2023.

are currently checking for meter payment would supplement the agency's other data-gathering efforts.[107]

Seattle's Performance-Based Parking Pricing Program

Seattle has had paid parking since the early 1940s.[108] Prior to 1990, the city's single-space meter rates increased slowly over the decades, going from $0.10 per hour to $1 per hour by 1990, and to $1.50 per hour by 1993.[109] Starting in 2004, the Seattle Department of Transportation (SDOT) began replacing the city's single-space meters with multi-space pay station kiosks.[110] Seattle was the first city to complete a citywide implementation of solar-powered multi-space meters, removing nearly all single-space meters by 2009.[111]

In 2010, as part of a more proactive paid parking management program, Seattle began considering higher meter rates and the possibility of different rates for different neighborhoods.[112] The Seattle City Council then made a push for a more data-driven and technical approach to rate-setting. Its effort directed the agency's first foray into performance-based pricing, learning from the recently launched efforts in San Francisco and Los Angeles. SDOT's goal was and remains pricing parking such that there are one or two available parking spaces on a blockface at a time, and this performance goal was established through the Seattle Municipal Code.[113] Funding has been provided to SDOT within the city's base budget for an annual parking data collection effort and study.[114]

From 2010 to 2019, SDOT completed a comprehensive parking study each spring that assessed almost every paid parking space in all of Seattle's paid parking areas, with a one-day count between 8 am and 9 pm in each area.[115] By 2019, the agency had almost 30 paid parking areas, either neighborhood commercial districts or subareas of districts.[116] The occupancy rates from the annual counts were applied to the agency's target occupancy of 75 to 80 percent. Rates were adjusted each fall based on the following formula:

- If occupancy is higher than 100 percent, raise the hourly rate by $1.[117]

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[107] Wilson, communication with author, May 15, 2023.
[108] Mary Catherine Snyder, communication with author, May 17, 2023.
[109] Snyder, communication with author, May 17, 2023.
[110] Snyder, communication with author, May 17, 2023.
[111] Snyder, communication with author, May 17, 2023.
[112] Snyder, communication with author, May 17, 2023.
[113] Snyder, communication with author, May 17, 2023.
[114] Snyder, communication with author, May 17, 2023.
[115] Snyder, communication with author, May 17, 2023.
[116] Snyder, communication with author, January 5, 2023.
[117] This part of the formula was added in 2021.

- If occupancy is higher than 85 percent, raise the hourly rate by $0.50.
- If occupancy is within 70 and 85 percent, do not modify the hourly rate.
- If occupancy is below 70 percent, lower the hourly rate by $0.50.

These rates range from $0.50 to $5 per hour, with this rate minimum and maximum set by City Council legislation.[118] The range has been adjusted over the years to provide additional flexibility in meeting the agency's occupancy goals.[119]

The agency's annual rate adjustments occurred until 2019.[120] Paid parking was made free during the pandemic and reinstated in July 2020, with all zones starting at the lowest rate of $0.50 per hour.[121] In 2022, SDOT began making three rate changes per year, every 12 to 15 weeks, in the spring, summer, and fall.[122] To produce parking rate recommendations three times a year, the agency moved away from the annual studies to an algorithm-based model. SDOT did not have sufficient resources to replicate the studies three times a year, but it discovered that transaction data and historical annual studies could guide a new approach. The agency's current model estimates street parking occupancy using all meter transaction data and strategically sampled data from previous quarters.[123] The data analysis is done by the consulting firm Turnstone, which also is developing a more user-friendly dashboard for the agency to access parking data.[124] Turnstone is also focusing efforts on more actively verifying the accuracy of the transaction data it receives from SDOT's payment providers.[125]

Like that of SFMTA, SDOT's pricing strategy also has three rates per day for the morning, afternoon, and evening time periods, although spanning 8 am to 8 pm or 10 pm, as compared to SFMTA's 9 am to 6 pm metered hours.[126] However, unlike SF*park* which has block-level rate changes, SDOT has neighborhood-based zones for pricing. SDOT also sets rates for six days of the week, as opposed to maintaining different weekday and weekend rates. This means SDOT manages about 300 demand-responsive parking rates, significantly fewer than the thousands SFMTA manages.[127] But this aligns with the agency's goal to manage zones on the neighborhood level, which is what motivated the citywide implementation, as opposed to testing pilot areas as SFMTA chose to do.[128]

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[118] Seattle Department of Transportation, "2021 Paid Parking Annual Report."
[119] Snyder, communication with author, May 17, 2023.
[120] Seattle Department of Transportation, "Reports & Studies - Transportation," Seattle.gov, n.d.
[121] Seattle Department of Transportation, "2021 Paid Parking Annual Report."
[122] Snyder, communication with author, May 17, 2023.
[123] Snyder, communication with author, January 5, 2023.
[124] Snyder, communication with author, January 5, 2023.
[125] Snyder, communication with author, January 5, 2023.
[126] Seattle Department of Transportation, "2021 Paid Parking Annual Report."
[127] Snyder, communication with author, January 5, 2023.
[128] Snyder, communication with author, January 5, 2023.

The pandemic emphasized the importance of efficient use of curb space for purposes such as outdoor dining, passenger pick-up and drop-off, and deliveries. SDOT collaborated with other cities and companies across the country to create an open-source Curb Data Specification (CDS) which provides a consistent data standard to digitally represent curb spaces.[129] This effort is led by the Open Mobility Foundation.[130] The CDS facilitates data sharing between cities, curb users, and curb data providers with flexibility and lower cost.[131] The tool aims to achieve more efficient curb management based on more precise data collection and representation efforts.[132] While preliminary applications seem to be focused on commercial vehicle usage, NYC DOT Parking should explore possibilities of using the CDS for the city's curb space.

Tables 3 and 4 summarize metered parking and demand-responsive pricing implementations, respectively, in New York City, San Francisco, and Seattle.

[129] Ethan Bancroft, "We're Working to Improve Curbside Access in Seattle as Part of a National Effort to Develop New Digital Tools and Provide Data-Driven Insights," SDOT Blog, January 25, 2022.
[130] Bancroft, "We're Working to Improve Curbside Access in Seattle as Part of a National Effort to Develop New Digital Tools and Provide Data-Driven Insights."
[131] Open Mobility Foundation, "Announcing: Curb Data Specification 1.0," January 24, 2022.
[132] Bancroft, "We're Working to Improve Curbside Access in Seattle as Part of a National Effort to Develop New Digital Tools and Provide Data-Driven Insights."

Table 3. Metered parking in major cities in the United States

	New York, NY	San Francisco, CA	Seattle, WA
Population	8,335,897	808,437	749,256
Land area (mi^2)	300.45	46.91	83.83
Population density (per mi^2)	29,303.2	18,629.1	8,791.8
Number of on-street parking spaces	3,000,000	275,500	500,000
Number of metered on-street parking spaces	85,000	28,000	11,500
Number of meters	13,420	22,005	1,425
Meter hours (typical)	7 am to 7 pm	9 am to 6 pm	8 am to 8 pm
Hourly rate range	$1.25 to $7.50	$0.50 to $8.00	$0.50 to $5.00
Payment options	Pay and display or pay by phone	Pay and display or pay by phone	Pay by plate or phone
Enforcement	NYC Police Department, with violations collected and processed by NYC Department of Finance	Parking and Traffic Enforcement within SFMTA Streets Division	Seattle Police Department, with violations processed by Seattle Municipal Court
Where meter revenue goes	General fund	Public transit system (Muni)	General fund

Note: Population data is from 2022. The number of spaces and metered spaces are estimates, and the number of meters is drawn from most recent city open data.

Table 4. Comparison of major cities' initial demand-responsive curb pricing implementations

	New York, NY	San Francisco, CA	Seattle, WA
Name	PARK Smart	SF*park*	Performance Pricing Program
Type	Progressive and peak pricing	Peak and performance pricing	Performance pricing
Year	2008	2011	2011
Area or scope	Neighborhoods or streets with identifiable demand constraints, such as retail	About 6,000 spaces in 7 pilot areas throughout the city, with 2 control areas	Citywide
Rate zones	Neighborhood level	Blockface level	Neighborhood level
Data sources	• Camera imagery • Parking occupancy • Parking durations • Parking surveys	• Sensor occupancy • Meter transactions • In-person occupancy counts	• Meter transactions • Historical occupancy • In-person occupancy counts
Model and rate adjustment	Initial rates set based on curb occupancy surveys and community input, adjusted based on data and feedback	Estimate parking occupancy from transaction data, rates adjusted using 60-80% occupancy target	Predict parking activity from transaction data and citywide counts, rates adjusted using 70-85% occupancy target
Frequency of adjustment	Varied	Around four times a year	Three times a year (spring, summer, and fall)
Current status of program and other city parking-related policies	• Replaced with citywide rate structure in 2018 • Central Business District tolling program to take effect soon • City Council bill for demand-responsive pricing is in committee	• Demand-responsive pricing program went citywide in December 2017 • Testing license plate recognition technologies • Extending meter hours starting July 2023	• Collaborating to develop Curb Data Specification • Exploring "cousin blocks" to reduce data collection efforts

Recommendations

The following recommendations are drawn from comparing and evaluating the demand-responsive pricing implementations in New York City, San Francisco, and Seattle.

Data collection

Sensors can be infeasible for large-scale implementations: they are historically expensive to install and difficult to maintain to ensure reliable data. Newer technology has made sensors more disposable and flexible in use, although this technology will remain somewhat expensive and inaccessible in the near future.[133] In-ground sensors are also not compatible with multi-space parking spaces, which New York City exclusively has. Technology such as parking sensors or cameras are also fairly static in that, once installed, they are limited to collecting data for a certain parking space or stretch of curb space. Vehicle-mounted LPR can help make collecting occupancy data easier and more accurate, while simultaneously covering greater area. The technology can also be useful for automated parking enforcement.

Modelling

A model that can estimate parking occupancy data from meter transaction data reduces the need for long-term maintenance of technology to collect accurate occupancy data. The occupancy data should be collected three times a year in the spring, summer, and fall, as SDOT is doing, so that the relationship drawn between occupancy and meter revenue remains valid.[134] While SFMTA is able to do quarterly updates, NYC DOT will likely have some data and revenue inconsistencies in the winter due to the weather. Areas that have high rates of parking placard use should be removed from the dataset before using transaction data to estimate rate adjustments, so that they do not bias the resulting estimate.

Context-specific factors

Instituting demand-responsive pricing in city code — and assigning implementation responsibility to city transportation agencies — can reduce political and community opposition. Starting with limited pilot areas can make permanent citywide implementations a more challenging and lengthy process, so larger or citywide scopes should be considered. Additionally, agencies with greater control over enforcement and

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[133] Garcia, communication with author, May 16, 2023.

[134] Wilson, communication with author, January 13, 2023.

finances have greater flexibility in implementation. For instance, enforcement of San Francisco's Demand-Responsive Parking Program is done by Parking and Traffic Enforcement, within SFMTA's Streets Division. SFMTA is currently testing out vehicle-mounted LPR technologies that are already being used for enforcement to additionally collect parking occupancies. Parking meter revenue is also put towards the city's public transit system, Muni, which helps justify the upcoming extension of metered hours.

Challenges in implementation

Several of the anticipated challenges in implementing demand-responsive pricing will not be unique to New York City and may be better targeted through policy changes.

Placard abuse

Placard abuse refers to the misuse of credentials, such as government or disabled credentials, by a driver to park in certain spaces and avoid paying for parking. Sometimes these are unofficial and counterfeit permits placed in vehicle dashboards, but most times they are officially granted and misused.

New York City government placards, which are a type of "Authorized Vehicle Only" parking permit, have been given out liberally in the past.[135] In fact, in 2008, there were over 142,000 free parking permits given to city employees and others, which was around twice as many permits as the city had actually thought were in circulation.[136] This misuse of city-issued permits has also been increasing in 311 reports in the past few years and has been the subject of some city council legislation.[137]

New York City also offers a Parking Permit for People with Disabilities (PPPD), which is a placard that must be displayed on the dashboard of a parked vehicle. This rectangular placard gives drivers the ability to park at the following locations in New York City:[138]

- Any metered parking space (passenger or commercial) without charge
- Any space with a "No parking" regulation at any time
- Most "Authorized Vehicle" parking spaces, referring to spaces for diplomats, the press, and other government agencies
- Most "No standing except for truck loading" zones

The city permit is different from the New York State permit, which is only valid to use where there are designated parking spaces for people with disabilities, and the state permit is additionally valid outside of the state.[139] In New York City, such designated parking spaces are all off-street.[140]

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[135] William Neuman and Al Baker, "No Parking Spot? Here Are About 142,000 Reasons," *The New York Times*, March 6, 2008.
[136] Neuman and Baker, "No Parking Spot?"
[137] New York City Council, "Placard Abuse," New York City Council, n.d.
[138] New York City Department of Transportation, "NYC DOT - Motorists & Parking - Parking Permits for People with Disabilities," New York City Department of Transportation, n.d.
[139] New York State Department of Motor Vehicles, "Parking for People with Disabilities," Text, New York DMV, November 10, 2013.
[140] New York State Department of Motor Vehicles, "Parking for People with Disabilities."

Without appropriate enforcement, placard abuse can go unnoticed and wrongly allow legal nonpayment. Drivers with access to these credentials are more likely to use on-street curb parking and park for longer periods of time as compared to other drivers.[141] In fact, a study found that the average parking duration for cars with disabled placards was over seven times longer than for cars without placards.[142] If more people use these placards, parking turnover decreases, and a demand-responsive parking rate would actually rise in response, making market-based parking challenging if not impossible.[143] Additionally, the meter revenue would not reflect the higher occupancies of these blocks, leading to revenue shortfalls and challenges in using transaction data to accurately estimate parking occupancy. Disabled placard abuse also makes convenient parking spaces more inaccessible for those with more serious impairments.[144] Placard abusers thus take spaces away from other drivers, especially disabled users, and take public revenue.[145]

Identifying placard abuse is difficult as the placards are assigned to people, as opposed to vehicles.[146] A potential solution comes from states like Illinois that have implemented a "two-tier" system for different levels of disability: in these implementations, drivers with serious mobility impairments and those who might not be able to operate a parking meter do not have to pay, while those with less serious disabilities do.[147] This would avoid harming drivers who cannot physically pay, although it would still harm those who might be financially unable to do so.[148] While having a disability can affect someone's earnings, disabled placards are not equitable to begin with, as they offer little benefit to those with the most serious disabilities who may be unable to operate a vehicle, or to the poorest people with disabilities who may lack a vehicle.[149] To garner greater support for such a two-tier system, New York City can dedicate any increased meter revenue to programs and policies that help increase accessibility for those with disabilities, such as greater curb cuts or other sidewalk repairs. Implementations of this system have only occurred at the state level, as in most states, disabled placards are only granted by the state; however, New York City is unique in that the city issues such permits with its own regulations.

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[141] Michael Manville and Jonathan A. Williams, "The Price Doesn't Matter If You Don't Have to Pay: Legal Exemptions and Market-Priced Parking," *Journal of Planning Education and Research* 32, no. 3 (September 2012): 289–304.
[142] Manville and Williams, "The Price Doesn't Matter If You Don't Have to Pay."
[143] Manville and Williams, "The Price Doesn't Matter If You Don't Have to Pay."
[144] Donald Shoup and Fernando Torres-Gil, "Ending Placard Abuse at Parking Meters: The Two-Tier Solution," *The Parking Professional*, January 1, 2015, 20-23.
[145] Shoup and Torres-Gil, "Ending Placard Abuse at Parking Meters."
[146] Manville and Williams, "The Price Doesn't Matter If You Don't Have to Pay."
[147] Shoup and Torres-Gil, "Ending Placard Abuse at Parking Meters."
[148] Manville and Williams, "The Price Doesn't Matter If You Don't Have to Pay."
[149] Manville and Williams, "The Price Doesn't Matter If You Don't Have to Pay."

Another solution is expanding curb uses where vehicles with placards cannot park. This is one approach taken by SFMTA to provide greater curb access for all other vehicles, as vehicles with disabled placards are not allowed to park in truck loading and unloading zones in San Francisco.[150] SFMTA also created a new "General Loading Zone" that allows any vehicle to load and unload along the curb, but limits vehicles with disabled placards from parking. New York City is beginning to address the impacts of placard use on curb space: a recent local law prohibits the use of certain city-issued placards in parts of Manhattan's CBD, including truck loading zones.[151] These regulations may not completely solve the issue of placard abuse for these areas, but the parking restrictions for vehicles with placards can increase parking availability or curb access for other uses.

Political or community opposition

Demand-responsive pricing is not welcomed in all areas, as it can lead to significant variation in parking rates between neighborhoods or at different times of day. It can also have a limited effect on parking demand based on other factors; for instance, an area may experience high levels of double parking by commercial vehicles that affect passenger parking availability and access, although fines may not deter the illegal parking from occurring. In these cases, pricing might have little impact in managing curb parking demand in the area and may make demand-responsive pricing rates appear futile and exorbitant.

As seen in the PARK Smart pilot in the Upper East Side, parking occupancy and vehicle turnover remained mostly unchanged and the community did not want to try higher parking rates, so it asked to have the program suspended. All the PARK Smart pilots were entirely opt-in. As mentioned earlier, however, requiring NYC DOT to implement demand-responsive pricing through city legislation, as has recently been done, will give the agency greater authority and may reduce some opposition. Furthermore, the fact that the law requires the selection of at least one location in each borough might make future citywide implementation less contentious, as previous PARK Smart pilots were limited to Manhattan, Brooklyn, and Queens.

In New York City, parking revenue goes directly into a general fund, known as "miscellaneous revenue."[152] Thus, varying meter rates and evolving meter locations due

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[150] Hank Wilson, communication with author, May 15, 2023.
[151] A Local Law to amend the administrative code of the city of New York, in relation to truck loading zones, Pub. L. No. 167, New York City Administrative Code (2021).
[152] "Annual State of the City's Economy and Finances," Office of the New York City Comptroller Brad Lander, December 15, 2022.

to demand-responsive pricing policies can make it difficult to estimate future citywide revenue forecasts.[153] In reality, parking violations can lead to greater revenue than parking meters: one estimate suggests that New York City, in 2015, collected more than twice as much parking revenue from fines as it did from meters.[154] This source of revenue has also been increasing — the New York City Comptroller estimates that revenues from parking and camera violation fines will exceed projections by $100 million and $120 million, respectively, in fiscal year 2023, with at least a combined $53 million increase annually for fiscal years 2024 through 2026.[155] But increased parking availability can increase meter revenue and reduce parking violations, which can still lead to a loss in revenue for the city. To avoid large fluctuations in revenue, NYC DOT can set a range for payment rates and use more standard adjustment increments, such as 50 cents, as both SFMTA and SDOT have done, to come up with both a conservative and optimistic estimate for parking-related revenue. Updating meter rates at a reasonable frequency, such as three times a year, can also reduce variation in revenue over the year.

The general fund makes it challenging to follow how parking revenue is used, and dedicating the revenue to the general fund does not create political support for pricing curb parking. New York City can consider establishing Parking Benefit Districts (PBDs), where some of the parking meter revenue will be used for added public services on the metered blocks.[156] This can also solve the issue of fluctuating annual revenue due to demand-responsive pricing, as the meter revenue would no longer go towards general city operations. PBDs have been shown to be politically, financially, and environmentally successful.[157] They have mostly been implemented in commercial areas, although they can be viable in dense residential neighborhoods: a case study of the Upper West Side found that implementing demand-responsive pricing at currently unmetered curb spaces would eliminate 22 tons of carbon dioxide emissions per block per year and yield at least $1,025 per household per year to improve public services.[158] Furthermore, cities can use power equalization to ensure that all PBDs will have the same revenue per designated unit (e.g., per foot of curb space or per resident), which reduces the inequity from having significantly different demand-responsive parking rates across neighborhoods.[159]

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[153] Matthew Garcia, communication with author, May 16, 2023.
[154] Michael Manville and Miriam Pinski, "The Causes and Consequences of Curb Parking Management," *Transportation Research Part A: Policy and Practice* 152 (October 2021): 295–307.
[155] "Annual State of the City's Economy and Finances."
[156] Donald Shoup, "Parking Benefit Districts," *Journal of Planning Education and Research*, March 31, 2023.
[157] Shoup, "Parking Benefit Districts."
[158] Shoup, "Parking Benefit Districts."
[159] Shoup, "Parking Benefit Districts."

Issues of scale

New York City has over three and seven times as many metered parking spaces as San Francisco and Seattle, respectively, which are the two cities in the United States with citywide demand-responsive pricing implementations. While the switch to multi-space meters has reduced the number of meters to reprogram when rate adjustments occur, it is undeniable that New York City must navigate operations on a very large scale. A solution is to simply begin with select pilot areas across the boroughs instead of a citywide implementation, as would be required by the City Council bill. Another option is rolling updates for parking meter rates, as SFMTA does, which involves adjusting rates one neighborhood at a time to reduce the amount of data collection, processing, and analysis needed. A fairly new possibility is being explored by SDOT: presently called "cousin blocks," this relies on the idea that blockfaces that are not adjacent to one another may have similar parking characteristics, such as meter revenue, parking durations, and even land uses.[160] This is an emerging research area for Turnstone, the consulting firm working with SDOT.[161] If these blocks tend to perform similarly, then results based on data from one block could be applied to the cousin blocks to allow for more efficient and reduced data collection.[162]

More parking spaces and meters also mean more enforcement issues. As discussed earlier, vehicle-mounted LPR can be useful for automated parking enforcement as well for occupancy data collection over a greater area. Greater parking availability as a result of demand-responsive pricing can also reduce some issues such as illegal and double parking in New York City.

[160] Mary Catherine Snyder, communication with author, May 15, 2023.
[161] Snyder, communication with author, May 15, 2023.
[162] Snyder, communication with author, May 15, 2023.

Conclusion

Given the forthcoming implementation of congestion pricing in Manhattan's CBD, New York City will become familiar with the use of pricing strategies to manage demand. This may reduce opposition to future demand-responsive parking pricing programs and policies. While a citywide implementation seems infeasible due to data constraints, a program that introduces demand-responsive pricing in areas chosen by NYC DOT, with rate adjustments influenced by data and modelling considerations as described in this report, will have greater success and permanence than the PARK Smart pilots. The City Council bill is still vague in its expectations of demand-responsive pricing; if passed, it would give NYC DOT greater flexibility in implementation, such as in the type of pricing or in setting rates and ranges. Exploring technologies and legislation that other cities have recently employed can further increase support for the program, reduce parking violations, and make demand-responsive pricing the most effective solution for increasing passenger curb parking availability in New York City.

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